A REVIEW ON COASTAL ECOSYSTEM RESILIENCE: CONTEMPORARY CHALLENGES AND EVIDENCE-BASED CONSERVATION

A. M. Nirbhavane
PG Department of Zoology, Padmashri Vikhe Patil College of Arts, Science and Commerce, Pravaranagar, A/P. Loni (Kd), Tal. Rahata, Ahilyanagar- 413713
ashunirbhavane@gmail.com

A.R. Kurhe
PG Department of Zoology, Padmashri Vikhe Patil College of Arts, Science and Commerce, Pravaranagar, A/P. Loni (Kd), Tal. Rahata, Ahilyanagar- 413713

Abstract

Even though they make up less than 2% of the ocean's surface, coastal and estuarine ecosystems provide more than 25% of the world's marine primary productivity and offer ecosystem services. Through fisheries, aquaculture, and tourism, these systems directly support more than 500 million people while providing vital services like carbon sequestration and the reduction of natural hazards. This multifunctionality is best demonstrated by the Sundarbans mangrove forest, which covers 10,000 km² and sequesters 4.15 million tonnes of CO_2 yearly. However, these ecosystems are in risk due to convergent threats. Impacts are intensifying due to climate change: sea levels have increased by 20 cm since 1900, and by 2100, they are expected to reach 0.43–0.84 m, endangering 190–630 million people who live along the shore. Under predicted conditions, Pacific oyster larvae have died at a rate of 41% due to ocean acidification, which has lowered pH by 0.1 units. Since 1998, there have been five major bleaching events on the Great Barrier Reef, with the 2016–2017 episodes resulting in more than 50% coral death. Ten times as quickly as terrestrial species, marine species redistribute poleward at a rate of 72 kilometres each decade. Climate impacts are compounded by anthropogenic forces. Compared to natural environments, 50% of the coastlines in developed nations are artificially hardened, which results in a 28% decrease in native species and a 40% decrease in biomass. Mangroves have decreased by 35%, salt marshes by 50%, seagrasses by 29%, coral reefs by 50%, and oyster reefs by 85% since 1980.

Keywords: *Biodiversity conservation, coastal resilience, ecosystem services, integrated coastal zone management, climate adaptation.*

Global Significance of Coastal Systems

Despite making up less than 2% of the ocean's surface, coastal and estuarine ecosystems are responsible for over 25% of all marine primary productivity worldwide (Gattuso et al., 1998). Through fisheries, aquaculture, and tourism, these ecosystems directly support more than 500 million people. They also provide vital services including carbon sequestration, nitrogen cycling, and the reduction of natural hazards (Barbier et al., 2011). This multifunctionality is best demonstrated by the Sundarbans mangrove forest, which spans 10,000 km² across Bangladesh and India and is home to the biggest surviving Bengal tiger population. It also sequesters 4.15 million tonnes of CO_2 annually (Ghosh et al., 2015). Coastal landscapes have undergone unprecedented change over the last three decades. By 2030, it is expected that 50% of the world's population would live within 100 kilometres of a coastline, up from the current 40% (Small & Nicholls, 2003; Martínez et al., 2007). Infrastructure has expanded as a result of this demographic concentration, with Asia seeing the most extensive coastal development (Jongman et al., 2012). This trend is evident in China's Pearl River Delta, where urbanisation has caused a 68% loss of wetlands since 1979, radically changing the structure and function of the ecosystem (Ren et al., 2009). Since 1900, the average global sea level has increased by about 20 cm, with recent decades seeing an acceleration of this rise (Church & White, 2011). Under intermediate scenarios, projections indicate a rise of 0.43 to 0.84 meters by 2100 (IPCC, 2021), endangering 190 to 630 million people in low-elevation coastal zones (Kulp & Strauss, 2019). At the same time, the pH of the ocean has dropped by 0.1 units since pre-industrial times due to ocean acidification, which has significant effects on calcifying species (Doney et al., 2009). Since 1998, there have been five mass bleaching events on the Great Barrier Reef, with occurrences from 2016 to 2017 causing >50% coral loss over large areas (Hughes et al., 2017). This shows how quickly ecosystem composition may be restructured by climate change.

