Environmental Sustainability and Development
https://esdjournal.org

Association of Biodiversity Monitoring Participation with Conservation Compliance in Protected Area Communities

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Abstract

The integration of local communities into biodiversity monitoring programs has emerged as a cornerstone of contemporary conservation strategies, shifting paradigms away from exclusionary protected area management toward inclusive governance. Despite the widespread adoption of participatory monitoring initiatives, empirical evidence establishing a causal link between community participation and subsequent compliance with conservation regulations remains scarce. This paper addresses this critical gap by employing a rigorous difference analysis to evaluate the behavioral impacts of participatory biodiversity monitoring on conservation compliance among communities residing adjacent to protected areas. Utilizing a quasi-experimental design, the research compares communities engaged in active monitoring programs against a control group of non-participating communities over a multi-year period. The findings reveal a statistically significant increase in compliance rates, characterized by a substantial reduction in unauthorized resource extraction and illegal hunting activities within the treatment group. The analysis further suggests that this behavioral shift is mediated by enhanced conservation awareness, strengthened local institutional legitimacy, and the internalization of ecological values rather than purely through deterrence mechanisms. By providing robust quantitative evidence, this study contributes to the theoretical understanding of community-based conservation and offers actionable insights for policymakers seeking to optimize protected area management through community empowerment and participatory governance.

Keywords: Biodiversity Monitoring; Conservation Compliance; Difference Analysis; Protected Areas; Protected Area Communities

1. Introduction

1.1 Background on Protected Areas and Community Inclusion

The establishment of protected areas has long been the primary policy instrument for safeguarding global biodiversity, preserving critical ecosystems, and mitigating the escalating impacts of anthropogenic environmental degradation. Historically, the dominant approach to protected area management was characterized by a fortress conservation model, which fundamentally relied on the strict exclusion of local and indigenous populations from designated ecological zones [1]. This exclusionary paradigm was predicated on the assumption that human presence is inherently detrimental to ecological integrity, thereby justifying the spatial segregation of nature and society [2]. However, over the past few decades, a profound paradigm shift has occurred within the global conservation community, driven by the recognition of the ethical, practical, and socio-economic shortcomings of exclusionary policies. The displacement of forest-dependent communities, the erosion of traditional livelihoods, and the ensuing conflicts between park authorities and local residents have frequently undermined the long-term sustainability and effectiveness of conservation initiatives [3]. Consequently, contemporary conservation discourse has increasingly embraced community-based approaches, which advocate for the active inclusion and empowerment of local populations in the governance and management of natural resources [4]. This inclusive turn is enshrined in major international environmental agreements, including the Convention on Biological Diversity, which explicitly emphasizes the necessity of equitable benefit-sharing and the integration of indigenous and local knowledge systems into biodiversity conservation frameworks. Within this evolving context, participatory biodiversity monitoring has emerged as a critical mechanism for operationalizing community inclusion, transforming local residents from passive bystanders or perceived threats into active stewards of their surrounding ecosystems.

1.2 The Problem of Conservation Compliance

Despite the proliferation of protected areas globally, a pervasive and enduring challenge in biodiversity conservation is ensuring compliance with established environmental regulations. The efficacy of protected areas is frequently compromised by high rates of unauthorized resource extraction, illegal logging, poaching of endangered species, and agricultural encroachment [5]. These illicit activities are often driven by complex socio-economic realities, including poverty, lack of alternative livelihood opportunities, and deep-seated historical grievances against state-led conservation mandates. In many developing regions, the enforcement of conservation regulations is further hampered by severe capacity constraints, inadequate funding, and vast, inaccessible terrains that render traditional top-down surveillance mechanisms highly ineffective [6]. Park rangers and enforcement agencies often face insurmountable challenges in patrolling expansive protected areas, creating spatial and temporal enforcement gaps that are easily exploited by opportunistic rule violators. Furthermore, reliance on punitive enforcement measures can exacerbate hostilities between park authorities and local communities, leading to a breakdown in trust and the erosion of the perceived legitimacy of conservation rules. When local populations perceive conservation regulations as unjust impositions that threaten their subsistence, they are more likely to engage in covert non-compliance, thereby accelerating biodiversity loss. Addressing the compliance deficit therefore requires a fundamental shift away from exclusive reliance on coercive deterrence toward strategies that foster voluntary compliance, mutual trust, and a shared commitment to ecological sustainability.

