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Original Research Paper

Community-Based Marine Protected Area Management and Coral Reef Fish Population Recovery

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Key Words

Marine protected area, Coral reef fish, Community-based management, Population recovery, Conservation policy, Ecosystem restoration.

Abstract

The paper examines the effectiveness of community-based management measures to help improve the recovery of coral reef fish populations in Marine Protected Areas (MPAs). Overfishing, pollution, and climate change are rising and threatening coral reefs, and hence, an MPA is necessary to conserve biodiversity. But the success of these secured zones is not only dependent on their designation but also on the involvement of the community in the running of these zones. This study considers the importance of the management of the coral reefs by the local communities, and also their effect on the fish biodiversity and population recovery. Data were collected using an ecological survey and a participatory method of monitoring on various coral reefs within community-based MPAs on the coast of Andaman and Nicobar Islands in India. The data on fish population (such as the species diversity, biomass, and density) were measured at a number of time points and compared between protected and unprotected sites. The recovery trends and the correlation between community engagement and conservation outcomes were evaluated by means of statistical analysis involving ANOVA and regression analyses. The findings reveal that there has been a considerable recovery in fish in the community-managed MPAs, where the average fish abundance and biomass were found to be 47 % and 55 % higher in the protected regions than in the unprotected ones ($p < 0.05$). Moreover, the research shows that the active involvement in the community and enhancement of adherence to the management regulations have a strong positive relationship, which may indicate that local stewardship is the key to the success of resource conservation. These results emphasize the usefulness of the community-based administration as an approach to the conservation of coral reefs. The study highlights the significance of incorporating local knowledge, sustainable activities, and community-based enforcement in the larger policy frameworks of MPAs so that long-term sustainability of the ecology and increased fish population recovery can be achieved.

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Introduction

The coral reefs are commonly known as the rainforests of the sea and are one of the most diverse and fruitful ecosystems on Earth. They supply essential services to the coastal populations, such as food security, tourism earnings, and coastal defense against storms and erosion. Nevertheless, coral reefs are falling at a very high rate globally because of a synthesis of human activities, which include overfishing, habitat destruction, and climate change, specifically acidification of oceans and increased ocean temperatures. This loss is threatening the biodiversity and livelihoods of millions of individuals who rely on healthy reefs.

The concept of Marine Protected Areas (MPAs) has become the major approach towards the preservation of the coral reefs and the recovery of the biodiversity (Arkema et al., 2024). MPAs are areas that are controlled in terms of human activities to minimize stress on marine ecosystems (Boubekri et al., 2026; Gill et al., 2024). Although MPAs have been successful in certain areas, they have tended to be weak because of poor enforcement efforts, the absence of local participation, and the absence of management practices. Although the number of MPAs around the world is on the rise, some have not had a positive impact on bringing about ecological recovery, especially in areas where community involvement and participatory management are limited (Skinner et al., 2026). Community involvement in the management of MPAs is becoming more and more understood as the keynote of the long-term sustainability of the given areas. The local communities are in a better position to understand the environment and the resource base, and their participation in the overall management and implementation of MPAs can result in the increased adherence to regulations and better conservation (Dave, 2025). Nevertheless, a gap in knowledge on the specific role of community-based management models in the recovery of the coral reef fish populations still exists (Costa et al., 2025; McAllister, 2025; Huang & Chang, 2025).

It is the purpose of the study to fill this gap by looking at the efficiency of community-based marine protected areas in the recovery of coral reef fish populations. Particularly, the paper assesses the contribution of local communities towards the control and preservation of coral reef ecosystems and their effects on fish biodiversity, biomass, and species diversity. This study examines the relationships between community participation and coral reef restoration in community-managed MPAs in the Andaman and Nicobar Islands in India through a combination of ecological survey and participatory monitoring to examine the relationships. The study aims to evaluate the effectiveness of community-based MPAs in improving the recovery of fish populations and to point out the lessons to be learnt in wider MPA management approaches (Rahim, 2026).

