A Canadian/US Gathering to Develop Direction and Research Priorities for the Gulf of Maine Council's Climate Network

September 10 & 11, 2013, University of Maine at Orono

Executive Summary

More than 60 people (including federal, state and provincial employees; university faculty and students; and representatives of nongovernmental organizations and first nations) met to discuss climate change issues in the states and provinces that border the Gulf of Maine (Nova Scotia, New Brunswick, Maine, New Hampshire and Massachusetts). Discussions focused on lessons learned; planning and strategies for adaptation and migration; further needs for management and policy; and ideas for future Climate Network (CN) initiatives.

Presentations centered on several themes: forest impacts; extreme events and adaptive management approaches; and marine fisheries/ocean acidification. Many of the gathering's presentations are posted on the CN page of the Gulf of Maine Council on the Marine Environment (GOMC) website: http://www.gulfofmaine.org/2/committees-and-programs/climate-change-network/.

Presenting scientists shared data confirming a modest increase since 1955 in GOM region air temperatures (0.8°C or 1.44° F.) and precipitation (9 percent). Precipitation from extreme events in the GOM region has increased 74 percent since 1958. IPCC models project a more rapid increase of 2.5 to 3.5°C (4.5 to 6.3° F) by 2050, with precipitation increasing 5-9 percent and more extreme precipitation events expected. Temperatures in the Gulf of Maine have risen much more in recent decades than many other coastal waters around the world, and an anomalous 2012 "heat wave" in sea surface temperatures had damaging economic impacts.

Extreme weather already poses challenges in ecological, economic and social terms for GOM communities and much discussion focused on ways to meet these challenges through planning, emergency preparedness and infrastructure adaptations. Extreme weather events can provide a valuable opportunity to raise public awareness and the will to take preventive action. More economic analyses demonstrating the cost-effectiveness of both mitigation and adaptive management might help persuade communities to make up-front investments (a dollar invested up front in adaptation can save four dollars in response costs).

Throughout the presentations and the ensuing discussions, seven over-arching themes emerged.
1) Local: It's important to apply research to the local level and connect it to communities.
2) Knowledge sharing: An informational clearinghouse would help facilitate improved sharing of research and best practices.
3) Communication: Citizens and communities need climate adaptation and mitigation conveyed through accessible stories and pictures, and clear web-based guidance on best adaptive management practices.
4) Data sharing: Data available across the GOM region need to be combined and shared through a readily accessible data-management system.

5) Monitoring: Monitoring, which is critical to tracking climate change impacts, must use consistent standards for data to be shared and effective.
6) Mapping: More detailed mapping is needed for many facets of the GOM region (including hydrology, habitats, water use and bathymetry). Accurate forecasting of the timing and degree of climatic changes may help foster greater resilience.
7) Analysis: More socio-economic analysis of what people value is needed in the GOM region to help guide climate change adaptation.

Following presentations and discussions, participants shared ideas for constructive roles that the GOMC and Climate Network (CN) could play in relation to the gathering's themes. Some participants had limited understanding of the Council's role as a regional partnership promoting the Gulf's long-term health through connecting people, organization and information; raising public awareness; conducting environmental monitoring; and translating science into management. Some ideas suggested by participants expressed more general needs for the Gulf of Maine region that are not within the GOMC's scope: these are recorded in Appendix A.

Recommendations for further GOMC Climate Network projects included the following:

- Reinforce the GOM region's capacity for place-based climate research, collaborative management and expanded funding (taking lessons from similar cross-border efforts such as the Gulf of Mexico Climate Community of Practice);
- Create outreach material on adaptation and planning for the general public, providing landowners and communities with examples of Best Management Practices (BMPs) related to climate change and with comparative cost-benefit analyses of adaptive changes;
- Create a list of indicator species to monitor how climate change is affecting GOM marine life;
- Help foster the sharing and coordination of data and modelling experiences, and help compile standardized and consistent land-based datasets (LIDAR, land-cover, LCC habitat classification map);
- Support development of high-resolution maps (at 5 km) in conjunction with federal, provincial, state, municipal, and private entities;
- Re-engage GOMC on subfloor mapping of the entire Gulf of Maine, and fund sediment/habitat/deposits mapping;
- Include more representatives from the forestry and transportation infrastructure sectors on the GOMC and engage them in discussion of climate-related issues; and
- Work with New England Governors-Eastern Canadian Premiers on resolutions concerning climate adaptation planning.

