All photos courtesy Fin Kaeka

THE MILL BROOK WATERSHED STUDY 2015

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EXECUTIVE SUMMARY

In general, the Mill Brook appears to be in good health. For most of its length it consists of a single channel less than one foot deep with a mud, sand and sometimes cobble bottom. In most places the water moves rapidly enough to create a series of runs and small riffles. There was also enough woody debris to create small pools.

The riparian area along the banks of the stream supports a healthy Mesic Forest, with the canopy layer dominated by red maple, beetlebung and beech trees. The most common shrubs were sweet pepperbush, swamp azalea, highbush blueberry and winterberry and there was a relatively robust herbaceous layer with poison ivy, skunk cabbage, Canada mayflower, wild sarsaparilla, jewel weed and cinnamon fern the most common understory plants.

There were no visual or olfactory indications of pollution; the water was clear and free of unusual smells such as sewage, rotten eggs or chlorine. Conductivity readings also gave no indication of the presence of pollutants such as nitrates, phosphates or sodium.
However, conductivity readings were low enough to suggest the possibility of the presence of petroleum products from road runoff.

Like most of the Vineyard, the water in the stream was somewhat acidic; however, it became less acidic as it moved from Waskosim"s Rock downstream. For most of its length, the pH was within the preferred range of most aquatic organism, including trout and many of their prey species such as mayfly, stonefly and caddis fly larvae.

The most significant human impacts on the Mill Brook are from the four man-made ponds. Our data show that water temperature increased as it passed through the first two ponds.

1. In June, water temperature below Fisher Pond was 5^0 F warmer than above Fisher Pond.
2. In August, our data show that water temperature below Fisher Pond was 14^0 F warmer than above Fisher Pond. However, the below reading is much higher than the temperature recorded by the data loggers maintained by Prudy Burt of the Sea Run Brook Trout Coalition (SRBTC), which indicate a change of 5 or 6 ^{0} F from above to below Fisher Pond on that date.
3. In June, water temperature below Crocker Pond was 3^0 F warmer than above Crocker Pond.
4. In August, our data show that water temperature below Crocker was 10^0 F warmer than above Crocker Pond.
5. However, in June water temperature was about the same above and below Priester Pond and above and below Alberts Pond.
6. We did not collect data from Albert's Pond in August and the readings above and below Priester Pond were taken on different days in August, so we do not have a valid comparison for that site.

An unanticipated consequence of the ponds was that the water behind the dams was high enough that it backed up into the stream above the ponds, changing the character of the Mill Brook in those areas. Just above the ponds, and continuing for an undetermined distance, the bottom consisted of a thick layer of very fine mud and silt, with a considerable increase in naturally occurring organic matter, primarily dead leaves. The water also flowed more slowly and had lower dissolved oxygen. This created a multi-channeled swampy area as opposed to the single channel of more rapidly flowing water in the rest of the Mill Brook.

We collected and identified aquatic macroinvertebrates (i.e. animals without backbones that live in fresh water and are large enough to see with the naked eye) at 11 sites along the Mill Brook; above and below each of the four ponds, at Wascosim's Rock Preserve and in two small streams entering the ponds from under North Road.

We calculated a simple Diversity Measure based on the number and abundance of different aquatic organisms and a Water Quality Index based on the number of pollution intolerant organisms for each site (Note that for the Water Quality Index, 'pollution' was defined as higher temperatures, extreme pH and low dissolved oxygen rather than chemical pollution).

Both the Diversity Measures and Water Quality Index were generally higher at Waskosim"s Rock and below the ponds than above the ponds.

One relevant question is whether the Mill Brook is a cold water stream, a relatively rare phenomenon in southeastern Massachusetts.

Some of the characteristics of a healthy coldwater stream are:

1. they are perennial and fast flowing due to their gradient and channel width.
2. they are bounded by native vegetation
3. they are made up of a series of riffles, runs and pools.
4. They have a maximum summer water temperatures usually no more than 20^{o} C (68^{o} F) and are quite often 15^{o} C (59^{o} F) or less.
   (Coldwater Streams, website published by The Community Stream Steward Program at www.ofah.org/stream.)

Massachusetts has a formal definition of cold-water fisheries—"waters in which the maximum mean monthly temperature generally does not exceed 20^{o} C (68^{o} F) and, when other ecological factors are favorable (such as habitat), are capable of supporting a year-round populations of cold water stenothermal aquatic life such as trout". (Massachusetts Department of Environmental Protection quoted in *Water-Quality Assessment of the New England Coastal Basins in Maine, Massachusetts, New Hampshire, and Rhode Island: Environmental Settings and Implications for Water Quality and Aquatic Biota,* p.30, on website at pubs.usgs.gov/wri/wri984249/pdf/geological.web.pdf).

The Massachusetts Division of Fisheries and Wildlife lists the Mill Brook as a Coldwater Fisheries Resource. By the above definition, our data confirm the Mill Brook is a coldwater stream except in a few locations where temperature exceeded 70^{o} F in June and 76^{o} F in August.

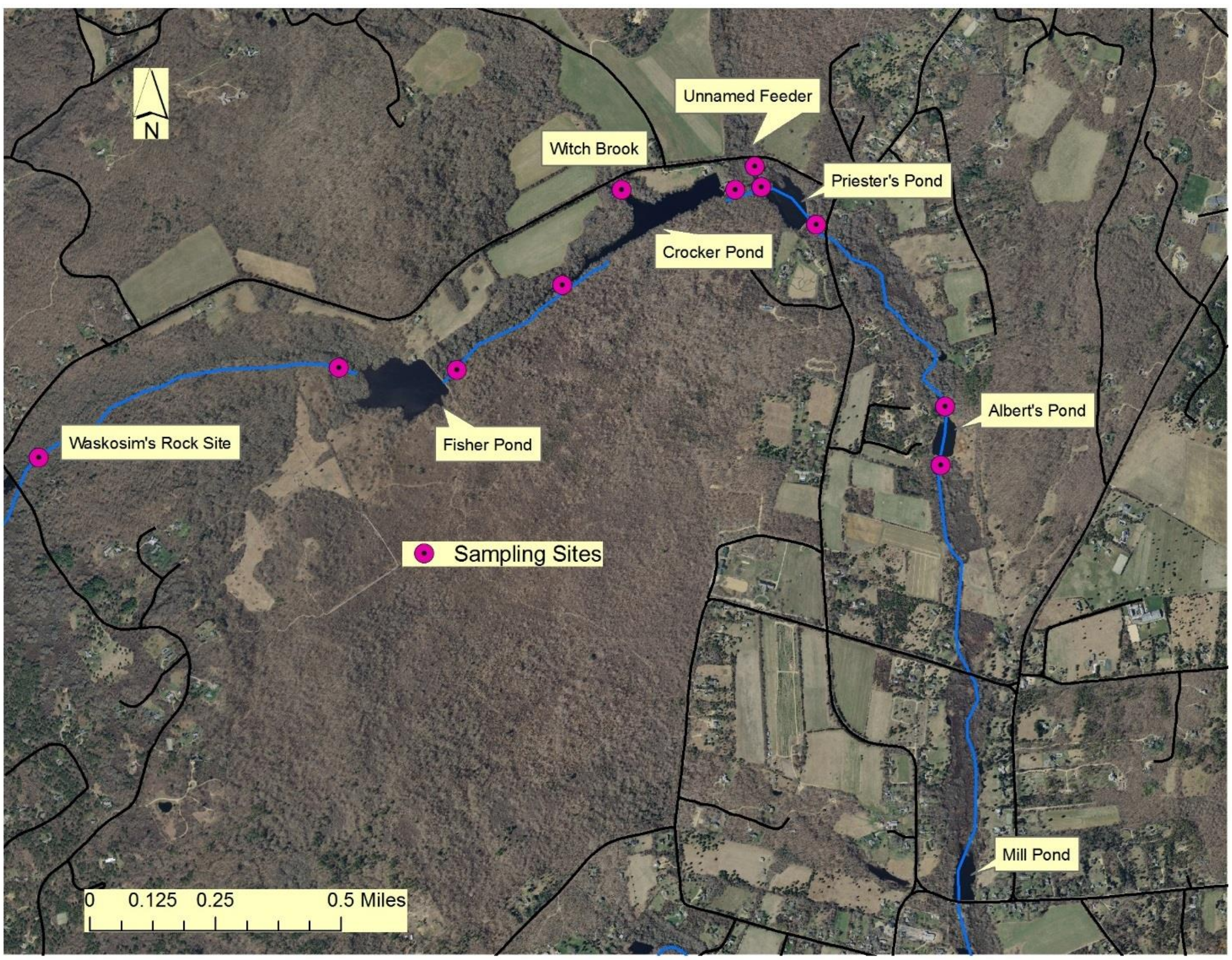
We did not attempt to sample fish. However, we observed small (1 to 3 inches) fish at several sites and inadvertently captured even smaller fish in our net. At least some of these appeared to be brook trout but we did not collect them for positive identification.

