Overview of the Manomet Climate Change Adaptation Project

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Center for Conservation Sciences

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Introduction

The Manomet climate change adaptation project is primarily concerned with climate change adaptation measures that restore, protect and enhance ecosystem service delivery. Ecosystem services are those benefits such as water supply, food production and climate regulation that intact and healthy ecosystems provide to humans. Manomet has been working with landowners and stakeholders at a variety of geographic scales and across several different sectors to identify vulnerabilities to climate change and develop and implement adaptation strategies. The landscape-scale sites include the Taunton River watershed in Massachusetts and two sites in Maine, the Sebago Lake watershed and the Sagadahoc region. The smaller landowner sites involve a mix of commercial and conservation initiatives including forestry and agricultural operations, rural residential development and environmental restoration projects. The challenges and opportunities vary significantly across the sites and sectors. While the adaptation decisions being made in association with the Manomet project are local and regional in geographic scope it is important to consider the broader global context and the effects of non-climate change stressors on ecosystem service delivery. In many cases these broader concerns impact the priority and viability of local and regional adaptation decisions.

Global Context

Two significant factors differentiate the current situation with climate change from previous periods of global warming. The first is that warming is projected to occur much more rapidly over the next century than during previous transitions. Researchers involved in a recent study of climate change adaptation in New York State found that "the pace of change projected for this century is faster by several orders of magnitude than that of the most recent ice age transition and other historical events in the paleobiological record."[1] The second factor is that approximately 60% of critically important ecosystem services such as air and water purification and climate regulation examined in the Millennium Ecosystem Assessment are being degraded or used unsustainably. In a related finding the Assessment states that "there is established but incomplete evidence that changes being made in ecosystems are increasing the likelihood of nonlinear changes in ecosystems (including accelerating, abrupt, and potentially irreversible changes) that have important consequences for human well-being."[2] Major anthropogenic impacts include loss of biodiversity, landscape fragmentation, and reduction in ecosystem complexity. Thus adaptation measures that are focused on maintaining ecosystem service delivery must be responsive to both the projected speed of warming and the full range of anthropogenic ecosystem impacts.

An approach to defining safe limits to natural resource impacts was proposed by the Stockholm Resilience Center in the paper Planetary Boundaries: Exploring the Safe Operating Space for Humanity. This framework defines limits for several categories of ecosystem impact including climate change, biodiversity loss, land system change and freshwater use. Biodiversity loss, climate change and nitrogen cycle impacts are currently identified in the study as beyond the safe target levels. Impacts related to ocean acidification, land system change, global fresh water use and phosphorus cycle impacts are all below the target levels but are increasing with time.[3] The theme of interdependence is important with increasing atmospheric Carbon Dioxide (CO_2) levels driving both climate change and ocean acidification while a combination of land system change, climate change, ocean acidification and nitrogen cycle impacts all factor into biodiversity loss.

Recent and Projected Climate Change

Climate has changed significantly in New England during the period 1900 through 1999. Average annual temperatures have increased by 0.08 degrees Celsius (ºC) per decade and average winter temperatures have increased by 0.12ºC. The rate of average temperature increase accelerated significantly during the period of 1970-2000 with average annual temperatures increasing by 0.25ºC per decade and average winter temperatures increasing by 0.70ºC. Driven by these changes growing seasons have lengthened, the number of days with snow on the ground has decreased for many locations and the timing of peak spring stream flow has shifted to earlier in the year.[4]

The continued increase in atmospheric greenhouse gas levels is also driving associated increases in extreme weather events. In 2008 the U.S. Climate Change Science Program found that:

- "Human-induced warming has likely caused much of the average temperature increase in North America over the past 50 years and in turn causing changes in temperature extremes.
- Heavy precipitation events in North America have increased over the past 50 years in conjunction with observed increases in atmospheric water vapor.
- Increasing greenhouse gas concentrations have contributed to the increase in sea surface temperatures in the hurricane formation regions. Over the past 50 years there has been a strong statistical connection between tropical Atlantic sea surface temperatures and Atlantic hurricane activity as measured by the Power Dissipation Index".[5]

The change in frequency and intensity of extreme precipitation events differs regionally within North America with the most pronounced increase taking place in New England. A recent study of the period of 1948 – 2007 found significant increases in both the occurrence and intensity of extreme precipitation with the most significant increases occurring most recently[6].

