Chapter 3

Climate Change & Conservation

2015

3. Climate Change & Conservation

Introduction

Ten years ago, when states across the nation were completing their Wildlife Action Plans, wildlife managers were just beginning to think through basic questions such as: 'How might climate change impact wildlife and wildlife habitat? 'How can we systematically identify wildlife, plants and habitats that might be vulnerable to climate change? And, 'What types of actions can be taken to help wildlife survive climate change?'

Ten years later, many states, including Vermont, have begun identifying how wildlife and habitats might be affected by climate change, which are most vulnerable, and how to best manage for the future. There are few clear or simple answers. Identifying vulnerable species and habitats requires teasing out myriad factors that climate change could influence, such as changes in precipitation rates, snow pack and soil moisture; changes in the number of freezing days; new diseases and invasive species; flooding, lack of flooding; movement of species and their habitats, and changes in predator-prey and plant-pollinator relationships. And, we don't know the capacity of species to respond to a changing climate.

An honest response to these very complicated questions is 'we don't know how most species will fare in the coming decades.' We can assume there will be winners and losers. Bicknell's Thrush and other alpine plants and animals found only at the tops of Vermont's highest peaks, for example, are likely to be losers here (though they may fare better north of here). Other species, such as the Virginia Opossum and Tufted Titmouse, which have been slowly moving north, might do better in Vermont in the coming decades.

What to do? We need to remain vigilant, expect to be surprised, foster adaptability and reduce other stresses on wildlife and wildlife habitat. In the short-term, riparian areas (the banks of rivers and streams) and adjacent land, including their floodplains, may be the best places to invest our conservation efforts because when healthy these areas are more resilient to flooding, reduce downstream flood impacts, keep waters cool and provide important habitat and connectivity to many wildlife species. Table 3.1 lists actions that are generally most important if we want to help wildlife in the coming decades.

Table 3.1. General adaptation goals to inform the identification of specific strategies that serve to increase the resiliency and/or adaptive capacity of wildlife and their habitats (Stain, B. et al. 2014). **Note**: There is significant debate over the pros and cons of assisted migration (relocating organisms).

Adaptation Strategy	Definition
Reduce non-climate stresses	Minimize localized human stressors (e.g., pollution) that hinder the ability of species or ecosystems to withstand or adjust to climatic events
Protect key ecosystem features	Focus management on structural characteristics (e.g., geophysical stage), organisms, or areas (e.g., spawning sites) that represent important "underpinnings" or "keystones" of the current or future system of interest
Ensure connectivity	Protect, restore, and create landscape features (e.g., land corridors, stream connections) that facilitate movement of water, energy, nutrients, and organisms among resource patches
Restore structure and function	Rebuild, modify, or transform ecosystems that have been lost or compromised, in order to restore desired structures (e.g., habitat complexity) and functions (e.g., nutrient cycling)
Support evolutionary potential	Protect a variety of species, populations, and ecosystems in multiple places to bet-hedge against losses from climate disturbances, and where possible manage these systems to assist positive evolutionary change
Protect refugia	Protect areas less affected by climate change, as sources of "seed" for recovery (in the present) or as destinations for climate-sensitive migrants (in the future)
Relocate organisms	Engage in human-facilitated transplanting of organisms from one location to another in order to bypass a barrier (e.g., urban area)

The remainder of this chapter is a deeper exploration of the climate change threat. It includes a summary of historic climate trends and projections of future climate; a look at the ecological impacts of climate change on species, forests wetlands and aquatic habitats. It also delves deeper into efforts to conserve wildlife in the face of climate change both in Vermont and regionally. This chapter concludes with a list of conservation strategies to help Vermont's wildlife, plants and wildlife habitat.

Taken in a broader context, this chapter will help to illustrate the interconnection between climate and non-climate stressors and conclude with a list of conservation strategies to help Vermont's wildlife, plants, and habitat.

From the waters of our lakes and rivers to the forests and wetlands abutting our communities, Vermont's diverse ecosystems are essential to a healthy and sustainable future for wildlife and people.

Vermont's fish, wildlife and plants and their habitats are already responding to climate change. Plants are leafing out and blooming earlier; birds, butterflies, amphibians, and other wildlife are breeding, feeding, metamorphosing or migrating earlier; and many species that can migrate are shifting ranges northward and to higher elevations (Betts, A. K. 2011a, Stager, C., and Thill, M. 2010, U.S. Global Change Research Program 2009). Of concern is the potential disruption of entire ecosystems. As diverse species and habitats in Vermont respond to climatic fluctuations in different ways, important inter-specific connections—such as between pollinators and the flowers they fertilize, or breeding birds and the insects on which they feed—will likely be disrupted. Further, the ecological impacts associated with climate change do not exist in isolation, but combine with and exacerbate other stresses on our natural systems. For instance, although climate pressures may be causing species ranges to shift, development and roadways have created a matrix of inhospitable habitat that may inhibit such movement. And while invasive species already have a major negative impact on many ecosystems in Vermont, many invasives may be favored under future climate conditions, making it even more difficult for native species to adjust and survive under new climatic regimes. These are just a few examples of the challenges that species and habitats in Vermont face under climate change.

Historic Trends and Future Projections

Since 1895, the average annual temperature in the U.S. has increased between 1.3°F and 1.9°F. Over the next 30 to 40 years, temperatures are expected to rise on average another 2°F to 4°F across most of the nation. By the end of the century, should carbon emissions continue to rise at the current rate (higher emission scenario) the U.S. can expect a rise in average annual temperature between 5°F to 10°F. On the other hand, if significant reductions in carbon emissions can be achieved (lower emission scenario), average annual temperature across the U.S. would rise approximately 3°F to 5°F by the end of the century (Melillo, J.M. et al. 2014) (Fig 1).

While the last decade has been the hottest on record, it is evident that there is significant regional variation - with northern latitudes experiencing greater warming. Therefore, the Northeast can expect a greater rise in average annual temperature. Depending on the different emission scenarios, temperatures in the Northeast are projected to increase by either 4.5°F to 10°F (under a higher emission scenario) or 3°F to 6°F (under a lower emissions scenario) by the 2080's (Horton, R. et al. 2014).