This presentation summary will help guide development of a Climate Network Plan (to be completed by April 2014) describing high-priority climate-related projects for the GOMC and region. Participants at the initial CN gathering in Orono found the sharing of perspectives across sectors to be valuable, and expressed a desire for the CN to organize additional forums fostering dialogue between scientists and those in management and policy. Future gatherings would draw participants from a broader spectrum of sectors such as agriculture, public health, public outreach, wastewater management and energy transmission.

Presentation Summary

The Impacts of Climate Change on Forests of the Northeastern United States and Canada (Lindsey Rustad, U.S. Forest Service Northern Research Station)

- Since 1955, there has been an air temperature increase of 0.8°C (1.44° F.) and 9 percent precipitation increase as well as longer growing seasons and less snow and ice.
- Climate models suggest that the climate in the GOM will become warmer with more extreme rainfall and droughts.
- Forest composition can shift in response to slowly changing climate, but it is not clear how forests will change with a more rapid rate of climate change.
- Mitigation Policy – enhance carbon storage in managed forests; prevent forest loss; and replace fossil fuel with biomass (which only releases CO2 accumulated during tree growth).
- Adaptation Policy – increase protected areas; conserve stepping stones, corridors and refuges; and reduce other stresses on forests.

Case Study: Planning and Actions to Mitigate and Adapt to Climate Change Impacts on Forests – Examples from the Canadian Portion of the Gulf of Maine (James MacLellan, University of New Brunswick)

- Future impacts on Canada's forests: extreme weather and climatic variability; forest fires; insect and disease disturbance; climate sensitive zones; and productivity changes. By 2080, timber quantity may be reduced by up to 5 percent in the Atlantic region.
- Acadian forests are subject to damage by wind which will likely increase in severity and frequency.
- Needs—an enhanced capacity to assess vulnerabilities to climate change at various scales and to embed principles of risk management and adaptive management into forest management.
- Timber adaptation strategy: enhance forest fire prevention; control and suppression; enhance pest control; and plant tree species suitable for the future climate.

Case Study: Planning and Actions to Mitigate and Adapt to Climate Change Impacts on Forests – Examples from the U.S. Portion of the Gulf of Maine (Andrew Milliken, U.S. Fish and Wildlife Service; Eric Walberg, Manomet Center for Conservation Sciences)

- Conserve sites with more landscape complexity and local connectedness.
- Forest adaptation recommendations: maintain species, structural and age class diversity; conduct low-impact and sustainable timber harvests; and improve road networks to make forests more assessable during warmer, wetter winters.
- Cranberry Farm adaptation recommendations: re-establish wetlands on site and maintain hydrology to maximize carbon storage in peat soils; and minimize non-climate stressors.
- Lessons learned: climate change is rarely a high priority for landowners but it's possible to engage in valuable dialogue (particularly when taking a risk management approach).
- Extreme weather events present both an opportunity for and an impediment to adaptation.

U.S. National Climate Assessment (Ellen Mecray, NOAA)

- Since 1895, temperatures have increased by 2°C (3.6° F) and annual precipitation has increased by 12.7 centimeters (5 inches).