INTRODUCTION AND METHODS

In the spring of 2015, the Mill Brook Watershed Committee of the Town of West Tisbury contracted BiodiversityWorks (BWorks) to conduct a *Morphometrics and Macroinvertebrate Survey of the Mill Brook Watershed.* The study was conducted by biologist Richard Johnson and a group of volunteers and Interns (BWorks and Nature Conservancy). Field work was conducted in two parts: spring (June 3- 25) and summer (August 6-27) of 2015.

Surveys were conducted at 11 sites: above and below each of four ponds along the Mill Brook in West Tisbury and Chilmark, a site at the Martha's Vineyard Land Bank's Waskosims Rock Preserve, at Witch Brook (which feeds Crocker Pond), and at an unnamed brook that feeds Priester Pond. The sampling sites for both the Witch Brook and unnamed feeder brook were after these brooks passed underneath the North Road (Figure 1).

Figure 1. Showing 11 Sampling sites for habitat assessment and macro-invertebrate collection in 2015



At each site the following information was collected:

1. Physical characteristics using the Stream Habitat Walk form from the EPA.
2. Basic water quality measures (pH, temperature, dissolved oxygen and conductivity) measured with a YSI 60 pH meter and a YSI 85 multimeter, both provided by the Martha's Vineyard Commission.

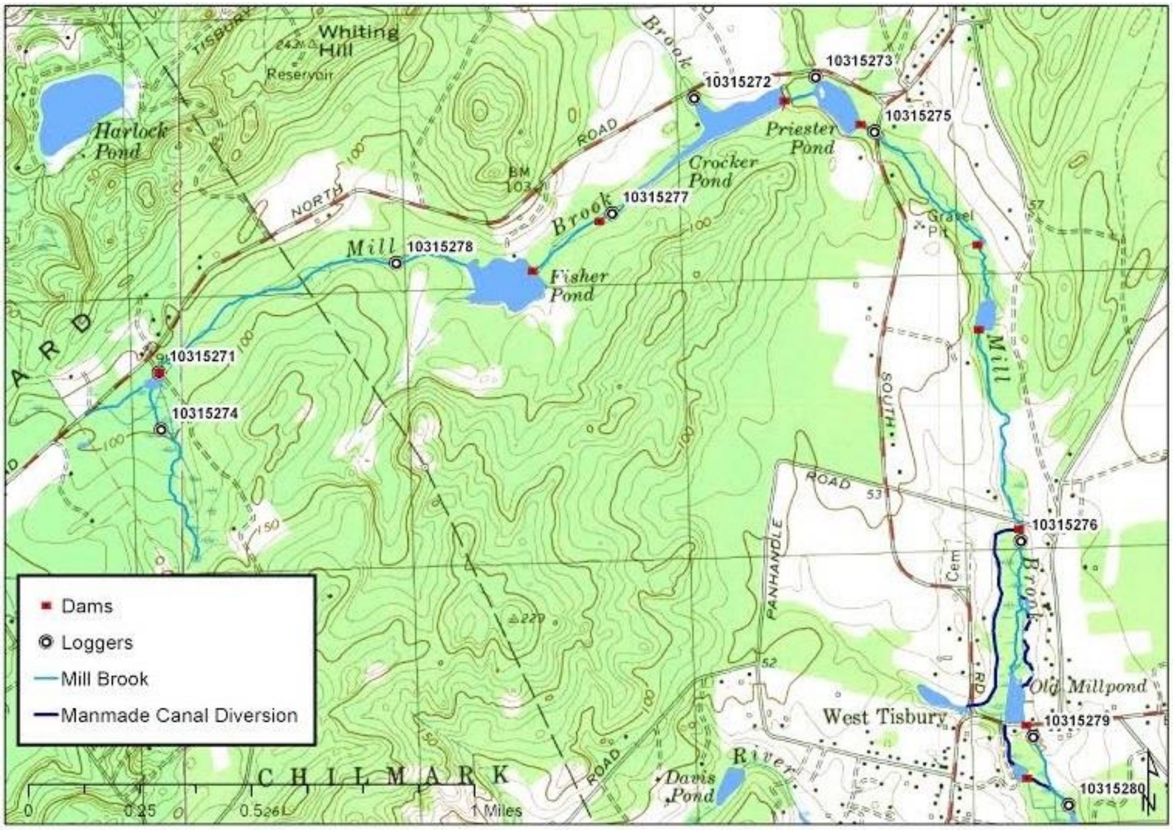
   It is important to mention that our water quality data were collected by staff with limited training using the equipment and the data we collected represents only a snap shot of conditions taken at the time of our sampling visit, which was between 9:00 and 11:30 am. Prudy Burt of the Sea Run Brook Trout Coalition (SRBTC) maintained data loggers that recorded water temperature every 15 minutes at several locations in the Mill Brook over a the past three years (Figure 2). Since water temperature is one of most important factors in determining the ecological health of the Mill Brook, we have included the SRBTC temperature in our report when both groups recorded data from the same locations. The data from both sources are consistent (within 1 to 3^0 F) at all sites and dates, except one. Our water temperature reading below Fisher Pond on August 6 was 9^0 F higher than the water temperature recorded by the SRBTC data logger on that date. Since it does not fit the general pattern of our data we assume this high temperature reading was a measurement error on our part.