Projections of future climate indicate a likely acceleration of the changes that have occurred during the last 100 years. A 2006 study downscaled output from several global climate models and produced output specific to New England for three different possible future emission scenarios.[7] Nine atmosphere-ocean general circulation models where utilized in creating the projections that were downscaled. The three emission scenarios were the B1, A2 and A1FI scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). The B1 scenario assumes a stabilizing of atmospheric CO_2 levels at or above 550 ppm by year 2100. The A2 scenario assumes atmospheric CO_2 levels of 830 ppm by 2100 and the A1FI scenario assumes CO_2 levels of 970 ppm by 2100. Results for the B1 and A1FI scenarios and two of the modeled variables, temperature and precipitation are shown in the following table.

Table 1. Results for the B1 and A1FI scenarios for Temperature and Precipitation

	UNITS	2035-2064		2070-2099	
Temperature	Degrees C	B1	A1FI	B1	A1FI
Annual		+2.1	+2.9	+2.9	+5.3
Winter		+1.1	+3.1	+1.7	+5.4
Summer		+1.6	+3.1	+2.4	+5.9
Precipitation	% change				
Annual		+5%	+8%	+7%	+14%
Winter		+6%	+16%	+12%	+30%
Summer		-1%	+3%	-1%	0%

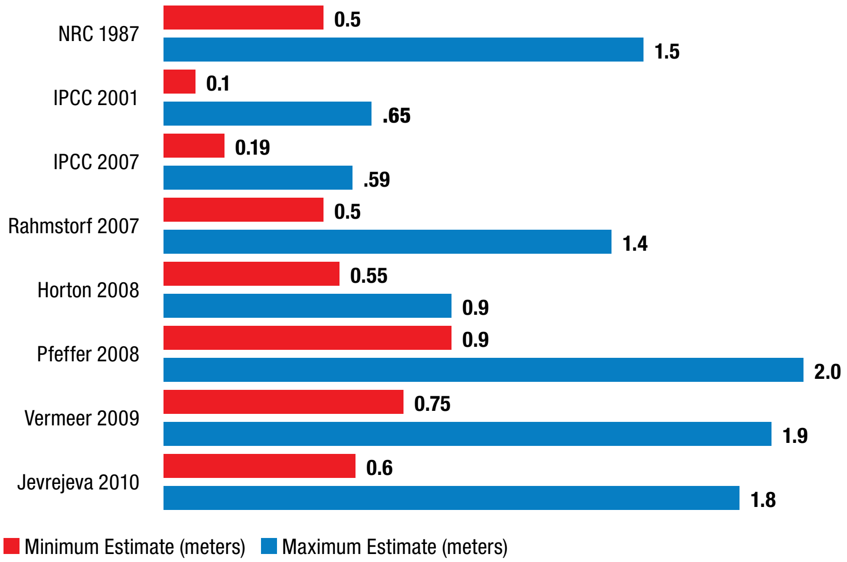
Source: (Reference number 4, Hayhoe)

Several other variables were modeled including stream flow and drought frequency. The projected changes in stream flow are mixed with low flow periods decreasing slightly for all but the A1FI scenario for the period 2070-2099, where the number of low flow days per year is projected to increase by 22 days. Drought is projected to increase for both scenarios and both time periods with the most significant increases for the A1FI scenario in the latter time period.[8]

Sea Level Rise

Sea level rise (SLR) projections through the year 2100 cover a broad range due to several factors including an uncertain trajectory for future greenhouse gas emissions and an incomplete understanding of future ice melt rates. Figure 1 provides a synopsis of sea level rise projections based on several different modeling approaches.[9]

