1/21/2011 DRAFT: Brook Trout Habitat Enhancement Project
Final Report

Michael Cline, Richard Fortin, and Chris Bottom
Tin Mountain Conservation Center
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INTRODUCTION

Eastern brook trout, (*Salvelinus fontinalis*), belongs to the order *Salmoniformes*. Although commonly called a trout, it is a char and more closely related to lake trout, bull trout, and arctic char. Brook trout have a long streamlined body with dorsal coloration varying from olive to blue-grey or even black-speckled with red and yellow spots and a silver-white underside (Behnke 2002). The native range of brook trout covers much of eastern North America from Canada to higher elevations in the Appalachian Mountains (Figure 1) (Page and Burr 1991). Since the late 1800s, brook trout have been introduced to lakes, ponds, rivers, and streams throughout North America largely for sport fishing. Today, they exist in 41 states in the US and all provinces of Canada as a result of stocking (Behnke 2002).

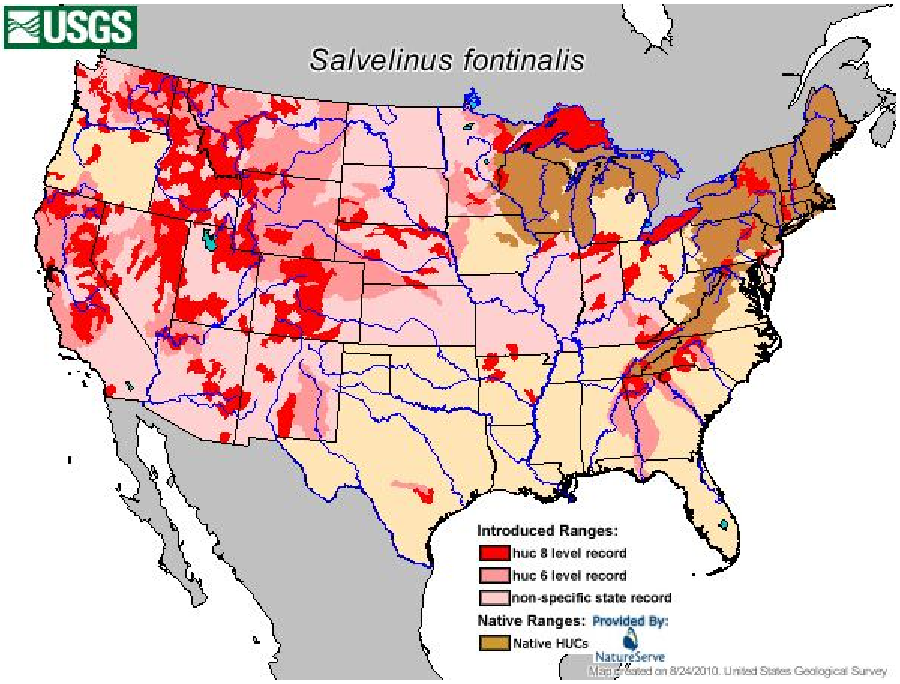


Figure 1. Range of eastern brook trout (native and introduced) across the U.S. (USGS Survey Data).

Most brook trout reach sexual maturity by two years, but some males may become mature as early as one year. As spawning season approaches, brook trout coloration intensifies, which is noted especially in males whose undersides become orange-red with a black stripe along each side. Many spawning brook trout move to small tributary streams and lake shorelines to spawn. From mid-September through mid-November, females dig nests, known as redds, where eggs are deposited during the daytime hours and covered with gravel. Opportunistic male fish move quickly to redds to fertilize the deposited eggs. Eggs will incubate for 30-165 days, depending on water temperatures, and typically hatch in February through April.

Because brook trout require cold, clean, highly-oxygenated water, they are good indicators of the health of aquatic ecosystems in the northeast. Brook trout are a coldwater species preferring temperatures between 11-16° C, but they are capable of surviving in a wide range of temperatures from 0-20° C. Brook trout are less tolerant of warmer water temperatures than brown or rainbow trout and unable to survive in waters with temperatures above 25° C. Research indicates that brook trout may migrate many miles to spawn or find thermal refuge.

Brook trout are the most acid tolerant of trout species with adult fish tolerating pH levels as low as 4.0. Their preferred pH range 6.5-8.0, with a tolerance range of 4.0-9.5 (Raleigh 1982). Pool density and depth (≥1m) are the major habitat features (particularly during low flow periods) and primary factors influencing trout abundance (USFS 1994). Key to creating brook trout habitat is the amount of large woody debris (LWD) present in streams that allows for damming of waters and scouring pools.

In the early 19th century, much of New England's forests were clearcut causing dramatic changes in water quality and degradation of brook trout habitat resulting in extirpation from many streams in the northeast. Although much of the area has been reforested, LWD levels have been reduced substantially throughout the region and are much reduced from pre-settlement levels. Good trout habitat requires downed trees and LWD in streams that alter flows gouging deep pools and providing thermal protection, hiding/resting areas, and distributing gravel for spawning sites (Figure 2).

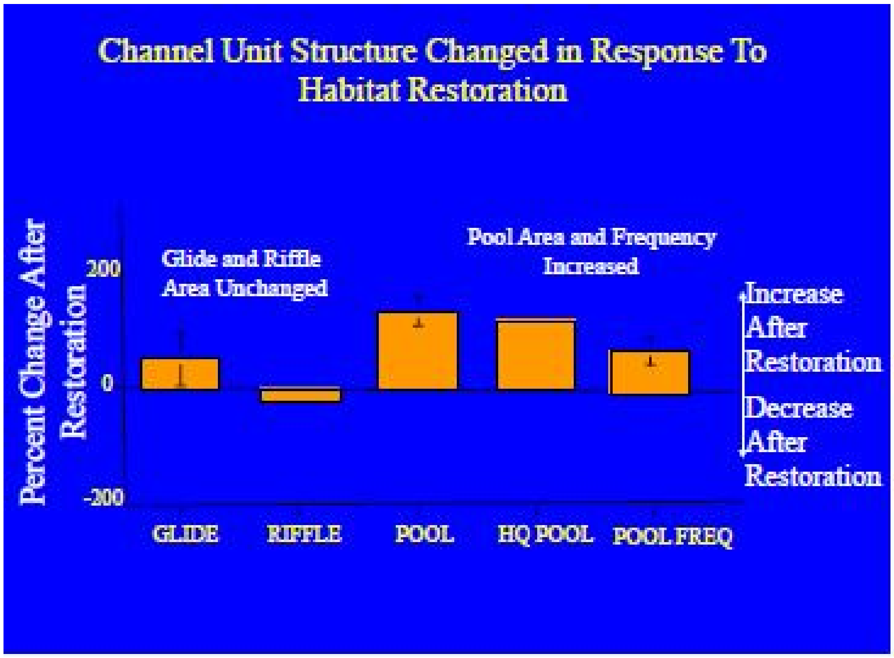


Figure 2. Stream habitat changes in response to LWD additions (Nislow 2001).

The accumulation of leaves, twigs, and other organic matter trapped by LWD allows the stream to hold more nutrients creating habitat for macro-invertebrates important to brook trout as food and the riparian habitat as a whole (Figure 3-5).

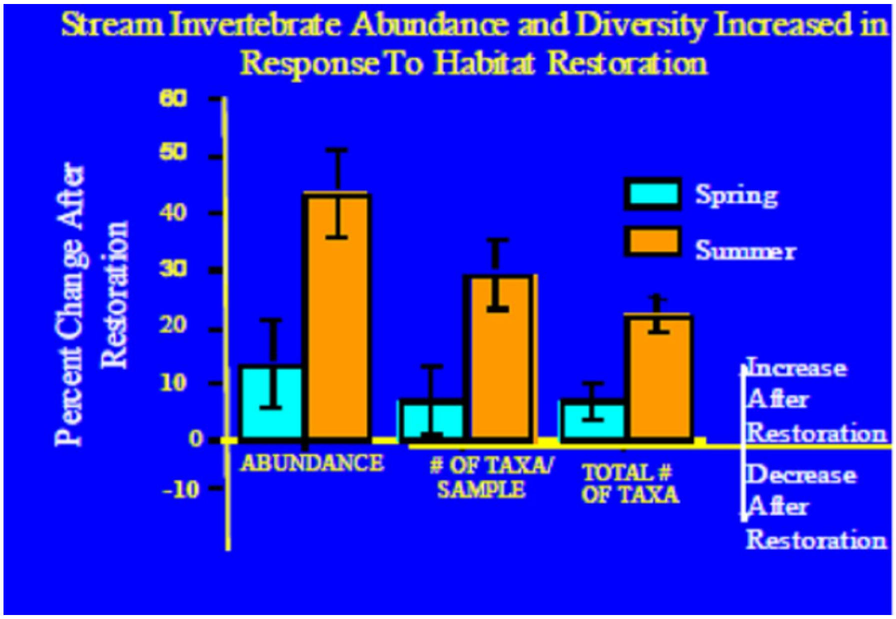


Figure 3. Invertebrate abundance and diversity in response to LWD additions (Nislow 2001).

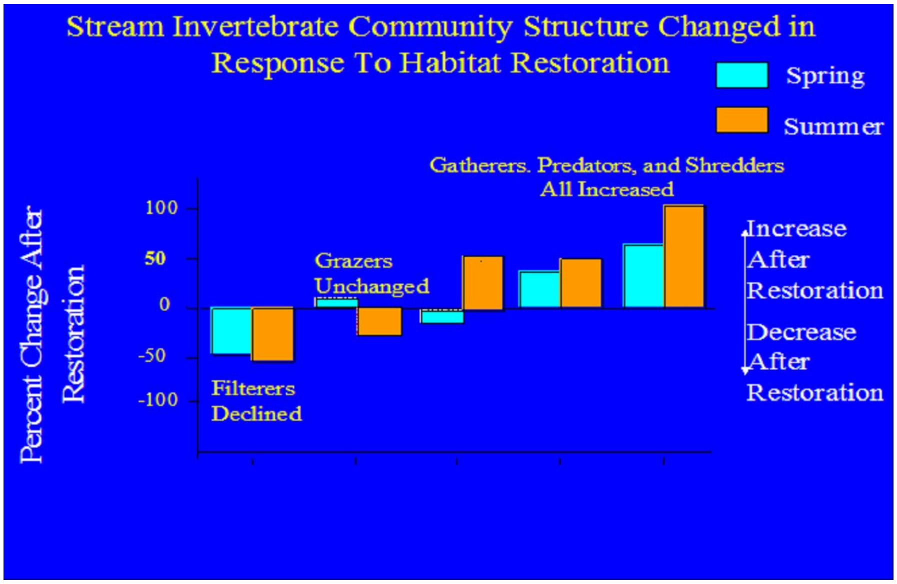


Figure 4. Changes in invertebrate community structure in response to LWD additions (Nislow 2001).

