Economic and ecological benefits of marine protected areas for fisheries resilience

Sarvar Aliev[1*]; Kosimov Khusniddin Badriddinovich[2]; Hassan Mohamed Ali[3]; Rajendran C[4]; Dr. Lalit Sachdeva[5]

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Abstract

This is the point at which MPA is now being defined as an essential tool for the conservation and sustainable management of fisheries in the sea, in response to the global crisis of overfishing and habitat destruction. This article will look at the dual purpose of the MPAs to ensure the economic prosperity of the coastal populations and ecological competitiveness of the corresponding fisheries therein, which makes it an extremely crucial insurance policy against a host of disasters, including climate change. The review utilizes the evidence regarding the mechanisms of MPA benefits, particularly the ideas of the spillover effects, exportation of larvae, and habitat protection as the leading causes of the increase in the fish biomass, catch-per-unit-effort (CPUE), and biological diversity in both the protected and adjacent fishing grounds. Secondly, there is the socio-economic dimension to the research that is the involvement of the local communities in ecotourism and sustainable livelihood development as a mandatory condition of MPA success. The new framework is proposed to be applied in order to assess the economic and ecological performance of MPAs without focusing only on simple measures but including indicators of social-ecological stability and good governance. The findings underline the need to have planned and executed MPAs, as components of a broader fisheries management plan, for the sustainability of the future and equity of resource distribution. The research provides evidence-based and valid grounds for policymakers to design and operate MPAs as a component of the blue economy and the sustainability of the coastline throughout the world.

1*- Tashkent Medical Academy, Tashkent, Uzbekistan. Email: sarvaraliev1984@gmail.com, ORCID: https://orcid.org/0009-0002-4831-807X
2- Faculty of Linguistics, Turan International University, Namangan, Uzbekistan.
Email: uzbekistan.husniddinqosimov1974@gmail.com, orcid: https://orcid.org/0009-0001-6725-9987
3- Department of Computers Techniques Engineering, College of Technical Engineering, Islamic University of Najaf, Najaf, Iraq; Department of Computers Techniques Engineering, College of Technical Engineering, Islamic University of Najaf of Al Diwaniyah, Al Diwaniyah, Iraq.
Email: eng.iu.comp.hassanaljawahry@gmail.com, ORCID: https://orcid.org/0009-0007-4447-5808
4- Department of Nautical Science, AMET University, Kanathur, Tamilnadu, India.
Email: rajendran.capt@ametuniv.ac.in, ORCID: https://orcid.org/0009-0007-0137-5700
5- Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.
Email: ku.lalitsachdeva@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0002-2214-282X
*Corresponding author
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Introduction

The ongoing pressure of human actions, which are mainly overfishing and the destruction of marine habitats, has severely affected the marine ecosystems all over the world, and this must be well managed through elaborate management systems (Laffoley *et al.*, 2019). The MPA has emerged as a new source of ocean conservation, and its purpose is not to uphold the biodiversity alone, but also to enhance the economic well-being of the locals surviving at the seamen (Ghate and Roy, 2024). In this report, the focus is on the disputable, yet significant, relationship between the MPAs and the long-term sustainability of the local fisheries, which shows that well-managed MPAs could be linked to two substantial and quantitative dual values, i.e., ecological enhancements and economic sustainability (Eli, Raimi and Amachree, 2025).

Key Contributions and Goals

- Synthesis of Dual Benefits: To unite empirical information that would unveil the ability of MPAs to achieve more fisheries production (economic benefits) and ecosystem health (ecological resilience).
- Mechanism Identification: To explain the most important ecological processes, namely, spillover and larval export, that transform conservation within an MPA to the ultimate yield external.
- Resilience Framework: To propose an integrative framework to gauge the performance of MPA in terms of indicators of social-ecological resilience, the biophysical, and the governance elements (Jones, 2014).

The remainder of this research study will be structured as follows: Section 2 will entail the systematic literature review of the MPA effectiveness. Section 3 has the theoretical MPA-Fisheries Resilience Framework. In part 4, Bioeconomic Dynamics of MPAs are discussed. There are case studies and Performance Metrics as examples in section 5. Finally, Section 6 offers the conclusions and future research.

Literature Analysis

The literature on the subject is overwhelmingly in favor of the ecological effectiveness of well-enforced MPAs, which demonstrate substantial growth in fish biomass, density, and average size within them (Mellin *et al.*, 2016). The reserves serve as critical refugia, safeguarding spawning stock and essential habitats, improving ecosystem integrity, and providing an objective addition to climate resilience (Game *et al.*, 2009; Puotinen *et al.*, 2008). It is also noted that the socio-economic issues that are considered complex, like displacing the fishing activity in the short term and the initial loss of revenue, can create resistance among local fishers (Ismail, Haron and Yusof, 2018).