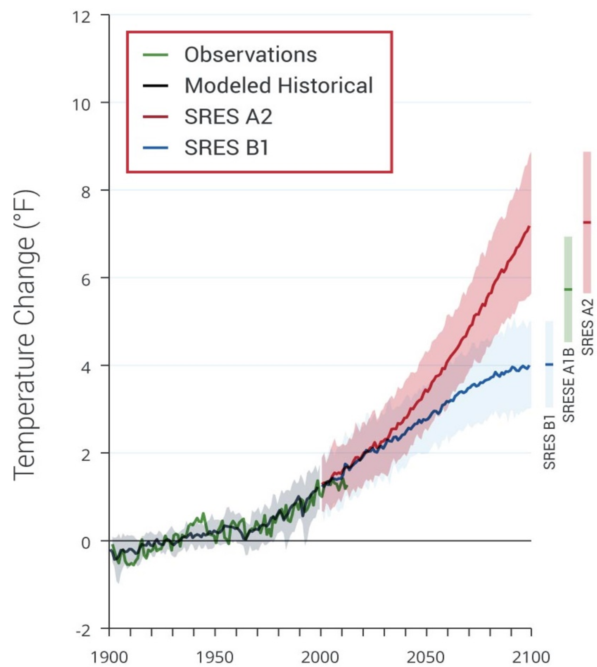

Figure 1. Estimated average rise in global temperature (relative to the 1901-1960 average) for the higher emissions scenario (A2) and lower emissions scenario (B1). A higher emissions scenario assumes a continued increase in emissions throughout this century, whereas a lower emissions scenario assumes a significant reduction. Shading represents the range (5th to 95th percentile) of results from a suite of climate models. Average temperatures are predicted to increase in both scenarios, however the difference between lower and higher emissions pathways is significant (Melillo, J.M. et al. 2014) (Figure source: NOAA NCDC / CICS-NC).

In Vermont, average annual temperatures have increased 1.6°F since 1960 and 0.9°F since 1990, with temperature increases even more significant in recent decades. For example, mountainous highland regions in Vermont have experienced average annual temperature increases of 1.8°F per decade from 1990-2012 and 2.5°F from 2000-2010. In addition, average annual winter temperatures are rising twice as fast as average summer temperatures. These trends are resulting in significant changes to Vermont's climate (Galford, G.L. et al. 2014).

Vermont's Changing Seasons

As temperatures continue to climb, the severity of Vermont's winters is decreasing. Compared to the 1940s-1960s, Vermont had a 20% decrease in the number of days below freezing in the last decade alone. As a result, lakes and ponds are experiencing an average of seven fewer freezing days per decade. Simultaneously, average precipitation rates have also increased in Vermont. For example, since 1960, decadal precipitation averages have increased by 0.9" in lowland areas and 2.3" in highland regions. The result has been increases in snowfall amounts at higher elevations. However, the projections suggest that while snowfall amounts will increase over the short term (20-25 years), as temperatures increase over the long-term winter precipitation will increasingly come in the form of rain (Galford, G.L. et al. 2014).

> "Warmer winters will lead to reduced accumulation of snow during some years. Less snowpack may mean less runoff during the late winter/early spring thaw. This effect may be offset by increased rains falling on frozen ground, leading to greater runoff. However, if winter temperatures rise to levels that decrease the duration of frost conditions by late in the century, runoff may be moderated by increases in soil infiltration – if soils do not become saturated by a rain event (Galford, G.L. et al. 2014)."

Overall, projections suggest more winter and spring precipitation over the coming century. "Average monthly flows in January and March, as well as July, August, and October through December, have increased while average monthly flows in April and May have decreased (Galford, G.L. et al. 2014)."

Moreover, high intensity precipitation events greater than one inch increased an average of four days between 1960-1980 and an average of 7-10 days a year over the past two decades. One of the outcomes of more frequent high-intensity rain events is that stream high flows are larger, more frequent, and are projected to occur more frequently in winter. An increased number of high-intensity rain events in conjunction with warmer temperatures will result in more flooding along Vermont's rivers and shorelines. At the same time, rising temperatures over the longer term and increased seasonal variability in rainfall suggest a potential increase in the number of short-term summer droughts resulting in periods of very low stream base flows and lake levels, and slow groundwater recharge rates by centuries end (Galford, G.L. et al. 2014).

Impacts of Climate Change on Vermont's Ecology

Significant deviations in the variability around historic climatic norms, including increased variability in temperature, precipitation and extreme weather events, has direct implications on the vulnerability of species and the habitats upon which they depend. In this context, vulnerability is defined as "the susceptibility of a species, system or resource to be negatively affected by climate change" and interactions with other non-climate stressors such as habitat degradation and habitat loss (Staudinger, M.D. et al. 2015). Climate change already presents a variety of challenges for species and ecosystems across the Northeast. These include the reduction in the "quality and distribution of habitats, the availability of food, increases in the abundance of parasites and diseases, and the increased incidence of stress from heat and drought (Rustad, L. et al. 2012)." How do the challenges driven by climate change affect the ecosystems in Vermont? To explore this question, we'll look at how Vermont's species and natural communities, including forests, wetlands, waterbodies and other habitats are currently responding to climate change and how such communities are likely to shift in abundance, composition, and range in the coming decades.

Forests

Vermont is predominately a forested landscape so climate-driven impacts to forests are of significant concern for Vermont wildlife as well as the forest products industry, rural communities and the Vermont way of life. Forest communities provide many important and complex ecosystem services including protecting water quality, reducing runoff, nutrient cycling, capturing air pollutants, providing wildlife habitat, and carbon sequestration among others (Galford, G.L. et al. 2014, Rustad, L. et al. 2012). However, predicting the specific future impacts of climate change on systems comprised in large part of long-lived species is difficult. Historic pollen and microfossil data tell us that in the past forest systems migrated, albeit slowly, to changes in climatic conditions (Rustad, L. et al. 2012). Over the past 12,000 years northern forests once dominated with spruce and jack pine have transitioned into larger ratios of white pine, oak, and eastern hemlock, and then to beech and maple dominance in the north, white pine, hickory and birch dominance in southern areas, and spruce and fir at higher elevations (Rustad, L. et al. 2012). While evidence suggest that forests have been able to migrate in the past, models of predicted climates, suggest that past migration rates are too slow to keep up with current and future changes climatic conditions (Rustad, L. et al. 2012).

Current evidence indicates that forests will increase evapotranspiration and water use due to warmer seasonal temperatures and an increase in the number of growing days (Rustad, L. et al. 2012). This scenario may lower overall soil moisture, increasing the persistence of droughts, reduce forest productivity, and in turn increase the susceptibility of forests to insect and disease outbreaks (Rustad, L. et al. 2012).

As a result, several dominant tree species may undergo significant range shifts as forest communities adjust to new conditions over time (fig. 3. 2) (Rustad, L. et al. 2012).

