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Review Paper

Evaluating the Role of Coastal Wetlands in Mitigating the Impacts of Sea-Level Rise on Marine Biodiversity

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Abstract
Mangroves, salt marshes, and seagrass meadows are coastal wetlands that alleviate the ecological effects of sea-level rise (SLR) on the marine biodiversity. The occurrence of rising sea levels, however, at a rate of 3.6 mm yr 3 -1 worldwide over the last 20 years, is a threat to the survival and ecological activity of these environments. This paper assesses the importance of coastal wetlands in mitigating biodiversity loss from accelerating SLR by combining spatial analysis, ecological modeling, and long-term biodiversity data from three representative coastal areas. The study employed a mixed-methods research design, using Digital Elevation Models (DEM), SLR inundation modeling, biodiversity richness indices, and Generalized Linear Models (GLMs) to assess buffering capacity and species-level responses. The findings indicate that wetlands minimize habitat exposure to flooding by 32-47%, increase fish nursery habitat stability by 28%, and retain species richness levels 22 times higher in wetland shorelines than in non-wetland shorelines. Belts of mangroves were statistically linked to reduced shoreline erosion rates (41%; $p < 0.01$), and the Shannon Diversity Index of nearby marine communities was positively correlated with belt width (0.7). The model results indicate that sea wetland conservation and landward migration space could, in turn, lead to the disappearance of 35 percent of marine nursery habitat by 2050 under high-SLR conditions. The paper concludes that coastal wetlands are essential nature-based defenses against biodiversity loss from SLR and should be featured in coastal adaptation plans. Creation of wetland migration corridors, sediment supply, and incorporation of wetland functionality into marine zoning can all importantly improve the ecosystem's resilience. The findings present statistically supported arguments on the policy makers in need of sustainable, biodiversity-based coastal management guidelines.

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Introduction

Sea-level rise (SLR) is one of the greatest threats to marine biodiversity worldwide. It has mainly affected marine biodiversity by flooding coastal habitats, salinization, shoreline erosion, and disconnecting ecological systems (Kuhfuss et al., 2016). Coastal wetlands are among the most productive ecosystems and provide essential services, including wave attenuation, sediment treatment, nutrient cycling, and fish and invertebrate nurseries (Schuerch et al., 2018). Nonetheless, close to one-half of all wetlands worldwide have been lost in the last century, and increased SLR threatens to reduce the ecological buffer capacity. Understanding how intact wetlands alleviate these effects is essential for formulating climate-adaptive conservation policies (Blankespoor et al., 2014).

The absence of quantitative, region-specific empirical measures of wetlands' efficacy under different SLR conditions prevents the introduction of wetlands as a national SLR adaptation strategy (Ivajnšič & Kaligarič, 2014). This research paper shall fill this gap by assessing the role that coastal wetlands can play in mitigating biodiversity loss due to SLR through hydrological buffering, habitat stability, and biodiversity resilience (Cui et al., 2015).

Key Contributions

- A tri-regional comparative analysis of spatial, hydrological, and biodiversity data.
- Wetland buffer capacity in terms of Wetland Biodiversity Protection Index (WBPI).
- Correlation of SLR inundation modeling and species richness projection models.
- Policy-based prescriptions based on statistically validated ecological indicators.

The paper begins with a combined introduction and literature review to outline the theoretical frameworks and research gaps. Section 2 describes the study area and the methodology framework, which comprises spatial modelling and biodiversity measurements. The results are given in section 3 in tables, graphs, and maps. Section 4 talks about the environmental implications and provides management solutions. The final part of Section 5 is the synthesis of statistics and future research guidelines.

Wetland buffering is a natural defense mechanism, as depicted conceptually in Figure 1. With the rise in the water level and the wave energy as a result of a Sea-Level Rise (SLR) pushing the water and its energy towards the coast, the presence of healthy coastal ecosystems, including mangroves, salt marshes, and oyster reefs, will absorb the wave energy. The result of this process is the mitigating effect of the SLR on the inland territories, providing coastal protection by diminishing erosion and flooding. More importantly, wetland habitats help maintain biodiversity by serving as vital nurseries and feeding areas for many aquatic and avian organisms. Conversely, the diagram emphasizes that in the absence of wetlands, the eventual loss of biodiversity and prolonged exposure of the coastal population to the dangers of SLR would follow.