- Since 1900, sea level has risen by about 0.3 meters (1 foot).
- Since 1958, precipitation from extreme events in the GOM region has increased by 74 percent.
- Heat waves, coastal flooding due to sea-level rise, and river flooding due to extreme precipitation events will pose greater challenges to the region's environmental, social and economic systems.
- Projections: Temperature increase from 1.67 C to 5.56 C (3°F to 10°F) by 2080; frequency, intensity and duration of heat waves will increase; sea-level rise of 0.3 to 1.22 meters (1 to 4 feet); hurricane intensity will increase but overall frequency will decrease.

Latest IPCC Assessment Report model outputs: general changes and some extremes (Adam Fenech, University of Prince Edward Island)

- Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) has more than 40 global climate models (GCM) projecting future climates. While providing no guarantees, an ensemble of all the GCMs can best represent historical climate and is more likely to accurately represent future climate conditions.
- An ensemble of GCMs project that the GOM area will have an increase in temperature of about 2.5 to 3.5°C (4.5 to 6.3° F) by 2050, and an increase in precipitation of 5-9 percent.
- When compared with previous IPCC assessments, ensemble projections from AR5 for Orono, Maine show slightly increasing temperature projection and increasing precipitation projections.

Case Study: Extreme Rainfall Events in New Brunswick (Rick Fleetwood, Meteorological Service of Canada)

- From December 12-15, 2010, parts of New Brunswick received over 150 mm (5.9 in) of rain and, in some places, almost 200 mm (7.9 in). Consequently, major flooding occurred in southwestern New Brunswick.
- For many of the hardest hit areas, this event exceeded the 1 in100 year return period for flood events.
- Canada is participating in a Community Collaborative Rain, Hail and Snow Network (CoCoRaHS.org) precipitation-monitoring initiative, with the goal of establishing 100 new monitoring sites in Atlantic Canada in coming months.

Case Study: Decisions before and after Hurricanes Irene and Sandy (Gina Campoli, VTrans)

- Climate change means more intense and frequent storm events and thus big changes in the timing and amount of stream flow. Consequently, Vermont is working toward flood resilience in response to climate change. The state is increasing its emergency preparedness; planning for recovery after an extreme weather event; and building resilience by acting to mitigate the problem.
- Confined and straightened rivers have greater power and erosive force. Access to floodplains dissipates the energy so Vermont's approach is to give rivers more room to move; elevate bridges; and slow stormwater flow to allow for infiltration.

Case Study: Infrastructure Decisions Accounting for a Changing Sea-level (Adam Fenech, UPEI, for Patrick Mazerolle, New Brunswick Department of Tourism)

- Since 2008, New Brunswick Department of Tourism and Infrastructure has spent $28 million to repair damage from 13 storms.

- Newer infrastructure is being built that is capable of performing under more extreme climate conditions.
- New Brunswick has formed intra-departmental committees to further address the challenges of climate change.
- Adaptation response: build new seawalls; raise the grade of roads in vulnerable areas; and replace smaller culverts with larger ones.

Use of LIDAR for Flood-stricken Areas in Charlotte County, New Brunswick (Real Daigle, Director, R.J. Daigle Enviro (formerly with Environment Canada)

- LIDAR (a remote-sensing technology) and analysis of precipitation climatology were used as part of the Climate Change Vulnerability Assessment Tool. This tool helps identify vulnerabilities to extreme weather and understand climate change impacts so as to develop solutions and adaptation opportunities.
- LIDAR maps displayed both flood impacts from recent extreme rainfall and coastal flooding scenarios.
- Community-based working groups helped communicate the findings and build public support.

Case Study: Managing the Coastline for Frequent Extreme Events—Actions from New Brunswick (Jeff Hoyt, New Brunswick Department of Environment and Local Government)

- The Regional Adaptation Collaborative (RAC) is helping communities in New Brunswick plan for sea-level rise and storm surge.
- New Brunswick Department of Tourism and Infrastructure is building risk into its asset management system.
- New Brunswick is developing a flood risk reduction strategy.
- Challenges: lack of public understanding; no overarching provincial policy; managing existing development in high-risk areas; and encouraging property owners to proactively invest for adaptation.

