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Original Research Paper

Evaluating the Effectiveness of Climate Adaptation Strategies in Protecting Biodiversity in Protected Areas

Dr. Priya Paul[1], Dr. Pokhraj Sahu[2], Dr. Tripti Desai[3]*

[1]Assistant Professor, Department of Biotechnology, Kalinga University, Naya Raipur, Chhattisgarh, India. Email: ku.priyapaul@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0008-7934-9307.*
[2]Assistant Professor, Department of Biotechnology, Kalinga University, Naya Raipur, Chhattisgarh, India. Email: ku.pokhrajsahu@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0007-7535-0848
[3]Professor, New Delhi Institute of Management, New Delhi, India. Email: tripti.desai@ndimdelhi.org, ORCID: https://orcid.org/0009-0002-1444-7316

Key Words

Climate adaptation strategies, Biodiversity conservation, Protected areas, Climate change, Biodiversity resilience, Conservation strategies, Ecological management.

Abstract

Climate change has posed a threat to biodiversity, paving the way for the implementation of climate adaptation measures in protected areas. These strategies aim to enhance ecosystem resilience and safeguard biodiversity against the adverse effects of climate change. This paper evaluates the effectiveness of various climate adaptation measures applied in protected areas and their impact on biodiversity conservation. A comprehensive literature review is conducted to familiarize oneself with available adaptation strategies, their success, and the problems associated with their implementation. The study paper discusses differences in biodiversity levels in the chosen regions before and after the implementation of the climate adaptation approach, using data collection and analysis. The findings indicate that not all of these strategies yield the same outcome, and ecological peculiarities, management routines, and external pressure are key factors that modulate their outcomes. Besides, the research notes that problem-specific solutions should be offered based on the systems and species. It also describes how these strategies can be enhanced by engaging stakeholders and governing them. The paper also examines the implications for future biodiversity conservation and offers recommendations to improve the effectiveness of climate adaptation strategies. The paper concludes that these measures should be continuously monitored and reviewed to ensure the long-term protection of the biodiversity of the protected areas.

* Corresponding Author's email: ku.priyapaul@kalingauniversity.ac.in
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Introduction

Strategies of climate adaptation are steps taken to help ecosystems and species survive a changing climate. These plans will help minimize the adverse effects of climate change on biodiversity, especially in protected areas, by providing shelter for the most endangered species Gillingham et al., 2024; Reginald, 2024; Zeng et al., 2022). Due to constant changes in weather patterns, extreme temperatures, and other effects of climate change, including rising precipitation, the need for these strategies has become even more urgent. The adaptability of the changing climate is endangering the existence of endangered species; therefore, there is a need to develop adaptation strategies to protect the areas of concern, which are mostly the remaining bastions of these species. These plans aim to promote ecological stability by conserving important habitats and species diversity and improving ecosystem functionality. Such strategies are even becoming necessary because climate change continues to influence environmental processes, and the risk of habitat loss is increasing (Rajan & Senthil, 2024).

The ability of ecosystems to withstand the shock of climatic change is declining; therefore, conservation efforts need to be transformed to reduce the unprecedented pressures they face (Graham et al., 2021). Preservation to ensure biodiversity and ecosystem services, and to protect species facing challenges due to climate change, will all be under conservation (Carroll & Ray, 2021; Coldrey et al., 2022). The paper shall evaluate the effectiveness of these strategies for biodiversity conservation in protected areas, noting the opportunities and challenges of climate adaptation programs (Rodríguez-Rodríguez & Martínez-Vega, 2022; Chen et al., 2023; De Marco Jr et al., 2023). The efficacy of these strategies is also imperative for understanding future conservation priorities and enhancing the resilience of protected ecosystems (Zhang et al., 2023).

Several approaches to climate adaptation have been proposed and applied in the preservation regions. The strategies include habitat restoration, the creation of ecocorridors, species translocation, and the manipulation of genetic diversity, among others. These strategies are intended to improve the health and sustainability of ecosystems and species, enabling them to adapt to changing environmental conditions. One of them is habitat restoration, which aims to undo habitat degradation and restore natural processes that support species (Condro et al., 2021). The ecological corridors also provide migratory routes for the species, helping them traverse fragmented habitats in response to changing climatic conditions. Species relocation involves transferring species to regions where they are better adapted to new climate conditions, and genetic diversity manipulation can enhance their adaptation to environmental stressors.

