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Increasing the resilience of human and natural communities to coastal hazards: Supporting decisions in New York and Connecticut

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Introduction

Coastal communities are increasingly vulnerable to coastal hazards including storms and sea level rise (SLR) (Bender et al., 2010; IPCC, 2007; Karl et al., 2009; Weiss et al., 2011). These increasing hazards threaten not only the human-built infrastructure and coastal communities but also natural habitats and ecosystems and the many services they support. The exposure and vulnerability of human and natural communities are increasing as development and urbanization continue and natural buffers, such as coastal wetlands and dunes, are degraded or lost (Jha et al., 2011).

Despite awareness of growing coastal hazards, local decision-makers often have only limited access to the critical information necessary to support choices for managing the current and future vulnerability of human and natural communities (Climate Change Science Program, 2009; NRC, 2009). Local decision-makers often lack the tools to visualize current and future scenarios and identify alternatives for effective management (Frazier et al., 2010a, 2010b; Gesch, 2009). As a consequence, they are unable to comprehensively integrate coastal hazard risk and SLR into their decision-making to reduce vulnerability and increase the resilience of human and natural communities. To make matters more challenging, land-use planning in the United States and many other countries has historically focused on facilitating residential development and private business, with far less regard for community resilience to natural hazards (Burby, 1998). By resilience, we mean both the ability to absorb

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perturbations before communities change states and the ability to bounce back or return to similar states after perturbations (for example, Adger, 2000; Folke, 2006). In this case study, we look primarily at the perturbations from coastal hazards created by flooding and inundation from storm surge and SLR.

Mitigation of coastal hazards has traditionally been undertaken using shoreline hardening and engineered defences. These are expensive and in some instances have had mixed success (Khazai et al., 2007). It has been estimated that current "business as usual" planning and regulatory policies in the United States will promote continued development and shoreline hardening (Climate Change Science Program, 2009) in the face of increasing coastal hazards. This hardening in turn will cause further habitat loss because it prevents the inland migration of coastal ecosystems that get caught in the squeeze between the rising sea and bulkheads (Climate Change Science Program, 2009; Nicholls, 2011).

With the increase in economic impacts of coastal hazards, local, state and federal planners in the United States are starting to see land-use planning as a tool for risk reduction (Burby, 2006). They are also increasingly aware of the need to integrate future change considerations, but the use of climate change scenarios including SLR is in its infancy (Frazier et al., 2010b). The relationship between strategies of adaptation to climate change and development policies is also an emerging research issue (Kok and Metz, 2008; Markandya and Halsnaes, 2002; Smith et al., 2003; Tanner and Mitchell, 2008).

Alternative approaches to built infrastructure using ecosystem-based solutions or green infrastructure are nascent yet increasingly recognized among hazard and climate planners and managers. A growing body of evidence indicates the values of coastal ecosystems in wave attenuation, wave deflection and erosion reduction (Beck et al., 2011; Costanza et al., 2008; Dudley et al., 2010; Gedan et al., 2011; Hale et al., 2011; Shepard et al., 2011; Sheppard et al., 2005). Indeed, coastal ecosystems provide many additional benefits that are highly valued by society, often referred to as ecosystem services (Costanza et al., 1997, 2006, 2008; Hale et al., 2009).

Here we present a case study addressing vulnerability to storm hazards and climate change around Long Island Sound (Connecticut and New York) in the United States (Figure 6.1). We use a programme of work, Coastal Resilience, to understand social, economic and ecological vulnerability to coastal hazards and identify integrated solutions to address them. The work was designed to help local stakeholders understand the impacts of coastal hazards, including future SLR, and to inform their planning, land-use, acquisition, investment and permitting decisions. To assist decision-makers and stakeholders, the project also included an Internet-based mapping application designed to provide interactive

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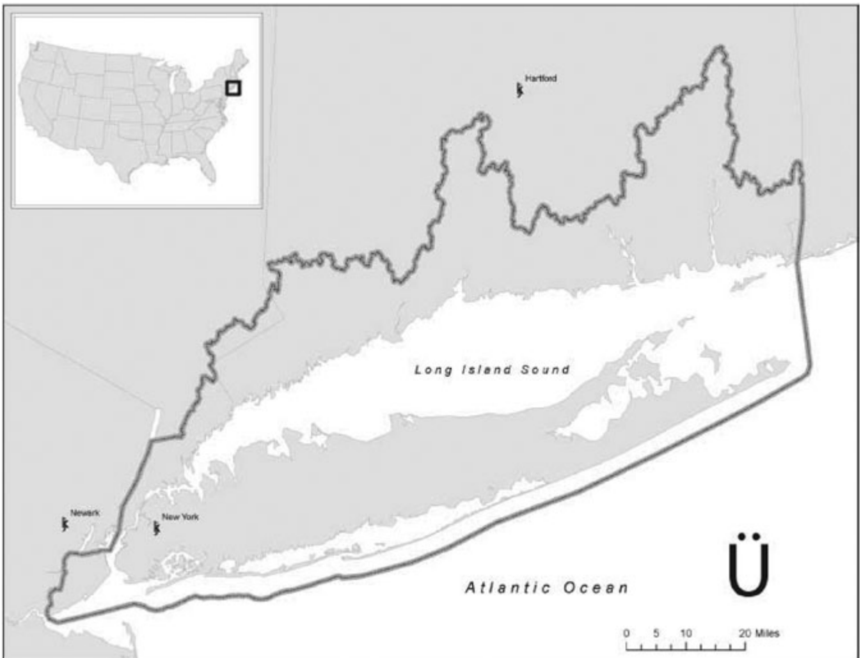

