Climate Vulnerability Assessment for Washington County

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GROW WASHINGTON AROOSTOOK

Embracing the Future

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Washington County in a Changing Climate

Introduction

In recent years, increasing evidence reveals that Maine's climate is changing. We are seeing more frequent and stronger storms, and a larger proportion of our precipitation is rain instead of snow. Summers are hotter and seasonal changes are shifting. Many industries important to Washington County show signs of change, including altered forest types and shifting ranges for commercially important fish species. Clam flats are closed more often due to red tides and bacterial contamination made worse by warming water. Streams that host commercially important species such as herring, alewives, elvers, and endangered Atlantic salmon are also warmer. Moose populations are declining because winter ticks that were formerly killed by colder winters plague them. A single moose may have thousands of ticks, so many that the animal becomes severely anemic from blood loss and dies.

While not all the effects of a warmer climate are bad, many of the changes will lead to serious local challenges. We've heard from municipal decision-makers, emergency managers and others that they need information about climate change that is relevant for them. They want to know...

- How will climate change affect Washington County's coastline?
- Which local industries are vulnerable? What can we do to help them weather changes?
- What factors will fire departments, first responders, public health officials, and emergency mangers need to consider?
- What issues will planning boards, shellfish managers, water treatment plant managers and other local officials need to consider to minimize the effects of climate change?
- What are the risks to important infrastructure like roads, bridges, working waterfront, and utilities?
- What important natural resources are at risk?
- What is the time frame for climate impacts? What's happening now, what will happen soon, and what will happen in the long term?

Municipal officials have also told us they need to know what they can realistically do at the local level to minimize the problems arising from changing climate. They want to know...

- What adaptation strategies make sense for their specific circumstances?
- What are people in other regions doing to address climate vulnerabilities?
- What resources and funding are available to help in setting priorities and choosing actions?

This report, a Climate Vulnerability Assessment (CVA) focuses specifically on the needs and concerns of Washington County officials. It's designed to help you incorporate climate adaptation strategies into usual activities, whether that's preparing for emergencies, planning for coastal infrastructure, making land use decisions, or any other function of municipal or county government.

This CVA was produced for Washington County as part of GROWashington-Aroostook (http://gro-wa.org/), a regional planning process focused on job creation, modern infrastructure, and healthy, affordable communities in the counties of Aroostook and Washington. The project, begun in 2010, included twelve initiatives aimed at supporting sustainable economic prosperity

throughout this rural region. Among these initiatives is the Climate Change and Infrastructure Resilience component (http://gro-wa.org/climate-change.htm). The Washington County Council of Governments (WCCOG) and the University of Maine at Machias (UMM) Geographic Information Systems (GIS) Service Center have worked together to address this initiative in Washington County, producing CVAs for individual municipalities, as well as county-wide assessments, to support disaster preparedness, disaster response, conservation, and land use planning.

The process of developing the CVAs involved several steps, including feedback from local officials throughout the process. First, UMM researchers and students used maps and computer models with best available science and data (local to global) to understand and map the vulnerable resources here in Washington County. We created maps of various storm surge scenarios showing areas vulnerable to damage from storms, sea level rise and flood waters. Drafts of these maps were presented at the public meetings and final versions are now available on-line in two formats. The first are static (PDF format) snapshots of specific storm surge scenarios in our highest population centers near critical infrastructure. The second are a set of links that provide access to on-line GIS mapping tools in five bays across coastal Washington County.

To prepare the CVA we identified elements of potential resilience including structures, institutions and practices that protect against the effects of climate change. An important part of this process was to comb climate information produced by scientists and government agencies to find information that would be useful and relevant locally. Where it was necessary , we adapted information to make it more useful locally. For instance, to make the maps of predicted storm surges and sea level rise, we “downscaled” data provided by federal agencies, using fine scale elevation data to make detailed prediction maps for use by local officials. We also reviewed predictions to determine which climate risks were the most realistic and relevant on a local scale.

Next, we held a series of meetings with municipal and county officials to review and discuss the preliminary results of the mapping and scientific work. Using feedback from these meetings, we revised and adapted the CVAs and related maps, to incorporate priorities and local knowledge. Finally, we have begun to assist local officials to identify funding and other resources to help implement adaptation strategies. For example, we have already secured a Coastal Communities grant from the Maine Coastal Program to help with mooring plans, more detailed mapping of working waterfront infrastructure, and specific adaptation strategies for our largest harbors and critical access points..

How to Use this Report

This report and the accompanying maps are not intended to prescribe specific actions. Instead, they can be used to identify potential risks and assess available options and opportunities for adapting to climate change locally. The CVA can serve as a reference in decision-making for all areas of local government and management, and it provides ideas and additional relevant resources to help with your work.

Climate Concerns Covered by this CVA

Climate change will affect virtually every aspect of our economy and our environment. However, some concerns are more immediate while others are more long term. For instance, sea level is rising just a few millimeters per year, so it's a long-term concern. On the other hand, plants and animals, pests and diseases are already shifting their ranges, and we're seeing significant changes in weather patterns now. So these are more immediate concerns. Also, some climate concerns are not relevant to us locally—the problems facing polar bears are unfortunate, but they are not an immediate local concern for eastern Maine.

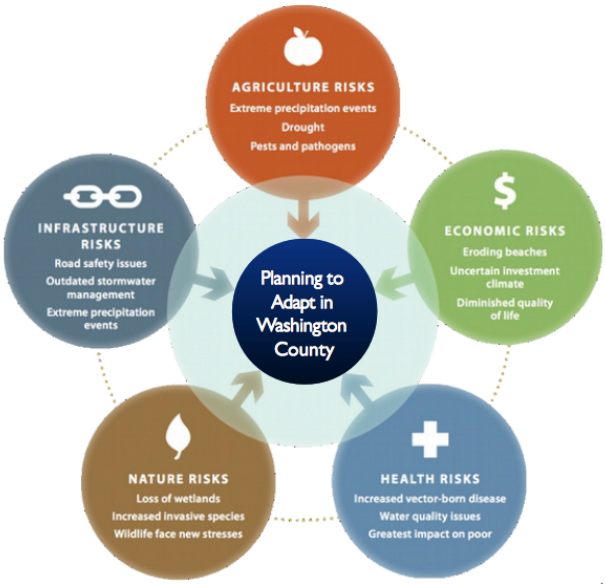


Figure 1 Adapted from "People and Nature Adapting to a Changing Climate, Charting Maine's Course." 2010.

This report covers the key climate concerns for Washington County and your municipality specifically. Local concerns include:

- More frequent, stronger tropical and winter storms
- Sea level rise
- Damage to private and public property from erosion and flooding
- Damage to infrastructure such as culverts, piers, water treatment, roads, facilities, and drinking water supplies
- Public health problems such as Lyme disease, heat stroke, and water supply issues
- Agricultural problems from pests and changes in growing seasons and precipitation patterns
- Forest problems such as pests/ disease and shifting ranges for trees
- Fisheries issues such as red tide, changing abundance and shifting ranges

In most cases, small changes in typical municipal and county government activities can help a community adapt to climate change. For example, with maps of roads that are vulnerable to flooding, emergency officials can position fire and rescue trucks strategically to cover areas of town that may be cut off during a storm. On the other hand, additional resources might be needed. For instance, a boat ramp may need to be modified to allow more effective storm preparations, or culverts may need to be widened to accommodate more storm water. In those cases, grants or loans may be available to help implement these changes. This report can help to identify such needs and provide background information to use in a grant or loan proposal.

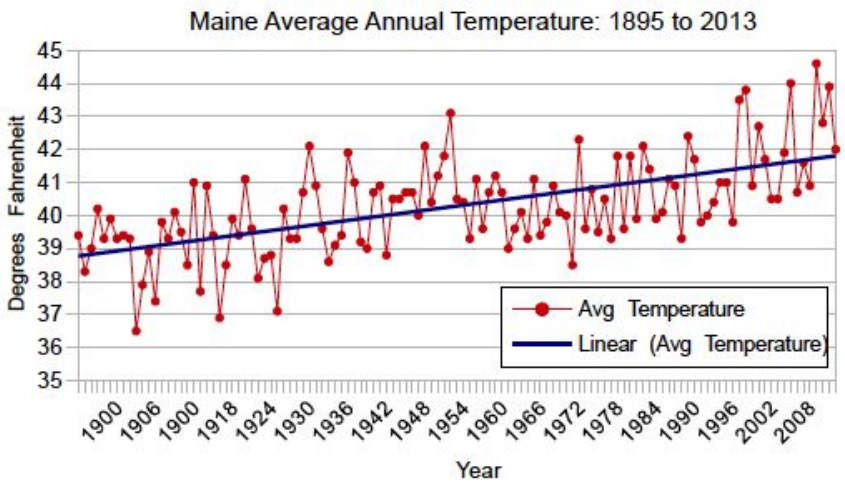
This report is accompanied by a summary for your town of key climate issues, as well as both PDF and web-based maps showing storm surge and sea level rise scenarios. The maps are easy to use in any web browser, as long as you have a good internet connection, and the website includes instructions for using the maps. In the coming year, we'll be providing additional training for local officials on using the web-based maps to help with decision-making. You can use the maps to identify roads, infrastructure, structures and natural resources that are vulnerable. Each town also has an interactive planning map with many more important features such as shellfish beds, parcels, and municipal buildings. Using the storm and sea level rise

maps along with the planning maps will be most effective in supporting decision-making.

