What is Thermal Stress?

Thermal stress is a term to describe a temperature change that is severe enough to cause unfavorable and even lethal conditions to aquatic organisms, their populations, community structure, or ecosystem. Aquatic organisms have evolved to function most efficiently within an optimal range of water temperature. Certain invertebrates, such as stoneflies and caddisflies, and cold-water adapted fish species, like the brook trout, Atlantic salmon, and slimy sculpins, require cold water to support all life stages. Water temperature in rivers and streams does vary by season, over the course of a day, and along the length of a river. However, certain land uses, activities, discharges, and the physical condition of the aquatic ecosystem can influence water temperatures beyond natural variation to cause thermal stress. Moreover, one of the anticipated impacts of climate change is an increase in ambient air temperatures that could, over time, influence water temperature to a point of exceeding incipient lethal limits for some cold-water dependent species. It is therefore extremely important to manage activities on the landscape and discharges to reduce their contribution to increased temperature stress.

The impacts of temperature on aquatic habitat are far-reaching, making changes in temperature one of the most influential stressors to aquatic habitat. Temperature can be a physical, biological, or chemical stressor. Physically, higher water temperatures reduce levels of dissolved oxygen, potentially creating a condition of hypoxia. Low oxygen levels can kill or affect species' life cycle functions, and can reduce species diversity and population sizes.

Biologically, higher temperatures directly affect the metabolic rates of aquatic biota, disrupt their life cycle thermal cues, and have an impact on their capacity to resist disease. Certain cold water aquatic macroinvertebrate species will be displaced. Higher water temperatures, coupled with sunlight and nutrients, create more favorable conditions for plant and algae growth. It can also result in blooms of microbial populations, such as cyanobacteria, which in some cases can be toxic to humans and animals. Higher temperatures can also cause E. coli populations to increase and remain viable for longer periods within a stream, causing and increased risk to recreational users. In extreme situations, extensive aquatic plant growth in lakes and ponds can result in critically low oxygen levels at night when photosynthesis stops, and respiration rates increase the biological demand for oxygen (BOD), that further depletes the water of oxygen.

Chemically, higher temperatures can alter concentrations of substances in water, which can have an impact on the ability of fish to withstand chemical exposure. Such impacts can also affect recreational uses and public enjoyment of rivers, lakes, and ponds. Climate change is resulting in shorter ice coverage seasons on many lakes and increased summer water temperatures. The full effects of these changes are not completely understood.

How important is Thermal Stress?

Based on the Watershed Management Division's evaluation, thermal stress is an important stressor. While excessively high temperatures impair a relatively small number of stream miles in Vermont, the impacts in those locations are significant. The potential for thermal stress in water bodies across the state is high, since over 60% of Vermont's streams are small, cold water habitats. Moreover, in many instances, thermal stress occurs in concert with other stresses to compound effects on aquatic organisms.

The 2010 statewide water quality assessment suggests that for rivers and streams, 76 miles are impaired due to excessively high temperature, and an additional 480 miles experience thermal stress (hyperlink 305b report).

What objectives achieved by managing Thermal Stress?

Addressing and preventing thermal stress promotes several surface water goals and objectives, including:

Objective A. ***Minimize Anthropogenic Nutrient and Organic Pollution***
A stable stream with adequate riparian woody vegetation and floodplain function will provide shade as well as the added benefits of filtering and storing sediment, nutrients, and organic pollution. Cooler water in shallow lake systems can mitigate the effects of nutrient pollution. Reducing impervious surfaces and encouraging infiltration can decrease temperatures of incoming waters while reducing flow and nutrient loading.

Objective B. ***Protect and Restore Aquatic, and Riparian Habitat***
Moderating and maintaining a suitable thermal regime for aquatic organisms avoids the physical, biological, or chemical impacts that higher temperatures can cause. It will also help to safeguard temperature-sensitive species from the impacts of climate change. Having healthy, vegetated river corridors, floodplains, wetlands, and lake shore lands is a key management tool for regulating water temperature to avoid exceeding incipient lethal limits, providing important sources of fine and coarse organic matter that benefits aquatic habitat, and filtering to minimize sedimentation from stream bank and shore land erosion. These areas will also provide important aquatic and terrestrial habitat connectivity within the watershed, including upland areas. Another important management tool is to preserve the natural or seasonal flow regimes, and in particular to ensure adequate flows during drier months. This can be achieved by promoting practices that mimic natural hydrology and function. These strategies will help to mitigate the impacts of climate change on aquatic habitat. Restoring and protecting these habitats will help to protect temperature-sensitive species and maintain public enjoyment of aquatic life and wildlife.

What are the causes and sources of Thermal Stress?

Thermal Stress

There are six principal causes of thermal stress to Vermont waters. Thermal stress becomes most apparent during periods of low flow or drought. The six causes are:

- The removal of vegetative buffers along lakeshores and riverbanks, allowing increased sunlight penetration into waters and warming of the water. Lack of riparian and lakeshore vegetation is widespread in Vermont;
- The direct alteration of the stream channel and floodplain, often to accommodate encroachment into a river corridor. This “channelized” condition inhibits the stream’s capacity to achieve equilibrium. The “channelized” condition is often characterized by having a history of being dredged or straightened, excessive stream bank and bed erosion in some locations, and structural measures such as bank armoring and berming in other locations. A vegetated buffer on an altered, unstable stream will only marginally influence the stability of that stream. Additionally, buffers on unstable streams don’t persist, since they are highly vulnerable to damages from fluvial erosion;
- Stormwater runoff. During the summer, rain falling on impervious surfaces such as roads and parking lots can quickly run off into nearby streams. These dark surfaces heat up and can cause a spike in stream temperatures by. as much as a 10ºC increase stressing the aquatic community. Over time, this can lead to the loss of high temperature intolerant fish and macroinvertebrates, leaving behind an altered community tolerant of warmer water.
- Impounding rivers and streams can create downstream reaches with warm, slow-moving and shallow water. Moreover, intake structures that draw water from the surface to feed hydropower turbines will discharge warmer water into receiving waters. There are numerous instances of on-stream ponds creating downstream warming in Vermont;
- Water used for cooling by some industries, wastewater treatment plants, and power generating facilities, that may be discharged at higher temperatures; and,
- Climate change, which implies that thermal stress will persist as water temperatures exceed the range of tolerance for vulnerable species. Although much of the thermal stress and associated water quality and ecological impacts observed today are due to causes and sources listed above, a warming climate will continue to contribute to increases in surface water temperatures if left unabated.