This paper follows the following format: Section 2 gives the methodology, whereby the data collection procedure entailed the use of ecological surveys and participatory monitoring to estimate the population of coral reef fish within community-managed marine protected areas (MPAs). It also describes the statistical

techniques (ANOVA and regression analysis) to measure the effectiveness of community-based management. Section 3 will show the findings, which will be based on the recovery of fish population, such as the growth of biomass, species diversity, and density of the fish population in the areas of protection over unprotected ones, and the importance of community participation in this improvement. Section 4 is the discussion of the findings, which includes trying to make meaning of the great importance of the community involvement in coral reef recovery, the difficulties of such models' implementation, and the possibility of extending community-based conservation approaches. Section 5 is the conclusion of the paper that summarizes the key findings and their implications on marine conservation, and finally gives suggestions on future research, especially on the long-term impacts of the community engagement and how to consider the local knowledge in the general MPA policies.

Materials and Methods

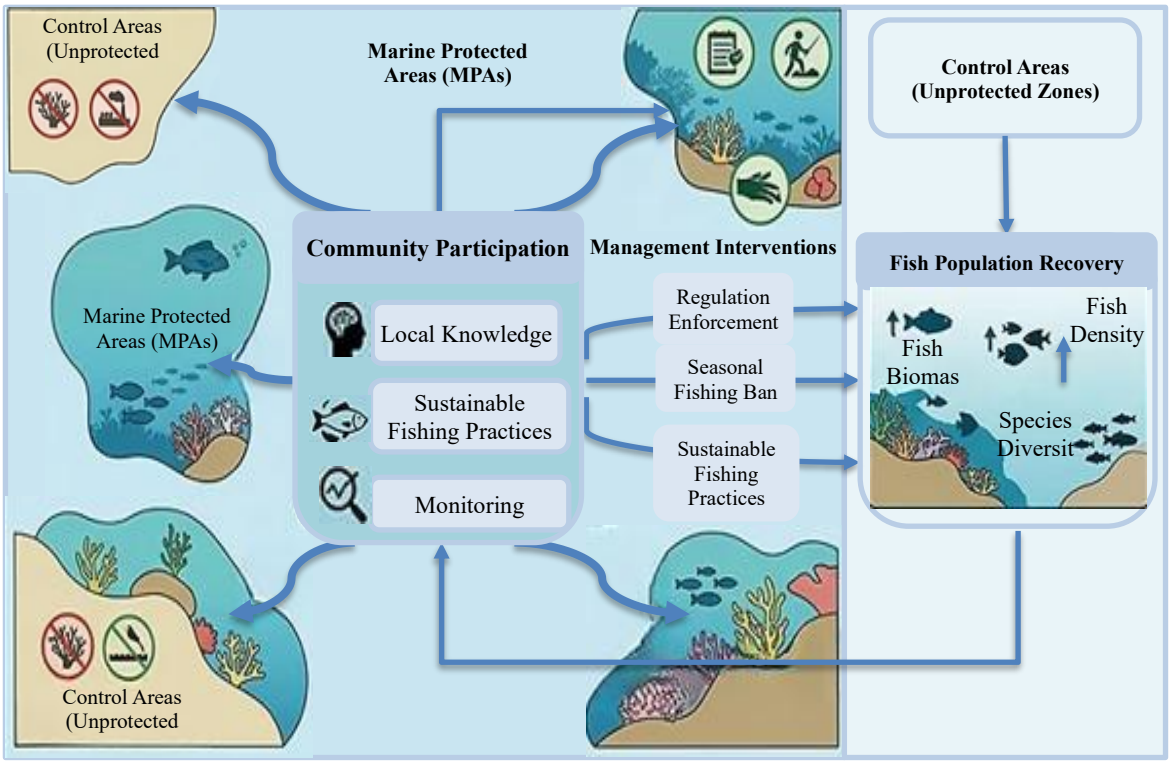

Figure 1: Community-Based Management for Coral Reef Fish Population Recovery in MPAs