Local Temperature Trends

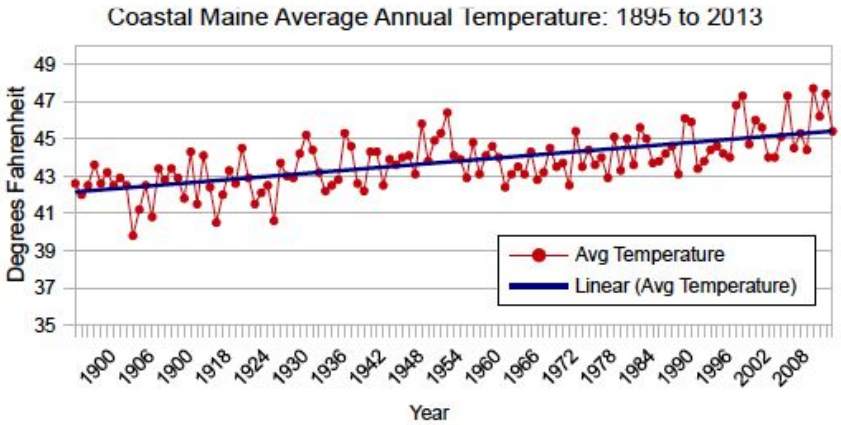
Maine Temperatures

- Maine ten-year average temperature, 1895 to 1904: 39.1°F (Std Dev: 1.03)*
- Maine ten-year average temperature, 2004 to 2013: 42.3°F (Std Dev: 1.47)*
- Change: +3.2°F



Coastal Maine Temperatures

- Coastal Maine ten-year average temperature, 1895 to 1904: 42.4°F (Std Dev: 1.02)*
- Coastal Maine ten-year average temperature, 2004 to 2013: 45.7°F (Std Dev: 1.35)*
- Change: +3.3°F



* Standard deviation (Std Dev) is a measure of variability.

National Climatic Data Center, National Oceanic and Atmospheric Administration. 2014. "Climate at a Glance | Time Series." http://www.ncdc.noaa.gov/cag/. (Note that farmers and water resource managers can use this site to look at monthly and seasonal trends related specifically to their work.)

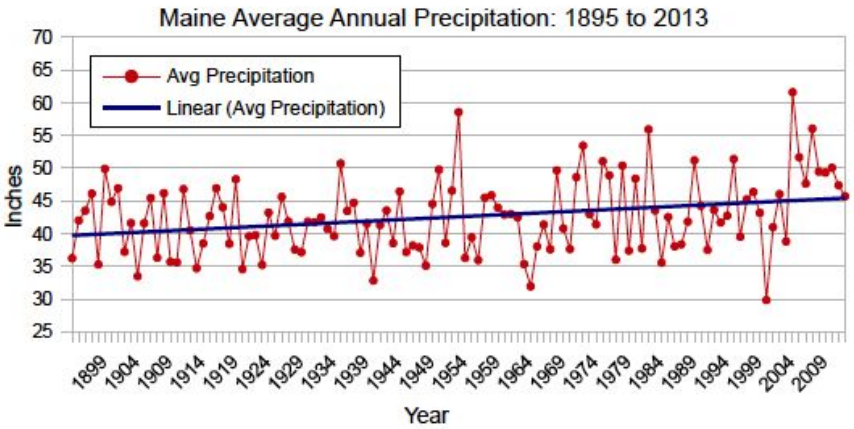
Local Precipitation Trends

Maine Precipitation

- Maine ten-year average precipitation, 1895 to 1904: 42.4 in (Std Dev: 4.88)*

- Maine ten-year average precipitation, 2004 to 2013: 49.8 in (Std Dev: 6.05)*

- Change: +7.4 in

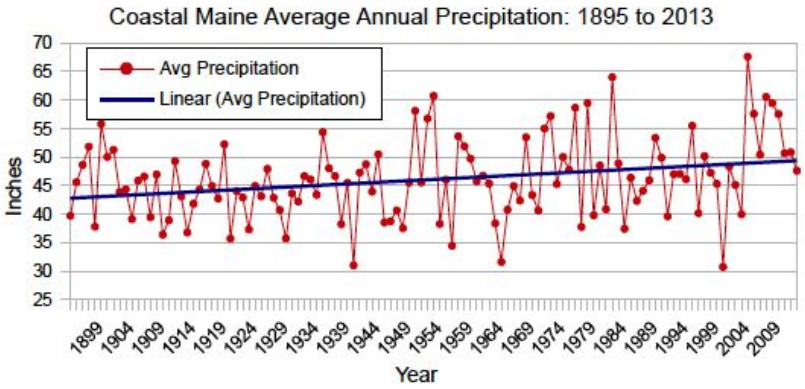


Coastal Maine Precipitation

- Coastal Maine ten-year average precipitation, 1895 to 1904: 46.9 in (Std Dev: 5.66)*

- Coastal Maine ten-year average precipitation, 2004 to 2013: 54.2 in (Std Dev: 7.85)*

- Change: +7.3 in



* Standard deviation (Std Dev) is a measure of variability.

National Climatic Data Center, National Oceanic and Atmospheric Administration. 2014. "Climate at a Glance | Time Series." http://www.ncdc.noaa.gov/cag/. (Note that farmers and water resource managers can use this site to look at monthly and seasonal trends related specifically to their work.)

Climate versus Weather

If you don't like the weather in New England, wait a minute.

- A droll Yankee one-liner, source unknown

It's important to know the difference between climate and weather. According to Merriam-Webster, weather is "the state of the air and atmosphere at a particular time and place" [1]. Weather refers to conditions locally in the short-term; it's changing all the time and may be

different in two nearby places. The sun may be shining in Calais on Tuesday morning, while it rains in Machias. By afternoon, it could be snowing all over Washington County.

Climate is "the average course or condition of the weather at a place usually over a period of years as exhibited by temperature, wind velocity, and precipitation"[2]. When we refer to climate change, we're talking about the average conditions over a long period of time and over a wide area. So, if we record the temperature and precipitation in Calais and Machias every day for several years and average all the readings together, we'll get an idea about the climate of the region. The graphs showing local temperature and precipitation trends show that Maine's climate has been changing steadily over the past century. Not only has the climate gotten warmer and wetter on average (indicated on each graph by the straight blue line), it has also become more variable with higher highs and lower lows (indicated by the red line). It's tempting to think that a stretch of extremely cold weather indicates that the warming trend is over, but unfortunately, that's not the case. The overall climate trends have persisted over many decades and are likely to continue for the foreseeable future.

Changes in climate affect weather patterns. So, as our climate becomes warmer and wetter, we are seeing more precipitation, on average, and more of that precipitation is falling as rain. As our climate becomes more variable, we are seeing more weather extremes with and more frequent stormy weather, as well as very dry years followed by very wet years. For example, in 2000, 31 inches of precipitation fell on Downeast Maine, and just four years later in 2004, we had more than twice that amount, a greater difference than in any other time on record for the region.

Extreme weather events are becoming more common, but it's impossible to predict in detail when and how a storm will affect the region. However, for this report we've identified storm scenarios that are realistic and likely to happen with increasing frequency and severity here in the coming years. It may be interesting to consider the potential devastation of a category 4 hurricane in Maine, but such a storm is extremely unlikely to occur in the foreseeable future. So, we provide maps showing such scenarios but don't discuss them seriously.

We've based these assessments on the best available science and have used mid-range estimates of sea level rise and temperature. Wherever possible, we try to give a general idea of the likelihood of each scenario. One important thing to remember is that Maine's climate is not only warming, the weather is also becoming more variable as a result of the warming climate. That makes it even more difficult to predict how any given storm will affect the region. So, remember that the scenarios and problems discussed in this report may vary from year to year.

Sources Cited:

[1] "Weather." Merriam-Webster.com. Accessed March 30, 2014. http://www.merriam-webster.com/dictionary/weather.
[2] "Climate." Merriam-Webster.com. Accessed March 30, 2014. http://www.merriam-webster.com/dictionary/climate.

Adaptation versus Mitigation

When people talk about responding to climate change, they often refer to some strategies as mitigation and others as adaptation.

Adaptation refers to activities that *reduce the problems caused* by climate change. Examples of adaptation strategies might include raising and reinforcing piers to withstand storms and sea level rise or cultivating heat-tolerant crops.

Mitigation refers to activities that *reduce the causes* of climate change. This might involve reducing carbon dioxide emissions by reducing energy consumption or conserving forests to maintain carbon in the biomass of the trees.

Both adaptation and mitigation are important, but this report focuses specifically on supporting climate adaptation in Downeast communities. Mitigation is typically addressed with regional or national policies, or through the actions of individuals conserving energy.

The effects of climate change are felt locally, however, and many adaptations are best applied at the local level.

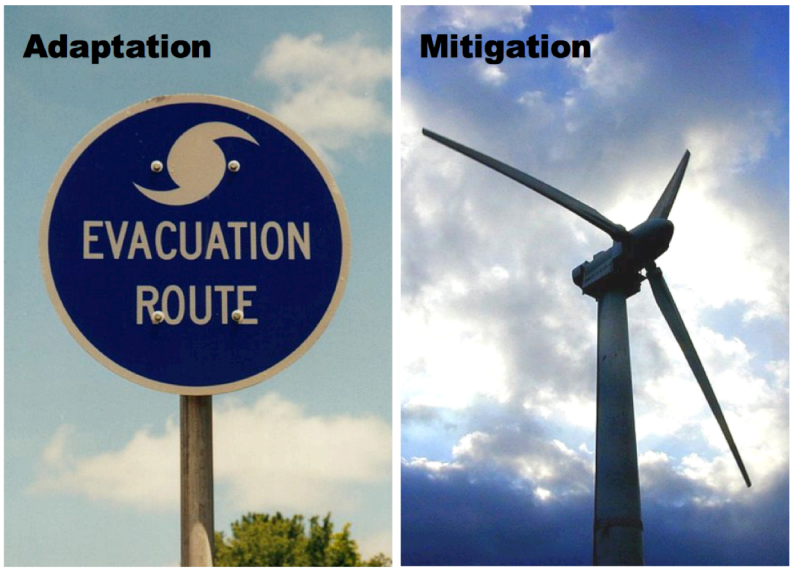


Figure 2: Adaptation involves responding to the problems caused by climate change, for instance, planning for stronger and more frequent storms. Mitigation addresses the causes of climate change, typically by reducing carbon dioxide emissions from fossil fuels.