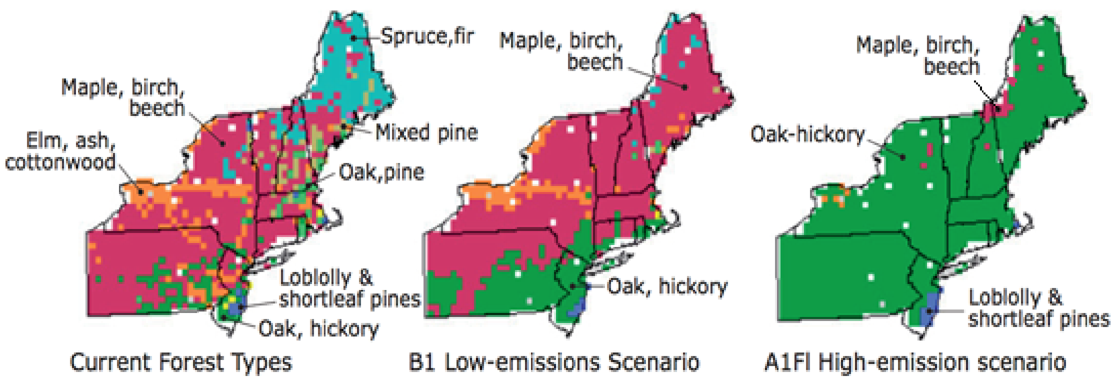

Figure 3.2. Current and projected suitable habitat for major forest types in New England under low and high emissions scenarios. See Figure 5 for details of the scenarios. Under the low emissions scenario, the conditions will favor maple- birch-beech forests, while under the high emissions scenario suggest that conditions they will favor oak-hickory forests. Adapted from Iverson et al. 2008 (Rustad et al. 2012).

Models predicting the ways in which forests will respond to long-term climate trends show that species such as sugar maple and balsam fir are likely to lose suitable habitat in Vermont, while several species of oak are projected to expand in the extent of suitable habitat (Rustad, L. et al. 2012). Moreover, shorter winters, longer growing seasons, and increased concentrations of CO_2 should result in an overall increase in forest productivity (net forest growth rate) (Rustad, L. et al. 2012). However, many factors, including life spans, dispersal rates, invasive species, and changes in soil moisture, will make it difficult to predict when, and if, tree populations will be able to reach predicted, suitable habitat (Rustad, L. et al. 2012).

Forest managers can play a critical role addressing these uncertainties by promoting healthy forests and their successful adaptation to climate change. According to the Vermont Department of Forests, Parks and Recreation (VFPR) (2015), human activity is one of the primary drivers of change in Vermont's forested communities. Therefore, influencing change through forest management in ways that improve forest resiliency could increase future suitable habitat.

Table 3.2. **Tree decline and associated climate factors**. A review of decline episodes for five different tree species in the Northeast indicates that there have been important associations with changes in climate and weather-related conditions, which may be further exacerbated as climate changes in the future. Adapted from Mohan 2009 (Rustad et al. 2012).

Species/ Group	History	Role of Climate	Other Factors	References
Birch	Widespread declines since 1944	Maps of birch decline areas coincide with areas of experiencing extended winter thaw cycles	None	Balch 1944 Bourque et al. 2005 Braathe 1995
Sugar maple	26 widespread decline episodes between 1912 and 1986	Prolonged thaw-freeze events and associated fine root damage have been implicated in sugar maple decline	Insects, disease, loss of soil nutrients	Millers et al 1989 Bertrand et al. 1994 Decker et al. 2003 Fitzhugh et al. 2003
Oak	Large areas of oak mortality recorded in New England and the Appalachian Mountains in the early 1900s	Drought stresses have been reported as important initiating factors in oak decline.	Insects, secondary pathogens	Millers et al. 1989
Ash	Widespread dieback in the Northeast since 1920	Drought and freezing damage have been identified as inciting factors, with drought playing a particularly important role	Phytoplasmal disease, Asian beetle, emerald ash borer	Millers et al. 1989 Poland and McCullough 2006
Red spruce	Widespread decline through the Northeast after 1960, increasing over the last few decades	Reduced cold tolerance leads to winter injury which is intensified rapid rates of thaw and subsequent exposure to refreezing	Acid deposition, anomalous weather	Friedland et al. 1984 Johnson 1992 Schaberg and DeHayes 2000 Bourque et al. 2005

Waterbodies

In Vermont and across the Northeast, hydrological cycles and processes are being affected by climate change. Increased average annual rainfall in conjunction with a larger fraction of precipitation falling as rain is increasing average annual streamflows resulting in more frequent and greater magnitude high flows (Galford, G.L. et al. 2014). Moreover, these high flows are occurring more frequently in winter months due to early snowpack thaw dates driven by warming temperatures (Galford, G.L. et al. 2014). Even though recent decades have seen higher summer base flows, projections suggest that warming temperatures in conjunction with greater variability in seasonal rainfall may increase the likelihood of short term summer droughts (Galford, G.L. et al. 2014). Together these changes in hydrological processes have serious implications for northeastern ecosystems.

One concern is the likely increase in frequency and amount of stormwater runoff. Nutrient and sediment loading into rivers exacerbates siltation and algae production and can limit the capacity of the waterway to support macroinvertebrates, fish, freshwater mussels, and other aquatic organisms. "In lakes, warmer temperatures and greater nutrient loading can result in more frequent blue-green algae blooms which are known to be detrimental to both animals and humans" (Galford, G.L. et al. 2014). Another concern is the expected increase in the "wider range of lake level fluctuations over the course of the year (Galford, G.L. et al. 2014, Stager, J. & Thill, M. 2010).

Changes in river hydrology, with larger and more frequent peak discharges, may trigger significant changes in river channel formation (Allan, 1995) which can result in greater channel instability and channel movement. The response to such instability in the past has been to channelize and harden riverbanks to prevent channel movement. This practice often has deleterious and homogenizing effects on in-stream and riparian habitat features (Poff and Zimmerman 2009). Moreover, catastrophic results can be expected when hardened and channelized banks fail during very high flow situations—as was seen many times over during Tropical Storm Irene-driven flooding.

Wetlands

Vermont has more than 290,000 acres of wetlands that provide critical habitat for many species of fish, wildlife and plants. Wetlands play an important role in the attenuation of storm water, sediment transport, and naturally improve water quality (Galford, G.L. et al. 2014). Similar to waterbodies in Vermont, increases in variability and overall seasonal extent of precipitation are a significant challenge to wetland ecosystems, with potential for greater frequency of flood events and short to mid-term droughts. Increased flooding will bring about changes to wetland shorelines, may facilitate the spread of invasive aquatic species (e.g., Japanese Knotweed), and cause an influx of runoff sediment. Reduced water clarity due to flooding will, reduce light penetration and greatly affect the productivity of aquatic organisms (Galford, G.L. et al. 2014). In addition, projected increases in summer temperatures and earlier snowmelt present a threat to wetlands as water levels may intermittently decrease or completely dry up because of drought in conjunction with increased evapotranspiration rates. If this were to occur, the breeding cycles and survival of amphibians, such as the Spotted Salamander, would be adversely impacted (Galford, G.L. et al. 2014). The potential for increased dry spells and low water conditions will have water quality implications too. With shallower water depths and warm temperatures, toxins and nutrients will be more concentrated and algae blooms will be more frequent (Galford, G.L. et al. 2014). Furthermore, non-climate stressors, such as habitat fragmentation and pollution, also threaten wetland ecosystems in Vermont. In assessing the vulnerability of wetland habitats, the Vermont Fish and Wildlife Department (VFWD), National Wildlife Federation (NWF) and others found Basin Swamps & Wetlands and Wet Shores to be particularly vulnerable to climate-driven impacts.