However, experience over a long period indicates that the ecological benefits are, in most cases, converted into economic benefits, and this is by the process of adult spill-over and export of larvae. The success of MPAs is not the biophysical issue alone; it heavily depends on the governance organization

and the level of the local community in it (Jones, Qiu and De Santo, 2013; Cinner, Fuentes and Randriamahazo, 2009). It is concluded that to fulfill their pledge of improving the fisheries resilience, MPAs need to be instigated with a powerful concentration on participatory management, equitable advantage allocation, and incorporated into a wider and versatile fisheries management strategy (Ghate and Roy, 2024).

Conceptualizing the MPA-Fisheries Resilience Framework

This part suggests a qualitative framework to conceptualize the relationship among the MPA features, their ecological and economic performance, and the subsequent fisheries resiliency. In this regard, the term resilience is used to mean the ability of the fishery system (both the stock and the community) to withstand disturbances and restructure in the process of change. The main point of the framework is that MPA design and management should be specific.

Integrated Management and Resilience Pillars

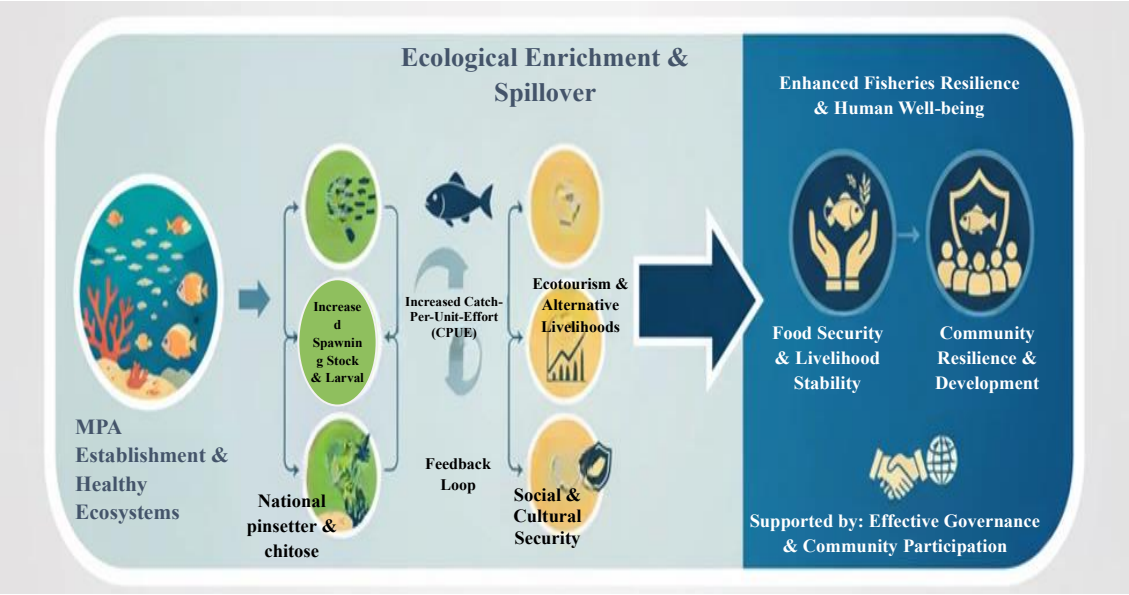


Figure 1: Integrated MPA pathways to fisheries and human resilience.

Figure 1 summarizes theoretical routes according to which Marine Protected Areas (MPAs) provide two sets of mandates of ecological and human resilience. The model starts with essential environmental performance in the MPA augmented biomass, bigger fish and integrity of the habitat that creates the vital spillover impact that expands neighboring fisheries Catch Per Unit Effort (CPUE). This stabilized catch and alternative sources of revenue, including ecotourism, result in greater food security, stability in the community, and general human resilience. This is the whole process maintained and regulated with strong community-engaging Governance and Climate Adaptation strategies, which is a clear example of the entire socio-ecological feedback loop.

The framework is designed based on the three pillars that are linked together and which determine the overall success and resilience dividend of an MPA:

Ecological Enhancement (MPA Internal): The environmental enhancement concentrated on the processes within the reserve, including habitat protection, greater spawning stock, and recovery of trophic structure (Mellin *et al.*, 2016). This is the motor that runs the system.