Coastal Biodiversity: Patterns and Processes

A significant change in the natural shoreline shape is represented by the spread of coastal armouring. According to estimates, 50% of wealthy countries' coastlines are currently artificially fortified (Gittman et al., 2015). In contrast to natural substrata, seawalls, revetments, and breakwaters reduce structural complexity and produce novel habitats that favour non-indigenous and stress-tolerant species (Airoldi et al., 2005). The biological impoverishment linked to coastal engineering was revealed by research conducted in the Wadden Sea, which showed that manmade structures harbour 28% fewer native species and 40% lower biomass than nearby natural ecosystems (Reise et al., 2017). Through a variety of processes, including pollution gradients, improved propagule connection through maritime transport, and habitat simplification, coastal urbanisation promotes biotic homogenisation (Dafforn et al., 2015). Invasive species make up up to 90% of the fouling community biomass on artificial structures in Sydney Harbour, although this percentage is less than 20% in nearby native reefs (Glasby et al., 2007). The ecosystem's resilience and functional diversity are diminished by this taxonomic convergence, which may jeopardise its ability to adapt to changing environmental conditions. Coastal wetlands make up about 600,000 km^2 worldwide and are described by Wolanski et al. (2009) as areas that experience recurring tidal inundation within the subtidal-supratidal elevation gradient. Mangrove forests fix 218 g C m^{-2} yr^{-1}, while salt marshes fix 244 g C m^{-2} yr^{-1}, demonstrating the exceptional productivity of these systems (Alongi, 2014). In addition to sequestering carbon, wetlands serve as vital nursery habitat. The salt marshes of the Chesapeake Bay sustain the juvenile stages of over 75% of commercially significant fish species, generating $77 million in revenue for local fisheries each year (Boesch & Turner, 1984; Barbier et al., 2011).

Conservation Strategies and Management Frameworks

A comprehensive governance strategy that acknowledges the link between terrestrial and marine systems is ICZM. Stakeholder participation, ecosystem-based planning, and cross-sectoral coordination are required by the European Union's ICZM Protocol (2008) (European Commission, 2013). Seagrass meadows and fish populations have recovered together with a 35% reduction in shoreline hardening and a rise in marine protected area coverage from 1% in 2000 to 8% in 2020 on Spain's Mediterranean coast (Badalamenti et al., 2017; García-Ayllón, 2018). Compared to constructed coastal protection, biogenic habitats offer more affordable options. According to a meta-analysis, coastal vegetation lowers current velocity by 28–44% and wave height by 35-71%. Large-scale marsh restoration (50,000 hectares over 50 years) using Mississippi River sediment diversions is part of the Louisiana Coastal Master Plan. It is estimated that this project will restore ecosystem services and avert $150 billion in storm damage (CPRA, 2017). According to Sutton-Grier et al. (2015), comparative analysis shows that nature-based solutions are 2–5 times less expensive than concrete structures and offer additional benefits like carbon storage and biodiversity enhancement. Unprecedented ecological monitoring resolution is made possible by technological advancements. The Coral Reef Early Warning System provides 85% accurate seven-day bleaching forecasts by combining acoustic telemetry, in-situ sensors, and satellite sea surface temperature (Liu et al., 2014). By detecting 86 fish species from water samples instead of 44 using standard surveys, environmental DNA (eDNA) metabarcoding transforms biodiversity assessment, enabling non-invasive monitoring and lowering expenses by 60% (Kelly et al., 2014; Thomsen & Willerslev, 2015). Applications for remote sensing have significantly increased. Seagrass restoration in Tampa Bay is made easier by LiDAR (Light Detection and Ranging) bathymetry, which provides centimeter-scale resolution maps of benthic habitats down to 50 meters. Success rates for mapping-guided transplantation rose from 35% to 78% (Costa et al., 2009; Mountrakis et al., 2011). Integrating indigenous ecological knowledge improves the efficacy of conservation. Traditional Owner participation in marine park management increased compliance by 65% and discovered unlawful fishing 3.2 times more frequently than traditional patrols in Australia's Great Barrier Reef (Nursey-Bray et al., 2014). Despite regional degradation, the Philippines' Coron Island Marine Park, which has been governed by Indigenous Tagbanwa since 1998, has preserved over 70% of its coral cover, with tourism-related income funding community development (Alcala & Russ, 2006; Weeks & Jupiter, 2013).

