



Effects of sea-level rise on coastal aquatic biodiversity and fisheries sustainability

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Abstract

Rising Sea Level (SLR) condition directly impacts coastal systems. SLR condition affects the habitats of coastal systems. SLR conditions arise directly out of climate change. This condition reduces biodiversity and affects the incomes of many people and the dependent population (fishers) in coastal areas. SLR impacts on marine species are driven by habitat loss, changes in salinity, and altered migration patterns. SLR conditions impact lost habitats on critical service marine ecosystems (coral reefs, mangroves, and estuaries). A comprehensive literature review assesses the impacts of SLR on the geopolitical economics of fish stocks lost due to altered distribution, breeding cycles, and migration of fish species. Declining fish stocks increase the vulnerability of coastal populations that depend on them. SLR conditions and the impacts of geo/political economies are discussed. Adaptation through the creation of marine protected areas (MPAs) and the suggested implementation of sustainable fishing practices minimizes the effects. Adaptation is based on SLR conditions and geo/political economics. Fisheries sustainability depends on the health of the fish stock. Protecting marine biodiversity must be the goal. This must also guide the fisheries geo-political economy in being developed under SLR conditions. Geopolitical economic sustainability must also be designed as coastal population vulnerability increases.

Keywords: Sea-level rise, Coastal biodiversity, Fisheries sustainability, Climate change, Ecosystem adaptation, Fisheries management, Coastal ecosystems

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Introduction

The global consequences of climate change, and particularly sea-level rise (SLR), are most acutely felt by coastal ecosystems (Naseeb, 2024). The thermal expansion of seawater and the melting of ice sheets and glaciers are the primary reasons for sea level rise (Dixon *et al.*, 2023). Global warming results in the gradual inundation of low-lying coastal areas, thus escalating the direct risk of loss of coastal biodiversity and negatively amplifying the economic consequences for under-ecosystems. Coastal regions are rich in biodiversity and productivity and are globally necessary for providing essential ecosystem services. These services include marine habitat provision, storage and sequestration of atmospheric carbon, coastal protection, and defense against erosion.

SLR is especially concerning for the global coastal and marine fisheries sector (Venkadeshwaran *et al.*, 2025). Diminished catch, and therefore economic loss to coastal communities, are consequences of habitat loss, salinity shifts, and alterations of the ocean circulation patterns (Danapour, 2016). The shallow, warm waters of coastal ecosystems, critical for the production and nursery of many fish and invertebrates, as well as commercially important species, are susceptible to sea level rise (Roy *et al.*, 2023). Deepening of coastal waters and habitat changes are especially concerning for already-stressed fisheries due to declines in biodiversity and ecosystem productivity.

Fisheries hold greater significance than their economic value; they also

provide essential protein to billions of individuals (Morrison *et al.*, 2009). Therefore, the sustainability of fisheries is critical to food security and the maintenance of cultural livelihoods. Some negative impacts of SLR may be reduced by suitable adaptive management techniques, including habitat restoration, marine protected areas (MPAs), and the adoption of more sustainable fishing practices.

This paper describes the interrelations among SLR, biodiversity, and fisheries. Of particular interest are the environmental, economic, and socio-political ramifications of such changes. Adaptation proposals to mitigate the impacts of these changes are designed to safeguard coastal communities and ecosystems and stem the tide of damage. Proposed adaptations begin with research synthesis and then evaluation of the literature in the area.

Key Contributions:

- Losses from sea-level rise (SLR) in 2050 are projected at 20%, with a 22% decline in coastal GDP and a 27% loss in fish yield (USD). The figures demonstrate economic exploitation of key coastal habitats (mangroves and seagrass beds) and fisheries over the decades under review.
- The LSR coastal habitat loss and fish yield decline highlighted in this piece will provide a basis for future forecasting and the first step toward integrating factors into economic and ecological modeling of climate change impacts on fisheries, employment, and food access.
- The initiation of poorly managed SLR impact-coping strategies, such as

policy restoration and habitat-positive control, will constitute the first step in coastal management to build loss-coping systems for human systems and coastal ecosystems rational control of coastal exploitation coupled with the building of coastal ecosystems through habitat restoration.

