



# ECOSYSTEMS AND WILDLIFE

## Climate Change Adaptation Plan

Amendment to the  
**New Hampshire  
Wildlife Action  
Plan**



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and  
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# New Hampshire Wildlife Action Plan: Ecosystems and Wildlife Climate Change Adaptation Plan

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## EXECUTIVE SUMMARY

The Ecosystems and Wildlife Climate Change Adaptation Plan is an amendment to the NH Wildlife Action Plan (WAP) (NHFG 2005). Although the WAP contained references to the effects of climate change in several sections, a comprehensive look at how climate changes will affect wildlife and their habitats was recommended by the Association of Fish and Wildlife Agencies in the document: “Voluntary Guidance for States to Incorporate Climate Change into State Wildlife Action Plans and Other Management Plans”. The Ecosystems and Wildlife Climate Change Adaptation Plan addresses this through a series of vulnerability assessments of critical habitat and development of a broad set of strategies to address those vulnerabilities. These assessments and strategies were developed by a broad range of stakeholders. This plan, having been developed by a broad range of partners, is a plan for the whole state, and will require the combined efforts of many agencies, organizations and individuals to accomplish. We welcome your participation.

This plan also addresses both specific actions and components of actions that were identified in *The New Hampshire Climate Action Plan* (NHDES 2009) including two sections: Ecosystems and Wildlife Climate Adaptation Plan for the State of New Hampshire and address mechanisms under Strengthen Protection of New Hampshire’s Natural Systems. The ability to address these needs through the WAP strengthens the actions recommended under both plans.

For consistency in analyzing climate effects, biologists at the New Hampshire Fish and Game Department (NHFG) compiled a set of climate stressors and predicted future conditions in New Hampshire based on low (B1) and high (A1f1) emission scenarios (from IPCC 2007). Predictions were compiled from three sources: Frumhoff et al 2007, NECIA 2006, and Hayhoe et al 2008. Most of the predictions are of actual changes to the climate, but also considered are: 1) changes due to human responses including mitigation and adaptation and 2) species’ responses including phenology and habitat shifts.

A major piece of this Plan is a set of habitat-based vulnerability assessments. Habitats were chosen based on the original habitat classification in the 2005 NH WAP, and modified to incorporate the Northeast habitat classification system (including both the terrestrial/wetland and aquatic components) (Gawler 2008), resulting in list of 24 habitat types. Habitat vulnerabilities were discussed at seven meetings (by habitat groupings) in the fall of 2011 and, for coastal habitats, in January 2012. For each meeting, NHFG invited experts on the relevant habitat(s) and instructed them to consider each habitat’s sensitivity and exposure to climate change, as well as its capacity to adapt.

### **Forest**

High Elevation Spruce-Fir  
Low Elevation Spruce-Fir  
Northern Hardwood-Conifer  
Hemlock-Hardwood-Pine  
Appalachian Oak-Pine

### **Freshwater Wetland**

Floodplain Forest  
Vernal Pools  
Northern Swamp  
Temperate Swamp  
Peatlands  
Marsh and Shrub Wetlands

### **Other Terrestrial Habitats**

Pine Barrens

Early Successional: Anthropogenic Grassland and Shrublands  
Alpine (incl. Talus and Rocky Ridge)

### **Aquatic**

Coldwater Ponds  
Stratified Lakes and Ponds  
Coldwater Streams  
Warm Rivers  
Lake and River Shores

### **Coastal**

Salt Marsh  
Dunes  
Coastal Islands  
Estuarine  
Marine

NH's coastal habitats are expected to be the most immediately affected by climate change due to sea level rise, which will inundate habitat, change salinities and increase the damaging effects of storm surge. For freshwater habitats, more precipitation occurring in stronger storms, and longer summer droughts will change stream flooding and wetland recharge. Increasing temperature will also affect marine and aquatic species ranges and reproductive cycles. In terrestrial habitats, species composition will shift as species track their preferred temperature and moisture ranges, potentially resulting in altered food webs and other natural process.

Following our effort to compile habitat vulnerabilities, NHFG hosted six strategy-setting meetings. Invitees included policy specialists, state and federal agency biologists, planners, permitting agents, land protection and stewardship staff from agencies and NGOs, natural resource professionals, regional planning commission staff, representatives from lake, stream and watershed advisory committees, academics, and educators. At each meeting, participants were first introduced to the major vulnerabilities and then worked in smaller groups to brainstorm strategies to address those vulnerabilities. The strategies collected were then compiled, assessed as to whether they directly addressed climate change vulnerabilities, and edited. Overarching strategies that apply to all habitats or to the larger habitat groups are listed in the Conservation Strategies section. These strategies have been organized by major types of actions.

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S3: Restore Watershed Connectivity
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response
- S8: Revise Water Withdrawal Policies
- S9: State Energy Policy
- S10: Funding
- S11: Modeling, Research and Monitoring
- S12: Technical Assistance and Outreach

Strategies addressing the needs of specific habitats are included in each Habitat Assessment in the appendices.

Three broader themes emerged from the development of the strategies. These themes encompass commonalities among actions that otherwise apply more specifically to individual habitats or vulnerabilities and that also address some of the most pressing current needs related to climate change.

**Short-term Implementation (short-term, small scale):** Despite the need for further assessment and ongoing planning, there are things that can be done now to minimize the effects of climate change on both ecosystems and humans.

**Landscape Assessment and Conservation (long-term, large scale):** Any response to climate change should take advantage of existing and emerging knowledge to identify areas that are more resilient, more likely to adapt, or that are at highest risk.

**Partnerships:** Because climate change occurs at a large scale, it is imperative that agencies, NGOs, planners, researchers and municipalities work together towards common solutions.



## INTRODUCTION

It is generally acknowledged that climate change is occurring and that it will have significant effects on wildlife and ecosystems in the United States and the world (IPCC 2007). Since 2005, when states originally developed their Wildlife Action Plans, the scientific community has refined and improved climate change models, resulting in a greater understanding of the potential changes and their magnitude at various spatial scales. In September 2009 the Association of Fish and Wildlife Agencies (AFWA) released the document: “Voluntary Guidance for States to Incorporate Climate Change into State Wildlife Action Plans and Other Management Plans” (hereafter “Guidance Document,” AFWA 2009). The Guidance Document aims to provide the information and tools that can help states update their Wildlife Action Plans to better reflect how climate change may affect wildlife and their habitats, including vulnerability assessments and conservation strategies to address these vulnerabilities. The Guidance Document also outlines more specifically how climate change can be incorporated into each of the “eight elements” required in the original Wildlife Action Plans. While not required of individual states, updating plans to better address climate change is a first step in the revision of Wildlife Action Plans that is required by 2015. This plan is an amendment to the 2005 NH Wildlife Action Plan and the elements within it will be incorporated into the next full revision of the WAP in 2015.

New Hampshire’s original Wildlife Action Plan (WAP) (NHFG 2005) mentioned climate change in multiple locations, centered on a four page risk assessment in Chapter 4. This summary of potential threats acknowledged that habitats – and by extension the wildlife they support – could be significantly altered if climate change was not addressed. Habitats at geographic extremes (e.g., high elevation, coastal) were noted as being particularly vulnerable, as were those characterized by relatively cool temperatures (such as alpine habitats and coldwater streams). A few wildlife species were considered particularly threatened, most of which were coastal, northern or high elevation in distribution.

No specific strategies were proposed to address climate change in the original WAP. Mention of climate change was notably absent in profiles for coastal habitats and most of the species that depend on them, particularly salt marshes and dunes, two of the most vulnerable habitats in the state based on sea level rise projections.

The NH revision effort is integrated with similar efforts in the northeast region. Maine and Massachusetts have undertaken similar exercises, and their results have informed New Hampshire’s plan. Data from larger regional efforts by the Manomet Center for Conservation Sciences and The Nature Conservancy have also been stepped down to NH where appropriate and feasible. Elements from *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment* (Glick and Edelson, eds, 2011) were incorporated.

This plan also addresses both specific actions and components of actions that were identified in *The New Hampshire Climate Action Plan* (NHDES 2009) including two sections: Ecosystems and Wildlife Climate Adaptation Plan for the State of New Hampshire (ADP Action 8) and address mechanisms under Strengthen Protection of New Hampshire’s Natural Systems (ADP Action 4). The ability to address these needs through the WAP strengthens the actions recommended under both plans.

This plan, having been developed by a broad range of partners, is a plan for the whole state, and will require the combined efforts of many agencies, organizations and individuals to accomplish. We welcome your participation.

## CREATING THE PLAN

### PAST TRENDS AND PROJECTIONS FOR CLIMATE CHANGE IN NEW HAMPSHIRE

Available evidence indicates that the global temperature has been gradually warming over the past 50 years. In New Hampshire, the average temperature has risen over 1.5° F since 1970, with winter temperature rising faster than summer (Frumhoff et al 2007). Twenty of the last 25 years have been warmer than the average across the past century (Northeast Regional Climate Center; <http://www.nrcc.cornell.edu/>; accessed 23-Jan-2013). There has also been an increase in heavy rainfall events indicating that precipitation patterns are starting to shift from historical norms (NECIA 2006).

For consistency in analyzing climate effects, biologists at the New Hampshire Fish and Game Department (NHFG) compiled a set of climate stressors and predicted future conditions in New Hampshire based on low (B1) and high (A1f1) emission scenarios (from IPCC 2007). Predictions were compiled from three sources: Frumhoff et al 2007, NECIA 2006, and Hayhoe et al 2008. Most of the predictions are of actual changes to the climate, but one is changes due to human responses including mitigation and adaptation, and the other two are species responses including phenology and habitat shifts. These predictions were used in the development of the vulnerability assessments and are presented in Table 1 and summarized below.

- Temperatures will increase, with a slightly larger median increase in winter than summer
  - More days per year with extremely high temperatures (> 90°F)
  - Fewer days with snow
  - Longer growing season (more frost free days)
  - Earlier ice-out, later ice-in of lakes and rivers
- Changes in total precipitation are uncertain, but seasonality and intensity is likely to vary:
  - Increased winter precipitation, with more of it falling as rain
  - More frequent heavy rains
  - Increased likelihood of summer drought
- Stream flow is likely to become more variable as a result of higher temperatures, drought, and more intense precipitation events
- Fire is more likely as a result of higher temperatures and increased drought
- Increased frequency of intense storms is predicted, including wind and rain
- Sea level is expected to rise
- Changes in ocean and estuary pH and salinity may occur as a result of increased freshwater runoff, temperature changes, shifting ocean currents, and increased CO<sub>2</sub> dissolution.

Many of these climatological changes are likely to have direct physiological effects on plants, wildlife, and physical processes. Species that are adapted to cooler temperature ranges or specific water chemistry may be most influenced. Other wildlife, while not sensitive to climate change *per se*, will need to adapt as their preferred habitats undergo changes in distribution, plant species composition, altered physical conditions or a combination of all these factors.

Included among the species whose ranges are likely to shift are a number of non-native invasive species, both plants and animals, which are currently uncommon or absent in NH because they cannot tolerate prolonged cold temperatures. These invaders may also add to the stress caused by various shifts in climate and thus be even better able to outcompete natives. Increases in the populations of some invasive species could significantly alter the distribution and abundance of the native species with which they interact. Increases in pests and pathogens are also expected, adding to the stress on plants and animals. These changes are true for species in all habitats, from marine to alpine systems.



A large suite of largely unpredictable changes involve phenology, in which the timing of key life stages shifts with changes in climate. Not all interacting species will shift at the same rate – if they shift at all – and the resulting “phenological mismatches” have the potential to disrupt reproduction, predator/prey cycles, and ecological interactions such as pollination. For example, some migrating birds have evolved to time their migrations to coincide with the emergence of insects. If insect emergence is too early because it is warmer, birds may miss their opportunity to feed in early spring, a time when they particularly need to recover from their migration and prepare for breeding. There are many such seasonally-linked cycles like that which are at risk and the effects can be very broad.

In addition, human responses to a changing climate have the potential to exacerbate many of the changes listed above. Examples of such exacerbating responses include seawalls, dams (to reduce flood risk), raised roadways, and increased water withdrawals. Such infrastructure may have unintended consequences that actually increase the risk to human health and infrastructure. In addition, the response to damage after storms can further damage habitats as well as replace infrastructure with the same vulnerable types. Examples include dredging gravel out of stream beds to repair roads and replacing washed out culverts with the same size instead of a larger one designed to handle future storm events. Populations may shift as people move away from areas strongly impacted by drought or sea level rise, thus creating pressures on areas otherwise less sensitive to climate change. And human efforts to reduce greenhouse gas emissions, particularly through the development of alternate energy sources (e.g., wind, biomass, and associated infrastructure), can also directly alter or supplant habitats or reduce their ability to adapt to climate change.

Table 1. Climate projections and other related information used in assessing species and habitat vulnerability in the NH WAP climate change addendum. Data from Frumhoff et al 2007, NECIA 2006, and Hayhoe et al 2008.

Stressor	Indicator	Changes expected by 2100	
		Low emissions (IPCC B1 scenario)	High emissions (IPCC A1f1 scenario)
Changes in Temperature	Winter temperature	Increases 5-8°F	Increases 9-13°F
	Summer temperature	Increases 3-7°F	Increases 6-14°F
	# days above 90°F	30	65
	# days above 100°F	6	23
	# days with snow	Decreases 33%	Decreases 50%
	River ice-out	Earlier by 11-13 days	
Changes in Precipitation	Winter precipitation	Increases 20-30% with a higher percentage as rain	
	Frequency of heavy rains	Increase	
	Summer drought	Increased frequency of 1-3 month droughts, becoming annual under high emissions scenario	
Changes in Hydrology	Stream flow	More headwater streams become intermittent during summer months. Reduced summer flow in most rivers.	
Fire	Fire frequency	Higher temperatures and more drought events lead to increased fire frequency	
Wind	Wind intensity	More frequent and more intense storms lead to higher frequency of damaging wind events.	
Sea Level Rise		31"	75"
Ocean Acidification		Decrease in pH	
Ocean Salinity		Salinity varies depending on freshwater runoff and latitude	
Human response to climate change	Infrastructure changes	Seawalls, dams, culverts, wind power, transmission lines and other changes in developed and undeveloped landscapes change habitat permeability and alter habitat type and quality	
Phenology	Growing season length	Up to 43 days longer	
	First leaf	Earlier by 6.7-15 days	
	Lilac bloom	Earlier by 6.3-16 days	
Habitat Shifts	Spruce-fir forests	Forests still exists in NH but declines in quality	Significant loss at higher elevations
	Northern hardwood-conifer Forests	Some increased forest productivity	Forests still present but reduced in quality
	Hemlock	Decreases in abundance 20%	Decreases in abundance 40%, hemlock woolly adelgid present throughout

## VULNERABILITY ASSESSMENTS

A major piece of this Plan is a set of habitat-based vulnerability assessments. Habitats were chosen based on the original habitat classification in the 2005 NH WAP, and modified to incorporate the Northeast habitat classification system (including both the terrestrial/wetland and aquatic components) (Gawler 2008). The resulting list of 24 habitat types can (in most cases) be cross-walked to the Northeast Classification and the original NH WAP. For the purposes of climate change vulnerability assessments, habitats were grouped into four categories: 1) Forest, 2) Freshwater Wetland, 3) Aquatic, and 4) Coastal. We also completed assessments for habitat types that did not fit into these categories, including pine barrens, early successional habitats, and alpine.

### **Forest**

- High Elevation Spruce-Fir
- Low Elevation Spruce-Fir
- Northern Hardwood-Conifer
- Hemlock-Hardwood-Pine
- Appalachian Oak-Pine

### **Freshwater Wetland**

- Floodplain Forest
- Vernal Pools
- Northern Swamp\*
- Temperate Swamp\*
- Peatlands
- Marsh and Shrub Wetlands

### **Aquatic\*\***

- Coldwater Ponds
- Stratified Lakes and Ponds
- Coldwater Streams
- Warm Rivers
- Lake and River Shores\*

### **Coastal**

- Salt Marsh
- Dunes
- Coastal Islands
- Estuarine\*
- Marine\*

### **Other Habitats Done Individually**

- Pine Barrens
- Early Successional: Anthropogenic Grassland and Shrublands
- Alpine (incl. Talus and Rocky Ridge)

Not considered vulnerable: Caves and Mines, Cliffs

\* This habitat not included in original NH WAP.

\*\* The original NH WAP used watersheds to classify aquatic habitats, so there is no correspondence here.

Habitat vulnerabilities were discussed at seven meetings (corresponding to the habitat groupings above) in the fall of 2011 and, for coastal habitats, in January 2012. For each meeting, NHFG invited experts on the relevant habitat(s) and instructed them to consider each habitat's sensitivity and exposure to climate change, as

well as its capacity to adapt. Participants were provided with a list of stressors and how they were expected to affect NH by the end of the 21<sup>st</sup> century (Table 1). Input from these meetings was compiled into a vulnerability narrative for each habitat and are included in the habitat assessments in Appendix A. Any input participants provided on conservation strategies that might address the impacts of climate change on that habitat were incorporated into the next task.

Some individual species or species groups may be more directly affected by climate change. These include moose, brook trout, and animals dependent on snowpack like American marten and snowshoe hare. The vulnerabilities of these species were analyzed by individual experts on those species. The results are in Appendix B.

## DEVELOPING STRATEGIES

Following our effort to compile habitat vulnerabilities, NHFG hosted four strategy-setting meetings. Invitees included policy specialists, state and federal agency biologists, planners, permitting agents, land protection and stewardship staff from agencies and NGOs, natural resource professionals, regional planning commission staff, representatives from lake, stream and watershed advisory committees, academics, and educators. Four regional meetings (Concord, Keene, Lancaster, and Greenland) were held to accommodate people from various regions of the state. Two additional meetings were held; one with NH's two largest land trusts (NH Chapter of The Nature Conservancy and the Society for the Protection of NH Forests) and the other with the NH Department of Environmental Services (DES) CLEANR team (a group of DES staff that is working to coordinate climate, land-use, energy, and natural resource efforts within the agency).

Prior to the meetings, participants had the opportunity to review the habitat vulnerability assessments posted on the NHFG website. At each meeting, participants were first introduced to the major vulnerabilities and then worked in smaller groups to brainstorm strategies to address those vulnerabilities. The smaller groups looked at major habitat groupings (terrestrial habitats, wet habitats, or coastal habitats) individually, and could provide inputs on specific habitat types, groups of habitats, or overall strategies. The smaller groups then prioritized the most important strategies. This helped to identify strategies that were most climate-focused for including in the final version of the plan. The participants were also invited to identify which strategies their organization might be interested in working on. For the two meetings with NGOs and DES, the whole group looked at all habitats simultaneously. The strategies collected were then compiled, assessed as to whether they directly addressed climate change vulnerabilities, and edited.

Overarching strategies that apply to all habitats or to the larger habitat groups are listed in the Conservation Strategies section. Strategies addressing the needs of specific habitats are included in each Habitat Assessment in the appendices.

## OTHER PUBLIC INVOLVEMENT

The process of creating the WAP Climate Change addendum began in the summer of 2010, when NHFG and its conservation partners convened "Wildlife Summit III" on June 11. The Summit was a one-day gathering with the morning devoted to overview presentations by agencies and partners on the issue of climate change, followed by a group discussion of critical issues. In the afternoon, the participants broke into five groups to further refine the issues identified in the morning and identify key players and next steps needed to address those issues in NH. Prior to the Summit, participating agencies and organizations submitted brief statements outlining their current activities related to climate change to help identify what was currently occurring in the state regarding climate change and so discover ways to integrate with them. Results for that meeting are found in Appendix D.

A group of the largest agencies and organizations that deal with ecosystems and wildlife met to discuss next steps. The group directed NHFG to develop a method for assessing vulnerabilities of species and habitats and developing strategies to address those vulnerabilities. NHFG assigned this task to the Wildlife Action Plan

Implementation Team, a standing committee of NHFG and conservation organization biologists who meet monthly to prioritize implementation of WAP strategies. Organizations represented in all meetings are found in Appendix C.

The Wildlife Action Plan Implementation Team developed the process for assessing vulnerability. They compiled and approved a list of climate stressors (Table 1) that would be the assumptions that the assessments would use. The vulnerability assessment and strategy planning activities were accomplished in a series of stakeholder meetings, which included a broader spectrum of experts in a variety of environmental and natural resources fields.

The draft of the Plan was sent out for review by all those who participated in the vulnerability assessments or strategy planning sessions. This public input was considered and incorporated into the plan where appropriate.



## RESULTS OF THE VULNERABILITY ANALYSES

In this section we summarize the major effects of climate change on each habitat grouping, based on the results from the vulnerability assessments. Results for each individual habitat type may be found in Appendix A: Habitat Assessments.

Coastal habitats are highly vulnerable to climate change due to sea level rise and the results of flooding and storm surge. Freshwater habitats are also vulnerable to flooding. Some effects on coastal and freshwater habitats have already been seen, such as more frequent 100-year floods and severe storms battering the coast. Forests and other terrestrial habitats are relatively more resilient, and the changes there are based more on the responses of individual plant species to climate stressors than major weather events. The effect on forests is expected to occur over a longer time period.

### COASTAL HABITATS

One of the most dramatic predicted effects of climate change in coastal habitats will be related to sea level rise. The predicted high water levels will inundate salt marshes, deepen estuaries, and convert marsh grass to mudflat and mudflats to subtidal zones. High tides and storm surges will move dunes, a habitat particularly threatened due to the lack of natural sediment movement as well as the lack of undeveloped places for these dunes to migrate to. If the rate of sea level rise is rapid, affected habitats will be inundated more frequently, putting their associated species at high risk. Total habitat and species losses are particularly likely in developed areas where there are no natural habitat retreat areas to allow for salt marsh migration.

In estuarine systems, influxes of freshwater from increased storm events may alter salinity. Increasing depths will change suitability of habitat for eelgrass and some marine animals. Changes in shallower areas include inundation of mudflats and creation of new ones.

Salt marsh habitats may also lose pioneer species and salt pannes due to reduced incidence of ice scour. This habitat is also sensitive to changes in salinity from freshwater inputs.

Rocky shores and islands will not be as affected except in low lying areas. Most intertidal species may shift to higher elevations but will be subject to more heavy surf during storms. Island-nesting birds may lose habitat or experience reduced productivity as a result of changes to available prey.

In marine systems, altered salinity may be a factor in the nearshore area, with freshwater inputs from increased flooding decreasing salinity. Other more complex interactions may change salinity concentrations up or down in certain areas. More problematic are trophic cascades and northward species migrations in response to warmer temperatures. Plankton blooms may no longer coincide with fish breeding and migration, thus impacting survival and reproduction. Invasive species and pathogens may also increase as the ocean warms. Changes in pH are also expected to alter calcium availability for mollusks.

### FRESHWATER HABITATS

Climate change is expected to affect hydrology in a number of ways. Total annual precipitation is not expected to change significantly, but the temporal distribution of the precipitation will. More severe storms, increased summer drought, and less snow cover are the most common predictions.

For wetland systems, this may mean increased surface water at various times of year, and decreased soil moisture at others. Higher temperatures may increase evaporation of surface waters and result in additional losses of moisture through transpiration resulting from increased plant growth (itself due to longer growing seasons and

warmer temperatures). Species that are more tolerant of a wide range of hydrologic conditions will be favored, and the total species richness may decrease. In peatlands, summer drought may increase decomposition rates of peat, decreasing peatland habitats. This is also predicted in wetlands with more organic soils, including northern swamps. Invasive plants may increase, particularly in more temperate swamps and marshes. Vernal pools may dry earlier, or have more inter-annual variation, affecting pool-breeding amphibian species in particular.

Surface waters may experience increased temperature and evaporation. Ice cover may be reduced in duration and extent. Increases in flooding will damage stream and river habitat and wash more nutrient and sediment from uplands into surface waters. Coldwater species will likely have to adjust to temperature shifts in both streams and lakes. Anoxic conditions in lake bottoms may increase. Human responses to increased flooding such as straightening, channeling, deepening, and sediment mining may have a more lasting effect on the streams than the flooding itself.

Floodplain habitats may experience more flooding, possibly with altered timing and duration, and will also be affected by summer droughts. The end result may be altered species composition, including more invasives and gradual colonization by southern species. Human responses to flooding may change flow patterns, if flood control dams or other structures alter where and how storm water is stored. However, if one human response is to abandon flood prone areas, those floodplains will be ideal for habitat restoration. Other shoreline habitats may experience increased erosions due to floods and provide more disturbed habitat for invasive plants.

## TERRESTRIAL HABITATS

Forests are expected to change, but the degree and how they will change may differ amongst forest types. It is likely that our species-based definition of Natural Communities may change, as individual plants react differently to increases in temperature and changes in the hydrological regime. Species' ranges will shift individually based on unique tolerances, and different associations may occur. Changes will occur due to specific site conditions, so will vary across the landscape.

High elevation spruce-fir forests may be the most affected, as warmer temperatures will allow species like yellow birch to migrate to higher elevations. The warmth will also reduce recruitment (seedling production) for species such as balsam fir. Additional stressors added to current stressors such as acid deposition might accelerate the loss of habitat. Pockets of high elevation spruce fir forest may remain, however, in areas where poor soils and rime ice prevent other tree species from colonizing. In general, hardwood-pine forests will move northwards and up slope. Appalachian oak-pine forests are likely to increase in extent, as warming conditions allow these more warm-tolerant species to move north.

Other factors likely to influence forest composition and condition include disturbance, invasives, and drought. More frequent disturbance events, such as ice storms and hurricanes, will open up more areas of forest to early-successional species like paper birch and aspen. This will also allow the recruitment of more southern species. An increase in forest pests is likely with warming conditions and summer droughts. Currently known pests, such as hemlock woolly adelgid, are likely to move northwards. New pest invasions are also likely including spruce-fir pests currently attacking southern Appalachian forest. Drought may change the soil composition and warming temperatures which reduce seedling recruitment in lowland spruce-fir forests. Drought may also increase fire risk in some forests, but this is unlikely to be a major change.

Increased demand for alternative energy facilities and their associated transmission lines is likely, and both have the potential to fragment forest landscapes. Wind facilities affect higher elevation and ridge top forests, where they create large openings that remain in early successional stages and provide corridors for movement of species, particularly predators. Transmission lines create areas of shrublands and avenues for invasive species. Increased interest in biomass production could affect forests, unless the harvesting is done with sustainability of the forest as a main goal.



Pine barrens are less vulnerable to climate change since their species are adapted to warmer temperatures and drier conditions. Local microclimate changes may affect some individual species. Early successional habitats may increase on the landscape as a result of increased disturbance (i.e. from storms or pest infestations). Management will still be necessary to maintain these habitats, and invasive species will continue to be an issue.

Alpine habitats in New Hampshire tend to occur above the planetary boundary layer (the lowest part of the atmosphere directly influenced by the planet surface). Above that the winds and temperatures move more freely above the earth. This means that climatic trends are usually decoupled from those at lower elevations (e.g., temperatures have not risen as significantly at the highest elevations) (Seidel et al 2009). As a result, this habitat may be more resilient to climate change than previously believed. That said, there could be increased encroachment of trees if snowfall increases at high elevation and shelters woody growth against the effects of wind and ice. Earlier snowmelt may allow alpine plants to bloom earlier, making them more susceptible to frost and potentially lowering seed production.



## CONSERVATION STRATEGIES

The strategies listed below represent ideas compiled during strategy brainstorm sessions with experts. We expect that strategies and priorities will require refinement as we learn more about the specifics of how climate change will affect habitats and species. Natural systems are highly integrated, and there are many places where terrestrial, aquatic and coastal habitats will be in close proximity and influence each other.

Human actions and behaviors in response to changing patterns in climate, weather, and environmental change can have significant impacts on ecosystems and wildlife. Conservation, environmental policy and regulation, and land management should anticipate changes in a way that maintains functioning natural systems. On the other hand, human activities that increase the risk to environmental integrity, human safety, or infrastructure loss should be avoided. There are issues, such as flooding, that affect humans and ecosystems, and the solutions can be beneficial to both. Some infrastructure solutions may worsen the impact for ecosystems, such as increased flood control dams or levees. Natural systems can play a key role in mitigation the effects of climate change. It is critical that agencies, NGOs, planners, researchers and municipalities work together towards common solutions. In particular, conservation of land and restoration of natural land features and functions will help maintain ecosystem integrity while building resilience against climate change.