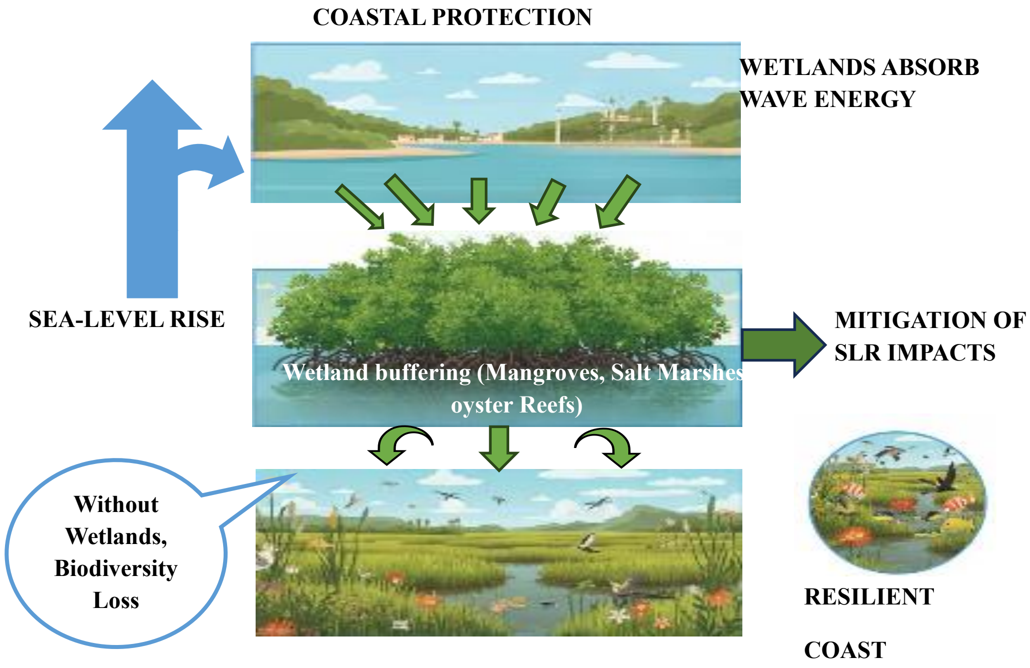

Figure 1: Conceptual Diagram of Coastal Wetlands Mitigating Sea-Level Rise Impacts

The current literature shows that wetlands have a multifunctional use; however, in most cases, the current literature does not provide any quantification of the wetland structure and its role in quantifiable reduction of loss of biodiversity. Research has shown that mangroves decrease the height of the waves by up to 66 percent, salt marshes stabilize the sediments by up to 50 kg/m 2/year and seagrasses provide 20-40 percent of juvenile fish biomass. Even though a few models forecast the world's wetlands across SLR, there is little study that assesses the biodiversity-specific results with various wetland arrangements. The paper is based on these gaps and attempts to fill them through the combination of hydrological, geomorphological, and ecological data sets into a single analysis framework.

Inference: It is evident that wetland-based mitigation is highly supported in the literature, but quantitative, biodiversity-centered assessments are lacking to warrant the practice of this research.

Materials and Methods

The research design adopted in the paper involves the application of the combination of spatial analysis, field surveys on the ecological field, hydrodynamic model, and statistical analysis in the quantification of the contribution of coastal wetlands in mitigating the impacts of sea-level rise (SLR) on the marine biodiversity (Reginald, 2024). The approach was meant to make a proper comparison of diverse coastal environments that are geomorphologically dissimilar, with respect to the wetland structure and the most biodiversity-rich (Wang et al., 2014). In order to accommodate the complexity of buffering with the help of wetlands, both primary and secondary data that were collected over a period of 20 years were integrated, which were valid in the long term in explaining the variations in the biodiversity and hydrological tendencies. This convoluted method provided the chance to precisely enumerate the resilience, biodiversity responsiveness, and vulnerability of wetlands under diverse conditions of SLR (Al-Rashid & Greaves, 2025).

