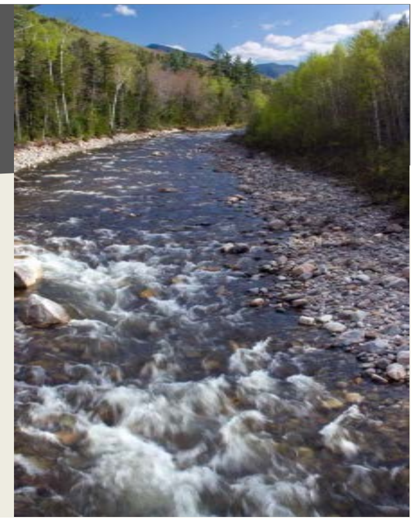
COLDWATER STREAMS
CLIMATE ASSESSMENT



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.

POTENTIAL CHANGES TO HABITAT

- 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.

WHAT DOES THIS MEAN?

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.

How does this affect wildlife?

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:

See the full Climate Change Adaptation Plan for strategy descriptions

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.

This Climate Assessment is a section of the **Ecosystems and Wildlife Climate Change Adaptation Plan (2013)**, an *Amendment to the NH Wildlife Action Plan*, developed by New Hampshire Fish and Game with the help of many conservation partners. The full plan can be found at http://www.wildlife.state.nh.us/Wildlife/Wildlife_Plan/climate.html. (Photo by Ben Kimball)