Figure 1. Projected Sea Level Rise by 2100



Source: (Reference number 9, U.S Army Corps of Engineers)

The most recent U.S. Army Corps of Engineers guidance indicates that two meters is the likely upper bound of SLR through 2100 but does not rule out higher maximum levels.[10] A recent study by the United States Geological Survey indicates that the section of the Atlantic coast from Cape Hatteras to Maine is subject to an additional increment of sea level rise associated with a slowing of the Atlantic Meridional Overturning Current.[11]

Sea level rise will increase the severity of storm surge flooding. A recent study estimated the change in frequency in occurrence of today's 100-year flooding event through the year 2050. The projected changes include a recurrence frequency of every 5 years for Portland, ME, a 30 year return frequency for Boston, MA and a 10 year return frequency for Providence, RI.[12]

Projected Changes in Extreme Weather and Climate

As average temperature and precipitation continue to increase in North America the projections indicate related changes in extreme weather and climate. The U.S. Climate Science Program projects that:

"Future changes in extreme temperatures will generally follow changes in average temperature: Abnormally hot days and nights and heat waves are very likely to become more frequent. Cold days and cold nights are very likely to become much less frequent. The number of days with frost is very likely to decrease.

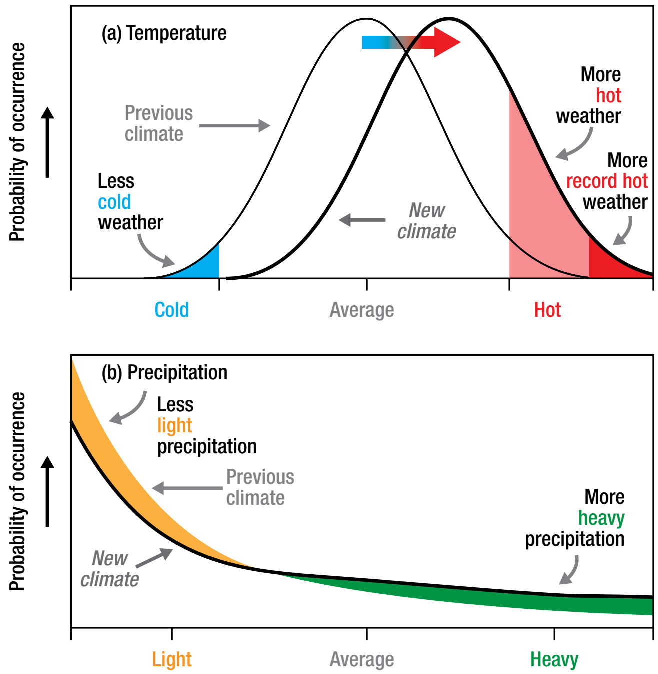
Over most regions, precipitation is likely to be less frequent but more intense, and precipitation extremes are very likely to increase.

It is likely that hurricane/typhoon wind speeds and core rainfall rates will increase in response to human-caused warming. Analyses of model simulations suggest that for each 1 degree C increase in tropical sea surface temperatures, hurricane surface wind speeds will increase by 1 to 8% and core rainfall rates by 6 to 18%.

Storm surge levels are likely to increase due to projected sea level rise, though the degree of projected increase has not been adequately studied.