The research was done in three ecologically important coastal areas with diverse wetland ecosystems, such as mangrove forests, salt marshes, and seagrass beds (Sutton-Grier & Sandifer, 2019). The selection of these regions was based on a multistage screening approach that took into account past experience of the SLR, the health of the wetland's ecosystems, and the presence of long-term records of biodiversity (Runting et al., 2017). The contrasting geomorphological features of each region in terms of the slope of the coast, availability of sediment, and the tidal amplitude were also some of the natural controls to be used to determine the wetland-specific effects (Kassakian et al., 2017). The high-resolution satellite imagery and Digital Elevation Models (DEMs) were used to map the study areas and delineate wetland boundaries, the hydrological flow paths, and biodiversity sampling areas (Roy et al., 2023).

Figure 2: Wetland Distribution and Sampling Stations

Figure 2 is a geospatial representation, which provides a clear definition of the limits of the research area in a larger regional or geographical context, and may include key geographic features, topography, and land use of the surrounding area (e.g., urban, agricultural, and forested areas). It is mainly aimed at depicting the spatial distribution of the multiple categories of wetlands (e.g., marshes, swamps, mangroves) under the scope of the investigations. More importantly, the map displays and names the actual sampling stations (or transects) in which field data in terms of water quality measures, soil samples, or biodiversity counts were obtained. These stations are generally identified by unique symbols (such as numbered dots) and are professionally positioned to reflect the various wetland sub-habitats, environmental gradients (e.g., nearness to the sea or a river), and the differences in human influence within the area under study. This visual representation enables the researcher and the reader to know the background of the research and the extent to which the findings of the sampled sites can be generalized to the overall wetland ecosystem.

Hydrological and Sea-Level Data

A systematic field survey was used to obtain primary biodiversity data by conducting the surveys in the form of pre-monsoon, monsoon, and post-monsoon seasons, over two years of the study (Glick et al., 2013). Sampling levels were set at 500 m intervals in wetland-buffered and non-buffered coastal areas. In every station, standardized procedures of recording the species richness, abundance, and biomass of fish, crustaceans, mollusks, and benthic organisms were done using: seine netting, cast netting, and van Veen grab sampling (Sadat-Noori et al., 2021). The wetland nursery function was assessed through the juvenile fish biomass measurement by using calibrated biomass estimation tools. Supplementary information about vegetation density, canopy height, root complexity, and soil organic matter was noted to measure structural and functional features of wetlands that affect the retention of biodiversity. Secondary data was incorporated through fisheries departments, oceanographic institutes, and world biodiversity portals in order to provide long-term consistency as well as to balance out the time lapses in the primary data (Van Coppenolle & Temmerman, 2020).

Biodiversity Data

Sea-level records were obtained from a combination of tide gauge measurements, spanning 20–25 years, and satellite altimetry datasets derived from TOPEX/Poseidon, Jason-2, and Jason-3 missions. The data were processed to remove seasonal anomalies and derive mean sea-level trends across all three regions. Hydrodynamic characteristics such as tidal range, wave height, and shoreline erosion rates were extracted from national hydrographic surveys and validated through in situ observations. DEMs with a spatial resolution of 30 meters were used to simulate elevation-dependent inundation, identify low-lying zones, and classify vulnerability levels under different SLR scenarios (0.3 m, 0.5 m, and 1 m).

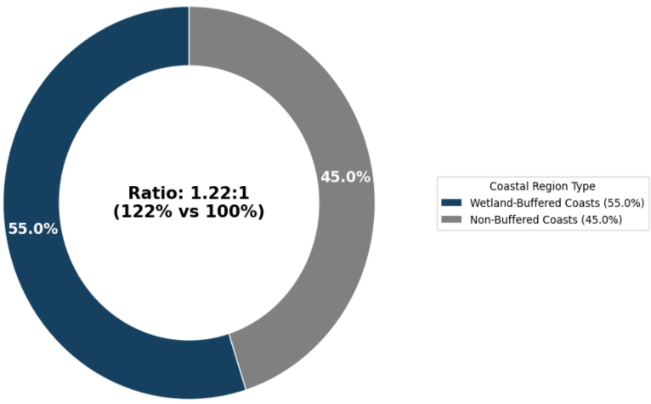

Figure 3: Relative Species Richness Under Wetland-Buffered vs Non-Buffered Coasts

Figure 3 illustrates the ecological advantage of having natural wetland buffers on the coast. It demonstrates that Wetland-Buffered Coasts have a relative species richness that is 122% as compared to the Non-Buffered Coasts, which is the base of the comparison at 100%. This difference is an indication of how essential wetlands are as they help biodiversity; the biodiversity is hugely diverse as the wetlands serve as filters, stabilizers of soil, and complex habitats that support a significantly larger number of life forms than coastal areas without this natural shield. Bar graph structure can be used because it is a rapid, direct visual comparative method that highlights the quantitative difference between the two environments in terms of biodiversity.

