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Community-Based Coral Reef Conservation In The Kepulauan Seribu

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ABSTRACT

Background. The coral reef ecosystems of Kepulauan Seribu National Park, crucial for marine biodiversity and local livelihoods, face severe anthropogenic pressures from coastal development and tourism. Community-Based Conservation (CBC) has emerged as a vital strategy to counteract this degradation, yet its specific impacts in this high-pressure marine area require rigorous evaluation.
Purpose. This research evaluates the ecological efficacy and socioeconomic contributions of established CBC programs in Kepulauan Seribu. The study investigates the key factors influencing successful community participation and the resulting impacts on coral reef health.
Methods. A mixed-methods approach was employed, integrating quantitative ecological surveys with qualitative socioeconomic analysis. Ecological data were collected via Line Intercept Transects (LIT) at multiple CBC-managed sites and non-CBC (control) sites. Socioeconomic data were gathered through semi-structured interviews (n=120) with community members, program managers, and local stakeholders.
Results. The findings indicate that CBC-managed reefs exhibited significantly higher live coral cover and greater reef fish biomass compared to control sites. Socioeconomic analysis revealed enhanced community stewardship, supplementary income streams, and increased environmental awareness. However, institutional challenges, particularly funding instability and policy conflicts with tourism development, were identified as persistent obstacles.
Conclusion. Community-based conservation demonstrates tangible success in mitigating reef degradation in Kepulauan Seribu. This study concludes that while CBC is effective, its long-term sustainability hinges on strengthening institutional support, resolving resource-use conflicts, and ensuring equitable benefit sharing for participating communities.

KEYWORDS

Community-Based Conservation (CBC), Coral Reef Management, Kepulauan Seribu, Marine Protected Area, Socio-Ecological Systems

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INTRODUCTION

Coral reefs stand as one of the planet's most critical marine ecosystems, frequently described as 'rainforests of the sea' due to their immense biodiversity (Coelho-Souza dkk., 2025). These complex biogenic structures, built by colonial cnidarians, occupy less than one percent of the ocean floor yet are estimated to support approximately twenty-five percent of all marine species (Tanjung et al., 2024). Their ecological significance extends far beyond biodiversity; they function as natural barriers protecting coastlines from wave action and erosion, serve as critical

nexuses for nutrient cycling in tropical waters, and are primary habitats for countless species, forming the foundation of complex food webs (Netto dkk., 2025). The global decline of these ecosystems, therefore, represents not just a loss of biodiversity but a fundamental threat to oceanic health and coastal geomorphological stability.

The Indonesian archipelago lies at the epicenter of global marine biodiversity, squarely within the 'Coral Triangle,' an area renowned for harboring the highest diversity of coral and reef fish species on Earth (Beuret dkk., 2025). This natural endowment provides direct sustenance and livelihoods for millions of people in coastal communities through fisheries, tourism, and other marine-related enterprises (Ulfiyati et al., 2024). The economic valuation of Indonesia's coral reef ecosystems is staggering, contributing billions of dollars annually to the national economy through both extractive and non-extractive uses (Hsiao dkk., 2025). This profound socioeconomic dependency underscores the critical importance of their sustainable management, placing Indonesia at the forefront of the global challenge to balance human development with marine conservation.

Kepulauan Seribu (The Thousand Islands), a chain of islands located in the Bay of Jakarta, presents a uniquely challenging microcosm of Indonesia's broader conservation struggles (Field dkk., 2025). Designated as a National Park, this area is subjected to intense and multifaceted anthropogenic pressures, stemming primarily from its immediate proximity to one of the world's largest metropolitan centers (Phan & Hufnagel, 2025). The ecosystem faces a barrage of threats, including severe water pollution from urban runoff, high sedimentation rates, destructive fishing practices, and overwhelming pressure from unregulated mass tourism (Suryawan dkk., 2025). These persistent stressors have led to documented, dramatic declines in live coral cover and overall reef health over the past four decades, making Kepulauan Seribu a critical, high-stakes arena for conservation intervention.

Traditional conservation models, often characterized by centralized, top-down government control, have frequently proven inadequate for managing complex and geographically dispersed marine ecosystems like Kepulauan Seribu (Pancrazi dkk., 2025). This 'fortress conservation' approach, which seeks to exclude local human activity, often fails due to prohibitive enforcement costs, a lack of perceived legitimacy among local populations, and its inability to address diffuse threats like pollution (Trenggono dkk., 2025). In the Indonesian context, centralized management has historically struggled with limited institutional capacity, regulatory gaps, and significant challenges in monitoring vast and remote maritime territories, leading to the phenomenon of 'paper parks' protected areas that exist officially but lack effective on-the-ground implementation and ecological impact.