These strategies have been organized by major types of actions. There is significant overlap among both categories and strategies; we attempted to assign strategies where there was the most direct connection to a particular category. The strategies included in broad categories affect multiple habitat types, while habitat-specific strategies are included in the Habitat Assessments in Appendix A. Discussions with partners who will be involved in the implementation of this Plan will aid in assigning priorities to these strategies.

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S3: Restore Watershed Connectivity
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response
- S8: Revise Water Withdrawal Policies
- S9: State Energy Policy
- S10: Funding
- S11: Modeling, Research and Monitoring
- S12: Technical Assistance and Outreach

Three broader themes emerged from the development of the strategies. These themes encompass commonalities among actions that otherwise apply more specifically to individual habitats or vulnerabilities and that also address some of the most pressing current needs related to climate change. These themes cover strategies in multiple categories, and are grouped partially by the scale (both spatial and temporal) at which actions are implemented.

**Short-term Implementation (short-term, small scale):** Despite the need for further assessment and ongoing planning, there are things that can be done now to minimize the effects of climate change on both ecosystems and humans. Many of these relate to floods and flood response, particularly given recent history in this regard. In cases such as these, it is beneficial to be both proactive - by re-engineering existing structures to better withstand climate change - and appropriately reactive by replacing damaged infrastructure to better suit new conditions. Such decisions should be informed by both assessment and planning as discussed above.

**Landscape Assessment and Conservation (long-term, large scale):** Any response to climate change should take advantage of existing and emerging knowledge to identify areas that are more resilient, more likely to adapt, or that are at highest risk. These areas, whether stream reaches, contiguous blocks of forest, or undeveloped coastal

wetlands, should be protected or restored while the costs of doing so are relatively low. Modeling can and should be applied to better determine priorities in this regard.

**Partnerships:** Because climate change occurs at a large scale, it is imperative that agencies, NGOs, planners, researchers and municipalities work together towards common solutions. Examples of effective partnerships include both planning and education. Proper planning will allow communities to understand how natural systems can provide key ecological services - such as flood water storage, erosion prevention, protection from storm surges - and take advantage of these free or low-cost alternatives to infrastructure that also preserve habitat. Associated with successful planning is a need for outreach to decision makers on the importance of ecological services and potential effects of climate change on communities. And broader-based education efforts directed at all members of the public are critical for future success of both planning and policy initiatives.

Finally, addressing climate change will also require a regional and national approach. Collaborating with regional entities and other states will be important as we go forward. One current initiative, to coordinate the northeast states' Wildlife Action Plans, offers a great opportunity to address climate change and implement more comprehensive strategies that impact multiple species. For instance, states to the south will be identifying and trying to stop the spread of cold-intolerant invasive species, and their actions will help prevent those species from spreading to New Hampshire. The collaboration among the northeastern states will provide a forum for region-wide strategy development and implementation.



## LIST OF STRATEGIES

Note: the numerical codes used for this section are for reference only, and do not reflect any prioritization.

### S1: CONSERVE AREAS FOR HABITAT EXPANSION AND/OR CONNECTIVITY

Ensuring long-term viability of wildlife includes providing ways for them to move across the landscape as climatic conditions change. Species composition in many habitats is likely to change. Land conservation should be focused on connecting habitats to facilitate migration of species and support intact ecosystems over time despite changes in climate. See also *S3: Protect Riparian and Shoreland Buffers* for strategies more related to aquatic systems.

S1.1: Protect large diverse areas of multiple habitat types, including the largest remaining forest blocks. Aim to maintain functionality within key assemblages of species.

- Focus land protection efforts on establishing linkages along latitudinal and elevation gradients that have been identified as important corridors for wildlife movement and potential habitat migration. Include consideration of key “pinch points” to wildlife movement (e.g., road crossings), riparian areas and floodplain forests and adjacent upland habitats surrounding all types of surface waters.
- Include consideration of physical features that will not change – topography, soils, etc. – to protect the biodiversity spectrum.

S1.2: Protect coastal lands to allow for migration of habitats.

- Protect land adjacent to existing intact coastal habitats to allow for migration due to sea level rise. Prioritize the areas that will have the greatest benefit for habitats and human safety. Ensure the prioritization is subject to adaptive management as new information becomes available. A large variety of tools for protection should be considered and may include rezoning and restrictions for rebuilding of infrastructure after flooding. Federal and/or state funding for buy-outs may be needed.

S1.3: Protect wetland and riparian habitats to increase resiliency from effects of climate change for wildlife and humans.

- Prioritize the preservation and restoration of wetlands that mitigate impacts of climate change (e.g. absorb floodwaters, release water during droughts) particularly in areas that still function as intact hydrologic units. Provide incentives to landowners to protect wetland functions. Create BMPs for forestry around and in wetlands that help wetlands retain water during droughts.
- Include features that protect other resources such as along streams and shorelines to help mitigate flood events and associated erosion.
- Increase land conservation focused on riparian areas and floodplain forests and adjacent upland habitats surrounding all types of surface waters and wetlands to allow for habitat expansion and recovery after disturbances.

S1.4: Build habitat migration capacities by using innovative land acquisition strategies. Use innovative methods like land exchanges and rolling easements for land protection. Land exchanges are land swaps involving government and private lands enacted to protect critical resources. Swaps could be used to acquire coastal habitat to allow for migration or to facilitate restoration of natural habitat. Rolling easements are a combination of options that allow for use of coastal lands that at some point will be inundated while preparing for the eventual abandonment to allow for natural coastal habitat migration (Titus 2011).

S1.5: Add climate adaptation scoring criteria to land protection funds such as the Land and Community Heritage Investment Program and the Aquatic Resource Mitigation program.

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## S2: HABITAT RESTORATION AND MANAGEMENT

Although habitats are likely to change in species composition over time, there are many actions that can increase resiliency in species populations. These activities may also reduce the effect of human responses to climate change (mitigation and adaptation). See also S3: *Restore Stream Connectivity* and S4: *Protect Riparian and Shoreland Buffers* for more strategies specific to stream and riparian habitat restoration and management.

S2.1: Develop restoration plans that meet multiple ecosystem and ecosystem service objectives, including those pertaining to human adaptation. Address both traditional needs and climate change adaptation needs to build efficiencies.

S2.2: If drought conditions cause a significantly increased risk of wildfires, establish statewide fire management plans with goals for fuel reduction and burning. Include a goal of educating the public on the importance of fire to reduce wildfire risk and maintain habitat condition.

S2.3: Use public and private conservation lands to demonstrate management activities that build resiliency. Focus work in areas identified as being more resilient (see S11.1).

S2.4: The New Hampshire Climate Action Plan identified the maintenance of working landscapes (i.e. forest and timberlands) as essential to avoiding habitat loss. Work with the Department of Agriculture and NH Department of Resources and Economic Development to support the retention of working landscapes while encouraging stewardship of the land that best supports wildlife. Promote BMPs that reduce impacts of harvesting and recreational use (especially due to trail erosion) on habitats sensitive to climate change impacts.

S2.5: Identify policies and tools (such as land regulations, incentives, building regulations) designed to maintain or restore pervious surfaces, nutrient barriers, vegetation buffers and wildlife passage.

S2.6: Initiate on-the-ground strategies, such as road barrier mitigation and efforts to influence driver awareness of wildlife crossings, to facilitate movement through wildlife linkages identified through modeling (see S11, S6). Additional possible strategies include increasing road visibility, signage, modification of guardrails, improved culverts, and reduced salt use in sensitive areas. A possible model to emulate would be the “Staying Connected in the Northern Appalachians” project.

S2.7: Monitor ecosystem recovery following disturbance events. Apply adaptive management to respond to changes in flood frequency and intensity and other effects of climate change.

S2.8: Provide incentives for removal or modification of infrastructure identified as barriers to ecosystem services integrity.

S2.9: Develop and promote guidelines for both timber harvesting and development that encourage maintenance of sufficient forest cover in watersheds to help mitigate high floods and reduce erosion hazards.

S2.10: Identify barriers to flooding and habitat migration and provide recommendations and incentives for removal of infrastructure that will be impaired or destroyed by sea level rise, increased storm surge, or riverine flooding. Tools could include incentives, abandonment, insurance increases, altering culvert sizes, etc. Encourage changes in public policy to affect this objective.

S2.11: Require new or modified infrastructure (roads, culverts, bridges, critical facilities) to account for sea level rise and larger riverine flooding events according to lifespan of infrastructure.

S2.12: Accelerate use and acceptance of town based ordinances that define, map, and regulate flood hazard zones along rivers

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### S3: RESTORE WATERSHED CONNECTIVITY

Rivers and streams connect aquatic and floodplain habitats across all gradients of topography and landform. Restoring connectivity that has been affected by dams and culverts will increase resilience of aquatic organisms and their habitats. For many aquatic species, the ability to move within a watershed to seek out suitable habitat under changing climate conditions will be the difference between survival and extirpation. Stream crossings designed to allow aquatic organism passage will be less likely to sustain damage during storm events.

S3.1: Restore or mimic natural flows to streams and rivers through changes in the ways dams are managed. Work with Federal Energy Regulatory Commission and DES to implement strategies developed by the DES Watershed Management Bureau that provide wildlife connectivity, habitat resilience and lead to intact ecosystems now and in the future.

- Work with dam owners including utilities to manage more natural water flow in rivers and streams below and above dams and to protect fragile shallow water habitats from winter drawdowns.
- Provide incentives or create regulations to encourage or compel hydropower dam owners to develop and maintain fish passage and run-of-river hydropower.
- Implement statewide instream flow regulations and policies that sustain vegetative communities and/or aquatic species (i.e., fish and mussels), and establish water rights to sustain those flows.
- Remove more dams based on emerging regional and state-wide models, e.g., recent Northeast Association of Fish and Wildlife Agencies projects) when said removal will result in demonstrable environmental and/or social benefits (e.g. habitat restoration, flood storage, etc.).
- Limit dam building and channelization of tributaries.

S3.2: Through improvements in both dams and culverts, re-connect fragmented stream reaches to provide habitats for aquatic organisms and the ability for fragmented populations to reconnect.

S3.3: Require all replaced culverts (by NH Department of Transportation and by towns) to be sized properly for the stream in question, in order to accommodate wildlife passage and increased flows anticipated due to climate change.

S3.4: Assess culverts to identify and prioritize the replacement of those with the most potential to exacerbate the effects of climate change including increased flooding, decreased connectivity, and increased potential to enhance the effects of sea level rise. Use the NH Geological Survey as a repository for existing and new data. This will help towns plan and prepare for or mitigate flooding events before storms occur. Prioritize culvert replacement using a risk study (e.g., Oyster River study, UNH 2011). Add to the model by including scoring for culverts that increase aquatic organism habitat connectivity the most.

S3.5: Research and distribute information on costs associated with maintaining/replacing undersized culverts to towns, road agents and select boards, including both initial upgrade and long-term maintenance costs (unblocking culverts).

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#### S4: PROTECT RIPARIAN AND SHORELAND BUFFERS

Because intact riparian buffers both protect wildlife habitat and reduce risks associated with flooding, accelerating and promoting their protection provides multiple benefits in the context of climate change, including water quality. From a wildlife perspective, buffers help by minimizing temperature increases, reducing habitat erosion, allow for enhanced stream connectivity, and provide corridors for movement across the landscape.

S4.1: Advocate for public policies that constrain development or redevelopment in floodplains; this may also include compensation for landowners for lost structures or reduced land values.

- Develop wetland, stream, shoreland and coastal buffer requirements for transportation, development, and post-flood restoration. Buffers should reflect site conditions.
- Strengthen Shoreland Water Quality Protection Act in response to predicted climate change impacts. Articulate the benefits of said changes in order to encourage public discourse on the subject. This would entail increasing the number of trees and other natural vegetation required to be left in the shore zone.
- Advance the use and acceptance of town based ordinances that define, map, and regulate flood hazard zones along rivers. Develop incentive programs that compensate landowners for removing infrastructure in floodplains, including creating floodplain easements and river meander easements in agricultural settings. Develop buy-out programs to reduce development density on shorelines.

S4.2: Since regulatory change is expected to take several years, work with groups of towns to enact town ordinances on floodplain protection and redevelopment. These regional efforts would provide consistency across towns, and provide examples for other towns to follow. The coastal communities are already engaged in climate adaption planning and would be a good starting location.

S4.3: Work with US Army Corps of Engineers, FEMA, US Geological Survey, and GRANIT to update floodplain maps taking climate change into consideration.

S4.4: Develop a set of BMPs for shoreline buffers, including information on shoreline hardening, bank stabilization, vegetation restoration, and agricultural practices.

- Create goals and guidelines for shoreline buffers to help stabilize banks for more frequent or higher volume flows by using natural vegetation, and proper building setbacks.
- Limit shoreline armoring and protect natural vegetation buffers on shorelines, particularly outside of urban settings.
- Work with Aquatic Resource Mitigation Program to strengthen floodplain, stream-bank and in-river restoration projects.
- Work with agricultural community to promote farm management plans and BMPs for crop and nutrient management that have the least impact on streams. BMPs should include the type of crop planted (e.g. pasture, hay, corn, grains, or vegetables) as well as the timing and use of plowing, fertilizers, pesticides, etc. Include naturally vegetated riparian buffers.
- Improve buffers and restore floodplains, shorelines, banks with natural vegetation, to improve natural flood storage and reduce storm erosion. Associated benefits include surface stabilization, flood mitigation, wetland enhancement, and improved water quality.



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## S5: INVASIVE SPECIES PLAN

Many invasive species (including terrestrial and aquatic plants and forest pests/pathogens) are currently limited by temperature, and are likely to expand northward into New Hampshire as a result of climate change. Such species are best controlled by coordinated regional action that identifies the most important threats and areas at greatest risk, provides best management practices, and engages in outreach on the issue.

- S5.1: Develop comprehensive regional invasive species planning by coordinating among northeast states and other entities. Goals are to minimize spread of terrestrial, aquatic and marine invasives and develop and implement strategies to strategically restrict spread of invasives.
- S5.2: Develop statewide invasive management plan that prioritizes areas for control based on ecological values and degree of threat. The plan needs to identify likely new invaders coming from the south as well as potential imports from other regions of the world. The plan should recommend the level and type of pest monitoring and ecologically sensitive control methods (Integrated Pest Management or IPM). This plan could utilize cooperative invasive species management areas to provide baseline information on invasives present.
- S5.3: Strengthen and implement regulations to protect against human introduction and natural movement of species from other states and other parts of the world.
- S5.4: Increase awareness of exotic invasive plants and animals through outreach to landowners and increase awareness of freshwater and marine invasives in inland and coastal communities and anglers.
- S5.5: Promote best practices to prevent the spread of invasive species from one site to another. Best logging practices should include high pressure washing of skidders etc. prior to moving to a new logging operation. Offer programs through the Professional Loggers Program on invasives species. Promote similar best practices for construction and road maintenance equipment, with workshops offered through other professional organizations.

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## S6: COMPREHENSIVE PLANNING

While most land use planning occurs at the local level, many of the tools and recommendations are created at the state level. Working together, state agencies, regional planning commissions and many other stakeholders can plan for multiple aspects of climate adaptation, incorporating ecosystem services into human mitigation and adaptation efforts. Ecosystem services are resources and processes that natural systems provide, including clean water, clean air, flood control, pollution mitigation, carbon sequestration, food, pollination, building products, medicines, and other functions and products. Many such services would actually be very expensive or difficult to provide through infrastructure. Since intact wildlife habitat improves and enhances multiple ecosystem services, both humans and wildlife will benefit through this process. Cooperative planning will ensure that recommendations made for one sector of planning will consider ecosystems as part of those recommendations.

- S6.1: Incorporate into statutes and promote or require the consideration of ecological services provided by wildlife habitat into land-use planning, municipal and regional master plans, hazard mitigation, transportation planning and infrastructure decision-making at all scales, e.g. floodplain habitats and wetland buffers mitigating flood events; properly sized culverts that allow natural flow regimes thus buffering upstream floods and reducing washouts; dunes and salt marshes buffering storm surge; vegetated shorelands protecting lake and stream banks; natural habitats promoting groundwater recharge, etc. Ensure that engineering/infrastructure does not exacerbate problems, especially those that can better be mitigated by natural systems. Diversions, barriers, shoreland hardening (e.g., rip rap) can all cause issues downstream or

along the shore in the event of flooding. Add criteria on climate change to the funding sources that pay for this type of planning.

S6.2: Develop a set of guidelines and provide incentives for communities to incorporate wildlife-friendly and climate-smart actions into master plans, hazard mitigation plans, adaptation plans, and town ordinances. This will include existing practices, like creating conservation plans, requiring conservation subdivisions, Low Impact Development (LID) practices, and road crossing design, as well as new ones developed as we learn more about climate impacts. This may be partially accomplished through the Granite State Future project. Elements of this include:

- Require low impact development/design to decrease impacts from extreme precipitation.
- Make connections between water quality and habitat protection with climate resiliency and how that can be expressed in local land use regulations.
- Encourage the use of wildlife habitat connectivity maps in conservation plans.

S6.3: Encourage the adoption of changes in the planning board and conservation commission New Hampshire Revised Statutes Annotated (RSAs) (i.e. NH laws) to include adaptation management strategies.

S6.4: Incorporate climate change into river management plans and identify at-risk reaches and sensitive habitats as well as opportunities for dam removal and culvert improvement.

S6.5: Identify and map fluvial erosion zones and floodplain zones for management and protection.

S6.6: Use the results of Sea Level Affecting Marshes Model (SLAMM) and other appropriate sea level rise models to understand where coastlines and where habitats might migrate. Create future scenarios that demonstrate changes if obstacles to habitat migration are removed or mitigated (e.g. roads abandoned, culverts appropriately sized, head-of-tide dams removed). Assess feasibility of these mitigation measures.

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## S7: STORMWATER POLICY AND FLOOD RESPONSE

Climate change is likely to result in more frequent and more severe storm events, causing more frequent and widespread flooding. This has already been seen in NH over the past few years. Emergency flood response has allowed activities that would not be allowed under normal circumstances, generally under emergency conditions that exempt permits. Examples include using excavators in stream beds to mine gravel for road repair and blown-out culverts not always being replaced by ones sized appropriately for the new flows. Proactive planning in preparation for floods will allow a more coordinated and environmentally safe response.

Protection of streams themselves is critical for the long term health of the streams. In addition, protection of headwater streams is critical for the long term health of aquatic ecosystems.

Traditional storm water management practices have directed runoff into surface waters. In addition to the potential to directly damage habitat and infrastructure, more intense precipitation events will also result in higher runoff into water bodies, resulting in higher levels of pollutants (particularly road salt and oil), nutrients, and sediments. Depending on location and season, runoff can also increase temperature and salinity in the receiving water body. Storm water runoff from increasing impervious surfaces in coastal New Hampshire has been linked to deteriorating habitat and water quality in the Great Bay Estuary (PREP 2013). Disconnecting storm water runoff from surface waters will require a fundamental shift in philosophy toward dealing with storm water at the local and state level. Replacing existing or newly constructed infrastructure with management practices that encourage groundwater infiltration will protect both water supply and water quality during periods of extreme

precipitation or drought. Directing runoff into the ground, rather than surface waters, reduces the flashiness of rivers and streams during floods, filters out pollutants, and increases groundwater storage, which improves flows during periods of low water and high demand.

- S7.1: Create guidelines or rules for flood disaster response in rivers to ensure flood response actions do not create conditions where flood damage will be worse in subsequent storms or increase the damage from the current storm. For example, replace culverts with culverts sized appropriately for the stream and able to handle the higher flows due to climate change; discourage the straightening of stream and river channels and the mining of gravel from stream beds. These strategies will require guidance and collaboration with multiple federal (such as Federal Emergency Management Agency (FEMA)) and state agencies (Safety: Homeland Security and Emergency Management, DES, Department of Transportation, etc.). Use the New England Interstate Water Pollution Control Commission to work with FEMA as appropriate.
- S7.2: Develop model ordinance language and/or policies and/or incentives to reduce redevelopment in flood prone zones after flooding. Support policy changes at FEMA, Coastal Zone Management, and other agencies to discourage post-storm rebuilding in areas vulnerable to sea level rise and storm flooding, increase setbacks, and change building codes to be climate smart. These policies should help municipalities make better land-use decisions.
- S7.3: Develop strategies and decision trees to respond to infrastructure that will be impaired or destroyed by sea level rise and increased storm surge. Tools could include abandonment, insurance cost increases, altering culvert sizes, financial incentives, etc.
- S7.4: Develop educational materials explaining how flooding impacts both aquatic life and human safety; provide to key partners (e.g. NH Silver Jackets Team (multi-agency flood response team) and the Coastal Adaptation Workgroup) so that they better understand the impact of their decisions on flood response to natural communities.
- S7.5: Create and require implementation of infiltration best management practices (BMPs) and Low Impact Development (LID) storm water management systems based on climate predictions to minimize impacts to aquatic habitats. These BMPs should address a wide variety of land uses.
- S7.6: Incentivize use of existing and new technology to increase infiltration including permeable pavement and other surfaces, catchment systems, green roofs, and other LID techniques.

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## S8: REVISE WATER WITHDRAWAL POLICIES

Longer and more intense summer droughts may occur due to potential precipitation changes wrought by climate change. Increased spring flooding may decrease groundwater recharge due to increased surface runoff. Water management through both stormwater policies and water withdrawal management is necessary to protect groundwater reserves, and the habitats like wetlands that depend on them.

- S8.1: Regulate cumulative water withdrawals, both for residential and commercial purposes, to prevent these withdrawals from exacerbating the effects of droughts on natural habitats.

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## S9: STATE ENERGY POLICY

Alternative energy sources and the infrastructure required to transport the energy (i.e. transmission lines) can degrade and fragment habitat. The best sites for wind are generally ridgelines and often associated with high elevation spruce-fir forests, which are already at risk from climate change. The balance between the ability of these energy sources to reduce carbon dioxide production and the damage to habitats must be considered. Careful siting of these facilities, including considering cumulative effects, can significantly reduce impacts to critical habitats. Unsustainable biomass harvesting can also degrade habitat.

- S9.1: Enact statewide policies and guidelines on wind facility siting that identifies the most critical wildlife habitats and helps steer wind companies away from those areas and into places where the impact would be less severe. The guidelines should consider habitat type, extent of habitat patch, needs of species, conservation designation, cumulative effects and wind potential. Possibilities for mitigation should be included. The development of these guidelines and policies should be done by a team which includes both wildlife biologists and wind company representatives, among others.
- S9.2: Balance incentives for renewable energy (biomass, wind, etc.) with the protection of other sustainable ecosystem values, particularly minimizing habitat degradation and fragmentation. Energy conservation programs (technical assistance and funding including the Renewable Energy Fund) should be a part of these policies.
- S9.3: Provide incentives to hydropower dam owners for the development and maintenance of fish passage and run-of-river hydropower.
- S9.4: Develop BMPs for biomass production that is sustainable both for biomass and wildlife. Evaluate biomass project guidelines for potential impact on forest type (e.g., does it speed community shifts in certain habitats?). Since there are conflicting studies on the effect of harvesting on carbon sequestration, the levels of biomass production should take into account the most recent accepted scientific understanding of carbon sequestration. These BMPs should be incorporated into *Good Forestry in the Granite State*.

**The following three sections apply to all habitats and all species.**

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## S10: FUNDING

Funding can provide incentives for changing the ways humans interact with the environment.

- S10.1: Maintain or increase major federal grant and funding programs and include climate adaptation points in proposal scoring.
- S10.2: Revise ranking criteria for grants and loans that provide funding for land protection, habitat management, planning and development to include climate adaptation elements. Define key metrics and encourage funding sources to consider incorporation of said metrics into their ranking process. Funding sources could include LCHIP, The State Revolving Fund, The Renewable Energy Fund, ARM, Drinking Water funds, wetlands restoration funds, NRCS funds, and others.
- S10.3: Create multi-organizational collaborative projects focused on habitats and adaptation to increase likelihood to obtain and leverage funds.

S10.4: Financially support efforts to maintain connectivity across political boundaries (e.g., US/Canada, between states).

S10.5: Include explanation and justification of economic and human benefits, such as health and safety, for each strategy to build community support for funding. Conduct cost-benefit analyses for both short and long-term costs.

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## S11: MODELING, RESEARCH AND MONITORING

Modeling, research and ongoing monitoring of species, species assemblages, and ecosystems are critical to improving our understanding of the effects of climate change on NH's natural systems. New knowledge will allow for adaptive management of species and habitats, changing how and where we act. It can also provide more information on the value of ecosystems services to human efforts at mitigation and adaptation. This list of strategies can be viewed as a beginning step. There will be more questions raised at every juncture. Monitoring provides data to trigger adaptive changes in management or other activities.

### Modeling

S11.1: Use data from Anderson et al. 2012 and other studies and models with New Hampshire-based data to create a statewide/local map showing habitats and areas that may be most resilient to climate change.

S11.2: Incorporate the resiliency work and other adaptation issues into the ranking for creating the Wildlife Action Plan Highest Ranked Habitat map. Use this to identify key high-priority areas for conservation in the context of climate change for both natural and ecosystem service demands.

S11.3: Identify priority landscapes to provide connectivity between habitat patches.

- Perform connectivity analyses throughout the state to identify key road crossings and current and incipient bottlenecks for movement of plant propagules and wildlife. These analyses could be done statewide or in smaller regions.
- Identify networks of corridors and associated fragmentation barriers whose restoration facilitate species movement over the long term.
- Develop predictive models and assess accuracy based on permanent monitoring sites (including Surface Elevation Tables (SETs), which measure saltmarsh accretion rates in salt marshes; and rocky shore, aerial mapping of rocky shores and dune extent; and biomonitoring for key indicators of climate change in all habitats.) Then develop an understanding of the feasibility of modifying policies on development and sea level rise, etc.

S11.4: Identify, through modeling, watersheds where water conflicts between humans and natural systems due to drought and flooding are likely to occur and protect a broad suite of interrelated ecosystem services that also protect natural habitats.

S11.5: Model hydrologic change based on climate models including the new US Geological Survey precipitation models for NH.

S11.6: Use Sea Level Affecting Marshes Model (SLAMM ) and associated sea level rise measurement infrastructure to understand where sea level rise will most affect the coast and where habitats might migrate. Create future scenarios that show the differences if obstacles to habitat migration are removed or mitigated (e.g. roads and other infrastructure abandoned or removed, culverts appropriately sized, head-of-tide dams

removed). Assess feasibility of these mitigation measures. Then re-zone and work to protect these areas that may be able to evolve to productive coastal habitats.

## **Research**

- S11.7: Use Forest Inventory Analysis (FIA) and other data to assess how forest communities have already changed to demonstrate potential associations with climate patterns, and use this information to project changes onto future landscapes.
- S11.8: Research how climate impacts soil and soil ecology, and use this to begin to determine how natural communities and habitats may change.
- S11.9: Connect soil-water movements across different catenas (topographic complex of soils) to shifts in plant community structure to better understand future effects of shifting groundwater.
- S11.10: Promote research on silvicultural techniques that can be used to manage forests for likely future species composition. Explore forest management techniques in the southern states with similar geology and soils so we can prepare for possible impacts.
- S11.11: Evaluate biomass projects for potential impacts on forest type (e.g., does it speed community shifts in certain habitats?). Develop new BMPs for biomass harvesting as appropriate.
- S11.12: Assess potential changes of fire risk from drier weather and increased downed wood.
- S11.13: Investigate changes in phenology that may cause species to become endangered.

