Parul Institute of Applied Sciences

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Title: "The Effectiveness of Marine Protected Areas (MPAs) in Climate Change Resilience"

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Abstract

MPAs serve as fundamental tools, to protect biodiversity while reducing climate-induced effects on marine ecosystems. However, climate change produces substantial effects on marine ecosystems because of natural factors and anthropogenic activities caused rise in temperature as well as increasing seawater acidity and water level elevation, influencing species distribution along with habitat condition. The combined impact of climate change and human activities such as human fishing practices, generating sophisticated ecosystem changes that keep natural systems more vulnerable. Understanding the impact of climate change on marine ecosystems enable researchers to tap into research and address the issues and identify solutions to minimize the environmental damages. This poster presentation aims to evaluate how Marine Protected Areas protect ecological diversity, ecosystem operations and blue carbon ecosystems through mangrove forests, seagrass fields and coral reef maintenance. MPAs demonstrate their worth as an essential measure for climate change adaptation because they support marine biodiversity. Furthermore, case studies will be reviewed based on established MPAs worldwide that demonstrate the effects of MPAs on species adaptation and climate stressor resistance for ecosystems. To improve MPAs, the government's collaboration with stakeholders, together with renewable energy solutions and adaptive management frameworks, will improve sea reserves' potentials to increase climate resilience and also address the sustainable development goals.

Objective

The primary objective of this research is to assess the effectiveness of MPAs in enhancing climate resilience by:

1. Evaluating the role of MPAs in conserving biodiversity and maintaining ecosystem functions.
2. Analyzing the contribution of MPAs to blue carbon ecosystems, including mangroves, seagrass beds, and coral reefs.
3. Investigating case studies of established MPAs worldwide to understand their impact on species adaptation and climate stressor resistance.
4. Proposing strategies to improve MPA effectiveness through stakeholder collaboration, renewable energy integration, and adaptive management frameworks.

Objective 1	Objective 2
Biodiversity Conservation	Biodiversity Conservation:
Maintaining Ecosystem Services	Buffering Against Climate Impacts:
Enhancing Resilience and Adaptation	Facilitating Species Migration:
Supporting Blue Carbon Ecosystems	Reduction of Carbon Emissions
Preventing Cascade Effects	Reforestation and Planting Programs

Objective 4
Stakeholder Collaboration: ✓ Community Engagement ✓ Fisheries Cooperatives ✓ Government and NGOs
Renewable Energy Integration: ✓ Offshore Wind and Solar ✓ Eco-Friendly Infrastructure
Adaptive Management Frameworks: ✓ Monitoring and Evaluation ✓ Climate-Resilient Design ✓ Dynamic Zoning

Case study

Case Study: Isla Natividad, Baja California, Mexico
Background: In 2006, the fishing cooperative of Isla Natividad established two marine reserves to recover depleted abalone populations. The reserves were designed to enhance larval spillover to adjacent fishing grounds.
Findings:

1. Despite a climate-driven hypoxia event in 2009-2010, abalone populations within the reserves showed greater resilience, with higher densities and reproductive output compared to fished areas.
2. Recruitment rates were significantly higher within reserves and up to 300 meters from reserve boundaries, demonstrating the benefits of larval spillover.

Implications: This case study highlights the effectiveness of community-led MPAs in enhancing climate resilience and supporting local fisheries.

Methodology

1.Study Area: The research was conducted in Isla Natividad, Baja California, Mexico, where two marine reserves were established in 2006 by a local fishing cooperative. The reserves cover 8% of the fishing grounds and are fully protected from extractive activities.
2.Field Monitoring:

1. **Dissolved Oxygen (DO) and Temperature**: Autonomous sensors were deployed at three sites around Isla Natividad to monitor DO and temperature every 15 minutes from May to December 2010.
2. **Abalone Population Monitoring**: Annual surveys were conducted from 2006 to 2010 to assess the abundance, size structure, and reproductive output of pink abalone populations within the reserves and adjacent fished areas. Belt transects and timed searches were used to estimate abalone densities and size distributions.