Evacuation sign image by Wusel007 (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

Wind turbine image by Harvey McDaniel from Naalehu, HI (South Point_Wind Farm 5_Aug_1_02) [CC-BY-2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons

Tropical and Winter Storms

Maine is already experiencing an increase in the frequency and strength of severe weather events, and this trend will continue as the climate warms. The most dangerous and costly of these weather events are powerful tropical storms such as hurricanes and strong winter storms. The atmospheric processes that produce tropical storms and winter storms are different, but they have many things in common. Warm ocean waters can increase the strength of all types of storms as they pass over the Atlantic. Winter storms over the ocean can also form cyclonic, spiral wind patterns like those of tropical storms. Impacts of major storms can include:

- Coastal flooding from storm surges
- Inland flooding of rivers and streams with rain events
- Coastal and inland erosion of shorelines, building foundations, and coastal and riverside infrastructure
- Salt damage to trees, crops and structures from sea spray carried inland by winds
- Isolation of vulnerable and/or remote residents due to flooded and damaged roads and bridges
- Wind damage to structures, forests, and infrastructure
- Power and utility outages

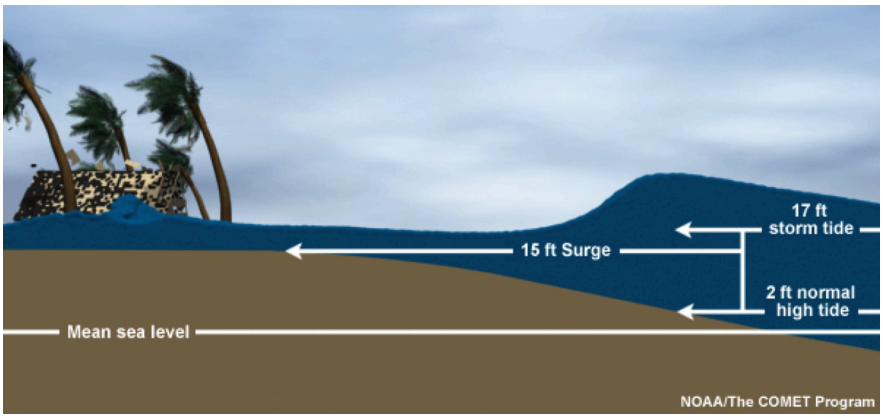


Figure 3: According to the National Weather service, a storm surge is *"an abnormal rise of water generated by a storm, over and above the predicted astronomical tides."*[1] Illustration from the National Weather Service's Storm Surge Overview page: http://www.nhc.noaa.gov/surge/

Effects of powerful storms vary depending on the shape of land and waterways, the direction and speed of the wind, and the timing of the storm relative to tidal height. An important factor is the height of the storm surge from an oceanic storm as it makes landfall.

Storm Surge

A storm surge is an abnormal increase in the height of water above the normal tidal height.[1] The storm surge and the tidal height together form the storm tide. Storm surges can occur with any strong storm, but they are particularly common in tropical cyclones or hurricanes. Storm surges cause coastal flooding and erosion, and they are responsible for most of the deaths inflicted by hurricanes. They carry storm waves inland with them, adding to the damage.

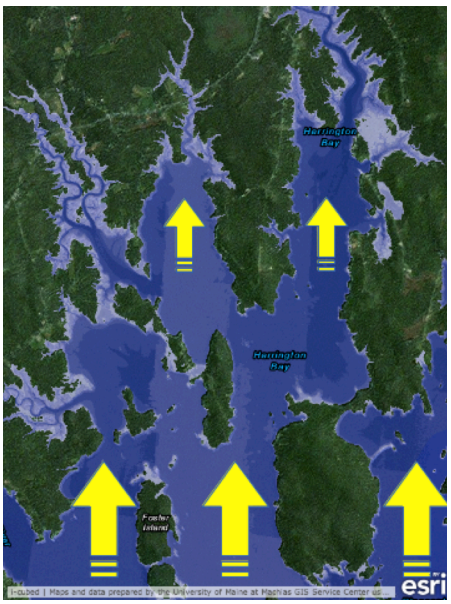


Figure 4: Strong onshore winds can drive a storm surge deep into the head of a narrow bay.

The size and severity of a storm surge depends on a combination of factors, but tidal height, speed and direction of the wind, direction of the storm's path, and the shape of the land are the primary factors. The low pressure at the eye of the cyclone contributes about five percent of the height of a storm surge. When

a storm surge comes ashore driven by the wind, the surge runs upslope like water sloshing at the end of a bathtub. Because of this run-up effect, surge heights are greater at the head of a bay, particularly if the bay is narrow and funnels the water as it surges in. Downeast Maine has many long narrow bays running roughly north/south, and storm surges are greatest at the heads of these bays with a southerly wind. Coastal wetlands and forests can absorb some of the energy of a storm surge and its accompanying waves, softening the blow to roads and structures.

Since wind direction is so crucial in determining storm surge height, it's helpful to know how winds vary in storms. Figure 6 shows a satellite image of Hurricane Irene as the storm made landfall in 2011. Hurricane winds are caused when air rushes in from the area surrounding the storm toward the extreme low pressure at the center.

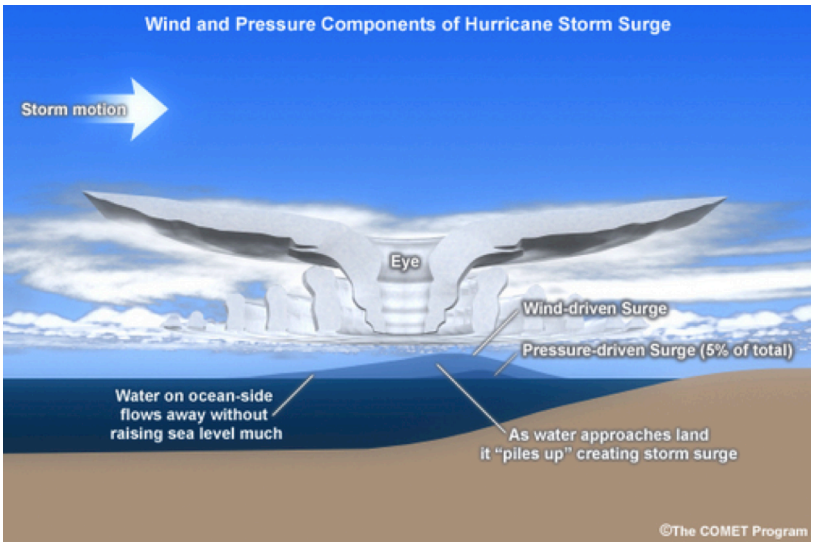


Figure 5: Powerful storm winds drive water toward land where it "piles up" as it approaches the shore. Surges that come ashore at high tide are most dangerous.[1] Illustration from the National Weather Service's Storm Surge Overview page: http://www.nhc.noaa.gov/surge/

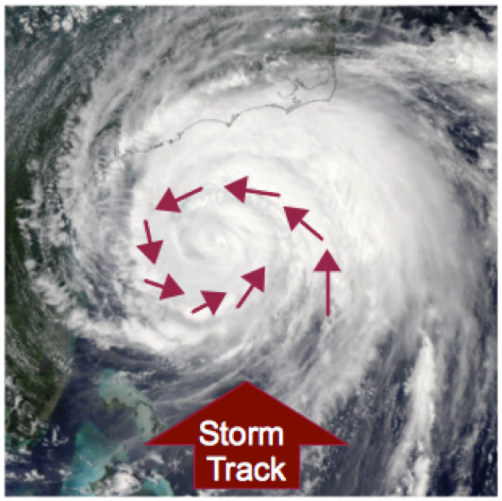


Figure 6: Hurricane Irene wind directions. Note that the most dangerous sector of the storm is to the east of the eye where wind speeds are increased by the forward momentum of the storm and winds blow storm surges up the south-facing bays of Maine. A day later, Irene, a category 2 hurricane, would dump 11 inches of rain on Vermont in a single day.

NASA image acquired August 27, 2011, courtesy Jeff Schmaltz, MODIS Rapid Response, NASA Goddard Space Flight Center. Caption by Michon Scott.

The winds spiral in toward the eye due to the rotation of the earth like water spiraling down a drain. Winds are strongest close to the eye and to the east of the eye where the storm's forward momentum adds to the wind's speed.

For Downeast Maine, the most dangerous sector of the storm is to the east of the eye where winds blow hardest and from the south, driving storm surges northward, deep into our narrow, north/south bays and estuaries.

To create this assessment, we developed storm surge prediction maps for all coastal areas of Washington County. To make the maps, we used data created by the National Weather Service's (NWS) Sea, Lake, and Overland Surges from Hurricanes (SLOSH) Model maximum envelope of water predictions for storm surges. NWS created these predictions from a computer model of a fictitious hurricane assembled from measured storm tracks and tide gauge data for historic storms. The track of the modeled storm would make landfall over Penobscot Bay to the east of Washington County. While the modeled storm itself is fictitious, it

follows a track recorded in prior storms.

The model estimates storm surges for mean and high tide landfall for hurricane categories 1 through 4. As a test of the SLOSH model's accuracy, NWS scientists have run the model for several storms and have compared the predictions with actual storm surge measurements. Based on these and other tests, NWS scientists estimate that the surge height predictions from the SLOSH model are accurate to within +/-20% for storms that follow the track and force patterns of the model.[2]

We combined the SLOSH model predictions with highly precise lidar elevation measurements to map predicted storm surge flooding. Lidar stands for “light detection and ranging.” It is a new, high tech method of mapping elevation precisely from an airplane using lasers. Using lidar data, we could map not only the ground elevation, but also the heights of trees and buildings to create a highly accurate three-dimensional model of the landscape. Then, using SLOSH surge height predictions, we could make precise maps of predicted storm surge flooding.

We did not use Federal Emergency Management Agency (FEMA) floodplain maps to develop the storm surge prediction scenarios. The old FEMA floodplain maps are highly unreliable and are not as fine-scale as the maps we produced using lidar data. New FEMA maps will be released in 2014 for Washington County but they weren't available for this project. Once they are released we will review them to determine if they are accurate enough for use in our storm surge scenarios.