Climate change has dire impacts on biodiversity, altering species distributions, the occurrence of ecological processes, and the functioning of ecosystems (Iyer & Verma, 2023; Hoveka et al., 2022). There is species displacement and changes in the productivity, composition, and resilience of the ecosystem. The disruptions have the potential to trigger a wave of ecological effects, disrupting ecosystems and the services they deliver. Climate change is normally irreversible, so there is an urgent need to evaluate the efficacy of these adaptation processes in mitigating biodiversity loss (Singh & Joshi, 2025; Silvestro et al., 2022). Given that adaptation measures must be carefully tailored to a specific ecosystem, otherwise, they can overlook the real causes of species disappearance and have side effects. The effectiveness of these strategies would be determined by their ability to monitor and adjust to long-term environmental changes.

Even though attempts have been made to adopt climate adaptation strategies, there remains a significant knowledge gap regarding their effectiveness (Tun et al., 2025). The literature has covered problems and the efficacy of adaptation strategies in specific regions. However, it has never explained how adaptation occurs in other ecosystems or how preservation is achieved. The absence of a global study of adaptation efforts to climate change prevents comparisons of results across different strategies within the same ecosystems. Furthermore, although in some areas of protection adaptations have been successful, the strategy's effectiveness can be situational and dependent on various factors. Local environmental conditions, management techniques, and external factors such as species invasions, pollution, and human intrusions can influence the efficacy of these strategies.

Local factors, including soil structure, water supply, and other species, may affect the extent to which an ecosystem can cope with climate change (Nzegbule & Obiajunwa, 2025). Also crucial to the success of adaptation efforts are management practices, such as funding levels, political support, and local community participation. The effect of external forces, such as the intrusion of human activities into protected zones, can erode the effectiveness of the adopted adaptation; in other words, these issues must be addressed simultaneously with climate adaptation. The present paper seeks to fill this gap by analyzing how various climate adaptation tools in the field can be practical, the primary factors that define their effectiveness, and the implications for biodiversity conservation endeavors (Pettorelli et al., 2021). Through case studies across a wide range of ecosystems, this paper will identify common challenges and successes to inform more efficient approaches to climate adaptation. Knowledge of these factors will aid policymakers and conservationists in formulating more effective interventions that account for the specifics of each ecosystem and ensure the conservation of biodiversity worldwide (Agung et al., 2022).

Key Contribution

- The article presents a critical analysis of the efficiency of different climate change practices in preserving biodiversity in parks.
- It identifies the factors that determine an effective adaptation strategy, such as ecological characteristics, bureaucratic protocols, and exogenous forces.
- The paper provides practical solutions to enhance climate adaptation strategies and underscores the need to maintain ongoing monitoring and evaluation to promote biodiversity conservation in protected areas.

The paper will consider the effectiveness of climate adaptation interventions in protecting biodiversity, with reference to how they have helped address climate change. Section I outlines the concepts of climate adaptation strategies and biodiversity preservation, and presents the paper's aim. It will examine existing efforts to adapt to climate change, the effects of climate change on biodiversity, and prior research on the effectiveness of such efforts. Section II presents the study's methodology, including the selection of the study samples (protected areas), data collection procedures, and data analysis procedures to assess the effectiveness of adaptation strategies. In Section III, the analysis results, including the efficiency of different strategies, comparisons of biodiversity levels before and after the implementation of specific strategies, and key success factors, are provided. Section IV describes the implications of these findings for biodiversity conservation, provides recommendations for enhancing adaptation strategies, and outlines future research directions.

