The many watersheds that comprise the drainage of the Winnipesaukee River were recently surveyed by the New Hampshire Fish and Game Department. These surveys were part of a statewide effort to quantify the presence of self-sustaining brook trout (*Salvelinus fontinalis*) populations and to gather some preliminary information on their habitat. These surveys also provide some information on the region's general fish community. An assessment to determine the status of brook trout within this region of New Hampshire is of particular interest to the overall goal of protection because information regarding this watershed does not currently exist. Current information indicates brook trout populations are abundant and secure to the north of the Winnipesauke River watershed, while impacts to habitats and localized extirpations appear to have reduced populations to the south of this region. As this region continues to grow, more pressure is placed on the ability to sustain water quality and habitat for wild brook trout populations.

Background

Brook trout are the only native stream dwelling trout species in New Hampshire, having a historic range that extended from Georgia to eastern Canada. It is believed that wild brook trout were once present throughout all watersheds in New Hampshire. Increased stream temperatures, changes to water chemistry, habitat fragmentation, increased rates of predation and competition, loss of spawning locations, and the loss of stream habitat complexity have led to reduced and isolated populations of wild brook trout both in New Hampshire and throughout the species' native range in the eastern portions of the United States.

Recognizing the reduction in the distribution of wild brook trout, the Eastern Brook Trout Joint Venture (easternbrooktrout.org/) was established. This public and private partnership of state fish and wildlife agencies, federal natural resource agencies, academic institutions, and local conservation organizations is working to protect existing wild brook trout habitat, enhance and restore impacted habitat, and raise public awareness about their current status. These efforts will also benefit other native stream dwelling species, because brook trout serve as an indicator for healthy aquatic ecosystems. Fortunately, it is believed that New Hampshire has more intact populations of brook trout when compared to the southern portions of the species eastern U.S. range. However, information to quantitatively describe the status of brook trout populations in central New Hampshire is limited.