Economic Uplift (MPA External/Adjacent): This quantifies the physical impacts on the fishing community, such as high catch, high CPU in adjacent areas because of spillover, and alternative livelihoods such as ecotourism.

Governance and Social-Ecological Fit (Management System): Evaluates the non-biological aspects such as the institutional variety, inclusion of stakeholders, the effectiveness of enforcement, and the capacity to react to changes in the environment (Cinner, Fuentes and Randriamahazo, 2009).

According to the model, it is the optimization of these three pillars that makes fisheries resilient to shocks so that the catches and livelihoods remain stable. As an example, a good MPA produces the ecological stability (Pillar 1) that, combined with the relevant rules of monitoring and equitable access (Pillar 3), leads to the long-term, increased yields in the nearby areas (Pillar 2) (Hailu *et al.*, 2023).

Bioeconomic Dynamics and Valuation of MPA Benefits

Modeling the Economic Impact of Spillover

The overall economic value of MPAs to fisheries is frequently estimated by evaluating the spill-over effect of net movement of adult fish out of the protection area into the surrounding fishery area, and the resulting impact on the fishery revenues. Although complex bioeconomic models may need many data, the central relationship is simple: A high density of large, fecund fish within the no-take zone causes an outward flux. This local stock growth outside of the MPA enhances the Catch Per Unit Effort (CPUE), which directly coincides with a decrease in operational costs and profitability of fishers (Costello, 2024). The qualitative description of the increase in the simple form of profit (P) improvement around the MPA can be given as the increase in the total revenue (TR) less the marginal cost of fishing effort (Ceffort) as CPUE increases:

$$P = (CPUE_{MPA-Adjacent} \times Price \times Effort) - C_{effort}$$

The point is that MPAs increase the revenue (CPUESMPA- Adjacent) compared to that of a non-MPA baseline. However, do not correspondingly increase the effort, increasing profit. Moreover, MPAs are a kind of insurance policy against the failure of management or the unknown environmental shock, and can, in effect, guarantee long-term economic stability, which is often lacking under the traditional single-species management (Rao and Tiwari, 2023). These other alternative sources of income, e.g., ecotourism operated by local communities, also play a role in overall economic resilience through the fact that they help avert over-dependence on fishing as the sole source of income.

Results and Discussion

Here, the empirical evidence on global case studies is used to prove a measurable impact of MPAs and offers performance

metrics that are needed to measure this performance.

Good MPAs testify to the fact that ecological benefits are convertible into economic ones, provided the management and establishment are appropriate (i.e., large enough and properly implemented) (White *et al.*, 2025). The measures of performance evaluation are:

Ecological Measures: Biomass Growth (as a percentage change in MPA compared to a control or baseline), Species Diversity (as indices including the Shannon index), and Fish Size (mean length or weight of the target species).

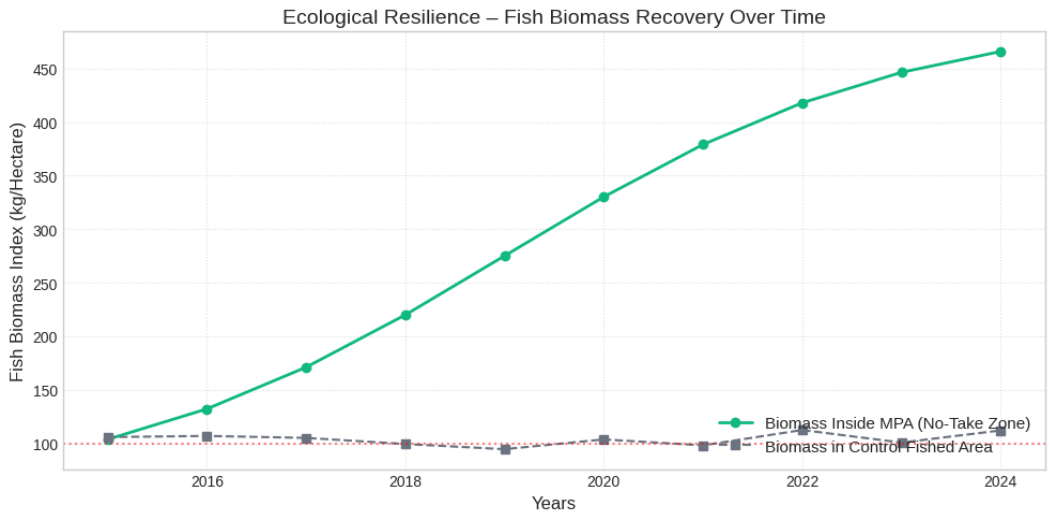
Fishery Measures: Alteration in Catch per Unit Effort (CPUE) in adjacent fishing grounds, aggregate Catch Volume constancy, and accrued Economic Revenue through the fishery (Costello, 2024).