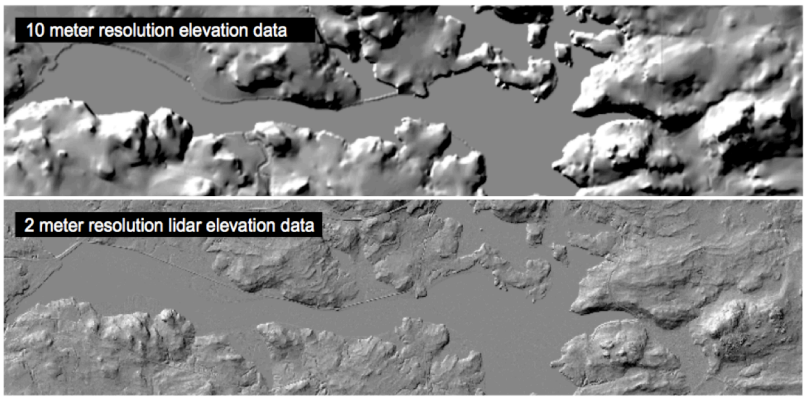


Figure 7: Newly available, high-precision lidar (light detection and ranging) data allowed more detailed mapping of flood predictions. Lidar uses lasers to map elevations, yielding more detailed, higher resolution elevation maps.

Lidar data was provided by the Maine Office of GIS; 10 meter elevation date was provided by the US Geological Survey's National Elevation Dataset

Key results are included here for your reference, but PDF maps and interactive online maps are also available. These are publicly accessible, easy to use, and may be used with other mapped information, as needed, for a variety of planning tasks. Visit this address to access the maps: http://gro-wa.org/washington-county-climate-change-response.htm#OnLineMaps.

It's important to note that the SLOSH model predictions are a worst-case scenario for Washington County. The modeled storm places the Downeast region in the most dangerous sector as the storm makes landfall. As a result, the predicted winds in the modeled storm would be blowing from the south, producing higher storm surges, especially at the heads of bays and harbors, than we would experience with a storm on another track. The predicted storm surges are also the maximums for each scenario, rather than the average or minimum. The chances that any given storm would produce those conditions are very slim, and it's impossible to predict when or how often such a scenario could occur. Such a scenario is, in fact, very plausible; remember that the SLOSH model is based on measurements from several real storms. And as the climate continues to warm, the likelihood of a storm producing those specific conditions will rise. It's reasonable to expect that we will experience a storm similar to this in the coming decades with increasing likelihood as time goes by.

While we did develop prediction maps for category 3 and 4 hurricanes, we believe a storm of that magnitude, while plausible, is very unlikely to occur under current climatic conditions. A category 1 or 2 hurricane is a greater possibility. Hurricanes of that magnitude have reached northern New England. In fact, Hurricane Irene was a category 2 storm when it struck New England and dumped 11 inches of rain on Vermont in a single day in 2011. So, we provide maps here for category 2 - high and median tide scenarios as they represent the most plausible but dangerous scenario. However, you can access the other scenarios on the GROWashington-Aroostook website (http://gro-wa.org/washington-county-climate-change-response.htm#OnLineMaps.).

Adaptation Options for Tropical and Winter Storms

There's a lot you can do to reduce your community's vulnerability to storm surge inundation. The following is a list if ideas to consider. The list was compiled from discussions at meetings with municipal and county officials here in Washington County, as well as reports about activities in other parts of the country where people are grappling with similar issues. Some items may not apply to your community. Note that many of these items can apply to any severe weather event.

Near term:

- Plan evacuation and emergency routes that avoid flooded roads, be ready to block flooded roads during a flood event, and plan to assess road safety as soon as floodwaters recede.
- Create a plan to place fire and rescue trucks and personnel strategically prior to a storm to make sure they are safe from floods and that all areas of town are reachable during a flood event.
- Educate residents about the dangers of driving over flooded or damaged roads.
- Arrange for storm shelters that are safe from potential floodwaters and accessible to residents throughout the region.
- Map the locations of housebound and elderly residents, nursing homes, assisted living facilities, etc., especially those who might be cut off by flooded roads. Plan to evacuate them or check on them during storm events. Remember, some medical equipment may rely on continuous power. Make sure to keep the locations of vulnerable residents confidential. The UMM GIS lab can help to create secure maps for emergency personnel.
- Coordinate with snowmobile and all terrain vehicle clubs and users to assess volunteer capacity to reach housebound residents who may be cut off due to flooded roads. Add map layers of all terrain vehicles and snowmobile trails to CVA maps.
- Make sure fuel storage tanks in flood-prone areas are built to withstand flooding.
- Coordinate with county EMC to track and assess storms as they approach the region. This will allow more specific estimates of storm surge height, wind speed and direction, and the timing of the storm's landfall.
- Maintain existing wetlands and floodplains by enforcing current regulations
- Identify and assess vulnerable infrastructure such as piers; boat ramps; wastewater and water supply; and transportation, particularly culvert sizes and, at “pinch points” where a flooded road causes a large area to be cut off, the vulnerability of the road substructure to complete failure.
- Determine emergency procedures in case critical facilities are flooded.
- It may be necessary to haul out a large number of boats, remove floating docks, and

shift or protect marine gear before a storm. Create a plan and make any necessary modifications to waterfront infrastructure. Make sure fishermen, recreational boaters and marine business owners have input, are aware of the plan, and are willing to help.

Long-term

- Set priorities for infrastructure improvement and seek grant or loan funding to help address vulnerabilities.
- Create ordinances that limit or discourage building in flood-prone areas. In particular, prevent destruction of wetlands and coastal forests that serve as buffers against surging waters. One option to address existing development in flood-prone areas is to grandfather existing structures but forbid rebuilding if the structure is destroyed by flood.
- Implement construction codes for coastal properties to require flood-modifications. These can apply to existing structures or only to new or newly-modified structures.

Resources:

National Weather Service page on hurricane storm surges, includes animations and maps of storm surges from major hurricanes: http://www.nhc.noaa.gov/surge/

National Weather Service storm surge animation showing run-up on a gradual slope (may take a long time to load): http://www.nhc.noaa.gov/surge/animations/surgea.swf

National Weather Service Saffir-Simpson Hurricane Wind Scale page, including descriptions of each storm category and an animation: http://www.nhc.noaa.gov/aboutsshws.php

Short National Geographic video, “Hurricane Surge.”
http://channel.nationalgeographic.com/channel/videos/hurricane-surge/

YouTube video of Hurricane Irene in 2011. Note that the jet stream keeps the storm over the Gulf Stream where it gains energy and strafes the eastern seaboard then plows ashore over New England: http://youtu.be/owtMg4pVmiM

Sources Cited:

[1] Storm Surge Overview. (2013, June 3). *National Weather Service National Hurricane Center*. Retrieved December 12, 2013, from http://www.nhc.noaa.gov/surge/

[2] Sea, Lake, and Overland Surges from Hurricanes (SLOSH). (2013, June 2). *National Weather Service National Hurricane Center*. Retrieved December 12, 2013, from http://www.nhc.noaa.gov/surge/slosh.php

Sea Level Rise

Mean sea level in Maine is currently rising about two millimeters per year due to melting glaciers and polar ice caps, thermal expansion of ocean waters, and slight subsidence of the coastal plane.[1] So far, this rise is perceptible only by careful, repeated measurements over time, though the rate is accelerating. Climate models predict sea level will continue to rise between six inches and six feet by 2100, an extremely wide range. The lowest estimates are widely regarded as much too low, however, and measurements in recent years show sea level is actually rising much faster than the lowest estimates. Scientists say the mid-range estimates are most likely, so we have developed scenarios for this report based on an estimated sea level rise of three feet by 2100. [2]

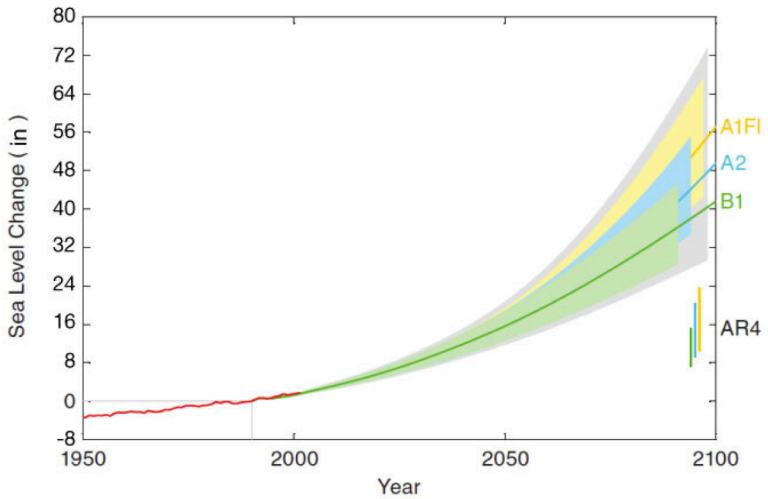


Figure 8: Predicted sea level rise based on three different emissions scenarios. The width of the colored cones indicate variability among different climate models. The AR4 estimates are UN estimates that ignore several key factors and are widely regarded as too low. The red line indicates observed sea level.

Adapted by EPA from Vermeer, M. and S. Rahmstorf. 2009. "Global sea level linked to global temperature." Physical Sciences - Sustainability Science:106 (51) 21527-21532, doi:10.1073/pnas.0907765106

The primary effect of sea level rise in the near term will be to add to the levels of storm surges and highest annual tides. During storms and very high astronomical tides, the water will move farther inland, causing erosion in wetlands and floodplains and flooding areas that were previously beyond the reach of floods.

For large areas along the Downeast Coast, the bold, hard shore will be largely unaffected by sea level rise in the near term. However, low-lying town centers built on flat ground along bays and estuaries will see increasing flood damage to buildings and infrastructure and erosion of roads and wetlands.