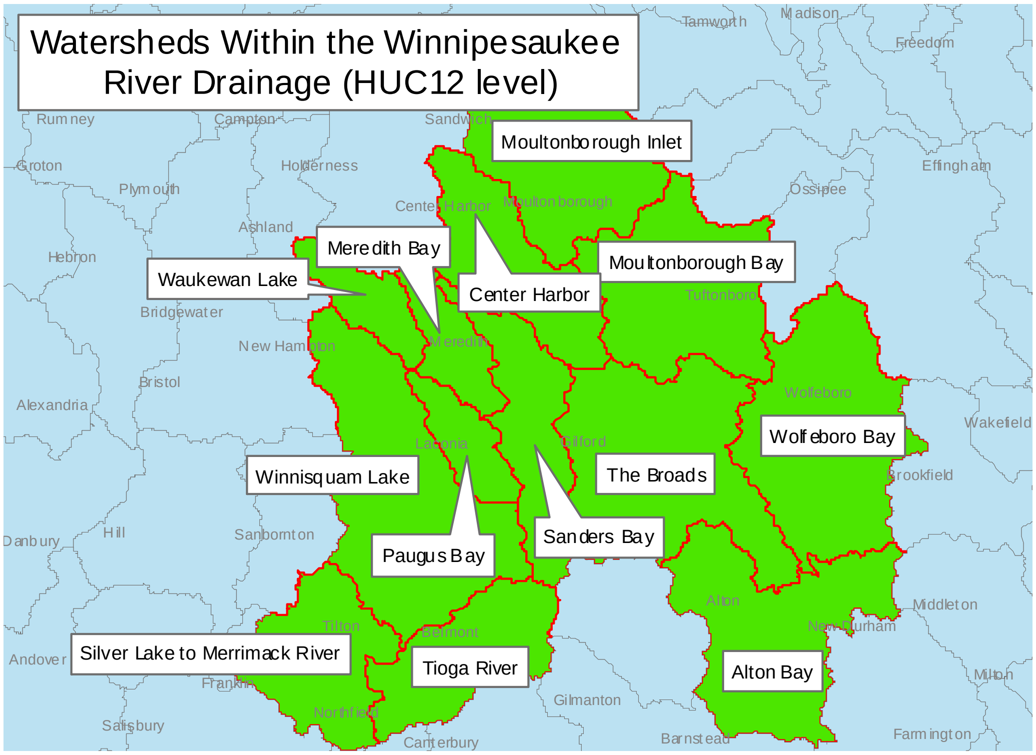
Project Justification

As with several fish and wildlife species found in New Hampshire, the presence or absence of wild brook trout populations can indicate the condition of aquatic habitat and water quality. Brook trout depend on cool, clean, and well oxygenated rivers and streams and can be very sensitive to environmental perturbations which may occur at rates ranging from instantaneous to gradual. Information collected on this species enables us to view the occurrence (or lack of occurrence) of brook trout as a sentinel species that represents the health of aquatic ecosystems, as well as our footprint on the landscape.

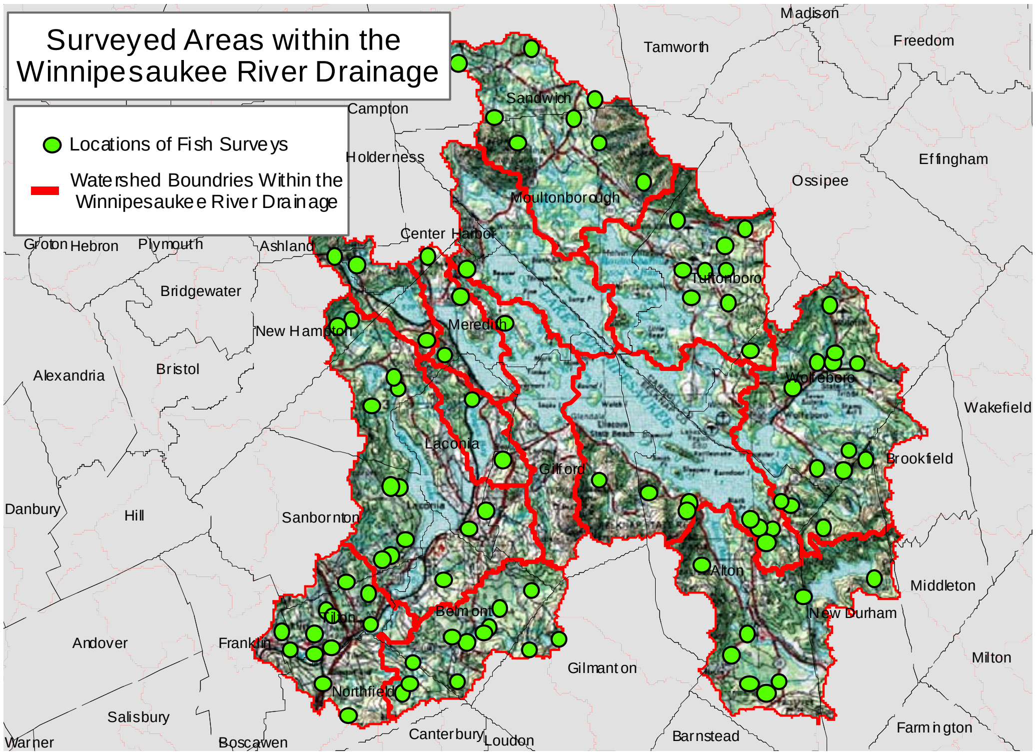
Brook trout are susceptible to changes in water chemistry and alterations to their physical habitat. Unfortunately, these changes to water chemistry and aquatic habitats may be difficult to recognize. Unlike a toxic chemical spill that may immediately kill aquatic organisms, the more common attributes that displace brook trout populations occur very slowly with no clear sign of obvious impact. Changes to natural stream substrate can significantly reduce the ability of a wild brook trout population to survive and/or reproduce. Excessive sedimentation from a variety of sources can embed and cover natural stream features in which brook trout have evolved to depend on. When this occurs, spawning locations, stream macroinvertebrates, cover, and holding areas can be lost or impacted negatively. The habitat needs of wild brook trout coincide with our own desires to protect the quality of water supplies and recreational areas.