There are likely to be more frequent deep low-pressure systems (strong storms) outside the tropics, with stronger winds and more extreme wave heights."[13]

Figure 2. Projected Changes in Extreme Weather and Climate



Source: (Reference number 5, Karl)

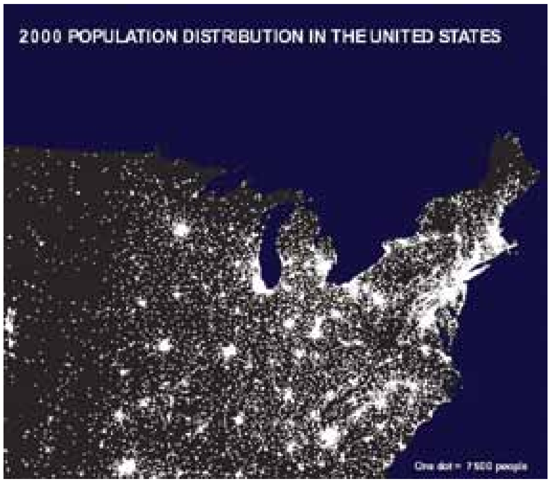
Non-Climate Change Factors that Impact Adaptation in New England

Several non-climate change factors are impacting ecosystem service delivery in New England and are worthy of consideration in adaptation planning. In many instances non-climate stressors such as landscape fragmentation and watershed degradation will limit the effectiveness of adaptation measures if it is not possible to manage them in conjunction with climate change related stressors. The need to respond to a mix of climate change and non-climate change stressors has been a recurrent theme encountered at all of the Manomet project sites.

Landscape Fragmentation and Urbanization

New England is a diverse region with several major urban centers, an extensive area of urbanization adjacent to the Atlantic coast and exceptionally remote and undeveloped areas in the interior and northern reaches of Maine. Despite the densely populated character of much of New England many of the less populated areas, both in the interior and along the coast, supply a rich set of ecosystem services.

Population growth in the Northeast for the period of 2000 – 2010 was 3.2%, the lowest of all regions of the United States. Unfortunately, as is the case with much of the United States the rate of land development in New England is roughly twice the rate of population growth. Much of this development is taking place at the outskirts of urban areas leading to increasing habitat fragmentation and loss of ecosystem connectivity. As urbanization continues and more land area is converted to impervious surface, an increasing number of watersheds in New England cross the threshold to water quality and ecosystem degradation. Watershed integrity typically starts to degrade at levels of imperviousness over 10% and significant impacts occur at levels of imperviousness above 25%. Increases in imperviousness also enhance flooding associated with heavy precipitation events.



A unique set of climate change related problems occur due to urbanization within the coastal zone. Rising sea levels and associated rising groundwater levels are increasing the frequency and severity of storm surge flooding. Many coastal communities in New England are dependent on septic systems that will cease to function as water tables rise. In addition, much of the supporting infrastructure for coastal communities including transportation systems and the power grid were not designed to withstand enhanced storm surge. Finally, tidal wetlands are being lost in many urbanized areas due shoreline hardening that prevents upslope migration as sea level rise progresses.

Riparian Corridor Continuity

Many of the stream corridors in New England have been highly modified. Extensive shoreline development has resulted in the loss of riparian forest and wetlands in many urban areas. A long history of manufacturing has resulted in numerous in-stream barriers including both old dysfunctional dams and improperly sized and placed culverts. Increasing rainfall intensity associated with climate change will exacerbate urban flooding and nonpoint source pollution in these degraded riparian areas. Fragmentation of riparian corridor habitats will also inhibit species redistribution under climate change.

Aging Infrastructure

The combination of aging infrastructure and lack of sufficient funding to repair or replace it has created a significant impediment to adaptation in the United States. Increasing storm intensity is exacerbating the problems associated with ageing infrastructure, particularly flooding and water quality problems associated with outstripping the treatment capacity of stormwater and wastewater facilities. In New England much of this infrastructure is extremely vulnerable due to a combination of age and outdated design standards. In all three of the watershed-scale sites studied in this project significant opportunities exist to limit future grey infrastructure costs through the protection and restoration of green infrastructure networks that limit the intensity of freshwater flooding while providing other climate change benefits such as limiting heat island effects.