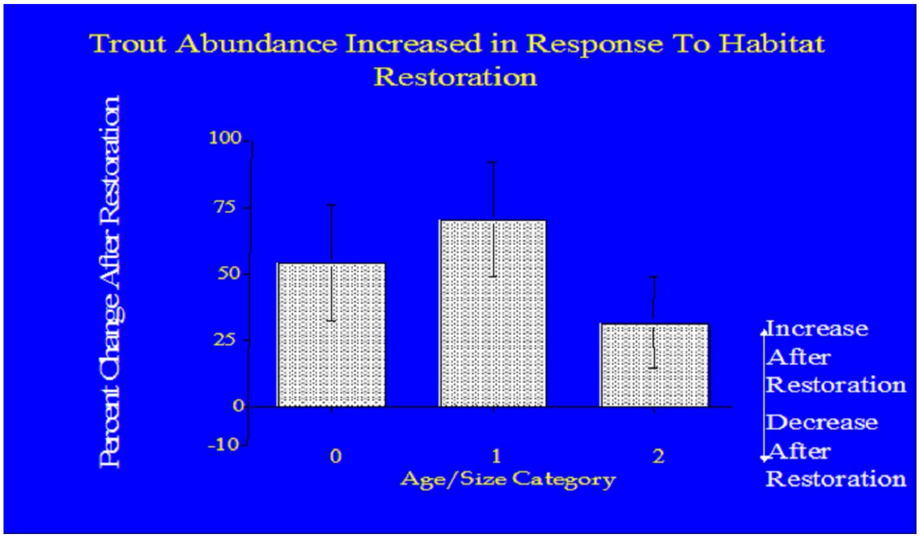


Figure 5. Brook trout abundance in response to LWD additions (Nislow 2001).

In the summer of 2010, Tin Mountain Conservation Center selected seven streams to study the effects of LWD additions on brook trout habitat. Prior to the wood additions, baseline stream measurements were obtained to allow for comparisons to any observed changes over time in stream attributes associated with LWD additions. The seven streams ranged from Wonalancet/Tamworth, NH to Chatham, NH, and represented a range of stream characteristics including width, depth, water quality, and initial trout abundance.

MATERIALS AND METHODS

Study Area Location

On each of the seven streams examined in the project, 1,000 feet of stream was selected for study. Beginning on the downstream end of the 1,000-foot section, the area was defined using a hip-chain to measure distance and global position system (GPS) to track the path for later plotting on a geographic information system (GIS). At each site, the 1,000-foot stream section was divided into 100’ sections designated with labeled grade stakes and flagging.

Initial Pool/Riffle Inventory

Each 1,000-foot study area was inventoried to determine the number and size of pools and riffles (shallow water, larger substrate, turbulent water flow) present. Pools and riffles locations were recorded, photographed, and a GPS waypoint established for each study area. In addition, notes and general observations about unique sections of the stream, e.g., a long, straight section where wood is absent, an unusually deep pool, or any major feature, also were recorded.

Stream Gradient Determination

Stream gradients for each 1,000-foot study area were determined using a transit and stadia rod over the entire 1000-foot study area. The gradient was obtained by subtracting the back shots from the forward shots and summing the differences; divide by 1,000 for percent gradient

Habitat Features Measurements

Stream habitat features were measured within each 100-foot section in each 1,000-foot study area. Each 100-foot section was previewed to determine an appropriate representation of depth, width, and length for an average pool/riffle in the 100-foot stretch. Measurements recorded were the length, wetted width, bankfull width, typical depth and maximum depth to the nearest 0.1 foot for both the representative pool and riffle. Percent stream cover to the nearest ten percent also was recorded as well as dominant and subdominant cover, stream substrate, bank erosion, and riparian vegetation using the habitat abbreviations sheet (Figure 6). The distance from the pool/riffle interface to the nearest 100' marking stake was recorded to ensure relocation for future monitoring. The process was repeated for each 100-foot section.

Wood Survey

The wood survey was conducted within each of the measured pool/riffle habitat features above. The wood survey involved measuring each piece of large wood debris (LWD) >1 inch diameter and recording the location of the wood as either pool or riffle and whether it is a single log or part of a jam. Diameter, length, orientation, stability, wood type, and decay class was recorded for each piece of LWD using the habitat abbreviations sheet (Figure 6). Additionally, the following questions were answered: 1) Does the log form a pool? 2) Indicate upstream (US) or downstream (DS) or both (US/DS). 3) Does the log store sediment, provide cover or have a function? Is it a key piece? 4) Estimate the percent of the log within bankfull width on a 10% scale.

Figure 6. Habitat abbreviations sheet.

STREAM PHYSICAL DESCRIPTION

Habitat Type
P = Pool
R = Riffle
G = Glide
C = Cascade

Substrate
SA = silt/sand
G1 = gravel (0.25-3.0 in)
G2 = gravel (3.1-6.0 in)
CO = cobble (6.1-12.0 in)
Bo = boulder (>12 in)
BR = bedrock (large solid mass)
OR = wood (wood/herbaceous)

Total Cover Type
A = aquatic plants
S = substrate
D = depth (>2.5 ft)
H = overhanging veg. (<10 " above)
T = turbulence
U = undercut bank
W = woody material

LARGE WOODY DEBRIS (LWD) DESCRIPTION

Wood Type
C = conifer
D = deciduous
U = unknown

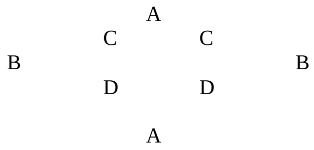
Size Class
Diameter in inches

Stability
R= roots attached
B = >50% buried at any point
P = pinned between structures
U = unstable

Decay Class	Bark	Twigs	Surface	Shape	Wood Color
1	intact	present	intact/firm	round	original
2	intact	absent	intact/firm	round	original
3	trace	absent	smooth to	round	original to dark

			some surface abrasion		
4	absent	absent	abrasion to some holes	round/oval	dark
5	absent	absent	many holes and openings	round/oval	dark

LWD Orientation



RIPARIAN VEGETATION

NH = northern hardwoods
PB = paper birch
QA = aspen
SF = spruce/fir
OP = oak/pine
EH = eastern hemlock
WT = wetland alder
OF = old field
AG = agricultural field, orchard, other
RL = rock ledge

Riparian Vegetation Survey

Variable radius forest inventory plots were established at the center of each pool/riffle interface using a basal area factor 10 prism to characterize riparian forest vegetation. All tally trees were measured for species, diameter at breast height (DBH), and height of tree.

Cross Section Characterization

Physical characterization of study area streams was determined by measuring cross-sections of three riffles located within the 1000-foot section (Figure 7). A horizontal measuring line was strung between two permanent endpoint marker stakes designated as left pin (LP) and right pin (RP). The left pin is located on the left bank when facing downstream. Stakes were placed above the bankfull level to avoid washing away during high flow periods. After recording bankfull width, the measuring tape was placed alongside of the string to record distances at which depth measurements were taken. The height of the string at the left pin always was recorded first to ensure accurate future measurements. Depth measurements were taken at distances representing 10 percent of the bankfull width and at locations of significant slope changes, e.g., top and bottom on bank slope, and water edge. Depth measurements (distance from string to streambed) and the distance of each measurement from LP were recorded.

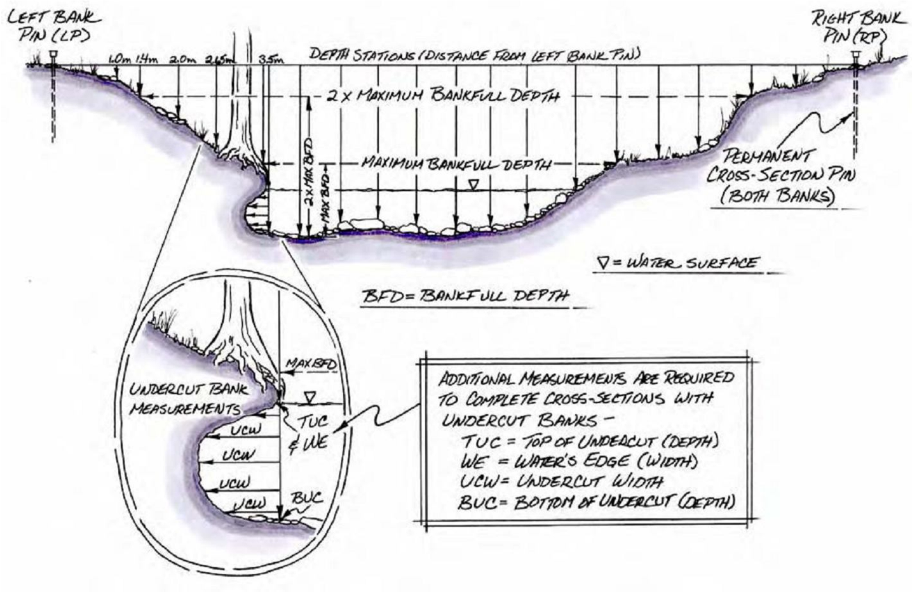


Figure 7. Cross-section detailing measurements taken to characterize streams.

To ensure future relocation on cross-section endpoints, the distance from the LP to the nearest 100-foot marking stake was measured. Photographs and drawings also were used to aid in future relocation. For further documentation, the distance from the LP to 2-3 prominent trees was measured, photographed, and sketched. Species and diameter of these witness trees were noted.

Riparian Herbaceous Vegetation

Riparian vegetation was inventoried by walking the 1000-foot study area and identifying all herbaceous and ground cover vegetation noting the general location of each species, e.g., in the 800- to 900-foot sections of the study area.

Water Quality

Water quality measurements were taken using a YSI multimeter water tester in a total of three riffles in the following order: 1) <50 feet downstream of the zero mark, 2) at the riffle closest to the 500-foot stake, and 3) <50' above the 1000-foot stake. Measurements were taken on all streams within a 24-hour period. Water quality measurements were taken monthly during July through October and included temperature, pH, conductivity, dissolved oxygen, and flow rate.

Macro-Invertebrates

At each study area stream, two sample sites were established; one above and one below the area to be treated. Sampling was confined to riffle habitats since this habitat type hosts the greatest diversity of macro-invertebrates. A Surbersampler (1 ft^2 sampling frame attached to a 0.5 mm mesh net) was used to take four replicate samples at each sample site. An attempt was made to sample riffle substrate including the following sets of conditions: fast, shallow water; slower shallow water, fast deeper water, slow deeper water.