The Economics of Extreme Events—The Case for Action (Sherry Godlewski, New Hampshire Department of Environmental Services)

- Extreme events have happened more often in the last decade than in the past and they are costing more. Educating about preventive cost can help motivate people: a dollar invested up front in adaptation can save four dollars in response costs.
- The New Hampshire Climate Action Plan, developed by the New Hampshire Climate Change Policy Task Force, has created eight adaption recommendations (out of 67).
- Communities don't have to make adaptation changes right away; they can plan ahead and do it over time.

Case Study: Including Sea-level change in Regulatory Frameworks and Municipal Planning (Kathy Baskin, Massachusetts Office of Energy and Environmental Affairs)

- Hull, Massachusetts created images of specific buildings to show what a sea-level rise of 0.15 meters (0.5 feet), 1.15 meters (3.8 feet) and 3.17 meters (10.4 feet) would look like. The Town reduces permit fees if a planned building is elevated at least 2 feet above the flood requirement.
- Boston has created evacuation routes that account for storm surge (avoiding areas that could be flooded in times of storm surge).

- State policies and regulations, such as the Massachusetts Environmental Policy Act and the Tidelands & Waterways Regulations, are being updated to address sea-level rise.
- Spaulding Rehabilitation Hospital was designed for a 2-foot sea-level rise with mechanical and electrical systems located on the roof.

The 2012 Warming Event: Observations and Trends for the Future (Kevin Friedland, NOAA/NMFS/NEFSC)

- Almost every month during 2012, sea-surface temperatures in the Gulf of Maine were above the mean.
- The timing of the Gulf of Maine's spring transition (phytoplankton bloom) has been occurring earlier (it's now about 2 weeks earlier than it was in 2004). An anomalous earliest-ever bloom occurred in March 2012. There was a negative anomaly (the latest bloom ever recorded) in April 2013. These events could possibly relate to a deep mixing layer in 2013 and shallow mixing layer in 2012.

Warmer Temperatures, Molt Timing, and Lobster Fishing Seasons in the Canadian Maritimes (John Tremblay, Department of Fisheries and Oceans)

- Since 1989, lobster landings have increased steadily, particularly in the last few years, but recent prices have been some of the lowest in years.
- More monitoring is necessary to study how molting timing, reproduction and heat stress will evolve with climate change. Molting usually happens in July and August, but lobsters have been molting earlier in warm years. Recently molted lobsters are of lower value.
- Temperatures may have been high enough in 2012 to increase activity and catchability of the lobsters.
- Improvement is needed in pre-season prediction and in potential responses to those predictions, perhaps through flexible fishing-season dates.
- There is an opportunity to change how lobsters are marketed thus changing the lobster-buying process.

The 2012 Ocean Heat Wave and Other Recent Climate Impacts on New England Lobsters: A Contrast of Economic and Biological Crises (Rick Wahle, University of Maine)

- Between 1982 and 2004, the GOM sea surface temperatures trended up by 1°C (1.8° F) every 40 years. Since 2004, that rate of increase has accelerated to about 1°C every 4 years. Of the four major economic events in Maine's lobster fishery over the last 15 years, three have been climate-related.
- The 2012 ocean heat wave in the Gulf of Maine was an economic crisis but not a biological crisis. Warmer water temperatures boosted the growth of the lobster so they molted early. Earlier recruitment of lobster fishers led to a glut of lobsters caught and then plummeting prices.
- In 1997, shell disease started to increase dramatically in Rhode Island, causing a collapse of the lobster fishery. Shell disease may be moving into the Gulf of Maine, with more lobsters off Maine being observed with shell disease.

Summary of the Breakout Discussions

Commonalities of discussions

Throughout discussions at the gathering, seven common over-arching themes emerged:

1) Local: It's important to break down research to a local level and connect it to communities so local residents can take action.

