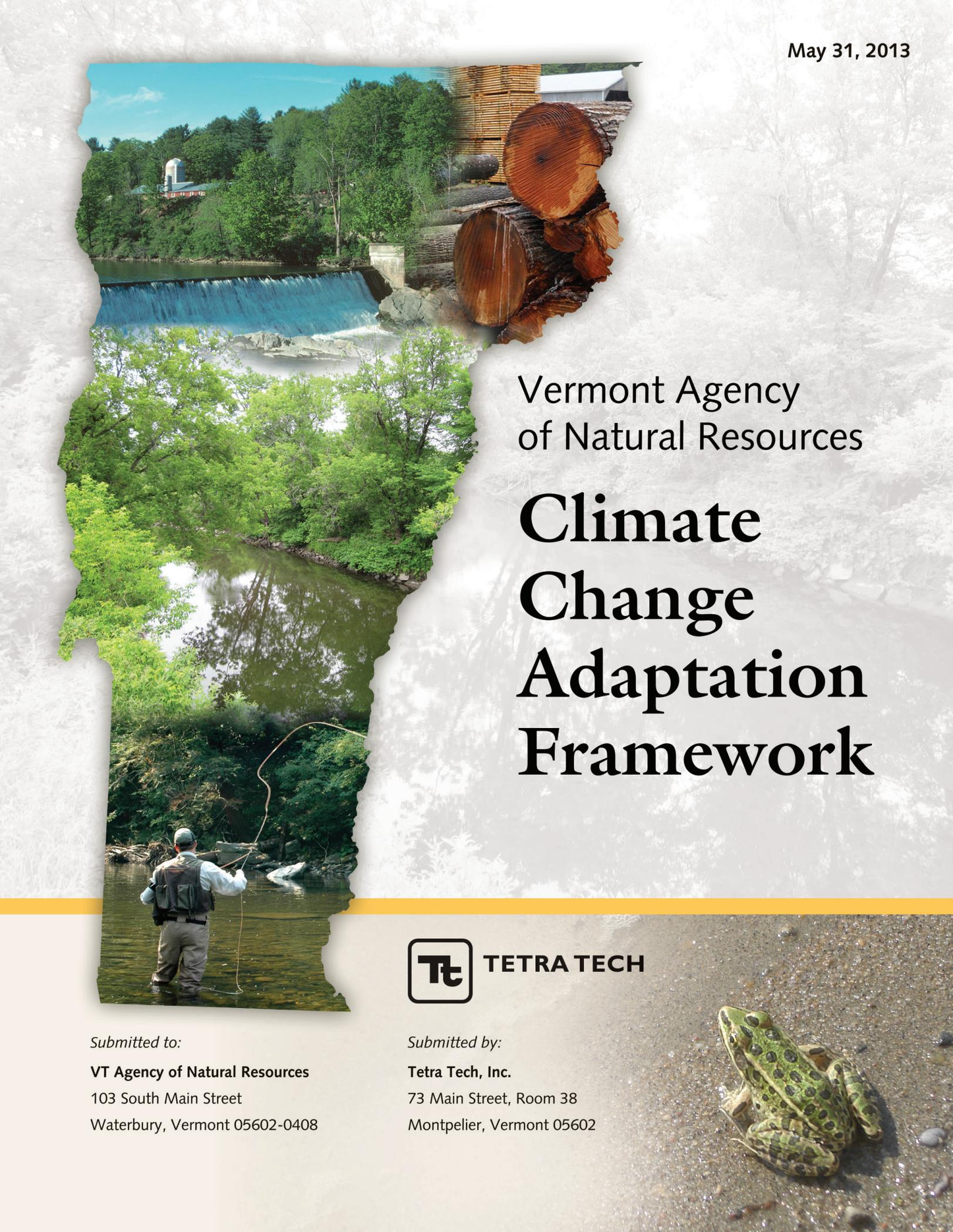


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Vermont Agency
of Natural Resources

Climate Change Adaptation Framework



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Executive Summary

INTRODUCTION

If you don't like the weather in Vermont, wait ten minutes. So the saying goes. The weather is in the conversations of Vermonters, those who visit for sports and scenery, and those who depend on Vermont products and commerce. Recent flooding events, especially Tropical Storm Irene in 2011, were catastrophic for several communities and natural areas throughout Vermont. These required heroic responses and unanticipated resources from individuals and towns, as well as State and Federal agencies. Climate affects so much of our lives that the possibility of significant disruption in patterns due to global climate change spurs us to speculation, and preparation. The regional climate models predict that the changing patterns we have observed so far – increases in temperature and more extreme fluctuations in precipitation – are likely to continue. If you don't like the climate in Vermont, wait 50 years, but we can't promise you'll like it any better.