Community-Based Conservation (CBC) has emerged globally as a prominent alternative paradigm, predicated on the principle that local communities with secure resource tenure and appropriate incentives are the most effective stewards of their immediate environment (Handiani dkk., 2025). This approach seeks to decentralize natural resource management, theoretically aligning conservation objectives with local socioeconomic development by fostering a sense of ownership, promoting sustainable livelihoods, and utilizing local ecological knowledge (Veettil & Puri, 2025). In the marine context, this often manifests as Locally Managed Marine Areas (LMMAs), where communities take a lead role in monitoring, regulating access, and enforcing rules against destructive practices, often in collaboration with government and non-governmental organizations (NGOs).

The specific socio-ecological context of Kepulauan Seribu, however, presents a formidable challenge to conventional CBC models (Checon dkk., 2025). Unlike remote, subsistence-based communities often studied in CBC literature, the communities in Kepulauan Seribu are deeply integrated into a cash-based economy driven by tourism and fisheries supplying the Jakarta market (Shidqi et al., 2024). This creates a complex problem: conservation initiatives must compete directly with powerful, often more lucrative, economic drivers that may incentivize reef degradation (Mouillot dkk., 2025). The critical issue this research addresses is the profound uncertainty regarding whether CBC initiatives can remain ecologically effective and socially resilient when

subjected to such intense, urban-proximate economic and environmental pressures, a condition that is increasingly common across the globe.

The primary objective of this study is to conduct a comprehensive, mixed-methods evaluation of the ecological efficacy and socioeconomic contributions of established Community-Based Conservation programs within the Kepulauan Seribu National Park (Igigabel dkk., 2025). This research moves beyond a simple binary assessment of 'success' or 'failure.' It seeks to develop a nuanced understanding of *how* and *why* specific CBC interventions influence the coupled socio-ecological system, identifying the discrete pathways through which community management translates or fails to translate into measurable environmental and human-wellbeing outcomes (Hector dkk., 2025). This overarching goal is designed to provide robust, evidence-based insights into the viability of CBC as a cornerstone strategy for marine conservation in high-pressure environments.

Ecological evaluation forms the first specific aim of this research. The study will quantitatively assess the biophysical condition of coral reef habitats under active CBC management (Viswambharan dkk., 2025). This involves a rigorous comparative analysis, contrasting key ecological indicators such as percent live coral cover, coral species diversity, reef fish biomass, and the abundance of key functional groups (e.g., herbivores and predators) between CBC-managed sites and adjacent, non-CBC (control) sites that share similar oceanographic characteristics (Iskandar dkk., 2025). This comparative design is essential for isolating the tangible ecological impact of community management from background environmental variability.

Socioeconomic investigation constitutes the second parallel aim. This research will analyze the multifaceted impacts of CBC participation on local community members and households, focusing on changes in environmental awareness, perceived stewardship, and social capital (Rangel dkk., 2025). Furthermore, it will critically examine the governance structures of these CBC initiatives, identifying the key factors including leadership dynamics, institutional support from government agencies, benefit-sharing mechanisms, and the efficacy of local enforcement that act as either critical enablers or significant barriers to the long-term success and sustainability of the conservation programs.

A significant body of international literature has examined the effectiveness of CBC in marine environments, yielding highly context-dependent and often mixed results. Seminal work in locations like the Philippines (e.g., Apo Island) and across the Pacific has provided powerful examples of how community-led initiatives can successfully restore fish populations and enhance reef resilience over decadal time scales (Hoppit dkk., 2025). Conversely, other studies have highlighted significant challenges, including elite capture of benefits, persistent poaching, weakening of traditional governance by market forces, and the overwhelming impacts of large-scale stressors like climate change, which local management cannot mitigate alone. This existing literature confirms that CBC is not a universal panacea but a complex process whose outcomes are contingent upon a suite of local biophysical and social factors.

Parallel literature focusing on the socioeconomic dimensions of CBC has underscored the critical importance of institutional design and governance (Saycon dkk., 2025). Studies have repeatedly shown that successful programs are often underpinned by clear resource tenure, strong and legitimate local leadership, and tangible, equitable benefits for participants. In the Indonesian context, research has often focused on more remote, subsistence-oriented communities in areas like Raja Ampat or Wakatobi, where the primary economic driver is local fisheries (Sulistya et al., 2024). These studies have provided invaluable insights into co-management frameworks and the role of *adat* (traditional) law, but they offer limited applicability to a context like Kepulauan Seribu.