2) Data sharing: Data available across the GOM region need to be combined and shared through a readily accessible data-management system.

3) Knowledge sharing: A clearinghouse is needed to facilitate sharing of research (and climate change presentations). To compile information, it would be useful to have a regional inventory of who is doing what kind of climate-related work around the GOM.

4) Monitoring: For tracking climate-change impacts in the GOM region, monitoring is critically needed using consistent standards so data can be shared and effective. Citizen monitoring can be a cost-effective way to accomplish some of the required monitoring, but it needs to be standardized.

5) Communication: Citizens and communities needs climate adaptation and mitigation conveyed through accessible stories and pictures, and clear web-based guidance. A climate change clearinghouse could help engage and educate the public, and maintain communication and consistency between communities and agencies.

6) Mapping and Forecasting: More detailed mapping is needed for many facets of the GOM region (including hydrology, habitats, water use and bathymetry). Accurate forecasting of the timing and degree of climatic changes may help foster greater resilience.

7) Analysis: More socio-economic analysis about what people value is needed in the GOM region to help guide climate change adaptation. What can and should we do if we cannot do everything?

Climate and Land Use Change Impacts to Gulf of Maine Watershed Forests and Wildlife: Implications for Management and Conservation

Management and Policy Lessons

From the three presentations on forests, participants learned that it was important to engage the landowners who can actually make changes and get them to understand the importance of climate change impacts (providing them with relevant information but not overloading them). If the landowner can manage the forest in ways that anticipate climate change, they can create more resilient forests.

Providing forecasts of when changes are expected can help landowners best plan for and mitigate the effects of a changing climate. It is also important to plan for extreme events and use examples of these with landowners to highlight potential impacts.

Warmer temperatures are expected in future winters, providing less time when the ground is frozen and forest owners can maneuver large equipment with minimal damage to the forest floor. Navigating forests on thawed ground may take an improved road network or better technology.

Some of the region's tree species or systems may not be able to adapt to a warmer climate so it would be inadvisable to invest further resources in them.

GOM states and provinces need to create policies that help private landowners prepare for climate change. There is also a need for federal policies on climate impacts on agriculture and forests (including how to certify forests in the future).

Gaps and Needs for Monitoring, Forecasting and Research

Monitoring is critical to tracking how forests, species, streams and weather respond to climate change. Yet private landowners are unlikely to invest the necessary time and money. To make the most of funds budgeted for monitoring, a strategy should be jointly developed with the landowners and the federal government. There also needs to be clear agreement on forestry climate indicators.

A forest inventory analysis is needed with higher-quality data for the Gulf of Maine region as well as comprehensive forest ecosystem data. Larger-scale land -use maps for the region are also needed.

Is there research being done on how climate change is affecting or might affect air quality and how that would influence the changing forest landscape?

It might be helpful to have more local examples of how landowners are adapting management practices in response to climate change, citing what influenced their decisions and how they chose to respond.

More local studies are needed to determine which restoration efforts have been effective with cold water fisheries. What areas are losing habitat and what areas still offer refugia? Can connections be established facilitating movement to cooler waters if the current conditions warm up beyond what a particular species—like brook trout—can tolerate?

Ideas for GOMC Climate Network – Actions and Requests

- Include more representation from the forestry sector on the GOMC to better underscore forest-related issues.
- Identify and agree on key forestry indicators for climate change in the GOM region.
- Provide examples of landowner Best Management Practices (BMPs) related to climate change so others can learn from what has been done.

Extreme Events and Actions Taken in the Region and What the Best-Available Science Tells Us

Gaps and Needs for Monitoring, Forecasting and Research

There are gaps in data and research and greater need for mapping and projections concerning extreme heat events, wind events, ice storms, pests and pathogens. Hydrological models need to

demonstrate what will occur in extreme conditions (*e.g.*, after a wind storm where there is widespread tree damage or where heavy rains occur on top of snow pack). The entire GOM region would benefit from detailed grid maps of climate extremes, along with past and projected geographical analysis of climate extremes. More comprehensive study needs to be done of trends and extreme events to direct the focus of mitigation efforts.