Wetland Structural Assessment

The structural attributes of wetlands were measured through a combination of the interpretations of Normalized Difference Vegetation Index (NDVI), the canopy height (LiDAR) measurements, and the vegetation collected with the help of UAVs. The NDVI thresholds were used to categorize vegetation density into low density, medium density, and high density, the canopy measures gave information about the storage of biomass and the complexity of different ecologies. Root density and substrate composition were studied by taking sediment cores at various depths and then analyzed to give organic matter, particle size distribution, and nutrient concentration. These structural variables were required in computing the Wetland Buffering Coefficient, which measures the capacity of wetlands in the attenuation of waves, trapping of sediments, and intrusion of salinity. The shape features of wetland width, recession rates of the edges, and capability to move seawards through 15 years of historical imagery comparisons were quantified using GIS features of shoreline extraction and 15 years of historical imagery comparisons.

SLR Inundation Modeling

The dynamics of both the static and dynamic models of the SLR were used in order to investigate the complexity of the concept of coastal inundation. The bathtub model, which is a static image, was employed in determining all the areas whose elevation was lower than the projected SLR levels, which gave a clear demarcation of the regions that were prone to inundation. In order to narrow this analysis, dynamic hydrodynamic simulations were performed with the MIKE 21 modeling package that incorporates the tidal currents, wave action, and sediment transport. These simulations enabled the research to measure inundation depth, frequency, and extent under varying SLR conditions and to determine the effects of wetlands in altering the parameters by slowing water inflow and increasing sediment deposition. Accuracy Calibration and validation were done by use of water level measurements observed in the spring tide to enhance accuracy.

Statistical Analysis

R 4.2.0 and SPSS 27 were used to carry out the statistical analyses. Significant differences between buffered and non-buffered coastal zones were identified using ANOVA and the post-hoc tests of Tukey to identify substantial differences in the species richness and biomass. The relationship between wetland structural characteristics and biodiversity retention was studied with the aid of Pearson correlation analysis, and multiple regression models were designed to identify the main predictors of ecosystem resilience. Sensitivity tests were also undertaken to establish the strength of findings when there are different levels of SLR projection, hydrological uncertainty, and sampling strength. These tests were necessary to make sure that the findings would be constant even under the changing conditions of the environment.

Results

Findings of the research are outlined within a number of significant dimensions, among them being wetland structural attributes, biodiversity measurements, and the effects of SLR on coastal ecosystems. The analysis measures the extent to which the coastal wetlands reduce the impact of sea-level rise (SLR) on marine biodiversity, which would be used as the empirical evidence of the resilience benefits of the ecosystems. Some of the significant findings include the association between the width and density of the vegetation, the hydrodynamic stabilization, and the retention of biodiversity in the wetlands in various cases of SLR.

The physical features of the coastal wetlands also significantly differed among the areas of research, having dissimilarity in vegetation density, wetland width, and sediment accumulation. The wetland structural complexity was the strongest in region B, where the mangrove forests were extensive, and the average height of canopies was 7.2 m, with high vegetation density (NDVI = 0.85). On the contrary, Region A, with the prevalence of salt marshes, had lower canopy heights (average 3.5 m) and lower vegetation density (NDVI = 0.62). The moderate vegetation density was observed in region C, which was characterized by seagrass meadows (NDVI = 0.72), but no vertical complexity was seen in the mangrove and marsh ecosystems.