3. A list of the plants that could be identified in the field or from photographs. We did not attempt to do a complete botanical inventory or collect samples for later identification; therefore some rare or hard to identify plants may not be included in the list.
4. Samples of aquatic invertebrates were collected using a dip net and kick net. The dip net was used at all sites to take samples from under the stream banks, from woody debris in the stream and a general bottom sample. The kick net was used in addition to the dip net at a site with a harder bottom and cobbles. At sites with scattered small rocks or cobbles, we scraped rocks by hand to collect organism attached to the rocks.

Richard Johnson and Margaret Curtin collect macroinvertebrates in the Mill Brook

Invertebrate samples were taken to the BWorks office where they were identified as specifically as possible using easily available general keys (*Guide to the Aquatic Insects* *and Crustaceans* published by the Isaak Walton League of America, 2006 and *Identification Guide to Freshwater Macroinvertebrates* published online by the Stroud Research Center) as well as more detailed keys from *An Introduction to the Aquatic Invertebrates of North America,* 4th Edition, by Merrit, Cummins and Berg.

Figure 2. Showing sampling sites for SRBTC data loggers. Map provided by SRBTC



ANALYSIS

A. The physical characterizations from the Stream Habitat Walk are included as background information about each site. They were also examined to potentially explain some of the differences in invertebrate samples among sites.

B. The water quality measurements were examined for differences between sites above and below each of the four ponds, as well as patterns of changes as the Mill Brook flows from its source off North Road in Chilmark to its outlet into Tisbury Great Pond

C. Plant lists are included to further a general understanding of the sites and the differences and similarities among them, as well as to provide a baseline for comparison with any future studies of the area.

D. Aquatic macronvertebrates are animals without backbones that live in fresh water and are large enough to see with the naked eye. They may range in size from a just visible speck to several inches long. Most were identified to the *Family* level, a few were identified to *Genus* and some we were only able to identify to *Class* or *Order.* A taxonomic list of all the macro-invertebrates collected and identified is attached as Appendix A. We also compiled a list of which aquatic invertebrates were collected at each site (Appendix B). Each organism was also placed into four abundance categories based on the number of individuals present at each site. The four abundance categories were:

1. Abundant - more than 25 individuals at the site
2. Common - 11 to 24 individuals at the site
3. Some – 3 to 10 individuals at the site
4. Rare- 1 to 2 individuals at the site

We used these categories instead of the exact number of individuals because the effort to collect the aquatic invertebrates, while similar, varied somewhat from site to site. We were more concerned with getting a representative sample of all the aquatic invertebrates present at a site than with getting numbers that could be directly compared.

We also calculated a rough measure of diversity of aquatic invertebrates at each site by taking the total number of the different types collected plus the number of those that were ranked Abundant or Common. Abundance category and Diversity Index for each site are included in Appendix B1.

Finally, we placed all organisms into three categories of pollution tolerance, using information from *Macroinvertebrates as Indicators of Stream Health* by Joan Schumaker Chadde, available online at www.wupcenter.mtu.edu/education/stream/Macroinvertebrates.pdf.

Chadde defines pollution sensitive species as those that require high dissolved oxygen, neutral pH and cold water. Conversely, pollution tolerant species can live with lower oxygen levels, more extreme pH and warmer water. She also includes a middle level of somewhat pollution tolerant species.

We used a scoring method described in *The Biotic Index Card* (Sharpe, Kimmel and Buda) available online at www.BICcard.pdf to calculate a Water Quality Score for each of our sites. Pollution intolerant species were given two points, somewhat pollution tolerant species one point and pollution tolerant species no points. The total score for a site is an indicator of overall water quality, with higher scores indicating better overall water quality.

Four of the organisms we collected were classified by Chadde as pollution intolerant: stone flies, mayflies, dobsonflies and case building caddisflies.

Clams, snails, beetles, phantom crane fly larvae, dragonfly larvae, free living caddisfly larvae and damsel fly larvae were classified as somewhat pollution tolerant.

Worms, planaria and biting fly larvae (Diptera) of all types except phantom crane fly larvae were classified as pollution tolerant.

Pollution tolerance ratings for all organisms collected are included in Appendix A.

RESULTS

A. Physical Characterization

At each site we recorded water appearance, water odor, stream depth, stream width, type of bottom, amount of woody debris, amount of naturally occurring organic matter, percent shade and water flow in feet per minute during our June site visits. A list of the physical characterization data is included as Appendix C.

1. Water appearance and odor

These two categories were included as indicators of pollution; water appearance choices included milky, orange, greenish and oily sheen. Odor choices included sewage, chlorine, fishy and rotten eggs. At all of our sites the water was clear or tinted light brown (presumably from oak tannins) and there were no odors or other indicators of pollution.

2. Stream depth

Although there are certainly deeper pools (including a few that we waded through), the water depth at all but two of our sites was less than 1 foot. The exceptions were above Fisher Pond where the water depth appeared to be about 1 to 2 feet and above Crocker

Pond, where the water depth appeared to be greater than 2 feet. The bottom was composed of such soft mud that it was hard to judge water depth because it was difficult to tell where the water ended and the muddy bottom began.

3. Stream width

The Mill Brook varied in width from 6 to 45 feet over the course of our study area, but was generally 10 to 20 feet wide. The narrowest point (6 feet) was closest to the source in Waskosim"s Rock. The widest points were above and below Crocker Pond, at 45 and 35 feet respectively. The streams feeding the Mill Brook were also narrow; Witch Brook was 5 feet wide at our study site and the unnamed feeder brook was 6 feet wide.

4. Bottom Type

At each of the 11 sites we recorded the predominant type of particles making up the stream bottom: mud, sand, gravel, cobbles, and boulders, or a combination of one or more of these types.

The stream bottom at most sites was composed of 2 or 3 of these types of particles. The most common types of particles were sand (9 sites), mud (7 sites) and gravel (6 sites). Cobbles (defined as stones 2 to 10 inches in diameter) were one of the predominant types at 3 sites. There were no sites where boulders (rocks greater than 10 inches in diameter) were a predominant type.

Above the ponds the bottoms were generally composed of mud or sand or a combination of the two. Sites below the ponds generally included gravel and cobbles along with the sand and mud.

5. Woody Debris

The amount of woody debris (logs and branches) was recorded in three categories: none, occasional or plentiful. Seven sites were recorded as occasional, three as plentiful and one had none. There was no easily discernible pattern for the amount of woody debris at sites above and below the ponds.

6. Organic Matter

The amount of naturally occurring organic matter such as twigs and leaves was recorded on the same 3 point scale: plentiful, occasional and none. Six sites were recorded as occasional, four as plentiful and one had none.

At three of the four ponds there was more organic matter above the pond than below; at Crocker Pond organic matter was recorded as occasional both above and below the pond.