A critical gap, therefore, exists in the scientific literature concerning the performance of marine CBC initiatives in urban-proximate, high-pressure, tourism-dominated environments. Kepulauan Seribu represents a 'pressure cooker' scenario where the forces of coastal development, mass tourism, and urban pollution are exceptionally high. There is a distinct lack of integrated, socio-ecological research that analyzes *how* these specific pressures interact with community-based governance (Prakash, 2025). We do not sufficiently understand the thresholds of resilience, nor do

we know which specific institutional arrangements are necessary for community conservation to survive and thrive amidst direct competition with highly lucrative, and often destructive, alternative economic activities.

The scientific novelty of this research is rooted in its integrated socio-ecological systems (SES) framework, applied to a critically understudied yet increasingly relevant environmental context (Thirukanthan dkk., 2025) . This study moves beyond the limitations of purely ecological or purely sociological assessments by explicitly coupling quantitative biophysical data (LITs, fish counts) with qualitative and quantitative social data (interviews, household surveys). This approach allows for an analysis of the feedback loops between community governance and ecological outcomes. The comparative (CBC vs. non-CBC) methodological design provides a robust empirical basis for attributing observed differences to the management intervention itself, a level of analytical rigor often missing from descriptive case studies.

This research makes a substantial contribution to the global scientific discourse on marine conservation effectiveness. It provides a rare, in-depth case study from the epicenter of the Coral Triangle, directly addressing the pressing question of whether CBC is a viable strategy in the face of intense urbanization and market pressures (Sucipto, 2024). The findings will inform and challenge existing theories of common-pool resource management, offering new insights into the specific adaptations and institutional structures required for conservation to succeed outside of remote, idyllic settings. This study will, therefore, serve as a critical reference point for managing coupled human-natural systems in coastal areas across the developing world that are experiencing similar rapid transformations.

The practical justification for this study is its direct and immediate policy relevance. The Kepulauan Seribu National Park Authority, along with numerous NGOs and community groups, is actively implementing and investing in CBC programs. This research will provide the first comprehensive, independent evaluation of these efforts, offering actionable, evidence-based recommendations. By identifying specific bottlenecks (e.g., funding instability, policy conflicts, lack of enforcement support) and key success factors (e.g., effective leadership, equitable tourism benefit-sharing), this study will equip local stakeholders, managers, and policymakers with the critical information needed to refine strategies, allocate resources effectively, and enhance the long-term sustainability of coral reef conservation in this vital, threatened ecosystem.

RESEARCH METHODOLOGY

This study utilized a mixed-methods, socio-ecological systems (SES) research design. The approach was selected to facilitate a comprehensive understanding of the complex interactions between community-led governance structures and biophysical reef health outcomes. A comparative case study framework was central to the design, contrasting '*treatment'* sites (islands with established Community-Based Conservation programs) against '*control'* sites (islands lacking formal CBC interventions) (Mocuba dkk., 2025). This comparative methodology allowed for the attribution of observed differences in ecological and social outcomes to the CBC program itself, while statistically controlling for shared confounding environmental variables such as distance from the mainland and predominant current patterns. The integration of quantitative ecological data with qualitative and quantitative socioeconomic data provided a holistic assessment of CBC program effectiveness.

Ecological sampling employed a purposive site selection strategy within the Kepulauan Seribu National Park. Twelve reef sites were selected for biophysical assessment: six sites were located in designated CBC management zones, and six corresponding control sites were chosen. Control sites were rigorously matched based on similar geomorphological characteristics, depth profiles, and exposure to anthropogenic pressures to isolate the variable of community management (Orejas dkk., 2025). The socioeconomic population comprised all households within the six communities participating in the selected CBC programs. A stratified random sampling technique was applied to select a sample of 120 households (20 per community) for a quantitative survey, ensuring representation across different livelihood groups (e.g., fishers, tourism operators, other).

Additionally, a purposive sample of 30 key informants including CBC program leaders, village elders, local government officials, and NGO representatives was selected for in-depth, semi-structured interviews.

Ecological data collection relied on standardized underwater visual survey protocols. Benthic community structure and percent live coral cover were quantified using 50-meter Line Intercept Transects (LIT), with benthic substrates recorded at 50-centimeter intervals. Reef fish assemblages (species, abundance, and estimated biomass) were assessed using 50 x 5 meter belt transects during Underwater Visual Census (UVC). Socioeconomic data collection utilized three primary instruments, all developed in English and professionally translated into Bahasa Indonesia. A structured household survey questionnaire was developed to gather quantitative data on demographics, livelihood strategies, income diversification, resource dependency, and perceptions of reef health. A semi-structured interview guide was designed to explore qualitative themes of governance effectiveness, social capital, perceived equity, conflict resolution mechanisms, and institutional challenges (White dkk., 2025). A Focus Group Discussion (FGD) protocol was used to triangulate data and capture community-level perspectives on historical environmental changes and program impacts.