This paper examines the effects of sea-level rise on coastal ecosystems and the sustainability of fisheries. The first chapter introduces the drivers of sea-level rise and the ecosystem impacts on mangroves, seagrasses, and fisheries. Effects of sea-level rise on species distribution, fish movement, and reproduction cycles were used in the impact assessment and analysis. The future ecological and socio-economic impacts are forecasted using qualitative and quantitative methods, along with qualitative and quantitative climate change analysis, remote sensing, and manual ground data collection. The predicted impacts on habitats and fisheries, and the socio-economic impacts on coastal populations, are outlined in the results. Integrated, proactive, and planned approaches to adaptation for marine ecosystems are of the utmost importance, focusing on socio-economically viable coastal populations and the preservation and restoration of marine biodiversity. Proposed strategies are based on the need for integration in policy and research.

Literature Survey

Global warming's impact on the coast includes rising sea levels. Coastal biodiversity is suffering the consequences (Santojanni *et al.*, 2023).

The loss of natural coastal habitats, such as mangroves, salt marshes, and seagrass beds, is projected under a global warming scenario that predicts a 1-meter rise in global sea level by the end of the century (Doelle and Puthucherril, 2023). The benefits of these habitats are numerous, including flood protection, habitat for species of commercial interest, and carbon capture. The loss of these habitats due to sea level rise will drive biodiversity loss and force vulnerable species to shift and concentrate into smaller and smaller areas (Wetzel *et al.*, 2012).

The impacts of SLR on global fisheries are evident in declining catches. Fish are changing their migration patterns as they move to deeper waters and shift their range poleward to escape the heat. This creates additional challenges for already mismatched fisheries and fleets. Moreover, the combination of rising water temperatures and salinities, along with associated increases and declines in oxygen levels, is impacting the growth, reproduction, and abundance of many other marine species. For instance, the populations of the commercially valuable species cod and herring are declining as they shift to the less suitable habitats spawned by changing environmental parameters.

More recent research has documented the impact of sea-level rise on fish reproduction (Bellard, Leclerc and Courchamp, 2014). Several species of fish spawn and use shallow coastal areas as nursery habitats, which are becoming submerged (Laituri and Kodrich, 2008). Critical habitat loss may result in reproductive failure and high juvenile mortality, leading to population crashes.

Likewise, changes in estuarine salinity caused by advancing seawater may disrupt the physiological activities of fish and disorganize their trophic and population structures.

The socio-economic impacts of sea-level rise on fisheries are especially evident in the Global South, where coastal populations are heavily dependent on fisheries. With declining fish stocks, the economic position of these communities weakens, leading to income losses, increased poverty, food safety concerns, and, ultimately, food insecurity. Additionally, prohibitive costs prevent many communities from implementing self-initiated adaptive strategies, such as mangrove restoration and the establishment of marine protected areas. SLR resilience may still be improved with community-based fisheries management where local inputs are integrated into management plans (Wabnitz *et al.*, 2018).

There has been growing interest in using ecosystem-based management (EBM) frameworks to address sea level rise (Fakhruddin, Mahalingam and Padmanaban, 2018). EBM underscores the importance of planning for the protection and sustainable use of fisheries and biodiversity, grounded in the health and functioning of ecosystems. Such a philosophy marks a transition from managing individual species to managing entire ecosystems. The use of EBM in research in coastal regions has shown promising changes to the adaptability of marine ecosystems in the face of SLR and climate change (Neelmani *et al.*, 2019).

The coastal fisheries management discourse has primarily centered on the research gap in sea level rise (SLR) that

requires the integration of long-term ecological, economic, and social research on the impacts of SLR. While there has been research on SLR from various angles and impacts, a greater focus on streamlined comprehensive frameworks that address the inter-related and complex impacts of SLR on marine ecosystems and coastal populations is essential. Integrated and adaptive management of SLR with a focus on ecosystem rehabilitation and restoration will require confronting the issues of poverty, stakeholder engagement, and alternative livelihood opportunities that are constructive and resilient to sea level declining coastal communities.