7. Percent Shade

We recorded the extent to which vegetation shaded the stream at each site on a five point scale: 0%, 25%, 50%, 75% and 100%. At eight of the eleven sites we recorded shade as 75%. Above and below Crocker Pond shade was recorded as 25% and 50% respectively, the Waskosim's Rock site was recorded as100 %.

There was no readily discernible pattern for the percentage of shade at sites above and below the ponds.

8. Water Flow

During June the speed at which water was flowing in the Brook was recorded in feet per minute by recording how long it took a tennis ball to travel 10 or 20 feet. We did not measure rate of flow above Fisher Pond, so we only have comparisons for the other three ponds. In June, water flow varied from 9 feet per minute at the unnamed feeder brook to 96 feet per minute below Priester Pond.

In general, the water flowed faster below the Ponds than above. The exception was at Crocker Pond, where in June it flowed at about the same speed above (23 ft/min) and below (21 ft/min) the Pond. We measured this site again in August, at that time flow was 0 ft/min above the Pond and 9 ft/min below the Pond, consistent with the pattern we observed in June at the other Ponds. We also measured water flow below Priester Pond in August, which increased to 128 ft/min. However, this measurement was taken the day after a very heavy rain.

B. <u>Water Quality</u>

At each site we recorded water temperature, pH, dissolved oxygen, conductivity and conductivity corrected for water temperature.

1. Water Temperature

As expected, our data show that water temperature increased as it passed through Fisher and Crocker Ponds. However, we measured very little change in temperature from above and below Priester Pond and above and below Alberts Pond, i.e the ponds that were further downstream.

- In June, water temperature below Fisher Pond was 5^0 F warmer than above Fisher Pond.
- In August, our data show that water temperature below Fisher Pond was 14^0 F warmer than above Fisher Pond. However, the below reading is much higher than the temperature recorded by the data loggers maintained by Prudy Burt of the Sea Run Brook Trout Coalition (SRBTC), which indicate a change of 5 or 6 ^{0} F from above to below Fisher Pond on that date.

- In June, In June, water temperature below Crocker Pond was 3^0 F warmer than above Crocker Pond.
- In August, our data show that water temperature below Crocker was 10^0 F warmer than above Crocker Pond.
- However, in June water temperature was about the same above and below Priester Pond and above and below Alberts Pond.
- We did not collect data from Albert's Pond in August and the readings above and below Priester Pond were taken on different days, so we do not have a valid comparism for that site.

See Table 1 below for complete data. All BWorks temperature readings were taken between 9 and 11:30 am. SRBTC morning temperatures were recorded at 9:00 am and afternoon temperatures at 5:00 pm.

Table 1: Showing Water Temperature (in Degrees Fahrenheit, rounded to nearest degree) for study sites along the Mill Brook, with data from SRBTC data loggers for comparison.

Site	Spring Date	Spring Temp. AM BWorks	SRBTC	Spring Temp. 5 PM (SRBTC)	Summer Date	Summer Temp. AM BWorks	SRBTC	Summer Temp. 5 PM (SRBTC)
Waskosims	6/25/2015	58			8/14/2015	62		
Fisher Pond above	6/3/2015	55	53	55	8/6/2015	62	61	64
Fisher pond below	6/3/2015	60	58	61	8/6/2015	76	67	69
Crocker Pond above	6/10/2015	69			8/27/2015	66		
Crocker Pond below	6/10/2015	72			8/26/2015	76		
Priester Pond above	6/17/2015	69			8/26/2015	74		
Priester Pond below	6/17/2015	68	69	67	8/12/2015	71	72	81
Alberts Pond above	6/13/2015	71			no access			
Alberts Pond below	6/13/2015	71			no access			
Unnamed feeder	6/24/2015		61	65	8/26/2015	64	66	67
Witch Brook	not done		62	67	8/27/2015	65	64	67

2. pH

pH is a measure of how acidic or basic water is (technically it is the ratio of hydrogen ions (H^+) to hydroxyl ions (OH^-). The pH scale ranges from 0 to 14. A neutral solution has an equal number of hydrogen and hydroxyl ions and a pH of 7. An acid has a pH of less than 7; a base has a pH of greater than 7. pH is based on a logarithmic scale, thus a positive change of one unit (e.g. from pH 5 to pH 6) indicates a tenfold increase in hydroxyl ions, a change of two units (e.g. pH 5 to pH 7) indicates one hundred times more hydroxyl ions.

In both June and August, the pH at the site in Waskosim"s Rock was 6.2 and thus fairly acidic. In June the pH increased (i.e. the water in the Mill Brook became less acidic) as it passed through Fishers Pond, with a measured pH of 6.1 above the pond and 6.5 below. The pH remained in the 6.4 to 6.6 range both above and below the other three ponds and was 6.5 below Alberts Pond.

In August, the pH at Waskosim"s Rock was again 6.2 and then increased to 6.4 above Fishers Pond and 6.6 at the other sites where measurements were taken (See Table 2). Thus the overall pattern of the data show that in 2015 the water in the Mill Brook became less acidic (pH increased) as it passed through Fishers Pond and then maintained at that higher pH as it moved downstream and through the other four ponds.

Table 2: Showing pH readings at sampling sites in Spring and Summer

Site	**Spring Date**	**Spring pH**	**Summer Date**	**Summer pH**
Waskosims	6/25/2015	6.2	8/14/2015	6.2
Fisher Pond above	6/3/2015	6.1	8/6/2015	6.4
Fisher pond below	6/3/2015	6.5	8/6/2015	6.6
Crocker Pond above	6/10/2015	6.4	8/27/2015	equipment problem
Crocker Pond below	6/10/2015	6.4	8/26/2015	6.6
Priester Pond above	6/17/2015	6.4	8/26/2015	6.6
Priester Pond below	6/17/2015	6.6	8/26/2015	6.6
Alberts Pond above	6/13/2015	6.5	no access	
Alberts Pond below	6/13/2015	6.5	no access	
Unnamed feeder	6/24/2015	6.0	8/26/2015	6.9
Witch Brook	not done		8/27/2015	

3. Dissolved Oxygen
   The amount of dissolved oxygen was highest at Waskosim"s Rock in both June and August. In June, in two ponds (Fisher and Priester), dissolved oxygen was lower above the pond and higher below the pond. In the other two ponds (Crocker and Albert's) it was the same above and below. In August, dissolved oxygen decreased as it went through Fisher Pond, increased below Crocker Pond and increased slightly both above and below Priester Pond. See Table 3.