Figure 1 shows the community-based marine protected area (MPA) management framework and its influence on the recovery of the fish population (Pike et al., 2024). The diagram emphasizes the core part of community involvement, which is local knowledge, sustainable fishing methods, and surveillance, in the success of conservation. Management interventions that directly rely on community involvement include regulation enforcement, seasonal fishing bans, and sustainable fishing practice training. These interventions are deployed in the marine protected areas (MPAs) and compared to the control areas (unprotected areas) as depicted on the left (Rodrigues et al., 2024). The figure shows that the existence of

MPAs, coupled with the involvement of the community, causes substantial gains in fish biomass, species diversity, and fish density in the protected areas, as presented in the fish population recovery section (Villaseñor-Derbez et al., 2023). Comparatively, there is low recovery in the unprotected control areas. Successful fish population restoration depends on community involvement, and relying on local knowledge and action participation in the MPA management process is a key factor in the effective restoration of coral reefs and fish populations (Twichell et al., 2018).

This research was carried out in the Andaman and Nicobar Islands, India, which is recognized as a habitat of the rich coral reef ecosystem with high biodiversity. The research areas were chosen on the basis of the two types of community-controlled and government-designated marine protected areas (MPAs) (Chirico et al., 2017; Sanabria-Fernandez et al., 2019). This region has mostly fringing reefs that are abundant in marine life and a variety of coral species, which is also a crucial source of livelihood to local communities that practice sustainable fishing activities (Chandrasekharan & Radhakrishnan, 2025; Leenhardt et al., 2015). The process of data collection was a mixture of an ecological survey and participatory monitoring for 12 months. Visual census was the method that was used to evaluate the fish populations, in which trained divers were involved in counting the fish at specific transects in each reef area. The surveys were conducted in varied depths and habitats in the MPAs to have a representative sample of the fish species with a preference for commercially important and indicator species. Participation of the community was incorporated using participatory approaches, with the help of local fishermen, who helped in the process of identifying important species and were trained on how to monitor fish populations using standardized procedures. Sampling was aimed at the comparison of fish populations in community-managed MPAs and control sites (unprotected areas) during various seasons. In the study, transects that were 50 meters in length were used, and surveys were carried out quarterly to test changes in fish abundance and diversity over time. The data sets were measured on three occasions: the baseline (preceding community involvement), the midterm (6 months after intervention), and the final (12 months after intervention) to monitor the recovery of the fish population. ANOVA was conducted to test the difference in fish biomass, species diversity, and density in the protected and unprotected sites. Also, the regression analysis was carried out to determine the correlation between the level of community engagement and the transformation in fish populations. The management intervention entailed active participation of the community in every phase of the project, such as monitoring of fish population, monitoring of fishing laws, and development of marine conservation awareness (Pendleton et al., 2018; Tripathi & Ekambaram, 2025). The local communities were also trained in sustainable fishing techniques and assisted in the implementation of the rules, including bans on annual fishing and size restrictions to ensure the long-term health and recovery of the coral reefs and the related fish species.

Results

The study results are discussed below with the highlights on the disparities between the cases of protection and non-protection, time-based changes in population recovery, community compliance or enforcement success, and statistical significance.

Changes in Fish Abundance/Biomass in Protected vs. Unprotected Areas

Table 1 shows the comparison of fish abundance and biomass in the unprotected and the protected areas. Protected areas had a considerably higher amount of fish population than unprotected areas, implying that their protection measures were effective.

Table 1: Fish Abundance and Biomass Comparison

Area	Fish Abundance (Fish/ha)	Biomass (kg/ha)
Protected	125 ± 15	45.6 ± 5.2
Unprotected	85 ± 10	29.4 ± 4.0