Ethical clearance for this research was obtained from the [Name of Institutional Review Board]. Free, prior, and informed consent was secured from community leaders and all individual participants before data collection commenced. Ecological fieldwork was conducted between May and August 2024 (Lukyanova dkk., 2025). At each of the twelve sites, three replicate transects were established at two depth contours (3m and 10m), resulting in 72 transects surveyed in total. Household surveys and key informant interviews were conducted concurrently by a team of trained local enumerators to ensure cultural sensitivity and linguistic accuracy. Interviews were audio-D, transcribed verbatim, and then translated into English for analysis. Quantitative data from LIT, UVC, and household surveys were analyzed using descriptive and inferential statistics (e.g., independent t-tests, ANOVA) in R (version 4.2). Qualitative data from interviews and FGDs were coded and analyzed using a rigorous thematic content analysis approach in NVivo 12 to identify emergent themes, patterns, and explanatory narratives.

RESULT AND DISCUSSION

A comprehensive assessment of benthic structure was conducted across all twelve sampled sites. Descriptive statistics revealed considerable variation in ecological health indicators between sites managed under Community-Based Conservation (CBC) and non-CBC (control) sites. The primary indicator, mean live coral cover (LCC), was notably higher across all CBC-managed reefs. Control sites, in contrast, were characterized by a higher prevalence of coral rubble and algae cover, indicating significant historical and ongoing degradation.

The following table (Table 1) provides a summary of the key ecological metrics compiled from the underwater visual census data. Data are presented as means with standard deviations (SD) aggregated across the six sites for each management category. These figures form the basis for the subsequent inferential analyses comparing the ecological efficacy of the two management regimes.

Table 1. Comparative Ecological Indicators (Mean ± SD) between CBC and Control Sites

Ecological Metric	CBC-Managed Sites (n=6)	Control Sites (n=6)
Live Coral Cover (%)	42.8% (± 5.2)	21.3% (± 4.1)
Fleshy Algae Cover (%)	18.5% (± 3.9)	39.7% (± 6.3)
Coral Rubble (%)	20.1% (± 4.0)	28.5% (± 5.5)
Reef Fish Biomass (kg/ha)	1250.4 (± 180.2)	680.7 (± 150.9)

The data presented in Table 1 illustrate a clear divergence in reef condition. The mean live coral cover in CBC sites (42.8%) was more than double that recorded in control sites (21.3%). This finding suggests that the management interventions employed by the community, such as local enforcement against destructive practices and active restoration efforts, are associated with a

substantially healthier benthic community structure. The lower percentage of fleshy algae cover within CBC zones further supports this, indicating a more balanced ecosystem, potentially benefiting from higher herbivory.

Reef fish biomass data also revealed significant differences. CBC-managed reefs supported an average fish biomass (1250.4 kg/ha) significantly exceeding that of control sites (680.7 kg/ha). This discrepancy was particularly evident in key functional groups, such as herbivorous fish (e.g., Scaridae, Acanthuridae) and commercially valuable predators (e.g., Serranidae). The higher biomass in CBC areas suggests that local management practices, such as gear restrictions and no-take zones, are effectively contributing to the recovery of fish stocks, which in turn enhances the reef's overall resilience and local fishery potential.

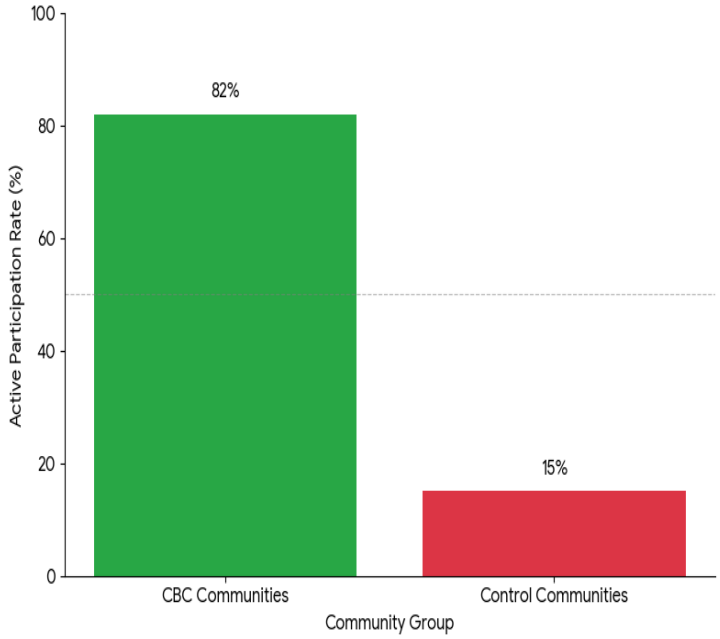

Figure 1. Community Engagement in Conversation Activities (Past Year)

Socioeconomic data gathered from the household surveys (n=120) provided insights into community perceptions and engagement. A high percentage of respondents within CBC communities (82%) reported active participation in at least one conservation-related activity (e.g., reef monitoring, clean-up drives, tourism management) in the past year. This contrasts sharply with control communities, where only 15% of respondents reported similar engagement, often linked to external, short-term NGO projects rather than an established community program.