Table 3: Dissolved Oxygen (DO) in mg/L at sampling sites in the spring and summer

Site	Spring Date	Spring DO	Summer Date	Summer DO
Waskosims	6/25/2015	8.4	8/14/2015	9.6
Fisher Pond above	6/3/2015	7.1	8/6/2015	7.9
Fisher pond below	6/3/2015	8.3	8/6/2015	6.0
Crocker Pond above	6/10/2015	5.7	8/27/2015	6.1
Crocker Pond below	6/10/2015	5.7	8/26/2015	7.1
Priester Pond above	6/17/2015	7.3	8/26/2015	7.3
Priester Pond below	6/17/2015	7.5	8/26/2015	7.5
Alberts Pond above	6/13/2015	6.5	no access	
Alberts Pond below	6/13/2015	6.5	no access	
Unnamed feeder	6/10/2015	4.9	8/272015	9.1
Witch Brook	not done		8/272015	5.2

4. Conductivity
   Conductivity is the most difficult water quality measure to understand and interpret. It measures the capability of a solution, such as water, to pass an electric current and indicates the amount of dissolved electrolyte ions, such as nitrates, phosphates and sodium, in the water. Conductivity is measured in microsiemens per centimeter (uS/cm) and is affected by water temperature. Measurements are generally reported as temperature corrected to 25^0 C for consistency, which is how they are reported here.

   Temperature Corrected Conductivity was similar in both spring and summer, with readings ranging from 110.6 uS/cm to 87.6 uS/cm in June and 108.8 uS/cm to 86.7

uS/cm in August, with the exception of a low reading of 66.5 uS/cm below Fishers Pond in August (Table 4).

The highest conductivity readings were from Waskosim"s Rock. Conductivity decreased as we moved downstream, with two exceptions: in June, conductivity increased from below Priester Pond to above Albert's Pond, and in August, there was the unusually low reading below Fishers Pond. See Table 4.

Table 4: Temperature Corrected Conductivity in Microsiemens per Centimeter (uS/cm)

Site	Spring Date	Spring	Summer Date	Summer
Waskosim"s	6/25/2015	110.6	8/14/2015	108.8
Fisher Pond above	6/3/2015	99.4	8/6/2015	108.5
Fisher pond below	6/3/2015	100.3	8/6/2015	66.5
Crocker Pond above	6/10/2015	96.7	8/27/2015	95.0
Crocker Pond below	6/10/2015	96.4	8/26/2015	94.3
Priester Pond above	6/17/2015	93.1	8/26/2015	94.8
Priester Pond below	6/17/2015	87.6	8/26/2015	86.7
Alberts Pond above	6/13/2015	101.4	no access	
Alberts Pond below	6/13/2015	101.8	no access	
Unnamed feeder	6/10/2015	89.0	8/262015	83.0
Witch Brook	not done		8/272015	97.4

C. <u>Plants</u>

We recorded 53 plant species from the eleven sites: 10 tree species, 14 shrub species, 4 species of vines, 1 aquatic species and 24 species in the herbaceous layer (flowers, ferns, grasses, sedges and rushes). See Appendices D1 and D2 for a list of plants.

Although there was some variability in the species present from site to site, the plant community was basically the same at all sites and is best described as Mesic Forest (*The Flora of Martha's Vineyard* by the Martha's Vineyard Sandplain Restoration Project). Mesic Forests occur on rich, moist, well-drained soils and have greater than 60% canopy cover.

Dominant trees were red maple, beetlebung and beech, and common shrubs were sweet pepperbush, swamp azalea, highbush blueberry and winterberry. The herbaceous layer had the greatest diversity (24 species). Six species occurred at four or more sites: poison ivy, skunk cabbage, Canada mayflower, wild sarsaparilla, jewel weed and cinnamon fern.

D. Aquatic Invertebrates

We collected 37 different types of aquatic invertebrates: 1 mollusc (fingernail clam), 3 types of gastropods (snails), 3 types of arthropods (1 isopod and 2 amphipods), 26 types of insects, 3 types of worms and 1 copepod. The numbers of individuals collected ranged from one (broad winged damselfly) to several hundred (snail 1). A list of the 37 organisms and their taxonomy is included as Appendix A. A list of all organism collected by abundance category at each site and season is included as Appendix B2.

In general, we found a greater number of different aquatic organisms below the ponds than above. The number of different types of organisms collected at a given site ranged from 7 above Crocker Pond in June to19 in the unnamed brook that feeds Priester Pond during August (See Table 5). The site with the second highest diversity was below Fishers pond in August (18). The lowest diversity of organisms was at Crocker Pond and above Fisher pond. We collected 10 or more different organisms at all other sites (Table 5).

We compared the number of different organism found at the same site in the spring and late summer. Season does not appear to influence species diversity.

Diversity scores ranged from 8 above Crocker Pond in June to 26 at the Feeder Brook in August (diversity = number of different organisms + number of abundant and common organisms, see Table 5). Since we collected 37 types of organisms, the highest possible diversity score is 74, i.e. if all 37 organisms were collected at a single site and all 37 were Abundant or Common.

Water Quality Scores (based on the number of pollution intolerant and somewhat pollution tolerant organisms found at each site) ranged from 5 – 13, with Above Crocker Pond having low scores in both seasons (see Table 5). The highest scoring sites, shown in red in Table 5, generally had 3 of the 4 pollution intolerant organisms and 7 of the 18 somewhat pollution tolerant. Waskosim"s Rock in June was an exception, having all 4 pollution intolerant organisms but only 5 somewhat pollution tolerant organisms. The lowest Water Quality Scores were at above Crocker Pond in June and August and below Crocker pond in August.

Table 5: Number of Types of Organisms, Diversity Measure and Water Quality Score (with high water quality scores in bold font and low water quality scores shaded in grey)

Site	# Types of Organisms	# Abundant/ Common	Diversity Measure	Water Quality Score
Waskosim"s June	**13**	**4**	**17**	**13**
Waskosim"s August	15	4	19	11
Fisher Above June	8	2	10	11
Fisher Below June	11	3	14	12
Fisher Above August	14	2	16	12
Fisher Below August	**18**	**2**	**20**	**13**
Crocker Above June	*7*	*1*	*8*	*5*
Crocker Below June	13	3	16	**13**
Crocker Above August	*8*	*2*	*10*	*6*
Crocker Below August	*8*	*1*	*9*	*5*
Priester Above June	14	1	15	**13**
Priester Below June	**15**	**8**	**23**	**13**
Priester Above August	12	3	15	10
Priester Below August	10	4	14	8
Alberts Above June	12	2	14	10
Alberts Below June	13	6	19	11
Feeder Brook June	**16**	**5**	**21**	**13**
Feeder Brook August	**19**	**7**	**26**	**13**
Witch Brook August	11	2	13	9

DISCUSSION

Stream Temperature

For most of its length, the Mill Brook is relatively narrow (15 to 20 feet) and shaded by forest canopy during spring and summer. It also moves fairly steadily, at a rate of from 10 to 100 feet per minute, depending on location and season. However, when the water enters the four man-made ponds, it slows down and no longer has any tree canopy to shade it from the sun. Thus, we expected to see an increase in temperature as the water moved through the ponds.

Our sampling data show that water temperature increased as it passed through Fisher and Crocker Ponds. However, we measured very little change in temperature from above and below Priester Pond and above and below Alberts Pond, i.e the ponds that were further downstream.

The Massachusetts Division of Fisheries and Wildlife lists the Mill Brook as a Coldwater Fisheries Resource. Our data are consistent with this designation, although in a few locations temperatures exceeded 70^{o} F in June and 76^{o} F in August. We discuss the potential impacts of these higher temperatures on Brook Trout later in the Discussion.