Figure 6.1 Study area along the shores of New York and Connecticut including Long Island Sound and the Atlantic Ocean coasts
Source: See <http://lis.coastalresilience.org/lis.html> (accessed 16 October 2012).

decision support and alternative scenarios for coastal hazard mitigation and conservation.[1]

Methods

Coastal Resilience provides a framework and tools to better inform local decision-making about current and future coastal hazard risks and choices for addressing them (Box 6.1). The project partners include The Nature Conservancy, the Center for Climate Systems Research (CCSR) at Columbia University, the National Aeronautics and Space Administration's Goddard Institute for Space Studies, the Association of State Floodplain Managers, the Pace Land Use Law Center, the National Oceanic and Atmospheric Administration's Coastal Services Center (NOAA-CSC) and the Department of Geography and Geology at the University of Southern Mississippi. We examine current ecological, biological, socio-economic and management information alongside locally relevant, down-

Box 6.1 Coastal Resilience: Conceptual framework

Coastal Resilience provides a framework that supports decisions to reduce the ecological and socio-economic risks of coastal hazards

The framework includes 4 critical elements:

- **Raise Awareness**: Develop integrated databases on social, economic and ecological resources critical to communities and provide mapping and visualization tools;
- **Assess Risk**: Assess risk and vulnerability to coastal hazards including alternative scenarios for current and future storms and sea level rise with community input;
- **Identify Choices**: Identify choices for reducing vulnerability focusing on joint solutions across social, economic and ecological systems. Provide decision support including web based guidance and scenarios to assess options;
- **Take Action**: Help communities to develop and implement solutions.

(*Source*: <http://coastalresilience.org/>, accessed 16 October 2012)

These resources are provided to communities and practitioners through a variety of products, including a website that explains the approach, methods, decision support tools and strategies for addressing coastal hazards. Community engagement is critical at every point in this framework.

scaled coastal flooding and inundation scenarios developed from widely accepted climate and hazard models (Ferdaña et al., 2010).

New York and Connecticut

The shores around Long Island Sound are densely populated and heavily developed. Current development places considerable pressure on natural habitats through nutrient loading, polluted surface and storm water runoff, and habitat conversion and degradation. Despite this, the coastlines of Connecticut and New York support a diverse array of marine and coastal organisms and habitats. The area is home to significant island and fringing saltmarshes and near-shore eelgrass beds. A number of beach-dependent birds come to these shores to breed and feed during spring and summer months (for example, Seavey et al., 2010). In addition, these shores support populations of shellfish and finfish that are important recreational and commercial resources, in addition to being important to overall ecosystem dynamics and water quality (Schimmel et al., 1999).

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Large storm events such as tropical storms and hurricanes and extra-tropical storms (particularly winter storms from the north-east known as nor'easters) have driven the formation and continued development of the shorelines in Connecticut and New York. During the past 75 years, hurricanes and nor'easters have caused rapid beach erosion, dune displacement, wetland loss and coastal flooding. The most significant was the Great Hurricane of 1938 (21 September), also known as "The Long Island Express". The storm produced winds that reached over 300 kilometres per hour, generated 5-metrer-high breakers, overwashed approximately one-half of Long Island, NY, and created 12 new inlets (Donnelly et al., 2001). The "Ash Wednesday" storm of 6 March 1962 was a major nor'easter that resulted in more than 50 washovers. With SLR, the baseline sea level on which storm surge operates will be higher, resulting in increased shoreward extent of flooding and severity of impact.

New York and Connecticut's coastal communities have a long history of trying to maintain their shorelines using a variety of structural mechanisms, including jetties, groins, beachfill and construction of bulkheads. This extensive shoreline armouring increases the pressure on natural resources by modifying the required sediment transport and deposition.

Data collection, analysis and interpretation

The collection and analysis of Geographic Information System (GIS) data were a core component of this project allowing visualization, exploration and analysis of multi-layered issues influencing coastal resilience.

Coastal flooding and inundation

A critical step in assessing coastal hazards risk is mapping coastal elevation data.[2] The elevation data used for mapping these SLR and storm surge scenarios came from LiDAR-based digital elevation models.[3]

To predict storm surge events we used the National Hurricane Center's Sea, Lake and Overland Surges from Hurricanes model (SLOSH), which estimates storm surge heights and winds resulting from historical, hypothetical or predicted hurricanes by taking into account pressure, size, forward speed, track and winds. From the model's outputs, we used the Maximum Envelopes of Water (MEOWs) result from the SLOSH model to portray what could happen when a specific storm makes landfall. MEOW Category 2 and 3 hurricanes, corresponding to storm surges with estimated 40- and 70-year return periods, respectively, were mapped.

The Columbia University CCSR members of the project team developed future SLR scenarios for three different emission scenarios using downscaled outputs from seven of the Global Circulation Models (GCMs) used for the 2007 report by the Intergovernmental Panel on Cli-

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mate Change (IPCC). The methods are described in detail in Horton et al. (2010). We modelled probability distributions of SLR in decadal periods from the 2020s through the 2080s. The three emission scenarios were IPCC scenarios A1b, A2 and A2 + added meltwater. The IPCC methodology (A1b and A2 scenarios) incorporates two global factors – thermal expansion and ice melt – and two local factors – local ocean water density changes and local uplift or subsidence. We then developed a modified scenario (A2 + added meltwater) assuming a more rapid ice melt, using paleoclimatic analogues. The latter scenario was undertaken because the IPCC GCMs for the Fourth Assessment Report (IPCC, 2007) were not set up to model dynamic ice-sheet changes that could result in increased ice melt; such an increase is now thought to be a real possibility. This approach gives a significantly higher set of SLR scenarios than the existing IPCC (2007) method.