The brook trout is also an important game fish and symbolic figure in the heritage of New Hampshire. Records illustrating the importance of the species as a food source and sport fish in New Hampshire date back to the 17th century. Even today, the species is consistently one of the most highly pursued fish for freshwater anglers in the state. Additionally, the brook trout has been designated as the state fresh water fish.

Assessment of Wild Brook Trout Populations
To assess the status of brook trout within the Winnipesaukee River drainage, the New Hampshire Fish and Game Department (NHFGD), in partnership with the Lakes Region Planning Commission conducted electrofishing surveys between 2008 and 2010. The scale used in the Eastern Brook Trout Joint Venture required that the Lake Winnipesaukee drainage be divided into thirteen watersheds. These watersheds include: Alton Bay, The Broads, Center Harbor, Lake Waukewan, Meredith Bay, Moultonborough Bay, Moultonborough Inlet, Paugus Bay, Sanders Bay, Silver Lake to the Merrimack River, Tioga River, Winnisquam Lake, and Wolfeboro Bay.



To summarize wild brook trout populations at the watershed level, each of the thirteen watersheds were further divided into smaller drainages called catchments. Attempts were made to survey every catchment with an established perennial stream. Streams with depths greater than 3 feet and intermittent flowages could not be effectively surveyed with backpack electrofishing gear. Length and weight data was collected on each fish sampled. Information that illustrates the current brook trout habitat condition was also collected.