## **Monitoring**

- S11.14: Establish or expand a network of monitoring plots to observe climate related changes, and coordinate among monitoring efforts. This includes continuing existing chemical and physical monitoring and the addition of new parameters and locations. Monitoring should include long-term wildlife population monitoring, invasive plant species, forest tree and other plant species composition, wetland hydrology, and phenology. In coastal areas, sentinel monitoring for climate change approaches should be instituted to track primary stressors such as temperature, sea level rise and changing physical and chemical regimes that affect ecosystem health. Should integrate and take advantage of existing programs such as FIA. Work in partnership with state and federal agencies, NGOs, universities, co-ops and others. Need to assign responsibility for data collection, compilation, analysis, and storage. This monitoring should provide data to inform adaptive management of species and habitats and to direct necessary changes in policies.
- S11.15: Establish locally relevant tide gauges and SETs in order to measure and predict sea level change hydrodynamics within Great Bay and Hampton/Seabrook. These could be set up on a short-term basis in order to establish the elevation relationship and changes in SLR between Fort Point data (the nearest active National Water Level Observation Network tide station) and other areas of the coast.
- S11.16: Incorporate biodiversity/species richness monitoring and benchmarking in a suite of conservation easements. This can be done as part of the management plan for the easement property. Conduct natural resource inventories at a predetermined frequency to assess system change. Establish thresholds that trigger a discussion of change in management to meet the goals of the easement.
- S11.17: Assess and monitor effects of impervious surfaces across a range of watersheds, focusing on runoff, temperature, and other climate indicators.

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## S12: TECHNICAL ASSISTANCE AND OUTREACH

Addressing the needs of ecosystems and wildlife in the context of human and climate change stressors requires a huge range of partners, from government agencies to individuals. Providing data and recommendations for action to diverse groups is critical to success.

### **For Everyone:**

- S12.1: Develop a short set of talking points on climate change and ecosystems (including ecosystem services and their ability to mitigate effects) that deliver the main adaptation messages to the public. Keep these messages positive and incorporate human values about natural areas, rural character and the economy, including the popularity of maple syrup and fall foliage.
- S12.2: Incorporate the concept of ecosystem services into a variety of education workshops that highlight how intact ecosystems help in flood mitigation, drinking water protection, storm surge protections, water storage during droughts, improved air quality, and our tourism economy.
- S12.3: Develop education and awareness initiatives for policy makers emphasizing the importance of protecting areas important for connectivity. Use maps and other means to illustrate the point.
- S12.4: Engage and educate existing local volunteer groups (Great Bay Stewards, Natural Resource Stewards, New Hampshire Coverts Project, Wonders of Wildlife docents etc.) to take action and educate others on issues related to climate change as it relates to habitats and wildlife.
- S12.5: Create educational and informational signage on the effects of climate change on coastal habitats, especially in public use areas (Parks/Marinas).
- S12.6: Provide government staffers and the legislature with specific stories of climate change and wildlife.
- S12.7: Provide training on ecosystem services and climate adaptation to the private sector so they can use this in their development of adaptation plans and projects considering societal, economic and environmental interactions in an ecosystem-based management framework.

### **For Municipalities and Regional Planning Commissions:**

- S12.8: Incorporate the concept of ecosystems services into municipal education workshops that highlight how intact ecosystems help in flood mitigation, drinking water protection, storm surge protections, water storage during droughts, improved air quality, and our tourism economy. Partner with regional planning commissions on these workshops.
- S12.9: Provide technical assistance to communities to incorporate ecological services into adaptation and other planning, acknowledging that most actions will be at the municipal scale in NH. Work with regional planning commissions so that individual town efforts are rolled into efforts at the state, regional and national scales.
- S12.10: Increase awareness within each community of the importance of green belts and conservation land to allow for the movement of wildlife into areas that are more suitable habitats as changes occur.
- S12.11: Provide examples of good projects that help both wildlife and humans adapt to climate change. The culvert replacements at Nash Stream, which survived the big storm in May 2012, are one such example. Floodplain forest restoration for flood storage is another.
- S12.12: Provide information on climate adaptation, particularly culverts and wildlife road crossings, at professional meetings of road agents, insurance agents, and engineers. Work with the University of New Hampshire Technology Transfer Center program to educate road agents and engineers.
- S12.13: Promote adaptive strategies for habitat management on town-owned as well as private lands.



**For Landowners:**

S12.14: Incorporate information about climate adaptation into the documents and websites that landowners use (Good Forestry in the Granite State, Taking Action for Wildlife, etc.). Address salvage logging after ice storms and pests such as hemlock woolly adelgid. Provide updated information on habitat management that increases resiliency.

S12.15: Educate the public and agencies on how to identify invasive plants that occur south of New Hampshire (but not yet in New Hampshire) so that new invasions are more likely to be reported early before they become too widespread to deal with. Promote best practices for invasive control particularly for logging, construction and road maintenance equipment and in the wood products, shipping and horticulture industries.

S12.16: Provide resource material to lake and river-front property owners showing ways in which simple efforts of property management can minimize erosion, storm water runoff, etc.

S12.17: Given that not all of the land in priority areas identified through modeling will be able to be permanently protected, facilitate development of neighborhood networks (peer to peer networks) to effectively convey issues of climate change and strategies that landowners can use to ameliorate impacts. Include the value of ecosystem services in the conversation.



## HABITAT ASSESSMENTS

### PART I: COASTAL HABITAT ASSESSMENTS

Including Coastal Islands and Rocky Shores, Coastal Dune and Beach Habitat, Salt Marshes, Estuaries, and Marine

#### COASTAL ISLANDS AND ROCKY SHORES ASSESSMENT

##### Habitat overview:

This habitat grouping includes the Isles of Shoals, islands in Great Bay and at the mouth of the Piscataqua River, and rocky shorelines along the New Hampshire coastline. Vegetation varies from low shrub or grass communities in island interiors, to exposed rock in the intertidal zone. Areas regularly inundated by tides support diverse communities of algae and sessile and slow-moving marine invertebrates.

##### Major vulnerabilities:

- Sea level rise may redistribute or reduce the overall extent of these habitats, as shoreline features are submerged and exposed with sea level rise and storm surge. Inland migration may not always be possible and some habitats will experience direct flooding. As an island's area is reduced, a greater proportion of upland habitat will be exposed to the effects of salt spray and other marine influences.
- Increased storm activity could physically alter the vegetation in the intertidal zone.

##### Vulnerability narrative:

Unlike other terrestrial or wetland habitats along the coast, islands and rocky shores are not capable of migration, and as a result will certainly be reduced in extent with sea level rise. For intertidal rocky communities, most species are expected to shift upward but otherwise maintain current zonation (all else being equal). Areas of islands currently above the intertidal zone will be reduced in area, and thus more subject to damage to vegetation from storm action, salt spray, or other factors unrelated to climate change. On the largest or highest islands, where vegetation is not entirely adapted to such conditions, there is potential for salt water intrusion with rising water tables, and negative effects on upland habitats such as forests or shrublands.

Within intertidal areas, increased storm activity has the potential to dislodge sessile plants and invertebrates and/or shift community dominance toward species more tolerant of such disturbance. Loss of some species may have detrimental effects on wildlife (e.g., Common Eider chicks) that forage extensively in this zone.

##### Specific Wildlife Vulnerabilities:

Marine invertebrates that occupy rocky intertidal regions are likely to be affected by many of the stressors identified for marine organisms overall. These include rising temperatures, shifting nutrient availability, and lower pH (reduced calcium availability), plus all secondary effects such as altered trophic interactions and phenological disruption. Increased CO<sub>2</sub> concentrations in seawater will lower pH, potentially to the point that marine diatoms and invertebrates with calcareous shells (e.g., mollusks, corals) are unable to form healthy shells, thus influencing their survival and reproduction (e.g., Green et al. 2009). Increased storm activity, especially during the breeding season, could potentially impact reproductive success of island-nesting seabirds, and these effects would be even more pronounced if nesting habitat was already reduced in extent. These seabirds will also be influenced by changes to marine food webs as described in the marine narrative (e.g., Montevecchi and Myers 1997, USFWS unpubl. data). Heat stress is unlikely to affect any nesting seabirds as their ranges extend far south of New Hampshire.

Competitive interactions have been shown to be important determinants of invertebrate species composition in intertidal communities. In many cases, these interactions are secondarily influenced by climatic variables, such that a dominant competitor prevents species from occupying habitats that are otherwise suitable. If a warming climate negatively affects such a dominant competitor, other species may be able to expand their ranges north (e.g. barnacles, Wethey 2002). These interactions can be complex, and the effects may cascade through the ecosystem in unpredictable ways.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response

#### Specific Strategies

1. Conduct transect monitoring from fixed elevation sites to document species elevational shifts and publicize results.

#### Linkages to other habitats:

- At the lower edge of the intertidal zone, rocky coastal habitats grade into marine benthic habitats. Birds nesting on coastal islands rely on marine fish and invertebrates for food.
- Small areas of salt marsh, beach, or dune may form in protected areas.
- On larger islands, there may be enough interior area to allow the formation of terrestrial habitats (e.g., shrubland, forest) more typical of mainland locations.

#### Citations:

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Montevecchi, W.A., and R.A. Myers. 1997. Centurial and decadal oceanographic influences on changes in northern gannet populations and diets in the north-west Atlantic: implications for climate change. *ICES J. Marine Sci.* 54: 608-614.

USFWS unpubl. data. referenced at: <http://bangordailynews.com/2011/11/29/news/state/changing-fish-diet-killing-baby-birds-say-maine-researchers/>

Wethey, D.S. 2002. Biogeography, competition, and microclimate: The barnacle *Chthamalus fragilis* in New England. *Integ. And Comp. Biol.* 42:872-880.

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## COASTAL DUNE AND BEACH HABITAT ASSESSMENT

### Habitat overview:

Dunes and beaches occupy a very small portion of the New Hampshire coastline, with the largest area in Hampton and Seabrook. While both are comprised primarily of sand and gravel, beaches are non-vegetated areas immediately adjacent to and regularly inundated by the ocean, while dunes occur farther inland and support vegetation. Dune vegetation varies with successional stage and frequency of disturbance, and ranges from relatively sparse grasses in more active dunes to shrublands and woodlands in areas farther from the ocean.

### Major vulnerabilities:

- Sea level rise will reduce the width of beaches, and under extreme scenarios eliminate their associated dune systems. Current human infrastructure (roads, houses, seawalls), largely prevents NH's remnant dune system from migrating inland.
- More intense coastal storms will cause greater beach and dune erosion, and alter patterns of sand deposition.
- If one human response to storms and sea level rise is to build additional protective infrastructure, this would further reduce these habitats' abilities to migrate, and also further alter sand deposition patterns.

### Vulnerability narrative:

As with any terrestrial habitat along the coast, beaches and dunes will be reduced in extent or forced to migrate inland in response to sea level rise. Given their already limited extent, impaired ecological function, and existing human infrastructure, the potential for effective migration in New Hampshire is minimal. Increased frequency of strong storms also has the potential to degrade these habitats through erosion or redistribution of sediment, and while dunes are normally resilient to such disturbance, such resilience may be compromised by poor habitat condition and rising sea levels. Existing infrastructure not only prevents habitat migration, but it can also alter patterns of sand deposition (e.g., behind breakwaters) and thus further alter existing dunes and beaches or their ability to recover. Such effects would only increase if one response to climate change was the construction of additional infrastructure to protect communities from storms and sea level rise.

### Specific Wildlife Vulnerabilities:

Although relatively few wildlife species specifically use dunes, some species (e.g., federally threatened Piping Plover) are restricted to this habitat and are of high conservation concern in the state. Direct loss of nesting habitat to sea level rise is probably the most important factor facing these species. However, increased storm activity, especially during the breeding season, could potentially impact reproductive success, and these effects would be even more pronounced if nesting habitat was already reduced in extent. Species such as migratory shorebirds that rely on dunes and beaches for roosting or foraging (respectively) may lack sufficient food and resting places as habitat area is reduced. Also, as these habitats narrow and push against human infrastructure, human activity and contact may further disrupt wildlife viability, especially in sensitive nesting areas during breeding and nesting seasons.

### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response

### Specific Strategies

1. Map current beach shoreline and then regularly update them to document change. Use existing historic shoreline data (Eberhardt and Burdick 2009) and add areas not already covered to show change that may have already occurred. Determine available habitat type projections with sea level rise based on soil types.
2. Identify areas for possible strategic un-development (areas with minimal infrastructure) to restore for current and future use by shorebirds.
3. Identify potential dune migration areas. Assess feasibility of dune creation and enhancement.
4. Protect dunes from paths and other degradation so that sand can move between dunes.
5. Develop a compensation program to remove and relocate structures in dune areas, particularly after storm damage occurs to structures.
6. Create policies that limit development of hardening structures (seawalls, riprap) which will prevent re-nourishment of these habitats.
7. Build retreat capacity with buffers and rolling easements (Titus 2011) to schedule retreat of structures to allow for inland migration. Note most viable for new development.

### Linkages to other habitats:

- Dunes often provide an important barrier between the immediate ocean and salt marshes, and in their absence the marshes are often smaller or more dynamic.
- Where breakwaters have been installed, these mimic rocky shore habitats and come into direct juxtaposition with beaches and dunes because they tend to alter patterns of sand deposition.

### Citations:

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## SALT MARSH ASSESSMENT

### Habitat overview:

Salt marshes are wetlands dominated by salt-tolerant grasses and forbs, and occur in salt water or brackish environments along the shoreline of Great Bay, the immediate coast, and upstream along unrestricted coastal tributary rivers. The largest area of salt marsh is in the Hampton-Seabrook estuary. These are among the most productive habitats on earth, and serve important roles as nurseries for several aquatic organisms. This habitat category also includes the small area of brackish marsh in New Hampshire.

### Major vulnerabilities:

- Sea level rise will drown existing low marsh (covered by daily high tides) and convert high marsh (covered by tidal extremes such as spring tides) to low marsh. In the absence of areas to migrate, high marsh is likely to be greatly reduced in extent.
- Shifting precipitation patterns (more winter rain, more intense events) could result in increased erosion of salt marsh channels, and less ice-borne sediment inputs during winter. Extreme storm events will be particularly damaging in combination with sea level rise.
- Periods of lowered salinity in association with precipitation events may benefit invasive plant and animal species.
- Increased temperature may accelerate peat breakdown.
- Human response to sea level rise and more frequent storms, in the form of sea walls or other protective infrastructure, will result in tidal restriction and create barriers to salt marsh migration.

### Vulnerability narrative:

By far the greatest threat from climate change to New Hampshire's salt marshes is sea level rise. There is some evidence that salt marshes in the Gulf of Maine have historically been able to keep pace with sea level rise (Goodman et al. 2007, Theriault 2008), but if sea level rises at greater than 4 mm/year, marsh accretion may not occur rapidly enough (Goodman et al. 2007). Under more rapid rates of sea level rise, existing marshes may not only be inundated and converted to estuarine habitats, but existing infrastructure and shoreline topography will severely limit their potential to migrate inland. As a result, there is likely to be a net loss of this habitat type.

Direct losses to sea level rise will be exacerbated by other climate change stressors, including temperature and altered hydrology (below). Warmer temperatures may accelerate breakdown of the peat layer that forms an important part of salt marshes, although data on this issue are unclear. Increased nitrogen fertilization from increased runoff due to more intense storms may also accelerate the breakdown of salt marshes (Deegan et al 2012). Higher temperatures may also facilitate colonization by invasive species that currently occur only in southern New England or points south. Other invasives (e.g., *Phragmites*) could benefit from increased freshwater inputs to salt marshes (e.g., Moore et al. 2011). Salt marshes also provide a sink for greenhouse gases as considerable carbon can be stored in the biomass and peat layers. Salt marshes in decline can release greenhouse gases during decay, thus contributing to accelerated climate change.

From a hydrologic perspective, climate change is expected to lead to increased winter rain, less ice, more frequent and intense precipitation events, and increased likelihood of summer drought. All of these can have negative effects on salt marsh habitats. Irrespective of timing, extreme precipitation events have the potential to increase erosion along salt marsh channels and otherwise redistribute sediment within and between habitats. An important habitat component of high marsh areas are pannes and pools. They provide important food sources for migratory water birds and breeding, nesting, and feeding habitat to many species of fish, including mummichugs. Pannes are shallower than pools and dry out on a periodic basis. Pools are deeper and more permanent and defined by the presence of *Rupia* spp. (widgeon grass). In many marshes, salt marsh panne formation and productivity depends

on drifting ice that contributes to the morphology of the panne and carries nutrients into the system, and warmer winters would ultimately eliminate this transport mechanism. Salt marshes also provide an important ecosystem service of carbon sequestration that may be compromised with marsh decline caused by sea level rise (SLR), temperature or nutrient enrichment, thus releasing GHGs, which are a primary driver of climate change.

In many places adjacent to salt marshes, the upland areas are developed or are land of relatively high slope. Both are a barrier to marsh migration. Additional infrastructure changes in response to climate change, including those designed to protect existing structure, will be a barrier to migration. Removal of structures may provide a place for marshes to migrate into. Conservation of low-lying undeveloped land adjacent to salt marsh is essential for the long term existence of this habitat.

#### Specific Wildlife Vulnerabilities:

For many salt marsh dependent species – particularly nesting birds – the loss of habitat to sea level rise is the dominant threat from climate change. Even if pockets of habitat remain for potential nesting, reproductive success is closely tied to tidal cycles. Anything that might exacerbate flooding due to extremely high tides (e.g., tidal restrictions, extreme storms) has the potential to significantly reduce reproductive output for an entire season. Warmer temperatures will likely lead to increased methylation of mercury in salt marsh sediments, and ultimately higher levels in salt marsh wildlife. Salt marsh nesting birds have been shown to possess abnormally high level of methyl mercury (Lane et al 2011), and there is increasing evidence that these levels have potential negative effects on reproductive success. These levels can get even higher in species of higher trophic levels – including humans - that consume more fish.

Although the effects are likely to be lower than in open water estuarine systems, sudden and extensive inputs of freshwater into salt marshes may pose a physiological stress to organisms already adapted to daily fluctuations in temperature and salinity. Many invertebrates show movement toward more saline environments (e.g., mouths of estuaries) after significant freshwater inputs, and in extreme cases will suffer mortality if they cannot move fast or far enough to avoid the stressor (Mills 2009).

As in any system, the varied responses of salt marsh fish, invertebrates, and plants to climate change increase the chances of disruption in local food webs. Species will shift in or out of salt marshes to track their physiological optima (temperature, salinity, etc.) and/or alter the timing of breeding or migration. As a result, predator-prey cycles could become unbalanced, herbivores could overgraze their food supplies, or species will miss out on cues needed for reproduction. These cascading effects are difficult to predict because ecosystems are so complex, and the interaction of climate change with other stressors complicate models.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response

#### Specific Strategies

1. Survey all affecting hydrology and hydraulics and retrofit for full tides predicted for 2050. Resurvey and re-evaluate all barriers and crossings with SLR scenarios using the methods deployed by NRCS from their 1994 and updated 2001 surveys (NRCS 2001).
2. Remove remaining tidal constrictions or barriers including small culverts or head of tide dams.
3. Establish “sentinel site” monitoring infrastructure and programs including vertical control points to quantify SLR, surface elevation tables (SETs) that measure sediment dynamics, and a network of locally



relevant water level monitoring stations that together measure the height of sea level relative to land height and the ability of salt marsh to keep pace. Identify and quantify current sediment loads in river systems and how much salt marshes need to keep up with sea level rise. Assess ability of salt marsh to accrete with sea level rise to better predict marsh losses and gains. Locally relevant accretion / erosion data needs to be measured over the long term as the degree of temporal and spatial variation is huge. To be effective, sentinel monitoring should be coupled with a range of water quality and biological indicators.

4. Develop locally relevant salt marsh migration models (e.g., SLAMM) under multiple scenarios of sea level change. Models will need to be improved over time with field monitoring and mapping data (e.g., LiDAR imagery; SET and SLR data) that can quantify high and low water conditions that define marsh boundaries and upland area effects.
5. Categorize individual salt marsh potential for migration. Prioritize opportunities for conservation and human modification.
6. Actively conserve large area marshes along the coast as well as those that provide stopover habitat for travel of wildlife between saltmarsh patches.
7. Conserve areas of undeveloped low lying land adjacent to salt marsh that will allow for natural salt marsh migration in response to sea level rise.
8. Ensure that all salt marsh restoration projects accommodate for sea level rise.

#### Linkages to other habitats:

- Salt marshes intergrade with the intertidal mudflats of estuarine systems in areas subject to more complete tidal inundation.
- The most extensive salt marshes (e.g., Hampton-Seabrook) often form in the lee of extensive dune and barrier beach systems, which protect them from wave action and ocean currents.
- If marshes are able to migrate inland in response to sea level rise, they will replace existing freshwater and upland communities, especially low-lying marshes (e.g., Theriault 2008) and agricultural grasslands such as those around Great Bay. Similarly, a rising water table may result in salt water intrusion that affects vernal pools and the species that depend on them.

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## ESTUARINE HABITATS ASSESSMENT

### Habitat overview:

For the purposes of this assessment, estuarine habitats include a mixture of intertidal and subtidal areas that are usually dominated by soft sediments. Typical examples include eelgrass beds, oyster reefs, and intertidal mudflats. Salt marshes, an important estuarine habitat, is treated separately. This habitat category did not appear in the original NH Wildlife Action Plan.

### Major vulnerabilities:

- More frequent freshwater run-off events would result in multiple impacts, including sudden inputs of warmer water during summer, increased sedimentation and turbidity, erosion, higher nutrient inputs (depending on timing), and periods of lower salinity.
- Extended summer droughts could result in lower nutrient inputs (a benefit to generally nutrient enriched NH estuaries), but in combination with high temperatures could lead to longer and/or more widespread hypoxia.
- Sea level rise will increase depth and alter the extent and character of intertidal and subtidal habitats, with potential effects on light levels for submerged plants that may result in migration to areas currently too shallow; SLR may also inundate new, shallow areas and wetlands.
- Higher temperatures may benefit pathogens or invasive species.

### Vulnerability narrative:

Because estuaries are dynamic systems at the interface of freshwater and marine ecosystems, they are particularly susceptible to changes in hydrology. Changes in the timing and volume of freshwater inputs can have both structural effects on these habitats (e.g., erosion and sedimentation, substrate stability and grain size distribution) and physiological effects (e.g., stress due to thermal regime, dissolved oxygen and salinity fluctuations) on the wildlife that dwell there. For this section the focus will be on habitat effects, with those specifically on wildlife. Hydrology of New Hampshire's coastal watersheds is predicted to change in three major ways. Warming overall temperatures may result in more winter precipitation falling as rain, and less ice may be present in both estuaries and their tributaries. The frequency of extreme rainfall events may also increase, while at the same time there may be an increased likelihood of extended summer droughts. In addition, existing or future infrastructure in the coastal watersheds has the potential to exacerbate any effects of precipitation events. Eelgrass is also directly susceptible to losses from heat stress with prolonged periods of unusually warm water temperatures.

Shifting winter precipitation from snow to rain increases the chance of erosion from upland habitats during a time of year when plants are dormant and thus neither absorb water from the soil nor bind soil with active root systems. As a result, there is potential for increased sediment inputs into estuaries, which in turn could smother habitats dominated by sessile organisms (e.g., eelgrass, oysters) or block sunlight needed for photosynthesis. Such sediment effects are also possible after extreme precipitation events during the growing season, as is the potential for sediment redistribution within an estuary. Such events would also carry additional nutrients into estuaries already subject to high nitrogen and phosphorus loads. The effects of summer drought on estuarine systems are less well understood, but lower run-off from agricultural fields or sewage treatment facilities may actually benefit estuaries by reducing excessive nutrient inputs during the growing season. But at the same time, reduced flows in combination with higher temperatures could lead to larger-in-extent or longer-lasting periods of hypoxic or anoxic conditions. Summer drought also produces high salinity events which promote oyster pathogens.

Ice scour is likely to be reduced with a warming climate and, although winter damage to eelgrass beds and intertidal oysters might be reduced, long-term consequences for habitat health should be assessed and monitored.

Rising sea levels will likely compound any of the hydrologic scenarios discussed above, while at the same time potentially expanding estuarine habitat as salt marshes are flooded (and likely converted to mudflats). At the same time, infrastructure built to counteract sea level rise may either prevent habitat migration or exacerbate the effects of hydrology already mentioned. For example, seawalls or larger culverts might channelize or otherwise enhance the rapid delivery of freshwater into estuarine systems. If infrastructure obstructions do not exist, additional shallow water habitat or wetlands may be created over time that mitigate flood and nitrification effects naturally and at no financial burden.

Multiple invasive species are extending their range north as temperatures increase and other climate change stressors promote favorable growth conditions (USEPA 2009)

#### Specific Wildlife Vulnerabilities:

Sudden and extensive inputs of freshwater into estuarine systems may pose a physiological stress even to estuarine organisms already adapted to daily fluctuations in temperature and salinity. Many invertebrates (e.g., lobster) show movement toward more saline environments (e.g., mouths of estuaries) after significant freshwater inputs, and in extreme cases will suffer mortality if they cannot move fast or far enough to avoid the stressor (Charmantier et al., 2001; Jury et al., 1994; Mercaldo-Allen and Kuropat, 1994). Rainfall onto heated impervious surfaces (e.g., roads, parking lots) may result in sudden run-offs of relatively hot water into estuarine environments, with potentially lethal effects on temperature-sensitive organisms (University of New Hampshire Stormwater Center, 2011). This stressor would only increase with increased incidence of hot summer days, at least in the absence of summer drought. Other hydrologic stressors with specific negative effects on estuarine wildlife include summer hypoxia (resulting from high temperatures and/or reduced precipitation) and increased sediment (e.g., smothering oysters for extended periods). Early life stages of fish and invertebrates may be especially vulnerable to these shifts, with potentially dire consequences for a specific year class.

As in any system, the varied responses of estuarine fish, invertebrates, and plants to climate change increase the chances of disruption in local food webs. Species will shift in or out of estuaries to track their physiological optima (temperature, salinity, etc.) and/or alter the timing of breeding or migration. As a result, predator-prey cycles could become unbalanced, herbivores could overgraze their food supplies, or species will miss out on cues needed for reproduction (e.g., temperature and anadromous fish). Temperature and salinity stress may also lower resistance to pathogens, or the changing physical regime may allow invasions of pathogens or predators, or even loss of nutrition if phytoplankton or invertebrate forage communities are altered. Brown tides or other harmful algal blooms (HABs) are examples of community shifts that may provide production of lower nutritional value, or even produce toxins.

A significant climate change stressor with potential effects on estuarine wildlife is a lowering of ocean pH (Guinotte and Fabry 2008). Increased CO<sub>2</sub> concentrations in seawater will lower pH, potentially to the point that marine invertebrates with calcareous shells (e.g., mollusks, corals) suffer reduced survival and reproduction (e.g., Green et al. 2009), and in turn lead to losses or declines in harvestable shellfish (e.g., clams and mussels, Cooley and Doney 2009). Increased CO<sub>2</sub> concentrations may also adversely affect the growth and reproduction of some fish species. Note that increased CO<sub>2</sub> concentrations in estuaries may actually be beneficial to eelgrass beds (Guinotte and Fabry 2008) and increase calcification rates in some crustaceans (*vide* Cooley and Doney 2009).

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S3: Restore Watershed Connectivity
- S4: Protect Riparian and Shoreland Buffers

S5: Invasive Species Plan  
S6: Comprehensive Planning  
S7: Stormwater Policy and Flood Response

#### Specific Strategies

1. Survey barriers and crossings affecting hydraulics and hydrology and retrofit for full tides predicted for 2050.
2. Work with local officials, state and insurance companies to develop a plan for addressing what happens to infrastructure as sea level rises and storms become more severe. Moving sewage treatment plants to higher ground would prevent pollution of salt marshes and estuaries and provide a buffering “service” against storms for infrastructure. Other infrastructure removal could increase the ability of ecosystems to mitigate coastal flooding and protect important fisheries.
3. Remove remaining tidal constrictions or barriers including small culverts or head of tide dams.
4. Preserve coastal lands and buffers to allow for SLR and coastal habitats migration upland.
5. Conduct oyster reef restoration using calcium carbonate amendments (shell) which provides substrate for spat recruitment as well as local pH buffering to counter acidification.