In each Surber sample, all substrate materials falling within the 1 ft^2 frame were manipulated by hand to knock off any attached fauna and debris. Dislodged materials (including macro-invertebrates) were swept by downstream-flowing currents into the mesh bag. When all larger

substrate elements were so handled, a screwdriver driven to the hilt was used to stir up the underlying substrate for a period of one minute to free any burrowing individuals.
The accumulated organisms and debris from the four replicates were pooled and transferred to a tight-sealing plastic container preserved in 70 percent ethanol. This represented the “sample” from one site.

Later in the laboratory, the preserved material was separated into equal piles (often 8-12 piles) for each sample. A random numbers table was used to select first debris piles, and each was transferred to a tray with 30 numbered squares marked on its bottom. Tap water was added and the sampled material spread evenly across the tray. The tray was placed on a light table, and using a random numbers table, a successive sequence of squares was selected in which the macro-invertebrates within each square were counted and rough-sorted by category into appropriate spots within a 24-cell culture plate. Sorted specimens were stored in 70 percent ethanol. This process was repeated until a subsample of at least 200 individuals was isolated and stored. The culture plate was sealed with tape to avoid evaporative loss.

For each sampling location, dissecting/compound microscopes and identification guides were used to identify the 200+ sample usually to the genus level. The 200+ macro-invertebrates so determined represented the community at a particular study area site. Appropriate metrics (e.g., benthic index of biological integrity (B-IBI), Beck Index) were used to characterize and compare the relative “quality” of the resulting communities.

Wood Additions

There were several approaches to making wood (LWD) additions; however, all additions were placed in the stream in a manner that maximized their stability in the streambed. Using hand tools (Peavey, hand winch, chainsaw), 12- to14-inch diameter logs were the largest manageable additions depending on the species. Therefore, it was necessary to use multiple logs to construct a satisfactory wood addition structure. Some trees were felled directly into the stream and left intact (Figure 8). In some cases, stumps from felled trees were left high (2 feet’) intentionally to act as ‘catches.’

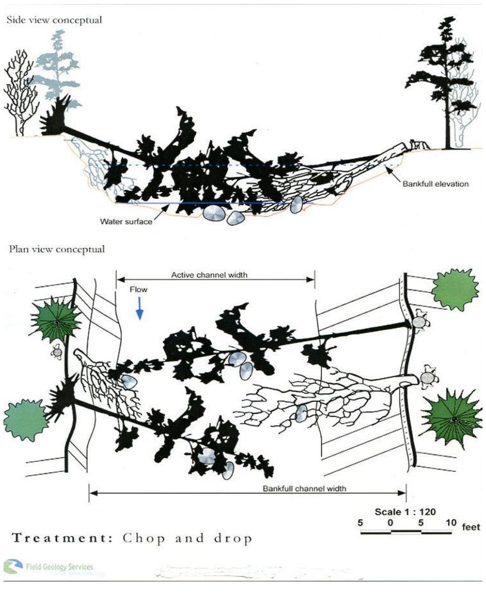


Figure 8. Various orientations for LWD additions to streams.

for future LWD movement, and the butt of felled trees were placed on the upstream side of stumps for further stability. Alternatively, logs were bucked to lengths that fit directly within the wetted width and pinned between natural features such as rocks or trees. With both approaches, chunkwood (2-3 feet length) were added on the upstream side of additions to augment structures. Shorter LWD do not necessarily need to be pinned. Wood additions included a diversity of types, whole vs. bucked trees, sizes, and orientations.

RESULTS AND DISCUSSION

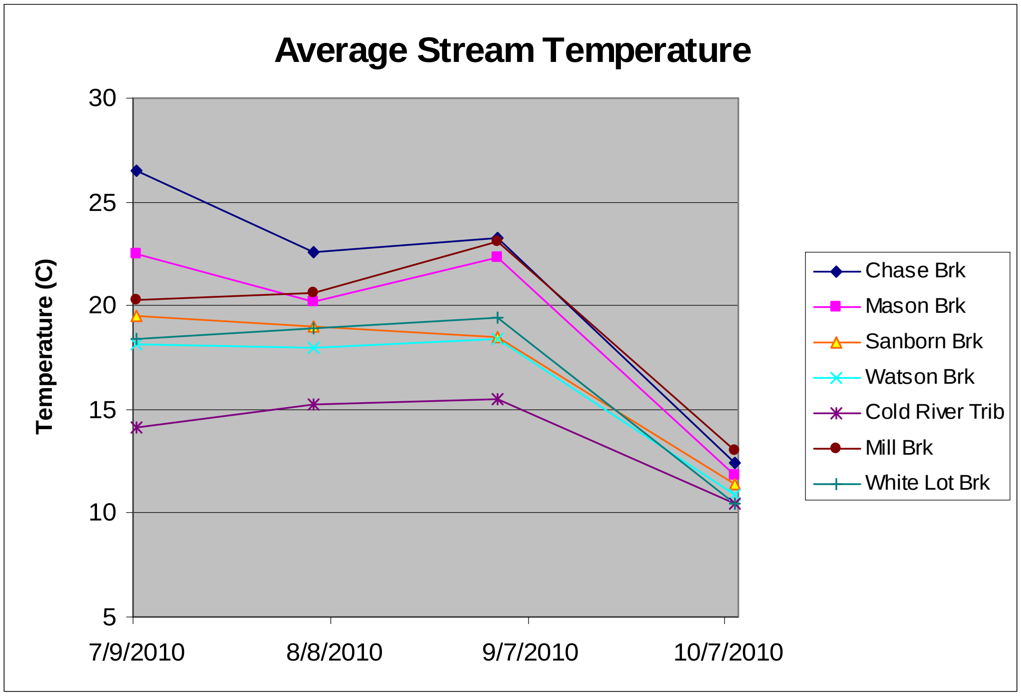
Information on the study area streams is presented in five major categories; 1) water quality attributes, 2) physical characteristics, 3) existing in-stream woody material, 4) fish populations of each stream, and 5) wood addition treatments made to each stream. This baseline information is critical to determining whether wood addition treatments significantly affect brook trout populations in these headwater streams, and if so, are there other stream characteristics that influence the success of treatments.

One very practical outcome of this multi-year study is to determine the time and cost required for treating streams with wood additions as well as to develop insight into whether physical attributes of streams can influence the success of treatments. This information can be helpful to the Natural Resources Conservation Service (NRCS) as they gather information for potentially developing a landowner assistance program for restoring and enhancing brook trout habitat.

Stream Temperature

The average temperature for each of the seven study streams was calculated from the three measurements taken each month at each study location during July through October (Figure 9). Results indicate that each stream has a unique summer temperature profile; however, the seven streams can be divided into three common temperature profile patterns. First, the Cold River tributary is pronouncedly colder than all other streams and remains so throughout the summer until October when temperatures of all streams begin to clusters between 10 and 14°F. The temperature of the Cold River tributary varied only 5°F from July 9 to October 8.

Figure 9. Average monthly summer temperatures for seven NH streams.



The second temperature profile pattern was displayed by White Lot Brook, Sanborn Brook, and Watson Brook revealing consistent stream temperatures between 18 and 20°F through the September sampling period after which temperatures of all three streams declined to about 10-11°F in October. Very small differences in monthly temperature readings were observed between the three streams at each sampling time, and all three were located in forested conditions that have not experienced much disturbance in the past 25 years. They may well be good representatives of typical small headwater streams in undisturbed forested areas of Carroll County, NH.

The last stream profile grouping includes Chase Brook, Mason Brook, and Mill Brook that show higher relative summer stream temperatures, but also exhibit a high degree of variation of stream temperature at each sampling date. Chase Brook and Mason Brook flow out of impounded areas that are open to sunlight, and Mill Brook flows through a relatively open area that was cut heavily within the past 10 years and an area recently colonized by beavers that have constructed a small dam that incorporated 300 feet of the study area. The higher temperatures in all three of these streams might be explained by the greater incident sunlight. Progressive temperature recordings downstream showed that stream temperature dropped with distance from the impoundments to a constant temperature.

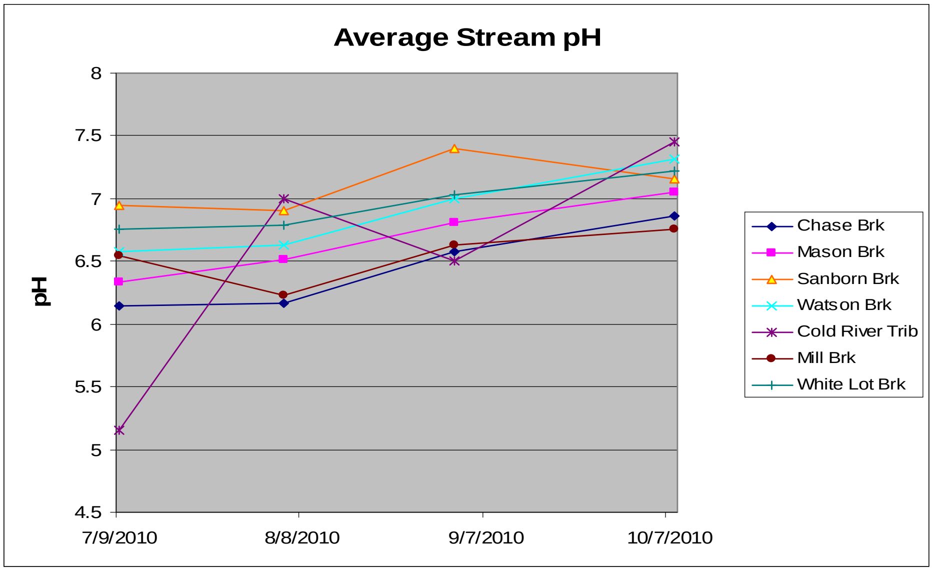
The July measurement period exhibited the greatest average temperature spread among streams for the four sampling dates. The stream temperatures at Chase Brook and Mason Brook were substantially higher than the other five streams, and the Cold River tributary was colder than all streams. The higher temperatures at Chase Brook and Mason Brook may be attributed to shallow impounded water directly upstream of the study area. Chase Pond is dammed by a split granite structure that has been enhanced by beaver activity to form a five-acre pond area that serves as the water source for Chase Brook. The study area is situated about 200 feet below the outflow of the dam. Temperature readings on July 9 at Chase Pond are consistent with water temperatures recorded at the Chase Brook study area. The temperature of the approximately two-acre impoundment directly above Mason Brook was nearly the same temperature as the study area in the brook itself. Measurements of the temperature on the Mason Brook pond in August and September showed consistency with Mason Brook temperatures during the same sampling times.