3.Reproductive Output Estimation: Reproductive output was calculated based on abalone size and density data, using established fecundity-weight relationships. Bootstrapping was used to estimate uncertainty in reproductive output.
4.Larval Recruitment: Post-larval collectors were deployed within and outside the reserves during the abalone spawning season (October-January) in 2008 and 2009. Recruitment rates were quantified and compared between reserves and fished areas, as well as at varying distances from reserve boundaries.
5.Statistical Analysis: Analysis of covariance (ANCOVA) and analysis of variance (ANOVA) were used to assess differences in abalone densities, reproductive output, and recruitment rates between reserves and fished areas.

Results

1.Climate-Driven Hypoxia: In 2010, prolonged periods of hypoxia (DO $\leq$ 2 mg/L) were recorded at Isla Natividad, consistent with climate-driven events observed in other regions. Hypoxia caused significant mortality of benthic invertebrates, including abalone, both within and outside the reserves.
2.Abalone Population Resilience: Despite widespread mortality, abalone populations within the reserves showed greater resilience. Densities in reserves were twice as high as in fished areas after the mortality event (2010: reserves = 0.017 individuals/m², fished = 0.007 individuals/m²). Larger individuals, which contribute more to reproductive output, were more abundant in reserves.
3.Reproductive Output: Reproductive output in reserves was significantly higher than in fished areas after the mortality event. In 2010, egg production in reserves was 2.6 times greater than in fished areas (reserves = 20,000 eggs/m²/year, fished = 7,700 eggs/m²/year).
4.Larval Recruitment: Recruitment rates were significantly higher within reserves and up to 300 meters from reserve boundaries, indicating larval spillover. In 2009, recruitment rates in reserves were 9.1 times higher than in fished areas.

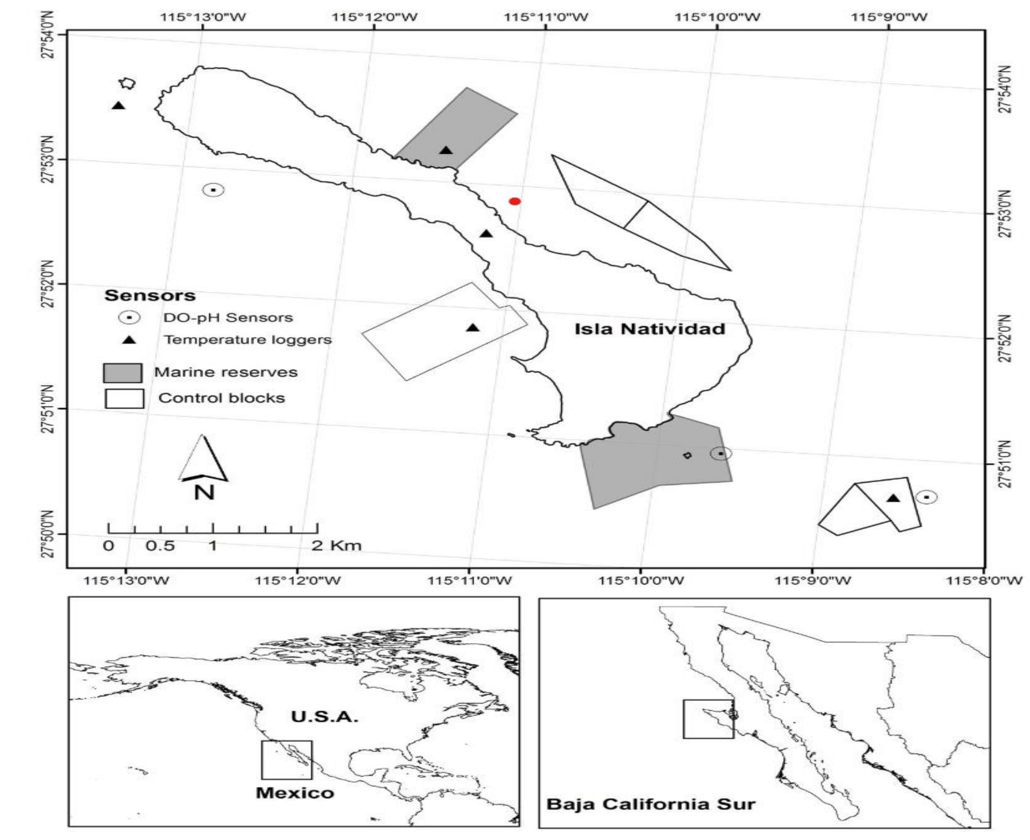

Figure 1: Map of the study area, in Isla (top panel), Baja California, Mexico (bottom panels), showing the location of the no-take (marine reserves) and fished, reference areas (control blocks). The location of oceanography sensors (temperature, DO, and pH sensors and loggers) is also shown.