Results

The Complete Winnipesaukee River Watershed

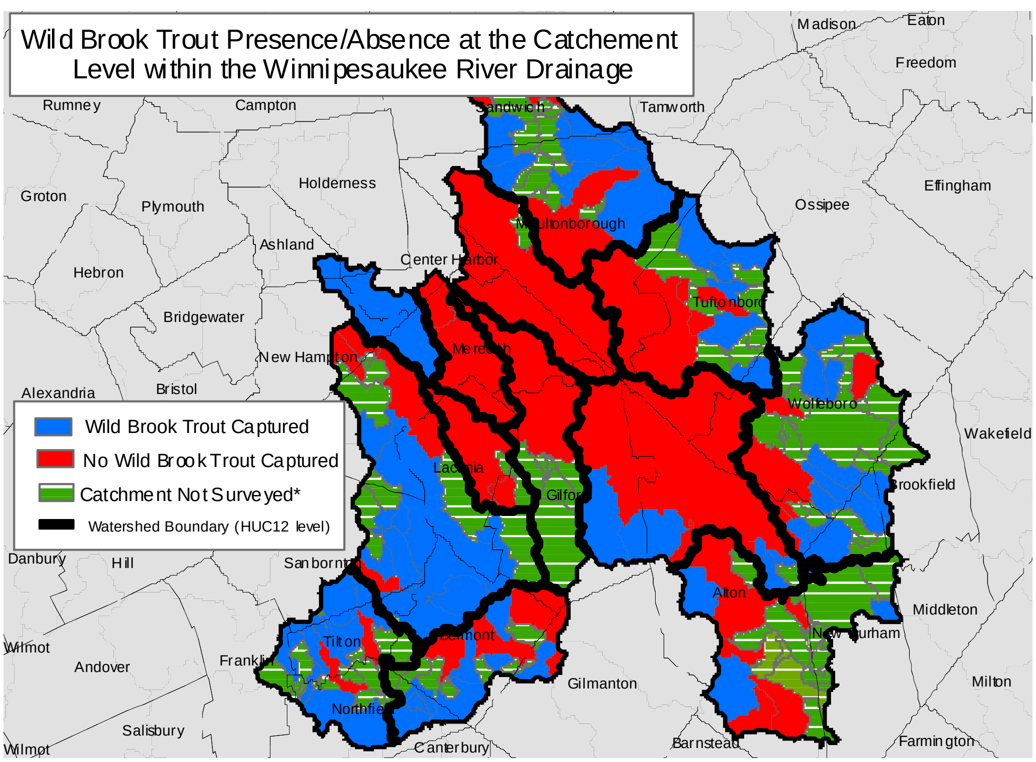
Data from 93 river and stream survey locations are available to help describe the status of wild brook trout and the general fish community within the Winnipesaukee River watershed. A total of 24 different fish species have been documented. These species include: brown bullhead (horn pout) (*Ameiurus nebulosus*), bluegill (*Lepomis macrochirus*), blacknose dace (*Rhinichthys atratulus*), bridle shiner (*Notropis bifrenatus*), burbot (cusk) (*Lota lota*), hatchery brown trout (*Salmo trutta*), creek chub (*Semotilus corporalis*), creek chubsucker (*Erimyzon oblongus*), common shiner (*Luxilus cornutus*), common sunfish (pumpkinseed) (*Lepomis gibbosus*), common white sucker (*Catestamers commersoni*), wild brook trout (*Salvelinus fontinalis*), hatchery brook trout (*Salvelinus fontinalis*), eastern chain pickerel (*Esox niger*), fallfish (*Semotilus corporalis*), golden shiner (*Notemigonus crysoleucas*), lake chub (*Couesius plumbeus*), landlocked salmon (*Salmo salar*), largemouth bass (*Micropterus salmoides*), longnose dace (*Rhinichthys cataractae*), rainbow trout (*Oncorhynchus mykiss*), slimy sculpin (*Cottus cognatus*), yellow bullhead (*Ameiurus natalis*), and yellow perch (*Perca flavescens*). No fish were captured at nine of the survey locations. The state threatened bridle shiner was found in Coffin Brook (Alton). Wild brook trout were the species most frequently encountered at 63% of the surveys (59 of 93 surveys found wild brook trout). Overall, species abundance within the Winnipesaukee River watershed was most strongly represented by blacknose dace (42.0% of total number of fish captured) and wild brook trout (33.0% of total number of fish captured). Burbot were the least abundant species captured (0.02% of total number of fish captured).

Looking at Wild Brook Trout at a Finer Scale

Brook Trout Presence/Absence Information

To explain the current status of wild brook trout at the watershed level, fish data from each catchment surveyed was assembled. Since the roughly 464 miles of stream within these thirteen watersheds could not be completely surveyed, the assembled fish data was used to illustrate a representative description of the entire watershed. The number of survey sites varied between watersheds based on the number of catchments (http://nh.water.usgs.gov/projects/sparrow/data/catchments_metadata.htm) and availability of streams suitable for electrofishing within each of the thirteen watersheds.

Surveys were focused at the approximate midpoint of each catchment. There are several advantages of using the scale of catchments for survey locations. The catchment model divides watersheds into smaller stream reaches based on drainages. Within each of these units, information has been already developed to describe several features related to effects on water quality. Land-use (% developed, % agriculture, % forested), atmospheric deposition, physical characteristics (size, slope, % wetland), and other variable data are available to quantify estimated nutrient loading. Eventually, it is expected that a regional model will be developed to predict fish species presence or absence in areas with no survey information based on catchment data attributes and fish survey data from other locations.