Adaptation Options for Sea Level Rise

Resilience over the long term is possible when coastal communities combine long-term adaptation strategies for storm surge with a variety of sea level rise estimates:

- When making infrastructure improvements, examine a range of sea level rise estimates and make a deliberate choice of which one you will use for design consideration to avoid reconstruction as seas rise.
- Ordinances that limit or discourage building in flood-prone areas can help to move development away from locations vulnerable to sea level rise. Again, one option to address existing development in flood-prone areas is to grandfather existing structures but to severely limit expansion and to forbid rebuilding if the structure is destroyed by flood.
- In making decisions about shoreland zoning, remember wetlands and coastal forests that serve as buffers against surging waters may need room to migrate upslope as

waters rise.

- Consider sea level rise when implementing new construction codes for coastal properties to require flood-modifications. These can apply to existing structures or only to new or newly-modified structures.

Resources:

Town of York, Maine, Comprehensive Plan on Adaptation to Sea Level Rise, includes a comprehensive discussion of the scenarios and decision-making processes used in developing the plan:
http://www.yorkmaine.org/Portals/0/docs/ADAPTATION%20TO%20SEA%20LEVEL%20RISE%202013_11_05.pdf

Sources Cited:

[1] Jacobson, George L., Fernandez, Ivan J., Mayewski, Paul A., and Schmitt, Catherine V., ed. 2009. *Maine's Climate Future: An Initial Assessment*. Orono, Maine: University of Maine. http://www.climatechange.umaine.edu/mainesclimatefuture/.

[2] Vermeer, M. and S. Rahmstorf (as cited by US Environmental Protection Agency). 2009. "Global sea level linked to global temperature." Physical Sciences - Sustainability Science:106 (51) 21527-21532, doi:10.1073/pnas.0907765106

Inland Flooding of Roads and Transportation Infrastructure

Climate change is increasing the likelihood of all types of flooding from storm surges, heavy rains, sudden thawing of snow pack, and ice jams. In our discussions about climate change with people across Washington County, they often expressed concern about inland flooding of roads, bridges and other transportation infrastructure. With aging roads and increasing precipitation, flooding and undermining of roadways is becoming a persistent problem throughout the county.

Impervious surfaces like asphalt roads and parking lots in the watershed allow run-off to gain momentum as it rushes downhill, increasing scour and erosion. Run-off over impervious surfaces also carries silt and pollutants with it into streams and rivers. On the other hand, vegetated areas in the watershed such as fields, forests and wetlands slow run-off and allow it to seep into the ground, minimizing scour and erosion and filtering out silt and pollutants.

While the scenario mapping depicts potential flooding from storm surge, it is important to note that storm surges and torrential rainwater can conspire in a storm event to increase the extent and duration of floods in the coastal region. If significant rain falls in a coastal watershed during a hurricane or major winter storm, floods can be prolonged by run-off after the storm surge recedes.

Unfortunately, mapping inland flood risk was beyond the scope of this project, and new FEMA floodplain maps were not yet available for Washington County. So, we plan to address the need for better flood risk mapping in the future.

In the meantime, we have heard from many municipal and county officials that certain roads flood or wash out consistently due to inadequate or degraded culverts. Few towns have mapped and inventoried their culverts, and many of these inventories are in paper (non-digital) format). To help assess and prioritize work on culverts, we have developed an online countywide culvert inventory and mapping tool for use by all transportation officials. In the coming year and as funding allows, we will work with local officials to add culverts to the inventory.

Since large, open bottom culverts are best for fish passage and flood prevention, transportation officials and fish biologists have a common purpose. In recent years, millions of dollars have been spent mapping and improving hundreds of culverts in Washington County watersheds to allow endangered salmon to move freely from ocean to stream. This work has the added benefit of improving flow and preventing floods. In the coming year, we will work with fish biologists and transportation officials to add culverts to the inventory.

Use of the culvert inventory is limited to public officials. To gain access to the inventory tool, contact Tora Johnson at the UMM GIS Service Center at tjohnson@maine.edu.

Adaptation Options for Road & Transportation

Improving transportation infrastructure can be expensive and challenging. So, mapping and assessing vulnerable areas is an important step that allows municipalities to prioritize and address major problems first and lesser problems later.

State and federal loans and grants are often available to help with infrastructure improvement, and the results of this report, as well as maps and inventories, can be important additions to a grant or loan proposal. Consult with planners at WCCOG for help in identifying funding opportunities. Some adaptation options include:

- Inventory and assess transportation infrastructure/ culverts and add them to the online culvert inventory. This will allow you to view the culverts over aerial photos, terrain, and other data to help in planning. UMM GIS students may be able to volunteer with transportation officials to help with this effort.
- Prioritize and improve problematic culverts beginning with the most vulnerable. Grant or loan funding may be available to help improve culverts.
- Coordinate culvert replacement and upgrades with neighboring municipalities and regional maintenance offices of the Maine Department of Transportation to avoid relocating flood problems to other parts of the watershed.
- Improve flow under causeways and through tide gates to increase capacity and ensure water doesn't get backed up behind the causeway.
- Keep salt and sand piles above flood prone areas.
- Improve storm water capacity in developed areas.
- Encourage on-site infiltration of storm water using low impact design techniques such as green swales, landscaping and velocity reduction techniques.

Climate and Public Health

Changing climate will have a variety of effects on public health, many relevant to our region. As with most health problems, the elderly, poor and infirm will be disproportionately affected.[1]

Heat-related illnesses

With an increasing number of summer days with temperatures in the 90s, heat-related illnesses such as heat stroke and dehydration will become more common. The elderly are less able to regulate their body temperature, and so are more susceptible to heat stroke than younger people.[2] In a region accustomed to cool summers, many elderly homeowners and residents of nursing homes will be without air conditioning during heat emergencies.

Also, small children (and pets!) can die or suffer severe brain damage if they are left in a hot car.[3] Again, in a region used to cool summers, it will be important remind parents, caregivers and pet owners of the dangers of leaving children or pets in vehicles on warm days.

Pest-borne illnesses

The warming climate has been a boon for ticks in Maine. Winters are no longer cold enough to kill off the deer ticks that carry Lyme disease. So, the stubborn, tick-borne bacterial infection has made its way Downeast. So far, only a handful of people have contracted Lyme disease in Washington County, but public health officials warn that it is making in-roads to the east and north. The number of cases is expected to continue rising. [4, 5] Other diseases carried by deer ticks, including anaplasmosis and Powassan encephalitis, have appeared in Maine in recent years as well and are expected to make their way north and east as the climate warms.

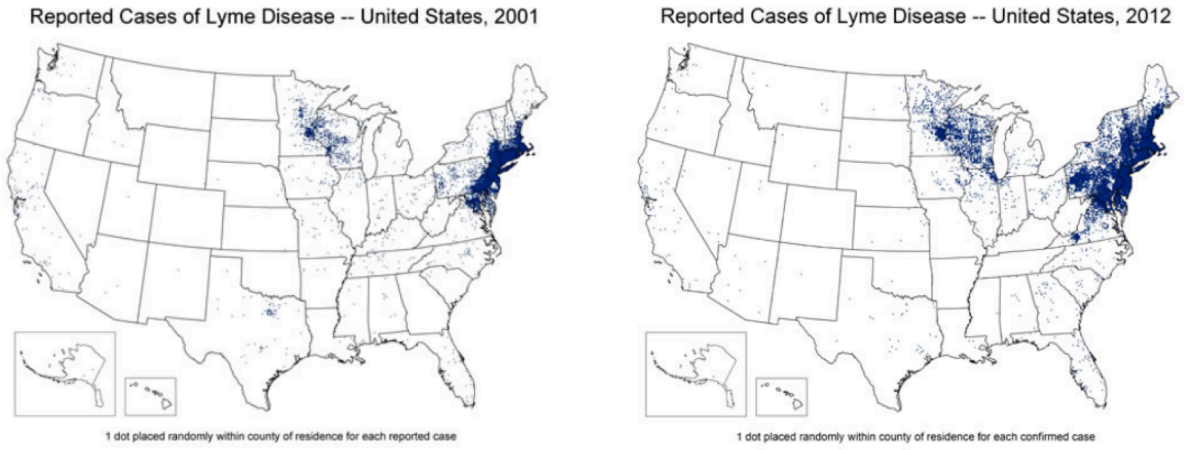


Figure 9: As the climate warms, deer ticks that carry Lyme disease survive in more northern areas, including Downeast Maine. Note that Maine saw only a handful of cases in 2001. In that period, the incidence of the disease in Maine grew five-fold with over 1,000 reported cases in 2012.

Maps from Centers for Disease Control and Prevention Lyme Disease Data page: http://www.cdc.gov/lyme/stats/index.html

As climate continues to warm, mosquito-borne illnesses are expected to expand their ranges too.[1] Eastern equine encephalitis and West Nile virus, both mosquito-borne illnesses, are now resident in Maine, though no humans have yet contracted the disease in Washington County. State public health officials are monitoring mosquitoes in Maine for signs of other mosquito-borne illnesses such as malaria and dengue fever, usually associated with more tropical

regions.[6]

Waterborne illnesses and paralytic shellfish poisoning:

Scientists at UMM and the Maine Department of Marine Resources monitor waters for signs of bacterial contamination and the organisms that cause red tide. Each summer, area shellfish beds are closed due to bacterial or red tide contamination. Warming waters and increased run-off from precipitation exacerbate both problems.

A "red tide" is a bloom of harmful algae, typically a single-celled dinoflagellate in the genus *Alexandrium* that produces a neurotoxic compound. The term red tide refers to the reddish tint in the water when these algae are abundant, though they are often present in harmful numbers without making a detectable change in water color. When these algae are present in large numbers, called a harmful algal bloom, filter-feeding shellfish accumulate the neurotoxin. People who eat the shellfish may develop numbness, tingling, and other neurological symptoms. Severe cases can cause paralysis of the respiratory system.