The Cold River tributary is relatively short stream that is less than 2,000 feet in length and essentially spring fed. Consequently, its lower summer temperatures are in keeping with the ground source of the majority of its water. The amount of variation among stream temperatures for the seven study areas decreased dramatically by the October 8 sampling date.

Stream pH

The average stream pH for each of the seven study locations was determined from measurements taken each month at each study location during July through October (Figure 10). Nearly all recorded pH values for all study streams were between pH 6 and slightly over 7 during the summer months and increased progressively over the summer. The groupings of streams with similar temperature profiles also shared common pH profiles over the summer.

Figure 10. Average monthly summer pH for seven NH streams.



For example, White Lot Brook, Watson Brook, and Sanborn Brook as a group consistently exhibited the highest pH values through the summer of all seven streams studied. In addition, the respective order of the three streams for pH was the same as that exhibited for stream temperature, i.e., Sanborn Brook had both the highest pH and temperature and Watson Brook the lowest of the three in the group.

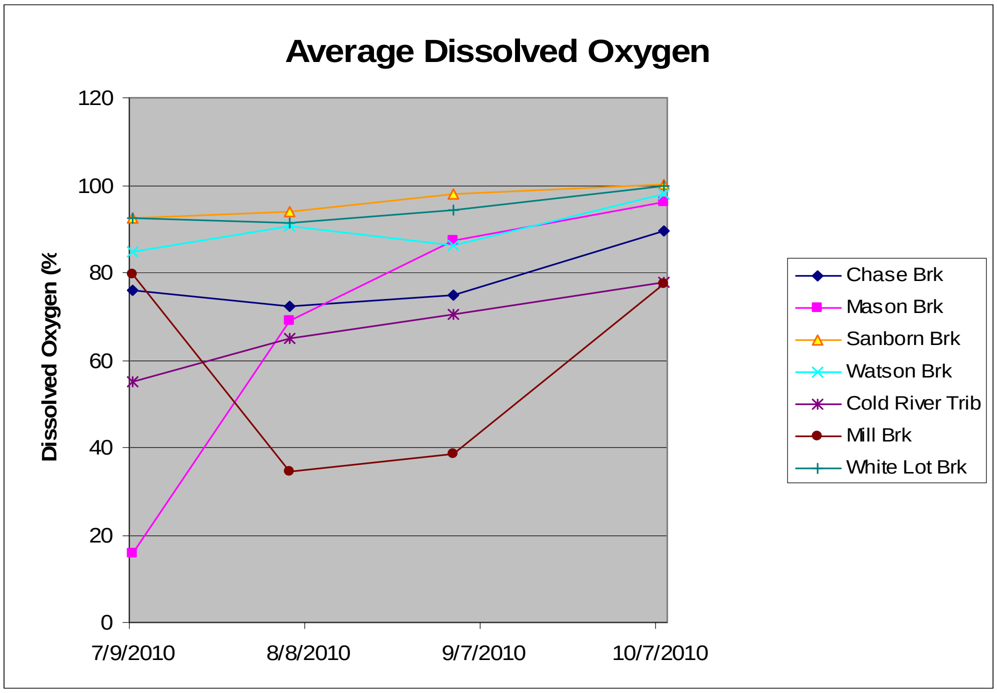
The streams with warmer summer temperatures associated with small impounded water bodies, i.e., Chase Brook, Mason Brook, and Mill Brook, also had the lowest pH values. The respective order of the values for the three streams was the same for temperature and pH. Chase Brook had the lowest pH and Mason Brook the highest of the three streams. The lower pH in these impounded streams could be associated with tannic and other organic acids that tend to accumulate in beaver flowages.

The Cold River tributary showed high relative variation in pH from one sample date to the next and registered one stream pH value approaching 5.0.

Stream Dissolved Oxygen

Values for dissolve oxygen for each of the seven study streams showed great variation with both stream and sample date (Figure 11). For all streams, there appeared to be a general upward trend in dissolved oxygen over the summer months; however, several streams showed substantial fluctuations. All dissolved oxygen values were clustered more closely together during the October sampling.

Figure 11. Average monthly summer dissolved oxygen for seven NH streams.



White Lot Brook, Watson Brook, and Sanborn Brook were grouped closely in terms of pH and stream temperature, and they also showed similar levels of dissolved oxygen at each sample date over the summer. The relative order of ranking of these three streams for dissolved oxygen was similar to the previous groupings as well with Sanborn Brook having the highest levels and Watson the lowest of the three. These three streams maintained the highest dissolved oxygen levels of the seven streams examined over the entire summer study period.

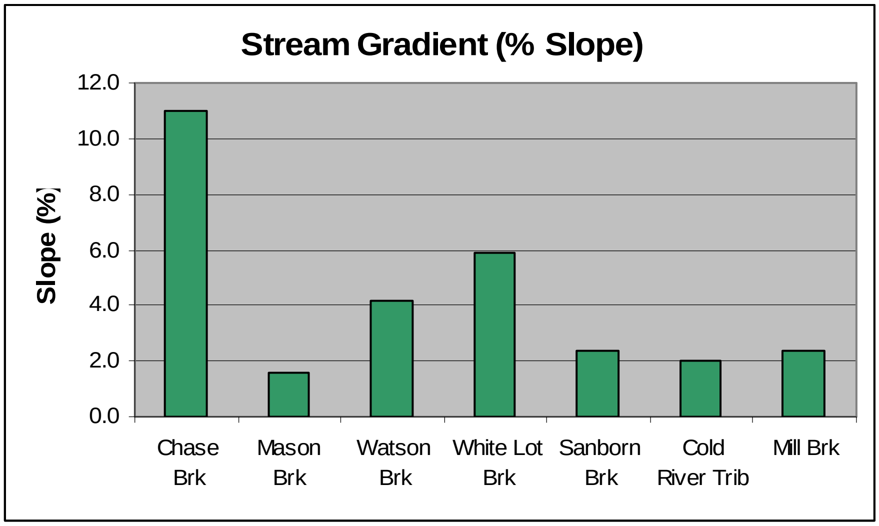
The streams with impoundments, i.e., Chase Brook, Mason Brook, and Mill Brook, maintained some of the lowest dissolve oxygen concentrations among the seven streams studied, and Mason and Mill Brooks showed large fluctuations over the summer. The lower relative dissolved oxygen levels in these streams were influenced largely by the adjacent impounded water upstream. Dissolved oxygen levels were very low near the beaver dams at each measurement time period; however, oxygen levels rebounded somewhat with distance from the dams.

The Cold River tributary exhibited relatively low dissolved oxygen levels that increased slightly over the summer despite having substantially lower water temperatures throughout the summer. There were two factors that perhaps help explain the lower dissolved oxygen in the stream. First, the stream is spring fed from ground water that would have inherently lower dissolved oxygen. Second, the tributary is less than 2,000 feet in length with very little gradient to provide mechanical oxygenation of the water.

Stream Gradient

The study streams represented a range of gradients from the strongly sloping Chase Brook with 11.0 percent slope to Mason Brook with 1.6 percent slope (Figure 12). Gradient affects several important stream characteristics including water aeration, stability of in-stream coarse woody debris, pool size, and accumulation of stream bottom substrate. The relatively steep slope on Chase Brook may provide high levels of aeration that allows this brook to maintain constant relative levels of dissolved oxygen throughout the summer despite originating from a large beaver flowage.

Figure 12. Stream gradients for seven NH streams.

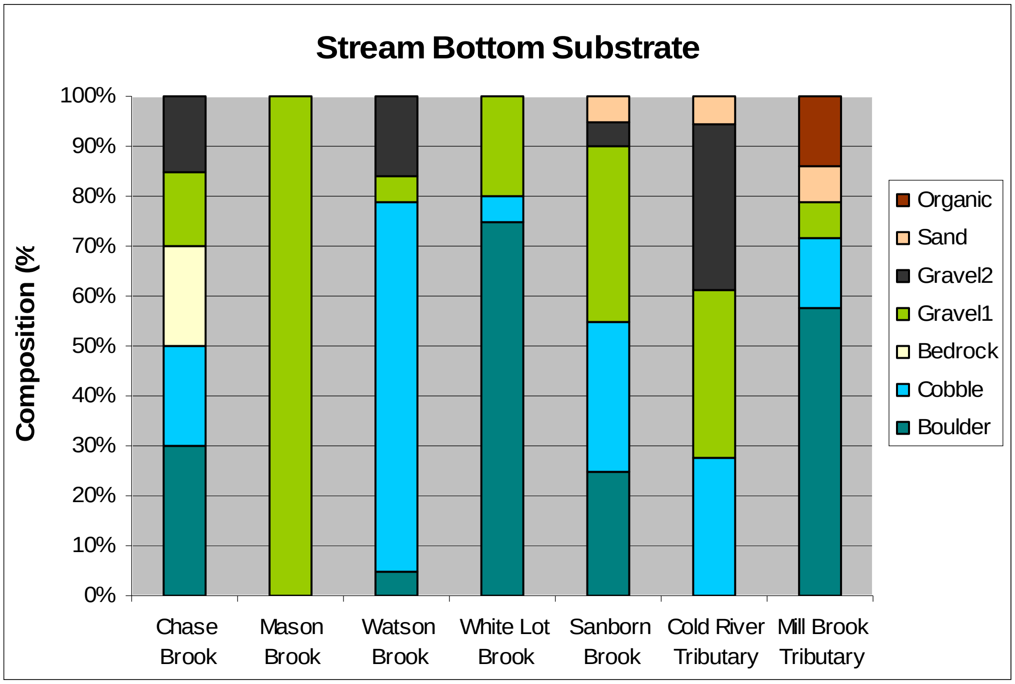


The gradient in Watson Brook and White Lot Brook also showed a somewhat steep grade; however, both were less than half the gradient on Chase Brook. The majority of streams had slopes slightly above or below two percent.

Stream Bottom Substrate

Stream bottoms of the seven study streams showed great variability in the composition of substrate (Figure 13). The only stream with exposed bedrock was steeply sloping Chase Brook, while the only stream displaying and accumulation of organic material in the substrate was Mill Brook. These two streams exhibited the most variable bottom substrates with five types present in each. Conversely, Mason Brook and White Lot Brook contained a relative uniform stream bottom substrates of G1 gravel (0.25-3.0 in) and BO boulder (>12.0 in), CO cobble (6.1-12.0 in) and G1 gravel), respectively. White Lot Brook contained a large amount of boulder-size material as did also Mill Brook. Sanborn Brook and the Cold River tributary possessed the greatest amount and widest spectrum of gravel- and smaller-size substrate that is associated with trout breeding habitat.