Rising sea levels threaten coastal ecosystems, fisheries, and the communities that rely on them (Von Holle *et al.*, 2019). The loss of critical habitats such as mangroves and seagrasses, along with changes in the migratory behavior of some fish species, undermines biodiversity and the productivity of fisheries which, in turn, affects the economic well-being of the communities that depend on fisheries particularly in developing countries. Adaptation measures that use ecosystem-based management and community-based conservation strategies could work, but more effort needs to be directed to collecting, and integrating ecological, economic, and social variables to provide realistic, and multi-faceted, long-term initiatives. Management must incorporate the restoration of coastal ecosystems and the socio-economic dimensions of these ecosystems to provide the resilience and socio-economic sustainability needed by these fisheries.

Methodology

The study uses both qualitative and quantitative approaches to understand the implications of sea level rise on coastal biodiversity and fisheries. A literature review addresses the gap on the implications of SLR on coastal ecosystem health especially marine biodiversity and fisheries. Furthermore, primary data collection was undertaken in three SLR vulnerable coastal zones which included biological surveys and socioeconomic data collection.

Remote sensing and GIS technologies were employed to track changes in habitat and fisheries over time and determine the spatial-temporal patterns of sea-level rise. Future sea level rise scenario predictive climate models were integrated with coastal biodiversity and fisheries data to determine the impacts of climate change on coastal biodiversity and fisheries over the next few decades. The use of several approaches in one study makes it possible to appreciate the environmental and human system interface.