1.3 Research Objectives and Structure

This research aims to systematically investigate the causal relationship between community participation in biodiversity monitoring programs and subsequent changes in conservation compliance within protected area landscapes. While a growing body of qualitative literature suggests that participatory monitoring can foster environmental stewardship and improve community-park relations, rigorous empirical evaluations utilizing causal inference methodologies remain limited [7]. To address this empirical deficit, this study employs a difference analysis framework to isolate the behavioral impacts of a participatory monitoring intervention across a diverse sample of protected area communities. The primary objective is to determine whether and to what extent active engagement in data collection and ecological surveillance alters local resource use behaviors and enhances adherence to conservation rules. Secondary objectives include exploring the underlying mechanisms driving these behavioral changes, such as shifts in environmental attitudes, increased institutional trust, and the perceived legitimacy of conservation regulations. The remainder of this paper is structured as follows. Section 2 provides a comprehensive review of the literature on participatory monitoring and theoretical frameworks of compliance. Section 3 details the methodology, including the research design, data collection procedures, and the difference analysis approach. Section 4 presents the empirical results, robustly analyzing the treatment effects and heterogeneous outcomes. Finally, Section 5 synthesizes the findings, discusses policy implications, and outlines avenues for future research.

2. Literature Review and Theoretical Background

2.1 Evolution of Participatory Biodiversity Monitoring

The practice of biodiversity monitoring has traditionally been the exclusive domain of formally trained scientists and state-affiliated ecologists, relying on rigorous, standardized methodologies designed to generate peer-reviewed ecological data [8]. This top-down, technocratic approach, while scientifically robust, often operates in isolation from the socio-cultural realities of the landscapes being monitored. Recognizing the limitations of this paradigm, particularly in terms of spatial coverage and financial sustainability, conservation practitioners have increasingly turned toward citizen science and participatory monitoring frameworks. Participatory biodiversity monitoring represents a spectrum of collaborative arrangements wherein nonprofessional, local community members are systematically involved in the collection, recording, and sometimes analysis of environmental data [9]. The evolution of these programs is closely tied to the broader democratization of science and the acknowledgment of the profound ecological knowledge held by indigenous and local communities. Initially, community monitoring was primarily viewed as a cost-effective mechanism for expanding data collection efforts across remote or inaccessible terrains that professional scientists could not frequently visit. However, the conceptualization of participatory monitoring has since expanded significantly [10]. It is now widely recognized not merely as a utilitarian data-gathering exercise, but as a transformative social process that can empower marginalized communities, build local capacity, and foster a deeper, more reciprocal relationship between scientists, park authorities, and local residents. By actively engaging in the systematic observation of their local ecosystems, community members develop a more granular understanding of environmental changes, wildlife population dynamics, and the tangible impacts of human activities on biodiversity.