Figure 13. Composition of stream bottom substrate in seven NH streams.



Stream Habitat Characteristics

Table 2 displays habitat characteristics relating to stream size, pools and riffles, and associated vegetation for the seven study areas. The average wetted width of the stream was not always a good indicator of the potential bank-full width of each stream. Comparison of the two measurements on Watson Brook and White Lot Brook show that the bank-full width was more than twice the wetted width for Watson and only about one-third larger than wetted width for White Lot Brook. One can speculate that watershed characteristics such as gradient and steep slopes adjacent to Watson Brook result in a quick and high discharge during heavy rain events or spring melt. Sanborn Brook was the largest stream in the study while Chase Stream and the Cold River tributary were the smallest

Table 2. Stream habitat characteristics of a 1,000-ft section of seven NH streams in July.

Stream	***Ave Pool Depth (in)***	***Ave R/P Length (ft)***	***Total #R/P***	***Ave Wetted Width (ft)***	***Ave BKF Width (ft)***	***Ave % Canopy***
Chase Brook	0.6	16.3	28	4.9	12.1	95
Mason Brook	0.9	28.9	45	7.0	16.0	86
Watson Brook	0.6	29.7	27	6.0	17.2	84
White Lot Brook	1.1	24.3	30	10.0	14.5	96
Sanborn Brook	0.9	50.7	19	14.0	21.9	86
Cold River Tributary	0.6	21.0	27	4.2	8.7	80
Mill Brook	0.9	22.4	18	7.0	10.8	43

The total number of riffle/pool combinations along the 1,000-ft study section of each stream was dramatically greater for Mason Brook, which had 15 more combinations than the next highest number on White Lot Brook. White Lot Brook, Mason Brook, Sanborn Brook, and Mill Brook exhibited the deepest average pool depth; however, the average length of riffle/pool combinations was much higher on Sanborn Brook that all other streams. Sanborn Brook, White Lot Brook, and Mason Brook are the larger streams in the study, and they tend to have the greatest number of riffle/pool combinations, longest length, and deepest pools.

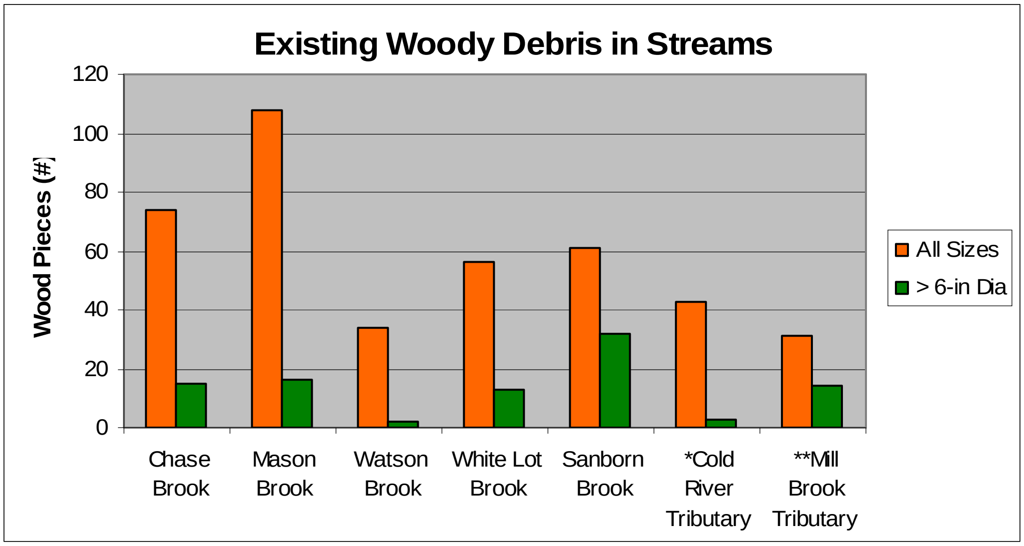
The average canopy cover over streams was generally intact and continuous and above 85 percent. The exceptions were Mill Brook and Cold River tributary that had 43 and 80 percent canopy cover, respectively. Mill Brook had experienced a heavy timber harvest within the past 10 years and the Cold River tributary was regenerating from a rather heavy timber harvest 15-20 years ago.

Existing Large Woody Debris

Inventoried existing large woody debris in each of the seven study streams indicated that Mason Brook with 108 wood pieces contained nearly twice as much woody material as five of the other six streams sampled (Figure 14). The next highest amount of wood present was in Chase Brook that had 74 pieces. Watson Brook and Mill Brook contained only 34 and 22 wood pieces in the entire 1,000-ft study area. The spread in the number of wood pieces present between Mason Brook and Mill Brook suggests that past management practices and perhaps the existing riparian overstory trees may influence the accumulation of down woody material and resulting stream habitat. In addition, the gradient of the stream in the study area and upstream also can influence wood accumulation. A steep gradient may increase spring flows that push woody material to locations further downstream.

A function of the size and stability of actively growing trees in the riparian area associated with these streams, the number of existing larger wood pieces >6 inches in diameter should be greater in streams with older intact riparian areas. Although Mason stream had by far the greatest number of wood pieces present, only one-sixth of the pieces were >6 inches in diameter. In contrast, Sanborn Brook had 61 total wood pieces and over half of the pieces were >6 inches diameter. Cold River tributary and Watson Brook had relatively low levels of woody debris present and only two and three pieces > 6 inches diameter, respectively. While the Cold River tributary area had been heavily harvested 10-15 years ago, Watson Brook has remained unharvested for 20-30 years.

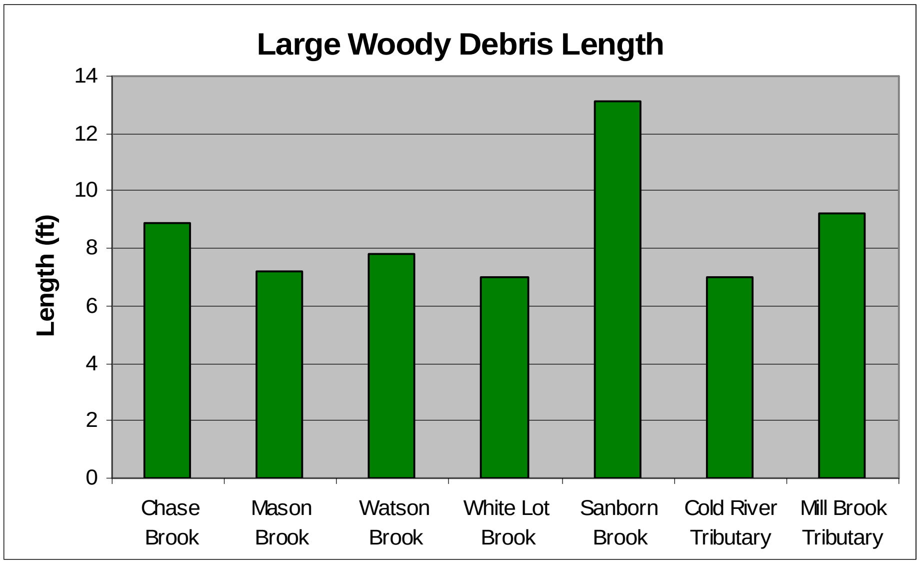
Figure 14. Number of pieces of existing large woody debris present in 1,000-ft sections of seven NH streams and the number of pieces > 6 inches diameter.



* Cold River study area was 900 ft in length; values adjusted to 1,000-ft equivalent treated area.
** Mill Brook study area was 700 ft in length; values adjusted to 1,000-ft equivalent treated area.

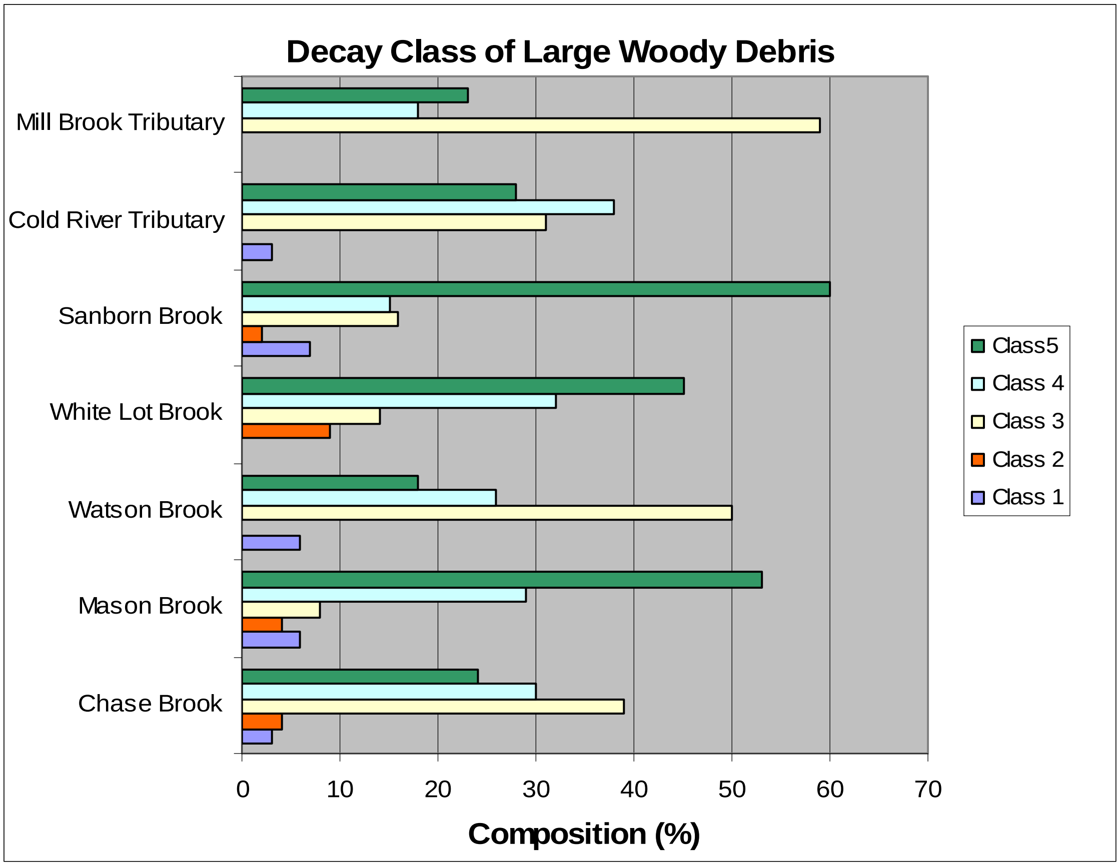
Most of the existing woody material found in the study streams averaged 6-9 feet in length (Figure 15). The exception was Sanborn Brook for which average length of woody debris was 13 feet. Sanborn Brook also was the only stream studied in which more than half of the existing wood pieces had diameters >6 inches. Results suggest that diameter and length of natural wood additions may be linked.