We used a bathtub fill approach to model inundation from SLR (see Poulter and Halpin, 2008). The bathtub fill approach fills low-lying elevation points with water; that is, we identified the new height of water based on SLR and "filled in" the coastal land with water to this elevation. This method can on occasion create erroneous inundated areas that are not connected to the ocean (that is, islands of water). An alternative approach forces coastal inundation to occur only where low-lying elevation is hydrologically connected to the ocean (Gesch, 2009), but that approach was beyond the scope of the current project.

Ecological analyses

We incorporated data on and analyses of critical coastal ecosystems that were important ecologically, were especially vulnerable to coastal hazards or provided critical ecosystem services. We focused in particular on coastal wetlands and marshes, as well as on the piping plover, barrier island habitats and submerged aquatic vegetation.

Intertidal habitats, including wetlands, require adjacent non-developed space to migrate over time in order to keep pace with rising sea levels. The project team modelled potential marsh advancement zones with SLR based on variables of accretion, erosion, land use/cover, elevation and projected sea level (Hoover et al., 2010).

Social vulnerability

We compiled and analysed socioeconomic information in order to better evaluate the consequences of SLR and storm surge hazards for human populations and infrastructure. A characterization of vulnerable communities provided managers with information to explore opportunities to minimize risk. We used socioeconomic data from the US Census Bureau

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(2000) to depict these distributions and to create various indices at the census block group level based on demographic attributes such as age, income and access to critical facilities such as hospitals.

The analyses presented here were based on published vulnerability assessment methodologies and primarily on the Social Vulnerability Index (SOVI) (Cutter et al., 2003). We also provided additional analyses based on the Community Vulnerability Assessment Tool and the Australian Geological Survey Organisation's Cities Project (Granger, 2003).

SOVI and these other indices are based primarily on census-derived variables, including, for example, population density; housing unit density; median income; households below poverty; those requiring public assistance; those that rent, live in houses seasonally, live in mobile homes; and those without an automobile. These variables were mapped at the census block group scale, which is the smallest geographical unit for which the census provides detailed demographic data.

Economic exposure

Demographic data at the census block level were combined with economic data to forecast the potential economic damage of future SLR and floods based on the present-day economic landscape. We examined economic exposure and losses from flooding for infrastructure, including housing, transportation and commercial structures. Economic loss represents the full replacement value of commercial and residential structures. Loss calculations were the result of geographical analysis using the Hazards U.S. – Multi-Hazards (HAZUS-MH) tool developed by the Federal Emergency Management Agency (FEMA). HAZUS-MH uses GIS software to estimate potential economic losses from earthquakes, hurricanes and floods. To further understand infrastructure exposure, we added data on hardened shoreline structures, land use and locations of critical facilities (hospitals, fire stations).

Results

Coastal Resilience provides spatial databases and combined indices that characterize ecological, social and economic resources and their vulnerability to current and future coastal hazards. We illustrate some of the types of data and decision support in Figures 6.2–6.6.[4]

First we examined exposure to current and future impacts using a variety of different and realistic scenarios based on past storms and likely future SLR. Among those scenarios, we illustrate the potential storm surge flooding from a Category 2 hurricane based on current sea level and the increased future flooding based on the same storm with sea levels

Figure 6.2 Visualizing storm surge and sea level rise in Bridgeport, Connecticut
Source: See <http://lis.coastalresilience.org/lis.html> (accessed 16 October 2012).
Notes: The storm surge is the predicted maximum surge from a Category 2 hurricane based on current sea level. SLR is based on the IPCC A2 scenario for the year 2080.

predicted from an A2 IPCC emissions scenario for the year 2080 (Figure 6.2).

We provide significant data on current wetlands and other biological resources (see, for example, Figure 6.3).

The SOVI summarized the communities most vulnerable to coastal hazards on a relative scale throughout the project area in New York and Connecticut (Figure 6.4). We examined numerous economic resources at risk from coastal hazards, including, for example, the geographical distribution of potential building losses (replacement costs) across the region (Figure 6.5).

All of these types of data (ecological, social and economic) have been used individually by others for planning. The real benefit is to be able to combine these data sets to better assess the present and future distributions of coastal ecosystems with data characterizing infrastructure and social vulnerability to identify choices that could conserve ecological