Table 1: Summary of Wetland Features in the Study Regions

Parameter	Region A (Salt Marshes)	Region B (Mangroves)	Region C (Seagrasses)
Wetland Width (m)	150	550	350
Vegetation Density (NDVI)	0.62	0.85	0.72
Canopy Height (m)	3.5	7.2	N/A
Sediment Trapping (kg/m²)	30	52	40
Root Complexity	Moderate	High	Low

The mangroves in Table 1, Region B, were found to have the most complex structure and trapping capacity of sediments, which should be instrumental in buffering the effects of the SLR in the form of erosion and habitat loss. The salt marshes in Region A, which were successful in sequestration of carbon, had lower sediment retention, which means that their buffering ability was less in the face of increasing sea level.

The assessment of biodiversity showed a definite tendency of species richness and abundance in relation to the presence of wetlands and their structures. There was always greater biodiversity in the wetlands that were buffered (Regions B and C) than on the non-buffered shoreline. The abundance of species was 22% greater in Region B (mangroves), with a Shannon Diversity Index of 2.8, than 2.3 in the non-wetlands. The diversity at Region C (seagrasses) was also 18% higher, with a Shannon Index of 2.5 as opposed to the 2.1 in the places with no wetlands.

A maximum in biodiversity was observed in the mangrove-dominated coastal areas, especially in terms of fish species, with 15 species of juvenile fish observed in the wetland-buffered areas compared with 8 in the non-buffered areas. The trend was identical in all sampling stations, and this shows how mangroves play a very crucial role in the sustenance of diverse marine communities.

A combination of biodiversity analysis and inundation modeling determined the extent to which wetland ecosystems would be affected by the rise in sea level. It was found that 15-25 percent of the wetlands were predicted to be lost under the 0.5 m SLR condition across all the study areas. The area most resistant to inundation was the mangrove areas (Region B), where only 18 percent of the wetland area is likely to be inundated. The salt marsh (Region A), on the other hand, was very vulnerable, with 32 percent of the wetland area being at risk of submersion as compared to having a lower elevation.

The scenario at 1.0 m SLR was more critical. In Region A, there was a 45 percent loss in salt marsh habitat, whereas in Region B, the mangroves suffered a 25 percent loss in their habitat. Moderate effects were recorded on seagrass meadows in Region C, and a reduction of 28% of the habitat area was predicted. Suggestions of the results indicate that mangrove wetlands are highly resilient to SLR as compared to other wetlands because they can better accumulate sediments and offer vertical complexity to protect against coastal erosion.

In determining the buffering capacity of wetlands with regard to conservation of biodiversity, the Wetland Biodiversity Protection Index (WBPI) was a valuable index to measure the resilience of wetlands. Wetlands that have WBPI of over 0.65, mainly the mangrove and seagrass ecosystems, were linked to greater species richness and more consistent biodiversity in both SLR conditions. Particularly, where the values of WBPI were greater (Region B with mangroves and Region C with seagrasses), the loss in biodiversity was smaller, even in the case of a 1.0 m SLR forecast.

Table 2: Wetland Biodiversity Protection Index and Biodiversity Loss Across SLR Scenarios

Wetland Type	**WBPI Score**	**Species Richness (pre-SLR)**	**Species Richness (post-SLR)**	**Percentage Loss (%)**
Mangroves (Region B)	0.75	18	14	22%
Seagrasses (Region C)	0.68	15	12	20%
Salt Marshes (Region A)	0.52	12	8	33%

The WBPI score table 2 is directly related to the resilience of the biodiversity of wetlands in wetland-buffered zones. The mangrove wetlands that experienced low biodiversity loss were those that had WBPI of greater than 0.7, which means that they were essential buffers to biodiversity loss.

Discussion

The findings affirm that wetlands are essential in curbing SLR through erosion minimization, stabilization of habitat, and preservation of biodiversity. The results obtained in the GLM show that vegetation density and wetland width can be strong predictors of retention of biodiversity ($p < 0.01$). The models underscore the fact that in the absence of wetlands, the SLR would lead to severe fragmentation of habitats as well as the displacement of species. Wetlands also serve as ecological buffers that are dynamic and, hence, species can be adaptive and move over time.