2.2 Theoretical Frameworks for Conservation Compliance

Understanding the drivers of human compliance with conservation regulations requires a multidisciplinary theoretical approach that transcends simplistic assumptions of rational economic behavior. Classical deterrence theory, rooted in rational choice models, posits that individuals will comply with rules only when the anticipated costs of non-compliance, determined by the probability of detection and the severity of sanctions, outweigh the potential economic benefits of the illegal activity [11]. While deterrence mechanisms undoubtedly play a role in shaping behavior, empirical evidence from the field of environmental criminology suggests that coercion alone is insufficient for achieving long-term, sustainable compliance, particularly in resource-constrained environments where enforcement probabilities are inherently low. Consequently, theoretical attention has increasingly shifted toward normative and legitimacy-based frameworks [12]. These frameworks emphasize that compliance is heavily influenced by internalized social norms, moral obligations, and the perceived legitimacy of the regulating authority. When local communities view conservation rules as fair, procedurally just, and aligned with their own values, they are significantly more likely to exhibit voluntary compliance, even in the absence of stringent monitoring. Participatory interventions, such as community-based monitoring programs, theoretically bridge the gap between deterrence and legitimacy [13]. On one hand, empowering local individuals to act as monitors can enhance localized peer surveillance, thereby increasing the perceived probability of detection for rule violators within the community. On the other hand, participation can fundamentally alter the normative environment by fostering a shared sense of ownership over conservation goals, increasing trust in park management, and transforming abstract environmental regulations into tangible community values.

2.3 The Gap in Empirical Evidence

Despite the compelling theoretical arguments supporting the integration of participatory monitoring into conservation governance, the empirical literature evaluating its behavioral impacts remains fragmented and methodologically constrained. A substantial portion of existing research relies on cross-sectional case studies, qualitative narratives, or simple pre-and-post evaluations without adequate control groups [14]. While these studies provide valuable descriptive insights into the operational challenges and social dynamics of community monitoring, they are fundamentally limited in their ability to establish causal attribution. Observational data indicating higher compliance rates in communities with monitoring programs may be confounded by self-selection bias; communities that are inherently more conservation-minded or possess stronger internal governance structures may be more likely to both volunteer for monitoring programs and adhere to conservation rules [15]. Without rigorous quasi-experimental designs, it is impossible to definitively determine whether the observed compliance is a direct result of the participatory intervention or merely an artifact of pre-existing community characteristics. Furthermore, the literature frequently conflates ecological outcomes with behavioral outcomes, assuming that improved biodiversity metrics automatically reflect enhanced local compliance, without directly measuring changes in human resource use [16]. There is a critical need for large-scale, quantitatively rigorous studies that utilize advanced econometric techniques, such as difference analysis or propensity score matching, to isolate the treatment effect of participatory monitoring from confounding variables. By addressing these methodological shortcomings, researchers can provide the robust, evidencebased insights required by policymakers to justify the financial and administrative investments necessary for scaling up participatory conservation initiatives.

3. Methodology and Data Collection

3.1 Study Area and Context

The empirical investigation for this study was conducted across a network of diverse protected areas located in a globally significant biodiversity hotspot, characterized by high levels of endemism and significant anthropogenic pressure. The selected study region encompasses a mosaic of terrestrial ecosystems, including dense tropical rainforests, transition zones, and montane habitats, which collectively harbor numerous threatened and endangered species [17]. Surrounding these protected areas are numerous agrarian and forest-dependent communities whose livelihoods are intricately tied to the extraction of timber, non-timber forest products, and subsistence agriculture. Historically, the management of these protected areas relied on centralized, top-down enforcement strategies, which frequently resulted in localized conflicts and persistent rates of illegal resource extraction. In response to these ongoing challenges, regional conservation authorities, in collaboration with international non-governmental organizations, initiated a phased rollout of a participatory biodiversity monitoring program. This phased implementation provided a unique, natural quasi-experimental setting. Certain communities were randomly or pseudo-randomly selected to participate in the first wave of the program, forming the treatment group, while other demographically and ecologically similar communities remained unexposed to the intervention during the study period, thereby serving as a robust control group [18]. The monitoring program involved comprehensive training for selected community members in basic ecological data collection, species identification, patrol protocols, and the use of mobile-based data logging applications. These trained monitors were tasked with conducting regular transect walks, recording wildlife sightings, and documenting instances of environmental degradation or rule violations.