BWorks staff are not experts with regards to Brook Trout or other aquatic organisms. We must rely on fisheries biologists and freshwater ecologists to interpret the data we collected. Nonetheless, it seems clear to us that the higher brook temperatures resulting from the ponds pose a potential threat to the fish and other aquatic organisms native to cold water streams.

Impacts of Dams Above the Ponds

What we had not expected to see were the changes upstream of the ponds. Apparently, the dams are high enough to raise the water levels so that the ponds back up into the streams a considerable distance upstream. Since we did not walk the entire Mill Brook, we don't know how far upstream from the ponds this occurred, but it appeared to be as much as a couple of hundred yards.

Dam impacts above the ponds included changes to the stream depth, bottom and amount of naturally occurring organic matter. In most cases, dams also reduced dissolved oxygen and rate of flow. At Priester Pond and Albert's Pond we were able to walk far enough upstream to avoid the area impacted most strongly by the backup from the dams, but our upstream measurements were taken within the impacted areas of Fisher and Crocker Pond. Thus, the effects show up most clearly above Crocker Pond, and to a lesser extent above Fishers Pond.

Impacts on Depth

At all sites except above Fisher Pond and above Crocker Pond the Mill Brook was less than one foot deep. Above Fisher Pond it was between one and two feet deep and above Crocker Pond it was more than two feet deep.

These differences appeared to be the result of the water backing up behind the dams. This also resulted in a swampy area with multiple channels of the Brook, as opposed to the single clear channel that characterized the Mill Brook for most of its length.

Impacts on Stream Bottom

At most sites the stream bottom was some combination of mud, sand and gravel, with a few sites also having cobbles. Above Crocker Pond the bottom consisted of very fine mud and above Fishers the bottom was a combination of considerable mud and some sand. These were the only two sites where we could not walk in the stream bed; when we stepped into the stream at these two sites we sank into the mud, sometimes over four feet. This is notable because the increase in mud covering the bottom may eliminate spawning habitat for brook trout and other cold water fish.

Impacts on amount of Organic Matter

For this study, organic matter is defined as small pieces of naturally occurring organic matter such as leaves, twigs and pine needles. Larger pieces such as large sticks and tree branches were classified as woody debris. Only three sites were described as having plentiful organic matter: above Crocker Pond, above Fishers Pond and Witch Brook. We believe that the slow moving water at these sites allowed leaves carried from upstream as well as those falling at the site to drop to the bottom.

Impacts on Rate of Flow

Water flowed faster below the ponds than above the ponds in three of the four measurements we took; in the fourth case the flow above and below the pond was about equal. The dams slow the water down as it enters the ponds, but once it spills over the dam it flows rapidly downstream. As noted earlier, this increases the water temperature in the ponds. The rate of flow also impacts the amount of dissolved oxygen in the water, because the warmer water can "hold" less oxygen and presumably because the ponds provide a much greater surface area for oxygen to diffuse back into the atmosphere.

When water is moving quickly, there is an opposite effect. Anything that churns up the water, such as riffles or small rapids, will increase the amount of dissolved oxygen in water. Thus as the water passes over the dam at the end of each pond, it is churned up and gets more oxygenated. In addition, when the water is flowing faster it creates very small rapids called riffles, and even small riffles allow oxygen to diffuse from the air into the water.

Impacts on Dissolved Oxygen

Since stream flow was generally faster below the ponds than above, we expected to see an increase in dissolved oxygen below the ponds. This was true for the three ponds where water flow was faster below the ponds than above the ponds. In the fourth case, where the flow above and below the pond was about equal, the level of dissolved oxygen was equal.

Impact of Water Quality on Aquatic Organisms

While these water quality measures are interesting and important in and of themselves, what is of greater interest is their influence the organisms that live in Mill Brook. For example, the amount of dissolved oxygen is a measure of how much oxygen is available in the water. Many species require a certain level of dissolved oxygen and cannot survive when dissolved oxygen is below that threshold.

Dissolved Oxygen

Oxygen enters streams from the surrounding air and as a product of photosynthesis from aquatic plants. Levels of dissolved oxygen vary depending on factors including water temperature, time of day, season, depth, altitude, and rate of flow. Consistently high levels of dissolved oxygen are best for a healthy ecosystem. Most aquatic organisms cannot survive in water with dissolved oxygen levels below 4 milligrams/liter (mg/L) and most fish populations need at least 4 to 5mg/L of dissolved oxygen to survive:

0-2 mg/L: not enough oxygen to support life.
2-4 mg/L: only a few fish and aquatic insects can survive.
4-7 mg/L: good for many aquatic animals, low for cold water fish
7-11 mg/L: very good for most stream fish

(Water Research Center, www.water-research.net/index.php/dissolved-oxygen-in-water)

Our measurements of dissolved oxygen in the Mill Brook ranged from 4.9 to 8.4 mg/l, so clearly it meets the minimum standards of 4-7 mg/l. However, these are minimum standards and a high quality coldwater stream is expected to exceed these minimums. For example, Washington State sets standards for freshwater streams based on dissolved oxygen as shown in the following chart:

Class	Amount of dissolved oxygen
AA	9.5+ mg/L
A	8.0 + mg/L
B	6.5+ mg/L
C	4.0+ mg/L

By these standards, during June the Mill Brook ranges from a class C (5.7 mg/l) above and below Crocker Pond to a class A at Waskosim"s Rock (8.4 mg/l) and below Fisher Pond (8.3 mg/l). At the other spots we measured in June it would be classified as a class B stream, with dissolved oxygen readings from 6.8 to 7.5 mg/l. During August, the Mill Brook would be classified as AA at Waskosim"s Rock (9.6 mg/l), class C below Fisher pond and above Crocker Pond and class B elsewhere.

pH

The pH of a stream is another important measure of water quality. Because many chemical reactions can only take place in a narrow range of pH, most organisms can only survive when pH is in the 5 to 8 range. The greatest variety of freshwater organisms prefer a pH range between 6.5 and 8. For example, trout and many of their prey species (e.g. mayfly, stonefly and caddis fly larvae) prefer pH of 6.5 to 7.5.

In June, the lowest pHs we found were at Waskosim's Rock (6.2) and above Fisher Pond (6.1). Below Fisher Pond the ph was 6.5 and it remained between 6.4 and 6.6 as it passed through the next three ponds and was 6.5 below Alberts Pond. The pattern in August was very similar, with the lowest pH at Waskosim's Rock (6.2), increasing to 6.4 above Fisher Pond and then increased to 6.6 below Fisher Pond and stayed at that level until below Priester Pond.

Thus the overall pattern of the data show that in 2015 the water in the Mill Brook became less acidic (pH increased) as it passed through Fishers Pond and then increased and maintained a higher pH (6.4 in June, 6.6 in August) as it moved downstream and through the other ponds.

Our measurements indicate that while the pH in the Mill Brook was on the acidic side (below 7.0), it was within the survival range for most organisms over the entire length of the Brook and for most of the sites we tested it was within or very close to the lower range of pH preferred by most organisms.

