Science to Enable Holistic Resilience in Dynamic Coastal Environments

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The coastal environment is highly dynamic and extremely complex. It includes an interconnected natural system with dynamic fluxes and cycles of sediments, freshwater, saltwater, and living organisms. The cultural, social, and economic dimensions of human communities are intimately tied to coastal ecosystems. The coastal zone also includes engineered structures and cultural resources that influence the physical, chemical, and biological properties of the system. These components interact with one another over multiple spatial and temporal scales.

The coastal environment is constantly changing. Its unique location at the interface of land, sea, and air, along with long-term human interventions, result in an environment that is exposed to significant stressors. Climate change is causing warming in the ocean and atmosphere, altering rainfall patterns and hence river flow and sediment supply, and causing sea levels to rise. Human activities provide their own stressors from increasing development, additions of nutrients or pollutants, and extraction of fish and other natural resources. The decisions that cause these stressors to be amplified or reduced are made at local, regional, and national levels and in the context of a complex array of plans, policies, and regulations. How humans respond to increasing changes in the coastal zone, whether through extreme events such as coastal storms or longer-term trends, will determine the future of this dynamic environment. This will influence the quality and quantity of the delivery of services that humans depend on, as well as the adaptive capacity and resiliency of human, built, and natural environments towards disturbance and alteration.

Specific differentiated recommendation

Guiding effective decision-making to create and maintain resilient coastal environments is a grand challenge. It requires advanced understanding of the processes in the coastal environment, the stressors driving changes, and the feedbacks between the natural, human, and built environments. It also requires a clear understanding of what humans value in the coastal zone and, ultimately, a collaborative definition of resilience that is grounded in realistic projections of the future. In addition, it requires cooperation rather than traditional single-use solutions to coastal issues.

Addressing this grand challenge will require a convergent approach that goes beyond traditional disciplinary boundaries. Scientists from across the natural sciences and social sciences must work together to define and use resiliency concepts to solve the challenging problems in the coastal region. Because humans are an integral part of the system, understanding their problems and finding solutions is vital. We must break down barriers between scientists and stakeholders. Stakeholders need to be given a strong voice in expressing problems, setting research priorities, and contributing to research.

This initiative will work to:

- Identify relevant indicators and metrics of resiliency for both natural and human communities;
- Improve projections of the coupled (human, built, and natural) systems within the coastal environment at multiple spatial and temporal scales;
- Understand the dynamic interplay between the natural environment and the human and built environments;
- Quantify ecosystem services and identify targeted stakeholder and socioeconomic groups;
- Examine various stakeholders' response strategies to extreme events, such as hurricanes, harmful algal blooms, and tsunamis;
- Quantify the strengths and benefits of different adaptation and mitigation approaches; and
- Understand the social or political contexts that enable the decision-making process based on

forecasts, and understand barriers to forward-looking, long-range decision-making.

Ongoing cooperation with key stakeholders regarding defining goals and tracking progress must be embedded in a nuanced understanding of resilience. At the outset, key stakeholders should participate in defining project goals. Many processes exist to link scientists and stakeholders, and these should be evaluated and tested across multiple projects. A major focus of the work with stakeholders should be devoted to understanding the environmental properties that groups value. This will lead to a clear vision for the coast and a unified definition of resilience. Based on this definition, metrics can be identified and tracked through time to quantify the efficacy of decisions.

What impact or value does it seek to deliver?

This endeavor will advance understanding of the complexity and dynamics of the coastal environment and its resiliency. It will identify the goals for adaptation--what do stakeholders value, what services do they require, what strategies can enhance resilience? This shared understanding and clear vision for the coastal system will advance the ecological and economic value of the coastal environment and will support inhabitants' overall well-being. Furthermore, it will strengthen cross-disciplinary collaborations and multi-stakeholder engagement, further supporting convergent research. Moreover, it will provide a foundation for science-based decision-making processes that incorporate projections (with their associated uncertainties), shared goals, and relevant metrics.

What is the reasoning or supporting evidence behind it, if any?

Services from complex and dynamic coastal environments are vital for humans. The level of reliance on particular services and the value of services to stakeholders may vary geographically. This service reliance and the unique socio-demographic characteristics of stakeholders determine the vulnerability of humans to coastal environment. This creates differential benefits.

The influences of global climate change are acute in the coastal environment. Warming of both the atmosphere and the water and changes in precipitation patterns alter the flow of water. Sea level rise erodes shorelines and amplifies risks from coastal storms. While the trends are clear, many decisions in the coast do not account for climate risks. For example, fishery management decisions are made based on historical conditions and historical data. Homeowners who lose their houses in a coastal storm often choose to rebuild in the same risky areas. Even towns that are planning for sea level rise often use the lower bound of the projections, viewing that scenario as equally likely (i.e., misinterpreting the risks) or politically expedient. Ensuring resilient ecosystems and building resilient communities require the ability to evaluate risk from uncertain projections.