Methodology

Selection of Protected Areas for Evaluation

A broad range of areas was selected to evaluate the effectiveness of climate adaptation strategies because they are ecologically relevant, vulnerable to climate change, and are addressed as adaptation measures. This has been done by selecting ecosystems across climatic regions, including forests, wetlands, and grasslands, to capture a wide range of climate change effects. The selection criteria may include biodiversity importance, the extent of exposure to climate threats (e.g., rising temperatures, changing precipitation patterns), and a history of adaptation measures. This was to ensure an even distribution of areas protected, with some exposed to varying climatic pressures and adopting varying adaptation strategies.

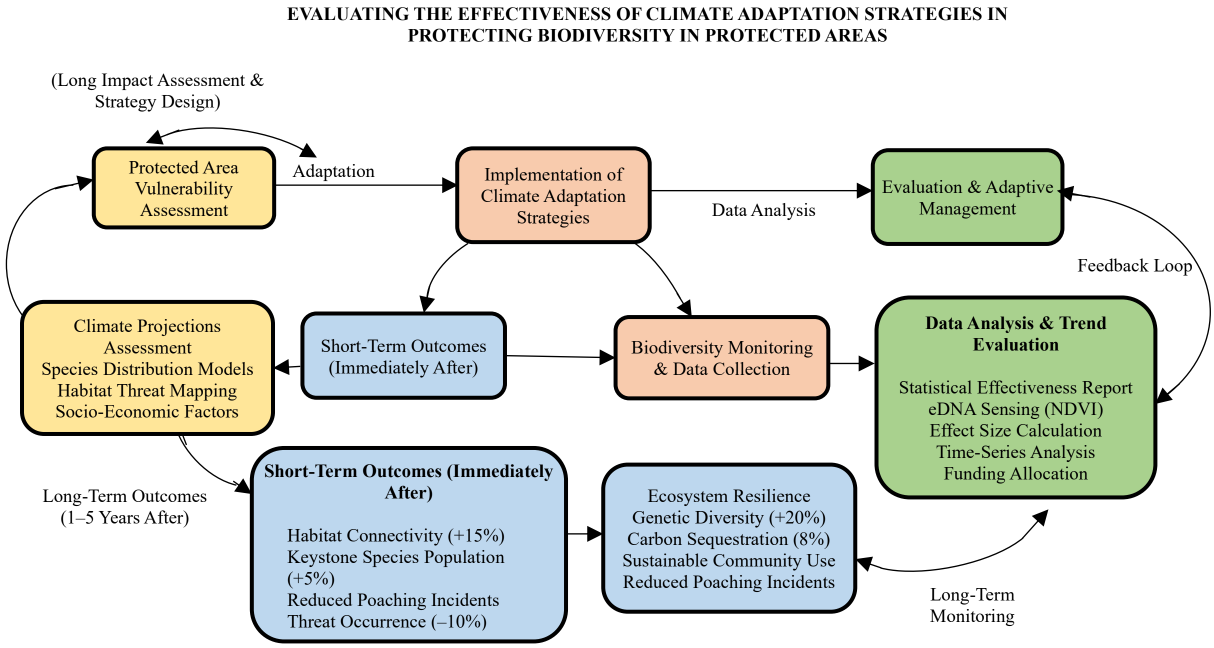

Figure 1: Climate Adaptation Strategy Framework

The general plan of the climate adaptation strategies assessment system to protect the biodiversity of the protected areas is presented in Figure 1. It focuses on key procedures, such as vulnerability testing of the area under protection, and accommodates climatology forecasts, field distribution models, and other socio-economic factors. The short-term results and monitoring procedures are then used in the model to execute the adaptation techniques. The diagram in question clarifies why information should be collected on biodiversity, trend assessment, and adaptive management, as all of them will be crucial for assessing the sustainability of actions in the short and long term. The final aim of such a process is to generate beneficial feedback to inform future adaptation strategies that enhance ecosystem stability and biodiversity conservation.