Ideas for GOMC Climate Network – Actions and Requests

- Support development of high-resolution maps (at 5 km) in conjunction with federal, provincial, state, municipal, and private entities.

Extreme Events and Actions Taken in the Region: How to Translate Climate Information into Action

Infrastructure and Inland Impacts

Management and Policy Lessons

Communities need to begin designing and building infrastructure to accommodate a higher magnitude and frequency of extreme events. With new culverts, downstream and upstream effects need to be considered. Culverts may allow for storm surge to move farther inland than before. In New Brunswick, if a culvert is not performing correctly, then it must be replaced.

Planning (including strengthening or relocating infrastructure like roads) will be critical to avoiding repeated losses. Tracking replacement costs of infrastructure due to extreme events can help build support for more storm-worthy infrastructure. Collaboration and integration among jurisdictions can improve pre-storm planning and actions.

More data and analysis are needed on hardened/stabilized and living (naturally vegetated) shorelines, and more of this information needs to reach municipalities. Communities will be more motivated to take action if they understand ways they can adapt to climate change. It's important that they incorporate new research as they update or create policies.

Gaps and Needs for Monitoring, Forecasting and Research

Transportation/engineering manuals, procedures and practices need to be updated to reflect climate change and extreme weather events.

IDF (Intensity Duration Frequency) curves need to be updated more frequently with new precipitation data. Jurisdictions in the GOM region need to coordinate data collection and share data for greater consistency. The region needs better data on snowfall. Increased monitoring after storm events would help to assess long-term impact and improve infrastructure design. It would also be helpful to have case studies with weather models illustrating the impacts from coastal flooding and storm surge for storms of different magnitudes.

Through citizen science projects, communities could map and monitor stream crossings. The region needs more shoreline-change mapping (including infrastructure—as Maryland has done).

Ideas for GOMC Climate Network – Actions and Requests

- Involve more transportation infrastructure planners and engineers in GOMC.

- Provide communities with information on the comparative costs of adaptive changes versus replacement.
- Work with New England Governors-Eastern Canadian Premiers on resolutions to infuse cross-agency cooperation and forward-looking science into climate adaptation planning.

Adaptive Management Actions/Approaches

Management and Policy Lessons

Communities need to be comfortable with climate-change models (the data and methods behind predicted impacts)—especially those concerning sea-level rise—to have those influence their policy decisions. One way to discourage building in areas likely to be most affected by sea-level rise is to limit the services (water/power) supplied.

Economic drivers and costs need to be integrated into public discussions about adapting to climate change (*e.g.,* for every dollar you spend on adaptation, you save four dollars on reactive spending). It's important to emphasize that climate change adaption can be phased in over time, but they should start incorporating it into their budgets (so costs don't become unmanageable).

Gaps and Needs for Monitoring, Forecasting and Research

Further study is needed on how the GOM region can use natural resources (such as wetlands, dunes, and barrier beaches) to reduce adaptation costs and protect development and infrastructure. Retroactive economic case studies examining how extreme events have affected infrastructure could help guide future infrastructure planning.

More research is needed on the most effective ways to visualize and present climate change information to specific audiences such as decision-makers, managers and the general public. Further mapping and inventories are needed to reflect the potential migration of plants/animals in response to climate, assess priority habitats and how to best protect ecosystem services. Mapping is also need to document how inland infrastructure might respond to extreme weather events and climate change.

Ideas for GOMC Climate Network – Actions and Requests

- Re-engage GOMC on subfloor mapping of the entire Gulf of Maine, and fund sediment/habitat/deposits mapping.
- Assist in the sharing of modelling experiences
- Aggregate cost-benefit analyses to frame funding requests and help communities understand up-front investment and economic benefits/tradeoffs.
- Create outreach material on adaptation and planning for the general public.