Habitats and Species

The interactions between climate-driven stressors including changes in temperature, precipitation, and storm events and non-climate stressors such as development-driven habitat loss and habitat degradation is currently impacting Vermont's habitats and the species that depend on them. Moreover, synergistic impacts are likely to increase over the coming decades.

Projections suggest that warming temperatures will expand the extent of suitable habitat for tree species such as oak, hickory, and red maple, while significantly decreasing the extent of suitable habitat for more cold-tolerant species such balsam fir currently found in Vermont's higher elevations (Galford, G.L. et al. 2014). With earlier leaf-out and flowering periods because of this warming, many species may be more susceptible to pests and pathogens

(Galford, G.L. et al. 2014). Changes in habitat suitability for many species can prompt a reshuffling and unraveling of currently recognized species assemblages and natural communities. Invasive species, which generally exhibit a competitive edge under warmer conditions, could further spread. Species that are ecological specialists are particularly vulnerable as their ranges are restricted, they are limited to a specific habitat, or they are geographically isolated (Rustad, L. et al. 2012). For example, ecological specialists [such as the Fowlers Toad, found in sandy outwash areas along Connecticut River], or those with populations already in decline [such as the Rusty Blackbird, a boreal wetland species], may be particularly vulnerable under changing habitat conditions (Rustad, L. et al. 2012). Bicknell's thrush is limited to high-elevation spruce-fir forests and is a good example of a species particularly vulnerable to climate-driven habitat change. Moreover, data suggests that many migratory bird species are arriving and breeding earlier in Vermont, and that the ranges of numerous migratory bird species are changing in response to climate change (Rustad, L. et al. 2012).

Climate change is also affecting the phenology, or timing of life-history events of many plant and animal species. Due to increasing spring air temperatures, many plants are leafing out and blooming earlier and numerous wildlife species are breeding or migrating earlier than they did during the previous century (Betts, 2011; Stein, B.A. et al. 2014). Current evidence, including shifts in entire ecoregions in some locations, suggests that over time these changes could exceed the ability of many species to adjust, leading to predictions of species declines and higher extinction rates globally (Loarie, S.R. et al. 2009). However, predictions ought to be species-specific as different species respond to climate-driven impacts in different ways and at different rates (Stein, B.A. et al. 2014). Evidence suggests that there are significant differences in response capacity between "short-lived species with high dispersal capacity (such as birds) and long-lived species with limited dispersal capacity (such as many trees)" (Stein, B.A. et al. 2014). Those species that have a greater capacity to adapt to new conditions, or have greater climatic tolerances, will have a competitive advantage and may expand their ranges while those with narrower climatic tolerances may experience range contraction.

In addition, climate-driven impacts from extreme weather events, direct thermal stress, changes in habitat availability, and increases in parasites and diseases will affect native wildlife "at all levels of organization from the physiology of individual animals to changes at the population level" (Rustad, L. et al. 2012). Two species that provide examples of the extent to which different suites of climate-driven stressors can increase vulnerability are the Little Brown Bat and Moose. The Little Brown Bat relies largely on insects with aquatic larval stages as a food resource (Rustad, L. et al. 2012). Changing precipitation patterns, alterations to stream flow and reduced soil moisture can significantly affect the availability of these insects (Rustad, L. et al. 2012). Apart from the vulnerability of Little Brown Bats to altered hydrology, there have been significant declines in the population because of White Nose Syndrome. Altered precipitation and disease may interact synergistically to exacerbate stress on this species in Vermont, though more water and shorter hibernation periods in a warmer climate could potentially be a direct benefit.

Moose appears to be vulnerable to climate change in Vermont. As a cold-adapted species, Moose begin to reduce food intake in response to high summer temperatures (Renecker and Hudson 1986). As annual summer high temperatures increase under climate change, the habitat range of Moose may shift northward. Warming winter temperatures may reduce the area of permanent winter snowpack. The reduction in snowpack may increase contact between Moose and White-tailed Deer, which are carries of a brain parasite (*Parelaphostrongylus tenuis*) that is potentially lethal to Moose (Whitlaw and Lankester 1994). In addition, Winter Ticks (*Dermacentor albipictus*) are becoming an increasing problem for Moose with the early loss of snowpack. When ticks fall off Moose in the spring, they have a greater likelihood of survival if they fall onto soil as opposed to snow.

Amphibians are particularly vulnerable to the interactions between altered hydrology and increasing temperature. With most amphibians breeding in water, the hydroperiod (the time that there is standing water) of ephemeral ponds is a critical component of their life cycle (Rustad, L. et al. 2012). Altered precipitation and increased seasonal warming which drive evaporation and the frequency and severity of droughts are of concern (Rustad, L. et al. 2012). "A reduced hydroperiod can increase competition, decrease size at metamorphosis, and kill larvae as ponds dry out (Rustad, L. et al. 2012)."

Conserving Wildlife in the Face of Climate Change

What makes the issue of climate change particularly intractable is the breadth of interconnections between these climate-driven impacts and numerous non-climate stressors such as habitat fragmentation, habitat degradation, and pollution – which have been the focus of conservation efforts for some time. Given the magnitude of climate impacts, rates of increasing variability, and the synergy between climate and non-climate stressors on wildlife and the habitats upon which they depend, there is an urgent need to prepare for and respond to these impacts (Stein, B. et al. 2014).

In planning for this new future, we face questions such as: (a) which species and habitats are likely to be more vulnerable; (b) which may benefit or be unaffected by climate change; (c) how will non-climate stressors contribute to vulnerability; (d) how might species adapt; (e) which strategies will be most effective and where should we apply our efforts; and, (f) how can we feasibly monitor species and habitats to inform our management actions? Significant efforts have been made at the Federal, regional, State and local levels to address these questions and identify strategies that benefit wildlife and their habitats under climate change.

Regional Efforts to Conserve Wildlife in the Era of Climate Change

The Northeast is well known for collaborative conservation efforts between states, municipalities, conservation organizations, and federal entities. A prime example is the Northeast Association of Fish and Wildlife Agencies (NEAFWA), which is a collaboration between State Fish and Wildlife Departments across the thirteen Northeastern States. Since 2007, the NEAFWA sponsored Regional Conservation Needs Grant Program has funded a large number of projects focused on identifying both the threats facing wildlife and their habitats under climate change as well as identifying strategies to benefit those species in a warming world.

Recognizing the need to conserve and restore habitat connectivity in the Northeast, the Staying Connected Initiative (SCI) was developed among a partnership of twenty-four private and public entities across New York, Vermont, New Hampshire, Maine, and Canada. The mission of this collaboration is to sustain connectivity for wildlife by protecting against habitat fragmentation and climate change. In doing so, SCI brings its partners together in an interdisciplinary approach that utilizes tools of conservation science, land protection, community outreach, land use planning, transportation, and policy to ensure that connectivity across the landscape is healthy for both wildlife and human communities.

