MIT Climate Policy Center

POLICY BRIEF

Coastal Protection:

Marsh Restoration Offers Cost-Effective Flood Defense

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MIT research shows that when planted in front of a seawall, a salt marsh of just 30m (100 ft) width can reduce the wave heights reaching a seawall by 20 to 70%. This means that the same level of flood protection can be achieved by a shorter seawall with marsh as achieved by a taller seawall without marsh. In addition, the marsh provides valuable ecosystem services including habitat and water quality improvements.

This nature-based solution can have benefit-cost ratios ranging from 2 to 10, meaning it returns $2-$10 in benefits for every dollar spent across most conditions, making marsh-fronted seawalls an economically justified alternative to raising seawall heights for coastal flood protection.

Policy Considerations

- **Prioritize marsh-seawall combinations for coastal protection upgrades** where underwater terrain and space allow, as the flood protection and ecosystem benefits they provide are greater than their costs.
- **Account for seasonal vegetation variation in flood risk planning**, as healthy vegetation during growing seasons provides 15% to 50% more wave reduction compared to dormant winter vegetation.
- **Use discount rates of 4% or lower when evaluating nature-based solutions** (consistent with Federal water resources planning guidance) to appropriately value long-term environmental services.
- **Ensure marsh has a minimum width of 15-ft** and adequate sediment supply to support sustainable vegetation establishment and long-term performance.
- **Develop region-specific vegetation databases** documenting plant shape and stiffness to enable accurate predictive modeling for local coastal protection planning.

The Policy Problem

Coastal communities face escalating flood risks from sea level rise and intensifying storms, with global assets exposed to coastal flooding projected to reach $14 trillion by 2100. Traditional grey infrastructure like concrete seawalls is costly to construct and maintain, and it merely reflects wave energy rather than dissipating it, and it provides no environmental benefits. In 2023, the Biden administration's Office of Management and Budget released modernized federal guidance (Circular A-4) directing agencies to incorporate ecosystem services (benefits nature provides like flood protection and habitat) into benefit-cost analyses of regulations and investments.

However, the Trump administration rescinded this 2023 update and reinstated the previous 2003 version, which lacks provisions for accounting for environmental benefits and distributional effects. Despite this federal policy reversal, state and local governments still need robust analytical frameworks that quantify both the coastal protection benefits and construction trade-offs of hybrid solutions combining natural ecosystems with engineered structures to make informed infrastructure investments. Our research demonstrates that the economic case for marsh-seawall hybrids stands on its own merits, independent of federal policy directives.

The Findings

Marshes in front of seawalls provide substantial wave reduction that varies by vegetation species, with stiffer plants like common reed reducing wave heights twice as effectively as flexible species like seashore bulrush. Even short marshes that extend 130-180 feet beyond a seawall in urban settings can achieve significant wave reduction, allowing seawall heights to be 3-6 feet shorter while maintaining equivalent flood protection.

The Research

This study developed a predictive wave reduction model incorporating plant-specific shape and structural stiffness, validated against field measurements from marshes in the Netherlands with excellent agreement. The model accounts for vegetation drag, shoaling, wave breaking, and seafloor friction to predict wave heights reaching seawalls across different marsh widths and vegetation types. Our economic analysis compared the costs of marsh restoration against the costs of seawall height increases needed to achieve equivalent wave overtopping rates, incorporating environmental services values and construction costs from published literature.

This approach enables prediction of wave reduction based on measurable plant characteristics rather than site-specific calibration, allowing transferability across locations and seasons. The framework was applied to a real- world case study at Juniper Cove, Massachusetts, analyzing 10-, 50-, and 100-year storm scenarios. Even in winter conditions, when most plants are dormant, the 30 ft width marsh proposed in the Columbus Avenue Seawall Reconstruction project would have provided the same coastal protection as adding 7 inches of height to the seawall. Unfortunately, the Juniper Cove seawall was breached in January 2024 before completion of the project. This research and its economic model could be used for redesigning the project in the future.

Future Work

We are currently developing methods to combine satellite and drone images with other coastal resource and infrastructure maps to identify coastal sites across the US that are suitable for marsh-seawall hybrid solutions. Suitable sites have existing marsh or have the coastal conditions to support marsh restoration; have seawalls or have the conditions to justify seawall installation; and have the potential to offer protection for key infrastructure, such as transportation or housing. This new method will enable us to more quickly perform benefit-cost analyses at these sites to inform local and state-level policies and investments.

Source: Lee, E.I.H. & Nepf, H. Marsh restoration in front of seawalls is an economically justified nature-based solution for coastal protection. Communications Earth & Environment 5, 605 (2024). https://doi.org/10.1038/s43247- 024-01753-5

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