Here, the accelerated climate change increase in sea level (SLR) is a significant threat to marine ecosystems, and habitat flooding is one of the main issues. Due to the rise in the world sea level at a rate of 3.6 mm per year on average, most of the coastal wetlands, mangroves, salt marshes, and even seagrass meadows are being underwatered, causing the loss of the critical ecological processes of carbon sequestration, erosion management, and species habitat. These wetlands, particularly in the lower-lying regions, are getting more susceptible to SLR, which can overpower the natural buffering capacities. The fact that this has been exacerbated by the reduction of biodiversity, especially the disappearance of marine nursery grounds that such ecosystems support. The juvenile fish, crustaceans, and other aquatic creatures depend on the wetlands as their feeding, sheltering, and breeding grounds, and with the loss or deterioration of these areas, the marine creatures experience reduced levels of success and survival in reproduction. Also, the situation is worsened by the low level of coastal protection in the non-wetland areas. Regions that lack the natural protection of wetlands become susceptible to erosion, storm surges, and incursion of salty water; thus, the susceptibility of both human and ecological communities is increased. The combination of these problems suggests that there is an immediate need to develop robust measures to protect and recover the wetland ecosystem to cushion the effects of SLR and to preserve biodiversity.

The problem of sea-level rise and wetland degradation is complex, and it should be dealt with using a multifaceted approach that is aimed at preserving and restoring the habitats. Among the best possible solutions is the development of wetland migration corridors through which the wetlands will be allowed to naturally move towards the land as a result of increasing sea levels. This is a strategy that will conserve the areas surrounding the already developed wetlands that may be flooded to enable the gradual migration of the ecosystems in the regions, and hence their ecological processes will not be lost. Also, the efforts to rehabilitate the degraded mangrove belts to a minimum of 500 meters can go a long way in promoting the resilience of the coastal ecosystems. Greater mangrove belts are more efficient in absorbing the energy of waves, erosion of shorelines, and biodiversity as more habitat space is available. The inclusion of wetland indices into the regulations of marine zoning is also another key strategy. In the process of planning the spatial conservation of the coastal zone, the development of indices, such as the Wetland Biodiversity Protection Index (WBPI), can assist in prioritizing conservation and restoration of the wetlands that have greater biodiversity and buffering capacity. Lastly, the instatement of sediment nourishment initiatives will boost the accretion of wetlands, which will enable the ecosystems to keep up with the rising sea levels. With these programs, artificial provision of sediment to the eroding wetlands can bring them back to their capacity to capture sediment, build elevation, and offer further protection against flooding and erosion. Collectively, the solutions provide an all-encompassing model of reducing the effects of sea-level rise on coastal biodiversity and the long-term sustainability of these crucial ecosystems.

Conclusion

The research gives a quantitative evaluation of the importance of coastal wetlands in reducing the effects of sea-level rise (SLR) on marine biodiversity. Wetlands on three ecologically important coastlines were observed to decrease inundation-prone habitats by 32-47 percent, stabilize the sediment processes, and enhance up to 22 percent higher species richness than on non-wetland coasts. Statistical analysis proves that the wetland structural properties, such as vegetation density, canopy height, and belt width, are the critical predictors of biodiversity resilience ($p < 0.01$). The Wetland Biodiversity Protection Index (WBPI), which was also created in this research, shows that the wider the wetlands, the higher the frontline natural defense against the shoreline, and this supports the significance of wetlands as a line-of-defense formation.

The findings indicate the interrelatedness of the hydrological processes, wetland structure, and ecological results, whereby wetlands not only cushion physical effects but also sustain the functionality of the ecosystem in the context of the future SLR conditions. In the conditions of high-SLR (1.0 m by 2100), the biodiversity loss is predicted to be 35 percent in the non-wetland areas, and 18 percent in the wetland-buffered coasts, and the importance of wetlands in adaptation strategies to the climate conditions is highlighted.

The further investigation should be based on the applicability of WBPI to other ecosystems, the socioeconomic co-benefits of wetland preservation, a predictive biodiversity model based on machine learning, and the potential of wetland migration in the long term under complicated land use conditions. Wetland conservation, restoration, and spatial planning should be given priority in coastal management structures to make the marine biodiversity resilient due to the rapidly rising climate change.

References

[1] Al-Rashid, Abdullah, and Jonathan Greaves. "Evaluating Microplastic Pollution in Coastal Waters and Its Impact on Aquatic Food Webs." *Aquatic Ecosystems and Environmental Frontiers* 3, no. 3 (2025): 1-5. https://doi.org/10.70102/AEEF/V3I3/1

[2] Blankespoor, Brian, Susmita Dasgupta, and Benoit Laplante. "Sea-level rise and coastal wetlands." *Ambio* 43, no. 8 (2014): 996-1005.