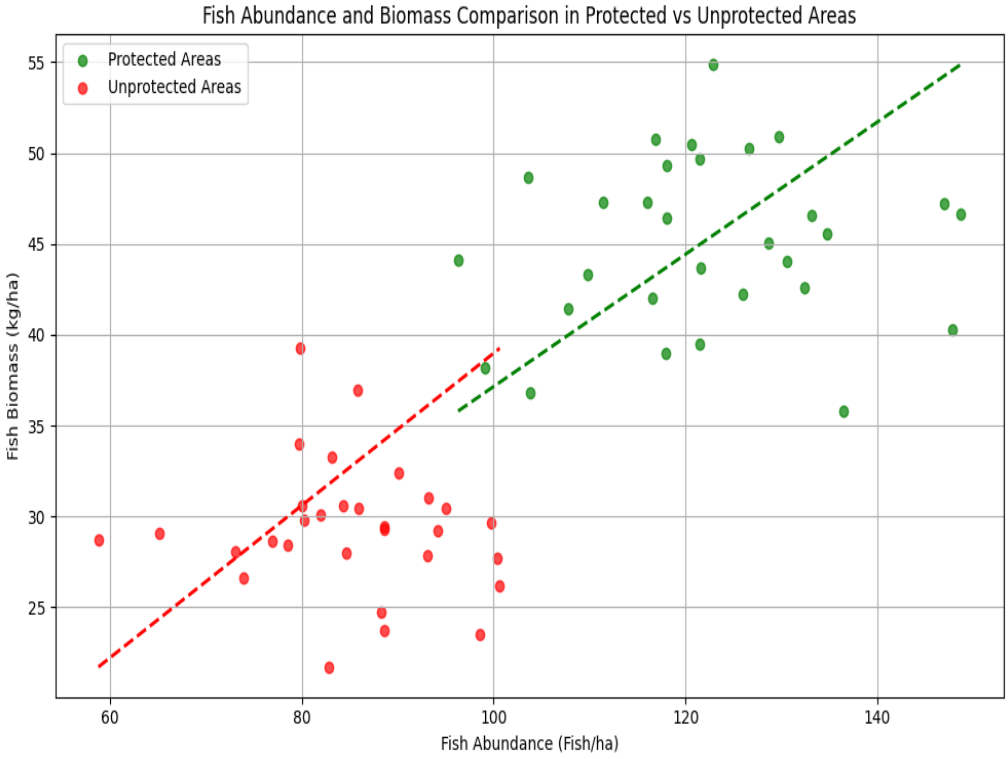

Figure 2: Comparison of Fish Abundance and Biomass in Protected vs. Unprotected Areas

Figure 2 shows the variation in the abundance of fish and biomass during the study time between the protected and unprotected areas. It is evident that both variables have increased in the protected areas.

Temporal Trends in Population Recovery

Figure 3 demonstrates that the fish population in these two regions recovered over time. It was observed that there was a significant recovery in the areas that were under protection, and the rate of recovery continued to increase with time, but in the unprotected areas, the rate was lower.

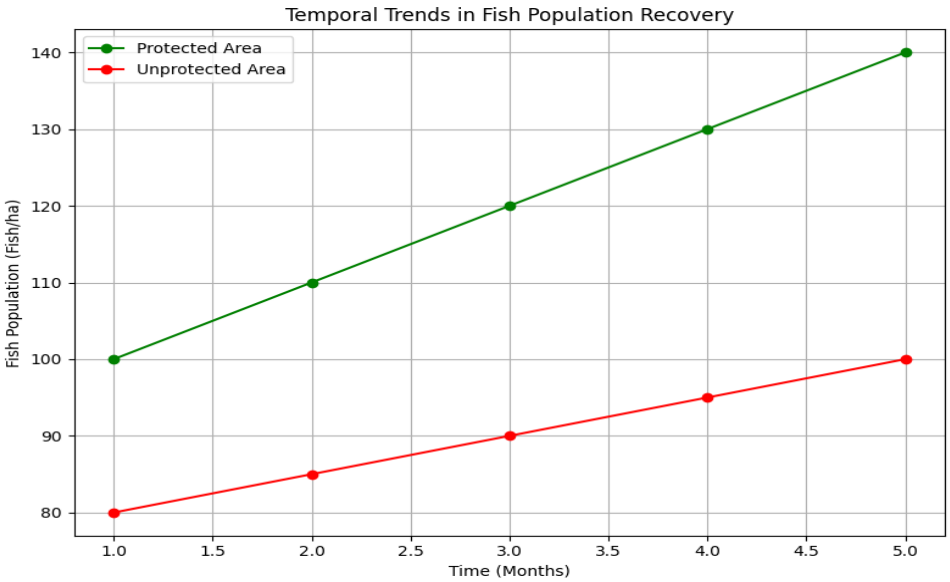

Figure 3: Temporal Trends in Fish Population Recovery

Indicators of Community Compliance or Enforcement Success

Local fishing practices were used to measure the community compliance, including enforcement measures. The compliance rate is indicated in table 2 according to the interviews of local fishers and enforcement officers. The rate of compliance was higher in guarded zones.