Discussion

Key points	Description
Resilience Mechanism	Community-led enforcement and management (e.g., Isla Natividad) proved effective in reserve success.
Resistance to Disturbance	Protected populations showed greater resistance to hypoxia-induced mortality compared to fished areas.
Recovery Potential	Higher juvenile recruitment in reserves indicates faster recovery potential.
Local vs. Global Stressors	Study demonstrates that local management (reserves) can counteract some effects of global climate change
Community Benefits	Reserves supported local livelihoods by maintaining abalone populations, a key economic resource.
Scientific Contribution	Provides empirical evidence that marine reserves enhance resilience to climate impacts.
Limitations & Future Directions	Long-term monitoring is essential to understand the impacts of recurring hypoxia and other climate stressors.

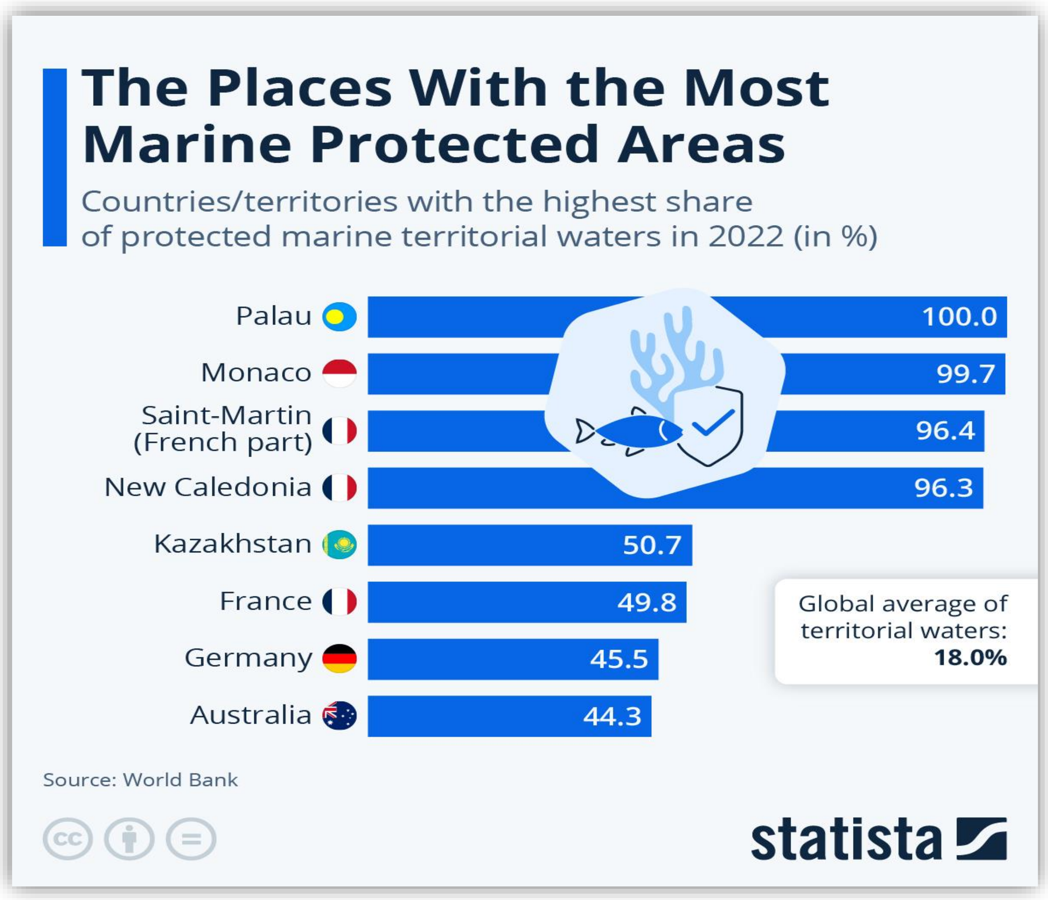

Figure 1: The image shows a ranking of countries and territories with the highest percentage of Marine Protected Areas (MPAs) in their territorial waters as of 2022. Palau leads with 100% protection, followed by Monaco (99.7%), Saint-Martin (96.4%), and New Caledonia (96.3%). Other countries on the list include Kazakhstan, France, Germany, and Australia. The global average for protected marine waters is 18.0%. The data source is the World Bank, and the infographic is created by Statista.