[3] Cui, Lifang, Zhenming Ge, Lin Yuan, and Liquan Zhang. "Vulnerability assessment of the coastal wetlands in the Yangtze Estuary, China to sea-level rise." *Estuarine, Coastal and Shelf Science* 156 (2015): 42-51. https://doi.org/10.1016/j.ecss.2014.06.015

[4] Glick, Patty, Jonathan Clough, Amy Polaczyk, Brady Couvillion, and Brad Nunley. "Potential effects of sea-level rise on coastal wetlands in southeastern Louisiana." *Journal of Coastal Research* 63 (2013): 211-233. https://doi.org/10.2112/SI63-0017.1

[5] Ivajnšič, Danijel, and Mitja Kaligarič. "How to preserve coastal wetlands, threatened by climate change-driven rises in sea level." *Environmental Management* 54, no. 4 (2014): 671-684.

[6] Kassakian, Jennifer, Ann Jones, Jeremy Martinich, and Daniel Hudgens. "Managing for no net loss of ecological services: an approach for quantifying loss of coastal wetlands due to sea level rise." *Environmental management* 59, no. 5 (2017): 736-751.

[7] Kuhfuss, Laure, Hélène Rey-Valette, Emmanuelle Sourisseau, Hugues Heurtefeux, and Xavier Rufray. "Evaluating the impacts of sea level rise on coastal wetlands in Languedoc-Roussillon, France." *Environmental Science & Policy* 59 (2016): 26-34. https://doi.org/10.1016/j.envsci.2016.02.002

[8] Reginald, P. Joshua. "Blue Economy 4.0: Smart Aquaculture and Fisheries Innovation for Coastal Community Resilience." *National Journal of Smart Fisheries and Aquaculture Innovation* 2, no. 2 (2024): 41-47.

[9] Roy, Paramita, Subodh Chandra Pal, Rabin Chakrabortty, Indrajit Chowdhuri, Asish Saha, and Manisa Shit. "Effects of climate change and sea-level rise on coastal habitat: Vulnerability assessment, adaptation strategies and policy recommendations." *Journal of Environmental Management* 330 (2023): 117187. https://doi.org/10.1016/j.jenvman.2022.117187

[10] Runting, Rebecca K., Catherine E. Lovelock, Hawthorne L. Beyer, and Jonathan R. Rhodes. "Costs and opportunities for preserving coastal wetlands under sea level rise." *Conservation Letters* 10, no. 1 (2017): 49-57. https://doi.org/10.1111/conl.12239

[11] Sadat-Noori, Mahmood, Caleb Rankin, Duncan Rayner, Valentin Heimhuber, Troy Gaston, Christopher Drummond, Anita Chalmers, Danial Khojasteh, and William Glamore. "Coastal wetlands can be saved from sea level rise by recreating past tidal regimes." *Scientific reports* 11, no. 1 (2021): 1196.

[12] Schuerch, Mark, Tom Spencer, Stijn Temmerman, Matthew L. Kirwan, Claudia Wolff, Daniel Lincke, Chris J. McOwen et al. "Future response of global coastal wetlands to sea-level rise." *Nature* 561, no. 7722 (2018): 231-234.

[13] Sutton-Grier, Ariana E., and Paul A. Sandifer. "Conservation of wetlands and other coastal ecosystems: a commentary on their value to protect biodiversity, reduce disaster impacts, and promote human health and well-being." *Wetlands* 39, no. 6 (2019): 1295-1302.

[14] Van Coppenolle, Rebecca, and Stijn Temmerman. "Identifying global hotspots where coastal wetland conservation can contribute to nature-based mitigation of coastal flood risks." *Global and Planetary Change* 187 (2020): 103125. https://doi.org/10.1016/j.gloplacha.2020.103125

[15] Wang, Heng, Zhenming Ge, Lin Yuan, and Liquan Zhang. "Evaluation of the combined threat from sea-level rise and sedimentation reduction to the coastal wetlands in the Yangtze Estuary, China." *Ecological engineering* 71 (2014): 346-354. https://doi.org/10.1016/j.ecoleng.2014.07.058