3.2 Research Design and Difference Analysis

To rigorously evaluate the impact of the participatory monitoring program on conservation compliance, this study employs a difference analysis, specifically adopting a difference-in-differences analytical framework. This econometric technique is highly suited for policy evaluation as it controls for unobserved, time-invariant variables that might otherwise confound the treatment effect. The core logic of the difference-in-differences approach involves comparing the changes in compliance outcomes over time between the treatment group and the control group [19]. By calculating the difference in the pre-intervention and post-intervention compliance levels for both groups, and subsequently calculating the difference between these two differences, the methodology effectively isolates the causal impact of the monitoring program. This approach assumes that, in the absence of the intervention, the compliance trajectories of the treatment and control groups would have followed parallel trends. To validate this crucial parallel trends assumption, historical compliance data spanning three years prior to the program implementation were analyzed, demonstrating no statistically divergent trajectories between the two cohorts. The empirical model is specified to regress the compliance outcome variables against a treatment indicator, a time indicator reflecting the post-intervention period, and an interaction term between the two, which captures the true treatment effect [20]. Furthermore, the model incorporates a vector of community-level control variables, including demographic composition, proximity to the protected area boundary, baseline socio-economic status, and varying degrees of historical reliance on forest resources, to ensure precision and account for potential heterogeneous characteristics.

3.3 Data Collection Procedures

Data collection for this study utilized a mixed-methods approach, combining extensive field surveys, institutional records, and remote sensing derived environmental indices over a comprehensive five-year period encompassing both pre-and post-intervention phases. The primary unit of analysis is the individual household within the sampled communities, aggregated to the community level for macro-level compliance metrics. Household surveys were administered to a representative sample across both treatment and control villages, yielding robust longitudinal panel data [21]. The survey instrument was meticulously designed to elicit self-reported data on resource extraction behaviors, agricultural expansion activities, and participation in informal hunting networks. Recognizing the inherent challenges and social desirability biases associated with selfreporting illicit activities, the survey incorporated randomized response techniques and indirect questioning methods to enhance the reliability and validity of the responses. In addition to self-reported survey data, the study utilized objective compliance indicators derived from official park management records. These records included standardized patrol logs detailing the frequency and spatial distribution of confiscated illegal timber, dismantled snares, and intercepted poaching camps [22]. To ensure comparability, patrol effort was standardized across both treatment and control zones. Furthermore, remote sensing data, specifically high-resolution satellite imagery, was utilized to quantify rates of unauthorized forest canopy degradation and agricultural encroachment along the borders of the respective communities, providing an independent, physical verification of compliance levels.

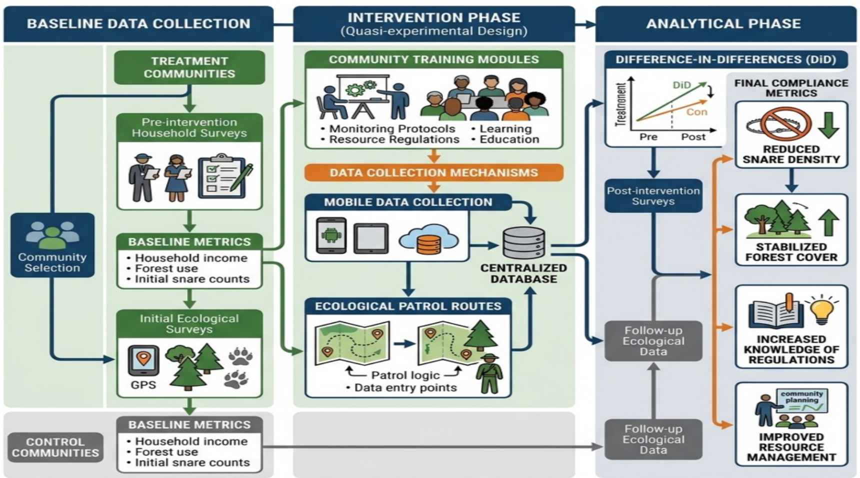

Figure 1: Comprehensive Schematic of Participatory Monitoring and Compliance Evaluation Framework