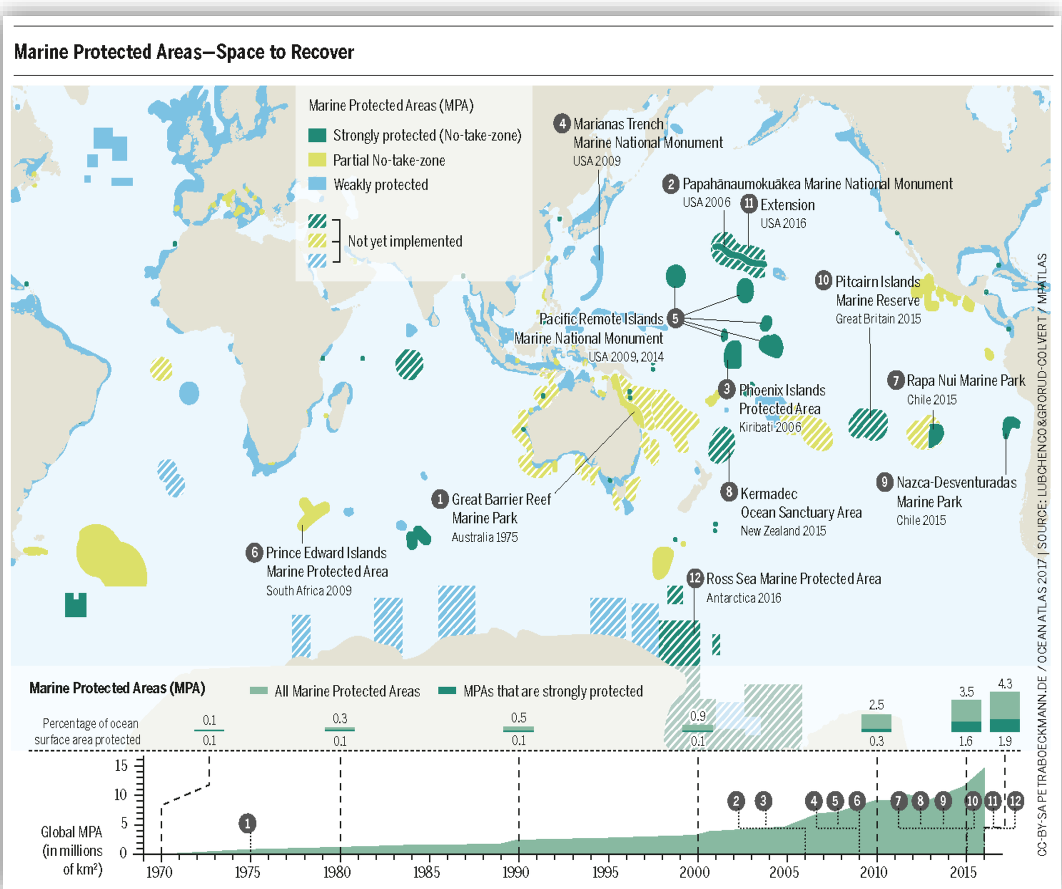

Figure 2: The image is a map showing Marine Protected Areas (MPAs) in the Indo-Pacific region, highlighting different types of protection levels, including no-take zones and partially protected areas. It also features graphs depicting the growth of MPAs over time. The map illustrates how spatial protection is distributed to support marine biodiversity and ecosystem recovery.

Conclusion

This research demonstrates that MPAs can enhance the resilience of marine populations to climate-driven disturbances such as hypoxia. By protecting larger, more fecund individuals, MPAs maintain higher reproductive output and support faster population recovery. Additionally, larval spillover from reserves to adjacent fished areas provides a buffer against climate impacts, benefiting both conservation and fisheries. The proposed strategies—stakeholder collaboration, renewable energy integration, and adaptive management frameworks—offer practical approaches to improve MPA effectiveness in the face of increasing climate stressors. These findings highlight the importance of MPAs as a local management tool to combat the global challenges posed by climate change.

Reference

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