* Catchment not surveyed due to intermittent flow, lack of access, stream type not suitable for backpack electrofishing survey

The surveys show habitat quality for wild brook trout varies by watershed throughout the Winnipesaukee River drainage. Currently, wild brook trout are not necessarily rare in central New Hampshire, but the projected status of wild brook trout in some parts of this drainage is exceptionally good. Due to limitations associated with backpack electrofishing gear, stream type, lack of public access, and stream flow, not every catchment could be surveyed within each of the HUC12 watersheds. The table below summarizes the number of catchments surveyed and the status of the wild brook trout populations within. The number of catchments within each watershed varies greatly throughout the Winnipesaukee River Drainage. The large lakes that encompass a significant amount of area within some of the watersheds can minimize the percentages of stream/river to be surveyed within some watersheds.

Watershed name	Number of surveys	# of Surveys where wild brook trout were found	Percentage of catchments with wild brook trout
Alton Bay	8	3	37.5
The Broads	8	6	75
Center Harbor	1	0	0
Lake Waukewan	3	2	66.67
Meredith Bay	3	0	0
Moultonborough Bat	8	6	75
Moultonborough Inlet	9	6	66.67
Paugus Bay	2	0	0
Sanders Bay	1	0	0
Silver Lake to Merrimack River	12	10	83.33
Tioga River	12	8	66.67
Winnisquam Lake	13	8	61.54
Wolfeboro Bay	13	10	76.92

Wild Brook Trout Density and Recruitment

An additional analysis that illustrates the health of wild brook trout populations is population density. In streams where wild brook trout were found, density calculations were performed. The results ranged between 0.13 (Tioga River, Belmont) to 94.17 (Cook Brook, Moultonborough) brook trout/100 square meters. No clear pattern for brook trout density by watershed is apparent. The ten most dense brook trout streams were found in five different HUC 12 watersheds. Similarly, the ten streams with the lowest brook trout densities were from five different watersheds.

The ability for wild brook trout to reproduce is imperative for a population to be self-sustainable. A population consisting of various age and size classes is an indicator of good habitat condition. Water quality and habitat types must be suitable to support all life stages of fish to sustain the population. Sustainable populations show the habitat present provides ample amounts of forage, thermal refuge, spawning gravel, cover from predators, and from various weather impacts (flooding, frazil ice, etc.). Flows that have been amplified by impervious surface and constriction during stormwater runoff events can scour areas where eggs have been deposited. This impact can also compromise reproductive success by increasing sediment and silt (associated with upstream erosion) depositing on eggs, causing suffocation.

Scale samples can be taken and analyzed to determine the age class structure of brook trout in a stream. This analysis goes beyond the scope of our assessments but the collected data can provide some indication on the population's ability to reproduce. As a surrogate to scale samples, a length metric can be used to indentify presence of juvenile fish hatched earlier in the year of the electrofishing surveys. A brook trout less than 90 millimeters is routinely expected to be a young of the year fish. Of the 59 streams where wild brook trout were detected, 47 of them contained young of the year brook trout (having at least one brook trout with a length <90mm).

Observed Impacts to Water Quality and Brook Trout Habitat

Current aquatic habitat conditions can be evaluated with modern day mapping software, but on the ground survey work is imperative to obtain a more complete sense of the health of aquatic systems. Survey crews have documented several alterations to the habitat and water quality that exists within the surveyed locations of the Winnipesaukee River drainage. These alterations range from clearly visible current impacts, to historic land use practices that have altered the landscape and its drainage for an incalculable period of time. Potential impacts to wild brook trout were recorded at every survey location. The lack of riparian vegetation, as a result of logging, lawns, parking lots, or adjacent road proximity, was the most common impact recorded. Impacts associated with erosion (scouring, sediment deposition, etc.) were routinely observed at these locations. Other observations noted were perched culverts, vehicles crossing through the streams, extensive stream bank armoring using riprap, washed out pavement entering the stream and litter.