In September 2012, the National Wildlife Federation (NWF) in partnership with Manomet Center for Conservation Sciences (MCCS) completed the Northeast's first regional vulnerability assessment (RVA) (MCCS & NWF 2012). The assessment utilized facilitated expert elicitation from a panel of 27 natural resource practitioners including staff from state fish and wildlife agencies in all Northeastern states, as well as other state and federal habitat professionals. The goal of the assessment was to (a) quantify the vulnerabilities to climate change of fish and wildlife habitats, and how these vulnerabilities vary spatially across the region, (b) project how the status and distributions of these habitats and species may be affected by climate change, and (c) to work with states to increase their institutional knowledge and capabilities to respond to climate change.

Another important regional collaboration working to "to address increasing land use pressures and widespread resource threats and uncertainties amplified by a rapidly changing climate" is the North Atlantic Landscape Conservation Cooperative (NALCC). "The partners and partnerships in the cooperative address these regional threats and uncertainties by agreeing on common goals for land, water, fish, wildlife, plant and cultural resources and jointly developing the scientific information and tools needed to prioritize and guide more effective conservation actions by partners toward those goals (NALCC)."

Efforts to Address Climate Change Impacts in the Northeast

State-level land conservation efforts vary considerably from state to state across the Northeast. They include efforts by state agencies, departments, and programs such as Open Space Programs and Land Conservation Programs across different state environmental agencies. All the northeastern States are developing Action Plans that address climate change as a significant stressor for wildlife and their habitats. Several of them have specifically conducted climate change vulnerability assessments on priority SGCN and associated habitats.

In 2011 New York conducted a species vulnerability assessment on 119 SGCN using NatureServe's Climate Change Vulnerability Index (Schlesinger, M.D. et al. 2011). The assessment found that nearly all the species identified as Highly or Extremely Vulnerable were associated with aquatic or seasonally wet habitats, with mussels rated as particularly vulnerable due to limited mobility (Schlesinger, M.D. et al. 2011). Another interesting finding was that "vulnerability was only weakly associated with conservation status (Schlesinger, M.D. et al. 2011)." In addition, a vulnerability assessment of key habitats, conducted by NWF in partnership with the New York Department of Environmental Conservation's Division of Fish, Wildlife and Marine Resources, found Acadian- Appalachian Montane Spruce-Fir and Coastal Plain Basin Peat Swamp as Vulnerable to climate change, and Boreal Bog and Alpine Tundra habitats as Highly Vulnerable (Hilke, C. & Galbraith, H. 2013).

New Hampshire Fish and Game Department (NHFGD) (2013) conducted a habitat vulnerability assessment in 2014 on 25 key habitats across the state. Due to climate impacts on the hydrology of freshwater habitats, findings suggested that species that are "more tolerant of a wide range of hydrologic conditions will be favored, and the total species richness may decrease (NHFGD 2013)." For terrestrial habitats, high-elevation spruce fir forest was identified as particularly vulnerable to climate change (NHFGD 2013). Moreover, findings suggested that "hardwood-pine forests will move northwards and up slope, while Appalachian oak-pine forests are likely to increase in extent" because of long-term warming trends (NHFGD 2013). Other findings of interest identified Pine Barrens as less vulnerable to climate change given the predisposition of species within those habitats to warmer and drier conditions, and more generally predicted an increase in early successional habitats because of increased disturbance (NHFGD 2013).

In 2010, Massachusetts conducted the first climate change habitat vulnerability assessment in the Northeast. The assessment was directed towards answering: "(a) how do the targeted fish and wildlife habitats rank in terms of their likely comparative vulnerabilities to climate change; (b) how will the representation of these habitats in Massachusetts be altered by a changing climate; (c) which vertebrate Species in Greatest Need of Conservation [SGCN] are likely to be most vulnerable to climate change; and (d) what degree of confidence can be assigned to the above predictions" (MCCS & MA Department of Fisheries and Wildlife 2010)? The assessment was conducted under two emission scenarios, a doubling and a tripling of atmospheric CO_2. Spruce-fir forests, smaller coldwater lakes and ponds, spruce-fir boreal swamp, brackish marsh, and intertidal mudflats and sandflats were identified as highly vulnerable to climate change under both emission scenarios (MCCS & MA Department of Fisheries and Wildlife 2010). The highly vulnerable representative SGCN associated with those habitats include the Northern Leopard Frog, Green Heron, American Eel, Blackpoll Warbler, Moose and Bobcat (MCCS & MA Department of Fisheries and Wildlife 2010).

Table 3.3. Numbers and percentages of vertebrate SGNC [SGCN] most at risk from doubling (2X) and tripling (3X) of atmospheric CO2 concentration (Manomet & MA DFW 2010).

	Amphibians (7)	Reptiles (19)	Fish (28)	Birds (63)	Mammals (20)
2X CO_2	2 (28%)	1 (5%)	2 (7%)	26 (41%)	3 (15%)
3X CO_2	4 (57%)	4 (21%)	14 (50%)	36 (57%)	7 (35%)

Vermont Efforts to Understand and Address Climate Change Impacts to Species and Habitats

Vermont has been actively involved in addressing the impacts of climate change for some time. In 2011, Governor Peter Shumlin established the Vermont Climate Cabinet charged with coordinating climate change efforts specific to reduction of greenhouse gas emissions, reliance of fossil fuels, as well as the implementation of climate adaptation efforts across State agencies. While initial efforts to address climate change focused largely on mitigation efforts, the Vermont Agency of Natural Resources developed a series of white papers addressing climate adaptation across its Programs and Divisions. In 2012 and 2013, the Vermont Agency of Natural Resources developed the Climate Change Adaptation Framework to gather information about climate change in Vermont as it relates to natural resources and to propose a strategic framework for continued climate change vulnerability assessment and action planning (Tetra Tech Inc. 2013).

Building on this assessment the Fish & Wildlife Department and National Wildlife Federation developed the Species & Habitat Climate Vulnerability Assessment for 18 key species, 20 upland habitats, 11 wetland habitats, and 13 freshwater habitats as part of our Action Plan revision (Table 3.4 and Appendix D). Species included SGCN and important "surrogate" species that are widely considered representative of habitat types. Species assessments culminated in an overall vulnerability rating for climate-specific and non-climate stressors and an associated confidence score.

The most important lesson taken from this exercise is that species responses to climate change will not be uniform. For some, climate change may not be a significant threat, however if that species is already subjected to other stresses, climate change impacts may push that species over the edge. This is an important consideration to consider.

Vulnerability rating criteria were standardized and applied across all assessments. Criteria were selected from similar assessments conducted by other states and from current literature. Vulnerability scores were designated for each species, habitat and system. Ratings account for the extent of vulnerability (extremely vulnerable, highly vulnerable etc.) based upon percentage changes in abundance or extent expected by 2050 and include an associated confidence rating of high, medium or low based upon the percentage certainty of the vulnerability score (Low = Not very confident, 0-30% certainty in vulnerability score). See Vermont Climate Vulnerability Assessment Rating Key Appendix E for details.