#### Linkages to other habitats:

- Estuarine habitats intergrade with salt marshes in areas subject to less tidal inundation.
- In conjunction with sea level rise, estuarine systems and associated habitats (e.g., salt marsh) are likely to displace freshwater or upland habitats. Similarly, a rising water table may result in salt water intrusion that affects vernal pools and other coastal wetlands and the species that depend on them. Sea level rise may also change groundwater characteristics, such as higher water table and higher salinity that can impact groundwater resources and human infrastructure as well as fish and wildlife habitats.

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## MARINE HABITATS ASSESSMENT

### Habitat overview:

New Hampshire's marine habitats comprise a portion of the Gulf of Maine offshore of its Atlantic Ocean coastline. These marine habitats are purely aquatic, in contrast to other coastal habitats such as salt marshes, rocky shores, and the intertidal portions of estuaries where significant portions are exposed to air over the course of the tidal cycle. Although quite broad, marine habitat can be generalized to refer to offshore waters including both pelagic and benthic zones as well as the surface of the waters where organisms such as waterfowl may periodically be found. Although State jurisdiction only extends three miles offshore, this delineation has no ecological basis, and marine systems shared by neighboring states are considered in their entirety for the purposes of this summary.

### Major vulnerabilities:

- Increasing sea surface temperatures appear to be the climate change stressor with the greatest potential to impact marine systems. Higher ocean temperatures could result in thermal stress for marine life, stronger thermal stratification and alterations of marine currents. Thermal impacts may be far-reaching and include: range changes in sensitive species including important commercial and recreational fish and shellfish species; disruption of migratory routes; varied life stage impacts of survival and growth; disruption of ecosystem integrity from loss of diversity or changes in phenology; increased success of invasive species; and alterations of key chemical processes including nutrient cycling to phytoplankton in the surface waters.
- Increased sea surface temperature also contributes to sea level rise through both thermal expansion of sea water and melting of polar ice.
- Changes in salinity may occur from changed precipitation patterns that alter runoff timing and intensity including increased flooding, reductions in snowpack, timing of snowmelt, and periods of drought. Ocean currents may also cause salinity change as polar ice cap and glacial melt water are transported to local marine habitats.
- Ocean acidification increases with CO<sub>2</sub> levels and productivity to a degree that may impact the ability of diatoms and shellfish to form their calcareous shells, thus affecting important components of the ocean food web.

### Vulnerability narrative:

Although the sheer size of the marine environment has the potential to buffer many effects of climate change, small changes in temperature may result in relatively large changes in ecosystem function. New Hampshire's marine waters are entirely within the Gulf of Maine, where marine thermal habitats and nutrient regimes are largely determined by interactions of two major ocean circulations: the Labrador Current (cold) and the Gulf Stream (warm). At present the warmer Gulf Stream is shifting northward, thus altering thermal conditions in a marine environment that is primarily populated by coldwater-adapted plants and animals. Many of these organisms will shift their ranges north or to deeper water to remain within their preferred thermal regimes. These shifts may compound vulnerabilities as key food resources or habitat conditions may be limited or out of synch in the new range, thus diminishing production of key species.

Increased temperature, in combination with freshwater inputs from extreme rainfall events and polar cap melting has the potential to shift currents and impede vertical mixing of the water column and alter salinity regimes. Increased stratification may prevent nutrients from being brought to the surface layer where they support phytoplankton. Under more enriched conditions, stratification may limit oxygen replenishment of bottom waters and create hypoxic zones. While "habitat changes" in the form of increased temperatures and freshwater inputs will obviously alter the physical environment in marine systems, their carry-over effects to wildlife

distributions and phenology are far more complicated, and in turn have the potential to significantly alter species relationships and composition, compromising ecosystem structure and balance as discussed in more detail below.

Freshwater inputs may change due to shifting precipitation patterns including winter rains instead of snow, more intense storm events and, in the other direction, longer periods of drought. The winter rains may add more freshwater to the surface, affecting stratification and therefore phytoplankton bloom timing. There may be some effects of increased intensity and frequency of floodwaters bringing fresh water and sediments past intertidal zones and into nearshore marine areas. This may affect essential habitat and species distributions by lowering salinity at the mouths of rivers and farther offshore depending on intensity. The sediments may cover and kill benthic animals and algae in areas of high deposition.

#### Specific Wildlife Vulnerabilities:

Shifts in spatial distribution of species are likely to be caused by changes in temperature regimes brought on by climate change (Nye, 2010). For cold-blooded fish and aquatic invertebrate species, water temperature is one of the most important drivers of distribution and factors controlling growth, development, seasonal migration, spawning success and ultimately the rate of population growth. As noted above, marine organisms adapted to colder waters may shift their ranges as the Gulf of Maine warms, but with varying degrees of success. For example, fish remain in their preferred temperature range by moving to higher latitudes and/or deeper waters where water temperatures are cooler and more stable, resulting in decreases in northern species (e.g., haddock) and increases in southern species. At present, there has been a shift in dominance from more “cold water” assemblages to more “warm water” species such as butterfish and lobster (Collie et al. 2008). Global climate models predict overall declines in commercially important marine fisheries (Fogarty *et al.*, 2007). However, these changes are complex. For example, warmer temperatures in the Gulf of Maine will positively influence the growth of adult cod, but negatively impact survival of cod in early life stages.

Such changes in species composition can have effects at higher or lower trophic levels that cascade through the ecosystem, even to the extent that important prey species are no longer available to predators. If warm winters allow zooplankton populations to persist, they could potentially suppress spring phytoplankton blooms, an outcome that could also result from increased stratification. Reduction in biomass at this foundation trophic level will have effects that cascade throughout the food web, rapidly impacting larger organisms like fish and marine mammals. For example, the phytoplankton feeding zooplankton *Calanus finmarchicus* is a major food item of many fish species, and the primary food source of endangered right whales and seals during the pupping period. The arrival and reproductive success of these mammals is dependent on the abundance and distribution of *C. finmarchicus* (Kane and Prezioso, 2008; Pershing *et al.*, 2009). Changes in the magnitude and timing of the peak abundance of *C. finmarchicus* may significantly alter whale migration, behavior, and population abundance. Forage fish population shifts may also impact seabird reproductive success if increasingly available species (e.g., butterfish, mentioned above) are less suitable as prey items to young chicks (USFWS unpubl. data). Conversely, increases in warmwater fish such as mackerel may be beneficial to other seabird species (e.g., Northern Gannet, Montevecchi and Myers 1997).

Finally, increasing water temperatures are also likely to alter the timing of ecological events (e.g., earlier springs, longer growing seasons). As a consequence, organisms will likely shift timing of their spawning and migration and accessibility to habitat, in some cases to a period that is out of phase with other vital aspects of their life cycle such as the prey upon which they rely. For example, ospreys time their spring return to New Hampshire to coincide with strong runs of river herring entering estuaries to spawn. Anadromous fish, such as the river herring and rainbow smelt, spend most of their lives in the ocean but migrate into freshwater rivers to spawn. Less snow melt runoff might change water temperature signals for these fish to begin movement upstream.

Other than temperature and salinity, the most likely climate change stressor to affect marine wildlife is a lowering of ocean pH (Guinotte and Fabry 2008). Increased CO<sub>2</sub> concentrations in seawater will lower pH, potentially to the point that marine diatoms and invertebrates with calcareous shells (e.g., mollusks, corals) are unable to form shells, thus influencing their survival and reproduction (e.g., Green et al. 2009). Increased CO<sub>2</sub> concentrations may also adversely affect the growth and reproduction of some fish species. Note that increased



CO<sub>2</sub> concentrations in marine environments may actually increase calcification rates in some crustaceans, although data are generally equivocal (Doney et al 2009).

#### General Strategies to Address these Vulnerabilities

S4: Protect Riparian and Shoreland Buffers  
S5: Invasive Species Plan  
S6: Comprehensive Planning  
S7: Stormwater Policy and Flood Response  
S9: State Energy Policy

#### Specific Strategies

1. Use research and modeling to increase understanding of potential shifts in marine food web. Consider the effect on fish stocks for management of these species.
2. Reduce nitrogen loading to nearshore coastal waters to offset additional hypoxia events due to climate change.
3. Develop regulations on the siting of infrastructure, including renewable energy facilities such as wind turbines, to minimize impacts to marine life.

#### Linkages to other habitats:

- Marine habitats are most closely tied to Coastal Islands and Rocky Shores, since the lower limit of the intertidal zone is effectively the upper limit to the marine zone.
- Migratory access to estuarine and freshwater rivers where diadromous fish spawn or grow may be restricted by altered temperature, salinity or hydrology.
- Marine currents and storm action are the major drivers of sediment deposition/erosion on dunes and beaches.
- Salinity, sea level rise or other influences on estuaries that may degrade key habitats used by marine organisms in various life stages or seasons, or provide structural ecosystem food resources from habitats such as salt marshes.

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## FRESHWATER HABITAT ASSESSMENTS

Freshwater habitats include: Freshwater Marshes, Peatlands, Temperate Swamps, Northern Swamps, Seasonally Flooded Wetlands, Cold Water Streams, Warm Water Streams, Coldwater Ponds, Stratified Lakes and Ponds, Lake and River Shores, and Floodplain Forests.

### FRESHWATER MARSH/WET MEADOW/WET SHRUB HABITATS ASSESSMENT

#### Habitat overview

This category includes herbaceous marshes as well as shrub-dominated swamps. Marshes occur primarily on mineral soils, distinguishing them from peatlands, which occur on organic soils. They are typically associated with basins along low-gradient streams, and are often the result of beaver activity. The range of marsh vegetation includes floating-leaved aquatic species in deep water locations, tall grasses and forbs in meadow marshes, and tall shrubs like dogwoods and alders in moist thickets.

#### Major vulnerabilities

- Changes in precipitation patterns will lead to changes in duration and seasonality of flooding. These changes will likely favor generalist species that can tolerate a broader range of hydrologic conditions, and lead to an overall loss of plant species diversity.
- As temperatures increase, invasive species currently present could become more abundant, and new invasive species could arrive.

#### Vulnerability narrative

In general, marshes may be more resilient to climate change impacts than other wetland types. They are typically characterized by widespread species, and cover a broad hydrologic gradient: from open water habitats with floating-leaved plants like water lilies, to shallow meadow marshes that are dominated by tall grasses, sedges and shrubs (Golet et al 1993). This broad range suggests that, even if there are hydrologic changes as a result of climate change, marshes will persist. However, there will likely be shifts in vegetation composition and structure at individual sites as water levels change in duration and seasonality. These potential changes may lead to a loss of species diversity, as generalist species that tolerate a wide range of conditions prevail over species that require a specific hydrologic regime.

Dramatic changes in hydrologic patterns would essentially function as new disturbances in these systems, making them more vulnerable to invasion by exotic plants. Invasive exotics that are currently present, such as phragmites and purple loosestrife, could become more abundant and other species may move in from the south or elsewhere as temperatures increase. Increased human development near marshes also opens additional pathways for exotic plant invasions.

#### Specific Wildlife Vulnerabilities

If wetland habitats change composition as a result of climate change, specialist wildlife species are likely to be more affected than generalists, but most SGCN marsh species are believed tolerant of a wide range of conditions. A net lowering of the water level in marsh or shrub wetlands may facilitate easier access by predators to nesting birds such as American Bittern and Pied-billed Grebe, especially if nests are initiated during periods of higher water in the spring.

#### General Strategies to Address these Vulnerabilities

S1: Conserve Areas for Habitat Expansion and/or Connectivity  
S2: Habitat Restoration and Management  
S4: Protect Riparian and Shoreland Buffers  
S5: Invasive Species Plan  
S6: Comprehensive Planning  
S7: Stormwater Policy and Flood Response  
S8: Revise Water Withdrawal Policies

#### Specific Strategies

1. Manage water control structures to maintain marsh hydrology in the face of changing weather patterns.
2. Identify marshes that are important for wildlife species that are considered vulnerable to climate change

#### Linkages to other habitats

- Freshwater wetlands, particularly marshes and fens, are frequently adjacent to open water aquatic systems, and often act as buffers to streams and ponds.
- Freshwater wetlands that occur on floodplains are addressed in the assessment for floodplains and river shores.

#### Citations

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## PEATLAND HABITAT ASSESSMENT

### Habitat overview

Peatlands include all open wetlands dominated primarily by shrubs and sedges that occur on organic (peat) soils. These organic soils are composed of partially decomposed plant remains, and are typically made up primarily of sphagnum (peat moss). These wetlands are referred to as bogs or fens, with the latter comprising the majority of peatlands in New Hampshire. Not included in this category are a variety of forested wetlands on organic soils; these are discussed separately as “northern swamp” and “temperate swamp.”

### Major vulnerabilities

- Increased temperature may result in increased decomposition rates, causing peat mats to decay more rapidly, and resulting in a loss of peatland habitat, and possible conversion to marsh
- Extended periods of drought may further promote increased decomposition.

### Vulnerability narrative

The potential effects of climate change on peatlands are expected to be more severe than on any other wetland type. Peatlands are defined by their saturated organic soils, comprised primarily of the partially decomposed remains of plants, particularly sphagnum mosses. Such soils develop in cold and wet climates, where the rate of plant matter accumulation exceeds the rate of decomposition. These systems are near their southern limit in the northeastern US, where most occurrences are only a fraction of the size of the huge peatlands of the boreal zone.

In a typical climate change scenario, higher temperatures and a longer growing season will result in an increased decomposition rate for peatlands. As this rate increases, organic matter accumulation will not be able to keep pace with decomposition, and peat soils will begin to break down (Gorham 1991, Gignac and Vitt 1994). Without this organic matrix, many plants restricted to peatlands will disappear, and likely be replaced with those more typical of marsh or open water habitats.

Changes in peatland hydrology also have the potential to increase decomposition rates for peat. The combination of increased temperatures and reduced precipitation (at least seasonally) will result in increased evapotranspiration, which in turn could lower surface water levels (Gorham 1991) and expose peat to air and wind. In addition, lowered water levels may foster colonization by trees that are otherwise unable to survive on saturated peatlands (Gignac and Vitt 1994).

In both cases, increased decomposition of peatland soils is likely to release significant amounts of carbon (both CO<sub>2</sub> and CH<sub>4</sub>) into the atmosphere, which has the potential to further increase global temperatures (Tarnocai 2006).

### Specific Wildlife Vulnerabilities

If wetland habitats change composition as a result of climate change, specialist wildlife species are likely to be more affected than generalists. For example, invertebrates that occur primarily in peatlands would suffer a net loss of habitat if higher decomposition rates shifted these habitats toward marshes or open water. One of New Hampshire's rarest mammals, the northern bog lemming, is thought to occur in peatland habitats in the northern part of the state. In the south, the Ringed Boghaunter (a dragonfly) inhabits small peatlands with extensive *Sphagnum*. Most areas occupied by boghaunters contain significant amounts of open water, so degradation of peat mats is not likely to negatively affect the species in the short term.

### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response
- S8: Revise Water Withdrawal Policies

### Specific Strategies

1. Conduct research on peatlands along a regional latitudinal gradient to assess the actual potential for peat decomposition under climate change.
2. Utilize research on peatland resilience to focus protection in areas where peatlands are likely to persist. Protect peatland/upland complexes to stabilize hydrology and minimize nutrient inputs.
3. Make rare peat and swamp community habitats priorities for permanent land protection. (if those communities are expected to persist in the face of CC).

### Linkages to other habitats

- In northern New Hampshire, open peatlands often occur in complexes with northern swamps.
- Peatlands often form a fringing wetland (or floating islands) associated with marshes or small ponds.

### Citations

Gignac, L.D., and D.H. Vitt. 1994. Responses of northern peatlands to climate change: effects on bryophytes. J. Hattori Bot. Lab. No. 75: 119-132.

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## TEMPERATE SWAMP HABITAT ASSESSMENT

### Habitat overview

Swamps are defined as non-floodplain wetlands dominated by trees, and can occur on both mineral and organic soils. For the purposes of this analysis, swamps were divided into northern and temperate types. Temperate swamps generally occur south of the White Mountains, and can occur on both mineral and organic soils. They are frequently dominated by hardwoods, especially red maple, but this habitat group also includes Atlantic white cedar swamps.

### Major vulnerabilities

- Temperate swamps may be vulnerable to invasive plant species, particularly species that are known to be invasive south of New Hampshire, but that have not yet arrived in the state. In particular, Japanese stiltgrass (*Microstegium vimineum*) is a serious problem in forested wetlands, and has been documented as far north as Massachusetts.

### Vulnerability narrative

In general, temperate swamps appear less vulnerable to climate change than northern swamps in New Hampshire. A number of temperate swamp plant species approach their northern limit in the state, and these species will likely see an expansion of their range under warmer conditions. However, some northern species (e.g., red spruce, balsam fir) occur in temperate swamps, and these species may decline and be replaced in these habitats.

Under a warmer climate scenario, there will probably be an increase in the diversity and abundance of invasive plant species. Temperate swamps are potentially vulnerable to a variety of invaders, in particular Japanese stiltgrass (*Microstegium vimineum*). This annual grass is very aggressive and has infested large areas south of New Hampshire. Warmer temperatures will also lead to increased problems with pests and diseases. Hemlock is a common tree species in this habitat, and the spread of hemlock woolly adelgid could dramatically alter the structure of some temperate swamps.

Most climate change scenarios predict an increase in strong storms. Swamps are susceptible to damage from strong storms because trees in these habitats tend to be shallowly rooted and vulnerable to wind throw, particularly when soils are saturated. If there are repeated events in which large numbers of trees are taken down by storms, it is possible that there will be a permanent change in community structure. These structural changes could lead to other changes in community composition associated with the desiccation of organic soils, and perhaps foster conversion to upland forest habitats (e.g., hemlock-hardwood-pine).

Temperate swamps are a widespread and common habitat in the southern and central parts of the state, particularly in the relatively flat terrain of southeastern New Hampshire. This is also the part of the state under the greatest pressure from human development, which will only increase as people respond to climate change by relocating further north and inland. Temperate swamps will be increasingly disconnected from one another by development in the intervening uplands, and they will experience an increase in pollution from that development. Nutrient and contaminant runoff and sedimentation are significant threats to these habitats as development increases.

### Specific Wildlife Vulnerabilities

If wetland habitats change composition as a result of climate change, specialist wildlife species are likely to be more affected than generalists. That said, there are few specialist species in temperate swamps, and any impacts to generalist species are likely minimal. Hessel's Hairstreak, a rare butterfly of Atlantic White Cedar swamps, would likely be affected in concert with increases or decreases in populations of its host tree, even if an

inhabited wetland remained a temperate swamp in the broadest sense. Fragmentation of temperate swamps may result in increased risks of mortality (e.g., road kill) for reptile and amphibian species that occur in this habitat.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response
- S8: Revise Water Withdrawal Policies

#### Specific Strategies

1. Protect upland buffers to reduce potential impacts of strong storms (wind throw) and exposure to invasive species introductions.
2. Revise BMPs for timber harvesting in swamps to minimize activities that may accelerate climate-related vegetation changes.

#### Linkages to other habitats

- Northern swamps and temperate swamps occur in similar landscape positions, with obvious differences in range. As the climate warms, northern swamps may see a shift to a species composition resembling temperate swamps.



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## NORTHERN SWAMPS ASSESSMENT

### Habitat overview

Swamps are defined as non-floodplain wetlands dominated by trees, and can occur on both mineral and organic soils. For the purposes of this analysis, swamps were divided into northern and temperate types. Northern swamps are dominated primarily by northern conifers, such as black spruce, balsam fir, and northern white cedar, frequently occur on organic soils, and in New Hampshire are found primarily north of the White Mountains.

### Major vulnerabilities

- Northern swamps frequently have organic soils, which are likely to decompose more rapidly under a warmer climate. The degradation of these organic soils could lead to significant changes in overall species composition, and the eventual conversion to a different habitat type.

### Vulnerability narrative

Northern swamps appear to have similar vulnerabilities as open peatlands, especially if they occur on organic soils (e.g., black spruce and northern white cedar swamps). As with peatlands, these soils are likely to experience increased decomposition with higher temperatures (Gignac and Vitt 1994), degrading the substrate of the community. It is likely that some of these swamps will convert over time to a composition more like that of temperate swamps, or possibly even marshes, if temperate woody species do not become established. Gradual conversion to upland forest habitat (e.g., lowland spruce-fir) could be accelerated under drying scenarios.

Most climate change scenarios predict an increase in strong storms. Swamps are susceptible to damage from strong storms because trees in these habitats tend to be shallowly rooted and vulnerable to wind throw, particularly when soils are saturated. If there are repeated events in which large numbers of trees are taken down by storms, it is possible that there will be a permanent change in community structure. These structural changes could lead to other changes in community composition associated with the desiccation of organic soils or invasion by more southern species adapted to warmer temperatures.

In recent years there has been increase in the development of biomass power plants. These plants are frequently fueled with low-grade wood that does not have value for other timber products. It is possible that there will be a significant increase in these types of facilities in the future as an attempt to transition away from energy derived from fossil fuels. An increase in biomass power plants could lead to increased pressure on New Hampshire's forest resources, particularly on areas that were previously considered marginal for timber production and forest management, such as swamps.

### Specific Wildlife Vulnerabilities

If wetland habitats change composition as a result of climate change, specialist wildlife species are likely to be more affected than generalists. That said, there are few specialist species in northern swamps, and any impacts to generalist species are likely minimal.

### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning

S7: Stormwater Policy and Flood Response  
S8: Revise Water Withdrawal Policies

#### Specific Strategies

1. Protect upland buffers to reduce potential impacts of strong storms (wind throw) and exposure to invasive species introductions.
2. Revise BMPs for timber harvesting in swamps to minimize activities that may accelerate climate-related vegetation changes.

#### Linkages to other habitats

- Northern swamps, in particular black spruce swamps, are often adjacent to extensive open peatland habitats.
- Northern swamps and temperate swamps occur in similar landscape positions, with obvious differences in range. As the climate warms, northern swamps may see a shift to a species composition resembling temperate swamps.

#### Citations

Gignac, L.D., and D.H. Vitt. 1994. Responses of northern peatlands to climate change: effects on bryophytes. J. Hattori Bot. Lab. No. 75: 119-132.

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## SEASONALLY-FLOODED WETLAND HABITATS ASSESSMENT

### Habitat overview

Seasonally-flooded wetlands generally occur in small basins that are inundated in the winter and spring, draw down over the course of the summer, and frequently become completely dry by the end of the growing season. They lack significant surface flows into or out of the basins. The vast majority of basins in this habitat group are classified as vernal pools. These are small basins in forested settings that are shaded by the surrounding tree canopies, and which are critical breeding sites for a variety of amphibian and invertebrate species. This habitat group also includes basin marshes, an unusual type of open wetland that supports rare natural communities and plant species, many of which have a southern distribution.

### Major vulnerabilities

- Higher temperatures could cause vernal pools to draw down earlier in season or have greater annual variation in hydroperiod, which could affect breeding amphibians and other species.

### Vulnerability narrative

The vast majority of seasonally-flooded wetlands are vernal pools, which are extremely sensitive to changes in hydrology (Brooks 2004). Most climate change scenarios predict a combination of increased temperatures and more frequent summer drought, both of which have the potential to dry pools out earlier in the season. Conversely, extended periods of heavy rain early in spring could potentially result in larger pools *not* drying out, or becoming hydrologically connected to adjacent permanent water bodies. Any such changes in hydrology could have significant effect on vernal pool wildlife, as discussed below.

### Specific Wildlife Vulnerabilities

Several species of amphibians and invertebrates rely on vernal pools to provide breeding habitat that is free of fish and other predators generally found in permanent ponds. They are also adapted to complete their life cycles in a relatively short window between spring rains and the drying that occurs in smaller pools by the end of the growing season. Shorter hydroperiods (a result of increased temperatures and more frequent summer drought) could make smaller vernal pools less habitable for amphibians and other vernal pool obligate species. If seasonal hydrologic patterns become more unpredictable, it may favor generalist species that can tolerate these variable conditions, and result in an overall loss of species diversity. State-endangered marbled salamanders (*Ambystoma opacum*) and species of special concern Jefferson's and blue-spotted salamanders (*A. jeffersonianum* and *A. laterale*) are vernal pool obligate species, and may decline due to hydroperiod changes. However, marbled salamanders are at the northern extent of their range in NH, and so may be able to expand their populations with warming temperatures.

### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S8: Revise Water Withdrawal Policies

### Specific Strategies

1. Develop a program for identifying and mapping the vernal pools that are most productive and/or support rare species. These should include areas with particularly high densities of vernal pools and all vernal pools on public lands. Mapping should identify connections between pools to protect metapopulation dynamics. Work with local citizen science groups to map vernal pools and monitor vernal pool functions.
2. Develop a monitoring program to identify temporal shifts or hydrologic changes in vernal pools.
3. Manage forests to protect vernal pools from degradation or loss of overhead canopy to keep temperatures stable.
4. Focus land protection efforts on connecting vernal pool areas to allow for vernal pool herps and other species to migrate.
5. Integrate vernal pool prioritization criteria into wetland decision-making.

#### Linkages to other habitats

- Vernal pools typically occur within upland forests, although they are also frequently present in floodplain settings. These floodplain pools are addressed in the floodplain forests vulnerability assessment.

#### Citations

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## COLDWATER STREAMS ASSESSMENT

### Habitat overview

This category generally includes lower order rivers and streams that tend to be higher gradient. These are waters that typically support coldwater fish species (e.g., brook trout and slimy sculpin). Coldwater streams can be further subdivided into those that are primarily groundwater fed and those that remain cold because they are located at higher latitude or elevation. Most such streams have substrates dominated by sand, gravel, or cobble, and even bedrock in headwater reaches.

### Major vulnerabilities

- Any increase in the intensity and frequency of flooding events will cause habitat damage and direct mortality to aquatic species, in particular freshwater mussels. This impact would be disproportionately larger in developed watersheds where human infrastructure exacerbates flood damage and limits recolonization.
- Higher temperatures will cause the distribution of species dependent on cold water to shift north and to higher elevations.
- Groundwater resources will be stressed by an increase in evapotranspiration due to climate change. This increase, in combination with water withdrawal for human consumption, may lower summer base flows in some watersheds, causing many perennial streams to become intermittent.

### Vulnerability narrative

Most climate change scenarios predict increases in the frequency and intensity of major flooding events, and the effects of such events on New Hampshire streams have been demonstrated several times since 2005. Flooding can either add or remove substrate from river reaches, and in the process alter habitat for fish, mussels, or macroinvertebrates. These effects are compounded by the highly fragmented nature of the state's river systems, in which dams and undersized culverts impede flows and migration by aquatic species. In addition, pressure to rebuild roads and restore access to flood damaged communities usually leads to reconstruction of the same infrastructure that was prone to flood damage in the first place. Efforts to prevent future flood damage (e.g., dredging, channelization, bank armoring, and tree removal) increase the erosive force of water by eliminating the flood storage capacity of floodplains. This increases bank erosion and sediment deposition downstream.

Populations of fish or other aquatic organisms that are already isolated as a result of river fragmentation may be particularly susceptible to additional perturbations resulting from climate change. In such cases, fragmentation reduces the ability for species to recolonize an area where they have been extirpated.

Many of the species typical of coldwater streams will be affected by climate change even in the absence of increased hydrological variability. The distribution of coldwater streams is expected to shift north and to higher elevations in New Hampshire and other northern states (Lyons et al. 2010). Forested watersheds provide a buffer against extreme temperature fluctuations. During dry periods in the summer, water levels currently become so low that many streams become a series of isolated pools. With adequate shading, these pools, which are connected by subsurface flow, provide refuge for resident fish, mussels, and amphibian larvae. In wider rivers, streams without riparian vegetation, or streams without adequate groundwater recharge, water temperatures can spike rapidly. Invasive warmwater fish, particularly smallmouth bass, will move into streams with rising temperatures. Watershed fragmentation will become increasingly important as aquatic species seek thermal refuge from rising water temperatures. Watersheds with limited connectivity will likely see a shift toward species with warmer temperature tolerances.

A USGS study in coastal New Hampshire estimates that the expected increase in evapotranspiration during a longer growing season will reduce groundwater recharge rates, which will result in lower summer base

flows in coastal rivers and streams (Mack 2009). At the same time, demand for water will increase with population growth, especially in southern New Hampshire. With the relative surplus of water in the northeast, there may be tremendous economic incentive to export water to regions of the country or world where there is a great demand for clean water.