As with most of New Hampshire, much of the land within the lakes region was cleared for cropland and livestock grazing. In as early as the 17th century, the water retaining ability of old growth forests with thick layers of moss and detritus was becoming altered by the hand of man. The once slow absorption of water from rain and snowmelt which kept water tables high throughout the year was replaced by readily drained plowed fields carrying sediment laden runoff to aquatic systems. It is likely these rivers and streams were afforded minimal riparian buffers. The loss of recharge to water tables caused stream flow rates to drop in the summer months. Countless streams were reconfigured to generate water powered mills, creating impoundments that resulted in warmer water temperatures and fragmentation of aquatic habitats. Signs of these historical practices were observed at several of the surveyed locations. Stonewalls, barbed wire, and mill structures were frequently documented.

The impacts on aquatic systems associated with modern day activities can be very similar to those which occurred centuries ago. Increased concentrations of impervious surfaces prohibit rain and snowmelt to infiltrate soils and recharge ground waters. Instead, streams become flashy; significantly increasing in flow rate directly after storms or melting events and then quickly returning to low flow levels. These large flushes of high water can increase erosion and sedimentation rates on streams. Additionally, runoff from impervious surfaces can introduce quick bursts of nutrients, petroleum hydrocarbons, warmer water temperatures, sand, chlorides, etc., into aquatic systems. Even low percentages of impervious surfaces (as low as 4% of watersheds) can significantly influence the presence or absence of wild brook trout. Stormwater drainage systems that convey runoff directly into streams were routinely observed during surveys within the Winnipesaukee River drainage. These were often associated with road/stream crossings or areas where development left minimal riparian buffer. Drainage from impervious surfaces should be directed away from aquatic systems to reduce the negative impact on aquatic communities.

There is a wide variety of stream crossing structures throughout the Winnipesaukee River Drainage. In some instances, stream crossings that were designed only to incorporate the passage of water flow can alter both stream habitat and aquatic communities. In addition to the ability for a crossing to facilitate the passage of a certain rate of flow, stream crossing design should also consider the specific geomorphic properties of the stream in question. Natural stream systems are in states of evolution or adjustment. Beyond water, streams are employed to convey organic (wood, leaves) and inorganic (sand) material. Several impacts related to crossing designs that do not incorporate the geomorphology of a stream include: culvert perching, scouring and sedimentation, blockage, undermining, road overtopping, and failure. Although the capital costs associated with a geomorphic design are expected to be larger, it is expected that costs related to maintenance overtime and replacement would be much less.

The most suitable stream crossing for fish is one that does not exist. Road design should first consider ways to avoid streams. If a stream crossing is unavoidable, designs should attempt to make the crossing invisible to the stream. Flow rate, sediment transport, gradient, water temperature, and substrate should be identical within the crossing structure to the reference condition of the stream. Impacts to fish communities and habitat result when these conditions become altered. Undersized culverts that constrict streams and increase flow rates (particularly during storm flow events) often create scour pools (or perching) at the culvert outlet. Overtime, these can become barriers to fish movement. This scenario was observed at several of the locations surveyed. If a fish manages to access the culvert, flows may be too overwhelming for the fish to navigate through it. The creation of barriers can lead to wild brook trout not being able to access more desirable habitats for spawning, refuge from warm water temperatures, forage areas, etc. As a result, the population could become extirpated.

Wild brook trout are not often thought of as migratory fish and subsequently not often considered during roads design. However, radio telemetry studies in New Hampshire have shown larger wild trout can move over 20 miles in a single year. When a population becomes isolated, concerns regarding gene flow are also present.

If a catastrophic event occurred upstream of an impassable barrier (i.e. dam, perched stream crossing) that decimated a wild brook trout population, fish may not be able to repopulate the area. This is of particular concern to the streams of this region. Several smaller streams that flow directly into the larger lakes in this drainage appeared to be suitable for wild brook trout but none were found. If a population lives in a high order stream that flows directly into these waterbodies and a stressful event occurs (i.e. acid flush event from snowmelt, extreme drought year, large plumes of sediment, etc.), the ability to repopulate the area may not exist.