Figure 15. Length of existing large woody debris present in 1,000-ft sections of seven NH streams.



Substantially decayed wood (i.e., higher level decay classes) are more prevalent in streams than more recent more intact woody debris (Figure 16). This is particularly true for Sanborn Brook, Mason Brook, and White Lot Brook where class five woody materials dominate. Less decomposed woody material was associated with streams that have experienced recent timber harvesting as well as those that had low values for numbers of wood pieces present, e.g., Mill Brook and Watson Brook.

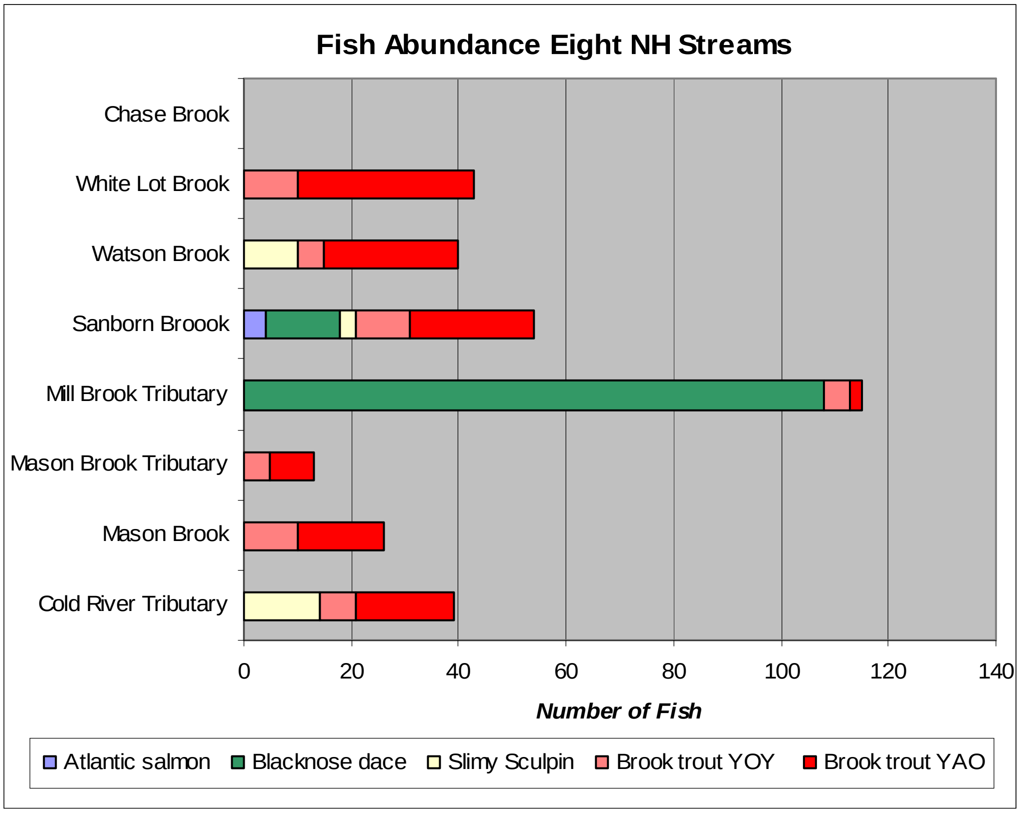
Figure 16. Decay classes of existing large woody debris present in 1,000-ft sections of seven NH streams.



Fish Populations

Fish populations in eight streams (includes one tributary of a study stream) that were assessed via electrofishing are displayed in Figure 17. Watson Brook and the Cold River tributary were the two streams located in the Town of Chatham and drain into the Cold River watershed. Both of these streams were similar in their fish abundance and species composition. Sanborn Brook and Mill Brook in the Tamworth/Wonalancet area were the only streams that yielded blacknose dace. Mill Brook was also the only stream with more first-year brook trout than one year and older fish. Mason Brook and White Lot Brook in East Conway contained only brook trout; and most were one year or older. Sanborn Brook had higher species richness than any other stream studied, and of particular interest was the presence of Atlantic salmon. It is speculated that the ultimate origin of these fist-year fish is a connection via Wonalancet River to Ossipee Lake. Sanborn Brook also contained a relatively high number of brook trout and a presence of slimy sculpin and blacknose dace. The lack of fish detected in Chase Brook may have been a result of isolation due to the stream location between two beaver flowages and the influence of the large beaver impoundment serving as the origin of the stream. Mill Brook and Mason Brook also were associated with impoundments near their origins and they both had among the lowest brook trout populations of streams sampled. Lower pHs, higher temperatures, and lower dissolved oxygen in these streams may have influenced brook trout populations. White Lot Brook, Watson Brook, and Sanborn Brook were characteristic of the least disturbed streams and supported the highest number of brook trout.

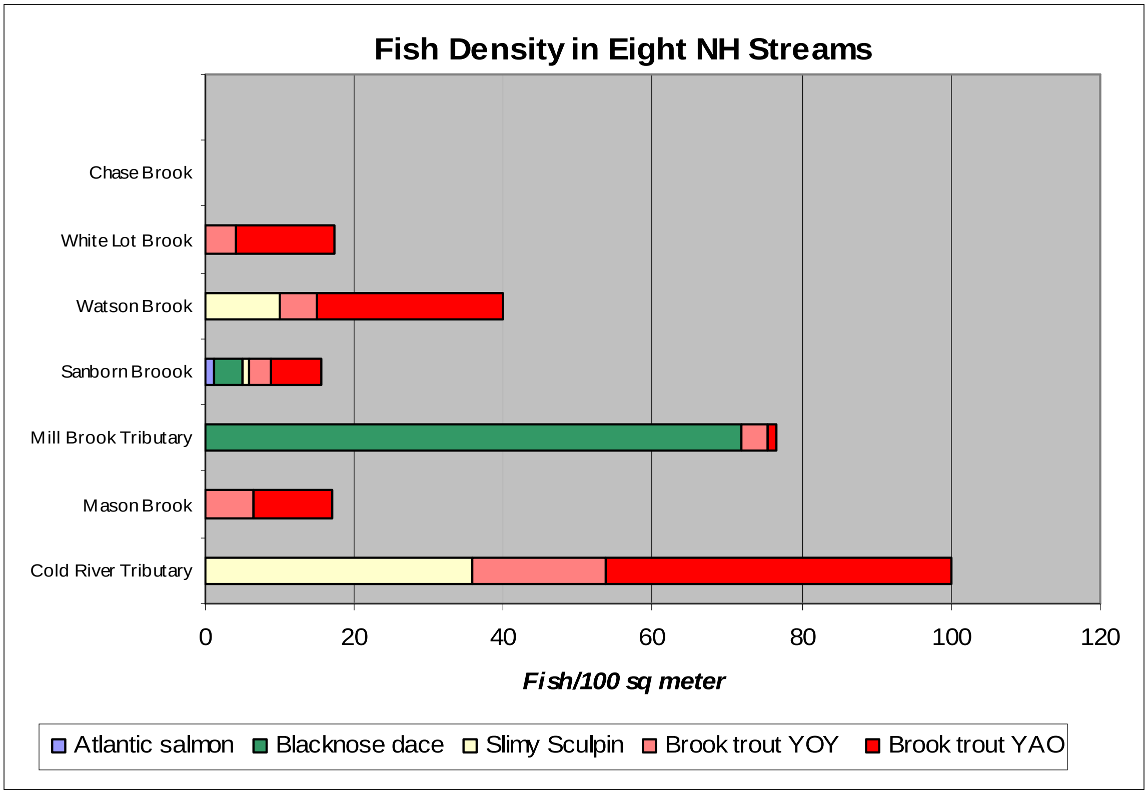
Figure 17. Fish abundance in 1,000-ft sections of eight NH streams (YOY = young of year, YAO = one year and older).



Fish density is a function of the number of fish present and the wetted surface area of the stream examined, and it is expressed most often as number of fish per 100 m^2 of stream. The Cold River tributary stands out as having the highest overall density of fish, and highest density of yearling and older brook trout (Figure 18). The mean length of young of year brook trout caught there was the highest of the five streams; however, it is not possible to accurately compare this mean length to that in the other streams because it was surveyed 28 days after the surveys at Sanborn Brook and the Mill Brook tributary, which is ample time for much growth to occur (Figure 19). In addition, electrofishing at the Cold River tributary occurred in a relatively dry period that may have served to concentrated fish into smaller areas and reduced the relative overall surface area of the stream.