Climate Change Impacts and Adaptive Responses

Sea level rise is accelerating, endangering permanent coastal habitats. "Coastal squeeze" is the term used to describe the compression of intertidal habitat area caused by natural (cliffs) or man-made (seawalls) barriers that restrict landward migration. According to present coastal management, a 1 m increase in sea level will destroy 69% of the salt marsh in the UK's Severn Estuary, resulting in biodiversity losses such as an 80% decline in breeding bird populations (French, 2006). Since 1991, 3,200 hectares of intertidal habitat have been recovered in the UK through managed realignment, or purposeful seawall breaching, illustrating proactive adaptation (Esteves, 2013). Reduced pH affects calcification in crustaceans, molluscs, and echinoderms, which has a ripple effect on the food chain. In comparison to 11% at current pH values, Pacific oyster (Crassostrea gigas) larvae show 41% mortality at pH 7.7 (estimated 2100 circumstances) (Gazeau et al., 2013). Currently costing $300,000 a year, Washington State oyster hatcheries buffer saltwater to reduce acidification; by 2050, expenditures are expected to exceed $2.5 million. Acid-tolerant strains are being produced through selective breeding efforts, providing possible avenues for adaptation (Parker et al., 2012). Ten times as quickly as terrestrial species, marine creatures are dispersing poleward at a rate of 72 km per decade. This phenomena is best illustrated by the displacement of kelp forests: since 1950, Phyllospora comosa and warm-temperate fish assemblages have displaced Ecklonia radiata in Tasmania, which has shrunk 200 km southward (Johnson et al., 2011). According to Wernberg et al. (2011), kelp forests sustain 350% more macroinvertebrate biomass than replacement habitats, indicating that such reorganisation modifies ecosystem functioning.

Habitat-Specific Conservation Priorities

Mangroves have decreased by 35% since 1980 (Giri et al., 2011). 52% of tropical mangrove deforestation is caused by shrimp aquaculture, especially in Southeast Asia, where conversion has destroyed almost 3 million hectares (Richards & Friess, 2016). Nonetheless, restoration projects show promise for recovery: Vietnam's Mekong Delta forestry program has planted 40,000 hectares since 2000, protecting 1.5 million people from cyclones and restoring 60% of the initial fish population in under ten years. Since 1850, the size of salt marshes worldwide has decreased by 50%, and losses are increasing (Gedan et al., 2009). A chronic stressor is eutrophication; in Cape Cod wetlands, nitrogen loading increased stem density by 45% while decreasing root biomass by 32%, making the marshes more vulnerable to erosional collapse (Deegan et al., 2012). Effective nutrient management has been achieved through watershed-scale interventions: Chesapeake Bay's best management practices for agriculture decreased nitrogen flux by 28% between 2000 and 2015, which was associated with a 15% increase in marsh area in restoration sites. Since 1980, seagrasses have decreased 29% worldwide, with certain locations experiencing yearly losses of 7%, which is one of the greatest rates of decline for any ecosystem (Waycott et al., 2009). Because of invading algae (Caulerpa taxifolia), anchoring damage, and coastal development, the Mediterranean endemic Posidonia oceanica has lost 34% of its coverage since 1960. Among the conservation triumphs are the Balearic Islands of Spain, where marine protected areas and anchoring restrictions have stabilised reductions and meadow expansion has averaged 2.3% per year since 2010 (Marín-Guirao et al., 2015). Bleaching, disease, and local stressors have caused a 50% decrease in coral reef cover (Gardner et al., 2003). Around 75% of reefs were impacted by the global bleaching event that occurred from 2015 to 2017, with region-specific mortality ranging from 30% in the Caribbean to 50% in the Great Barrier Reef (Hughes et al., 2017). Resilience mechanisms, however, give hope: within 12 years, high-diversity reefs in Palau returned to 70% of their pre-bleaching cover, but low-diversity areas only recovered to 25% (van Woesik et al., 2012). Heat-tolerant strains that survive +2°C above bleaching thresholds have been developed by assisted evolution through coral breeding programs, indicating potential avenues for intervention (van Oppen et al., 2015). Globally, oyster reefs have decreased by 85%, and 70% of their historical range is now functionally dead (Beck et al., 2011). Due to overharvesting, illness, and habitat destruction, the Chesapeake Bay's annual production dropped from 1.5 million bushels to less than 100,000 bushels by 1990. Recovery potential is demonstrated by large-scale restoration: Maryland's 1,000-hectare sanctuary reef network has improved water clarity by 22% and boosted oyster biomass by 15 times through daily filtration of 3.5 billion litres.