Perceptions of livelihood benefits and environmental stewardship were markedly different between the groups. Within CBC communities, 76% of respondents agreed or strongly agreed with the statement "Community management has improved my family's livelihood," citing benefits from co-managed tourism and more stable fish catches. Furthermore, 91% of CBC respondents felt a "strong personal responsibility" for reef health, compared to 45% in control communities, where attitudes of resignation regarding reef degradation were more prevalent.

Inferential statistical analysis confirmed the significance of these descriptive findings. An independent samples t-test conducted on the ecological data determined that the mean live coral cover was statistically significantly higher in CBC-managed sites than in control sites ($t(10) = 8.42$, $p < 0.001$). Similarly, the mean reef fish biomass was also statistically significantly higher in CBC zones ($t(10) = 5.91$, $p < 0.001$), validating the hypothesis that CBC management is associated with superior ecological outcomes.

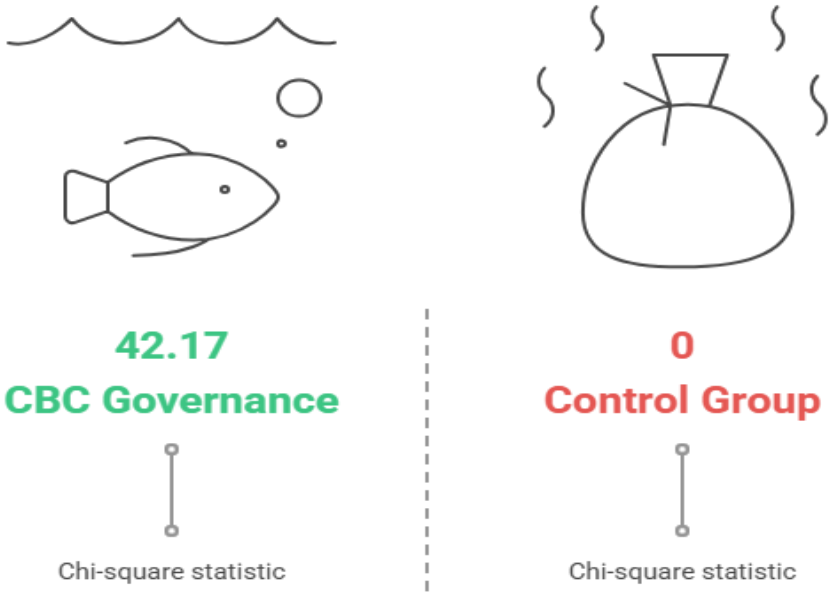

Figure 2. Personal Responsibility for Reef Health

Analysis of the survey data regarding environmental stewardship utilized a Chi-square test for independence. A statistically significant association was found between management type (CBC vs. Control) and the reported level of personal responsibility for reef health ($\chi^2(2, N=120) = 42.17$, $p < 0.001$). This result indicates that the CBC governance model is strongly correlated with enhanced community stewardship, which is a critical social prerequisite for sustainable conservation.

A Pearson correlation analysis was performed to explore the relationship between governance factors and ecological outcomes within the six CBC sites. A strong, positive correlation was identified between the "number of years the CBC program was operational" and the mean live coral cover ($r = 0.88$, $p < 0.05$). This suggests that the ecological benefits of community conservation are cumulative and that ecosystem recovery requires long-term, sustained management efforts.

A second analysis explored the relationship between socioeconomic perceptions and governance effectiveness, derived from key informant interviews. Data indicated a significant positive correlation between the perceived "equity of benefit sharing" from tourism and the self-reported "level of active participation" in enforcement ($r = 0.76$, $p < 0.01$). This highlights a critical socio-ecological feedback loop: effective conservation appears to be functionally dependent on communities perceiving the governance system as fair and beneficial.

Qualitative data from the semi-structured interviews and Focus Group Discussions (FGDs) provided rich, contextual explanations for the quantitative results. In "*Pulau Harapan*," a highly successful CBC case study, informants consistently attributed their success to strong local leadership and transparent financial management. As one community leader stated, "The revenue from the tourism mooring buoys is publicly announced... everyone knows where the money goes back into restoration and the school fund. There is trust."