Non-climate Stressors: Non-climate stressors included acidity & pollution, habitat alteration & altered hydrology, invasive species, channel erosion & sedimentation, encroachments, land erosion, nutrient loading, thermal stress, toxic substances/pollution, and habitat fragmentation.

Sensitivity Factors: assessments factored in how likely a species, habitat, or ecosystem is to be affected by or respond to climate change given (1) habitat specificity, (2) edge of range, (3) environmental or physiological tolerance, (4) interspecific or phenological dependence, (5) mobility, and (6) exotic pathogens or invasive species.

Exposure & Key Climate Change Factors: The four categories of climate change and exposure factors are temperature, hydrology, extreme events, and phenology. Within each category, several factors were selected along with an associated trend and specific projections for each trend (see Appendix D. Vermont Vulnerability Assessment Rating Key for details).

> ***Temperature:*** Annual temperature, seasonal temperature, number of hot days, number of cold days, and variability. Each factor has an associated trend and specific projections. As an example, annual temperature (code=A) had an increasing trend with projections suggesting a 3.7 to 5.8°F increase by 2050, and a 5.0 to 9.5°F increase by 2100.
>
> ***Hydrology:*** Ten hydrology factors were selected, including annual precipitation, seasonal precipitation, heavy rainfall events, soil moisture, snow, spring flows, summer low flows, ice dynamics, fluctuating lake levels, and lake stratification.
>
> ***Extreme Events:*** Extreme weather events include flood events, number of short-term droughts, storms, and fire.
>
> ***Phenology:*** Phenological factors include length of growing season, onset of spring, onset of fall, and biological interactions.

Of the 18-species assessed, eight were identified as highly vulnerable to climate-driven impacts. Of those, five are SGCN: Jefferson Salamander, Canada Lynx, Brook Trout, Eastern Pearlshell Mussel and Bicknell's Thrush.

Climate change vulnerability assessments were similarly conducted for Vermont's upland and wetland natural communities. For efficiently, the 95 natural community types were grouped into categories based on the environmental factors that drive their development and that could affect their susceptibility to climate change. Some natural community types were assessed individually.

Of the upland habitats, Subalpine Krummholz, Alpine Meadow, Cold-Air Talus Woodland, and Dry Oak Woodland were identified as highly vulnerable to climate-driven impacts, and Upland Shores and Hemlock Forests were identified as particularly vulnerable to non-climate stressors. Of the 11 wetland habitats, Basin Swamps and Wetlands, Floodplains, Floodplain Forests, and Wet Shores were identified as highly vulnerable to climate change. As with the species analyses, habitat assessments culminated in an overall vulnerability rating for climate-specific and non-climate stressors and an associated confidence score. The assessments also detailed key climate change/exposure factors and non-climate stressors that contributed to the overall vulnerability rating.

The effort also included an assessment of 13 freshwater habitats including six river types and seven lake types. River types were delineated primarily by stream order and pH, and include; high gradient, cold-water acidic, 1-2 order, high gradient, cold-water, not acidic, 1-2 order, medium-sized rivers (4-6 order) etc. Lake types were delineated by trophic type and extent of stratification and included; Oligotrophic lake (stratified), Mesotrophic-Eutrophic lake (stratified), Mesotrophic-Eutrophic Lake (unstratified) etc. For the 13 freshwater habitats, High gradient, cold water, not acidic (1-2 order), and High gradient, cold water acidic (1-2 order) lakes were also identified as highly vulnerable to climate change.

Table 3.4: Vermont Species & Habitat Climate Vulnerability Assessment (SGCN in bold)

Vulnerability Rating Key (Abundance and/or range extent in Vermont change by 2050)

E = Extremely Vulnerable: Extremely likely to substantially decrease (>75% loss) or disappear
H = Highly Vulnerable: Likely to decrease significantly (25-75% loss)
M = Moderately Vulnerable: Likely to decrease (10-25% loss)
L = Slightly Vulnerable: Available evidence does not suggest change (decrease, 5-10% loss)
N = Not Vulnerable, No Effect: Likely to increase or decrease by less than 5%
B = Increase Possible or Likely: Likely to increase (>15% increase)
U = Unknown/Uncertain: Available evidence not available or not conclusive at this time.

Confidence Ratings

H = High: Very confident (>60% certainty in vulnerability score)
M = Moderate: Somewhat confident (30-60% certainty in vulnerability score)
L = Low: Not very confident (0-30% certainty in vulnerability score)

Species and Habitats	Climate Vulnerability Rating	Confidence Score	Non-climate stressors Vulnerability
Key Species			
Jefferson salamander	H	H	H
Northern white cedar	M	M	H
Fingernail clam	L	H	M
Beaver	N	H	M
Bobcat	L	M	M
Lynx	H	H	M
Brook Trout	H	H	H
Wood Turtle	M	H	H
Pearlshell mussel	H	M	M
Fallfish	L	M	L
Smelt	M	H	M
Lake trout	H	H	H
Bald Eagle	L	M	L
Bicknell's Thrush	H	H	H
Common Loon	M	L	L
Red Oak	N	M	N
Sugar Maple	H	M	L
West Virginia White (butterfly)	H	H	M
Wetland Habitats			
Cattail Marsh	L	M	L
Shallow Emergent Marsh	M	M	M
Marsh and Sedge Meadow (Formation)	M	M	M
Alluvial Shrub Swamp	M	M	L
Basin swamps & wetlands	H	M	M
Floodplains	H	M	M
Ground water seepage & Flood swamp	L	M	L
Open peatlands (precipitation-dependent)	M	M	L
Open peatlands (ground-fed)	L	M	M

Species and Habitats	Climate Vulnerability Rating	Confidence Score	Non-climate stressors Vulnerability
Floodplain Forests	H	M	M
Wet Shores	H	M	M
Upland Habitats			
Alpine Meadow	E	M	M
Spruce-Fir-Northern Hardwood	M	M	M
Northern Hardwood Forest	L	M	L
Oak-Pine–Dry Mesic Forests & Woodlands w/deeper soils	L	M	M
Oak-Pine Northern Rocky–Northern Dry Rocky Forests and Woodlands	L	M	L
Oak-Pine Southern Rocky–Southern Dry Rocky Forests and Woodlands	M	L	L
Outcrops and upland meadows	N	L	L
Cliffs and Talus	L	M	L
Upland shores	M	M	H
Subalpine Krummholz	E	M	
Montane Spruce-fir	M	M	
Red Spruce-Heath Rocky Ridge	M	M	
Montane Yellow Birch-Red Spruce Forest	M	M	
Red Spruce-Northern Hardwood	L	M	
Lowland Spruce-Fir Forest	M	M	
Boreal Talus Woodland	M	M	
Cold-Air Talus Woodland	H	M	
Limestone Bluff Cedar-Pine Forest	L	M	
Transition Hardwood Talus Woodland	L	M	
Dry Oak Woodland	H	L	
Freshwater Habitats			
Medium-sized river (4-6 order)	M	M	
Large river (7+ stream order)	L	M	
High gradient, cold water acidic, 1-2 order	H	H	
High gradient, cold water, not acidic, 1-2 order	H	H	
Low gradient marsh	M	M	
Lake Champlain valley	M	M	
High Elevation Lake	M	L	L
Dystrophic Lake	M	L	L
Lake–Oligotrophic, Stratified	L	H	L
Mesotrophic-Eutrophic Lake (stratified)	M	M	M
Mesotrophic-Eutrophic Lake (unstratified)	H	M	M
Unstratified lakes	M	H	H
Stratified Lakes	M	H	H