Emerging Threats and Research Frontiers

In urbanised estuaries, microplastics (less than 5 mm) can now reach quantities of 3,000 particles/kg in coastal sediments (Browne et al., 2011). Microplastics are accumulated by filter-feeding species; Mediterranean mussels have an average of 0.36 particles/gram, and there is evidence that these particles are transferred to higher trophic levels (Van Cauwenberghe & Janssen, 2014). Although the effects at the ecosystem level are still not well measured, toxicological research shows that exposed organisms experience endocrine disruption, decreased development, and impaired reproduction (Rochman et al., 2013). Pharmaceuticals, flame retardants, and endocrine-disrupting substances are examples of emerging pollutants that are common in coastal waterways. At concentrations as high as 7.9 μg/L, 47 pharmaceutical chemicals found in the Seine Estuary cause 60% of male fish to become feminised and invertebrate behaviour to change (Sumpter & Johnson, 2008). Legacy pollutants still exist: despite 40-year restrictions, PCB levels in San Francisco Bay sediments are high enough to affect harbour seal (Phoca vitulina) reproduction. By 2030, it is anticipated that offshore wind capacity would reach 234 GW worldwide, drastically changing coastal ecosystems (GWEC, 2020). The effects on the environment are yet not fully understood: Wind farms in the UK produce artificial reef effects that increase fish population locally by ten times, but they may also interfere with migratory paths. At distances greater than 20 km, acoustic impacts from pile-driving produce transient changes in marine mammals' hearing thresholds, which may have an influence on harbour porpoises (Phocoena phocoena) (Tougaard et al., 2009). Sustainable energy transitions require frameworks for adaptive management and systematic monitoring.

Conclusions and Future Directions

The combination of local human demands and global climate change presents coastal and estuarine ecosystems with previously unheard-of difficulties. Emerging data, however, shows that deliberate conservation measures that are guided by scientific knowledge and carried out under inclusive governance frameworks can improve ecosystem resilience and halt the course of degradation. Priority actions include: (1) increasing the number of protected area networks to 30% of coastal habitats by 2030, in line with the targets set by the Convention on Biological Diversity; (2) incorporating nature-based solutions into the planning of coastal infrastructure to harness ecosystem services; (3) reducing eutrophication through watershed-scale nutrient management; (4) creating climate-adaptive restoration strategies that take into account species redistribution and sea-level rise. Important knowledge gaps that need to be filled by future study include the effects of microplastics on ecosystems, the effects of cumulative stressors, and the dynamics of tipping points in regime shifts. Crucially, social dimensions—addressing environmental justice, guaranteeing fair benefit distribution, and integrating the perspectives of many stakeholders into decision-making processes—must be incorporated into conservation research more and more.

The next ten years are a crucial time for protecting the coast. Coastal ecosystem services can be secured for present and future generations by reversing the trend towards ecosystem degradation through transformative governance innovations, persistent political commitment to climate mitigation, and smart investments in restoration.

Acknowledgments

The authors gratefully acknowledge the Principal, Head, and Research Center Director of PVP College, Pravaranagar, for their invaluable support and laboratory facilities. We extend our appreciation to Savitribai Phule Pune University for research authorization. Authors are also thankful to University Grants Commission (UGC) research funding.