Data Collection Methods

The quantitative and qualitative methods are included in the data collection process. Biodiversity measurements provide quantitative data used to monitor the population of the species, the condition of the habitat, and the well-being of the ecosystem before and after the introduction of the measures to be adopted. The quantity and diversity of species are identified through the survey, and the health of the habitats is assessed using indicators such as vegetation cover and ecosystem integrity. Qualitative data regarding the strategies of adaptation followed, the management practices, and perceived challenges are collected in the interviews and discussions with the park managers, local stakeholders, and conservation practitioners. Other information, such as climate predictions and land-use changes, is added as well to provide context for the environmental conditions under which these regions operate.

Figure 2: Global Network of Protected Areas and Climate Adaptation Strategy Assessment

Figure 2 presents a world map of the network of protected areas and an evaluation of the climate adaptation measures implemented in these territories. The map will depict the effectiveness of climate adaptation policies across the various areas of protection, using color-coded icons to indicate the approach's high, moderate, or low success. The Amazon Rainforest, the Great Barrier Reef, and the Great Plains are some of the prominent areas. The map is also a visual tool to comprehend which ecosystems were more successful in adapting to climate change with the help of the strategies, and which are threatened. By comparing these areas, the map also shows differences in success and how targeted interventions should be directed to improve conservation efforts in less-adaptive areas.

Analysis of Data

To analyze the data, both statistical and thematic analyses are used. The statistical analysis of quantitative data includes the changes in biodiversity with time, paired t-tests, regression analysis, and multivariate analysis in order to define the significant differences between the states of analysis before and after the application of the adaptation strategies. Differences in ecological types, management strategies, and external influences, such as species invasions or human activities, are also controlled for in the analysis. Interpretation and analysis of qualitative data through interviews and stakeholder feedback are coded and themed in order to get a sense of the perceived effectiveness of various adaptation strategies, the success barriers, and the social-ecological context in which such methods are implemented. The combination of the two types of data gives a comprehensive evaluation of the effectiveness of the processes and their effect on the conservation of biodiversity.

Results

Climate Adaptation Strategy Effectiveness

The study findings indicate the different levels of effectiveness of the diverse strategies of climate adaptation measures that are in place in the sampled areas of protection. Conservation techniques like habitat rehabilitation, species translocation, and establishment of ecological corridors were identified to be more or less successful with regard to specific environmental circumstances and management approaches. The movement of species was also promoted by the presence of ecological corridors in regions where ecological corridors were created, which increased the genetic diversity and the capacity to resist climate stresses. Nonetheless, the success was not universal in those places where the relocation of species was undertaken, and some species could not adjust to the new environment. In general, one of the most successful measures was habitat restoration, particularly in those regions where human activity was limited, and nature left the natural processes to reclaim their course.

Table 1: Climate Adaptation Strategies

Adaptation Strategy	Protected Areas Evaluated	Impact on Biodiversity	Effectiveness Rating (1-5)
Habitat Restoration	Forests, Wetlands	Increased species richness and habitat quality	4
Species Relocation	Grasslands, Wetlands	Mixed results, some species failed to adapt	2
Ecological Corridors	Forests, Grasslands	Improved species movement and genetic diversity	5
Invasive Species Removal	Forests, Wetlands	Increased native species abundance	4
Controlled Burns	Forests	Increased plant diversity, improved ecosystem function	3

Table 1 gives a summary of the various climate adaptation strategies used in the different types of protected areas and their effectiveness on the basis of biodiversity outcomes. Some of the strategies that have been reviewed are habitat restoration, species translocation, ecological corridors, eradication of invasive species, and controlled burns. The table contains the names of the specific areas that were under protection and the strategy that was applied, the measured effect on biodiversity (richness of species, abundance of species, and quality of habitats), and a rating of the effectiveness of the strategy between 1 and 5. A high effectiveness rating of 5 has been assigned to the relevant rating, and high positive effects on the biodiversity were noted, whereas a rating of 1 implies that there were low or no effects. The given table will assist in comparing and contrasting the relative performance of each of the adaptation strategies and provide us with information on which strategies have worked better in improving the biodiversity resilience of the protected areas.