Recent Projects Helping Address Climate Impacts to Species and Habitats

Vermont has developed several tools that provide a strong foundation for addressing the impacts of climate change on wildlife and their habitats. Examples include VFWD's 2014 BioFinder project, which identifies Vermont's lands and waters supporting high priority ecosystems, natural communities, habitats, and species. BioFinder's 21 datasets represent biological, ecological, and natural heritage data stacked together for a co-occurrence analysis which identified the locations of greatest overlap (concentration) for priority ranking at the statewide scale. The Habitat Block project, another spatial analysis tool, prioritized 4,055 habitat blocks and identifies likely wildlife road crossing locations for all of Vermont's roads. Maintaining a connected network of unfragmented habitat blocks is recognized as a primary strategy for conserving biological diversity in the face of a rapidly changing climate, and is one of the most widely used of VFWD's datasets in conservation planning technical assistance provided to towns and Regional Planning Commissions.

Vermont's iMap Invasives database aids in assessing the spread of invasive species anticipated under climate change. The database allows ANR, TNC, and other land management organizations to document and track the spread of invasive species throughout the state, provides an early warning of the arrival of new invasives into the state or into new areas of the state, and allows ANR to follow management actions taken to control any given population. In 2015, a new ANR Invasive Plant Coordinator position was created to help further invasive species management.

Vermont is engaged in wildlife species monitoring and management efforts to further of understanding of climate impacts, which may help us develop management strategies. VFWD is monitoring Moose populations through indices of ticks, hair loss, and mortality; assessing the impacts of climate change on the interactions between Fisher and American Marten; surveying for recently documented Canada Lynx; and is actively engaged in management activities to raise the elevation of targeted turtle nesting beaches in response to higher Lake Champlain water levels. Similar activities include monitoring deer populations and the implications of deer browsing under climate change. Projects such as the Vermont Breeding Bird Atlas may also have significant value for monitoring changes over time that may be related to climate change.

VFWD has recently developed a sampling regime that includes annual trout population monitoring concurrent with stream temperature data. The resulting datasets will allow biologists to monitor changes in fish abundances and stream temperatures at specific locations. Stream temperature monitoring also takes place in various streams across the state for specific fisheries management projects.

Changes to state lands management planning: 1. Beginning in 2010 the ANR began addressing climate change in new Long-Range Management Plans (LRMPs) for state lands. 2. ANR is currently developing new LRMP for Victory State Forest and Wildlife Management Area with climate change as a key concept to drive management decisions. Key factors include boreal habitat conditions and the presence of rare and edge-of-range species (e.g., Canada Lynx, Spruce Grouse, American Marten, and Black-backed Woodpecker). 3. To address the uncertainty of assisted migration as a climate change strategy, the ANR Lands Team is reviewing options, impacts and management guidelines for state lands.

ANR has a new state lands management policy and guidelines for management and protection of riparian buffers. Good management of riparian areas is often referred to as a "No Regrets" climate strategy because it makes such good sense to maintain vegetated habitats along our rivers and streams for a variety of benefits. While the buffer policy is a work in progress, a draft is complete and is based on all currently available science on the values and protection strategies for riparian areas. The policy is not based solely on climate and flood resilience, but it intentionally addresses these important considerations.

In 2015 VFPR presented a report to the legislature on forest fragmentation. Strategies to address forest fragmentation complement habitat conservation efforts needed for climate change. The Vermont Forest Roundtable is focused on implementing solutions to address forest fragmentation that will be essential to wildlife species habitat protection goals.

Other important State efforts to address the impacts of climate change on wildlife species and habitats include:

- The ANR Stewardship Team funded a pilot project on four areas of state lands where the Department of Environmental Conservation (VDEC), in coordination with the Forests, Parks & Recreation Department (VFPR) and VFWD, is investigating flood resilience conditions and related management opportunities. This was intentionally developed to better understand state lands management decisions relative to climate change and flood resilience.

- VFWD and VDEC Rivers Program have been evaluating culverts for fish and aquatic organism passage and stream geomorphic compatibility since 2005. The objectives are to gain a greater understanding of the scope of fish and aquatic organism passage (AOP) barriers and undersized culverts that may be having a negative impact on physical stability and quality of stream habitat in Vermont and work toward addressing these issues where appropriate; and improve the understanding and communication between VFWD, VDEC, state and local road managers and state and federal regulators in addressing AOP and geomorphic compatibility issues at stream-road crossings.

- The Vermont Dam Task Force is dedicated to restoring rivers through the assessment, prioritization, and facilitation of dam removal or modification. This work is particularly important considering climate change because dams can significantly degrade a river's water quality (e.g., temperature and dissolved oxygen), aquatic habitat, the movement of aquatic organisms and the transport of sediments downstream. The Dames Task Force is a statewide cooperative effort among federal and state agencies (including VFWD and VDEC), private organizations, and individuals allows participants to share information and dam removal advice; coordinate efforts to accomplish the removal of dams whose negative effects exceed their benefits; and, to reach out to the public.

- The Narrows Wildlife Management Area in West Haven was selected for a pilot project by VFPR for assessing and monitoring timber management and its attendant consequences on climate change factors including the presence and movement of invasive species, and regeneration success. Additional demonstration areas are in development as part of the Mount Philo State Park, the Putnam State Forest, and the Okemo State Forests.

- VFWD recently updated the Conserving Vermont's Natural Heritage document to include a section that discusses climate change, how it may impact habitats, natural communities, plants and animals, and how to consider those effects in the context of local and regional land use planning.

- VFPR is working with private landowners to conserve and manage one of five priority habitat linkages identified by Two Countries, One Forest as critical to maintaining the integrity of the entire Northern Forest. This landowner cooperative involves over 13 properties known as Cold Hollow to Canada and employs climate smart forest management strategies.

- Forest changes are monitored by FPR through forest health monitoring plot networks to track current and future habitat suitability and tree species distributions.

- VFWD's Community Wildlife Program (CWP) provides technical assistance to municipalities and Regional Planning Commissions emphasizes the importance of integrating climate change effects on land, fish and wildlife conservation into planning. VFWD intentionally shifted to a greater focus on landscape and habitat connectivity through the efforts of this program for several reasons, including our understanding that creating a well-connected landscape is important for landscape resilience relative to climate change.