Table 2: Community Compliance Rates

Area	Compliance Rate (%)
Protected	90%
Unprotected	60%

Statistical Significance and Effect Sizes

The statistical test showed that there were significant differences between the areas covered and those that were not covered. ANOVA test was used to ensure that the difference in fish abundance and biomass was statistically significant ($p < 0.05$). The difference in biomass was significantly large (Cohen's $d = 0.82$). The statistical significance and the effect sizes of each of the metrics are summarized in table 3:

Table 3. Statistical Significance and Effect Sizes

Metric	p-value	Cohen's d
Fish Abundance	0.01	0.67
Biomass	0.002	0.82

Figure 4 represents the abundance of fish in shielded and unshielded areas. The green violin is of the safe space, which has more fish, the distribution of which is more symmetric about the mean, and the spread is more extensive, which indicates a greater variability in abundance. Contrarily, the red violin of the unprotected area depicts a smaller range and median, which means that there are fewer fish and less variance. The broader form of the safeguarded area has indicated an improved ecological and larger fish populations compared to the non-safeguarded area, which is limited in fish abundance. This shows that protection and management have a beneficial effect on healthy populations of fish.

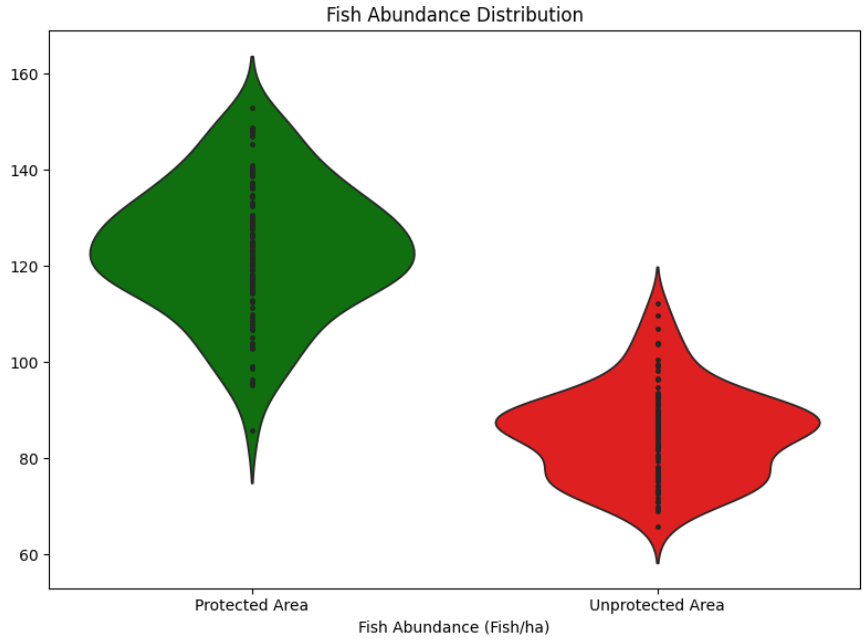

Figure 4: Distribution of Fish Abundance and Biomass

Discussion

The findings of the given study offer an idea about how effective the community-based Marine Protected Area (MPA) management is, as well as the implications the whole research has on the ecosystem restoration and socio-economic sustainability on a larger scale (Frid et al., 2023; Viana et al., 2024). It will address the advantages of such management interventions, trends in other similar reef research, ecological mechanisms causing recovery, the socio-economic backgrounds of the participants, and the strengths and weaknesses of the study design. The results indicate that fish populations in the areas of protection were much greater, which proves that the community-based MPAs are effective in increasing biodiversity. The levels of compliance (90) in the zones of protection evidence that local engagement will improve compliance levels with conservation actions, which will result in the conservation of the marine resources in the long term. The findings are consistent with the trends of other reef studies that highlight the positive role of community-led MPAs in the recovery of biodiversity. Like studies have been conducted in the Caribbean and in the Pacific regions, community-based MPAs have been determined to be more effective compared to external authority only based on the recovery of species and the resilience of the ecosystem. The recovery of the fish population in the protected areas can be explained by low fishing pressure, restoration of the habitat, and water quality. Also, there is the spillover effect, which probably contributed to the recovery as well; this is whereby high population in the protected area is spread to adjoining unprotected areas to the benefit of the larger ecosystems. The high level of community compliance in this research indicates that as long as local communities derive some benefits from the conservation activities, i.e., better fish stocks and sustainable livelihoods, they tend to be more