Biodiversity Levels

The level of biodiversity prior to and after the application of climate adaptation strategies had both positive and neutral results. The improvement in the richness and abundance of the species was significantly observed in most of the cases, especially in the protected areas where there was an implementation of adaptive management strategies like controlled burns, eradication of invasive species, and restoration of vegetation cover. As an illustration, restoration of native plant species in forested protected regions resulted in the reappearance of important pollinators and herbivores, which, in turn, sustained a broader biodiversity range. Nevertheless, there are regions where biodiversity remained the same or had slight improvement, which proved that climate adaptation measures were not enough to address all difficulties.

Figure 3 demonstrates how the biodiversity indices vary in different protected areas prior to the implementation of the climate adaptation strategies and after the implementation of the latter. Data points reflect the levels of biodiversity at three time intervals, i.e., before the implementation (blue solid line), at the implementation (green dashed line), and one year after the implementation (red dotted line). The graph demonstrates the overall improvement in biodiversity in most of the areas where the strategies have been implemented, with specific regions exhibiting a long-term positive growth even after a year of the strategy having been implemented. The trends indicate the ways in which various ecosystems like forests, wetlands, and savannahs react to climate adaptation processes with time. The visual comparison points to the significance of the situation-based approach, as some places had witnessed the instant positive effect, whereas others experienced the gradual positive result.

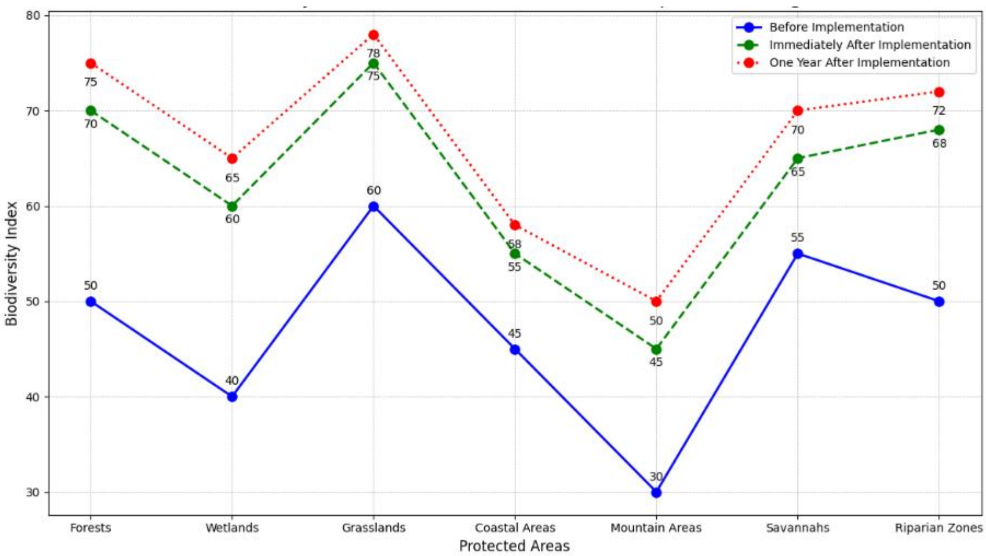

Figure 3: Biodiversity Trends Before and After Climate Adaptation Strategies

The Major Success Determinants

A number of important factors were detected to be the determinants of climate adaptation strategy success. The ecological factors, including the habitat type, sensitivity of the species to climate change, and fragmentation of the ecosystem, were found to be significant factors in the success of adaptation measures. More ecologically connected areas and intact ecosystems were more effective in putting in place adaptation strategies than the fragmented or degraded habitats. Also, the management practices that were identified to contribute to the success of climate adaptation strategies include adaptive monitoring, stakeholder involvement, and resource availability. Outside forces such as illegal poaching, tourism, and pollution were also cited as a serious source of hindrance to success, particularly where the capacity to enforce is low. The concept of local communities being incorporated in decision-making and adaptive management also became one of the determinants of the positive outcomes of the adaptation strategies.