Marine Fisheries and Climate Change (Acidification)

Management and Policy Lessons

Environmental changes (such as temperature increases) need to shape management plans and decisions, and small changes can be taken experimentally to reflect these (such as creating flexible start dates for a fishery).

The Gulf of Maine region's economic dependence on a single fishery (lobster) decreases the region's resilience. Fishery management plans need to anticipate the timing of major changes and address the potential decline of this species and the possibility of other species moving in. Given the iconic value of this species, discussion of its future could help educate and involve the public in climate-change planning. The impacts of climate change on the lobster fishery may be minimized if other stressors (such as aquaculture and pesticides) are reduced.

Gaps and Needs for Monitoring, Forecasting and Research

The GOM region lacks adequate maps showing the sea floor; human uses of the marine environment; areas suitable to various species; and the influence of estuaries on the ocean and seafloor. There is also a need for inshore and nearshore temperature modeling and mapping. Marine species need to be identified for phenology studies of long-term climate change. Research needs to be continued on the impacts of environmental changes on genetics/individuals. More sampling of lobsters (potentially with fishers involved in coordinated annual monitoring and trawling) would help provide more information on lobster migration and habits.

First nations research has found heavy metals in lobster around ports. More research is needed on the impacts of consuming lobster from these settings. Further monitoring and research is needed on pH, salinity and acidification (and how these elements interact); and on feeding interactions among species and how these may be influenced by climate change.

Additional research is needed on how water flows will change with climatic shifts, and the impact these changes may have on anadromous fish (*e.g.*, drawing them upstream before food supplies are present there causing fish populations to crash).

Ideas for GOMC Climate Network – Actions and Requests

- Help foster data sharing and management around the region.
- Identify and monitor invasive species across jurisdictional borders.
- Create a list of indicator species to monitor how climate change is affecting GOM marine life.

Potential Actions for the GOMC Climate Network

Near-term Actions

An online gathering spot, such as a dashboard, would be helpful for sharing information, topics, common problems, research, pictures and stories. Meeting participant would like to have a list of who attended, with e-mail contacts and brief summaries of their areas of expertise and interest.

The Climate Network could establish working groups or shared online workspaces to address certain problems or to bring related sectors together to discuss climate-related issues.

An online data center could be developed to share data related to climate change in the GOM. The Climate Network could encourage the Gulf of Maine Council to involve more foresters, transportation infrastructure planners, and engineers (particularly those with expertise in climate change adaptation and mitigation).

Overarching Information Gaps

To better understand climate-change impacts on different sectors, there's a need for further analysis of extreme-weather events in the GOM region. It would be valuable to have a database with a grid resolution of 3-6 miles (5 to 10 kilometers) that encompasses different parameters (*e.g.*, forestry, meteorology, biology, hydrology, geography, and infrastructure).

Additional research is needed on the potential impacts of a changing freeze-thaw cycle; what might be done to prepare for a northward migration of the ice storm belt (and how likely that is); and the hydrologic impacts of major precipitation events when there is snow or frozen ground.

Further guidance is needed on how to translate scientific research and models into information that local engineers, designers and planners can use for "boots-on-the-ground" actions.

Who was missing from the meeting?

The meeting did not have representatives from agriculture; public health; public outreach; defense; water resources management (such as rivers and streams, and flood forecasters); wastewater management and energy transmission. Representatives from other regional organizations, such as Northeastern Regional Association of Coastal and Ocean Observing Systems (NERACOOS), Northeast Association of Fish and Wildlife Agencies (NEAFWA), American Association of State Highway and Transportation Officials (AASHTO) and Northeast States for Coordinated Air Use Management (NESCAUM) would have contributed to the discussion.