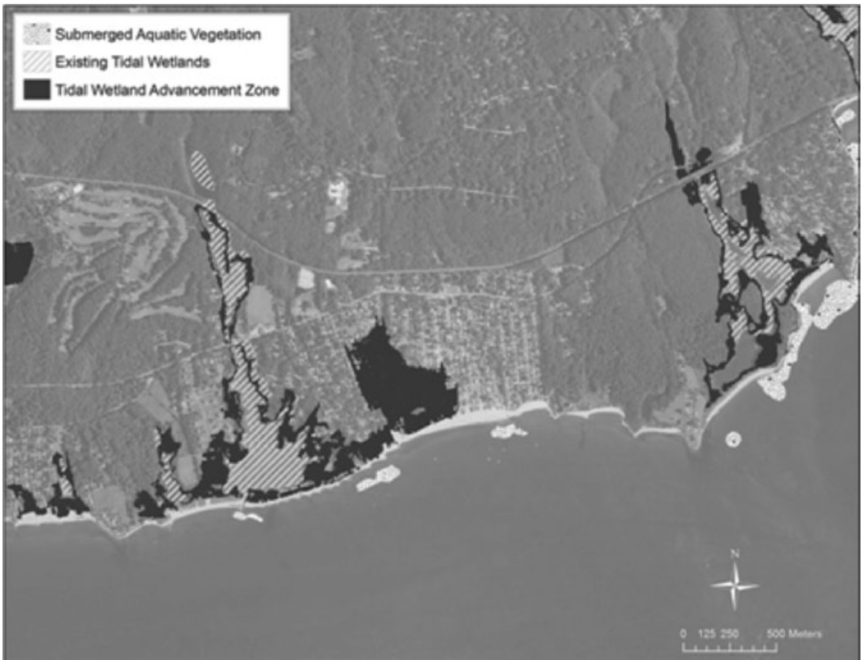

Figure 6.3 Ecological systems around Old Lyme, Connecticut
Source: See <http://lis.coastalresilience.org/lis.html> (accessed 16 October 2012).
Notes: The future advancement zones are areas in which marshes may migrate based on considerations of current elevation, land cover, accretion and erosion and future sea level in 2080 based on IPCC A2 emissions scenarios (see Hoover et al., 2010).

resources while mitigating coastal hazards. Figure 6.6 illustrates one example of these types of integrated analyses. It shows "advancement zones" in vacant parcels for conservation, into which marshes could potentially migrate or advance under future SLR scenarios. One way that land-use planners use this integrated analysis is to identify areas that should remain undeveloped to allow for the landward advancement of tidal wetlands in order to maintain the continued protection of some of the most vulnerable low-lying human communities.

Discussion

Mutually beneficial solutions for improving the resilience of human and natural communities lie in examining relationships between coastal haz-

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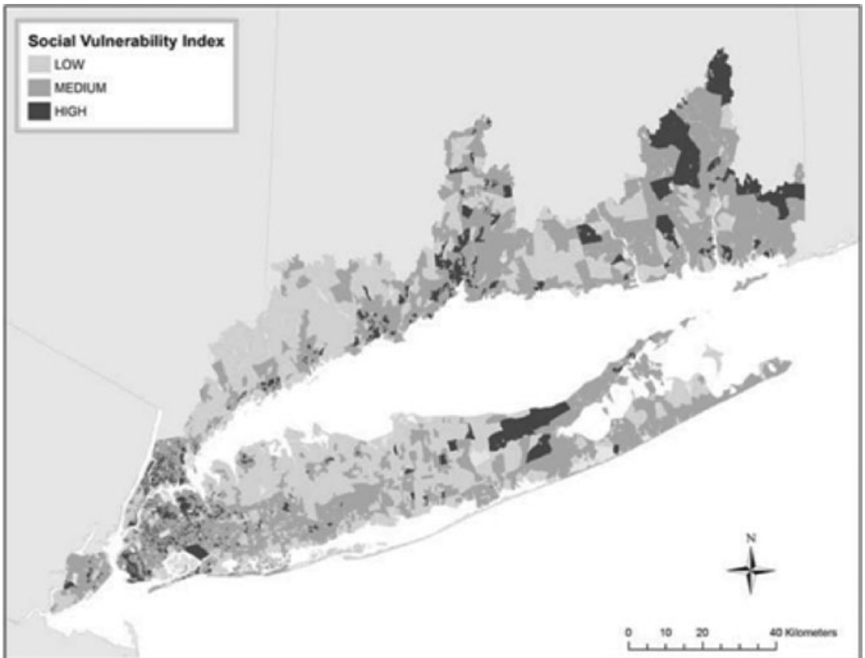

Figure 6.4 Social vulnerability: Low, medium and high social vulnerability of census block groups throughout the study area in New York and Connecticut
Source: See <http://lis.coastalresilience.org/lis.html> (accessed 16 October 2012).
Notes: Vulnerability is based on SOVI and provides a prediction of those most vulnerable to coastal hazards.

ard mitigation and biodiversity conservation to preserve lives, infrastructure and livelihoods while protecting nature. Decision-makers will address people's needs first, but it is possible to reduce coastal losses to both people and nature. Ecosystem-based solutions can present a common ground to achieve both objectives. Processes such as urbanization, environmental degradation and climate change shape and configure hazards, which means it is becoming increasingly difficult to disentangle their natural and human attributes (UNISDR, 2011).