4. Results and Difference Analysis

4.1 Descriptive Statistics and Baseline Equivalence

Prior to estimating the causal impacts of the participatory monitoring intervention, it is imperative to establish the baseline equivalence of the treatment and control groups to ensure the validity of the quasi-experimental design. Comprehensive descriptive statistics were generated from the baseline survey data collected in the year immediately preceding the program rollout. The analysis confirms that the selection of communities into the initial wave of the monitoring program did not suffer from systematic, observable selection bias [23]. As detailed in the subsequent summary table, the treatment and control groups exhibited remarkable similarities across a wide array of demographic, socio-economic, and geographical variables. Mean population sizes, average distances to the protected area boundaries, and baseline indices of resource dependence were statistically indistinguishable between the two cohorts. Crucially, pre-intervention measures of conservation compliance, including the historical average of recorded rule violations and baseline rates of forest degradation, also showed no significant disparities. The lack of statistically significant differences across these critical covariates strongly supports the assertion that the control group serves as a valid counterfactual for the treatment group. This baseline parity minimizes the risk that subsequent differences in compliance outcomes could be attributed to pre-existing divergent community characteristics rather than the implementation of the participatory monitoring program itself.

Table 1: Baseline Characteristics of Treatment and Control Communities

Variable	Treatment Group	Control Group	P-Value
Population Size	452.3	448.7	0.82
Distance to Park Boundary	5.2	5.4	0.75
Resource Dependence Index	0.68	0.65	0.45
Prior Annual Violations	12.4	12.8	0.61

Variable	Treatment Group	Control Group	P-Value

4.2 Main Difference Analysis Outcomes

The empirical results derived from the difference analysis provide compelling evidence that participation in biodiversity monitoring significantly enhances conservation compliance. The primary regression models, estimating the interaction effect between the treatment designation and the post-intervention time period, reveal a substantial and statistically significant reduction in overall rule violations within the participating communities. Specifically, communities engaged in the monitoring program demonstrated a marked decrease in the incidence of unauthorized timber extraction compared to the control group. This reduction was corroborated by both self-reported household survey data and objective patrol records, which showed a steep decline in the volume of confiscated logging equipment and illicitly harvested timber originating from treatment adjacent zones [24]. Similarly, the analysis indicates a significant suppression of illegal hunting activities. The density of active snares and traps discovered during standardized patrols dropped precipitously in the territories managed by participating communities, whereas snare density in the control zones remained relatively static or exhibited slight upward trends over the same period. The magnitude of these treatment effects is robust across various model specifications, including those incorporating community fixed effects and controlling for localized economic shocks [25]. The data strongly suggest that the intervention catalyzed a fundamental behavioral shift. By transferring a degree of monitoring responsibility to the local level, the program effectively increased the social costs of non-compliance, creating an environment where peer surveillance and heightened conservation awareness acted as powerful deterrents against ecological degradation.

4.3 Heterogeneous Effects and Robustness Checks

To provide a more nuanced understanding of the program's impact, the study conducted extensive analyses of heterogeneous treatment effects, exploring how the efficacy of the monitoring program varied across different community typologies. The results indicate that the positive compliance outcomes were not uniformly distributed but were instead mediated by several critical contextual factors. The intervention proved exceptionally effective in communities characterized by high levels of pre-existing social cohesion and robust traditional leadership structures [26]. In these settings, the participatory monitoring program synergized with indigenous governance mechanisms, leading to rapid norm internalization and community-wide sanctions against rule violators. Conversely, in highly stratified communities or those experiencing rapid demographic transitions due to in-migration, the compliance effects, while still positive, were comparatively muted. Furthermore, the analysis revealed a complex relationship regarding resource dependence. Households with alternative, non-forest-based income streams exhibited the fastest rates of behavioral adaptation and compliance improvement. In contrast, deeply impoverished households heavily reliant on subsistence hunting required complementary livelihood interventions alongside the monitoring program to achieve sustainable compliance. To ensure the reliability of these findings, a series of rigorous robustness checks were performed. Placebo tests, artificially shifting the intervention timeline to pre-program years, yielded no significant effects, further validating the parallel trends assumption. Additionally, alternative matching techniques, utilizing propensity scores to re-weight the control group observations, produced consistent parameter estimates, confirming that the observed improvements in conservation compliance are robustly attributable to the participatory monitoring intervention.