Water storage, using flood control or other dams, may increase as a management strategy for maintaining adequate water supplies in the summer. New dam construction comes with the environmental cost of restricted movement, increased water temperatures, and lower oxygen levels for aquatic species.

Lower base flows will cause many of the smaller, perennial headwater streams to become intermittent, which will lead to local extirpations, especially in streams where groundwater influence is already low. Coldwater streams in southern New Hampshire, where a steady supply of groundwater is needed to maintain cool temperatures throughout the summer, will suffer from any reduction in base flow. However, streams with adequate sources of groundwater will be more resistant to climate change (Chu et al. 2008). The amount of groundwater necessary to buffer against increases in summer temperatures will depend on the rate of climate change. Groundwater recharge may increase with higher rates of precipitation, although recharge rates are affected by storm intensity, with heavy rainfall resulting in more surface runoff. Where groundwater recharge is prevented by impervious surfaces and stormwater management designs that divert runoff into surface waters, rivers and streams will have flashier flows.

#### Specific Wildlife Vulnerabilities

Freshwater mussels are particularly vulnerable to flood events, especially in higher gradient sections or streams. In addition to direct mortality from scouring and crushing during floods, sediment deposition has buried mussel beds in lower gradient sections. There has already been a significant reduction in mussel distribution due to floods over the last 10 years (e.g., Nedeau 2011). This trend is expected to continue. Mussels have found refuge in the relatively stable flows downstream of certain flood control and hydropower dams.

Many species that occur in coldwater streams are poorly adapted to warmer water. Species' response to climate warming will vary with individual temperature tolerances and life history traits (e.g., Nebeker and Lemke 1968). Strict coldwater species (e.g., brook trout, slimy sculpin, some macroinvertebrates) will likely be extirpated from many streams in south central New Hampshire. Species less sensitive to direct temperature changes (e.g., stream salamanders, dragonflies) will be influenced more indirectly by changes in habitat as opposed to direct increases in water temperature. Eastern pearlshell mussels, which depend on cold water fish for dispersal, will experience declines that correspond with their host species. As temperatures increase, we would expect an expansion in range of warmer water species, while the response of cool water species will vary depending on habitat integrity (Lyons 2009; 2010).

One of the hardest things to predict about climate change will be its influence on the timing of certain behaviors, like spawning or hibernation, as well as its influence on interactions between species. For several species of fish, important life history events such as migration and spawning are cued by photoperiod and/or temperature. For example, American shad rely on water temperature cues to trigger upstream migration during spawning, while salmon rely more on photoperiod (Quinn and Adams 1996). Under a warming scenario, shad would migrate earlier if water temperatures rise faster in the spring, while salmon may not shift their timing and potentially experience lethal water temperatures during migration. Similarly, changes in the timing of spawning for certain fish species may affect the availability of eggs for egg predators.

#### General Strategies to Address These Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S3: Restore Watershed Connectivity
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan

S6: Comprehensive Planning  
S7: Stormwater Policy and Flood Response  
S8: Revise Water Withdrawal Policies

#### Specific Strategies

1. Monitor the abundance and distribution of invasive species (fish, aquatic vegetation, etc.) as those more tolerant of higher water temperatures displace those less tolerant.
2. Increase temperature monitoring on rivers and streams and regulate thermal impacts under the Clean Water Act.
3. Using the Northeast stream classification, map existing coldwater streams and model the potential for stream temperature changes due to climate change. Include identification of areas more likely to be resilient to warming, including those with cold groundwater inputs. Add data on stream crossings and dams and their proximity to existing cold water habitat to identify prioritized areas for conservation and/or restoration of cold water habitats. Target protection for resilient stream reaches.
4. Identify perennial versus intermittent streams and make sure there are stable perennial streams, especially for coldwater species. Periodically monitor the status of streams to make sure they are still perennial.
5. Better understand the role intermittent streams have on hydrology and aquatic systems in the northern landscape.
6. Research how water withdrawal practices impact instream flows and aquatic life.
7. Identify and map natural cold-water refuges for fisheries and rate these in terms of productivity for cold water fish to prepare for increasing temperatures in streams.
8. Maintain or restore climate resilient shade cover along important reaches of streams so as to keep seasonal temperatures within the tolerance limits of focal aquatic organisms (e.g., Brook Trout). Restoration may be particularly important at sites where hemlock is lost due to hemlock woolly adelgid.
9. Add in-stream habitat features (e.g. chop and drop wood) where needed to provide cooler microclimates, especially in more exposed streams.
10. Provide more protection for intermittent streams.
11. Identify and protect watersheds (including headwaters) of coldwater streams that are considered intact.
12. Expand and/or enforce regulations (e.g., Basal Area law, Shoreline Protection Program) that minimize negative impacts (e.g., excessive harvest, impervious surfaces) to habitat adjacent to streams. Included in this strategy should be additional emphasis on low impact development that decreases impacts from precipitation inputs to streams.
13. Increase public and landowner awareness about habitat value of headwater streams, especially in upper reaches of watersheds.

#### Linkages to other habitats

- Freshwater wetlands, particularly marshes and fens, are frequently adjacent to open water aquatic systems, and often act as buffers to streams and ponds.
- Species which inhabit headwater streams depend on inputs from upland forests, including leaves, sticks, and terrestrial invertebrates, as a source of energy. These inputs also serve as important microhabitat features.

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## WARM RIVER ASSESSMENT

### Habitat overview

This category generally includes higher order rivers and streams that tend to be slow flowing. Examples include the main stems of the Connecticut and Merrimack and their major tributaries. Substrate in these rivers is usually dominated by silt, mud, and sand, with coarser substrates limited to higher gradient stretches.

### Major vulnerabilities

- Any increase in the intensity and frequency of flooding events will cause habitat damage and direct mortality to aquatic species, in particular freshwater mussels. This impact will be disproportionately larger in developed watersheds where human infrastructure exacerbates flood damage and limits recolonization.

### Vulnerability narrative

Larger rivers and warmwater streams are generally believed less vulnerable to climate change (Lyons et al. 2010). Many of the species typical of these habitats are already adapted to warmer temperatures, so any major impacts from climate change are more likely to result from changes to hydrologic regime. Increases in the frequency and intensity of major flooding events have the potential to alter habitat in warmwater rivers. Flooding can either add or remove substrate from river reaches, and in the process alter habitat for fish, mussels, or macroinvertebrates. At the other extreme, long periods of summer drought can cause stress or mortality even to those aquatic species usually considered to be tolerant of warmer temperatures (Adams 2011).

New Hampshire's river systems are already highly fragmented by dams and other human structures, which can significantly impact the ability of aquatic species to move between river segments. Fragmentation reduces the ability for species to recolonize an area where they have been extirpated (Jackson 2003). In some cases, this fragmenting infrastructure exacerbates the effects of severe storm events, as has been demonstrated several times since 2005. Road fill adds a tremendous amount of excess sediment to rivers during floods. Pressure to rebuild roads and restore access to flood damaged communities usually leads to reconstruction of the same infrastructure that was prone to flood damage in the first place. Efforts to prevent future flood damage (e.g., dredging, channelization, bank armoring, and tree removal) increase the erosive force of water by eliminating the flood storage capacity of floodplains. This increases bank erosion and sediment deposition downstream.

### Specific Wildlife Vulnerabilities

Freshwater mussels are particularly vulnerable to flood events, especially in higher gradient sections or streams. In addition to direct mortality from scouring and crushing during floods, sediment deposition has buried mussel beds in lower gradient sections. There has already been a significant reduction in mussel distribution due to floods over the last 10 years (e.g., Nedeau 2011). This trend is expected to continue. Mussels have found refuge in the relatively stable flows downstream of certain flood control and hydropower dams.

One of the hardest things to predict about climate change will be its influence on the timing of certain behaviors, like spawning or hibernation, as well as its influence on interactions between species. For several species of fish, important life history events such as migration and spawning are cued by photoperiod and/or temperature. For example, American shad rely on water temperature cues to trigger upstream migration during spawning, while salmon rely more on photoperiod (Quinn and Adams 1996). Under a warming scenario, shad would migrate earlier if water temperatures rise faster in the spring, while salmon may not shift their migration timing and potentially experience lethal water temperatures during migration. Similarly, changes in the timing of spawning for certain fish species may affect the availability of eggs for egg predators.

### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S3: Restore Watershed Connectivity
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response
- S8: Revise Water Withdrawal Policies

### Specific Strategies

1. Develop and promote guidelines for timber harvesting and development that encourage maintenance of sufficient forest cover in watersheds to mitigate high flood levels.
2. Incentivize river meander easements in agricultural settings.
3. Provide incentives to hydropower dam owners for the development and maintenance of fish passage and run of river.

### Linkages to other habitats

- Lower gradient river systems are associated with a variety of floodplain forest and rivershore habitats, and can depend on these habitats to absorb floodwaters. Freshwater wetlands, particularly marshes and fens, are frequently adjacent to open water aquatic systems, and often act as buffers to streams and ponds.

### Citations

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Quinn, T.P. and D.J. Adams. 1996. Environmental changes affecting the migratory timing of American shad and sockeye salmon. *Ecology* 77(4):1151-1162.

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## COLDWATER PONDS HABITAT ASSESSMENT

### Habitat overview

Coldwater ponds tend to be small, high elevation water bodies in the White Mountains or northern New Hampshire. They tend to be near the headwaters of stream systems and replenished primarily by springs or direct run-off. They are separated here due to their unique biota and their potential vulnerability to climate change.

### Major vulnerabilities

- Higher temperatures will cause the distribution of species dependent on cold water to shift north and to higher elevations, and such species could be eliminated from some coldwater ponds in the state.
- Smaller lakes and ponds that stratify, but lack extensive deep water habitat, may lose their ability to support coldwater species.

### Vulnerability narrative

Coldwater ponds are most likely to be affected by rising temperatures, which may facilitate their colonization by species more tolerant of warmer water and/or select against species adapted to colder conditions. Because of their degree of isolation, any such changes are likely to be gradual, with the exception of highly dispersive taxa such as insects. Warmer water may also facilitate more extensive aquatic vegetation, with uncertain effects on the water body as a whole. Due to their location on the landscape, coldwater ponds are unlikely to experience secondary climate change effects such as those brought on by human activity. They are thus largely immune to excessive nutrient run-off, siltation, or shoreline alteration.

### Specific Wildlife Vulnerabilities

Relatively few wildlife species are restricted to coldwater ponds, but included here are several species of dragonflies that reach their southern range limits in the White Mountains. Although dragonflies are generally believed tolerant of warmer temperatures (Nebeker and Lemke 1968), it is unknown how these populations may respond to overall warming and the potential colonization of coldwater ponds by more southern species (Hassel and Thompson 2008).

### General Strategies to Address these Vulnerabilities

- S1: Habitat Restoration and Management
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S9: State Energy Policy

### Specific Strategies

1. Inventory and research coldwater biota to determine the level of uniqueness, physiological needs and constraints and potential effects of climate change to discover how vulnerable they actually are.
2. Identify three high elevation ponds, above 3000 feet and below tree line for monitoring.
3. Develop criteria to identify coldwater streams, lakes and fisheries areas likely to be resilient to warming. Prioritize protection of those coldwater habitats with greatest opportunity to maintain the coldwater ecosystem.

#### Linkages to other habitats

- Freshwater wetlands, some types of peatlands, are frequently associated with coldwater ponds.
- Coldwater ponds are usually the headwaters for coldwater streams.

#### Citations

Hassal, C., and D.J. Thompson. 2008. The effects of environmental warming on Odonata: a review. *International J. of Odonatology* 11: 131-153

Nebeker, A.V., and A.E. 1968. Lemke. Preliminary studies on the tolerance of aquatic insects to heated waters. *J. Kansas Ent. Soc.* 41: 413-418.

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## STRATIFIED LAKES ASSESSMENT

### Habitat overview

This category includes lakes and ponds that stratify during the summer, meaning that they develop a thermocline separating warm surface waters from colder deeper water. In winter such lakes “turn over,” attaining a more uniform temperature profile with slightly warmer denser water at the bottom and (usually) ice on the surface. It is important to note that only a small subset of lakes and ponds that stratify contain enough oxygenated cold water below the thermocline to provide suitable habitat for aquatic species.

### Major vulnerabilities

- Smaller lakes and ponds that stratify, but lack extensive deep water habitat, may lose their ability to support coldwater species.

### Vulnerability narrative

Larger and deeper lakes and ponds will be more resistant to the effects of warming temperature. The average depth of the thermocline may increase with climate change, which would result in a reduction of cold, deep water in the summer (Schindler et al. 1996). Oxygen levels below the thermocline are also reduced by microorganisms as they feed on the dead cells of algae and zooplankton that drift to the bottom. Longer growing seasons and increased temperatures may increase the rate of oxygen depletion below the thermocline, as more algae and zooplankton decompose on the lake bottom (Visconti et al. 2008). Only a small fraction of smaller ponds that stratify currently maintain adequate oxygen levels below the thermocline, due to mixing currents or groundwater, to support aquatic life. In such ponds, warmer summer conditions may result in uniform warming and the absence of a thermocline, and species that require cold oxygen-rich water would be eliminated. Changes in the timing of ice-in and ice-out will have unknown implications for lake and pond ecosystems.

Stratified lakes may also be affected by perturbations in their watersheds. For example, high run-off from storms could bring excess sediment and/or nutrients to a water body. Sedimentation could alter substrate in fish nesting areas or facilitate invasion by invasive plants. Excessive nutrient inputs could also favor invasives, as well as contributing to algal blooms and associated oxygen depletion.

### Specific Wildlife Vulnerabilities

Cold water species, including lake trout, burbot, and round whitefish, require well oxygenated cold water below the thermocline, and could not persist in lakes where this layer is reduced or eliminated.

### General Strategies to Address these Vulnerabilities

- S1: Habitat Restoration and Management
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response

### Specific Strategies

1. Develop criteria to identify coldwater streams, lakes and fisheries areas likely to be resilient to warming. Prioritize protection of those coldwater habitats with greatest opportunity to maintain the coldwater ecosystem.

2. Regulate drawdowns. Maintain appropriate water levels. Maintain constant, appropriate lake levels. Leave lakes with deeper water to protect plant life and therefore keep dissolved oxygen levels higher. Work more closely with lake associations and dam owners on timing, frequency and levels of drawdowns to reduce impacts to native species.

#### Linkages to other habitats

- Freshwater wetlands, particularly marshes and fens, are frequently adjacent to open water aquatic systems.
- Lakes and ponds are usually embedded within river and stream networks, and thus influenced by changes to flows in these networks.

#### Citations

Quinn, T.P. and D.J. Adams. 1996. Environmental changes affecting the migratory timing of American shad and sockeye salmon. *Ecology* 77(4):1151-1162.

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## LAKESHORE AND RIVERSHORE ASSESSMENT

### Habitat overview

This habitat includes beaches and shorelines along both lakes and rivers, but not habitats associated with floodplain terraces that typically receive regular floodwaters from spring meltwaters and/or storm runoff. These habitats are somewhat adapted to scouring, and typical vegetation consists of grasses, sedges, and shrub species on a sand or gravel substrate.

Many rivershore natural communities and ecosystems no longer experience large storm flooding because of the influence of dams. However, annual flooding and two to three year recurrence interval floods do still occur in the lowest floodplain terraces.

### Major vulnerabilities

- Changes in precipitation patterns, such as longer periods of drought, unpredictable large storms, higher flows, and run-off events.
- Increased mechanical alteration of habitat, including erosion, higher energy flooding, and ice scour along rivershores.
- Increased risk from invasion by invasive species.
- High wind and excessive wave energy along lake beaches and shorelines.

### Vulnerability narrative

Almost all predicted changes in these habitats are associated with increasing unpredictability in the patterns of large storms, increased precipitation and runoff, and resulting changes in hydrology (Aldous et al 2011, Kingsford 2011, Grubin et al 2009). Associated changes in habitats may include increased erosion of beaches and shorelines, longer duration and higher energy flooding, early or late ice-out on lakes, and ice scour along rivershores. Additionally, high wind during storms may erode lake beaches and shorelines because of increased wave energy and duration.

Increased stress, new deposits of mineral soil, eroded surfaces and edge habitat may lead to increases in invasive species which specialize in disturbed edge habitats. Flooding events may also disperse invasive species into new areas, and increased sediment deposition could facilitate their establishment on previously unsuitable substrates.

One possible human response to increased flooding is to build additional dams and other infrastructure designed to control and/or channel storm effects. If such structures significantly alter hydrology either up or down stream, there are likely to be impacts on shoreline habitats. Similarly, existing and historic infrastructure designed to manage historic flows (e.g., old/ageing culverts, historic dams, shoreland riprap), may in fact exacerbate runoff impacts and damage to human health and property. For example, ageing and failing dams and culverts present higher risks during flood events to downstream resources and human infrastructure.

### Specific Wildlife Vulnerabilities

Several specialist species may be affected by increasing and highly variable precipitation. For example, tiger beetles that use cobble or sandy shores exposed during low water may be impacted by large storm flows or drought, particularly during sensitive life cycle stages. Sandy riverbanks provide nesting habitat for bank swallows, and high river flows and erosion events at sensitive nesting times could impact breeding success or destroy colonies entirely.

### General Strategies to Address These Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response
- S8: Revise Water Withdrawal Policies

### Specific Strategies

1. Create goals and guidelines for shoreline buffers to help stabilize banks for more frequent or higher volume flows.
2. Where possible, encourage an increase in the percentage of shore in native forest or shrubland to protect the water body from temperature increases due to high runoff events especially in hot summers.
3. Plant trees along stream banks where they have been eliminated to help shade streams and strengthen banks.
4. Encourage and advocate for land-use policies that increase development setbacks from shorelines and that prevent any further development on river floodplain/floodways.
5. Explore possible buyout programs to reduce development on sensitive shorelines.
6. Incentivize buffers along shorelines, such as a reduction in property tax for permanently protecting a shoreline buffer of 300 feet or more.
7. Prohibit shoreline armoring and protect large lake shoreland natural vegetative buffers.
8. Encourage regulation of beach construction to minimize loss of shoreline buffers.
9. Provide educational materials to lakefront property owner showing ways in which simple efforts of property management can change erosion, storm water runoff, etc.

### Linkages to other habitats

- Changes in river and lake hydrology will impact the breeding and migration of freshwater species, particularly fish.

### Citations

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## FLOODPLAIN HABITATS ASSESSMENT

### Habitat overview

Floodplain habitats occur on river terraces subject to regular flooding, usually during spring run-off or during storms. They are typically dominated by trees, including silver and red maples, American elm, and balsam fir in northern New Hampshire. Embedded in these forests are several wetland types, and many have also been converted to agricultural use (e.g., hayfields).

Many floodplain ecosystems no longer experience large storm flooding because of the influence of dams. However, annual flooding and two to three year recurrence interval floods do still occur in the lowest floodplain terraces (Nislow et al 2002).

Loss of natural floodplain ecosystems to development and agricultural land uses has also resulted in reduced natural valley flood storage. Floodplain forests and associated wetlands trap nutrients and sediment, while reducing flood energy and reducing peak flows compared to cleared or developed land.

### Major vulnerabilities

- Changes in precipitation patterns, such as longer periods of drought, unpredictable large storms, higher flows, and run-off events which can erode areas and change species composition.
- Increases in invasive species.
- Slow migration of southern species north.

### Vulnerability narrative

Almost all predicted changes in these habitats are associated with increasing unpredictability in the patterns of large storms, increased precipitation and runoff, and resulting changes in hydrology (Kingsford 2011, NOAA 2011, Opperman 2011, Palmer 2008). Associated changes in habitats may include longer duration and higher energy flooding, potential loss of species and habitat during extended droughts, and ice scour along rivershores.

Increased stress, new deposits of mineral soil, eroded surfaces and edge habitat may lead to increases in invasive species which specialize in disturbed edge habitats. Flooding events may also disperse invasive species into new areas. Invasives can not only reduce ecological integrity, but also potentially spread into agricultural and early successional habitats, particularly low terrace grasslands and hay fields.

Direct temperature effects may include slow migration of southern dominant tree species north along N-S trending river valleys such as the Connecticut and Merrimack Rivers. Maple dominated systems may shift to other southern species, and balsam fir floodplains may become more rare.

One possible human response to increased flooding is to build additional dams and other infrastructure designed to control and/or channel storm effects. If such structures significantly alter hydrology either up or down stream, there are likely to be impacts on floodplain habitats. Similarly, existing infrastructure designed to manage historic flows (e.g., old/ageing culverts, historic dams, shoreland riprap), may in fact exacerbate runoff impacts and damage to human health and property. For example, ageing and failing dams and culverts present higher risks during flood events to downstream resources and human infrastructure.

### Specific Wildlife Vulnerabilities

Floodplain wetlands are an important source of nutrients and provide multiple habitat niches. Species that use backwater sloughs and riparian vernal pools rely on regular recharge from high waters. Certain fish species also use floodplain areas for rearing. Wood turtles and other turtles use river cutbanks. All these habitats niches are vulnerable and sensitive to large changes in river hydrology.

### General Strategies to Address These Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S3: Restore Watershed Connectivity
- S4: Protect Riparian and Shoreland Buffers
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S7: Stormwater Policy and Flood Response
- S8: Revise Water Withdrawal Policies

### Specific Strategies

1. Develop a set of criteria to identify the best places on the landscape to restore floodplain forest habitat. Prioritize and map these.
2. Conduct floodplain forest restoration for multiple benefits, including habitat, surface stabilization, increased flood mitigation, wetland enhancement and water quality buffering. Maximize ecosystem health to better prepare for additional stressors from climate change. Use floodplain forest tree planting *and assisted migration of key floodplain tree species* as one restoration tool.
3. Monitor disturbance events for regeneration. Use adaptive management to respond to changes in flood frequency and intensity and the resulting spread of invasive species.
4. Preserve and protect areas of suitable slope adjacent to existing floodplains or lake shores to allow for habitat expansion.
5. Work with farmers to increase or restore floodplain forests through conservation easements and BMPs, while creating agricultural lands in other areas to mitigate loss of cropland acreage.
6. Develop incentive programs that compensate landowners for removing infrastructure in floodplains, including creating floodplain easements.

### Linkages to other habitats

- Extreme storm damage may result in more early successional habitats.
- Many wetlands and grasslands are in floodplains, and changes in land use and/or hydrology may shift a given area between these various habitats.

### Citations

Kingsford, R. 2011. Conservation management of rivers and wetlands under climate change – a synthesis. *Marine and Freshwater Research* 62, 217-222.

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## TERRESTRIAL HABITAT ASSESSMENTS

Including Appalachian Oak-Pine Forests, Hemlock Hardwood Pine Forests, Northern Hardwood Conifer Forests, Lowland Spruce-Fir Forests, High Elevation Spruce-Fir Forests, Early Successional Habitats, Pine Barrens, and Alpine.

### APPALACHIAN OAK-PINE FOREST ASSESSMENT

#### Habitat overview

Appalachian oak-pine is the southernmost forest type in New Hampshire, occurring primarily in southeast New Hampshire and further north along major river valleys. It is dominated by southern oaks like white, black, and scarlet oaks, and includes other southern species like hickories, sassafras, and flowering dogwood. This forest type reaches the northernmost limit of its range in southern NH.

#### Major vulnerabilities

- Although the species that dominate Appalachian oak-pine are tolerant of warmer and potentially drier conditions, and thus believed resistant to climate change, expansion of this habitat is likely to be limited by site conditions. Timing of range shifts will also vary considerably among species, and any migration is also likely to take place over timeframes longer than the present assessment considers.
- Drought-induced water shortages may make this habitat more susceptible to fire, but this is unlikely to significantly alter its extent or composition. Note that fire is still relatively rare even in similar habitats well to the south of NH, so the likelihood of increased fire events is probably low.
- As with other forest types, some forest pests may increase with warmer and/or drier conditions (e.g., gypsy moth), although the potential impacts of these on the overall habitat is unknown.

#### Vulnerability narrative

Predicting the responses of forests to climate change is a complicated endeavor. The response of a particular habitat to climate change is actually comprised of the individual responses of the habitat's component species. As a result, it is unlikely that forest types will simply shift their positions on the landscape. Instead, some species will increase and others decrease depending on specific climate needs and site conditions, resulting in subtly different forest types than those currently described (e.g., Zhu et al. 2011). These changes will likely take place over a much longer time frame than the roughly 100 years under consideration for this current assessment, although the rate of change will be heavily influenced by local conditions.

As a more southern habitat type, Appalachian oak-pine is not expected to suffer significant negative impacts from climate change. To the extent possible, it is generally predicted to increase where site conditions allow, especially where disturbance opens up areas previously dominated by northern hardwood-conifer or hemlock-hardwood-pine habitats. The potential for increased fire is unlikely to convert this forest type into another, since its dominant species are already adapted to occasional major disturbances of this sort. Of potentially greater importance is the introduction or proliferation of pests or pathogens that do well under a warmer climate. Although specific cases of the latter have not been identified (with the possible exception of gypsy moth), available evidence from other pests and pathogens indicates that changes in tree species composition can result.

Perhaps the greatest risk to Appalachian oak-pine forests comes from the human response to climate change. Because this habitat occurs primarily in southern New Hampshire, it has already suffered heavy losses to development, including fragmentation. Not only does existing human infrastructure impede species' ability to

colonize new areas, it also serves as the starting point for future development. Any shifts in human population – or in how humans use forests (e.g., firewood) – will initially affect those habitats in closer proximity to existing population centers. If people move north in response to higher temperatures, sea level rise, or drought, they will initially settle in areas currently dominated by (or in proximity to) Appalachian oak-pine forest.

#### Specific Wildlife Vulnerabilities

Most wildlife characteristic of oak-pine forest are unlikely to be significantly influenced by climate change. These species are already adapted to warmer climates, and are likely to be supplemented by new species moving in from farther south. Changes in hydroperiod could have strong negative impacts on species that use vernal pools embedded in this forest type.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S9: State Energy Policy

#### Specific Strategies

1. Manage Appalachian oak pine habitat with prescribed burning to maintain habitat and reduce the risk of wildland fires.
2. Provide education and outreach to the public on the importance of fire in Appalachian oak pine habitats.

#### Linkages to other habitats

- Pine barrens habitats are found on sandy soils and are maintained by recurrent fires. On pine barrens sites where fire has been suppressed for a long period of time, the habitat type can shift to oak-pine forest.
- Appalachian oak-pine forest transitions to hardwood-conifer types as one moves north or up slope.
- Vernal pools are common in this habitat type.

#### Citations

Zhu, K., C.W. Woodall, and J.S. Clark. 2011. Failure to migrate: lack of tree range expansion in response to climate change. *Global Change Biology*. Doi:10.1111/j.1365-2486.2011.02571.x

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## HEMLOCK-HARDWOOD-PINE FOREST ASSESSMENT

### Habitat overview

Hemlock-hardwood-pine forest covers about half the forested area of New Hampshire, much of that south of the White Mountains. The tree species composition of this forest type can vary significantly from site to site, but red oak and white pine are usually present in early to mid-successional forests, while hemlock and beech are more frequent in older stands.

### Major vulnerabilities

- Because these forest types are so widespread, overall impacts from climate change are likely to be highly variable, and often limited by specific site conditions (soil, existing species composition, etc.). In general, hemlock-hardwood pine species are more likely to shift north or up slope, and replace those more typical of northern hardwood-conifer forests. The timing of such shift will vary considerably among species, and any migration is also likely to take place over timeframes longer than the present assessment considers. At the same time, Appalachian oak-pine forests may replace hemlock-hardwood-pine in some areas in southern New Hampshire.
- More frequent disturbance events (e.g., hurricanes, ice storms, tornadoes) will likely favor shade-intolerant, early successional species (paper birch and aspen) over shade tolerant, late successional species (beech and hemlock). Higher rates of disturbance would also alter the relative proportions of different seral stages of forest.
- Some forest pests are likely to increase with warmer and/or drier conditions (e.g., hemlock wooly adelgid). The adelgid in particular has the potential to remove significant amounts of hemlock and dramatically alter forest composition.
- Both disturbance and pest/pathogen related mortality could result in larger areas of salvage logging and resulting habitat changes. This could in turn affect nutrient cycling and local hydrology.