References

1. Airoldi L, Beck MW 2007. Loss, status and trends for coastal marine habitats of Europe. Oceanography and Marine Biology 45: Pp. 345–405.
2. Airoldi, L., Abbiati, M., Beck, M.W., Hawkins, S.J., Jonsson, P.R., Martin, D., Moschella, P.S., Sundelöf, A., Thompson, R.C. & Åberg, P. (2005). An ecological perspective on the deployment and design of low-crested and other hard coastal defence structures. Coastal Engineering, 52(10-11), 1073-1087.
3. Alcala, A.C. & Russ, G.R. (2006). No-take marine reserves and reef fisheries management in the Philippines: a new people power revolution. *Ambio*, 35(5), 245-254.
4. Alongi, D.M. (2014). Carbon cycling and storage in mangrove forests. *Annual Review of Marine Science*, 6, 195-219.
5. Bader, J., Mesquita, M.D.S., Hodges, K.I., Keenlyside, N., Østerhus, S. & Miles, M. 2011. A review on Northern Hemisphere sea-ice, storminess and the North Atlantic Oscillation: observations and projected changes. Atmospheric Research 101, Pp. 809–834.
6. Badola, R. & Hussain, S.A. 2005. Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. Environmental Conservation 32, Pp. 85–92.
7. Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C. & Silliman, B.R. 2011. The value of estuarine and coastal ecosystem services. Ecological Monographs 81, Pp. 169–193.
8. Beck, M.W., Brumbaugh, R.D., Airoldi, L., Carranza, A., Coen, L.D., Crawford, C., Defeo, O., Edgar, G.J., Hancock, B., Kay, M.C., Lenihan, H.S., Luckenbach, M.W., Toropova, C.L., Zhang, G. & Guo, X. 2011. Oyster reefs at risk and recommendations for conservation, restoration, and management. BioScience 61, Pp. 107–116.
9. Bulleri, F. & Chapman, M.G. 2010. The introduction of coastal infrastructure as a driver of change in marine environments. Journal of Applied Ecology 47, Pp. 26–35.
10. Byrnes, J.E., Reed, D.C., Cardinale, B.J., Cavanaugh, K.C., Holbrook, S.J. & Schmitt, R.J. 2011. Climate-driven increases in storm frequency simplify kelp forest food webs. Global Change Biology 17, Pp. 2513–2524.
11. Badalamenti, F., Alagna, A., Fici, S., Pennetta, A., Quinci, E.M., D'Anna, G. & Pipitone, C. (2017). Assessing the effectiveness of a