Multiple dams exist within the Winnipesaukee River drainage for a variety of purposes (i.e. hydro power, recreation, farm pond creation, water supplies, etc.). Beyond the obvious impact of habitat fragmentation, impoundments have the ability to alter water chemistry and habitat. Outlets of dams can supply oxygen deficient water at increased temperatures to downstream reaches. Upstream sections can be converted to shallow wetlands that displace brook trout. Although more commonly observed in lake and pond environments, human delivered nutrient inputs can lead to eutrophication in rivers and streams. While the simple dynamics of flow provide aeration and dissolved oxygen to streams on most occasions, excessive growth of algae can slow flows, allowing oxygen levels to become reduced.

Local Strategies for the Conservation of Wild Brook Trout

Land conservation and guidance on land use practices are essential to protecting brook trout habitat. Wild brook trout populations and humans can coexist, but concerted efforts must be made to limit impacts to the brook trout habitat. Land and water use guidance should be given for streams of all sizes within a watershed. Presumably, minor human impacts to smaller streams can be additive throughout the watershed and create problems that are not readily apparent until further downstream. Land use practices have to occur in ways that minimize their impacts on brook trout and their habitats. The cost to restore a population of any species is always higher than the cost to protect them. Restoration actions require a great deal of effort and may not always guarantee self-sustaining populations would return.

Headwater Stream Protection

The level of protection for headwater streams varies by town and is usually accomplished through zoning ordinances. Local zoning ordinances should be reviewed to determine whether they provide sufficient protection. Best management practices for agriculture and silviculture should also be promoted among landowners who abut headwater streams. Local environmental stewards need to be attentive and vocal when projects are proposed within the watershed that could impact aquatic systems. The Comprehensive Shoreline Protection Act (RSA 483-B) already offers some regulatory protection for the Merrymeeting, Red Hill, and Winnipesaukee rivers (as well as several lakes and ponds) within the drainage. At a minimum, 100 feet (30 meters) of naturally vegetated buffers along all streams should be maintained. Preferably, vegetated buffers should be 300 feet (~100 meters). As buffer widths increase, more terrestrial species will use the wooded area as a travel corridor.

Additionally, riparian vegetation slows sediment and pollutant laden stormwater before it enters an aquatic system. Stormwater drainage designs that discharge directly into the stream should be avoided in favor of systems that filter stormwater into the ground (i.e.

rain gardens, properly designed catch basins). Maintaining larger riparian areas also allow the ability for trees to fall into streams. The presence of large woody debris creates pools, cover, stream bank stability and complex habitat for fish species. When wood cover is allowed to persist in streams it may also slow and retain nutrient particulates. Taking steps to protect headwater streams will prevent irreversible losses to New Hampshire's biodiversity, as well as save countless dollars by protecting water quality and preventing flood damage. Therefore, communicating these protective measures to local policy makers is imperative.

Restoration

Efforts should also be implemented to restore riparian buffers and stabilize banks. These restoration efforts will protect both aquatic habitat and water quality. Since the demand for more development and land alteration and their subsequent strains put on aquatic systems is expected to continue throughout the lakes region, the need to provide systems that slow, stabilize, and infiltrate flows will always be needed. There are several different options and resources available to help guide the reestablishment of riparian areas and bank stabilization. As fisheries resource managers, we believe prioritization should be given to those streams where wild brook trout and/or species found on the state's threatened and endangered list exist (i.e. Coffin Brook in Alton).

Stream Crossing Inventories

Stream crossings should be evaluated within the Winnipesaukee River drainage to determine if they are degrading habitat and/or obstructing fish passage. Stream crossing inventories used in conjunction with fish survey data can be used to determine the level of degradation of aquatic habitat as well as provide restoration focus areas. This should be communicated to local road agents and the New Hampshire Department of Transportation so that stream crossing upgrade projects can be developed, prioritized, and implemented.