### Vulnerability narrative

Predicting the responses of forests to climate change is a complicated endeavor. The response of a particular habitat to climate change is actually comprised of the individual responses of the habitat's component species. As a result, it is unlikely that forest types will simply shift their positions on the landscape. Instead, some species will increase and others decrease depending on specific climate needs and site conditions, resulting in subtly different forest types than those currently described (e.g., Zhu et al. 2011). These changes will likely take place over a much longer time frame than the roughly 100 years under consideration for this current assessment, although the rate of change will be heavily influenced by local conditions.

In a very general sense, specific climate tolerances predict that most species typical of hemlock-hardwood-pine habitats will shift north or upslope, replacing northern hardwood-conifer species and being replaced in turn by Appalachian oak-pine. However, these same species are often broadly tolerant of variation in temperature and moisture, so any changes will likely be subtle as mentioned above. In cases where a given species disappears because of climate change, site conditions may prevent colonization by new species, resulting in a less dramatic shift of dominance among those species that remain (e.g., loss of American chestnut).

The effects of altered precipitation patterns on hardwood-conifer forests are harder to predict, and are largely tied to the interactions between precipitation and temperature. Increased drought may reduce seed set in some species, and thus limit their ability to migrate or recolonize after disturbance. Drier summers could also increase the chance of fire, although fire is historically rare and unlikely to increase to such an extent that it would dramatically alter existing habitats.

The role of altered disturbance regimes in these habitats will similarly affect species composition rather than outright forest type. Post-disturbance species composition is likely to be more influenced by existing understory composition and nearby seed sources than by climate tolerances. Shade-tolerant species like hemlock may be disproportionately negatively affected by more frequent disturbance events.

Increased numbers and diversity of forest pests and pathogens is potentially one of the most important results of climate change in these habitat types. Species currently kept in check by cold winters will increase, and in extreme cases have the potential to dramatically reduce the abundance of their host species. Currently the hemlock wooly adelgid is moving north as temperatures increase, and has already destroyed significant areas of hemlock to the south. Not only does this alter a forest's tree species composition, but there are secondary effects resulting from the loss of the dense shade that hemlock typically provides. Similarly, the almost inevitable colonization of New Hampshire by the emerald ash borer will result in loss of ash, and the potential for future pests is large and immeasurable.

In addition to insect pests, non-native invasive plant species are likely to increase with climate change. Already-established invasives will expand their ranges and increase in abundance, while southern species are more likely to colonize the state. High densities of invasives can potentially alter the type of forest that regenerates after a major disturbance event.

Human response to climate change could affect this habitat type in three broad ways: 1) direct losses to development (including energy infrastructure), 2) conversion through harvest, or 3) facilitation of other stressors. In the former category, hardwoods along ridgelines could be vulnerable to wind power development, and all forests could be removed to make way for the infrastructure related to power transmission. Increased population pressures as people move north (to avoid heat, drought, sea level rise, etc.) will result in expanded areas of housing and transportation infrastructure, although this impact is still largely speculative. Accelerated harvest of hardwoods could result from either salvage logging after major disturbance events or through an increased demand for wood as fuel. Finally, existing or future human infrastructure can serve as a conduit for invasive species whose colonization would otherwise be limited.

#### Specific Wildlife Vulnerabilities

Moose are already experiencing extreme stress related to increased infestation of winter tick with a warmer climate. An increase in deer with changing habitat will also expose moose to increased incidences of brain worm. Some birds that currently occupy wide elevational ranges (e.g., Black-throated Blue Warbler) experience lower productivity at their lower limits, probably a result of habitat-influenced food supplies (Rodenhouse et al. 2008). Extrapolation of these results suggests that a warming climate would reduce the range of elevation where habitat is most suitable, and thus result in potential population declines. Many forest birds are important predators of defoliating insects, and phenological decoupling of bird migration and insect emergence may reduce predation pressure, with negative impacts on both forest trees and the birds that depend on these insects to feed their young.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S9: State Energy Policy

### Specific Strategies

1. Increase monitoring and management for hemlock wooly adelgid, especially in deer wintering areas. Incorporate into adaptive management.
2. Research and develop effective biocontrol for hemlock wooly adelgid.

### Linkages to other habitats

- Hemlock-hardwood-pine forest often intergrades with wetlands, particularly red maple swamps.
- Vernal pools are common in this habitat type.
- Hemlock-hardwood-pine forests transition into oak-pine, northern hardwood-conifer, spruce-fir, and floodplain forests across their range in the state.
- Reduced shading of streams resulting from loss of hemlock may increase water temperatures, with concomitant affects on aquatic organisms that require cooler water.

### Citations

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## NORTHERN HARDWOOD-CONIFER FOREST ASSESSMENT

### Habitat overview

Northern hardwood-conifer forest is found primarily in the northern half of the state and at elevations between 1500 and 2500 feet. It is characterized by sugar maple, American beech and yellow birch, with American hemlock at lower elevations and red spruce at higher elevations.

### Major vulnerabilities

- Because these forest types are so widespread, overall impacts from climate change are likely to be highly variable, and often limited by specific site conditions (soil, existing species composition, etc.). In general, northern hardwood species are more likely to shift north or up slope, and be replaced by hemlock-hardwood-pine species. The timing of such shifts will vary considerably among species, and any migration is also likely to take place over timeframes longer than the present assessment considers.
- More frequent disturbance events (e.g., hurricanes, ice storms, tornadoes) will likely favor shade-intolerant, early successional species (paper birch and aspen) over shade tolerant, late successional species (sugar maple and beech). Higher rates of disturbance would also alter the relative proportions of different seral stages of forest.
- Both disturbance and pest/pathogen related mortality could result in larger areas of salvage logging and resulting habitat changes. This could in turn affect nutrient cycling and local hydrology.
- Pressure to develop alternative energy sources (wind turbines) could have significant effects on some areas of northern hardwood-conifer forest. Associated shifts in government policy may open currently protected areas to such development.

### Vulnerability narrative

Predicting the responses of forests to climate change is a complicated endeavor. The response of a particular habitat to climate change is actually comprised of the individual responses of the habitat's component species. As a result, it is unlikely that forest types will simply shift their positions on the landscape. Instead, some species will increase and others decrease depending on specific climate needs and site conditions, resulting in subtly different forest types than those currently described (e.g., Zhu et al. 2011). These changes will likely take place over a much longer time frame than the roughly 100 years under consideration for this current assessment, although the rate of change will be heavily influenced by local conditions.

In a very general sense, specific climate tolerances predict that most species typical of northern hardwood-conifer habitats will shift north or upslope (Beckage et al. 2008), replacing spruce-fir species and being replaced in turn by hemlock-hardwood-pine species. However, these same species are often broadly tolerant of variation in temperature and moisture, so any changes will likely be subtle as mentioned above. In cases where a given species disappears because of climate change, site conditions may prevent colonization by new species, resulting in a less dramatic shift of dominance among those species that remain. For example, sugar maple requires richer soils, and will likely be limited in its ability to migrate out of its current range, irrespective of its climate tolerance.

The effects of altered precipitation patterns on hardwood-conifer forests are harder to predict, and are largely tied to the interactions between precipitation and temperature. Increased drought may reduce seed set in some species, and thus limit their ability to migrate or recolonize after disturbance. Drier summers could also increase the chance of fire, although fire is historically rare and unlikely to increase to such an extent that it would dramatically alter existing habitats.

The role of altered disturbance regimes in these habitats will similarly affect species composition rather than outright forest type. Post-disturbance species composition is likely to be more influenced by existing understory composition and nearby seed sources than by climate tolerances. Shade-tolerant species like sugar

maple may be disproportionately negatively affected by more frequent disturbance events. In extreme cases, loss of forest cover in combination with poor site conditions (e.g., compacted soils, shallow mountaintop soils, etc.) may result in replacement communities being dominated by shrubs rather than trees.

Increased numbers and diversity of forest pests and pathogens is potentially one of the most important results of climate change in these habitat types. Species currently kept in check by cold winters will increase, and in extreme cases have the potential to dramatically reduce the abundance of their host species. Currently the hemlock woolly adelgid is moving north as temperatures increase, and has already destroyed significant areas of hemlock to the south. Not only does this alter a forest's tree species composition, but there are secondary effects resulting from the loss of the dense shade that hemlock typically provides. Similarly, the almost inevitable colonization of New Hampshire by the emerald ash borer will result in loss of ash, and the potential for future pests is large and immeasurable.

In addition to insect pests, non-native invasive plant species are likely to increase with climate change. Already-established invasives will expand their ranges and increase in abundance, while southern species are more likely to colonize the state. High densities of invasives can potentially alter the type of forest that regenerates after a major disturbance event.

Human response to climate change could affect this habitat type in three broad ways: 1) direct losses to development (including energy infrastructure), 2) conversion through harvest, or 3) facilitation of other stressors. In the former category, hardwoods along ridgelines could be vulnerable to wind power development, and forests could be cleared to make way for the infrastructure related to power transmission. Increased population pressures as people move north (to avoid heat, drought, sea level rise, etc.) will result in expanded areas of housing and transportation infrastructure, although this impact is still largely speculative. Accelerated harvest of hardwoods could result from either salvage logging after major disturbance events or through an increased demand for wood as fuel. Finally, existing or future human infrastructure can serve as a conduit for invasive species whose colonization would otherwise be limited.

#### Specific Wildlife Vulnerabilities

Moose are already experiencing extreme stress related to increased infestation of winter tick with a warmer climate. Some birds that currently occupy wide elevational ranges (e.g., Black-throated Blue Warbler) experience lower productivity at their lower limits, probably a result of habitat-influenced food supplies (Rodenhoust et al. 2008). Extrapolation of these results suggests that a warming climate would reduce the range of elevation where habitat is most suitable, and thus result in potential population declines. Many forest birds are important predators of defoliating insects, and phenological decoupling of bird migration and insect emergence may reduce predation pressure, with negative impacts on both forest trees and the birds that depend on these insects to feed their young.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S9: State Energy Policy

#### Specific Strategies

1. Map areas where the elevation and topography might allow for cold pockets. Encourage timber management for spruce fir or sugar maple as appropriate for the soil conditions.
2. Identify suite of calcium-dependent indicator plants and their change in dominance at semi-rich to rich mesic sites. Used to assess habitat change due to  $\text{Ca}^{+2}$  loss.

3. Protect a sufficient acreage and dispersion of high quality northern hardwood-conifer to allow for natural successional processes and the possibility of migration.
4. Develop programs and materials that capitalize on the popularity of fall foliage and maple syrup to educate people on the importance of this type of habitat and its potential response to climate change.

#### Linkages to other habitats

- Northern hardwood-conifer forests intergrade with wetlands, particularly red maple swamps.
- Vernal pools are common in this habitat type.
- Northern hardwood-conifer forests transition into oak-pine, hemlock-hardwood-pine, spruce-fir, and floodplain forests across their range in the state.

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Zhu, K., C.W. Woodall, and J.S. Clark. 2011. Failure to migrate: lack of tree range expansion in response to climate change. *Global Change Biology*. Doi:10.1111/j.1365-2486.2011.02571.x

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## LOWLAND SPRUCE-FIR FOREST ASSESSMENT

### Habitat overview

Lowland spruce fir is dominated by black spruce in wetlands and red and white spruce and balsam fir in drier areas. The majority is found at elevations between 1000 and 2500 feet and in the bottom of valleys. Most lowland spruce-fir is found in the northern part of the state, but in the south it also occurs in the higher elevations of the western highlands. Spruce-fir forests in general are characterized by poor soils, short growing seasons, and adaptation to cold temperatures (frost free 90-120 days/year).

### Major vulnerabilities

- As cold adapted species, spruce and fir are likely to experience reduced recruitment and eventually be outcompeted by hardwoods and pines under warming scenarios. The timing of such shifts will vary considerably among species, and any migration is also likely to take place over timeframes longer than the present assessment considers.
- Lowland spruce-fir forests occur on our coldest sites, and tend to have nutrient-poor soils with a high organic content. Under warming conditions, this organic material would break down more rapidly, enriching the soil and making it more suitable to invasion by hardwood species. This phenomenon is more likely on the warmest or driest of lowland spruce-fir sites.
- Drought-induced water shortages may make spruce-fir habitats more susceptible to fire, as well as foster invasion by more drought-tolerant species (e.g., white pine).
- Pressure to develop and distribute alternative energy sources (especially the associated transmission lines) could fragment spruce-fir forest in the lowlands of Coos County or along ridgelines in western New Hampshire. Associated shifts in government policy may open currently protected areas to such development.

### Vulnerability Narrative

Predicting the responses of forests to climate change is a complicated endeavor. The response of a particular habitat to climate change is actually comprised of the individual responses of the habitat's component species. As a result, it is unlikely that forest types will simply shift their positions on the landscape. Instead, some species will increase and others decrease depending on specific climate needs and site conditions, resulting in subtly different forest types than those currently described (e.g., Zhu et al. 2011). These changes will likely take place over a much longer time frame than the roughly 100 years under consideration for this current assessment, although the rate of change will be heavily influenced by local conditions.

As the most cold-adapted forest type, spruce-fir is the habitat most likely to experience negative effects from climate change. Because lowland spruce-fir occurs near the southern edge of its range in New Hampshire, it is at the greatest risk of range reduction, including disappearance from isolated and/or peripheral areas to the south. At the same time, it appears that spruce-fir habitats are relatively resilient to many climate change impacts, at least in part because their dominant species outcompete hardwoods and pine on poor soils or in extreme environments (e.g., subalpine zone). However, if current spruce-fir soils warm significantly, they may be enriched by decomposing organic material, and thus be more susceptible to invasion by hardwoods. Hardwoods more tolerant of poor soils that could invade spruce-fir include American beech and yellow birch.

The effects of altered precipitation patterns on spruce-fir are harder to predict, and are largely tied to the interactions between precipitation and temperature. Higher summer temperatures in combination with more frequent or longer summer droughts will dry out forests, resulting in an increased chance of fire. Although fire has historically been rare in all New Hampshire forests, and spruce-fir is relatively well-adapted to it, such disturbance under a warming climate may facilitate invasion by hardwoods, pines, or non-native invasives. Species particularly adapted to wetter soils – such as black spruce – may disproportionately disappear from this habitat under a warm and dry scenario.

Human response to climate change may affect spruce-fir forests through increased demand for renewable energy. Under this scenario, large areas of lowland spruce-fir could be converted to earlier successional stages as a result of harvesting for biomass fuels. It is important to note, however, that such effects are likely to be limited to relatively small areas of spruce-fir habitat were they to occur. In addition, fragmentation of habitat due to new transmission lines may degrade habitat.

#### Specific Wildlife Vulnerabilities

Moose appear to be experiencing extreme stress related to increased infestation of winter tick with a warmer climate. Habitat changes may exacerbate this through altered patterns of herbivory related to snow depth, and migration of deer into moose habitat brings increased exposure to brain worm. Changes in snow depth could impact the ability of marten and small mammals to survive the winter. In general, any loss of spruce-fir forest will reduce habitat availability to an entire suite of boreal wildlife that reach their southern range limits in New Hampshire.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S9: State Energy Policy

#### Specific Strategies

1. Develop a model to determine where lowland spruce fir might persist in the landscape. Factors should include where elevation and topography might allow for cold pockets, soil types, geology and other features. Identify areas of spruce forest that have higher existing condition. Identify strategies for corridors/networks between patches. Map areas more likely to persist with climate change based on these factors. Prioritize these for future conservation or management.
2. Determine the soil-water and air-water minimum requirements for lowland spruce fir.
3. Research the impact on winter adapted species such as those who are dependant on snow for shelter or camouflage (small rodents, those that change color) to see which might decline due to climate change, and how that might affect their predators.
4. Encourage timber management for spruce fir in areas identified as likely long-term refuges for this forest type.
5. Limit use of biomass harvesting in this forest type.
6. Protect areas identified in the planning effort as most likely to persist as spruce-fir forests. To this add the conservation of north-south corridors through multiple habitat types to allow migration of tree species and wildlife along riparian corridors and adjacent lowlands. Also protect areas where lowland spruce-fir forests and wetlands are contiguous to help with both wildlife movements and hydrological stability.
7. Find ways to inform and engage foresters in management strategies that encourage the persistence of some spruce and fir despite climate change.

#### Linkages to other habitats

- Lowland spruce-fir intergrades with peatlands and swamps in some areas of northern New Hampshire.

- At the southern extent of this habitat, it transitions to hardwood-conifer types.

#### Citations

Zhu, K., C.W. Woodall, and J.S. Clark. 2011. Failure to migrate: lack of tree range expansion in response to climate change. *Global Change Biology*. Doi:10.1111/j.1365-2486.2011.02571.x

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## HIGH-ELEVATION SPRUCE-FIR FOREST ASSESSMENT

### Habitat overview

High elevation spruce-fir forest is dominated by red spruce and balsam fir and is generally found at elevations above 2500 feet. It is restricted to the northern half of the state, with the major concentration in the White Mountains. At its upper elevation limit it forms a stunted forest type known as krumholtz that transitions into alpine habitats. Spruce-fir forests in general are characterized by poor soils, short growing seasons, and adaptation to cold temperatures (frost free 90-120 days/year).

### Major vulnerabilities

- As cold adapted species, spruce and fir are likely to experience reduced recruitment and eventually be outcompeted by hardwoods and pines under warming scenarios. The timing of such shifts will vary considerably among species, and any migration is also likely to take place over timeframes longer than the present assessment considers.
- High-elevation spruce-fir species, already stressed by other factors (e.g., acid deposition), may be replaced by other species at a higher rate, especially at the lower limits of its climatic tolerance.
- Pressure to develop alternative energy sources (wind turbines) could have significant effects on high elevation spruce fir. Associated shifts in government policy may open currently protected areas to such development.

### Vulnerability narrative

Predicting the responses of forests to climate change is a complicated endeavor. The response of a particular habitat to climate change is actually comprised of the individual responses of the habitat's component species. As a result, it is unlikely that forest types will simply shift their positions on the landscape. Instead, some species will increase and others decrease depending on specific climate needs and site conditions, resulting in subtly different forest types than those currently described (e.g., Zhu et al. 2011). These changes will likely take place over a much longer time frame than the roughly 100 years under consideration for this current assessment, although the rate of change will be heavily influenced by local conditions.

As the most cold-adapted forest type in the state, spruce-fir is the habitat most likely to experience negative effects from climate change. Because spruce-fir occurs near the southern edge of its range in New Hampshire, it is at the greatest risk of range reduction, including disappearance from peripheral areas at lower elevations. There is already some evidence that the transition zone between hardwoods and spruce-fir is shifting upslope (Beckage et al. 2008), a phenomenon that may be exacerbated by non-climate stressors such as acid deposition (e.g., acid deposition kills off spruce at its lower limits, where warmer conditions enhance the ability of hardwoods to replace it). Upslope migration of spruce-fir is likely to be limited by the extreme physical environment in the alpine zone, where wind and ice prevent the establishment of most non-prostrate woody vegetation (Seidel et al. 2009). These same factors, were they to increase (e.g., more winter moisture at high elevation), could even result in the down-slope expansion of the alpine zone at the expense of spruce fir, again depending on local site conditions.

At the same time, it appears that spruce-fir habitats are relatively resilient to many climate change impacts, at least in part because their dominant species outcompete hardwoods and pine on poor soils or in extreme environments (e.g., subalpine zone). Hardwoods more tolerant of poor soils that could invade spruce-fir include American beech and yellow birch.

The effects of altered precipitation patterns on spruce-fir are harder to predict, and are largely tied to the interactions between precipitation and temperature. Higher summer temperatures in combination with more frequent or longer summer droughts will dry out forests, resulting in an increased chance of fire. Although fire has

historically been rare in all New Hampshire forests, and spruce-fir is relatively well-adapted to it, such disturbance under a warming climate may facilitate invasion by hardwoods, pines, or non-native invasives.

Human response to climate change may affect spruce-fir forests through increased demand for renewable energy. At high elevations, this demand is primarily met through development of wind power facilities, which will both fragment existing habitat and open up these areas to potential invasion by non-native plants. However, because high-elevation spruce-fir naturally experiences regular disturbance (e.g., fir waves), it is unclear whether such anthropogenic disturbance will significantly fragment this habitat.

#### Specific Wildlife Vulnerabilities

Predicted reductions in the extent of high-elevation spruce-fir will dramatically reduce habitat for Bicknell's Thrush, an obligate species in this habitat (Lambert and McFarland 2004). Secondary stressors at high elevation (acid deposition, wind development) will interact with overall habitat reduction in currently uncertain ways. Changes in snow depth could impact the ability of marten and small mammals to survive the winter. In general, any loss of spruce-fir forest will reduce habitat availability to an entire suite of boreal wildlife that reach their southern range limits in New Hampshire. Although some high-elevation birds appear to be expanding their distribution downslope (W. DeLuca, pers. comm.), higher predation pressure at lower elevation may negate any advantages of such a range change.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S9: State Energy Policy

#### Specific Strategies

1. Develop a statewide or regional plan that identifies areas of high-elevation spruce-fir where such wind facilities or other energy infrastructure can be sited with minimal impact to habitat integrity or connectivity. Work with the wind power industry on this so as to facilitate adoption of the plan.
2. Monitor bird diversity and abundance (especially Bicknell's Thrush) along an altitudinal gradient in high elevation spruce-fir. Changes in centers of distribution may be important indicators of changes in habitat composition or condition in this habitat.
3. Identify areas of spruce forest that have higher existing condition, may be more resilient to climate change (e.g. particularly poor soils), and are better connected to each other. Prioritize these for future conservation or management.
4. Where management occurs, ensure that it promotes regeneration of spruce-fir rather than hardwoods.
5. Implement and/or enforce regulations dealing with air pollutants that cause acid rain so as to minimize additional stressors that may act in synergy with climate change in high-elevation spruce-fir.
6. Advocate for practices that promote acceptable forestry and land use practices in high elevation spruce fir. Conserve this forest type when possible.

#### Linkages to other habitats

- At high elevations, spruce-fir is limited by the conditions that create alpine habitats, and which, as discussed above, may limit or prevent up-slope expansion.
- At the lower elevations, it transitions to hardwood-conifer types.



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## EARLY SUCCESSIONAL HABITATS ASSESSMENT

### Habitat overview

This habitat category includes those habitats that are primarily anthropogenic in nature, broadly divided into “shrublands” and “grasslands.” Shrublands are dominated by low wood vegetation, and include old fields, coastal thickets (e.g., in dunes), regenerating forests, and maintained shrublands such as power line rights of way. New Hampshire grasslands are almost entirely agricultural in origin (e.g., hayfields), but also include airstrips and reclaimed landfills. When left unmanaged, grassland habitats tend to succeed into shrublands, and shrublands into forests, with exceptions to the latter in cases where soil conditions may preclude the establishment of trees (e.g., very wet or dry) or where natural disturbance regularly eliminates more mature woody plants.

### Major vulnerabilities

- In general these habitats are currently believed resistant to climate change as long as management continues.
- Increased diversity and abundance of invasives (particularly plants).
- Potential for loss of wildlife value to these habitats from intensified management resulting from a longer growing season and an increased demand for biomass fuels.

### Vulnerability narrative

For the most part, the plant species common in early successional habitats are not believed sensitive to direct temperature effects, and are thus unlikely to suffer from the increased temperatures predicted by all climate change models. A longer growing season may allow for more rapid annual growth, thus speeding up natural succession rates, and this response may be facilitated by higher levels of CO<sub>2</sub> in the atmosphere. In addition, southern species – including invasives – may be better able to colonize NH with warmer temperatures and a longer growing season. It is important to note that there are limited data available on how productivity will vary with climate change (e.g., interactions between temperature and precipitation), and that any potential interactions are highly speculative (e.g., Parton et al. 1995, Thornley and Cannell 1997).

The effects of shifting precipitation patterns are even harder to predict. Many grasses are drought tolerant (especially the native bunch grasses [C3 plants]), and unlikely to be significantly affected by increased summer droughts. At the same time, if disturbance events (fire, flood, drought) become increasing erratic, generalist species (again including many invasives) would likely benefit, and come to dominate early successional communities (note that many already do so). Given that many agricultural grasslands are in floodplains, changes to flood regimes have the potential to both enhance these habitats (e.g., sediment deposition) or otherwise alter them (e.g., extensive standing water), depending on when the flooding occurs. Changes to hydrology also have the potential to shift habitats back and forth between grasslands/shrublands and similar wetland types (marshes and shrub swamps, respectively).

Much of how these habitats respond to climate change will be tied to how people respond. For example, increased pressures for local agriculture or locally produced biomass energy may drive conversion of forest to grassland or shrubland, and existing grasslands may be converted to more intensive agricultural use (and thus be of lower value to wildlife). Increased productivity in grasslands may allow for more frequent hay harvests, to the detriment of grassland birds and other species. Intensified agriculture, in conjunction new populations of invasive plants and insects, may result in increased pesticide application, with uncertain effects on wildlife, water quality, and habitat composition.

### Specific Wildlife Vulnerabilities

Because these habitats are unlikely to change significantly in response to climate change, most early successional wildlife are more likely to be affected by changes to management of grasslands and shrublands. For example, intensified agriculture may adversely affect grassland wildlife through crop conversion or more frequent mowing (which can cause mortality). Increased disturbance (e.g., fire, intense storms) may actually benefit shrubland wildlife species by facilitating understory or opening vegetation. The potential effects of invasive plant species on shrubland bird productivity and habitat occupancy are poorly known, and warrant additional study.

#### General Strategies to Address These Vulnerabilities

S1: Conserve Areas for Habitat Expansion and/or Connectivity  
S2: Habitat Restoration and Management  
S5: Invasive Species Plan

#### Specific Strategies

1. Establish permanent shrub plots to research how shrub species composition changes as climate changes.
2. Determine the value to rare wildlife of old and new invasive species.

#### Linkages to other habitats

- Shifting hydrologic regimes have the potential to convert early successional habitats to wetlands and vice versa.
- Increased harvest or disturbance in forested habitats will result in increased availability of young forests, at least in the short term.
- See pine barrens narrative for more detail on the potential effects of fire under climate change.

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## PINE BARRENS ASSESSMENT

### Habitat overview

Pine barrens habitats are dominated by pitch pine and scrub oak interspersed with grassy openings. They occur primarily on sandy, nutrient poor soils associated with glacial sediments or outwash. These communities are typically maintained by frequent disturbance, particularly fire, and in the absence of disturbance are likely to gradually mature into primarily forested habitats. Pine barrens are globally rare ecosystems, and support a suite of regionally and globally rare species including several Lepidoptera (e.g., Karner blue butterfly, frosted elfin, *Persius duskywing*) whose larval host plants also depend on frequent fire or similar disturbance.

### Major vulnerabilities

- At the habitat level, pine barrens are believed less vulnerable to climate change, since their dominant species are adapted to warm temperatures and dry conditions.
- Range of microclimate variability may be reduced, with negative effects on specialized rare plants and invertebrates.
- Increased resistance to using prescribed fire for management, reliance on mechanical maintenance only will result in organic matter covering sandy soils.

### Vulnerability narrative

Pine barrens vegetation is very tolerant of drought and disturbance (e.g., fire, extreme wind events), and as a result is not expected to be adversely affected by most climate change stressors. There is a possibility that the dominant pine species may shift with increased temperatures, but this will most likely increase the distribution of pitch pine as it takes over in traditional red pine areas to the north. There is a possibility that increases in understory competitors (e.g., grey birch) could alter the structural characteristics of pine barrens.

Much of the heterogeneity within pine barrens is the result of variation in microclimate. Interactions between frost, fire, and existing vegetation create a range of successional stages which can serve as refugia for specialized species (Motzkin et al. 2002). Under a warming scenario, it is currently unclear whether the “frost pockets” that promote dense shrubby vegetation would become more or less prevalent, with results dependent upon the degree of canopy closure. Although higher temperatures would reduce the incidence of frost overall, higher radiational cooling associated with openings (e.g., from fire or harvest) could – at least temporarily – increase frost. In the long run, a warming climate would reduce the number of frost pockets on the landscape, with associated losses in plants and animals that rely on these microclimates.