There has been an increased interest by the hazard management community in coastal protection options that are environmentally friendly, driven by increasing evidence of (i) the role of ecosystems in coastal protection, (ii) their cost-effectiveness in both initial costs and added benefits, and (iii) the opportunity in some areas to create sustainable livelihood alternatives. Evidence increasingly demonstrates that conservation and management of coastal ecosystems can play a key role in reducing coastal

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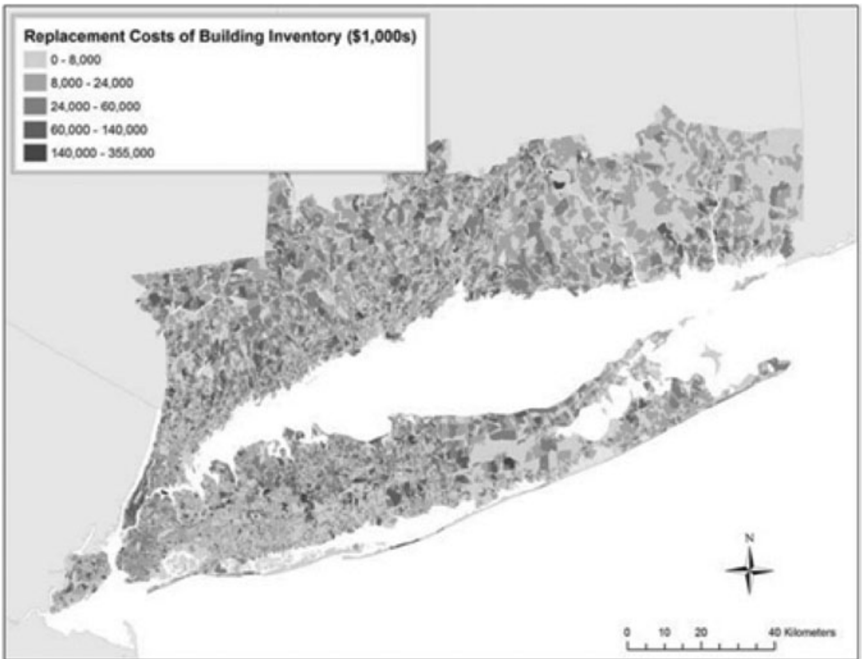

Figure 6.5 Potential economic impacts: Estimated replacement costs (i.e. potential economic losses) of built infrastructure from across the study area based on the HAZUS model
Source: See <http://lis.coastalresilience.org/lis.html> (accessed 16 October 2012).

hazards (Beck et al., 2011; Dudley et al., 2010; Costanza et al., 2008; Gedan et al., 2011; Hale et al., 2011; Sheppard et al., 2005) and thus the vulnerability of communities. For example, Shepard et al. (2011) examined the protective role that marshes can play in providing coastal protection services by doing a meta-analysis combining results from field studies that compared these coastal protection benefits with and without marshes (Figure 6.7).

The second major factor driving interest in green infrastructure solutions is the increasing evidence that they can be a cost-effective part of hazard mitigation and climate adaptation solutions (Campbell et al., 2009; Entergy Corporation, 2010; McKinsey & Co., 2009; World Bank, 2009; World Bank and United Nations, 2010). Further, ecosystem-based approaches can address multiple coastal management objectives, including natural resource protection with which local officials are charged. An ecosystem-based approach of protecting and restoring "green infrastructure" such as healthy coastal wetlands could be a more cost-effective, lower-maintenance means of protecting large coastal areas (Moberg and Rönnbäck, 2003). Strategies that aim to enhance the resilience of eco-

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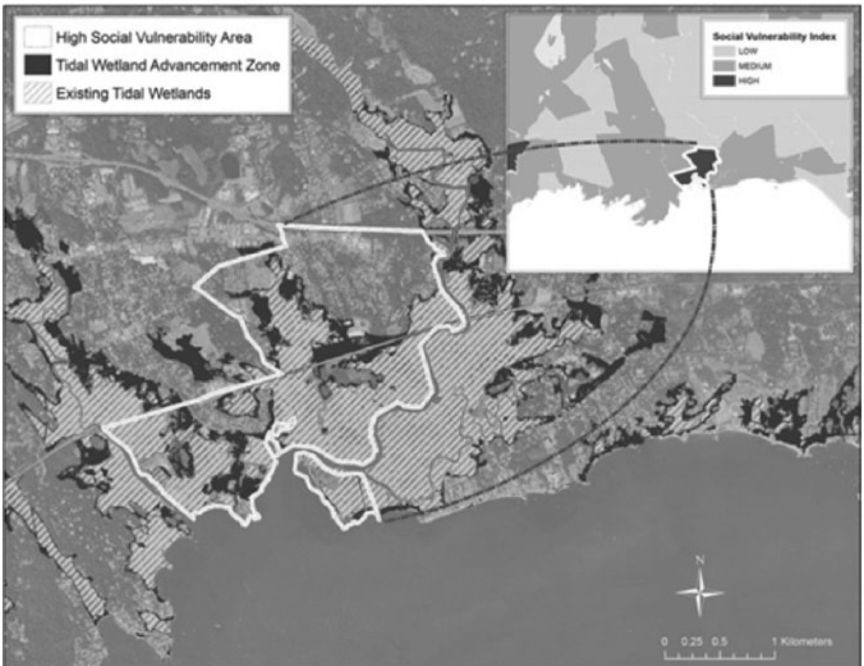

Figure 6.6 Integrating socioeconomic and ecological data to support land-use planning decisions to meet hazard mitigation and conservation objectives
Source: See <http://lis.coastalresilience.org/lis.html> (accessed 16 October 2012).
Notes: This figure shows the present-day distribution of tidal wetlands (grey hatched), the low elevation areas where marshes are predicted to advance between now and 2080 (black polygon), the communities of highest social vulnerability in the area based on SOVI (white polygon), and residential and commercial developments directly adjacent to tidal wetland advancement zones (aerial photography), Guilford, CT.

systems to enable the continued provision of goods and services can be particularly important for vulnerable communities that depend upon natural resources.