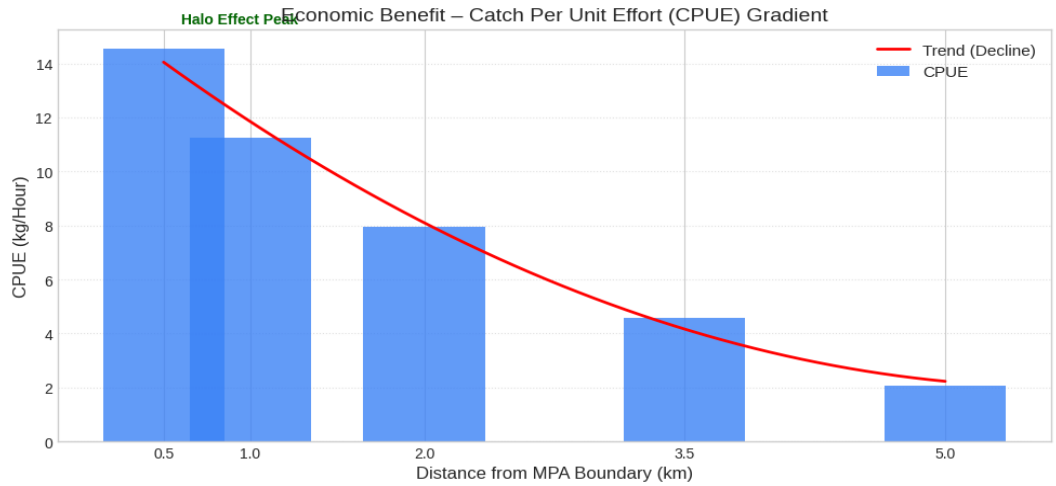
Table 1: Comparative analysis of marine protected area efficacy: ecological, economic, and governance outcomes.

MPA Outcome Domain	Performance Metric/ Indicator	Description of Impact on Fisheries Resilience
I. Ecological Enhancement	Fish Biomass and Density	Significant increase in spawning stock biomass and density within the MPA, leading to a larger reservoir of reproductive individuals, which is key for larval export and overall stock health (Mellin *et al.*, 2016).
	Species Diversity & Habitat Integrity	MPAs protect critical habitats (e.g., coral reefs, seagrass beds) from destructive fishing, maintaining ecosystem integrity and reducing the vulnerability of associated fish populations to external shocks (Bates *et al.*, 2019).
	Larval Export and Spillover Potential	An increased number of larger, more fecund fish leads to greater larval production, which disperses and replenishes adjacent fishing grounds, while adult fish spillover provides immediate localized stock increases (Game *et al.*, 2009).
II. Economic Benefits	Catch Per Unit Effort (CPUE)	Increased CPUE in the areas immediately adjacent to the MPA boundary, resulting from the spillover effect, which lowers fishing costs and increases profitability for fishers (Costello, 2024).
	Alternative Livelihoods/Ecotourism	The conservation of charismatic megafauna and pristine ecosystems supports marine ecotourism, diversifying the local economy and reducing direct fishing pressure on strained stocks (Eli, Raimi and Amachree, 2025).
	Long-term Revenue Stability	MPAs act as a biological insurance mechanism, providing greater catch stability and revenue security, especially following environmental disturbances (e.g., thermal stress or storms) (Puotinen *et al.*, 2008).
III. Social-Ecological Governance	Community Participation and Buy-in	High levels of local involvement in the planning, monitoring, and enforcement of the MPA which is a critical predictor of compliance and long-term management success (Jones, Qiu and De Santo, 2013).
	Institutional Diversity and Adaptability	The use of varied management tools (e.g., temporary closures, co-management) and the ability of the governance structure to adapt to new scientific data or climate-driven changes (Jones, 2014).
	Equity and Benefit Sharing	Ensuring that the economic gains (from spillover and ecotourism) are distributed fairly among the community members, mitigating conflict and enhancing the social resilience of the fishery (Hailu *et al.*, 2023).