Monitoring and assessment activities addressing Thermal Stress

Key Monitoring and Assessment Strategies to Address Thermal Stress

- Conduct stream biological, geomorphic, and reach habitat assessments at sentinel sites to evaluate the condition of the biological community, the vegetation along streambanks and shorelands and within the river corridor or waterbody. These data will provide insight to the overall health of the riparian and aquatic ecosystems, including the degree of shade, changes over time, and the potential impacts from climate change.

- Pair monitoring with active restoration projects on longer time scales to evaluate the improvements in water temperature.

- Complete river corridor plans in stream and river watersheds to identify opportunities to restore vegetated conditions along the riparian areas, river corridors, and floodplains.

- Increase the number of temperature monitoring units in lakes and streams to provide state-wide coverage to better understand the extent of the problem, identify specific problem areas, and evaluate the cumulative impacts of thermal stress from all sources, including buffer loss, discharge from impoundments, and stormwater runoff.

- Monitor changes in land use and vegetation cover near lakeshores using on-site sampling or remote sensing.

- Develop and maintain a temperature gauge network in conjunction with a flow gauge network on rivers.

- Identify locations of potential thermal stress (i.e. parking lots within 50 feet of a river or stream, etc.)

- Assess thermal stress associated with the detention of stormwater for water quality treatment.

Technical assistance activities addressing thermal stress

Key Technical Assistance Strategies to Address Thermal Stress

- Develop and maintain the capacity to technically assist landowners, municipalities, land developers, agencies, and organizations in the:
  - Design and execution of data collection and analytical methods necessary to understand temperature impacts;
  - Identification of critical management areas outside a river corridor where excess surface runoff can be infiltrated, evapotranspired, or stored and reused;
  - Development and implementation of strategies to delineate, re-establish, and maintain vegetated buffers along river corridors, wetlands, and lake shorelands; and,
  - Alternatives analysis, project design, and implementation of appropriate river corridors, setbacks, and vegetated buffers, assessments and river corridor planning.

- Continue to support programs and other efforts to install vegetated buffers.

Regulatory activities addressing thermal stress

Key Regulatory Strategies to Address Thermal Stress

- Develop a set of meaningful incentives for municipalities to adopt plans and bylaws that protect floodplains, river corridors, lake shorelands, and buffers.

- Better utilize the water quality standards for temperature to minimize thermal stress from activities within shorelands, corridors, and floodplains by convening an internal workgroup to develop a proposal for modified temperature standards that address non-discharge related sources and propose these modifications during triennial standards review.

- Promote dam removal projects and develop regulatory tools to expand existing authorities to remove unsafe dams that no longer serve a useful purpose.

- Improve stormwater regulations and promote stormwater Best Management Practices to include temperature controls that promote infiltration over detention.

- Continue to uphold minimum flow standards in permitting of hydropower projects, impoundments, and other withdrawals, and manage releases from existing and new impoundments to mitigate thermal load.

  Promote the use of vegetation and biodegradable materials for shoreland stabilization projects to mimic the natural shoreland.

- Continue to uphold the Vegetation Protection Standards under the Shoreland Protection Act to protect and enhance shoreland vegetation on lakes and ponds

- Work with other agencies and ANR enforcement to ensure compliance with Act 250 permits that contain river corridor or buffer protection requirements.

- Increase technical assistance capacity within the Division to review proposals that encroach into buffers directly under State purview (Act 250).

Implementation funding activities addressing Thermal Stress

Key Funding Strategies to Address Thermal Stress

- Per Act 110, develop a set of meaningful incentives in relevant State funding programs for municipalities to adopt plans and bylaws that protect floodplains, river corridors and lakeshore buffers.

- Consider a stable funding program to conserve floodplains, river corridors, lakeshores, and wetlands, including vegetated buffers.

- Work with the Agency of Agriculture, Food, and Markets, NRCS, and FSA to evaluate buffer practices. As part of that effort, consider a more substantive buffer requirement for all landowners interested in cost-share programs that contain state funding.

- Continue to promote "trees for streams" programs to provide funding for landowners to plant vegetated buffers.

- Work with the Vermont Department of Fish and Wildlife to promote restoration and protection of buffers into the Statewide Wildlife Action Planning effort.

- Evaluate, as an incentive, tax policy that recognizes the societal value of permanent river corridor and buffer protection.

Information and education activities addressing thermal stress

Key Information and Education Strategies to Address Thermal Stress

- Develop Adopt-a-Stream program.

- Develop a marketing strategy to educate the public about the importance of river corridors, lake shorelands, buffers, and natural hydrology.

- Develop and maintain information & education materials on the causes and effects of thermal stress and the important strategies to address the causes and sources for both lay and technical audiences.

- Work with ANR Climate Team to develop and maintain web-based information & education materials on the thermal stresses associated with climate change for both lay and technical audiences.