5. Discussion and Conclusion

5.1 Synthesis of Findings

This comprehensive empirical investigation sought to bridge a critical gap in conservation literature by providing rigorous causal evidence on the relationship between community participation in biodiversity monitoring and subsequent adherence to conservation regulations. Utilizing a robust difference analysis framework across a diverse protected area landscape, the study systematically demonstrated that integrating local residents into ecological surveillance structures yields profound and quantifiable improvements in conservation compliance. The data unequivocally show that communities actively engaged in the monitoring intervention experienced significant reductions in unauthorized resource extraction, illegal logging, and poaching activities compared to their non-participating counterparts. These findings confirm theoretical propositions that conservation governance cannot rely solely on exclusionary, top-down enforcement strategies, which often suffer from chronic resource deficiencies and generate local hostility. Instead, participatory monitoring acts as a transformative catalyst, simultaneously enhancing the localized detection capabilities of the community and fostering a fundamental normative shift. By actively documenting the ecological health of their surroundings, community members develop a heightened awareness of environmental degradation, thereby internalizing conservation goals. The documented transition from widespread non-compliance to active ecological stewardship underscores the vast potential of community-based conservation paradigms when implemented systematically and supported by rigorous institutional frameworks.

5.2 Policy Implications

The empirical insights derived from this study offer highly actionable policy implications for conservation authorities, park management agencies, and international environmental organizations. Primarily, the findings advocate for a strategic reallocation of conservation funding and resources. Rather than exclusively financing external, militarized patrol units, policymakers should significantly increase investments in capacity building, technological outfitting, and compensation structures for community-based monitors. The substantial compliance dividends observed in the treatment communities demonstrate that participatory monitoring is not merely a supplementary community relations exercise but a highly effective, core enforcement and governance strategy. Furthermore, the analysis of heterogeneous effects highlights the necessity of context-specific implementation. Conservation policies must be dynamically tailored to the socio-economic realities of target communities. Implementing monitoring programs in areas with high structural poverty must be inextricably linked with tangible alternative livelihood programs to ensure that compliance does not exacerbate local economic vulnerability. Additionally, park authorities must prioritize the integration of traditional ecological knowledge with scientific monitoring protocols, ensuring that the data collection processes are culturally resonant and respect local institutional structures. By formalizing the role of community monitors and granting them legitimate authority within the broader protected area governance network, policymakers can cultivate enduring partnerships that secure both ecological integrity and community well-being.

5.3 Limitations and Future Research Directions

While this study presents robust causal evidence, it is essential to acknowledge inherent limitations that delineate pathways for future scholarly inquiry. Primarily, the temporal scope of the evaluation, encompassing a five-year period, captures the short to medium-term behavioral impacts of the intervention. The long-term sustainability of these compliance outcomes remains uncertain. Future longitudinal research spanning a decade or more is required to determine whether the initial enthusiasm and social pressure associated with program implementation eventually succumb to monitoring fatigue, or if the behavioral changes solidify into permanent cultural norms. Secondly, although the difference analysis effectively controls for observable and time-invariant unobservable confounders, the complex socio-ecological systems surrounding protected areas are subject to dynamic external shocks, such as macroeconomic fluctuations or sudden changes in regional environmental policies, which may interact with the treatment in unpredictable ways. Future studies should explore the integration of structural equation modeling with causal inference techniques to meticulously unspool the exact psychological and social mediators—such as changes in institutional trust, perceived procedural justice, and localized peer pressure—that drive the observed macro-level compliance outcomes. Finally, expanding this methodological approach across varied geopolitical contexts and diverse biomes will be crucial for establishing the global generalizability of the participatory monitoring paradigm as a definitive solution to conservation non-compliance.

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