Public Outreach and Education

Educational programs should be developed that inform both children and adults about the importance of the link between wild brook trout presence and good water quality. Educators should emphasize the realization that environmental impacts caused by one person or one family in the Winnipesaukee River drainage could have a lasting effect on them and their neighbors downstream. The key is to stress the needs of the wild brook trout, a focal species that is the essence of New Hampshire's rich heritage.

For More Information

Interested individuals and groups are encouraged to request site specific information by contacting the Inland Fisheries Division at New Hampshire Fish and Game (phone (603) 271-2501 or email benjamin.nugent@wildlife.nh.gov).

Useful Information:

- New Hampshire Stream Crossing Guidelines: http://www.unh.edu/erg/stream_restoration/nh_stream_crossing_guidelines_unh_web_rev_2.pdf

- Importance of Shoreline Protection and Buffers, The NH Department of Environmental Services: http://des.nh.gov/organization/divisions/water/wmb/repp/documents/ilupt_chpt_2.6.pdf

- Buffers for Wetlands and Surface Waters, A Guidebook for NH Municipalities: http://www.nh.gov/oep/resourcelibrary/referencelibrary/b/buffers/documents/handbook.pdf

- New Hampshire Strategies for the Conservation of Wild Brook Trout Habitat: http://www.easternbrooktrout.org/docs/EBTJV_NewHampshire_CS.pdf

Photos from Surveys

An example of a wild brook trout captured in a stream flowing through Belmont.

An example of a perched stream crossing in Gilmanton where various fish species may have difficulty accessing essential habitats throughout the year.

A stream crossing that facilitates fish passage in Belmont (note the natural stream substrate within the stream channel under the crossing). The established riparian buffer seen here also promotes good water quality while providing shade to keep stream temperature cool.

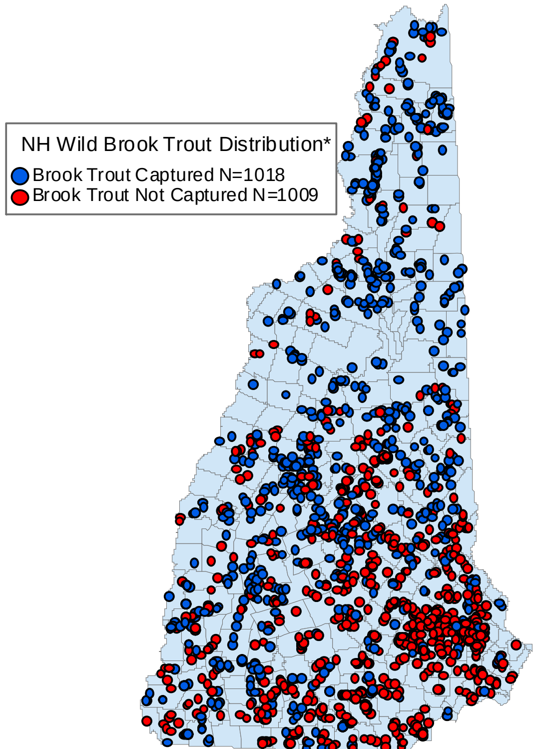
Trees allowed to fall and remain in stream systems provide ideal habitat features (food sources and protective cover) for wild brook trout. These features can also help dissipate erosive forces.

The state threatened bridle shiner captured at Coffin Brook, Alton.

The New Hampshire Fish and Game Department conducting a stream backpack electrofishing survey.

The removal of vegetation along a stream corridor (seen here in Gilford) can increase stream temperatures and allow sediment from runoff to enter streams. Excessive sedimentation can fill important spawning gravel and essential pool habitats.

The loss of riparian buffers along stream corridors allows pollutants associated with parking lots a pathway to enter streams and lakes. Pulses of very warm water, particularly from storm events after a warm day can shock wild brook trout and other fish species. Impermeable surfaces can increase erosion and sedimentation rates as well as decrease ground water recharge rates.



*Data from NH Fish and Game, NH Department of Environmental Services and the US Forest Service (1983-2010)