Table 1 is an essential resource in the generalization of empirical data on the effectiveness of various Marine Protected Area (MPA) projects in the world. It goes beyond the success/failure stories as it subdivides MPA results into three important and interrelated dimensions: ecological status, economic benefits, and management effectiveness (governance). This systematic analogy enables a reader to immediately understand how different forms of MPA, the context in a particular region, and management ideologies, like the contribution of ecotourism and community input, affect the final provision of both fisheries resilience and local economic empowerment. Through the outline of important indicators such as biomass growth, CPUE, and management systems, the table gives a ready evidence-based basis to justify the claims presented in the study related to the dual mandate of MPAs (Bates *et al.*, 2019).

All of these studies, together with theoretical models, establish that the economic benefits of MPAs are usually achieved in the form of higher yields and stability beyond the area of protection and amortize any costs incurred in the short-term. The above comparison chart has identified the diverse but always positive results in the case of well-designed and implemented MPAs to become a template in future conservation efforts (Eli, Raimi and Amachree, 2025).





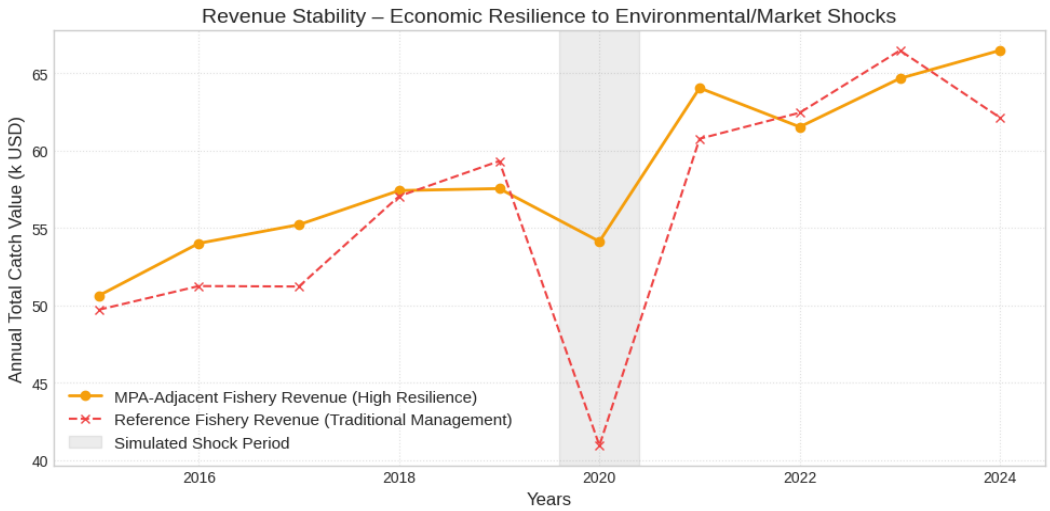


Figure 2: Comparative analysis of MPA performance across ecological, economic, and resilience metrics.

Figure 2 offers a combined display of the two-fold benefits of a well-managed Marine Protected Area (MPA) system. The ecological strength is displayed in Panel (a), where recovery of fish biomass at a high level in the designated area is robust compared to a control area, which determines the source population (Mellin *et al.*, 2016). The economic advantages, as shown in Panel (b), are through the spillover effect, the peak Catch Per Unit Effort (CPUE) at the immediate boundary of the MPA, which enhances fisher profitability (Costello, 2024). Lastly, in Panel (c), the fisheries resilience is mentioned, which demonstrates that an MPA can be an economic insurance policy in maintaining a higher degree of stability and reduced revenue volatility in the nearby fishery in the case of a simulated environmental or market shock.

Conclusions

Marine Protected Areas have become an essential tool in fulfilling ecological conservation and resilience of sustainable fisheries in the face of increasing global threats. This research concluded that the positive results of the improved reproduction of fish, export of larvae, and adult spillover are measurable and result in a crucial economic boost to coastal communities because of the rise in yield and diversification of the economy through ecotourism. The case study analysis and conceptual framework highlight that the success of the MPA will not only depend on its biophysical characteristics but, most importantly, on the inclusion governance and the incorporation of the MPA into the greater and adaptive fisheries management approaches. This powerfully demonstrates that MPAs are a potent yet non-extractive instrument that serves as a necessary insurance policy for the future of the marine resources and socio-economic stability of the fishing communities. The future policy should be dedicated to the strategic MPA network design, its practical implementation, and the development of mechanisms that could create equity in the benefit sharing so that the dual mandate of MPAs could be fully unleashed to a fully-fledged, resilient, and sustainable blue economy.

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