While impacts on communities and infrastructure tend to grab the spotlight after storms and other extreme weather events, Vermont's natural resources are the backbone on which our livelihoods and quality of life depend. **Changes to climate will directly affect Vermont's natural resources, the services they provide, and the natural heritage they bestow.**

Therefore, through this report and efforts that will follow, the Vermont Agency of Natural Resources (ANR) is addressing climate change impacts on four natural resource sectors: wildlife, (Division of Wildlife), fisheries (Division of Fisheries), forestry (Division of Forestry), and water resources (Watershed Management Division).

The purpose of this report is 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. Climate-driven changes in plant and animal communities, and climate change impacts on other aspects of Vermont's environment, will likely affect the way Vermonters perceive their natural surroundings,

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engage with natural resources for livelihoods and enjoyment, and do business in the state.

Developing **vulnerability assessments**, which describe the types of changes expected, and **adaptation strategies**, which help manage or reduce negative effects, will be essential to prepare Vermonters for these impending changes. The **strategic adaptation framework** in this report is based on our scientific understanding of climate change exposures (the types of climatic changes expected that affect resources), our understanding and expectations of natural resource

vulnerability to those exposures, and our perceptions of cooperative opportunities for addressing these vulnerabilities. In this report, we present the groundwork for the framework through chapters addressing climate change exposures, vulnerability-specific elements within each of the natural resource sectors, and ongoing and proposed actions that can be or have been taken to prepare for the expected changes.

There are two types of adaptation strategies that we do not address in this report: Mitigation of climate change exposures by reducing greenhouse gas emissions; and adaptation strategies involving the modification of infrastructure, such as roads and water/wastewater systems. Mitigation is an essential strategy for reducing the exposures, vulnerabilities, and the need for adaptation actions. However, Vermont is already addressing mitigation through established goals for reduction of greenhouse gas emissions. These goals require broad participation beyond that of the ANR, so while those efforts are supported strongly by ANR they are not described in this report. Likewise, infrastructure modification can have important links to natural resources, but infrastructure modification and maintenance is beyond the scope of ANR's immediate responsibilities. That being said, many infrastructure adaptation strategies, such as promoting stable stream and river channels, can also be beneficial to vulnerable habitats and species.

EXPOSURES

One component of vulnerability assessments is to evaluate **exposure**, or the amount of climate-related change a species or habitat is likely to experience. For this project, we assessed exposure by examining historical trends in climatic data and future modeled projections. Together, the historical and projected trends provide a best estimate of exposures that will be experienced in Vermont through mid-century (Betts 2011a).

During the past 50 years, there has been a consistent pattern of warming in Vermont. Mean annual air temperature at long-term weather stations in Vermont has been increasing at a rate of 0.28 °C (0.5 °F) per decade (Betts 2011a, Betts 2011b). Seasonal differences are evident, with mean winter temperatures rising fastest. There has also been an increase in the number of extremely hot days and a decrease in the number of extremely cold days (DeGaetano and Allen 2002, Hansen et al. 2012). The length of the growing season has increased (Betts 2011a). **These warming trends are projected to continue** (UCS 2006).

Historical trends in annual precipitation are highly variable **but there has been a long-term trend towards overall wetter conditions in the Northeast** (Karl et al. 2009, Hayhoe et al. 2007). In Vermont, precipitation has increased by 15-20% in the past 50 years, and total precipitation is expected to continue increasing in all seasons except summer (Betts 2011a, UCS 2006). Heavy precipitation events also have been increasing across much of the Northeast in recent decades, and **this trend is also expected to continue** (Hayhoe et al. 2007, UCS 2006, Karl et al. 2009).

These warming temperatures and changing precipitation patterns affect snowpack and the timing and volume of streamflow. Over the last several decades in the Northeast, less winter precipitation has been falling as snow and more as rain, resulting in a reduced snowpack, more streamflow in winter and spring, and less streamflow in summer and fall. There also has been a clear trend towards earlier snowmelt runoff/spring peak flow (Hayhoe et al. 2007). Ice dynamics are changing as well. The duration of ice on rivers and lakes has been decreasing, with later freezing dates and earlier ice-out dates (UCS 2006). All of these trends are projected to continue (UCS 2006, Hayhoe et al. 2007).