- Since Tropical Storm Irene in 2011, VFWD and VDEC has worked together with Vermont Agency of Transportation (VTrans) to change how we address road-stream crossings and other river/road conflicts. The net result is larger stream crossing structures, a more rigorous application of Aquatic Organism Passages (AOP), and a more holistic approach to river management practices driven in part by flood concerns related to climate-driven impacts. VFWD, VDEC and VTrans created a rivers and roads training program targeted at state and municipal employees and contractors that work on roads to increase the knowledge base of river/road best management practices, especially as they pertain to post-flood scenarios when the likelihood is greatest for in-channel work that can harm channel stability and in-stream habitat.

- In 2011, the VTDEC Lakes and Ponds Management and Protection Section identified 13 reference lakes across a gradient of lake sizes for a Sentinel Lakes Program Monitoring program to track the effects of climate change on Vermont's inland lakes. These lakes are visited annually at spring turnover to tease out trends related to climate change from trends related to land use and acid precipitation. In 2011, full summer lake assessments were conducted where littoral macroinvertebrates and sediment diatoms were collected along with other water chemistry. Over time, quantitative macrophyte surveys will be conducted to augment the existing data set. Ultimately, if funding can be secured, chains of continuous temperature and dissolved oxygen sensors will be deployed at the deep hole in the lakes. In addition, continuous water level monitoring devices will be deployed. Temperature, frequency of lake mixing and water levels are expected to change because of climate change. Understanding the magnitude and frequency of these changes due to climate change will be important for the management of other lakes in the state and contribute to our understanding of how Vermont's inland lakes are changing due to climate change.

- Currently, VFWD staff members are developing a guidance document that sets out a vision for future land acquisition efforts. This guidance will take into consideration important factors related to climate change and landscape resilience, in particular, landscape and habitat connectivity.

- VFWD staff and ANR's Office of Planning and Legal Affairs collaborated on revisions to Act 250 criterion 8 to better address necessary wildlife habitat, rare, threatened and endangered species and their habitats, rare and irreplaceable natural areas, forest blocks, and landscape connectivity. Riparian corridors are identified as especially important for wildlife movement, biological diversity, and river stability. The primary impetus for this work was to improve how Act 250 addresses habitat fragmentation and landscape connectivity, two factors recognized as being critical to climate change adaptation. These revisions must be implemented to achieve the desired results.

- To maintain the reciprocal flow of information between the State and Federal programs, Governor Shumlin serves on the Presidential Task Force on Climate Preparedness and Resilience. In this capacity, the Governor works to ensure that lessons learned from Vermont's climate-related activities inform Federal climate change considerations.

Identifying Climate Adaptation Strategies for Vermont's Species and Habitats

Before selecting actions to help wildlife species and their habitats respond to climate change it is important to bear in mind the ways in which climate change may impact the evaluation of management alternatives (Stein, B. et al. 2014).

Performance: Changing climate conditions that could affect the outcome of some conservation strategies. For example, shifts in the intensity of peak flows or extent of low stream flow may affect the performance of some of fish passages structures.

New constraints: Climate change may add new constraints, limiting what is technologically, ecologically, or culturally achievable. Changing conditions may make local persistence of some species or habitats impossible, or climate-related shifts in land uses may create new obstacles to species movements.

Relative weight: Because climate considerations could increase costs of some actions significantly these costs should be considered up front.

Perceived value: Climate change may affect the perceived value of various resources. For example, as floods become more frequent and severe in some places, marshes and wetlands may become increasingly valued for their ability to mitigate flood risk.

Priority Actions to Address Climate Change Impacts to Species and Habitats

1. Protect large habitat blocks, riparian habitats and climate refugia, and promote landscape integrity and connectivity to facilitate the movement of species across habitats based on the VFWD report "Vermont Conservation Design: Maintaining and

Enhancing an Ecologically Functional Landscape" (Sorenson et al. 2015), the Aquatic Organism Passage program, River Corridor Planning and other conservation plans.

2. Increase riverine, floodplain, and riparian connectivity based on Aquatic Organism Passage program and River Corridor Planning recommendations.
3. Restore rivers through the assessment, prioritization, and facilitation of dam removal or modification.
4. Support the Staying Connected Initiative, Cold Hollow to Canada, and similar programs focused on maintaining and enhancing landscape integrity and connectivity.
5. Complete and implement a state river corridor protection plan, riparian buffer policy and vernal pool management guidelines.
6. Expand river corridor and floodplain protections similar to the Lakeshore Protection Act.
7. Support and help implement the recommendations of VFPR's Creating and Maintaining Resilient Forests in Vermont: Adapting Forests to Climate Change
8. Support and help implement the recommendations of VFPR's Forest Fragmentation Plan.
9. Implement Vermont's Clean Water Initiative to improve water quality statewide particularly in Lake Champlain.
10. Protect and expand riparian habitats to increase habitat connectivity, increase cold water habitats, reduce the spread of invasive species, accommodate river channel dynamics and mitigate the impacts of flooding (Hilke, C. & Galbraith, H. 2013).
11. Protect ecosystem health and stability by preventing new introductions of invasive species and pests and controlling infestations of existing species via integrated pest management programs.
12. Minimize climate change impacts by employing management strategies that sustain fundamental ecological functions, promote habitat resiliency and adaptive capacity, and restore habitats with future conditions in mind.
13. Invest in research and monitoring programs that can inform species and habitat management with future conditions in mind such as monitoring indicators of changes in species distribution and abundance; stream temperatures, cold-water refugia and cold groundwater inputs to streams, Sentinel Lakes, early detection of invasive species, pests and pathogens; identification of genetically adapted species.
14. Develop incentive, education and technical assistance programs to help landowners, land managers, municipalities and others adopt and implement climate smart conservation programs, such as: culvert replacement, streamside shading, stream bank stabilization, sediment control river corridor easements and other types of conservation easements.

Managing Vermont's Wildlife and Habitats into the Future

As states across the country grapple with climate change impacts to our natural heritage, the need to set management priorities based on a sound understanding of projected impacts is becoming increasingly apparent. Climate change typically amplifies existing ecological stressors including rates of change, disturbance, habitat degradation and fragmentation. As such, isolating specific climate change impacts is difficult because it interacts with and compounds a host of non-climate stressors. To that end, this chapter provides important baseline information about how to protect Vermont's species and habitats under climate change including, (a) the climate-driven threats facing Vermont's wildlife and habitats, the vulnerability of key habitats and species to climate change, and (c) potential strategies for increasing the resiliency and/or adaptive capacity of select habitats and species. Climate change is not the singularly most detrimental stressor to Vermont's ecological systems, but it cannot be brushed aside with the thinking that what we are already doing is-sufficient. Complex problems often require holistic problem solving. Vermont's Wildlife Action Plan can serve as an important role in an integrated approach to protecting our wildlife and the habitats upon which they depend.

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