In fact, the incorporation of these approaches is imperative given the very high costs to society of engineered solutions. In many places, putting up enough artificial defences is impractical, too expensive, maladaptive and often with ongoing debt service and maintenance costs. One of the areas where there are real opportunities for identifying better joint solutions for human and natural communities is in building approaches that combine hazard mitigation and biodiversity conservation in coastal zones to preserve infrastructure while protecting human communities. In some of the most highly developed areas (for example, major urban cities), ecosystem-based options alone will rarely be viable alternatives. However,

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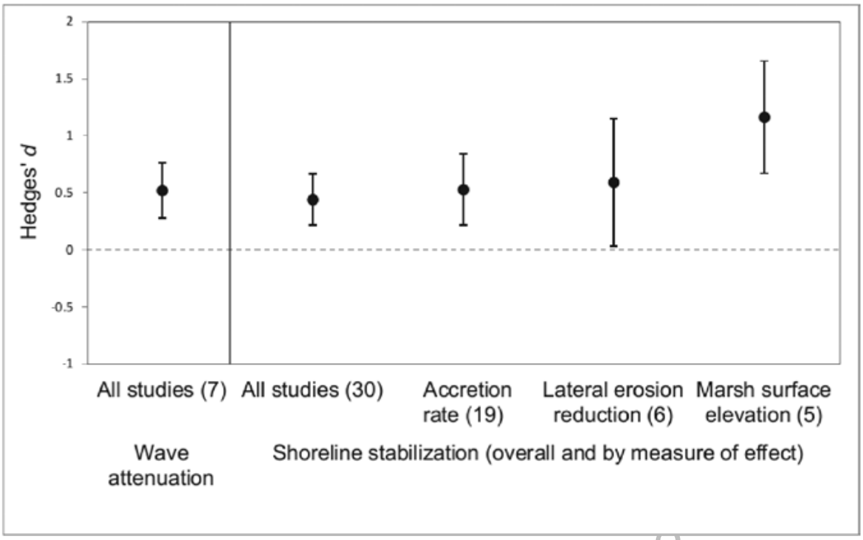

Figure 6.7 Average effect size of marsh vegetation (Hedges' *d*) on (a) wave attenuation and (b) shoreline stabilization as measured by increases in accretion/marsh surface elevation change or decreases in lateral erosion
Notes: The results are based on a meta-analysis of multiple studies that compared attenuation and stabilization in areas with (treatment) and without marshes (control). The numbers of separate studies are in parentheses next to the services. Positive values of *d* indicate that, overall, treatments (marsh) attenuated waves and stabilized shorelines. The errors bars are 95% confidence intervals. Because they do not overlap 0, the positive effects of treatments are significant. See Shepard et al. (2011) for further information.

we are finding that, even just outside of one of the largest urban areas, there are viable nature-based solutions. Changing approaches (and mindsets) to include green infrastructure is not simple, and there are strong vested interests that support only engineered approaches. Nonetheless, in a time of shrinking budgets, most municipalities are looking for cost-effective infrastructure approaches (because these works are almost all taxpayer supported).

To advance ecosystem-based approaches for risk reduction and adaptation, we need to integrate hazard and climate science with local decision-making processes. This work is just beginning; the present case is one of the first to attempt this integrated approach. This experience illustrates how the management of saltmarshes can be integrated into coastal zone hazard mitigation and climate change adaptation policies. There are, however, significant considerations and challenges in jointly informing decisions about hazard mitigation and conservation.

Access to relevant information and data

Providing communities and key decision-makers (for example, local planning agencies and natural resource managers) with easy access to information is critical to assist in coastal planning and management decisions regarding resources at risk from coastal hazards. One of the criteria that has increased use of Coastal Resilience is that it does not promote a specific outcome. Rather, it enables easy access to targeted information in one location for planners, elected officials, managers and citizens so that they can visualize the vulnerability and risks that communities face from coastal hazards and work within the given context of their specific communities or regions.

Mapping predictions of SLR and storm surges is best done with high-resolution bathymetric, topographic and airborne gravimetric data. These data can be expensive to acquire but costs are coming down and the data are becoming more available in many regions. These data are needed to provide a description of elevation characteristics throughout the coastline. When lower resolution data are all that is available (such as the global elevation data sets), it is still possible and necessary to plan for the future. However, a more precautionary stance in development planning is justified with lower-resolution elevation data because confidence in the flooding and inundation predictions (that is, where surges and sea level will reach) is lower.

Improvements in the quantification of ecosystem services will further their integration in risk management frameworks. Indeed, most studies on the role of ecosystems in coastal protection are often descriptive or limited to a singular experience, but new and better efforts in field experiments, models and global reviews are becoming available, such as Gedan et al. (2011); Scyphers et al. (2011); Shepard et al. (2011, Figure 6.7 above); see also Chapter 5 in this volume.

The importance of a flexible framework

Public management of risks is a multidisciplinary and multi-sector field often entrusted to a variety of institutions that operate at different spatial and temporal scales. The differing scales and responsibilities of these institutions present coordination challenges. Flexible decision support is critical for incorporating new information into development planning accessible by multiple partners, agencies and institutions.

With Coastal Resilience, we have endeavoured to create a framework that provides information to local communities, but it is also relevant at state and national scales. By focusing first on local decision-makers, we address the needs of stakeholders within their communities while

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providing a robust framework for identifying place-based ecological, social and economic relationships and appropriate solutions for hazard mitigation. Coastal Resilience accommodates adaptive planning; centralizes and provides decision support online; advances structured community dialogue; and is transferable to other geographies.