Alexandrium is normally present in the water column in low numbers, but resting cysts can lie dormant in the sediment for years at a time. When the cysts are exposed to warm temperatures, nutrients and light, they emerge from the cysts to swim in the water column and reproduce. If warm temperatures persist, they will reproduce rapidly, causing a harmful bloom.[7] As average water temperatures rise due to climate change, conditions are increasingly favorable for these harmful algae. Blooms are now more frequent, prompting state officials to close shellfish beds more often. Nutrients from run-off and faulty septic systems can help feed the bloom. In the past two years, scientists at UMM have observed a new, even more harmful single-celled alga in the waters of Washington County. They suspect the newcomer is expanding its range north, taking advantage of warmer waters.

State officials also close shellfish beds because of bacterial contamination from wastewater or sewage treatment plants, poorly maintained septic systems, marinas, and run-off from major rainfall events. They monitor shellfish and waterways for bacteria typically found in human and animal waste. While these bacteria themselves are rarely harmful, they are indicators that human or animal waste is making its way into the water, potentially bringing more harmful organisms with it.[8] Increased precipitation due to climate change can overwhelm wastewater treatment facilities and carry run-off from aging septic systems. Also, major storms can damage treatment facilities, causing contaminated water to leak into waterways.

Storm-related public health issues

More frequent and stronger storms can lead to health problems among Washington County residents. Of course, major storms can be very dangerous, causing car accidents, drowning due to floods, and other storm-related injuries. More insidious is the threat to isolated residents. When a storm surge or inland flood overtops area roadways, people in outlying areas may be cut off from help by floodwaters without power, water, food and access to medicines or medical care.

According to Vermont Secretary of Natural Resources Deborah Markowitz[9], the most significant public health issue faced by Vermont residents during the recovery period after the devastating floods caused by Hurricane Irene was mental health. She noted that for those who owned property and had reliable employment the impacts were extremely difficult. However for those with low incomes and limited resources it was devastating. Vermont Commissioner of Housing

and Economic Development Noelle MacKay[10] also observed that those municipalities with hazard mitigation plans were far better equipped to respond to immediate community needs than those who did not. She specifically cited provision of childcare facilities and playgroups so that adults could clean, grieve and pick up the pieces while their children were occupied and sheltered in safe surroundings.

Adaptation Options for Public Health

Here are some options to address climate-related public health issues:

- Plan for heat emergencies by establishing cooling shelters and making sure first responders are ready to address heat stroke and heat exhaustion.
- Educate the public about the dangers of heat stroke among the elderly and of leaving small children and pets in vehicles.
- Educate the public about how to avoid pest-borne and waterborne illnesses such as Lyme disease and harmful algae blooms.
- Map vulnerable populations and incorporate them into disaster planning and emergency response protocols.
- Assist elders and the poor in purchasing air conditioners and other means of keeping cool during heat emergencies.
- Maintain and/or upgrade septic and wastewater treatment facilities to keep bacterial contamination to a minimum.
- Plan for immediate post-disaster sheltering of children in safe environments to allow parents to deal with clean up needs
- Engage the mental health community in grief counseling and referrals to help residents in re-establishing normality in daily life.

Resources:

Centers for Disease Control and Prevention Climate and Health Program:
http://www.cdc.gov/climateandhealth/

Maine Department of Marine Resources Public Health- Shellfish Program:
http://www.maine.gov/dmr/rm/public_health/index.htm

Sources Cited:

[1] US Centers for Disease Control and Prevention. 2014. “Climate and Health Program.” http://www.cdc.gov/climateandhealth/

[2] National Institutes of Health. 2014. “Hyperthermia: Too hot for your health.” http://www.nih.gov/news/health/jun2012/nia-27.htm

[3] National Highway Traffic Safety Administration. “Heatstroke: Keeping Kids Safe: Inside and Out.” http://www.nhtsa.gov/safety/hyperthermia

[4] Maine Center for Disease Control and Prevention. 2013. “Report to the Maine Legislature: Lyme Disease, 2013.” Department of Health and Human Services. http://www.maine.gov/dhhs/mecdc/infectious-disease/epi/vector-borne/lyme/documents/2013-lyme-legislature.pdf

[5] US Centers for Disease Control and Prevention. 2014. "Lyme Disease Data." http://www.cdc.gov/lyme/stats/index.html?s_cid=cs_281

[6] Maine Center for Disease Control and Prevention. 2013. "Infectious Disease Epidemiology Program: Vector-Borne Diseases." http://www.maine.gov/dhhs/mecdc/infectious-disease/epi/vector-borne/index.shtml

[7] Maine Department of Marine Resources. 2014. "Red Tide in Maine." http://www.maine.gov/dmr/rm/public_health/redtide.htm

[8] US Environmental Protection Agency. 2014. "5.11 Fecal Bacteria." http://water.epa.gov/type/rsl/monitoring/vms511.cfm

[9] Plenary Panel; Local Solutions: Northeast Climate Change Preparedness Conference; May 19-21, 2014 Manchester New Hampshire.

[10] Panel presentation to Northeast Climate Solutions Conference, Amherst, Massachusetts; January 11, 2013.

Climate Change and Fisheries

More than 2,000 people—one in every 16 residents—in Washington County make some or all of their living as a harvester of fish, shellfish and other marine resources. Many more indirectly depend on fisheries to support families and businesses. Lobster landings in Washington County commanded $61.6 million in 2013,,17% of all lobster landings and 12% of all fisheries landings in Maine[1]. In some towns, lobster landings comprise the majority of the local economic activity.

Clams are the second most valuable wild marine resource in Maine, behind lobsters. Over 600 people, or 40% of shellfish harvesters in Maine, derive income from clamming in Washington and Hancock counties, according to the Maine Department of Marine Resources (DMR)[1]. In 2011 the value of clam landings in Washington County exceeded $3.2 million dollars.

While the elver fishery is relatively new as a high earning fishery in Maine, statewide in 2013 it was worth nearly $33 million[1]. DMR has not released elver landing data by county, but the fishery added significantly to the incomes of many fishermen in Washington County.

How are fisheries being affected by climate change?

Climate change is already affecting local fisheries in a variety of ways, as many Maine fishermen can attest. Most of these changes are negative, causing problems with the resource or making it harder to harvest. Other changes are positive, at least in the short term.

Here are the primary negative impacts relevant to Washington County fishermen:

- Ocean acidification makes it harder for animals to grow and maintain shells.
- Warmer waters provide better habitat for the organisms that cause red tides, leading to longer and more frequent blooms.
- Animals and plants shift their ranges to the north in response to warming water and change their seasonal movements as season transitions shift.
- Food webs are changing as the distribution of prey species shifts along with changes in the timing of their reproductive cycles.
- Lobster shell disease has made its way into southern Maine and may continue to move north.
- Introduced species such as green crabs and Asian shore crabs are expanding their ranges and may be helped by warming waters.
- Storms are becoming stronger and more frequent, and sea level is rising slowly, threatening working waterfront infrastructure and boats owned by fishermen.
- Wetlands that serve as habitat for larval fish and shellfish as well as a filter for polluted run-off are vulnerable to erosion from storms and inundation from sea level rise.
- More precipitation means more run-off, which can carry harmful bacteria into bays and estuaries. This problem is exacerbated when wastewater treatment plants overflow or are damaged by strong storms.
- Fuel prices continue to rise as fossil fuel reserves become more scarce and the government implements incentives to promote conservation and limit carbon emissions.

The lobster fishery is currently healthy in Washington County though fishermen are seeing

some changes in the seasonal behavior of the lobsters. Scientists believe that as waters have warmed slightly, eastern Maine has become even more hospitable for lobsters. This and other factors, such as effective local management, have led to strong catches in recent years. However, fishermen here are financially strapped due to low prices for lobster and high costs for bait and fuel. With such heavy dependence on the lobster fishery and such narrow profit margins, any disruption in the system—decline in landings, increase in fuel or bait costs, damage to boats or infrastructure—could have serious consequences for the region. In the long term, local waters will continue to warm, and eventually some of the problems now worrying lobster fishermen in southern Maine will make their way Downeast.

Closure of shellfish areas due to red tides is becoming more frequent and extensive. Scientists at University of Maine at Machias can also recently found new and more toxic organisms, which they suspect is due to warming waters. Extra nutrients from run-off and wastewater (which also contains fecal coliform bacteria) feed blooms of red tides. Red tides and wastewater pose serious health threats, prompting state officials to close flats to commercial and subsistence harvesters. Clam flat closures severely impact local economies, with effects going far beyond the individuals who harvest clams on a full- or part-time basis. In fact, a week-long closure in August would eliminate $1.8 million in harvester sales and lead to a total economic loss of $2.9 million for Maine's economy (in 2006 dollar values), according to research prepared by Dr. Kevin Athearn of the University of Maine at Machias. Add to that introduced crabs preying on shellfish, and local clammers face a lot of uncertainty.

It's important to remember that some fisheries will likely decline as a result of these changes, though other opportunities may arise as new species become more common or move into the region. So the region is likely to see a series of economic and ecological changes in coming years. Scientists believe that warmer waters are behind the flourishing elver fishery, which is a plus side of climate change for Washington County. However, the increased abundance of the juvenile eels may be temporary as waters continue to warm.

Adaptation Options for Fisheries

Many fisheries management decisions are made by state and federal agencies. However, there are many things we can do locally to support fisheries in times of change. Ideas offered in the following discussion come from meetings with coastal communities in Washington County, as well as a report called “A Climate of Change.” In 2013, the Island Institute sponsored a workshop that brought together fishermen, scientists, government officials, and others concerned about the future of New England's fisheries in the face of climate change. You can read the report on the workshop here: http://www.islandinstitute.org/events/A-Climate-of-Change/15374/. While the workshop developed recommendations for New England fisheries generally, several insights are relevant to the local level.

As with other resource-dependent industries, we can expect change. Local adaptation options involve minimizing the impacts of change and supporting all who depend on the fishing industry as change occurs.