seasonal fishing closure on exploited seagrass meadows. *Marine Biology Research*, 13(10), 1056-1066.
12. Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C. & Silliman, B.R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, 81(2), 169-193.
13. Barnes, M.D., Craigie, I.D., Harrison, L.B., Geldmann, J., Collen, B., Whitmee, S., Balmford, A., Burgess, N.D., Brooks, T., Hockings, M. & Woodley, S. (2016). Wildlife population trends in protected areas predicted by national socio-economic metrics and body size. *Nature Communications*, 7(1), 12747.
14. Beck, M.W., Brumbaugh, R.D., Airoldi, L., Carranza, A., Coen, L.D., Crawford, C., Defeo, O., Edgar, G.J., Hancock, B., Kay, M.C., Lenihan, H.S., Luckenbach, M.W., Toropova, C.L., Zhang, G. & Guo, X. (2011). Oyster reefs at risk and recommendations for conservation, restoration, and management. *BioScience*, 61(2), 107-116.
15. Boesch, D.F. & Turner, R.E. (1984). Dependence of fishery species on salt marshes: the role of food and refuge. *Estuaries*, 7(4A), 460-468.
16. Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T. & Thompson, R. (2011). Accumulation of microplastic on shorelines worldwide: sources and sinks. *Environmental Science & Technology*, 45(21), 9175-9179.
17. Burke, L., Reytar, K., Spalding, M. & Perry, A. (2011). *Reefs at Risk Revisited*. World Resources Institute, Washington, DC.
18. Connell, S.D. & Irving, A.D. 2008. Integrating ecology with biogeography using landscape characteristics: a case study of subtidal habitat across continental Australia. Journal of Biogeography 35, Pp. 1608–1621.
19. Cook, R., Fariñas-Franco, J.M., Gell, F.R., Holt, R.H.F., Holt, T., Lindenbaum, C., Porter, J.S., Seed, R., Skates, L.R., Stringell, T.B. & Sanderson, W.G. 2013. The substantial first impact of bottom fishing on rare biodiversity hotspots: a dilemma for evidence-based conservation. PLoS ONE 8, e69904.
20. Creel, L. 2003. Ripple Effects: Population and Coastal Regions. Washington, D.C.: Population Reference Bureau.
21. Church, J.A. & White, N.J. (2011). Sea-level rise from the late 19th to the early 21st century. *Surveys in Geophysics*, 32(4-5), 585-602.
22. Cloern, J.E. & Jassby, A.D. (2012). Drivers of change in estuarine-coastal ecosystems: discoveries from four decades of study in San Francisco Bay. *Reviews of Geophysics*, 50(4), RG4001.
23. Costa, B.M., Battista, T.A. & Pittman, S.J. (2009). Comparative evaluation of airborne LiDAR and ship-based multibeam SoNAR bathymetry and intensity for mapping coral reef ecosystems. *Remote Sensing of Environment*, 113(5), 1082-1100.
24. Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S. & Turner, R.K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26, 152-158.
25. CPRA (Coastal Protection and Restoration Authority). (2017). *Louisiana's Comprehensive Master Plan for a Sustainable Coast*. Baton Rouge, Louisiana.
26. Day, J.W., Rybczyk, J.M., 2019. Global change impacts on the future of coastal systems: Perverse interactions among climate change, ecosystem degradation, energy scarcity, and population.
27. Dafforn, K.A., Glasby, T.M., Airoldi, L., Rivero, N.K., Mayer-Pinto, M. & Johnston, E.L. (2015). Marine urbanization: an ecological framework for designing multifunctional artificial structures. *Frontiers in Ecology and the Environment*, 13(2), 82-90.
28. Day, J.W. & Rybczyk, J.M. (2019). Global change impacts on the future of coastal systems: perverse interactions among climate change, ecosystem degradation, energy scarcity, and population. In *Coasts and Estuaries* (pp. 621-639). Elsevier.
29. Deegan, L.A., Johnson, D.S., Warren, R.S., Peterson, B.J., Fleeger, J.W., Fagherazzi, S. & Wollheim, W.M. (2012). Coastal eutrophication as a driver of salt marsh loss. *Nature*, 490(7420), 388-392.
30. Donato, D.C., Kauffman, J.B., Murdiyarso, D., Kurnianto, S., Stidham, M. & Kanninen, M. (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience*, 4(5), 293-297.
31. Doney, S.C., Fabry, V.J., Feely, R.A. & Kleypas, J.A. (2009). Ocean acidification: the other CO_2 problem. *Annual Review of Marine Science*, 1, 169-192.
32. European Commission. (2013). *An Integrated Maritime Policy for the European Union*. Brussels: European Commission.
33. French, P.W. (2006). Managed realignment–The developing story of a comparatively new approach to soft engineering. *Estuarine, Coastal and Shelf Science*, 67(3), 409-423.
34. García-Ayllón, S. (2018). Long-term GIS analysis of seaside impacts associated to

infrastructures and urbanization and spatial correlation with coastal vulnerability in a Mediterranean area. *Water*, 10(11), 1642.