Discussion

The results of this paper highlight the importance of the climate adaptation approach in the preservation of biodiversity, particularly in artificial reserves. There are other types of strategies, such as restoration of habitats and ecological corridors, which have been found to have a positive effect on biodiversity and help to increase the abundance of species and their population stability. These findings indicate how well-managed protected areas can conserve biodiversity, despite the fluctuating climatic conditions. Nevertheless, the research also shows that the effectiveness of such strategies strongly depends on the context of the particular area of protection. The level of habitat fragmentation, the level of external pressure (poaching, tourism), the nature of the ecosystem, and so on, are all factors that can affect the effectiveness of the strategies. The restoration of habitats, as an example, was very effective in forested regions but with little success in more degraded ecosystems. It implies that despite the necessity of climate adaptation strategies, they should be specific to the ecological and socio-economic circumstances of the given area so that they can be maximally effective.

In coming up with climate adaptation strategies, one should consider a more holistic approach, which involves ecological, social, and management aspects to enhance the success of the climate adaptation strategies. The improvement of environmental connectivity is one of the essential aspects. Creation and preservation of ecological corridors between small habitats can support the environmental exchange of species and enhance the genetic diversity, enabling ecosystems to be less susceptible to climate change. It is also essential to monitor the biodiversity and climatic conditions continuously. This will allow them to manage it in an adaptive way, whereby, depending on changes and new climate data, strategies can be changed on the fly. Additionally, these strategies require the participation of local communities in order to be successful in the long run. With the local communities being proactively involved in the management and protection of the protected areas, conservation is more likely to achieve success since those communities usually have some helpful information and are generally interested in the state of the environment around them. Besides, risks can be mitigated by creating early warning mechanisms of threats posed by climate, e.g., extreme weather patterns or the spread of invasive species, before the situation deteriorates. There can be a lot of adverse effects on biodiversity reduced by an early intervention.

In the future, one needs to focus on conducting more studies on the long-term impacts of climate adaptation measures in conserved locations. Long-term monitoring studies will also play a decisive role in establishing whether the changes in biodiversity that will be realized following the adoption of the adaptation strategies will be maintained over time or whether additional interventions will be necessary. More comparative studies in different ecosystems are also required to determine which methods are most universally effective and those that require adaptation to particular environmental conditions. Climate models should also be combined with conservation planning to be done in future research. Conservationists will be able to act in advance and respond to changes in the environment by predicting the effects of climate change in the future. Also, more in-depth knowledge about the social-ecological processes of the protected regions is required. This would involve research into the influence of human activities and other socio-political elements of climatic adaptation, like governance and involvement of the community. Lastly, it is essential to assess the cost-effectiveness of various measures of adaptation. Cost-benefit analysis will make sure that conservation resources are deployed in the most efficient and effective way that will maximize the impact of each strategy.

Conclusion

This paper has assessed the efficacy of climate adaptation measures in the preservation of biodiversity in the conserved zones, and it was found that, although such measures tend to improve biodiversity, their effectiveness in conservation differs among ecosystems. Habitat restoration, ecological corridors, and species relocation were some of these strategies that showed positive effects, especially in areas that had fewer external demands, such as poaching and over-tourism. Nevertheless, habitat fragmentation, ecological aspects, and the severity of management activities played an essential role in the results. These results highlight the need to adopt context-specific approaches and strategies that would meet the individual needs of every protected region. Moreover, the strategy must be adjusted whenever the needs of climate change occur, which needs to be monitored and evaluated. Constant monitoring is used to make sure that the efforts of adaptation are sensitive to the current environmental conditions and that new problems are identified and the strategies are adjusted to them in a timely manner. Along with monitoring, community participation is essential to the success of these strategies in the long run, as in most cases, local stakeholders can help significantly in the minimization of threats and preservation of ecosystem health. Climate management is not a quick fix answer, but a continuous task that requires institutions to be flexible and resilient in conservation thinking preparation. The subsequent research should be on the sustainability of these approaches in the long run, where the objective would be to examine both how effective they would be in the long term and in different ecosystems. Also, comparative research that can assess the adaptation strategies under various climatic conditions will be helpful in offering insights into the universally effective methods. Finally, scientific research, adaptive management, and community engagement will need to be integrated to enable conservation of biodiversity in the long run in the context of climate change, and ensure that the protected areas persist as an effective refuge for threatened species.

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