Coastal Resilience is being used in Connecticut and New York by local agencies to inform decision-making regarding natural resources and community land-use/policy planning. At the municipal level, communities such as Guilford, Old Saybrook and Westbrook (CT) are incorporating the SLR and storm surge projections from Coastal Resilience into their Natural Hazard Mitigation Plans, along with specific identification and prioritization of "at risk" neighbourhoods and infrastructure. Figures from Coastal Resilience have been incorporated in the Plan of Conservation and Development for Waterford, CT. Town planners and emergency managers across the coast of Connecticut are using the storm surge projections to reconsider evacuation routes and refuge locations in the face of increased storm activity. Ten communities in Connecticut reported using Coastal Resilience for preparedness and response before Tropical Storm Irene. This information is also being used by the Greater Bridgeport Regional Council for transportation (bus and rail) assessments and contingency planning in densely populated portions of the project area. In addition, the information is being used for detailed vulnerability assessments in Stamford, CT, and reconsideration of zoning restrictions elsewhere on future growth in future flood and inundation areas. The Town of Easthampton, NY, is using the decision support to evaluate revetment applications.

At the state level, the New York State Sea Level Rise Task Force (NYSSLRTF) uses Coastal Resilience for vulnerability mapping in coastal New York. Just recently, figures from Coastal Resilience provided a primary motivation in Connecticut for the development and senate approval of a shoreline preservation task force in that state. A primary aim of the task forces is to develop new policies to address the unique needs of shoreline and waterfront residents and businesses with respect to shoreline erosion, rising sea levels and future storm planning.[5]

In New York, the SLRTF found that coastal wetlands provide a cost-effective approach to reducing vulnerability of people and property. It recommends that New York "support increased reliance on non-structural measures and natural protective features to reduce impacts from coastal hazards . . . and prevent further loss of natural systems that reduce risk of coastal flooding" (NYSSLRTF, 2010). It is evaluating state and local wetlands regulations in the face of SLR and identifying where retreat-oriented policies can be effective (that is, identifying where marshes can and should be allowed to migrate upslope).

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Our aim is to increase the robustness of analyses for integrating assessments of ecological and social vulnerability and in the identification of options for reducing them. Figure 6.6 identifies one of the ways in which we have approached this problem systematically. We identify where communities are socially vulnerable and where marshes are at risk, as well as where development and conservation priorities could align to ensure that future vulnerabilities do not increase.

State and federal agencies are using the "advancement zone" analyses as a guide to rebalance management objectives directed at the acquisition, restoration and habitat conversion of saltmarshes for private preserves and national wildlife refuges and management areas to meet conservation and hazard mitigation management objectives. We are working with several National Estuary Programs (NEPs) towards providing decision support to communities in the Environmental Protection Agency's Peconic Estuary Program and the Long Island Sound NEP. Coastal Resilience is a part of NOAA-CSC's Digital Coast efforts to inform communities about the risks posed by coastal inundation.[6]

Community engagement

Planning for hazard mitigation and adaptation can be challenging when there is much uncertainty and disagreement about the best management practices to minimize risks. Nonetheless, there is a need to take anticipatory adaptive action. Extensive community engagement is essential for accessing information, understanding issues and building support for actions. It has been a key principle in the development of Coastal Resilience. During the development of Coastal Resilience we conducted extensive interviews and hosted multiple stakeholder workshops (in New York and Connecticut) to better understand community awareness and readiness; the resources at risk; and the planning support required to address existing and future impacts (see Table 6.1). At each workshop we asked for critical feedback on the issues being assessed and the tools being developed. In the subsequent workshops we identified how we responded to the feedback. Since the primary development period (two years), we have been deeply engaged with several municipalities in using the decision support tool. Stakeholders who have been engaged in the process included town planners, environmentalists, scientists, local elected officials and agency staff (county, state and federal representing environment, transportation and hazard management, among others). Engagement of stakeholders provides opportunities for coastal communities to employ local knowledge and for direct participation in developing and applying solutions. Structured dialogues with our pilot communities

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Table 6.1 Stakeholders participating in the process

Towns/cities	Town of Guilford, CT Town of Old Saybrook, CT Town of Southold, NY Town of Stonington, CT Town of Waterford, CT Town of East Lyme, CT Town of Old Lyme, CT Town of Westbrook, CT City of Bridgeport, CT City of New Haven, CT
Regional planning organizations	Connecticut River Estuary Regional Planning Agency Southeastern Connecticut Council of Governments South Central Regional Council of Governments Greater Bridgeport Regional Council
Key working partners	Clean Air – Cool Planet Regional Planning Association Association of State Floodplain Managers NOAA Coastal Services Center
Academic partners	Columbia University Yale University University of Connecticut Clark University Pace University
Participating fields	Emergency management Public health Engineering Planning and zoning Conservation/environmental management Transportation/infrastructure Elected officials Citizen groups Land-use planning Marine and coastal science

(Guilford and Old Saybrook, CT, and Southold, NY) have resulted in initiatives to rewrite master planning documents.

Many local elected officials do not fully appreciate the threat posed by SLR, or they see the issues as occurring too far in the future to be a major consideration in current planning and capital expenditures. The outreach efforts for this project focused initially on increasing the receptivity to and importance of this issue with and between local and state regulatory agencies. Ongoing community engagement that provides a forum to comprehensively receive and consider common and conflicting interests is a central focus of Coastal Resilience.