Temperature

When thinking about stream water temperature and the organisms that inhabit the stream, it is important to consider both maximum and optimum temperatures. The maximum temperature is the highest water temperature at which an organism will live for a few hours, while the optimum temperature is the temperature at which it will thrive.

We were not able to find maximum and optimal temperatures for aquatic invertebrates, however these values are available for brook trout, another important inhabitant of the Mill Brook. The optimal temperature for brook trout spawning is about 48^{o} F. While they can live in higher temperatures, they can only survive for a few hours in water temperature up to 75^{o} F. (*Testing the Waters: Chemical and Physical Vital Signs of a River* by Sharon Behar. Montpelier, VT: River Watch Network, 1997. ISBN-0-782-3492-3, website of the Friends of Sligo Creek, http://fosc.org).

In June we measured temperatures ranging from 55^{o} F (above Fisher Pond) to 72^{o} F (below Crocker Pond). Thus in June the water temperatures in the Mill Brook appear to be within the maximum survival range for Brook Trout. However, in August we measured temperatures ranging from 62^{o} F (Waskosims Rock and above Fisher Pond) to 76^{o} F (below Crocker Pond). Thus in August maximum temperatures in some parts of the Mill Brook are at or above the maximum survival temperature for Brook Trout, while other locations are below this maximum.

In both June and August, all temperatures we measured were above 48^{o} F., the optimal temperature for brook trout spawning. However, Brook Trout on the Vineyard spawn in November and it is likely that water temperatures at that time are within spawning range.

Studies elsewhere have documented decreases in abundance of brook trout due to water temperature increases from dams or impoundments. Lessard and Hayes (2003) studied small streams with dams in the lower peninsula of Michigan and reported that brook trout were not found in stream water above 66 degrees F. They noted that brook trout abundance decreased by 96% below impoundments while brown trout abundance decreased by only 54%, suggesting the brown trout are more tolerant of higher temperatures. In a different study of brook trout, Marod (1995) noted that movement and catch rates decreased as the number of days when stream temperatures exceeded 61 degrees F increased. While native brook trout are present in the Mill Brook, it is likely that they are stressed by man-made ponds, and that the ponds have reduced brook trout and other cold water fish species abundance and distribution along the watershed.

Conductivity

Conductivity is a measure of the capability of a solution such as water to pass an electric current, which is an indicator of the concentration of dissolved electrolyte ions in the water. The basic unit of measurement for conductivity is micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µS/cm). Every creek will have a baseline conductivity depending on the local geology and soils. Higher conductivity indicates the presence of various pollutants, including nitrate, phosphate, and sodium. Significant increases in conductivity may be an indicator that the stream is being polluted. Distilled water has a conductivity ranging from 0.5 to 3 µS/cm, while most streams range between 50 to 1500 µS/cm. Freshwater streams should have a conductivity between 150 to 500 µS/cm to support diverse aquatic life. (*Testing the Waters: Chemical and Physical Vital Signs of a River* by Sharon Behar. Montpelier, VT:River Watch Network, 1997. ISBN-0-782-3492-3 from the website of the Friends of Sligo Creek, http://fosc.org).

Since water temperature affects conductivity, conductivity is usually measured and reported as temperature corrected to 25^{o} Celsius (about 77^{o} F). Temperature corrected conductivity in the Mill Creek ranged from 87 µS/cm below Priester Pond to 111 µS/cm at Waskosim"s Rock. All other measurements fell between 93 and 102 uS/cm.

The low conductivity measurements in the Mill Brook give no indication that nitrates, phosphorous or other similar pollutants are a problem. However, gas, oil and other petroleum products in the water lower conductivity, so the low measurements may indicate that petroleum products entering the Mill Brook in road runoff are a potential problem. Our second lowest conductivity reading was 89 µS/cm, measured at the unnamed feeder brook that goes under North Road before joining the Mill Brook above Priester Pond. In combination with the decrease in conductivity as the water moves downstream, this suggests the potential for pollution from road runoff at this site and other sites along the Mill Brook.

We also measured conductivity on both sides of the State Road Bridge, since this seemed a likely place for road runoff to be entering the stream. Our results were surprising. Upstream, before the Mill Brook passes under State Road, conductivity measured 87µS/cm. After passing under the State Road bridge, roughly 25 meters downstream from the bridge, conductivity measured 94S/cm., close to the middle of all conductivity measurements and higher than the measurement recorded before the water passed under the bridge and road.

Conductivity readings are most useful when they can be compared over time. It is generally difficult to draw conclusions from a single set of readings but significant changes over time generally indicate a problem. Overall, our conductivity measurements suggest the possibility of pollution from road runoff and we believe it is a situation that bears further investigation.

Macroinvertebrates as Indicators of Water Quality

In addition to the direct measurements of water quality discussed above, we also used aquatic macroinvertebrates as indirect indicators of the water quality and health of the Mill Brook. Aquatic macroinvertebrates are good indicators of water quality and stream health because they spend up to a year in the stream, have limited mobility, making them good indicators of localized conditions and are the primary food source for many fish. They are also relatively abundant, big enough to see with the naked eye, and easy to collect.
(*Macroinvertebrates as Indicators of Stream Health* by Joan Schumaker Chadde, available online at www.wupcenter.mtu.edu/education/stream/Macroinvertebrates.pdf).

We compared the three water quality measurements listed by Chadde as affecting pollution sensitive species (dissolved oxygen, pH and water temperature) to the Water Quality Score and Diversity Measure. The water Quality Score most closely matched dissolved oxygen (See Table 6), suggesting that the amount of dissolved oxygen in the water may be a limiting factor for aquatic invertebrates in the Mill Brook.