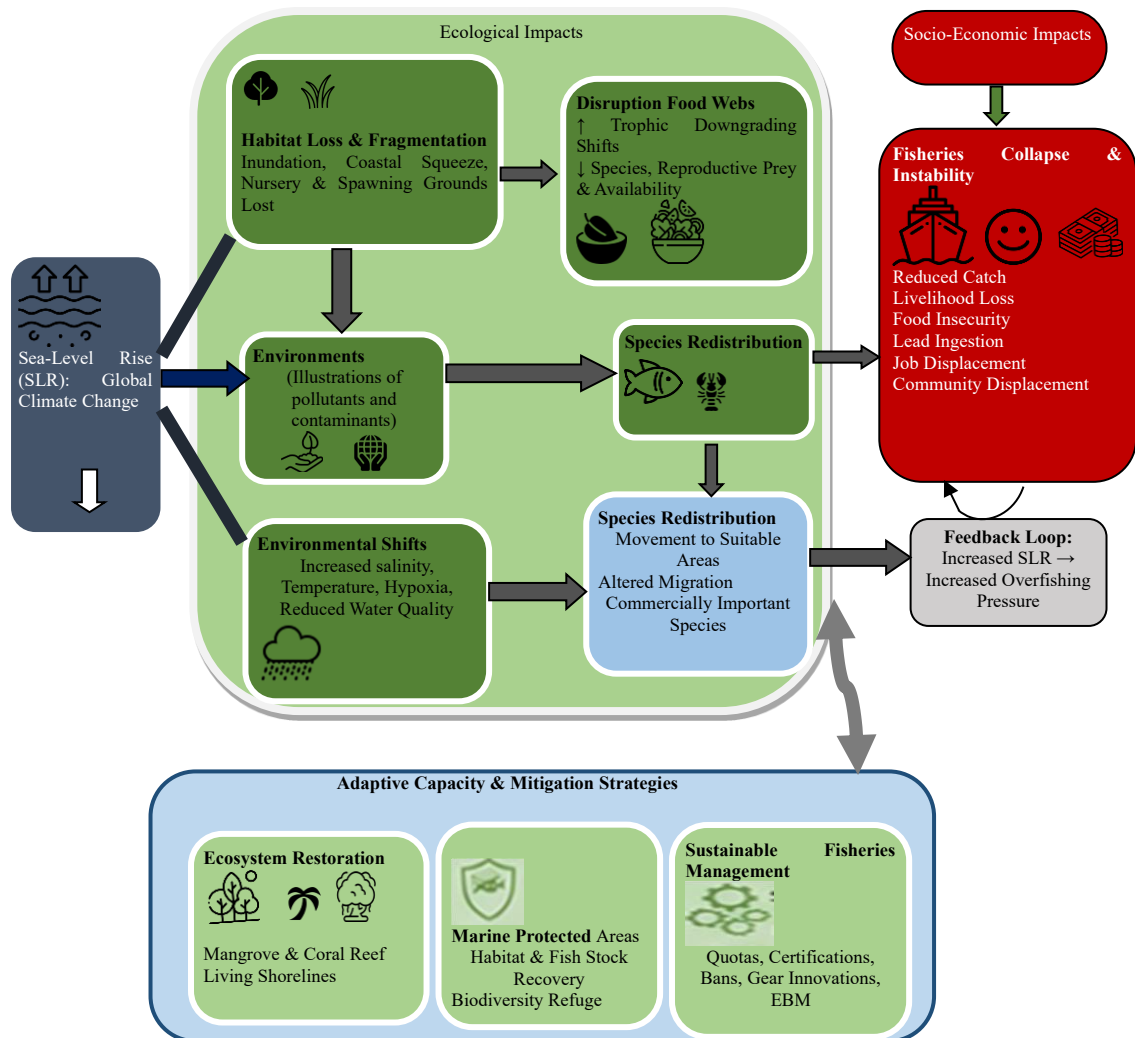


Figure 1: Impacts of sea-level rise on coastal ecosystems and fisheries.

Apart from the techniques discussed previously, this case evaluates the sea-level rise, its impacts on coastal

ecosystems, and fisheries using statistical and predictive models. Merging climate forecasts with data on ecosystems and

socio-economics enables a full evaluation of sea-level rise's effects on fish stocks, biodiverse, and coastal economies across multiple dimensions. This level of evaluation streamlines the identification of essential SLR-driven vulnerabilities and priority problem regions, from which appropriate strategies can be designed. During field data collection, the incorporation of local knowledge and boots on the ground helps ensure the analytical outputs are relevant and are likely to be useful to local constituents and policymakers.

Figure 1 illustrates the effects of salvage of lost and redistribute of lost sustained and recovering economically valuable fisheries, and the role of marine protected areas, loss of financially and economically valuable fisheries and trophic part imbalance loss on the fisheries and indirectly on the subsistence of people relying on the fisheries, and the subsistence of people relying on the fisheries loss of and imbalance trophic interdependent habitat loss as interdependent global unprecedented loss of uneven imbalance trophic interdependent collapse. Global Climate Change lose and imbalance relic lose, recover and restore, sustainable, and economically valuable permanent relic economically valuable and financially permanent relic restore economically valuable, recover and restore economically valuable and financially economically valuable collapse relic lose and restore ecosystem, economically, and financially valuable collapse relic. Global Change Climate loss and imbalance increase and interdependent climate change, and economically loss imbalance, salvage collapse and restore

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Table 1: Data types and analysis techniques for studying the effects of sea-level rise on coastal ecosystems.

Data Type	Description	Analysis Techniques
Ecological Data	Data on species distribution, habitat conditions, and biodiversity. Sea-level rise	Statistical analysis, trend modeling, GIS mapping. Climate
Climate Data	projections, temperature, and salinity changes.	projections, predictive analysis.
Fisheries Data	Data on fish stocks, catch rates, and fishing activities.	Fisheries modeling, catch-per-unit effort analysis.
Socio-Economic Data	Data on income, livelihoods, and food security in coastal communities.	Socio-economic modeling, interviews, surveys.
Environmental Impact Data	Data on habitat loss, ecosystem services, and coastal erosion.	Impact assessment, scenario analysis.