Objectives Achieved at the GOMC Climate Network Gathering

- ✓ *Gather key federal and provincial/state representatives to discuss lessons learned and planning for climate change*
  More than 60 representatives from the GOM region attended and discussed climate-related presentations.
- ✓ *Connect research, monitoring, and management communities (natural science/management interface, across sectors (resource management, infrastructure and planning, preparedness and recovery) at federal and jurisdictional levels.*
  Through small-group discussions following each presentation theme, participants could connect with experts and representatives of different sectors.
- ✓ *Exchange experiences and strategize for climate change adaptation and mitigation*
  These exchanges occurred during presentations and in breakout group discussions.
- ✓ *Rebuild the bilateral climate network by outlining a way forward with key goals and objectives*
  Participants shared ideas for GOMC Climate Network actions, which are included in this meeting summary.
- ✓ *Identify key messages for Climate Network, including specific requests to the Gulf of Maine Council*
  Through discussion of ideas for the Gulf of Maine Council, this objective was achieved and documented.

Funding Ideas and Actions for the GOMC

- Reinforce the GOM region's capacity for place-based climate research, collaborative management and expanded funding (taking lessons from similar cross-border efforts such as the Gulf of Mexico Climate Community of Practice).
- Map bathymetry and habitat in the Gulf of Maine.
- Assist with compiling standardized and consistent land-based datasets (LIDAR, land-cover, LCC habitat classification map), and help coordinate usage among jurisdictions.
- Publicize costs of replacement versus planned adaptation to climate change.
- Update the New England Federal Partners (NEFP) climate group.
- Create a list of indicator species to monitor how climate change is affecting marine life in the GOM.

Appendix A: Suggested Actions that Extend beyond the Scope of the GOMC/CN

From Forestry discussion:

- Study whether it is feasible to assist the migration of plants and animals to areas where the climate will be more suitable.
- Study land use and connectivity issues across jurisdictional borders to assist in forestry planning and pest management.
- Identify and monitor invasive species across jurisdictional borders.
- Engage large cross-border companies in working to mitigate impacts of climate change.
- Encourage GOM states and provinces to create policies that help private landowners prepare for climate change. Support federal policies on climate impacts on agriculture and forests (including how to certify forests in the future).
- Conduct a forest inventory analysis with higher-quality data for the Gulf of Maine region as well as comprehensive forest ecosystem data. Larger-scale land-use maps for the region are needed.
- Promote local food initiatives in the GOM region.

From Extreme Events discussion:

- Create an inventory of culverts and road-stream crossings, and then develop standards based on projected future flooding events.
- Research and publicize historical extremes in the GOM region.
- Coordinate the planning and management of "working waterfronts" in GOM ports.
- Create a clear way for the public to see in real time an extreme precipitation event based on hydrometric-monitoring stations.
- Prepare community-scale projections of sea-level rise and storm surge.

From Infrastructure and Inland Impacts discussion:

- Continue funding "on the ground" engineering projects such as the ferry and waste treatment project.
- Extend the decision-making process used in the Natural Resources Canada coastal engineering project into the larger GOM region.
- Produce technical guidance on best practices for road and engineering upgrades
- Develop hydrodynamic models that go beyond predicting static conditions and reflect the dynamic nature of water.

From Adaptive Management discussion:

- Help build consistency by creating/supporting regional planning groups to communicate and share information and lessons learned to communities
- Fund and promote a high-water-level marking campaign so the last major flood remains visible to the public.
- Advise property owners on how to manage shorelines and how to adapt to climate change.

From Marine Fisheries/Acidification discussion:

- Support monitoring of lobster shell disease and assess the lobster fishery's economic vulnerability should the disease spread.
- Help encourage regional coordination through co-branding GOM lobster as sustainably harvested
- Identify underutilized species and the economic and environmental impacts of enhancing those fisheries.
- Determine the differences in bottom-trawling practices between Canada and the US and how the region can work collaboratively to better understand the lobster population.
- Help coordinate across jurisdictions to avoid market gluts of lobster