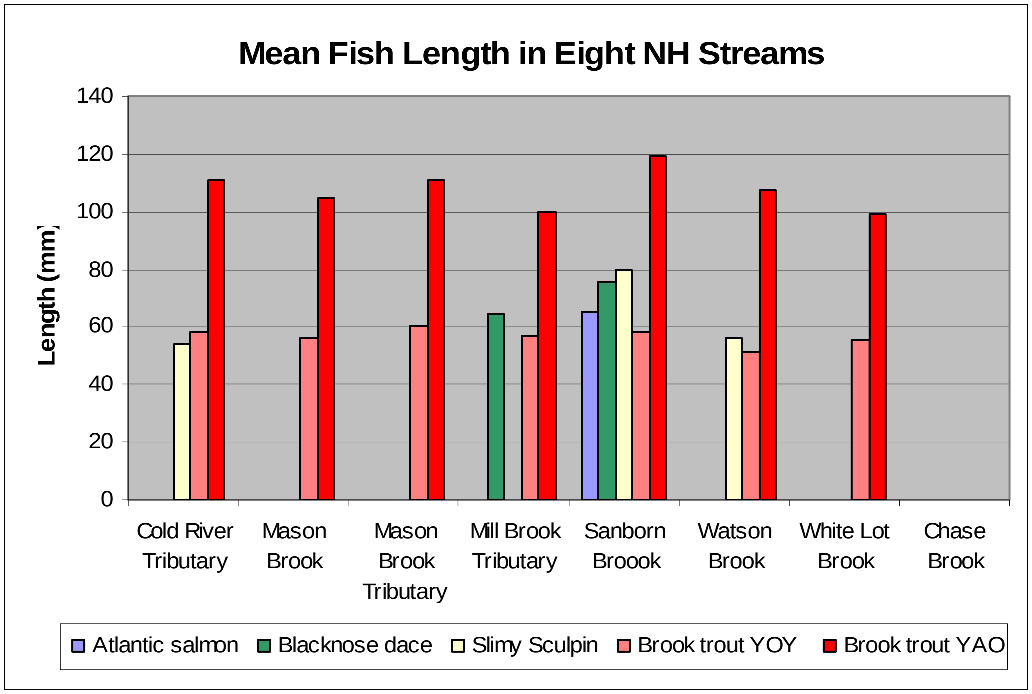
Watson Brook had the second highest density of wild brook trout, but the young of year appear to grow very slowly there. White Lot Brook had one species, brook trout. This was surveyed in October, so the relatively lower mean length of the young of year brook trout there indicates that they grow slowly in this stream. The Mill Brook tributary's fish community was numerically dominated by blacknose dace, and had a very small number and density of brook trout. Mason Brook had a relatively low density of fish, all of which were brook trout. Because so few fish were caught in what otherwise appeared to be a stream with excellent habitat, a small tributary there was also surveyed. Interestingly, the mean length of young of year brook trout was nearly 10% higher than in Mason Brook. Based on pH data collected in summer 2010, it appears the pH of Mason Brook is typically about 6.1, while in the tributary the pH is about 6.9. Summer low flow pH values below about 6.3 have been shown to be detrimental to brook trout populations (i.e., lower density of brook trout).

Figure 18. Fish density in 1,000-ft sections of eight NH streams (YOY = young of year, YAO = one year and older).



Sanborn Brook had the greatest number of species caught, which included Atlantic salmon young of year. Generally, young of year Atlantic salmon move very little in the spring and summer of their first year; therefore, those in Sanborn Brook likely originated from the spawning of landlocked salmon in Wonalancet River or possibly in Sanborn Brook itself. Adult landlocked salmon would have to migrate from Ossippee Lake, up the Bearcamp, Swift and Wonalancet Rivers to produce young of year in Sanborn Brook. The young of year brook trout in Sanborn Brook were relatively large, especially given that they were caught on July 14, 28 days before surveys of the Cold River tributary and Watson Brook, and 85 days before the survey of White Lot Brook. This larger size may have influenced fish densities that were relatively low in Sanborn Brook.

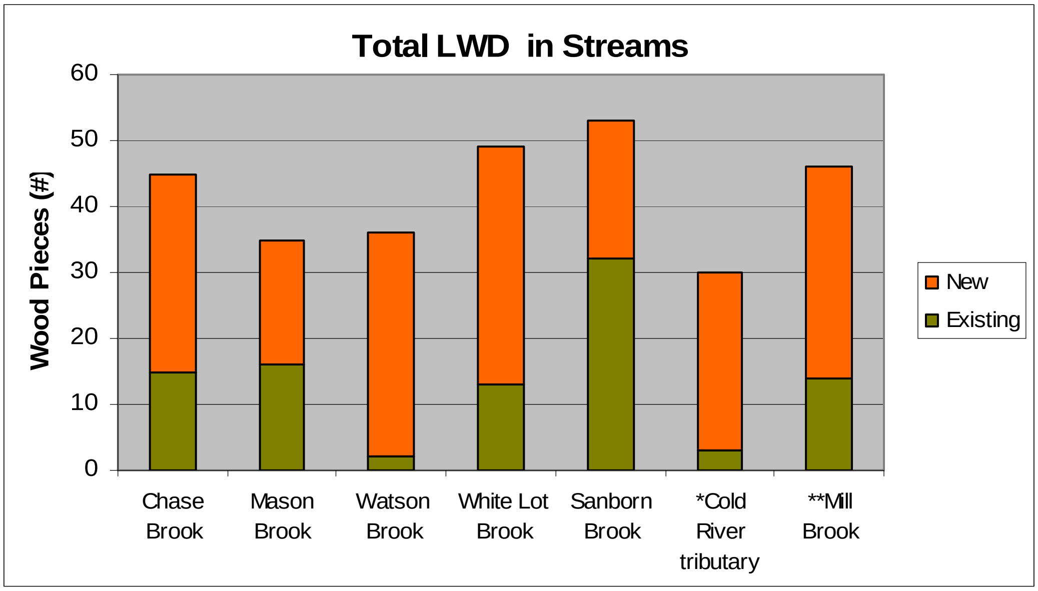
Figure 19. Fish length in 1,000-ft sections of eight NH streams (YOY = young of year, YAO = one year and older).



Wood Additions

The eventual amount of LWD greater than six inches in diameter present in the study streams ranged from 2 pieces to 32 pieces per 1,000-ft stream section, but most streams eventually contained 30 to 53 LWD pieces after treatment (Figure 20). In most instances, new LWD additions elevated existing levels of woody materials by a factor of 0.3x to 15x; however, new wood additions to Watson Brook comprised essentially all of the total LWD present after treatment. Watson Brook was nearly devoid of LWD prior to treatment. The existing LWD in Sanborn Brook was within the target amount for each stream after treatment, and after treatment, LWD in Sanborn Brook was the highest of all treated. Although ‘number’ of wood structures is important to stream habitat, size and function of those wood pieces are the major determinants influencing habitat..

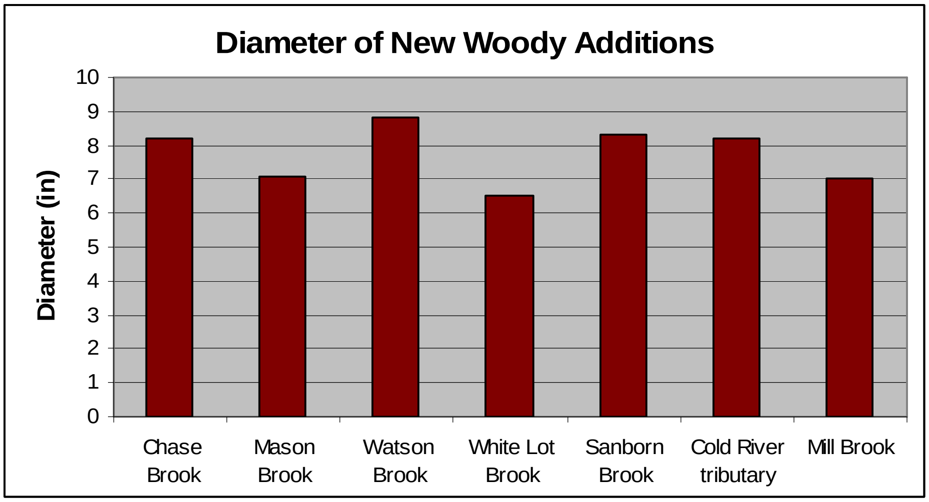
Figure 20. Number of pieces of existing large woody debris present in 1,000-ft sections of seven NH streams before and after new wood additions.



* Cold River study area was 900 ft in length ; values adjusted to 1,000-ft equivalent treated area.
** Mill Brook study area was 500 ft in length; values adjusted to 1,000-ft equivalent treated area.

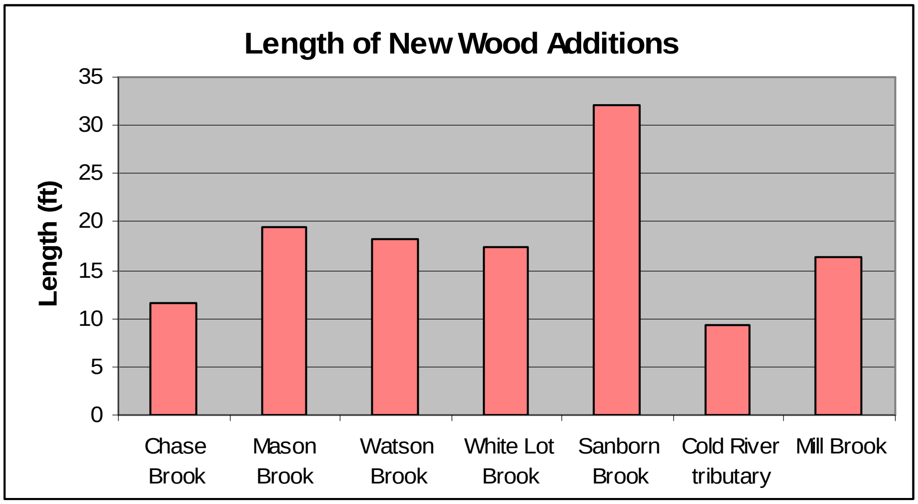
The size of new wood additions to the study streams were a function of the available material in close proximity to the stream; and therefore, it was related to trees growing in the riparian area along the streams. Overall, additions were smaller diameter than existing wood. Older stands like those along Watson Brook, Sanborn Brook, Chase Brook, and White Lot Brook would be expected to have larger new wood additions available, whereas Mill Brook and Cold River would be expected to yield smaller material since they had been harvested in recent times. Data presented in Figure 21, fails to support this reasoning perhaps due to a bias for selecting the largest manageable wood available. For the Cold River tributary, significant numbers of additions were from material harvested outside the riparian area and carried by tractor. Streams with older and larger riparian trees should contain larger diameter wood additions.

Figure 21. Diameter of pieces of new large woody debris present in 1,000-ft sections of seven NH streams before and after new wood additions.



The length of new wood additions to streams was fairly uniform (16-20 ft) from one stream to the next (Figure 22). Sanborn Brook is one exception owing to the large woody material available directly streamside. The rather short length of wood additions to the Cold River tributary could be a function of the narrower stream width and the specific material sought to install. Wood additions were much larger in length than the pre-existing wood in the streams.