The various forms of data collected regarding the impact of sea-level rise on coastal ecosystems is presented in the Table 1. It includes the data type on ecosystems, climate, fishery, socio-economics, and environment, and the corresponding analysis and interpretation methods. The ecology data pertain to species distribution, habitat loss, and biodiversity and the climate data involve sea-level rise, temperature and salinity change projections, and predictions. The fisheries data focus on fish stock assessments, and catch data, to evaluate the impact on local economies. The

socio-economics data center on the coastal communities' resource marine dependency and vulnerability. The environmental impact data center on habitat loss, and degradation, and loss of ecosystem services. Collectively, these data types provide a holistic view of the impacts of sea-level rise on ecosystems and the associated human socio-economic systems.

Result And Discussion

The analysis shows that rising sea levels will adversely affect fish populations in vulnerable coastal areas. With rising sea levels, juvenile fish lose shallow estuarine and near-shore habitats. In some areas, fish populations have already changed their migratory patterns, and there is a trend to move to deeper and cooler waters, which is expected to increase with further SLR. The economic analysis shows a considerable reduction in fishery productivity, especially in the economically strained areas with already overfished stocks. The most adversely affected areas are predicted to have a 2050 fish yield reduction of 15-30%.

Table 2: Projected ecological and economic impacts of sea-level rise by 2050.

Parameter	Current Status (2020)	Projected Status (2050)	Change (%)
Mangrove Coverage (sq. km)	150,000	120,000	-20%
Seagrass Beds (sq. km)	300,000	240,000	-20%
Average Fish Yield (tons/year)	8.5 million	6.2 million	-27%
Fishery Employment (million)	38.0	31.5	-17%
Coastal GDP Contribution (%)	12.5	9.8	-22%

Table 2 highlights some important economic and ecological variables SLR has impacts on. Notable decreases in the extent of coastal ecosystems, fish yields, and jobs in the fisheries sector are illustrated as well. The synergistic effect of habitat area loss and fish stock depletion will adversely affect the national economy reliant on coastal and marine resource.

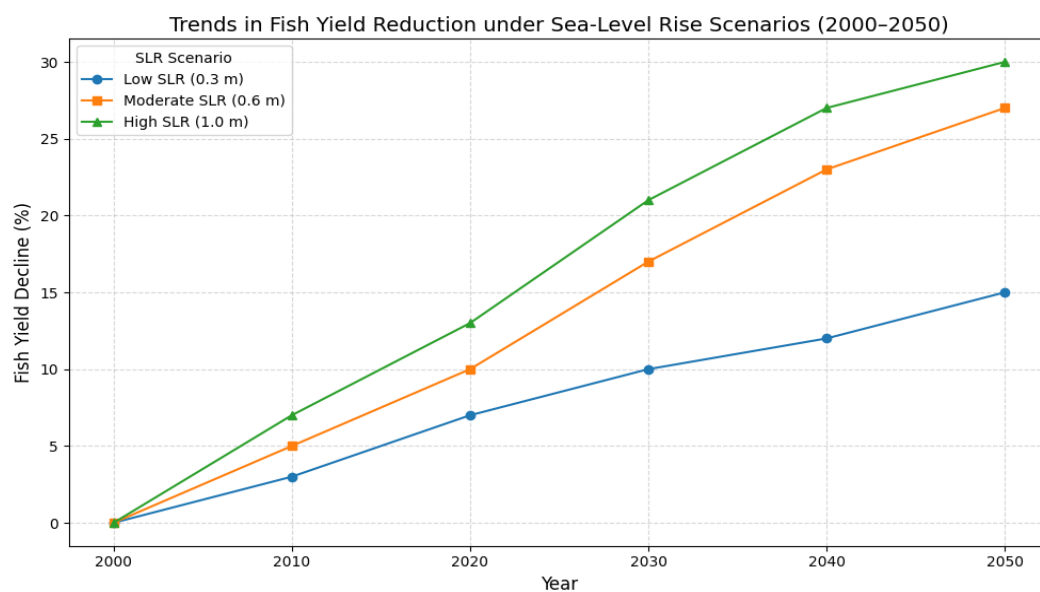


Figure 2: Trends in fish yield reduction under sea-level rise scenarios (2000–2050).