Although increased summer droughts and higher temperatures could facilitate more fires – and thus benefit pine barrens – human response to increased fire risk actually has the potential to *reduce* the incidence of fires. Prescribed fire in particular may be more difficult to implement as a management tool as a result of shifting burn windows and increased public resistance. In the absence of fire, organic matter (e.g., leaf litter) will accumulate on top of the sandy soils and reduce the ability of some rare plants to germinate. Increasing organic matter could also facilitate colonization of pine barrens by invasive species. However, when fires *do* occur, extreme drought and high summer temperatures may increase their severity, thus consuming more organic matter and allowing pitch pine to expand.

The potential effects of climate change on groundwater are poorly understood, as are the implications of any such changes for pine barrens vegetation. Higher overall precipitation has the potential to recharge groundwater, but much will depend on the timing and magnitude of precipitation events. If more precipitation comes as rain, in larger events, and/or while the ground is still frozen, more water will run off rather than percolate into the aquifers that underlie New Hampshire’s pine barrens. Pine barrens that occur in or near

wetlands, on the other hand, may risk inundation. Increasing human populations may impose additional extractive pressure on pine barrens aquifers.

There is some concern about the interactions between defoliating insects (e.g., gypsy moth) and climate change in pine barrens (e.g., Hom et al. 2008). If gypsy moth is able to expand its range north (Vanhanen et al. 2007), this non-native pest may become more prevalent in New Hampshire, with yet unknown affects on pine barrens and other native vegetation.

#### Specific Wildlife Vulnerabilities

Phenological shifts may shift species interactions such as food availability for breeding birds and developing larvae of Lepidoptera. Loss of microclimate variability due to reduced disturbance and more severe temperatures will impact availability of refugia for reptiles and Lepidoptera in years of extreme weather fluctuations. Loss of rare plants could result in the loss of dependent fauna.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S2: Habitat Restoration and Management
- S5: Invasive Species Plan
- S6: Comprehensive Planning
- S9: State Energy Policy

#### Specific Strategies

1. Continue prescribed fire management to ensure regeneration of pine barrens habitat during ideal conditions. Allow for alternative management or no management in years with excessive wet conditions or drought conditions.
2. Create conservation buffers to provide increased protection for private property surrounding pine barrens management areas.
3. Encourage pervious surface materials in developments originally settled on pine barrens habitat (sandy soils) to help maintain groundwater levels.
4. Develop and implement a communication strategy on the benefits and safety of prescribed fire.
5. The persistent nature of shrub structure in pine barrens makes them an important source population for bird species that live in other areas as available. It is important that pine barrens are included in the regional discussion on early successional habitat strategies and assessments.

#### Linkages to other habitats

- In the absence of disturbance or management, pine barrens are likely to shift toward Appalachian oak-pine or hemlock-hardwood-pine.
- Pine barrens share many species with early successional shrublands.

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## ALPINE HABITAT ASSESSMENT

### Habitat overview

In New Hampshire, the true alpine zone is climatically-defined, and generally occurs above 4900' in the White Mountains. It is one of the rarest habitats in the state, consisting of roughly 12 square miles of contiguous alpine habitat in the Presidential Range, and much smaller patches on a few other mountains (particularly Mt. Moosilauke and the peaks of Franconia Ridge). To a lesser extent, the category includes subalpine areas, which are dependent on local site conditions and found as low as 3000'. Alpine habitats are characterized by low, mat-forming shrubs, sedges, rushes, mosses, and lichens, and by stunted, twisted trees in the krummholz zone. Research has indicated that the factor limiting the distribution of alpine vegetation is not temperature per se, but the mechanical degradation of woody plants through accumulation of rime ice and abrasion by snow and ice particles. Vegetation similar to that in the true alpine zone can occur at lower elevations on isolated mountains, usually resulting from past anthropogenic disturbance such as fire. Post-disturbance loss of soil through wind and rain significantly delays succession to forest at such sites, and they retain aspects of alpine vegetation for decades or centuries.

### Major vulnerabilities

- New Hampshire's alpine habitats may be less vulnerable to climate change than once thought, since the prevailing trends on the high summits seem to be "uncoupled" from those at lower elevations. As a result they have not experienced significant warming over the past several decades.
- Increased snowfall could shelter tree seedlings and allow for woody encroachment in the alpine zone.
- Earlier snowmelt may result in species flowering earlier, with these flowers vulnerable to subsequent frost kill, depressing seed production and regeneration.

### Vulnerability narrative

Until very recently, it was thought that a significantly warming climate would significantly reduce or eliminate alpine habitats in New England. Under a warming scenario, woody vegetation would move up-slope in elevation and encroach upon open alpine areas, eventually resulting in forested summits and the loss of alpine-restricted species (e.g., Lesica and McCune 2004).

However, recent research has suggested that this anticipated trend is not as likely to occur as was once believed (see Seidel et al. 2009). Pollen records indicate that alpine vegetation has occupied the higher summits of the White Mountains for thousands of years, including the hypsithermal period (9,000-5,000 years ago) when the climate was significantly warmer than it is today. These results suggest that temperature alone is not limiting the growth of trees at these elevations. Instead, trees are excluded from the alpine zone through mechanical degradation: branches and stems break under accumulations of rime ice and are abraded by wind-driven ice and snow particles. Somewhat counter-intuitively, it is possible that *increased* snowfall poses a greater risk to alpine habitats. With a warmer climate, more moisture is held in the atmosphere, potentially leading to increased snowfall amounts on the high peaks. Increased snow depth could shelter woody plants from the effects of wind and ice accumulation, allowing krummholz vegetation to expand into previously open habitats dominated by alpine-restricted species. However, if elevated atmospheric moisture levels lead to an increase in the amount and duration of rime ice deposition, it is possible that the open alpine zone could actually expand through the degradation of marginal krummholz.

The planetary boundary layer is an atmospheric layer above which climatic conditions (wind, temperature) are not influenced by the local character of the earth's surface. Because of their isolated position (i.e., away from any other areas at similar elevations), the high peaks of the Presidential Range lie above the planetary boundary layer for roughly half of the days in both winter and summer. As a result, the New Hampshire

alpine zone may be largely decoupled from the temperature changes being documented at lower elevations across the majority of the state.

Although increasing temperatures may not result in the encroachment of woody species into the alpine zone, they may impact plant species by altering their flowering times. If snow melts earlier, and warmer temperatures stimulate now-exposed plants to flower earlier, these flowers may be vulnerable to killing frosts, resulting in the loss of that year's seed production. Although most alpine plants are fairly long-lived (20+ years), several consecutive years of lost seed production could negatively affect species populations.

One additional effect of climate change may be an interaction between stresses caused by climate change and higher nitrogen deposition resulting from increasing air pollution. Increased nitrogen could have a fertilizing effect on alpine plant species, and if some species respond more dramatically than others, it could potentially change the composition and structure of some alpine communities.

Subalpine peaks may be vulnerable to wind energy development, but this is likely a greater threat to high-elevation spruce-fir forests. Further research should confirm whether the conclusion of a resilient alpine zone is correct.

#### Specific Wildlife Vulnerabilities

Two subspecies of butterflies and a population of the American pipit are restricted to the alpine zone of the Presidential Range. Any effects of climate change on these three taxa are likely to be closely linked to habitat changes, with the two butterflies particularly vulnerable to changes in the distribution and abundance of their host plants (McFarland 2003). In addition, changes in butterflies and host plant phenology could reduce the hosts' availability to butterflies during critical periods in their life cycles.

#### General Strategies to Address these Vulnerabilities

- S1: Conserve Areas for Habitat Expansion and/or Connectivity
- S9: State Energy Policy

#### Specific Strategies

1. Manage alpine habitat so that vegetation changes occurring either due to increased snowfall or earlier snowmelt will not significantly alter the habitat for alpine butterflies.
2. Research paleo-climate and model micro-climate sites to better understand the resiliency of alpine habitats.
3. Research and monitor alpine plants, wildlife species (in particular American pipit, white mountain butterfly, and white mountain fritillary), and physical features to better understand the effects of climate changes.
4. Encourage the reduction of anthropogenic nitrogen input and other air pollutant stressors that may have impacts to alpine habitat.
5. Implement recreation thresholds to mitigate disturbance and additional stress on alpine habitat.

#### Linkages to other habitats

- Krummholtz currently forms the boundary between alpine habitats and high-elevation spruce-fir forest. Local site and microclimate conditions result in isolated patches of each habitat within the general range of the other, and the future distribution of such patches will be determined by specific climatological factors such as snow depth and wind intensity.



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## SOME SPECIES DIRECTLY AFFECTED BY CLIMATE CHANGE

While all wildlife is affected by climate change through changes to their habitats, a few species are also directly susceptible to either climate stressors or interacting organisms that have responded to these stressors. This section provides a brief overview of species or group specific threats associated with climate change. In addition, all species are at risk from phenological decoupling. This occurs when the timing of important life history events (migration, breeding) is under some degree of climatic control, and the animal adjusts its timing as climate changes (e.g., Dunn and Winkler 1999). However, not all cues are based on climate (e.g., photoperiod) and different species are likely to respond at different rates or to different cues. As a result, interacting species may no longer follow the same phenological patterns. For example, if plants advance their flowering time to track warmer springs, but pollinating bees do not (or advance at a different rate), there is the potential for reduced seed-set in the plants and reduced foraging efficiency in the pollinators. The same effects can occur if migratory species arrive too late to capitalize on important food supplies (e.g., Visser et al. 1998).

Because these threats are usually tied to climate stressors such as temperature or precipitation, there are relatively few strategies available beyond those that deal directly with reducing greenhouse gas emissions. In some cases research or monitoring opportunities may provide valuable insight into if or how a species responds to climate change.

## MOOSE (ALCES ALCES)

Increasing temperatures will have both direct and indirect effects on moose. Moose are perfectly adapted to cold but do poorly in warm weather. A highly insulative coat, thick skin, and low surface to volume ratio make it difficult for moose to stay cool. At summer temperatures above 57°F and winter temperatures above 23°F moose start to show symptoms of heat stress. When moose experience heat stress, their respiration and heart rates increase, they seek shade and cooling winds or cool water and they bed down and eventually cease foraging (Franzmann & Schwartz 1998). Spruce, fir and hemlock offer moose the best source of shade in the late fall, winter and spring, and all are species predicted to decline. Moose that don't eat in summer don't gain weight and by fall may not have enough body fat to sustain themselves through winter. Lowered body weights in cows lead to reduced calf production (Adams 1995). It is theorized that within the next 100 years temperatures will rise on average 5-13°F in winter and 3-14°F in summer (Table 1). Current average temperatures in NH are 21.1°F in winter and 65.5°F in summer. We are already at the southern limit of moose range.

Heat stress in domestic ruminants leads to lowered immune response which in turn leaves the animal more vulnerable to parasite and disease impacts (Lenarz et al. 2009). Murray et al. (2006) concluded that increasing temperature acting in concert with disease and parasites is responsible for the recent dramatic decline of moose in northwestern Minnesota. Currently in NH we have two parasites that have the ability to dramatically reduce moose numbers. These are winter ticks and brain-worm. Both of these parasites (whose primary host is the white-tailed deer) will become more numerous given shorter, warmer winters, sufficiently wet summer months and higher deer densities. While winter tick impacts will be lessened with decreasing moose densities, brain-worm impacts will remain high in the face of higher deer densities which are the primary host for this parasite. After reviewing the research on continental moose declines unrelated to predation or over-harvest, Lankester (2010) concluded that brain-worm was the driving force in the recent depletion of moose stocks over much of North America.

## CANADA LYNX (*LYNX CANADENSIS*) AND AMERICAN MARTEN (*MARTES AMERICANA*)

Canada lynx and marten prefer unfragmented northern spruce-fir forest habitat and need large expanses of land to satisfy their home ranges and need to find their preferred prey, snowshoe hare for lynx and a variety of small mammals for marten. Lynx have long legs, large paws, and a thick fur coat that has given them a competitive advantage over other mammal predators when hunting in the deep snow conditions of the northern forest (Carroll 2007). Martens obtain a significant portion of their prey through moving over or under the snow, and snow also may provide some protection against predation by larger carnivores. Without the snow pack however, they will have to compete with other predators such as bobcat and fisher, and their prey may be more difficult to capture. New Hampshire's small population of Canada lynx will likely continue to shift with changing snow pack, changing habitat, and changing snowshoe hare populations. Land managers can help by promoting early successional habitat in the northern forest to promote snowshoe hare.

## LONG-TAILED WEASEL (*MUSTELA FRENATA*), ERMINE (*MUSTELA ERMINEA*) AND SNOWSHOE HARE (*LEPUS AMERICANUS*)

Even with the occasional snow storm in the late fall and early spring seasons, the number of days without snow on the ground has increased and this is expected to increase. This is not particularly advantageous for wildlife species that have evolved cryptic coloration patterns to blend in with their white winter surroundings. Snowshoe hare and weasels (long-tailed and ermine) sense changes in the daylight length through their pineal gland, causing a hormonal change exhibited in their color coat. This trait has been tested and found to be a long standing evolutionary trait rather than one caused solely on present environmental conditions. However not all hares (or weasels) are destined to change their colors completely; snowshoe hare in other regions of the country turn a patchy mix of white and brown in the winter, other snowshoe hare populations remain brown (Kays and Wilson 2009), and weasels in their southern range molt into a light brown (Hall 1951) instead of the white coat that most turn in New Hampshire. Scientists are unsure how quickly this adaptation can occur. Genetic research is underway in northwestern United States on the snowshoe hare. In the meantime, snowshoe hare will have little chance of blending into a snowless winter environment and escaping from predators such as Canada lynx, bobcat, coyotes, foxes, American martens, and birds of prey. The slight shift in synchronicity will make the bright white hare and weasel an easy meal for predators and could cause some local populations to decline until and unless evolution has a chance to adjust to the new normal winter snow cover.

## MIGRATORY SPECIES

Migratory species (primarily anadromous fish and migratory birds) can be affected by climate change in widely disparate locations when compared to resident species. In addition to breeding habitat alteration and phenological decoupling (see habitat narratives and above), they can also be affected during the non-breeding season, when they occupy completely different habitats and geographies. In birds, it is now well-established that conditions in winter habitats can influence both annual survival and reproductive success in the subsequent breeding season. By extension, the effects of climate change on habitats used in winter or migration may be just as – if not more – important than effects on the breeding range. Many of the long-distance migratory birds that breed in NH spend the winter in the Caribbean or Central America, an area expected to experience increased dry periods under most climate change models (Neelin et al. 2006), and there is increasing evidence that drought has negative effects on the physiological condition of overwintering migratory birds (Silllett et al. 2000, Studds and Marra 2007). Similarly, habitats in wintering areas are likely to shift in response to temperature, rainfall, or sea level rise, with effects similar to those of habitat shifts in New Hampshire. Migratory birds are also highly vulnerable during migration itself, and it is believed that most annual mortality occurs during this period. Phenological decoupling, in addition

to the possibility of more intense storms (Butler 2000), could further reduce survival during this critical stage in the annual cycle.

To maximize survival of migratory species over their annual cycle, many of the same strategies outlined in the habitat assessments can be applied, albeit outside of New Hampshire. Protection, restoration, and management of key habitats and stopover sites may be critical to species conservation, even if habitat is secure on the breeding grounds. Strategies that encourage regional or international cooperation (including funding, research, monitoring, and outreach) in the conservation of migratory species could thus be added to those more specifically focused on activity within the state.

## BROOK TROUT (*SALVELINUS FONTINALIS*) AND OTHER COLD-WATER FISH

Brook trout are more common in northern New Hampshire where cooler summer air temperatures maintain suitable summer water temperatures. As one moves south, brook trout become increasingly dependent on groundwater streams as a steady source of cool water in the summer. The distribution of brook trout is expected to shift north and to higher elevations with climate change. The extent of this shift will be determined by the level of warming that occurs across the region (summer air temperatures in the northeast are predicted to increase by between 3°F and 14°F). Water temperature in most streams is tightly linked to air temperature. As the average temperature of a stream increases above 20°C, the stream will no longer support brook trout. Groundwater fed streams will provide isolated refuges for brook trout in southern New Hampshire, but many populations in central New Hampshire, south of the White Mountains, will be at risk of extirpation. The viability of brook trout populations within a watershed will depend largely on habitat quality. Relatively unfragmented and undeveloped watersheds with intact riparian zones will be more likely to support brook trout as stream temperatures become warmer. In watersheds with marginal summer temperatures for supporting brook trout populations, the ability to access areas with cooler water during periods of thermal stress becomes critical to the persistence of brook trout. Fragmentation of stream systems by impassable culverts and dams is a threat to local populations if trout cannot move into cold water refugia. Groundwater-fed streams are more resilient to both human impacts and climate change as long as adequate groundwater recharge is allowed to occur.

In addition to warming temperatures, brook trout will have to deal with an increased frequency and intensity of storm events, according to climate change predictions for the northeast. This may lead to more flashy spring and fall stream flows and lower baseflows in the summer. A reduced winter snowpack may also lead to more variable stream flows during spring, which is a critical period of growth for juvenile brook trout. Road washouts, erosion and sediment deposition, and increased acid deposition will likely impact brook trout habitat, especially in smaller streams. As with warming stream temperature, unfragmented watersheds are more likely to allow brook trout to find refuge during extreme flow events. Implementing stormwater management practices that promote groundwater infiltration, maintaining naturally vegetated riparian zones, and reducing watershed fragmentation are important strategies for maintaining resilient brook trout populations in the face of climate change.

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## PERFORMANCE MONITORING AND REVISIONS

Strategies listed in this plan will be monitored along with the full NH Wildlife Action Plan.

This plan will be incorporated into the full NH Wildlife Action Plan revision due in 2015, and will include newer data on species and habitat vulnerabilities and predicted changes as it becomes available.

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NOTE: DOES NOT INCLUDE REFERENCES FOR INDIVIDUAL HABITAT OR SPECIES ASSESSMENTS. THESE ARE LOCATED WITHIN EACH ASSESSMENT.

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## APPENDICES

### APPENDIX A: PARTICIPATING PARTNERS

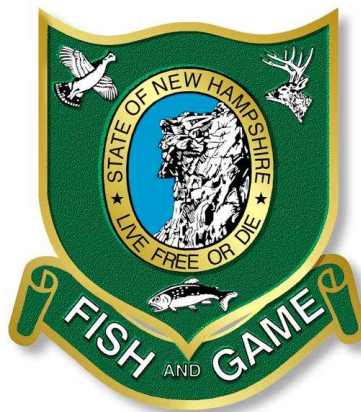
Albany Pine Bush  
Appalachian Mountain Club  
Audubon Society of New Hampshire  
Bear Paw Regional Greenways  
Biodiversity  
Ducks Unlimited  
Ecosystem Management Consultants  
Energy and Climate Collaborative  
Friends of Pondicherry  
Great Bay National Estuarine Research Reserve  
Harris Center for Conservation  
Hubbard Brook Experimental Forest  
Jefferson Conservation Commission  
Manomet Center for Conservation Sciences  
Moosewood Ecological Consulting  
Mt. Washington Observatory  
Narragansett Bay National Estuarine Research Reserve  
National Oceanic and Atmospheric Agency (NOAA)  
National Park Service  
Natural Resource Conservation Service (NRCS)  
National Wildlife Federation  
NH Association of Conservation Commissions  
NH Department of Environmental Services (Air Resources Division, Coastal Program, Dams Bureau, Drinking Water and Groundwater Bureau, Watershed Management Bureau, Wetlands Bureau, Office of the Commissioner)  
NH Department of Resources and Economic Development (Division of Forests and Lands, Division of Parks and Recreation and Natural Heritage Bureau)  
NH Energy and Climate Collaborative  
NH Fish and Game Commission  
NH Fish and Game Department  
Piscataqua Region Estuaries Partnership  
Shoals Marine Lab, Cornell University  
Society for the Protection of NH Forests  
Southwest Region Planning Commission  
The Nature Conservancy – New Hampshire  
Trout Unlimited  
University of Maine at Orono  
University of Massachusetts  
UNH Cooperative Extension  
UNH Jackson Estuarine Laboratory  
University of New England  
US Environmental Protection Agency  
US Fish and Wildlife Service (New England Field Office, Great Bay, Parker River and Rachel Carson National Wildlife Refuges)  
US Forest Service (White Mountain National Forest and Northern Research Station)  
US Geological Survey (New England Water Science Center and Patuxent Wildlife Research Center)  
Weeks Brick House and Gardens  
Wells National Estuarine Research Reserve



Winnicut River Watershed Association  
Wildlife Management Institute

# **Wildlife Summit III: Safeguarding Wildlife and Ecosystems from the Effects of Climate Change**

**New Hampshire Fish and Game Department**



Friday, June 11, 2010  
8:30 a.m. – 4:00 p.m.  
New Hampshire Technical Institute,  
Concord

*Facilitated and notes compiled by:*



**Wildlife Summit III:  
Safeguarding Wildlife and Ecosystems from the Effects of  
Climate Change**

**Wildlife Action Plan Revision  
June 11, 2010  
8 a.m. to 4 p.m.**

**Co-hosts**

*NH Fish and Game Department  
National Wildlife Federation  
NH Department of Environmental Services  
NH Natural Heritage Bureau  
NH Audubon  
Society for the Protection of NH Forests  
The Nature Conservancy – New Hampshire  
UNH Cooperative Extension  
NH Fish and Game Commission*

**Agenda**

8:00 to 8:30 a.m. Registration

8:30 a.m. Welcome and Meeting Purpose – Glenn Normandeau, Executive Director, NH Fish and Game Department

8:45 a.m. Wildlife Action Plan: Past, Present and Future – John Kanter, Nongame Program Coordinator, NH Fish and Game Department

9:05 a.m. Connecting the WAP revision to the N.H. Energy and Climate Collaborative – Sherry Godlewski, Adaptation Coordinator, Department of Environmental Services

9:20 a.m. Northeast Region Fish and Wildlife Service Climate Change Initiative: Land Conservation Cooperatives – Rick Bennett, Regional Scientist, Northeast Region, US Fish and Wildlife Service

9:40 a.m. Status of National Climate Legislation and Adaptation Planning Throughout the Region – George Gay, Senior Manager, Climate Change Program, National Wildlife Federation

10 a.m. Break

10:20 a.m. Estimating Climate Change Resilience for Species and Habitats – Mark Anderson, Eastern Region Conservation Science Director, The Nature Conservancy

10:50 a.m. Using Vulnerability Assessment Results to Inform Agency Decisions – John O’Leary, State Wildlife Action Plan Coordinator, Massachusetts Division of Fisheries & Wildlife

11:10 a.m. Identify Issues to Safeguard New Hampshire’s Wildlife and Ecosystems in a Changing Climate – Summit Participants with Charlie French facilitating

12:10 p.m. Lunch – Box lunch provided.

1:10 p.m. Breakout sessions based on issues identified in morning session

3:10 p.m. Break

3:25 p.m. Report of results of breakout discussions and wrap up

4:00 p.m. Adjourn

## **Wildlife Summit III: Safeguarding Wildlife and Ecosystems Stakeholder Meeting**

### **Group Process Elements**

#### **11:00 Formation of Working Groups**

- Sticky Notes Activity:
  - Each participant to succinctly write on a 3” X 5” sticky note one key issue or concern they have regarding how climate change could impact wildlife or habitat (10 minutes)
  - Participants place sticky notes on table and begin grouping them into 4-6 common themes, with rough titles to be coined for each (25 minutes).
  - Facilitator to read off common themes with issues grouped under each for group consensus. The common themes will serve as basis for afternoon’s breakout groups (15 minutes).
  - Participants select which group they want to work with for the post-lunch breakout.

#### **12:00 Lunch Break**

**1:00 Participants Break out into Work-Group Sessions:** Each theme that emerged from the morning session is associated with a breakout group number. Charlie will describe which theme is associated with which breakout group number. Facilitators will spread around the room, hold up their group’s number, and guide participants to breakout rooms.

**Breakout 1** – (facilitator: Charlie French, UNHCE, note taker: Liza Poinier)

**Breakout 2** – (facilitator Dan Reidy, UNHCE, note taker: Marilyn Wyzga)

**Breakout 3** – (facilitator Michele Gagne, UNHCE, note taker: Nick Solerno)

**Breakout 4** – (facilitator Andy Fast, UNHCE, note taker: Lindsay Webb)

**Breakout 5** – (facilitator Judy Stokes, NHF&G, note taker: Judy Silverberg)

#### **1:10 Introductions & Sign-in Sheet**

- Have each person give their name and briefly outline their interest with respect to the group’s theme/breakout discussion topic.
- Pass around the sign-in sheet for names and phone numbers. Be sure that the session’s theme is listed on the easel paper.
- Go over ground rules (from poster).

#### **1:25 Overview of Theme**

- Briefly review the issues/concerns that fall under the theme.
- Invite open discussion about issues/topics relevant to the theme.

#### **1:45 Issue/Problem Definition**

What is the overarching issue/problem/thread that the issues identified in the morning speak to?

What are the key elements of this issue/problem/thread?

Craft an issue statement: A good issue statement concisely states who/what is impacted, what the basic elements or drivers of the issue/problem are, and what the consequences are (25-30 words is a general rule of thumb)

## **2:20                    Group's Purpose and Next Steps**

If a working group were to be formed to address this issue, what should this group's charter be? (i.e. *what* is it that the group is set out to do, *why*, and generally speaking, *how*?)

Who needs to be at the table?: What other individuals, organizations or other stakeholders have a stake in the problem and should be pulled in?

What are the next steps?: Before getting to the strategic level of how to address the problem, there are likely small steps that need to be taken, such as reaching out to other stakeholders, setting a next meeting date (and agenda), deciding how the group will communicate and share ideas, etc.

**3:00                    Break**

**3:15                    Report-Outs**

**3:50                    Next Steps**

**4:00                    Adjourn**

## **Wildlife Summit III – Issue Statements**

### **1. Weather**

Significant weather events and past (and forecasted) trends have and will continue to change habitats, wildlife populations, and their distribution on the landscape.

### **2. Education**

As climate changes, habitats and wildlife are potentially shifting, all people – in all their roles (landowners, voter, consumer, etc) make decisions that directly and indirectly affect wildlife. We (all) need compelling, useful, current information to make informed decisions.

### **3. Sea Level Rise and Aquatics**

Climate change will affect

- Hydrologic regime
- Water quality
- Physical habitat

These in turn will affect plant and wildlife communities. Human infrastructure (built environment) exacerbates these problems. Rethinking our approach to development to integrate future needs of aquatic ecosystems will alleviate some of these problems related to climate change. These sound practices help protect ecosystems and wildlife from existing threats.

### **4. Habitat Loss and Extinction**

Habitat and species protection models and mapping is needed to focus funding and resource allocation decisions to ensure that New Hampshire invests wisely in conservation strategies that cope with climate change.

Society faces dramatic change in habitat and species diversity because of climate change. The potential consequences of climate change include shift in habitat and wildlife ranges. This in turn results in shifts in economic drivers, such as travel and tourism, forest products, and recreation.

### **5. Phenology**

Changes in timing and intensity of meteorological events alter interaction among plants and animals resulting in enhanced or compromised reproduction and survival and affect the value of these resources to society.

## Breakout Group 1

### Weather

**Facilitator:** Charlie French (UNH Cooperative Extension)

**Recorder:** Liza Poinier (NH Fish & Game)

**Participants:** Meade Cadot, John O'Leary, Sherry Godlewski, Allison Briggaman, Pate Tate

#### **Sticky Notes:**

- How will extreme precipitation events affect wildlife habitat?
- Loss of highly vulnerable wetland habitat due to changes in precipitation and temperature.
- Flood control/mitigation will impact the most productive part of the landscape.
- How will changes in precipitation patterns, increased flashiness, longer periods of drought, decreased snow pack, etc. affect water quality and quantity and subsequently affect natural resources?
- Significant weather events are and will continue to change habitats, wildlife populations, and their distribution on the landscape.