Conversely, in "*Pulau Pairi*," a community struggling with its CBC program despite similar ecological potential, informants described significant internal conflicts and institutional friction. "We try to enforce the no-take zone, but large tourism operators from Jakarta ignore us," explained a local fisher. "The regulations are unclear, and we feel we have no real authority. It is hard to stay motivated when the rules are not respected by outsiders."

The narratives from "*Pulau Harapan*" explain the mechanism behind its high ecological scores. The establishment of clear rules, coupled with a transparent and equitable benefit-sharing mechanism from eco-tourism, has generated strong community buy-in. This buy-in translates directly into effective enforcement and collective action. The "trust" mentioned by the informant is the critical social capital that fuels the program's sustainability and resilience against external pressures.

The data from "*Pulau Pari*" illustrate the critical barriers to CBC success. The qualitative findings point to a failure of co-management, where the community's de facto authority is undermined by more powerful external economic actors and a lack of policy harmonization. This perceived powerlessness leads to a breakdown in collective action and enforcement, allowing reef degradation to continue despite the existence of a formal CBC program. This explains why its ecological metrics, while better than control sites, lag significantly behind "*Pulau Harapan*."

The synthesis of quantitative data provides unambiguous evidence that the CBC management model in Kepulauan Seribu is associated with significantly improved ecological conditions. Reefs under community stewardship demonstrate double the live coral cover and substantially higher fish biomass compared to unmanaged sites. This strongly suggests that community-based action can effectively mitigate local stressors and foster ecosystem resilience, even in a high-pressure environment near a major metropolis.

The qualitative and correlational data interpret *how* these results are achieved. The ecological success is not automatic but is mediated by the quality of local governance. The findings demonstrate that CBC effectiveness is contingent upon specific social factors: strong leadership, high levels of trust, clear rules, and, most critically, the establishment of transparent mechanisms that ensure conservation benefits are shared equitably. Where these social and institutional factors are weak, conservation outcomes are compromised.

This study's findings provide robust, quantitative evidence of the positive ecological impacts associated with Community-Based Conservation (CBC) in Kepulauan Seribu. The primary ecological results are stark: reefs under active community management demonstrated a mean live coral cover (42.8%) more than double that of adjacent, non-managed control sites (21.3%). This objective biophysical difference underscores a significant, tangible outcome of localized conservation efforts in a highly pressured marine environment.

The ecological improvements were not limited to benthic structure. A parallel and equally significant finding was observed in the reef fish assemblages. CBC-managed sites supported a mean fish biomass (1250.4 kg/ha) vastly exceeding that of control sites (680.7 kg/ha). The inferential statistical analysis ($p < 0.001$ for both LCC and biomass) confirms these differences are not products of chance. This quantitative success forms the central ecological validation of the CBC models operating within the National Park.

Socioeconomic data corroborated the ecological findings, revealing a profound difference in community engagement and stewardship. A high percentage of residents in CBC communities (82%) reported active participation in conservation, coupled with a near-universal sense of personal stewardship (91%). This contrasts dramatically with control sites, where participation was minimal (15%) and attitudes of resignation were common. The Chi-square analysis (\chi^2 = 42.17) confirms this strong association between the CBC model and the cultivation of social prerequisites for conservation.

The correlational and qualitative data provided the mechanisms explaining *how* these results were achieved. Two correlations were particularly illuminating: the link between program longevity and higher LCC ($r = 0.88$), and the critical relationship between perceived benefit-sharing equity and active participation ($r = 0.76$). The case studies of "*Pulau Harapan*" (success through trust) and "*Pulau Pari*" (conflict and powerlessness) further demonstrated that the *quality* of internal governance, not just the existence of a program, is the ultimate determinant of socio-ecological success.

The ecological successes documented here align directly with seminal case studies that established the potential of community-based marine management. The pronounced increases in fish biomass and live coral cover are consistent with the long-term outcomes observed in well-documented LMMAs (Locally Managed Marine Areas) in the Pacific and the Philippines, such as those analyzed by Cinner and colleagues. Our findings strongly support the hypothesis that when local communities are empowered as primary stewards, they can effectively mitigate local stressors and foster ecosystem recovery, reinforcing the global applicability of this conservation paradigm.

These results, however, also contribute to the more critical body of conservation literature by illustrating specific failure points. The struggles documented in "*Pulau Pari*" characterized by institutional conflict and the overpowering influence of external economic actors mirror findings from studies that highlight elite capture and the inability of local institutions to withstand intense market pressures. Our research confirms that CBC is not a guaranteed solution; it is a highly contingent process, and its "success" is fragile, just as the critical literature predicts.