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Bringing together mismatching mandates

In theory, better integration of hazard mitigation, adaptation and conservation objectives could be developed through comprehensive adaptation plans. In practice, they are more likely to be components of pre-existing planning processes such as master plans; hazard mitigation plans; capital expenditure and economic development plans; wetlands management plans; and other resource management plans.

One major issue in planning for coastal hazards and climate change is that many local and state managers have divergent and sometimes conflicting mandates and timelines for addressing coastal hazards. In the United States, the state agency participants have purview to promote planning for SLR through existing federal coastal zone management acts and state statutes, but, since most land-use planning is undertaken by local governments, state agencies generally are in a regulatory review position for consistency. State-level agencies should be more proactive in asserting their responsibilities and helping local governments with their long-term planning requirements.

More important in terms of conflicting timelines and mandates are the differences between emergency and infrastructure decision-makers. Both types of decision-makers are charged with dealing with hazard management. The former principally address short-term crises (hour by hour) and the latter long-term development planning (decade by decade). It is increasingly recognized however that some of the most significant development planning decisions are made in the weeks following crises, and that effective long-term planning could reduce some, and possibly many, of the losses associated with crises.

As the hazard management community moves further towards pre-disaster planning to reduce risk and potential loss, it should broaden participation from sectoral and spatial planning, including natural resource management agencies, and plan at a longer time-scale. The dividing lines between sectoral and spatial planning, civil protection and natural resource management are often rigid, making it difficult sometimes to secure communication and coordination between these communities. This often leads to a fragmented response–preparedness–prevention–remediation chain, reproducing situations where the information, knowledge and policy actions run in parallel without any linkages, feedback and mutual interactions (Sapountzaki et al., 2011). The increased awareness of the need to integrate future climate change impacts in hazard and development planning is a critical opportunity that will improve communication and coordination amongst these actors, resulting in more resilient communities. As noted above, the local leaders with whom we have worked have realized and embraced the requirement that coastal climate change is not a stand-alone issue and needs to be incorporated comprehensively across the sectors and functions of their communities. This recognition provides the platform from which multiple objectives and inherently conflicting interests can be balanced and directed towards the ultimate outcome: more resilient communities able to accommodate coastal change.

Recommendations

Coastal towns and villages around Long Island Sound and other coastal portions of New York are willing to explore different approaches for addressing coastal hazards and climate change, including nature-based solutions. Few have addressed these challenges head-on; New York City stands out in this regard (Rosenzweig and Solecki, 2010).

The achievement of more integrated strategies for hazard mitigation, adaptation and conservation will require substantial changes in the present shoreline management paradigm. There are six key recommendations to enable progress in the design and implementation of ecosystem-based solutions in the Northeastern United States and beyond.

1. *Enhance data and decision support to inform community choices*. We have found that the keys to effective engagement are robust and reasonable scenarios of impacts and alternatives. We do not believe that the further development of support should slow decision-making processes, but we have consistently found that robust scenarios are critical for handling difficult decisions and conflicting interests.
2. *Amend and pass key legislation*. Most shoreline management regulations and laws currently do not account for growing coastal hazards. Amendments to the Coastal Zone Management Act, the National Flood Insurance Program and FEMA Natural Hazard Mitigation Plans would increase the ability to both plan for and fund ecosystem-based approaches at the regional, state and local levels.
3. *Promote voluntary land acquisition*. The passage and/or amendment of progressive legislation at the federal and state level should provide financial incentives to local governments to enable the voluntary acquisition of coastal property as a means to protect human life and adjoining property and permit natural, sustaining processes to occur in the coastal zone.
4. *Relocate vulnerable infrastructure and development*. In some cases where risk to human communities is extremely high, moving vulnerable infrastructure may be advised and even necessary.
5. *Engage in comprehensive, pre-storm planning and post-storm redevelopment*. Adoption of suitable future development and redevelopment

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programmes at the local level should be considered as an opportunity to minimize future additional risk and remedy previous land-use decisions that did not address current and longer-term risks and costs. The recognition of and need for linking pre-storm planning and post-storm redevelopment strategies should be reinforced and enabled through the federal programmes mentioned above.

6. *Restore and protect natural resources*. Central to the advancement of ecosystem-based approaches is the need to invest in habitat restoration and protection. A continued and sustained investment in natural resources will provide a highly leveraged return of important ecosystem services and increased nature-based solutions for shoreline protection and erosion control.

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Notes

1. See <http://www.coastalresilience.org> (accessed 16 October 2012).
2. There is limited agreement on the basic definitions of risk and vulnerability even among the disaster risk reduction and climate change adaptation communities (Renaud and Perez, 2010). Following Shepard et al. (2012), we characterize vulnerability, hazard and risk as follows: "vulnerability" is the susceptibility of both biophysical and social systems to a "hazard", which is an event or occurrence that has the potential to cause harm to people and/or property; "risk" is the likelihood or probability of such harm.
3. LiDAR stands for Light Detection and Ranging.
4. Much more information is available online through the web mapping application at <http://lis.coastalresilience.org/> (accessed 16 October 2012).
5. *Connecticut Mirror*, 9 January 2012 and "Speaker Donovan Announces Shoreline Preservation Task Force", 6 February 2012, <http://www.housedems.ct.gov/Donovan/2012/pr084_2012-02-06.html> (accessed 16 October 2012).
6. See NOAA-CSC, "Coastal Inundation Toolkit", <http://www.csc.noaa.gov/digitalcoast/inundation/longisland.html> (accessed 16 October 2012).

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