#### **Issues:**

- Emergency planning for natural weather disaster – specifically, getting species out of harm's way.
- Climate = accumulation of weather....Would like to see understanding of relationship of weather to C.C. (climate change). What ability do we have to understand or predict what weather will be like in future under climate change?
- What's gone on in 10 yrs/what are trends? Will it get worse? Warmer, wetter, individual events that are more intense. Preparing for those trends if you can.
- Trends – What's trajectory and what will impacts be on different habitats??
  - Precipitation
  - Snowpack
  - Temperature
- We only have what models tell us – do we need different kinds of data/what are info needs for us as planners?



- Effects of CC will be weather effects. What are examples from past weather events (ex. drought) that can help us predict impacts? What were ecosystem responses? Need to ID examples.
- If examples of places in the world that look like we might look X years in the future.... Will New England become more like England/Ireland?..... and if so what can we learn?
- No \$ for staff to do what needs to be done. Feds should be planning more to use (volunteer) monitors to “keep track of the environment” – need class of citizen scientist taking measurements, collecting data re: wildlife and other facets..... need a big increase in this.
- See problem statement. What are dimensions of problem/leverage points?
- Culvert study/THC: salamanders, fish passage – culverts are inadequate, under-sized, designed wrong. Design improvements improved conditions for critters and infrastructure, etc.
- “Co-benefits”

### **Weather Problem Statement:**

Significant weather events and past (and forecasted) trends have and will continue to change habitats, wildlife populations, and their distribution on the landscape.

### **Leverage Points:**

- Also need civilian engineer corps. – volunteers with knowledge/equipment to help.
- Aquatic systems are driven by groundwater or precipitation, so you need to understand those to create appropriate strategies.
- Use CC to involve landowners/managers more in land conservation/habitat
- Enviro review process – ex. Suncook/mussels need more thorough review process to protect known locations of species/habitats \* Use WAP to inform e-review process.
- Conservation Commissions need education on e-reviews and WAP – esp. for wetland and other permit approvals, Zoning Boards, Planning and other town boards)
- Some towns are developing rapidly – there is board burn-out so we may need to do more frequent WAP reviews (invite ourselves)

- Circuit rider to provide tech. support in communities so that board turnover doesn't hurt continuity.
- Volunteers (see above) to gather data – better relationships/ppl could help with models.
- Tapping existing data/coordinating groups (ex. Maple growers phenology data)
- One central volunteer place to coordinate all natural resource volunteers (could we use volunteer NH for this?)
- FEMA/insurance companies must have data?
- See OEP database (not very up-to-date)
- Make use of exiting data on historic weather events – impacts and recovery
- Regulation changes to prevent land-use change loophole (wetland to cornfield to development)
- Another monitoring need: intermittent streams.
- Need education--common understanding that
  1. CC affects weather trends
  2. weather trends have habitat/wildlife impacts
- CC is a regional issue and this is an opportunity to take a regional approach. How can we fit state WAPs in?
- SWG \$ can't be spent on education, so..... need outreach help – staff and volunteers – not SWG funded.
- What would the effort look like to move these things forward?
- Hook up with phenology folks on volunteer research/data collection (make regional if possible). Also tap GCM – what we need vs what they produce.
- e-reviews: review the process and regulations to make sure WAP (cc part) is a piece of it (moving beyond using WAP only to choose land to protect)
- WAP/CC outreach effort to (towns: town boards) stress the weather part – point up do-benefits: link ecosystem intactness to other improvements/benefits to town
- Coordinate with info/outreach/education people to help with marketing the volunteer opportunities.

- Coordinate info from past extreme weather events to help us predict probably future impacts.
- Funding for volunteer coordination, data gathering, galvanizing/marketing the effort.
- Funding for outreach/marketing
- Tap existing (NOAA?) weather volunteers.

(Note: Coop Ext. has a big volunteer database – how can we cross-reference?)

- CONTACT Volunteer NH

### **Who needs to be at the table?**

- People who've been responsible for starting/managing volunteer data collectors

UNH

Lakes monitoring

program River

assessment

Coverts

Breeding bird survey

Christmas bird count

Winter severity index

NOAA

Water Quality

monitoring programs

USGS

RAARP

- Need Steering Committee to guide the efforts – including body to guide what data is needed – who will collect it?
- Sewage; water treatment; water supply – should be involved – need to make case that they have anything to do with WAP
- Funders
- F&G and existing WAP implementers/partners
- Towns
- Regional counterparts (NEAFWA/LCC)
- Forest Service – Hubbard Brook
- Cold Regions Research Labs (CRRL) Hanover
- UNH/other research programs
- WMUR/meteorologists

#### **Next Steps:**

- Get agreement that weather is something to look at and that we understand difference between weather and CC
- Form Steering Committee
- Steering Committee looks at leverage points
  - Will guide efforts to coordinate and mobilize volunteers for monitoring, research, etc.
  - Engage implementing partners
  - Coordinate the incorporation of leverage points into WAP

## Breakout Group 2

### Engagement, Involvement, Education

**Facilitator:** Dan Reidy (UNH Cooperative Extension)  
**Recorder:** Marilyn Wyzga (NH Fish & Game)  
**Participants:** Tom Sintros, Rob Shanks, Kristine Rines, Ellen Snyder, Matt Tarr, Charles Williams, Chris Wells, Marilyn Wyzga, Eric Aldrich, Beth McGuinn

#### **Sticky Notes:**

- Public motivation to address (X Memory) beyond function cycle
- Maintaining public motivation (X Memory) regarding need to address climate changes beyond election year cycles
- Attitude/break political, personal, corporate paradigms and use science to inform policy now
- Policy – laws – regulation
- One key issue: Human response to extreme events
- Main Concern – could climate change our wildlife? Most comments made by speakers seemed to stress potential negative impacts on wildlife. Aren't there just as many possible good things that could happen to benefit some species?
- Lack of citizen landowner/community involvement, participation in climate change planning "adaptation" – lack of a land ethic.
- Of concern is how people who live in the state of NH will accept that there will be change and how we have to approach wildlife conservation differently.
- Key Issue/Concern: The cost of continued BAD ACTION (i.e., fossil fuel use... habitat conversion, etc.) remains too low.
- The reduction in species will bring about the loss of revenue for all Fish and Game department activities because it will lose its ability to draw in people to the activity.
- Key Issue: Develop a map of priority habitat areas for real estate acquisitions.
- Unknowing or apathetic public who don't take the implications of climate change seriously and don't take action.

- How to identify specific practical actions to address change when a specific outcome is uncertain.
- How are people going to react to or handle/deal with the loss of and change to the biological communities they identify with their home/state.
- Conservation agencies and organizations are not designed and organized to rapidly respond to environmental catastrophes (i.e., oil spill in Gulf/white nosed syndrome in buds) that will likely increase as climate warms.

#### Engagement, Involvement, Education of People

- Land use decisions are local, not regional. This is a problem when developing/adopting plans.
- Need to pass federal land international climate legislation. Without it we don't have the sideboards in which to plan and execute mitigation strategies. By sideboards I mean maximum concentration of CO<sub>2</sub>, and when we hit the peak.
- Key Issue: Complacency of the general public regarding climate change. Effects on wildlife; challenges to convincing them it's REAL.

#### Open Discussion:

- Changing paradigms (see relevant post-it); legislation and policy = also funding – need slush fund to help people with other choices to avoid bad choices (make better decisions), support good decision with policy.
- Educating landowners and legislators policy makers (current use legislation helpful, could be more) – by foundation funding? – mitigate loss of small local parcels in addition to on habitat/landscape level.
- First and foremost – make sure everyone is educated on what we do and do not know so people are not on their own; regional (NE) perhaps in morning session, message – involve every agency and division and disseminate through all.
- Channels – the info we saw/heard in morning session needs to be available more broadly; takes 3 years to get a message delivered/absorbed/accepted; even with our agencies people don't believe climate change is issue.
- We all learned something new this morning.
- Succinct well put together and delivered – in a way we can adapt to an educational presentation.
- Understanding climate change and combating it on individual level vs adaptation and scaled up and down between.

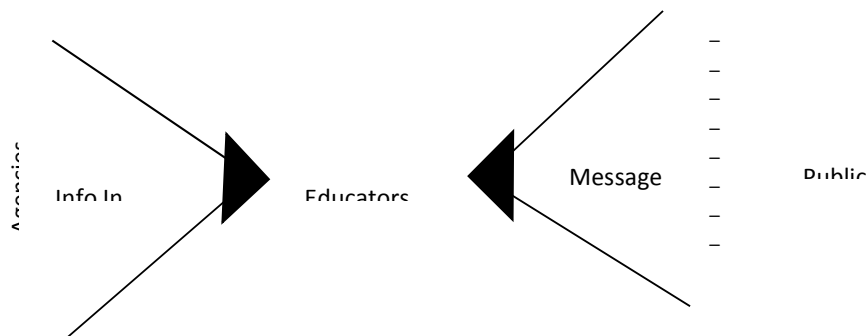
- Education needs to include involvement and engagement of public not just scientists; everyone has experience to contribute.
- Assume public complacency; need public awareness campaign; reach people in different ways – what are most compelling signs of climate change to wildlife that people can see? (because people relate to wildlife) in their daily lives?
- Who is “them”? What do we want them to do?
- Always couched in negative “don’ts” – we need positive messages – what you will get if you do x; needs to be on variety of scales.
- Hard to do – point to specifics (it’s a slow, gradual change) – because people observe weather not climate, their world, close focus.
- When you have that opening – connect it (their experience) to the science of the bigger picture, what’s documented.
- Questions of junk research/junk science; public more confused than complacent; We don’t know for sure what is happening/will happen; is current apparent trend truly all man-made? (reference mini-ice-age within past 200 years) – not prepared to give unbiased facts and figures.
- Whether we believe or not in climate change, aren’t proposed actions a good thing? (such as healthier forests)
- Reality – climate change is still a debate – surveys suggest number of those who don’t believe is decreasing.
- Concern at using climate change as the issue will make it a political football – focus on civic involvement, being good stewards.
- Habitable planet program – teaching professors to teach climate change; do ourselves a disservice if we don’t claim the issue.
- Need education for right now and what will be happening. These are issues and actions we should be promoting/taking whether or not there is real climate change. Resources are finite.
- Overarching Issue - problem – thread
- Do we address just those things that impact wildlife and habitats or energy/economy, etc. ? Other aspects of conservation climate change impacts?

- Expand to realm of ecosystems/habitats begins to encompass human communities and brings in these other issues, because humans are embedded in landscape – we are part of ecosystems.
- What can we do to make a better community? Some choices can be guided by climate change issues. Some people like turtles, some are driven by economics.
- DES promoting E efficient and economics on a flyer – how to relate this to wildlife?
- For some, the DES message does resonate – how do you connect with others for whom it doesn't? Choose a species or 3 they can relate to – to make it personal.
- Need regional message that resonates with a wide audience to include what we do and don't know; be specific so people can see there is a change; and positive things to do to make their lives better and things better for wildlife.
- Need different messages for different audiences. Do not lead with climate change. Include good science.
- Understanding there are different levels of facts, detail, etc., relevant to different audiences – most want it simple.
- People are really busy – need different places to engage.
- No consequences for what is going on though we have information scientists who largely agree on it; because of our lifetimes/spans we can't grasp an issue/change that exceeds it, that level of change.
- Think more broadly at knowledge we do have and convey to people in way they can grasp within their life spans and locales.
- Overlay of understanding wildlife/natural systems makes it more complex; need to build on this knowledge – more informed people – or we're just telling people what to do.
- We have seen improvements in wildlife populations, conservation success stories, contact with wildlife we never had before – people believe it's all hunky-dory, do not believe warnings about projected changes/loss; need to put climate change in perspective, go beyond bumper sticker mentality.
- Are birds and mammals the right indicators? They are what people see, but are not as affected.



- Average person not going to be convinced to change because of our message – our role to make sure wildlife professionals have best info to educate their constituents.
- Our agency role to bring back wildlife due to change humans caused (gross over-hunting and habitat loss) – with climate changes we will be perceived as failing because we cannot save all these species.

Scientists



### Other Summit Groups:

- Recommended actions won't stop, only slow global warming. Some actions create new problems (mercury in compact fluorescents).
- We have tools and know-how to get info/message out – ability to educate is there – need right info., scientifically backed, not just emotional or political.
- Re: Wildlife Action Plan – global warming could seriously impact habitats we work with regardless of lack of public knowledge – don't have specific science to show what impact will be.
- We want to protect habitats as best we can for resilience and adaptation. Need for everyone to be concerned, involved and help us.
- So many things beyond our control; our work focused on habitats.
- Conserve larger blocks of land where natural processes can take place and animals can adapt – can have consistent action message without pointing to climate change.
- CORE MESSAGE – Preserving and enhancing habitat
- These are the things to protect to allow life processes to change, things to grow and maintain.

- Our job is not to suggest solutions – working group will address.
- So many things beyond our control; our work focused on habitats.
- Conserve larger blocks of land where natural processes can take place and animals can adapt – can have consistent action message without pointing to climate change.
- Make connections to/with other groups in the state also addressing climate change, natural resources education, etc; fit our role in within those – shared outreach.
- Wildlife incredibly touching and moving subject for people – real opportunity to bring the message to people via wildlife (polar bears on ice flows; oil soaked pelicans, tick covered moose); can change behaviors.
- Impact – wildlife and habitat
- Driver – A changing climate which is affecting the above
- As climate changes, habitats and wildlife are potentially shifting.
- All people make decisions that directly and indirectly affect wildlife and habitats – in all their roles (landowners, voter, consumers, etc.).
- Because things are changing, we all need info (compelling, accurate, useful, current) to make informed decisions.
- Poster child – moose/tick example – possible NH example

### **Who at the table?**

- Public Affairs, NHFG – DES
- NHFG non-game
- Carbon Coalition
- NH Environmental Educators
- Weather monitors at UNH – Earth Oceans & Space
- Land Trusts
- Cooperative Extension
- Foresters
- Center for whole communities – retreat group (see Beth McGuinn)
- Wildlife Orgs
  - Grouse Society
  - Ducks Unlimited
  - Turkey Federation

- Etc.

**Issue Statement:**

As climate changes, habitats and wildlife are potentially shifting, all people – in all their roles (landowners, voter, consumer, etc) make decisions that directly and indirectly affect wildlife. We (all) need compelling, useful, current information to make informed decisions.

Possible NH example (poster child) – moose/ticks

## **Breakout Group 3**

### **Sea Rise and Aquatic**

**Facilitator:** Michele Gagne (UNH Cooperative Extension)

**Recorder:** Nicholas Salerno (Grad Student Intern with UNH Cooperative Extension)

**Participants:** Ethan Nedeau, Matthew Carpenter, Sandi Mattfeldt, Rob Calvert, Sam Demeritt, Emily Brunkhurst, Glenn Normandeau

#### **Sticky Notes:**

- Relate sea level change (and impacts on coastal habitats and wildlife) to current land acquisition prioritization
- Key Issue or Concern – Sea level increases
- The affect of sea level rise on the seacoast of NH
- Additional thermal stress to aquatic ecosystems due to poorly designed storm water management
- Climate change will exacerbate the adverse ecological effects of past and future human disturbance on stream corridors/aquatic ecosystem health.

#### **Issues:**

- Species ..... based on rising sea level – nesting
- Managing storm water
- How we can design built environment
- Quality and quantity of water
- Fragmentation of aquatic habitat
- Hydroperiod of wetlands
- Changing of vegetation type
- Loss of shade trees
- Changing in the times of spring flooding and ice melt
- Human response to climate change that causes future problems

- Proactively keeping current environment, e.g., wetlands
- Ground water recharge/protection
- Identifying natural flood storage area
- Rapid changes in where streams bed course flow
- Undoing the structural controls (dams, burns, undersized, rip rap)
- Prioritizing the structures
- Loss of dunes, salt marshes—takes a long time to be built for essential coastal islands
- Lack of room for salt marsh migration
- Invasive species

### **Issue Statement:**

Climate change will affect

- Hydrologic regime
- Water quality
- Physical habitat

These in turn will affect plant and wildlife communities. Human infrastructure (built environment) exacerbates these problems. Rethinking our approach to development to integrate future needs of aquatic ecosystems will alleviate some of these problems related to climate change. These sound practices help protect ecosystems and wildlife from existing threats.

Note: consider whether sea level rise and aquatic ecosystems should be combined or two separate groups

### **Existing Groups**

- Stream crossing guidelines group:
  1. Expand Oyster River culvert assessment model;
  2. Develop standardized methodology for road stream crossings assessment;
  3. Expand outside NH.
- River Restoration Task Force – currently working on dam removals. Future goal: provide more resources, e.g., staff

- Coastal Adaptation Group (coordinate with existing)

#### Add/Develop Groups or Expertise

- Wetland effects
- Reach out to municipalities and DOT
- Coastal wildlife/islands
- Talk with neighboring states
- RPC's
- DES; wetlands; alteration of terrain watershed; rivers; GS

#### **Actions Needed:**

1. Form sub-groups/identify topics; i.e., stream crossing, dams, coastal, stormwater
2. Bring in other expertise
3. Sub-groups research their issues and make recommendations
4. Whole group develops objectives and actions – assessing species and habitat vulnerability; prioritizing

## **Breakout Group 4**

### **Habitat Loss and Extinction**

**Facilitator:** Andy Fast (UNH Cooperative Extension)

**Recorder:** Lindsay Webb (NH Fish & Game)

**Participants:** Mike Marchand, Brendan Clifford, Paul Nickerson, Ed Boyle, Dan Dockham, Beth McGuinn, Don Kent, Ken Kimball, Roger Simmons, Kim Tuttle, Andy Whitman, J.T. Horn, Steve Weber, Charlie Bridges

#### **Sticky Notes:**

- What one key issue/concern regarding how climate change would impact wildlife or habitat?
- Conservation easements have purposes that describe important habitats, typically. How satisfactory are legal requirements re: easement.? What's the status today and is there flexibility for new habitats in the future? What future habitat is no longer "high-value"?
- Loss of species diversity, resulting in less stability and therefore large fluctuations in undesirable effects (e.g. insect pests, disease outbreaks, habitat loss, etc.)
- What is one key issue or concern with regard to climate change/wildlife or habitat?
- Ability of non-native invasive species to out-compete native species. Need identification, mapping and control strategies to deal with nni species.
- When to give up on an area overrun with invasive?
- Connectivity of critical habitat
- Concern: Highest (alpine) and Lowest (coastal) elevation. Habitat loss,
- Species extinctions at the local/regional level

#### **Issues:**

- Increased warming eliminating many of our current cover types and dependent species.
- How the assemblage of plants and animals is expected to change in major ecosystem community types.

- Increase in (prevalence and diversity of) invasive plant species, change to/of native plant communities and subsequent impact on native wildlife habitats (loss of native foods, changes in hydrology, etc.).
- The impact of evolving alternative energy sources (biomass, co-ind power, hydro) to further stress or reduce the resilience of habitats that currently are least influenced by other human activities.
- Extinction
- Key issue or concern re: climate change affecting wildlife/habitat
- Increase in insects such as ticks, mosquitoes; leading to more cases of Lyme disease, EEE, etc.
- How climate change could impact wildlife or habitat.
- Loss of species because of climate change when “habitat” for that species was specifically protected.
- Species extinction due to loss or change in habitat.
- Facilitating wildlife movement across the landscape.
- Reduction in wildlife species diversity distribution and abundance.
- Loss of current habitat types in NH to a shift in habitats and wildlife currently found in the south.
- Habitat conversion – change from one community type to another (includes aquatic species).
- The future of both wildlife and its habitat.
- Increase risk to diseases that are unplanned for.
- Key concern: loss or large decline in habitat for common (not-species of greatest conservation concern) species (e.g., s4 and s5 species).
- Reduction or disappearance of rare habitats.
- Shifting of plant and habitat distributions.
- What is the one key issue or concern with regard to climate change and wildlife and habitats
  - Easements and legal requirements (habitats)



- Loss of species (# of species and abundance) diversity/extinction/extirpation.
- Increase vulnerability to invasives, disease, pests (wildlife and human).
- Connectivity of critical habitats in facilitating movement
- Habitat loss (types and amount)
- Functional suitability of habitat (habitat value)
- Uncertainty of future community assemblages
- Access to scientific data
- Changes in hydrology
- Loss of native foods
- Impact of alternative energy (negative)
- Changes in flora and fauna
- Recognition of policy implications
- Elevate the WAP in state planning and policy

### **Overarching Issues:**

- Direct and indirect threats
- Impacts
- Management issues
- Time scale (WAP – present day); how fast will climate change come? How far out do we plan?
- WAP as a guide for managing for uncertainty (state climate plan)
- Products – maps easily accessible and interpreted habitat and conservation focus areas
- WAP needs to link in with state climate/adaptation plan
- Scale – micro habitats vs. macro habitats regional groups of species or individual species

### **Assumptions**

- Low emissions profile – high emissions 2025 – 2050

### **Issue Statement**

Human dominance of the land and climate has greatly reduced natural habitat and species diversity. NH has a strong SWAP that identifies many critical areas. The SWAP needs to have legal recognition as important criteria in NH's climate action plan to protect ecosystems for their important climate adaptation role.

Issue:

Changing climate could by increasing CO2 emissions worldwide will affect species diversity and habitat suitability in NH. The WAP must recognize and plan for these effects to protect species resiliency and habitat on a landscape scale.

#### Issue Statement:

Habitat and species protection models and mapping is needed to focus funding and resource allocation decisions to ensure that New Hampshire invests wisely in conservation strategies that cope with climate change.

Society faces dramatic change in habitat and species diversity because of climate change. The potential consequences of climate change include shift in habitat and wildlife ranges. This in turn results in shifts in economic drivers, such as travel and tourism, forest products, and recreation.

#### Actions Needed:

##### Charter:

- Develop key issues – refine issue statements; refine issues
- Describe impacts
- Identify strategies to address impacts

##### Work Groups (Different Charter for each)

- Technical Groups
- Policy
- Communication

##### Working groups inform WAP and State Climate Adaptation Plan

- Using current use model, created added (financial) incentive to encourage long-term ownership (20 years) higher penalty for leaving current use

## **Breakout Group 5**

### **Phenology**

**Facilitator:** Judy Stokes (NH Fish & Game)  
**Recorder:** Judy Silverberg (NH Fish & Game)  
**Participants:** Steve Fuller, Mark Ellingwood, Eric Orff, Cathy Goodman, Pete Bowman, Pam Hunt, Chris Hilke

#### **Sticky Notes:**

- Plant phenology will change impacting tree survival and fruit production
- How do we address phonological mis-matches?
- Being able to monitor for this potential change throughout the state.
- Change in seasonal lengths – e.g. earlier spring, promotes earlier plant growth and doesn't coincide with the feeding cycle of the animals eating that food (disconnect between plant & animal cycles)
- Conserving cold tolerant plant and wildlife species on habitats as best possible and publicly accepted and supported.
- Timing of various life stages of plants and animals in relation to seasons.

#### **Issues:**

- Lack of fruit production, (i.e., apples/high bush cranberry)
- Wide early fluctuations are deadly to a wide variety of plants and insects
- Early spring blooms timing with pollinators food supply for insects
- Insect emergence not lining up with key peaks of migratory birds
- Most of lupine flowers affected by frost so not producing seeds not just season affect.
- Frosts when trees were sending out of leaves (i.e., oak trees, horn beam, pepper bush)
  - May affect acorns for two years
  - Killed new leaves
  - May be high mortality of plants within a short period of time

- Potential discord between shed timing of big mammals
- Warm weather could cause expansion of bear population – problems
- Winter tick caused mortality of moose
- Longer growing seasons facilitating invasive species occurring, i.e., woolly adelgid
- Longer growing season affecting above and below ground interactions i.e., soil bacteria which could affect plant production.
- Peat lowlands – warmer weather will cause peat soils to decompose faster – so may change wetland type
- Vernal pools this year have dried up more quickly with shortened time with water presence.
- Peak nutritional quality of plant can affect productivity of larger herbivore population.
- Changes in time of leaf out affecting ground cover communities
- Thank God we are not VT
- Extra generations (broods) for many species
- Disease vector cycles shifting effecting both wildlife and humans, i.e., allergies
- Lake eutrophication/turnover time.
- Ski later, golf earlier.... Effect of those management on wildlife
- Less hunting opportunity because of shift in season, i.e., turkey hunting
- Management perspective may change
- Ability of turkey to change nesting habitats may be less plastic than environmental change
- Spring melt and stream condition, i.e., bass nesting – timing
- Length of snow-cover and affect on species i.e., snow-shoe hare weasels increased predation?
- Can natural selection keep up with environmental changes?

- Soft selection will have a lesser effect. Hard selection will kill off more.
- Some species will benefit, i.e., insect availability
- Deer will survive – with milder winter, deer yards will be devalued.
- No ice – some businesses can't survive – spring floods
- Sporting goods store, snow-machine dealers, human impacts
- Growing different crops – less use of heating oil
- # of species will benefit in human population
- Disruption of relationship between species
- Unknown Interactions
- Mgt., issues for disruptions such as monitoring, acquisition

#### **Key Elements:**

- Change in seasonality and weather
- Timing of snow/ice melt
- Timing of plant/animal life cycles, length of growing season
- Variability and intensity of temp and precipitation
- Sudden change

#### **Issue Statement:**

Changes in timing and intensity of meteorological events alter interaction among plants and animals resulting in enhanced or compromised reproduction and survival and affect the value of these resources to society.

Fish, wildlife their habitats and life cycles interrupted by changes in phenology.

#### **Next Steps:**

Economically – WHO

- Affecting economics of the state
- Changes in timing of meteorological events alter interaction among plants and animals, resulting in enhanced or compromised reproduction and survival and affecting value of these resources.
- Niche

## WHAT

- Working Group – Charter
  - Relocate the issue statement to the wildlife action plan
  - Take the possible meteorological scenarios and assess responses of species to identify vulnerability of species
  - Knowing phenology is changing which species are likely to fill in the niche
- What is the capacity through management to affect the impacts of phenology – metrics that we now have in WAP that we can use to take action at a higher levels – so public will act.
- Need to educate
- If we can ID doomed species take them to zoos and to big outreach actions so public will act to preserve/prevent others.
- Support basic ecological concept education to classrooms.....get students involved with collecting phonological data; monitoring system.....show actual change – documenting change and magnitude
- To see if we can investigate and see if feasible – anything we can do about it.
- Have to quantify in order to educate and compel political action and identify potential management actions, i.e., if you know water temp is problematic in trout stream could create shade.

## HOW

- Have to monitor and have long term data. Need to drop other things to monitor.
- Organize information so can ID cause/effect
- Compiling existing data
- Monitoring may need to shift to time of various events: courtship, reproduction.

- What is state of phenology in a particular area covering a whole suite of things – ecological services.

## WHY

- Quantify the problem in order to educate and compel management and political action
- How:
  - Monitor
  - Compiling data
  - Educate.

## **Who needs to be at the table:**

### **Phenologists**

Foresters  
 Botanists  
 Population ecologists  
 Mammalogists  
 Ornithologists  
 Ichthyologist  
 Agricultural  
 Horticulturist  
 Meteorologists/climatologists

### **Administrators**

Land Manager  
 Recorders  
 Facilitators  
 Biometricians  
 Educators  
 Cons. Historians  
 Funders  
 Communicator

### **Next Steps:**

- Connect to other working groups
- Set a meeting date
- Identify who players are by name that should be on this working group

- Come to a meeting with suggestions about what kinds of things could be done
- Check to see what others have done – don't reinvent wheels
- Compile data sources
- Steering committee that is updating WAP should convene the first meeting
- Working Group Charter
- Relate the issue statement to the wildlife action plan.
- Vulnerability assessment
- Developing appropriate strategies



### **Final Activity – Common Themes**

- Piggy backing on other work already done.
- Including broad base of partners
- Taking a regional approach
- Great deal of uncertainty of ability to impact problems
- Need to coordinate with state climate change collaborative
- Need for more data
- Need to compel political change
- Time Scale – short or long – term
- Ability to react quickly as things change (fluid method)
- Missing today: mitigating impact