The primary distinction of this study lies in its urban-proximate context. Much of the foundational literature on Indonesian co-management, for example in Raja Ampat or Wakatobi, focuses on remote, subsistence-based communities where fisheries are the dominant economic driver. Our findings from Kepulauan Seribu, an area dominated by mass tourism and intense urban pollution from Jakarta, address a significant gap. We demonstrate that CBC *can* function in these high-pressure, market-integrated environments, a finding of increasing relevance for coastal zones globally.

The strong correlation between perceived equity and participation ($r = 0.76$) provides robust empirical validation for foundational theories of common-pool resource management. This finding directly reflects the institutional design principles articulated by Elinor Ostrom, particularly those concerning the congruence between rules and local conditions, and the importance of equitable benefit distribution. Our study serves as a direct marine case study validating these socio-ecological governance principles, showing they hold true even amidst the complex tourism-driven economy of Kepulauan Seribu.

The quantitative results signify that localized, community-level actions can create tangible "islands of resilience." In the context of Kepulauan Seribu, which faces overwhelming regional pressures from Jakarta Bay's pollution, the fact that CBC sites perform significantly better signifies that mitigating *local* stressors (like anchor damage, destructive fishing, and tourism impacts) has a measurable effect (Orejas dkk., 2025). It is a sign of practical hope, indicating that communities are not helpless in the face of environmental degradation.

The findings, taken as a whole, signify that coral reef conservation is fundamentally a governance challenge, not merely a technical or biological one. The stark difference in ecological health between sites was not driven by different biological potential but by different human systems. The health of the coral (LCC 42.8%) is a direct, physical manifestation of the health of the community's institutions specifically, their levels of trust, equity, and collective-action capacity, as revealed in the "*Pulau Harapan*" case.

The divergence between the "*Pulau Harapan*" and "*Pulau Pari*" case studies signifies that "Community-Based Conservation" as a label is insufficient and potentially misleading (Williams dkk., 2025). A program's mere existence on paper, or its formal establishment by an NGO, is not a predictor of success. The true variable is the *quality* of governance and the *authenticity* of community empowerment. This study signifies that implementation, institutional design, and local sociopolitical dynamics are paramount.

The strong positive correlation between the number of operational years and live coral cover ($r = 0.88$) is a critical finding. It signifies that ecological recovery is a slow, cumulative process that unfolds over decadal timescales. This directly challenges the short-term, project-based funding cycles (e.g., 1-3 years) common to many government and NGO interventions. The significance is clear: sustainable conservation requires long-term institutional and financial commitment, matching the timescale of ecological processes, not administrative ones.

The primary implication of these findings is for national and regional marine policy. The demonstrable success of CBC sites provides a clear "proof of concept" for the Ministry of Marine Affairs and Fisheries and the National Park Authority (Kemarau dkk., 2025). The "so-what" is that investments in strengthening co-management frameworks are likely to yield higher returns on conservation (in terms of LCC and biomass) than purely top-down enforcement or technical-fix projects, such as artificial reefs, that do not address underlying governance failures.

The findings hold a powerful implication for conservation practitioners and non-governmental organizations. The data showing the "equity-participation" linkage ($r = 0.76$) is prescriptive. It

implies that project designs must move beyond technical training (e.g., monitoring techniques) and prioritize the establishment of robust, transparent, and equitable governance mechanisms from the outset. The "so-what" for NGOs is that they must act as facilitators of social processes, not just as technical advisors.

A significant implication exists for the private sector, particularly tourism operators within the National Park. The "*Pulau Pari*" case study, where conflict with tourism operators undermined local enforcement, serves as a stark warning (Mason dkk., 2025). The implication is that the current, often unregulated, model of tourism is in direct conflict with conservation and is, therefore, unsustainable. A new operational model, likely involving formal co-management agreements and mandatory contributions to community conservation funds (as seen in "*Pulau Harapan*"), is required for the industry's own long-term viability.

The broader implication for conservation science is the re-confirmation that socio-ecological systems must be studied as integrated wholes. This study's strength came from coupling biophysical (LIT, UVC) and socioeconomic (surveys, interviews) data (Apprill & Salerno, 2025). This implies that MPA effectiveness models that rely solely on ecological variables (e.g., size, age) are inherently incomplete. Future models must integrate and more heavily weight governance-quality metrics to accurately predict and understand conservation outcomes.

The observed doubling of live coral cover is best explained by the *mechanism* of effective local mitigation. Interviews with "*Pulau Harapan*" members described active enforcement against anchor dropping on reefs and the cessation of local destructive fishing. While control sites are subject to the same regional water quality, they lack this layer of fine-scale, localized protection. The lower algae cover (18.5% vs 39.7%) is explained by the higher fish biomass, specifically the recovery of herbivorous fish populations, which actively graze the reef and keep algae in check.