Climate Change in the Context of Ecosystem Services

The ecosystem services framework provides a useful construct for the identification and evaluation of benefits that people receive from both natural and modified ecosystems. The articulation of benefits and the analysis of the linkage of those benefits to ecosystem function provide an important step in understanding human dependency on the services. Ecosystem services are often categorized as provisioning (food, water), regulating (climate and flood regulation), cultural (recreational, aesthetic) and supporting services (photosynthesis and nutrient cycling).[14] In addition, the ecosystem service framework provides a structure for linking ecosystem function and economic value.

Adaptation Planning Framework

The following adaptation planning framework is a response to many of the fiscal and implementation challenges encountered in this project. The framework is most appropriate for landscape-scale sites with a mix of different land uses. Many of the concepts are also applicable to smaller landowner sites, particularly when evaluating local adaptation actions in a broader regional context. The framework is intended to provide a structure for specific adaptation decisions that will be driven by the idiosyncrasies and management goals of individual sites.

Avoid Creating Additional Adaptation Need

- Adaptation decisions must be made within the broader framework of climate change mitigation. Failure to mitigate climate change will likely result in the loss of many adaptation options. At higher levels of climate change, multiple barriers to successful adaptation will be encountered including:
  - Increasing expense of adaptation,
  - An increasing number of situations in which incremental adaptation measures become insufficient and more extreme and disruptive adaptation measures are required,
  - In some instances, particularly in the natural resource sector and in the coastal zone, all viable adaptation options could be lost.[15]

- In landscapes that are not yet significantly urbanized, applying a green infrastructure approach to land use planning can reduce long-term infrastructure costs, enhance ecosystem service delivery and support transit oriented development patterns.
- Intelligent planning and siting of new infrastructure in light of climate change will minimize life-cycle costs and the inadvertent creation of health and safety risks. In particular, minimizing new development in areas of increasing flood hazard will limit the extent to which tax dollars must be used in the future to maintain the viability of poorly sited communities and infrastructure.

Keep Options Open

- While climate models provide good general guidance on the rate and extent of climate change, it is impossible to know how complicated social-ecological systems will respond. Therefore it is important to keep future options open, particularly in regard to basic human needs such as food production and water supply. New England will likely become an increasingly important geographic area for food production under climate change due to projected continued water availability and a lengthening growing season. Minimizing loss of agricultural soils to development and protecting the integrity of surface and groundwater supplies will be important as climate change progresses.

Employ a Multiple-Benefits Approach to Adaptation

- Extreme limitations in fiscal and staff resources make it possible to address only a small fraction of adaptation needs. This fact combined with the need to simultaneously address both climate change and non-climate stressors make it necessary to prioritize adaptation actions based on the extent to which multiple management objectives can be addressed. A related concept is the prioritization of "no regret" strategies, management approaches that provide benefit regardless of the rate and extent of climate change.

The Economic Case for Proactive Mitigation and Adaptation for Ecosystem Services

Strong economic arguments can be made for a proactive approach to both mitigation of and adaptation to climate change. As the atmospheric concentration of greenhouse gasses increases, the emission path required to reduce and stabilize at safe levels involves an increasingly large and costly correction. Delay in taking action to mitigate climate change is projected to both increase the extent of climate change and the total mitigation costs.

Similar economic arguments can be made for adapting to climate change. The New York State adaptation plan includes a sector specific analysis of the costs and benefits of adaptation. By the year 2050 the agricultural sector impacts of climate change through dairy and crop losses are projected to range from $140 – 289 million. The related adaptation measures are projected to cost $78 million and result in benefits of $347 million. The adaptation analysis for several other sectors, including but not limited to ecosystems, transportation and public health, all resulted in projected benefits that far outweigh the costs.[16]

The economic benefits of proactive mitigation and adaptation efforts are further underscored when the value of ecosystem services that are not commonly represented in economic transactions are added to the analysis. Manomet recently completed an evaluation of the value of ecosystem services provided by natural systems in Maine and determined them to be over $14 billion per year.[17] Many of these services are vulnerable to climate change, further tipping the economic ledger in favor of a proactive response.

Endnotes

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