These are options available for adapting to changes in fisheries:

- Manage wastewater to minimize shellfish closures by keeping nutrients and fecal coliform out of the water. This includes improving municipal wastewater treatment, protecting facilities from storm damage, and enforcing and/or upgrading rules on septic systems. Grant and loan programs can help municipalities make these upgrades.
- Protect fish and shellfish nurseries and storm buffers by maintaining existing marine wetlands and preventing development in floodplains. WCCOG and UMM scientists can offer assistance in developing town ordinances and enforcement of state and federal regulations.
- Harvesters will need flexible regulatory frameworks that allow them to adapt to changes in natural resources and to take advantage of new opportunities as they arise. Cooperation among regional and municipal shellfish managers, zone councils, scientists, DMR officials and fishermen can lead to creative solutions.
- Expect change in the workforce and the economy, especially for fisheries-dependent communities. UMM, Penobscot East Resource Center, the Island Institute, the Downeast Institute for Applied Marine Research and Education and Maine Sea Grant are all engaged in efforts to help Downeast communities weather change and can offer help and collaboration.
- Cooperate with scientists in research on shifting species, changing habitats, economic and regulatory strategies, etc.
- Diversify within the fishery in response to anticipated threats by targeting different species and trying out new gear or fishing methods.
- Support additional activities that rely on the existing maritime skills such as aquaculture, whale watching or other tourism, and creative arts activities.
- Preserve and enhance the working waterfront with regular maintenance, affirmative easements that protect land and infrastructure that provides access,

Resources:

Video produced by the Island Institute: “A Climate of Change: Warming Waters in the Gulf of Maine” http://vimeo.com/78754353. Looks at the challenges facing the Maine lobster industry and current and future issues related to climate change.

Bangor Daily News story and video about lobster shell disease in Maine (August 2013): https://bangordailynews.com/2013/08/15/business/lobster-shell-disease-inching-into-gulf-of-maine/

Other Sources Cited:

[1] Maine Department of Marine Resources. 2014. “Recent Maine Commercial Marine Fisheries Landings.” http://www.maine.gov/dmr/commercialfishing/recentlandings.htm.

Preparing for Change in Washington County: Agriculture

According to the 2012 Census of Agriculture (released May 2014) by the United States Department of Agriculture (USDA) the number of farmers in Maine aged 34 and younger grew by nearly 40% in the five years between 2007 and 2012. This represents an increase from 396 to 551 young farmers. The USDA Survey of Agriculture also shows that the value of agricultural products in Maine increased by 24%, that a growing number of landowners list farming as their primary occupation, and the amount of land in farms has increased in the same time period.

In Washington County the value of cash receipts from the wild blueberry harvest exceeded $75 million in 2011 due largely to price increases (near doubling since 2009) as harvest volume remained relatively constant.

According to the 2012 Census of Agriculture the total number of farms in Washington County declined between 2007 and 2012 from 472 to 392 and the total number of acres farms also declined from 158,459 acres to 149,047 acres. The detail behind these numbers however tells a very different story. As described in the Table below, between 2007 and 2012 the number of farms, the land in farming, and the production of broilers increased substantially. [1,4] If the energy and attendance (over 135 people) at the March 8, 2014 Washington County Food Summit are any indication, the interest in farming and the productivity of farms in Washington County will continue to grow.

	2007 Census of Agriculture	2012 Census of Agriculture	% change
Total # of Farms	472	392	-16.95%
Total land in Farms	158,459	149,047	-5.94%
Beef (# of farms)	19	36	89.47%
Beef (acres)	73	161	120.55%
Vegetables (# of farms)	34	71	108.82%
Vegetables (acres)	54	104	92.59%
Layers (# of farms)	54	62	14.81%
Layers (acres)	1262	1350	6.97%
Broilers and other meat-type chickens (# of farms)	4	18	350.00%
Chickens (#)	145	61,075	42020.69%

Agriculture and the local food movement in general are gaining strength in Washington County. The current map of Local Food in Washington County (http://gro-wa.org/wcfood) lists 79 farms, and a survey is available for others to add themselves to the map (https://www.surveymokney.com/s/LocalFoodSystemMaine). In addition to the many long-established and large scale blueberry growers, there is a growing number of small scale producers of vegetables, hogs, chickens, beef and small fruit; some are certified organic and many practice no or minimal spray cultivation. Also Washington County is working toward improvements in its agricultural infrastructure with growing distribution networks and investments in processing and storage.

How is agriculture being affected by climate change?

Climate change is already affecting agriculture in a variety of ways. These effects are due in most part to an overall increase in temperature but also to increasing and highly variable amounts of precipitation As noted in the figure below, the USDA revised the plant hardiness zones map in recent years based on data from 5,000 national Climatic Data Center cooperative stations across the United States.[2]

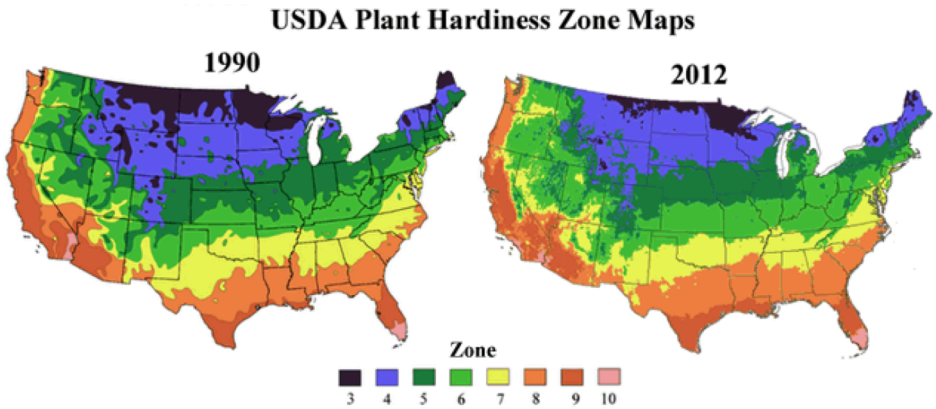


Figure 10: The US Department of Agriculture has revised their hardiness zones based on new climate data.

Map from USDA via Dr. Jeff Master's Weather Underground blog
http://www.wunderground.com/blog/JeffMasters/new-usda-plant-hardiness-zone-map-for-gardeners-shows-a-warming-climate

Most of these climate changes are negative, causing uncertainty with the resource or making it harder to harvest. Other changes are positive, at least in the short term.

Here are the primary negative impacts that are relevant to Washington County farmers:

- Cool season crops like potatoes are projected to see 25-35% declines in yield with projected temperature increases
- Some cool season grains could also see declining yields.
- Warmer winter temperatures can negatively influence perennial crops (forage grasses and legumes, tree fruits and wild blueberries) in a few ways:
  - Warm winter periods may de-acclimate the plants causing them to lose winter hardiness; subsequent cold weather increases can then cause injury or winter kill
  - Winter warming can also cause loss of consistent insulation from snowpack or ice sheet formation that increases winterkill
  - Warming in winter and during the growing season can also shift development events (bud break and flowering)
- Trends in the last several years show both increases and increasing variability in the amount and frequency of precipitation (see graphs on pages 5 and 6). Farmers must therefore plan for extremes in both drought and excessive rainfall.
  - Even if precipitation is uniformly distributed over the growing season less water will be available for plants because higher temperatures cause greater transpiration (from plants) and evaporation (from soil).

  - More frequent, high-intensity rainfall events, already occurring and predicted to worsen, are less effective at replenishing the soil or water table and more likely to cause erosion of vital agricultural soils.
  - Crops that complete development and set yield during the summer (like blueberries and potatoes) will experience severe impacts without irrigation
- Agricultural pests (insects, weeds, viruses and other pathogens) will worsen.
  - Higher temperatures increase development rates in insects that will affect plant-pest interactions in several ways. The Colorado potato beetle which completes one generation per season in Maine may complete multiple generations increasing crop damage and the cost (and environmental impacts) of pest control; warmer temperatures will allow new pests to arrive and survive like the blueberry gall midge, formerly a problem in New Jersey and now seen in Downeast Maine; pests that are migratory and sporadic could successfully overwinter such as aphids that arrive with storm fronts; finally the ranges of beneficial insect predators may also increase but it is more likely that new pests will be treated with more pesticides.
  - The spotted wing Drosophila, a fruit fly from China, Korea and Japan was accidentally introduced in California in 2008, first found in Maine in 2011 and by 2012 had spread throughout the Canadian Maritimes and Quebec. While its arrival is not a direct result of climate change, initial research indicates that some fly traps are more effective in cooler conditions and that the spotted wing Drosophila appears to be a mid to late season pest.[3]
- Prolonged periods of high temperature and high humidity reduce the productivity of semi-confined animals such as dairy cows; as the cumulative amount of heat stress increases these animals also experience reproductive problems and increases in the incidence and severity of infection.
- Feed stored in silos can spoil when exposed to heat and humidity and feed degrades rapidly in warmer temperatures.
- Higher winter temperatures and a greater proportion of rain to snow all result in muddier conditions which stress large animals and may also increase the populations of the organisms responsible for mastitis.

There are some opportunities associated with a warming climate for agriculture. Some crops will benefit from a warmer climate including tomatoes, pumpkins, warm season grasses like corn and hybrids that were formerly not viable in Maine. Climate change in California and the severe drought they are experiencing will, unfortunately for them, likely increase demand for products grown in New England. As energy prices continue to increase the cost of trucking food across the country Maine-grown products will become more attractive to regional markets in New England and New York – home to 71 million people.