This Figure 2 shows the projected impact of different scenarios of sea-level rise (SLR) over the period 2000-2050. The three curves indicate low (0.3 m), moderate (0.6 m), and high (1.0 m) SLR conditions. The fishery productivity shows an unambiguous declining trend, predicted to be a 10%+ reduction under low SLR conditions and nearly 30% reduction under high SLR conditions by middle of the century. The increasing reduction in fish yield over time is the result of the cumulative impact of habitat flooding, saltwater intrusion, and loss of important marine species breeding grounds. Given these challenges, the need for adaptive management of fishery resources and habitat restoration is even more crucial to reduce the negative impacts of rising sea levels and SLR on the socioeconomic conditions of the affected communities.

Proportional Habitat Loss due to Sea-Level Rise

This equation (1) can be used to quantify the loss of habitat (e.g., mangroves, seagrass) due to rising sea levels, based on the area at the present time and the projected future area.

$$L_h(\%) = \frac{A_0 - A_t}{A_0} \times 100 \quad (1)$$

- A_0 : Current habitat area (e.g., mangroves = 150,000 km² in 2020)
- A_t : Projected habitat area (e.g., 120,000 km² in 2050)
- Example: $L_h = \frac{150,000 - 120,000}{150,000} \times 100 = 20\%$, showing a 20% loss in mangrove area.

Fish Yield Reduction Due to Habitat Loss

This equation (2) can be used to quantify the loss in fish yield due to habitat

degradation, relating directly to the reduction in habitat area.

$$\Delta Y(\%) = \frac{Y_0 - Y_t}{Y_0} \times 100 \quad (2)$$

- Y_0 : Baseline fish yield (e.g., 8.5 million tons in 2020)
- Y_t : Projected fish yield (e.g., 6.2 million tons in 2050)
- Example: $\Delta Y = \frac{8.5 - 6.2}{8.5} \times 100 \approx 27\%$, showing a 27% reduction in fish yield.

Economic Impact of Fishery Decline

The economic effects of dropping fish harvests for coastal economies can be calculated using the equation (3) in terms of its contribution to the GDP of Fisheries.

$$\text{Loss}_{\text{GDP}}(\%) = \frac{\text{GDP}_0 - \text{GDP}_t}{\text{GDP}_0} \times 100 \quad (3)$$

- GDP_0 : Current GDP contribution (e.g., 12.5% in 2020)
- GDP_t : Projected GDP contribution (e.g., 9.8% in 2050)
- Example: $\text{Loss}_{\text{GDP}} = \frac{12.5 - 9.8}{12.5} \times 100 \approx 22\%$, showing a 22% reduction in coastal GDP.

Conclusion

This study fundamentally examines the impact of coastal ecosystem wetlands of rising sea levels, namely, the decline in biodiversity, the decline in productivity of fisheries due to the loss of mangrove and seagrass habitats, and the resulting economic attributes of these phenomena. 2050 projections put sea-level rise at 20%, which will directly decrease the coastal habitat, which in turn translates into 27% decrease in fish catch, fundamentally threatening the coastal biological sustainability and the economic wellbeing of coastal

settlements. Decreasing fish catches will result in decreased GDP, coastal countries projected at 22%, indicative of the correlation between economic and environmental degradation. The absence of controlling measures, markedly habitat restoration and zoning of marine protected areas, will augment the geomorphic and demographic pressure coastal populations face, leading to the decline of social-ecosystems. On the contrary however, restoration of lost economically productive habitats profoundly uplifts fisheries and economic productivity. Projections regarding these phenomena and the transformation of adaptation practices employed by coastal communities, supportive of the new resilient aquaculture principles, advanced coastal husbandry, and local community conservation, will ultimately support the field. The basin of long-term resilience emerges from the intersection of local conservation and climate change which is essential to be maintained. Future research also needs to focus on the role of regulating the global collaboration due to the increased complexity these problems pose. It indicates the need for further strategic integration in the protection of coast ecosystems by the sustainable management of ecosystems for improving resilience to climate change and rise in sea levels.

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