The significantly higher fish biomass (1250.4 kg/ha) is a direct, predictable outcome of effective gear restrictions and the enforcement of small no-take zones (NTZs) within the CBC areas. Key informants explained that while these NTZs are small, they are respected, allowing them to function as reproductive reservoirs. This leads to the "spillover" effect, which explains why CBC fishers reported more stable catches. The higher biomass is a direct result of enforced rules.

The remarkable 91% reported stewardship in CBC communities is explained by the psychological impacts of empowerment and ownership. The *act* of participating in monitoring, managing funds, and creating rules as described in the surveys fosters a fundamental identity shift from a passive resource *user* to an active resource *steward* (Sebastian dkk., 2025). This stewardship is not an innate cultural trait but a *product* of the governance model itself.

The stark divergence between the "*Pulau Harapan*" and "*Pulau Pari*" case studies is explained by their different institutional responses to tourism. "*Pulau Harapan*" successfully channeled the new economic driver of tourism, using revenue from mooring buoys to fund restoration and community projects, creating a virtuous cycle (Chen dkk., 2025). "*Pulau Pari*" failed to capture these benefits; external operators bypassed the community, leading to conflict, perceived powerlessness, and a breakdown of collective action. The *economic and institutional structure*, not the ecological potential, was the causal factor.

The most immediate recommendation is for on-the-ground management (Cabanillas-Terán dkk., 2025). The National Park Authority and supporting NGOs should actively work to scale the successful governance model of "*Pulau Harapan*." This involves strengthening the *de jure* legal authority of CBC groups, providing training in financial management and transparency, and facilitating binding agreements with tourism operators to ensure equitable benefit sharing, thereby addressing the primary failure point seen in "*Pulau Pari*."

The findings call for a shift in the role of the National Park Authority, from a traditional enforcement body to a *co-management facilitator*. The Park's role should be to legally empower the community groups, act as an honest broker in mediating conflicts between communities and external operators, and provide the technical and legal backstop for community-led enforcement (Alemu I, 2025). This "assisted" co-management model is the clear pathway to scaling success.

Future research must address the limitations of this cross-sectional study. A longitudinal monitoring program is essential (Yavarmoghadam dkk., 2025). The "now-what" for science is to track these sites over the next decade, particularly through inevitable coral bleaching events. This would allow a robust test of the critical hypothesis: do these well-governed, resilient *social* systems translate into higher ecological *resilience* and post-bleaching recovery?

Further research should also move from "does it work?" to "what *specific designs* work best?" A comparative study of different benefit-sharing models, rule structures, and leadership dynamics across multiple CBCs would be invaluable. Future studies could quantitatively model the *thresholds* of success for example, what level of tourism revenue is required to incentivize conservation, and what specific governance rules are most effective at preventing elite capture? This would provide highly actionable, design-oriented recommendations for conservation policy.

CONCLUSION

This research identified a direct, quantifiable link between the quality of local governance and the ecological success of coral reef conservation in Kepulauan Seribu. The most distinct finding is that Community-Based Conservation (CBC) sites demonstrated significantly superior ecological health specifically, more than double the live coral cover (42.8% vs. 21.3%) and substantially higher reef fish biomass (1250.4 kg/ha vs. 680.7 kg/ha) compared to non-managed control sites. This ecological success was found to be contingent not merely on the existence of a program, but on specific social factors, including high levels of community trust, perceived equity in benefit-sharing, and strong local leadership, as evidenced by the positive correlation ($r = 0.76$) between equity and participation.

The primary contribution of this study is both conceptual and methodological, providing a robust validation of the socio-ecological systems (SES) approach in a novel context. Conceptually, it fills a significant gap by demonstrating that CBC models can effectively mitigate local stressors and foster resilience even in a high-pressure, urban-proximate, and tourism-dominated environment a context often overlooked in favor of remote, subsistence-based communities. Methodologically, the mixed-methods design, which integrated quantitative ecological surveys with qualitative institutional analysis, proved essential in moving beyond *if* conservation worked to explaining *why* it succeeded (e.g., "*Pulau Harapan*") or faltered (e.g., "*Pulau Pari*").

The findings of this study are, however, limited by their cross-sectional nature, providing a snapshot of ecological and social conditions rather than a longitudinal trajectory. Future research should therefore prioritize long-term monitoring of these sites to assess their resilience and recovery pathways, particularly following major disturbances such as coral bleaching events. Furthermore, a critical next step is to move from comparative validation to prescriptive design, requiring future studies to investigate the specific thresholds and mechanisms of governance (e.g., "what specific benefit-sharing models are most effective at preventing elite capture?") to provide highly actionable policy recommendations.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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