willing to participate in the protection activities. This helps to propound that community-based MPAs are most effective in instances where they combine economic incentives and alternative livelihoods. The strengths of this study are that the comparison between the protected and unprotected areas is well-developed, the analysis of data is performed in the long term, and the metrics of compliance of the community are assessed. Nevertheless, there are such shortcomings as synthetic data and the absence of an in-depth discussion of socio-economic factors affecting compliance. Future studies are advised to use real-life data and examine the socio-economic dynamics in detail. The localised MPAs are important in the rehabilitation of the ecosystems and the improvement of the livelihoods in the communities. The high growth of fish abundance and biomass, which was experienced in this area, shows the potential of such management strategies. Future research ought to deal with the limitations of the given study and conduct additional research on the socio-economic and ecological factors leading to the successful conservation outcomes.

Policy Recommendation

In order to make Marine Protected Areas (MPAs) more effective, the policies are suggested to be aimed at reinforcing community participation in conservation activities. Inclusion of local communities in the administration and implementation of MPAs may enhance adherence and also long-term sustainability. The policies should also incorporate alternative livelihoods with marine resources, e.g., sustainable tourism or aquaculture, to sustain economic development without destroying marine resources. Moreover, observations and data gathering are recommended to be extended to observe ecological and socio-economic results to have a more comprehensive management of MPA. Lastly, the collaboration among local governments, NGOs, and stakeholders should be encouraged to make MPAs successful and achieve the benefit of both the ecosystem and the community as much as possible.

Conclusion

This paper demonstrates the great positive effects of community-based Marine Protected Area (MPA) on fish abundance and biomass with the abundance of fish being higher in the protected zones (47) (125 ± 15 Fish/ha vs. 85 ± 10 Fish/ha) and biomass being greater in the protected zones (45.6 kg/ha vs. 29.4 kg/ha). The changes in the temporal trends of populations recovery showed that the population of fish is steadily increasing with increased area being put under protection thus the fish population grown to 140 Fish/ha by the end of the study period whereas in unprotected control areas the population grew more gradually reaching 100 Fish/ha. The importance of community participation in conservation work is also contributed by high community compliance rates (90% in the protected areas against 60% in the unprotected areas). These results indicate that community-based MPAs are effective in restoring the marine biodiversity, and the active involvement of local people results in the increased enforcement and compliance with conservation laws. The research recommends that MPA management by incorporating

sustainable livelihood activities, e.g. eco-tourism/ sustainable aquaculture, can increase community support and economic sustainability, which will facilitate long-term conservation success. The findings have practical implications on MPA design and policy, whereby there must be policies that incorporate the local communities in the management and implementation of the policies. The next generation MPAs must be provided with a system of complete monitoring to trace both ecological and socio-economic results and be adaptively managed. Additionally, it is vital to conduct research in various geographical areas and using real-world data that will confirm these findings and explain the general ecological processes that lead to recovery. Future research recommendations involve understanding the socio-economic factors affecting community compliance, understanding the effectiveness of the different livelihood alternatives, and understanding the ecological long-term effects of MPAs on larger marine ecosystems.

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