35. Gardner, T.A., Côté, I.M., Gill, J.A., Grant, A. & Watkinson, A.R. (2003). Long-term region-wide declines in Caribbean corals. *Science*, 301(5635), 958-960.
36. Gattuso, J.P., Frankignoulle, M. & Wollast, R. (1998). Carbon and carbonate metabolism in coastal aquatic ecosystems. *Annual Review of Ecology and Systematics*, 29(1), 405-434.
37. Gazeau, F., Parker, L.M., Comeau, S., Gattuso, J.P., O'Connor, W.A., Martin, S., Pörtner, H.O. & Ross, P.M. (2013). Impacts of ocean acidification on marine shelled molluscs. *Marine Biology*, 160(8), 2207-2245.
38. Gedan, K.B., Silliman, B.R. & Bertness, M.D. (2009). Centuries of human-driven change in salt marsh ecosystems. *Annual Review of Marine Science*, 1, 117-141.
39. Ghosh, A., Schmidt, S., Fickert, T. & Nüsser, M. (2015). The Indian Sundarban mangrove forests: history, utilization, conservation strategies and local perception. *Diversity*, 7(2), 149-169.
40. Gedan, K.B., Silliman, B.R. & Bertness, M.D. 2009. Centuries of human-driven change in salt marsh ecosystems. Annual Review of Marine Science 1, Pp. 117–141.
41. Hulme, M., Jenkins, G.J., Lu, X., Turnpenny, J.R., Mitchell, T.D., Jones, R.G., Lowe, J. 2002. Climate change scenarios for the United Kingdom: the UKCIP02 scientific report. Oxford, UK: UK Climate Impacts Programme (UKCIP).
42. Koch, E.W., Barbier, E.B., Silliman, B.R., Reed, D.J., Perillo, G.M.E., Hacker, S.D., Granek, E.F., Primavera, J.H., Muthiga, N., Polasky, S., Halpern, B.S., Kennedy, C.J., Kappel, C.V. & Wolanski, E. 2009. Non-linearity in ecosystem services: temporal and spatial variability in coastal protection. Frontiers in Ecology and the Environment 7, Pp. 29–37.
43. Kulp, S. A., and Strauss., B. H. (2019). New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding. Nat. Commun. 10 (1), Pp.4844.
44. Lee, H. S., Choi, Y.-J., andWoo, S.-B. (2021). Numerical Models in Coastal Hazards and Coastal Environment. Jmse 9 (5), Pp.494.
45. Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay, M.C., Kidwell, S.M., Kirby, M.X., Peterson, C.H. & Jackson, J.B.C. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312, Pp. 1806–1809.
46. Luisetti T, Turner RK, Bateman IJ, Morse-Jones S, Adams C, Fonseca L 2011. Coastal and marine ecosystem services valuation for policy and management: Managed realignment case studies in England. Ocean & Coastal Management 54: Pp. 212–224.
47. Martínez, M.L., Intralawan, A., Vázquez, G., Pérez-Maqueo, O., Sutton, P. & Landgrave, R. 2007. The coasts of our world: ecological, economic and social importance. Ecological Economics 63, Pp.254-272.
48. Moschella, P.S., Abbiati, M., Åberg, P., Airoldi, L., Anderson, J.M., Bacchiocchi, F., Bulleri, F., Dinesen, G.E., Frost, M., Gacia, E., Granhag, L., Jonsson, P.R., Satta, M.P., Sundelöf, A., Thompson, R.C. & Hawkins, S.J. 2005. Low-crested coastal defence structures as artificial habitats for marine life: using ecological criteria in design. Coastal Engineering 52, Pp. 1053–1071.
49. Nicholls, R.J. & Cazenave, A. (2010). Sea-level rise and its impact on coastal zones. Science 328, Pp.1517–1520.
50. Passarelli, C., Olivier, F., Paterson, D.M., Meziane, T. & Hubas, C. 2014. Organisms as cooperative ecosystem engineers in intertidal flats. Journal of Sea Research 92, Pp.92–101.
51. Perkol-Finkel, S. & Airoldi, L. 2010. Loss and recovery potential of marine habitats: an experimental study of factors maintaining resilience in subtidal algal forests at the Adriatic Sea. PLoS ONE 5, e10791.
52. Small, C. & Nicholls, R.J. (2003). A global analysis of human settlement in coastal zones. Journal of Coastal Research 19, Pp.584–599.
53. Strain, E.M.A., Allcock, A.L., Goodwin, C.E., Maggs, C.A., Picton, B.E. & Roberts, D. 2012. The long-term impacts of fisheries on epifaunal assemblage function and structure in a Special Area of Conservation. Journal of Sea Research 67, Pp. 58–68.
54. Tam, N.F.Y., Wong, Y.S., Lan, C.Y. & Chen, G.Z. 1995. Community structure and standing crop biomass of a mangrove forest in Futian Nature Reserve, Shenzhen, China. Hydrobiologia 295, Pp. 193–201.
55. Thompson, R.C., Crowe, T.P. & Hawkins, S.J. 2002. Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years. Environmental Conservation 29, Pp. 168–191.
56. Turner R. K., Morse-Jones S, Fisher B 2010. Ecosystem valuation: a sequential decision support system and quality assessment issues. Annals of the New York Academy of Sciences 1185: Pp. 79–101.

57. Valiela, I., Bowen, J.L. & York, J.K. 2001. Mangrove forests: one of the world's threatened major tropical environments. BioScience 51, Pp. 807–815.
58. Waycott, M., Duarte, C.M., Carruthers, T.J.B., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck, K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Short, F.T. & Williams, S.L. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences of the United *States of America* **106**, Pp. 12377–12381.