Extreme weather events have become more frequent and intense during the past 40 to 50 years (Karl et al. 2009). In the Northeast, more frequent short-term droughts are projected to occur as the rising temperatures increase evaporation rates and reduce soil moisture in the summer. There are also projected to be reduced streamflows during the summer due to declining springtime snowpack and rises in temperatures and evaporation (Karl et al. 2009, Hayhoe et al. 2007).

VULNERABILITY

Vulnerability assessments were conducted to identify which habitats or species are likely to be most strongly affected by projected climatic changes and to understand why these resources are likely to be vulnerable. **The habitat assessments focused on 4 major habitat groups: upland forests, wetlands, rivers, and lakes.**

A number of climate-related impacts are expected to affect all habitat groups, including: compositional shifts resulting in the eventual loss of cold-adapted species and an increase in warm-adapted species; an increase in physiological stress from heat and/or water limitation in the summer, which is likely to result in increased susceptibility to pests and disease; and an increase in the spread of invasive species due to increased disturbance from extreme climatic events. Habitats in the Champlain Valley could be particularly vulnerable to heat stress and water limitation since this area is naturally warmer and drier than other parts of Vermont.

Forest health and productivity are likely to be compromised in many regions of the state. With respect to forested habitats, montane/high elevation spruce-fir forests in southern Vermont and associated species like the Bicknell's thrush are expected to be most vulnerable, while oak-pine forests are likely to benefit from warming temperatures and expand northward. Of particular, immediate concern are impacts from increased heat stress and water limitation in the summer, increasing spreading of pests like the hemlock and balsam woolly adelgid, and weather patterns with early spring thaws and late frosts, which can impact regeneration in species like apples and sugar maples by damaging buds, blossoms and roots.

Water sources and soil composition are the key factors in the vulnerability of wetland habitats. **Acidic bogs are expected to be particularly vulnerable** because of their specialized habitat

requirements (cold climate, short growing season, and slow rate of decay of organic matter). Wetlands that receive groundwater inputs are expected to be less vulnerable to changing precipitation patterns, since regional ground water flow systems provide buffering from possible disruptions in surface water inputs to wetland areas.

Coldwater habitats and species associated with river and lake habitats (e.g., brook trout and eastern pearlshell mussel) **are expected to be highly vulnerable to climate change.** Impacts from warming temperatures will be mediated and potentially reduced by localized, protective factors, such as groundwater influence, stream shading and orientation.

Due to expected changes in precipitation patterns, both increased flooding and extended dry periods are expected. The increase in heavy precipitation events could lead to more flooding and is likely to exacerbate existing problems related to nutrient (particularly phosphorous) and sediment loading, as well as shoreline erosion. Extended summer low flow periods in combination with warming temperatures are likely to cause increased physiological stress, mortality to aquatic species, along with algal blooms and decreases in water quality.

Assessments of vulnerabilities in this document should be reviewed and further developed as more information becomes available. The process that was developed for documenting exposures, sensitivities, and mediating factors at the vulnerability workshop could be used if additional habitats and species of interest are assessed in the future, or to update the initial assessments prepared for this report.

ADAPTATION

The Vermont ANR can prepare for the changes associated with vulnerabilities by planning and implementing adaptation actions. Climate change adaptation actions are *adjustments in natural or human systems in response to actual or expected climatic effects that moderate harm or exploit beneficial opportunities*. Specific actions that can be taken were cataloged during a climate change adaptation workshop. These steps represent individual strategies that will move ANR towards a comprehensive adaptation plan.

During the workshop, it was made clear that **many of the actions needed to adapt to climate change are strongly aligned with actions needed and already initiated to reduce various types of pollution in Vermont's watersheds.** This alignment relates to the ecological resiliency that is built into an environmentally intact system. For example, many of the non-climatic stressors affecting lakes and streams are likely to be exacerbated by climate change. These stressors include nonpoint source nutrient and sediment runoff, reductions in groundwater flow during summer, loss of riparian shading, degradation of shoreline habitat, loss of river functions from encroachment, spread of aquatic invasive species, etc. Many potential climate change adaptation strategies could entail management of these same stressors to protect habitats and biological communities from the effects of warming and changing hydrology.