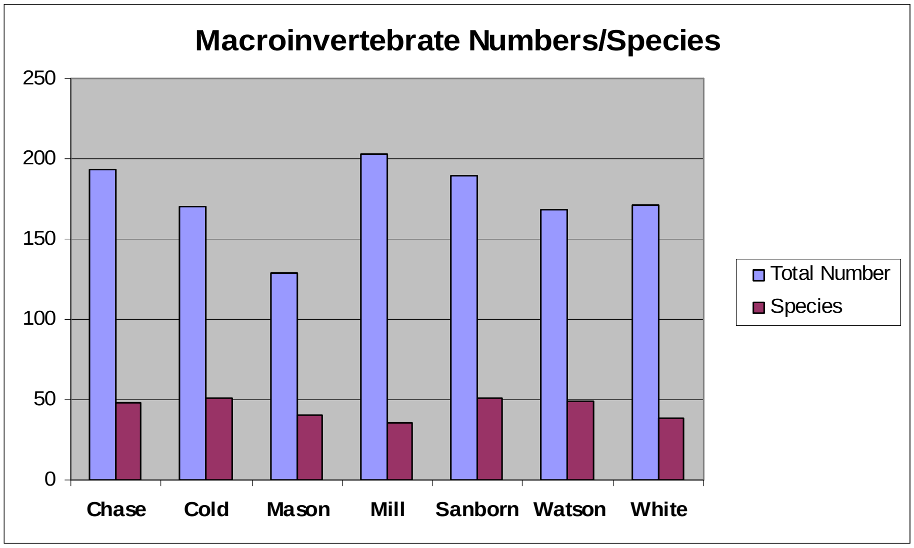
Figure 22. Length of pieces of new large woody debris present in 1,000-ft sections of seven NH streams before and after new wood additions.



Macro-Invertebrates Sampling for macro-invertebrates occurred above and below the areas of stream that were treated with wood additions. Since the first year data was collected before or immediately following wood additions, data from both sample areas in each stream were combined to establish a baseline of data for the presence or absence of aquatic macro-invertebrates. All captured macro-invertebrates were classified to species (Appendix A); however, results presented in Figure 24 are for major families of macro-invertebrates present in each of the seven study streams. Four replicates of 1-ft^2 sample plots were established at each sampling area (two sampling areas/stream), making a total of eight square feet of stream bottom sampled in each stream.

Species richness is often a good measure of aquatic habitats. The greater number families and genera present suggests healthier aquatic environment with diverse habitats. The relationship between macro-invertebrates and fish communities is not well-studied, but macroinvertebrate densities have been linked to fish production (Gore et al. 2001; Mundie, 1974). Recent studies have revealed an increase in macro-invertebrate abundance and a shift to grazer and chironomid dominated macro-invertebrate communities in streams with increased trout abundance (Nislow and Lowe, 2006). The seven study streams showed relatively small differences in species richness; however, the total macro-invertebrate abundance varied among streams (Figure 23). While Mill Stream had the greatest macro-invertebrate abundance, it also had the lowest species richness suggesting a few species may account for a large number of the macro-invertebrates present. The three streams with the greatest species richness, Watson Brook, Sanborn Brook, and the Cold River tributary, also were among the streams with the greatest number of brook trout captured

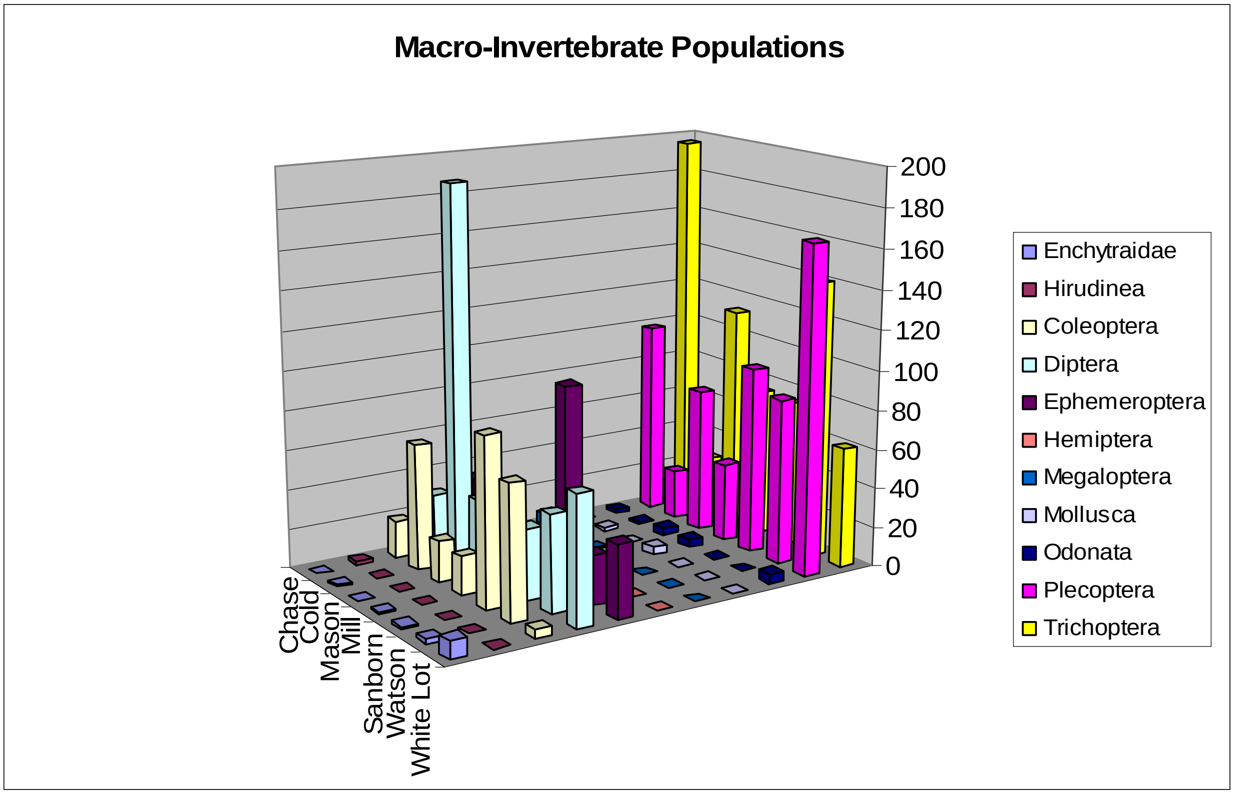
Figure 23. Macro-invertebrate species richness and total abundance in seven NH streams.



Differences within that macro-invertebrate population were evident among the seven streams, but several families were more plentiful across all streams (Figure 24). Trichoptera, Plecoptera, Diptera, Coleoptera, and Ephemeroptera were by far the most common occurrences, but the numbers of these organisms in each stream exhibited great variation. For example, Trichoptera numbers in Chase Brook were twice those of most other streams, Plecoptera were similarly much higher in White Lot Brook than all other streams, Sanborn Stream had nearly three times the number of Ephemeroptera as found in other streams, and Cold Brook Diptera numbers were well over three times those of other streams. Some families of macro-invertebrates were only found in one or two streams and absent in others, e.g., Hemiptera in Chase Brook and Mill Stream as well as Hirudinea in Chase Brook.

Brook trout abundance has been shown to be positively correlated with the relative combined abundance of the disturbance-sensitive macro-invertebrate species Ephemeroptera, Plecoptera, and Trichoptera (EPT) (VanDusen *et al.* 2005). The EPT macro-invertebrates have been shown to be replaced by more tolerant Diptera following stream disturbances including logging (Anderson 1992, VanDusen *et al.* 2005). On the Cold River tributary, high numbers of EPT appeared to have replaced by Diptera.

Figure 24. Macro-invertebrate populations by family occurrences in seven NH streams.



Gore, J.A., Layzer, J.B., and J. Mead. 2001. Macroinvertebrate Instream Flow Studies After 20 Years: A Role in Stream Management and Restoration. Regulated Rivers: Research and Management. 17: 527-542.

Mundie JH. 1974. Optimization of the salmonid nursery stream. Journal of the Fisheries Research Board Canada 31: 1827–1837.

Nislow, K.H. and W.H. Lowe, 2006. Influences of Logging History and Riparian Forest Characteristics on Macroinvertebrates and Brook Trout (*Salvelinus fontinalis*) in Headwater Streams (New Hampshire, U.S.A.) 51: 388-397.

VanDusen, P.J., C.J.F. Casey, and D.J Flaspohler. 2005. Associations among selection logging history, brook troput, macroinvertebrates, and habitat in northern Michigan headwater streams. Transac Am Fish. Soc. 134:762-774.

Conclusion

Seven headwater streams in Carroll County, NH were selected for the study of making wood additions to streams to enhance brook trout habitat. Past work suggests that current levels of woody debris in streams are below optimal levels for creating high-quality brook trout habitat, and wood additions can act to increase the number of pool/riffle combinations and average pool depth, provide greater amounts of gravel substrate suitable for redds, and trap greater amounts of organic material that provides food source for prey and hiding areas for trout. Results reported provide baseline information on each stream in terms of physical features, water quality, existing wood in streams, fish populations, and the amount of wood added to each study stream.

Results further showed variations in: 1) water quality attributes associated with impoundments and past land use, 2) physical characteristics such as stream bottom substrate, gradient, and number and depths of pools, 3) the amount and size of pre-existing wood that has accumulated in streams, 4) fish populations in streams, both numbers and species composition, and 5) the amount of wood additions required to approach optimal levels described in the literature. The data collected in this report will serve as the baseline against which the influence of wood treatments can be compared to determine the influence on brook trout populations and habitat.

As of the writing of this report, the influence of the 2010 wood additions already has been observed.

1. Physical changes in stream characteristics have been noted.

   The fall drop of leaves has added significant organic matter to the streams and become integral parts of instream wood jams. Field observations since the wood additions indicate a large volume of material is collecting upstream of the newly placed wood. This will accomplish two things: an increase in water depth upstream of the obstructions and nutrient trapping associated with the release of leaves. The increase in depth of pools may only be temporary but may play an important role in improving the chances of fish survival rates this winter. Fish gravitate to deeper pools during the winter months, especially if cold temperatures forces ice formation in other parts of the stream course limiting fish habitat.

   The other benefit of organic matter retention in streams is related to nutrients. The new wood additions now are trapping material that would have otherwise flowed downstream. This increase in nutrients and organic matter is beneficial to benthic macro-invertebrates, a crucial fish food. Increasing the stream’s ability to capture this annual influx of nutrients can only be beneficial to the general health of the existing fish population.

2. Wood additions appear to be somewhat stable.

   This late summer and fall have generated approximately seven significant rain events with rainfall amounts that have ranged from 1–3 inches in each event. This has produced a number of high flows, and although some wood movement was anticipated, it appears that most of the wood additions are remaining intact and slowing stream discharge and secondarily increasing pool depths.

   More significant changes to the wood addition placement will most likely occur in the spring with the snow pack melt. This is a natural process that can be anticipated as the stream re-adjusts the woody material, and it begins to accumulate material that would otherwise flow unimpeded. This process of slowing stream flow, especially in high water events is also an important component of this project.