Adaptation Options for Agriculture

- Plan for changing seasons, precipitation patterns, and pests. While some crops will no longer be viable or profitable, new crops can take their place. Explore new crops and varieties.
- Raised mound row cropping for vegetable production will allow soils to dry out early in the growing season and from heavy rain events thereafter; heavy mulching will also protect

raised mounds from drying out in extreme summer heat.
- Provide shade and ventilation for livestock in areas that provide water but are not directly within stream/river and lakeside shorelines.
- Explore ways of capturing rainwater (cisterns, barrels, ponds) to withstand extremes of drought and heat.
- Farms that grow diverse varieties are often more resilient to weather variations. If one crop or variety fails, others may survive.
- Keep abreast of news about pests and plan to fight them. Cooperative Extension and the Maine Organic Farmers and Gardeners Association can help in identifying pests and devising strategies to fight them.
- Support a diverse local food economy that allows farmers to be adaptable and resilient. Try new foods!

Resources:

Maine's Climate Future: An Initial Assessment. Orono, Maine: University of Maine. http://www.climatechange.umaine.edu/mainesclimatefuture/CVA Washington County.docx.

Climate Change Adaptation for Agriculture in New England by Grund, S., Walberg, 2013. Manomet Center for Conservation Sciences, Plymouth, MA. http://www.manomet.org/sites/default/files/publications_and_tools/Agriculture_fact_sheet%205-13.pdf

Maine Cooperative Extension: http://extension.umaine.edu/

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[3] Drummond, F. and David E. Yarborough, Wild Blueberry Fact Sheet: Spotted Wing Drosophila: Pest Biology and IPM Recommendations for Wild blueberries. Fact Sheet 210. The University of Maine, Orono, ME 04469. February 2013.

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Preparing for Change in Washington County: Forestry

Forest covers more than 90% of the land in Washington County[1] providing local jobs, hosting important habitat for animals and plants, and contributing to Maine's $8 billion dollar forest products and recreation industries.[2] As the climate warms, conditions here will still be hospitable for forests, but their composition will change. As ranges shift many local species will decline while others from the south take their place.

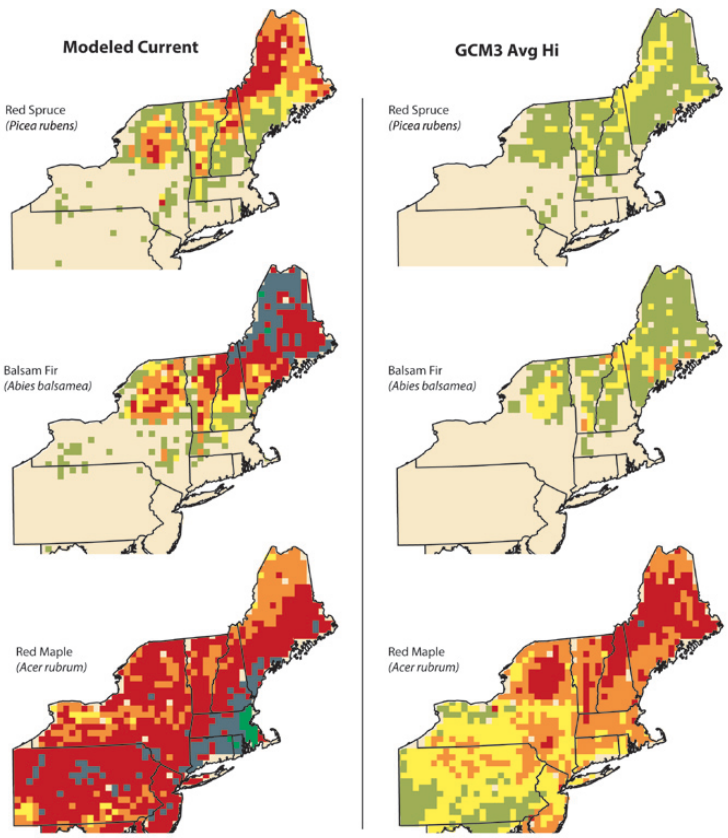

Figure 11: From *Maine's Climate Future*[1]: "Maps showing modeled current and predicted future ranges for three important Maine tree species based on Forest Inventory and Analysis (FIA) data (Prasad et al. 2007) and 38 predictor variables. Future model projections were made using the average of three general circulation models (CM3Avg Hi), and the high future greenhouse gas emission scenario (A1fi) for potential suitable tree habitat in the year 2100 (Iverson et al. 2008). Importance values reflect species basal area and number of stems as determined by FIA protocols."

Maine's forests are already changing under the influence of climate change. As in agriculture warmer temperatures and changing precipitation patterns—more precipitation overall and a new late-season dry period—are affecting the mix of species in the forests of the region. Increased carbon dioxide in the atmosphere can help some species to grow more quickly. However, faster productivity may well be offset by several pests and diseases that are now affecting Maine's forests or will soon due to warmer temperatures. The increased strength and frequency of storms will also inflict damage with wind, ice and snow. Some tree species will adapt to these stressors better than others.[3]

Recent forest research forecasts that Maine's spruce-fir forests will shift northward in coming decades. This shift will eventually leave very little of this coniferous forest in Washington County, other than pockets along the immediate Downeast coast where cooler summer temperatures will persist under the influence of maritime cooling. Maple, beech and birch will move into areas previously dominated by spruce and fir, and over the very long term, these will eventually be replaced by the oak, hickory and pine forests that are now common to the south. [3, 4, 5, 6, 7]

These changes will have major impacts on several local industries, including logging, pulp and paper, wreath making, and Christmas tree farming. Key species will no longer grow well but will be replaced by other species representing new opportunities. Sugar maple is expected to be a winner in the climate race, becoming more common in Washington County.[4] However, shorter winters may mean that local sugar bushes are less productive.[3] Eastern hemlock is expected to decline significantly in the coming decades due to a combination of heat stress and the hemlock wooly adelgid, a deadly pest that is expanding its range with help from the changing climate. [3, 4]

Southern hardwood species will migrate north where they will contribute to fall foliage, though leaves will continue to show autumn colors later than in prior years. As leaves turn later, their colors become less vibrant, so deep reds may be less prominent in the fall. So, the timing of "leaf peeping" tourism will change, and we may see a decline if the colors fade too significantly.[3]

It is difficult for scientists to predict the rate at which forests will change. In general, since trees are long-lived, change will be slow, with one species replacing another gradually over many decades.[3] However, pests and diseases, expected to be more numerous with warming climate, can have fast and unpredictable impacts with the potential to decimate a tree species in just a few years.

A new opportunity in Washington County may arise from efforts to mitigate climate change. The State of California has established a "cap-and-trade" program to reduce greenhouse gas emissions in the state. Companies who emit greenhouse gasses such as carbon dioxide can purchase credits to offset these emissions. The Downeast Lakes Land Trust (DLLT) in Grand Lake Stream has registered more than 19,000 acres of forestland for the California carbon offset program, a deal valued at more than $2 million. In exchange, DLLT is contractually obligated to manage the forest according to set practices that maintain carbon in the forest. This is the first project of its kind in Maine.[8]

An array of forest pests has begun to arrive in Maine from the south including the emerald ash borer, browntail moth, tent caterpillar, gypsy moth, hemlock wooly adelgid are among these.[3, 9] Some forests will be particularly vulnerable.

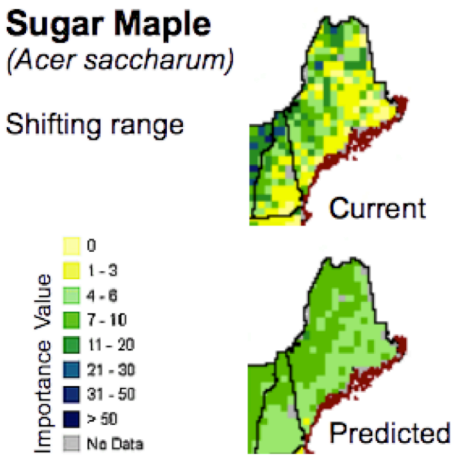

Figure 12: Modeled current and predicted importance of sugar maple (Acer saccharum) in Maine. Sugar maples are expected to become more common with warming climate.

Landscape Change Research Group. 2014. Climate change atlas. Northern Research Station, U.S. Forest Service, Delaware, OH. http://www.nrs.fs.fed.us/atlas.

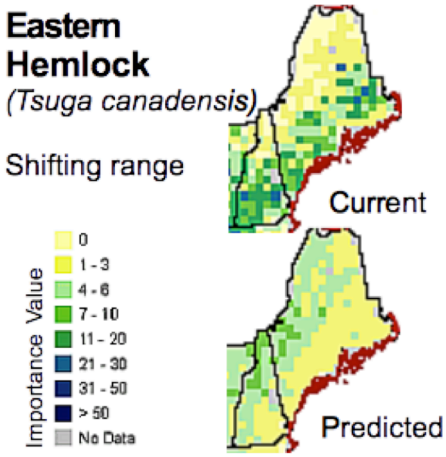

Figure 13: Modeled current and predicted importance of eastern hemlock (Tsuga canadensis) in Maine. Eastern hemlock is expected to decline in Maine due to heat stress and pests, particularly the hemlock wooly adelgid.

Landscape Change Research Group. 2014. Climate change atlas. Northern Research Station, U.S. Forest Service, Delaware, OH.

Adaptation Options for Forestry

Change will be inevitable for the forests of Washington County, and economic change will follow. This will be particularly important for communities and families dependent on forest products or forest-related tourism. Adaptation options are largely dependent

on anticipating the change, and taking advantage of new opportunities as they arise:

- Keep abreast of new of forest pests as well as the means and best practices to fight them to forestall or prevent invasion.
- Consult with foresters and other woodlot owners on management practices to maintain the health and profitability of the forest.

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US Forest Service. 2014. "Climate Change Atlas." includes climate predictions for over 100 tree species, including state-by-state assessments: http://www.fs.fed.us/nrs/atlas/

Maine Forest Health, Maine Forest Service, includes information about all forest pests: http://www.maine.gov/dacf/mfs/forest_health/index.htm

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[6] Iverson, L. R., A. M. Prasad, S. N. Matthews, and M. Peters. 2008. Estimating potential habitat for 134 eastern US tree species under six climate scenarios. Forest Ecology and Management 254:390-406. http://www.treesearch.fs.fed.us/pubs/13412

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