More than in almost any other area of environmental management and policy, **climate change will require the use of innovative management approaches**. For example, adaptive management will be required as we make assumptions about future conditions and how best to cope with them, monitor the results of management actions closely, and then use the monitoring results to inform future decision making. In addition, management actions will include many sectors and many managers that might otherwise remain focused on a single sector. The climate change strategies will be most effective if they address common ground and common objectives for climate and sound natural resource management. Management actions will have four general goals, as follow:

- **Increase Resistance:** Retain existing ecological conditions, assist the habitat or species forestall impacts
- **Promote Resilience:** Buffer impacts and improve the capacity of a system to return to desired conditions after disturbance, or as a means to retain the same essential function, structure, identity, and feedbacks in an altered state
- **Enable Transformation:** Efforts that enable or facilitate the transition of ecosystems to new functional states; proactive strategies that anticipate the nature of climate-change induced transitions and, working with these anticipated trends, include actions that facilitate transitions that are congruent with future climate conditions, while minimizing ecological disruption and undesired outcomes
- **Realignment:** Focus on systems that already have been disturbed beyond historical ranges of natural variability, and recognizing the irreversible change, plan to optimize the system, which might not necessarily include restoration to the historic or pre-disturbance condition

Within the management goal types, the actions can be further categorized by action type:

- **Monitoring and assessment**
- **Technical assistance related to climate and adaptation issues**
- **Regulation**
- **Education and outreach/engagement**
- **Conservation/land stewardship and land use planning**

Finally, the applicability of actions can be qualified by evaluating the following aspects:

- **Effectiveness at mitigating** (and the scientific basis for recommending actions)
- **Operational feasibility** (amount of money and resources required to implement)
- **Degree of current implementation**
- **Level of alignment with current policies, procedures, BMPs**
- **Social/political acceptability and feasibility**
- **Potential for securing funding**

With this structure for identifying management actions in place, a list of potential actions was compiled for each natural resource sector by reviewing regional climate change strategies and through the interactive workshop of ANR and other scientists and managers. The actions and strategies were varied, though cross cutting themes were identified and selected actions were explored in further depth. Some of the critical actions are extensions of existing efforts. The specter of exacerbated effects due to climate change adds urgency to these actions. Examples of critical actions are as follow:

- **Restoring beneficial functions of natural areas**
- **Identifying and conserving natural areas that provide important ecosystem services**
- **Capturing as much clean water precipitation as possible using low impact development**
- **Building bigger crossings and culverts to accommodate sediment transport and connectivity**
- **Analyzing groundwater issues related to agricultural tile drainage and water withdrawals**
- **Promoting riparian stability and filtering functions through appropriately sized stream, river, lake, and wetland buffers.**
- **Improving connectivity and corridors for wildlife movement through intact habitats**
- **Monitoring pests and invasive species**
- **Wetland mitigation in relation to disturbance and increased water stress at both flood and drought stages**

Climate Change Planning Actions

The next steps that the ANR needs to take to move ahead with climate change planning can be implemented in three areas, including establishment of guiding principles, continuing work on vulnerability assessments and adaptation strategies, and follow-up in specific focus areas. At a broad scale, the ANR should **adopt guiding principles and tools for managing** in light of uncertainty, including a formal endorsement or acknowledgement of the spectrum of management actions (resistance, resilience, enabling transformation, and realigning management). In addition, a formal process should be established for integrating climate change and management actions into Agency planning processes. The Agency also needs to define end products and objectives of the climate change adaptation planning process. One possible end product is a comprehensive adaptation plan. These plans are typically a multi-sector effort involving water resources, agriculture, forest and terrestrial ecosystems, bay and aquatic ecosystems, growth and land use, energy development, and public health. The higher level and

other efforts should be supported by the Agency through planning for programs, budgets, staffing, and regulations.

A cooperative effort must continue so that work initiated at the vulnerability assessment and adaptation strategies workshops can be completed or resolved as needed. The workshops successfully introduced planning and assessment processes that should be repeated to address remaining questions about vulnerability and exposure, and to go further in depth for certain vulnerabilities and adaptation strategies. ANR could continue the work that was initiated during the vulnerability assessment and adaptation strategies workshops by reconvening the four major habitat work groups (forests, rivers, lakes/ponds and wetlands) to continue and build on this work. In addition to the four major habitat groups, we recommend initiatives to address climate, species-specific planning, and documentation of existing on-the-ground management actions.

At a smaller scale, focus areas were identified as **important cross-sector themes** at the adaptation strategies workshop. The areas identified were as follows:

- **Promote resilience and resistance by reducing other stressors**
- **Conserving refugia**
- **Monitoring and assessment**
- **Data infrastructure**
- **Landscape-level planning**
- **Groundwater**
- **Sustainable flows**
- **Ecosystem services**