Table 6: Comparisons among Different Measures of Water Quality

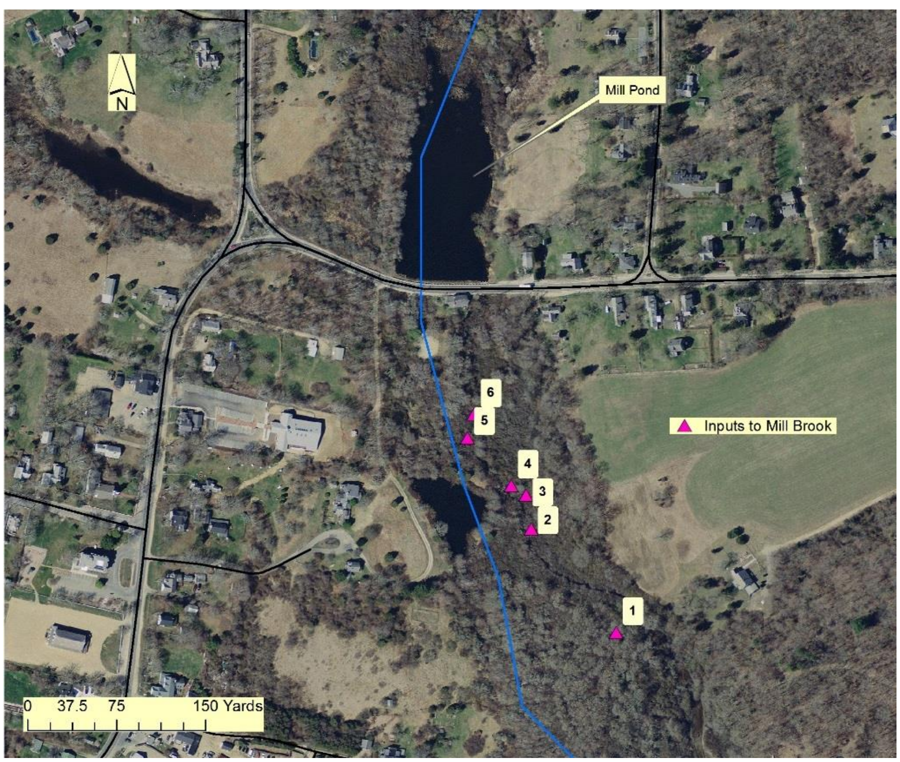
Site	pH	Temp	Dissolved O_2	H_20 Quality	Diversity Measure
Waskosim's June	6.2	57	8.4	13	17
Fisher Above June	6.1	55	7.1	11	10
Fisher Below June	6.5	60	8.3	12	14
Crocker Above June	6.4	69	5.7	5	8
Crocker Below June	no data	72	5.7	13	16
Priester Above June	6.4	69	7.3	13	15
Priester Below June	6.6	68	7.5	13	23
Alberts Above June	6.5	71	6.8	10	14
Alberts Below June	6.5	71	7.4	11	19

A freshwater stream specialist may have more insight into the macro invertebrate data from this study and how species composition/diversity relates to water quality.

Inputs, Runoff, & Diversions Mapped October 2015

In late October, after most leaves were off the trees, Richard Johnson and Prudy Burt walked up the Mill Brook from Town Cove to Mill Pond to map and photograph groundwater and run off inputs (Figure 3). They also walked from Mill Pond to Scotchman's bridge mapping diversions from the brook (Figure 4).

Figure 3. Map showing locations of inputs to the Mill Brook mapped in October 2015



#1 – Outlet of Maley's Pond at Town Cove

#2 – Groundwater input from east side of brook

#3 – Groundwater input from east side of brook

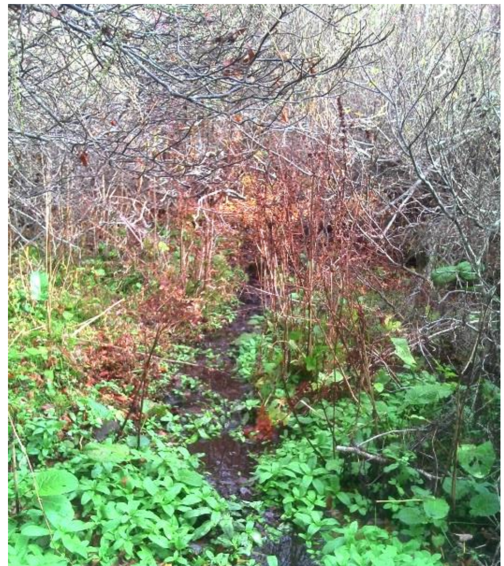
#4 – Groundwater input from east side of brook

#5 – Outlet of breached factory brook

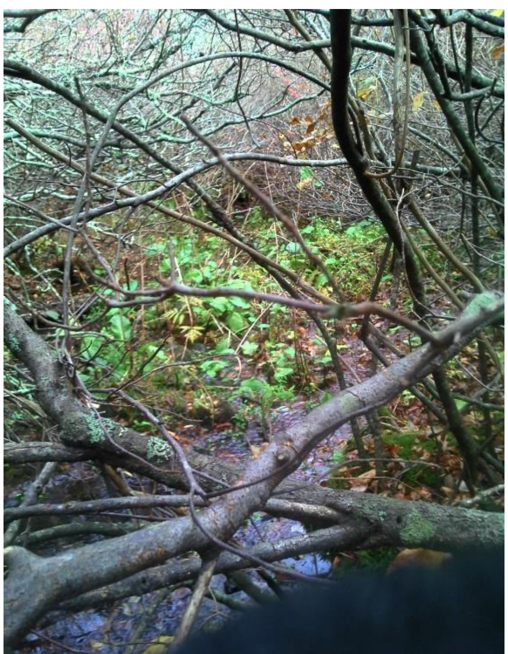
#6 – Outlet of millrace where it meets the brook

Photographs from points on the map in Figure 3

Point 1 – Outlet of Maley Pond at Town Cove

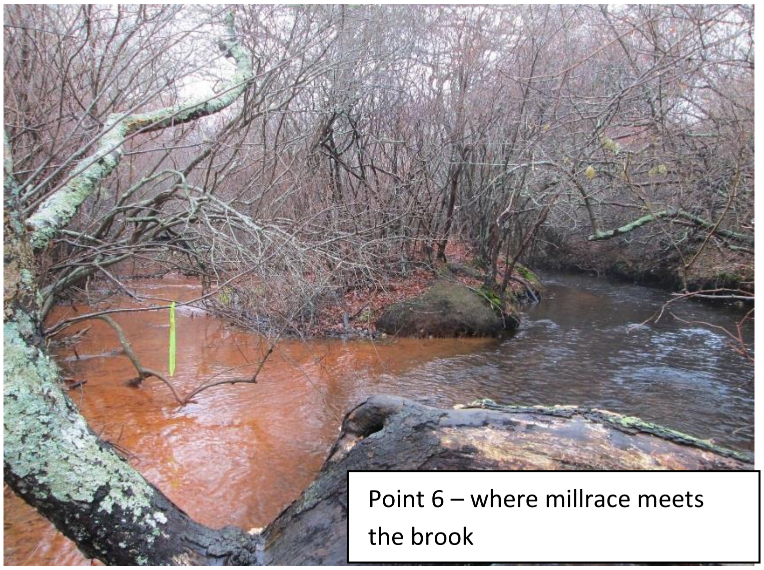


Point 2 – Groundwater input on east side of brook

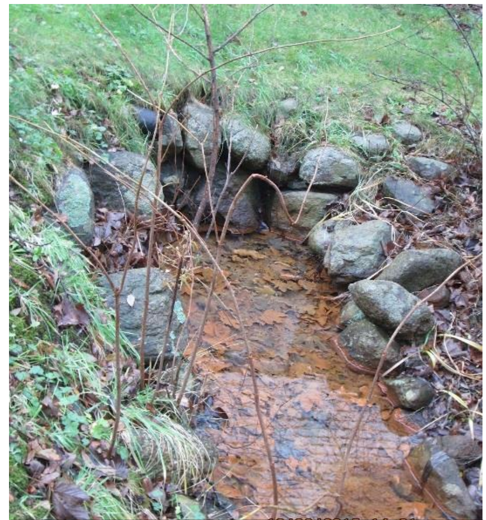


Point 3 – Groundwater input from East side of brook

Point 5 – Outlet of the breached factory brook

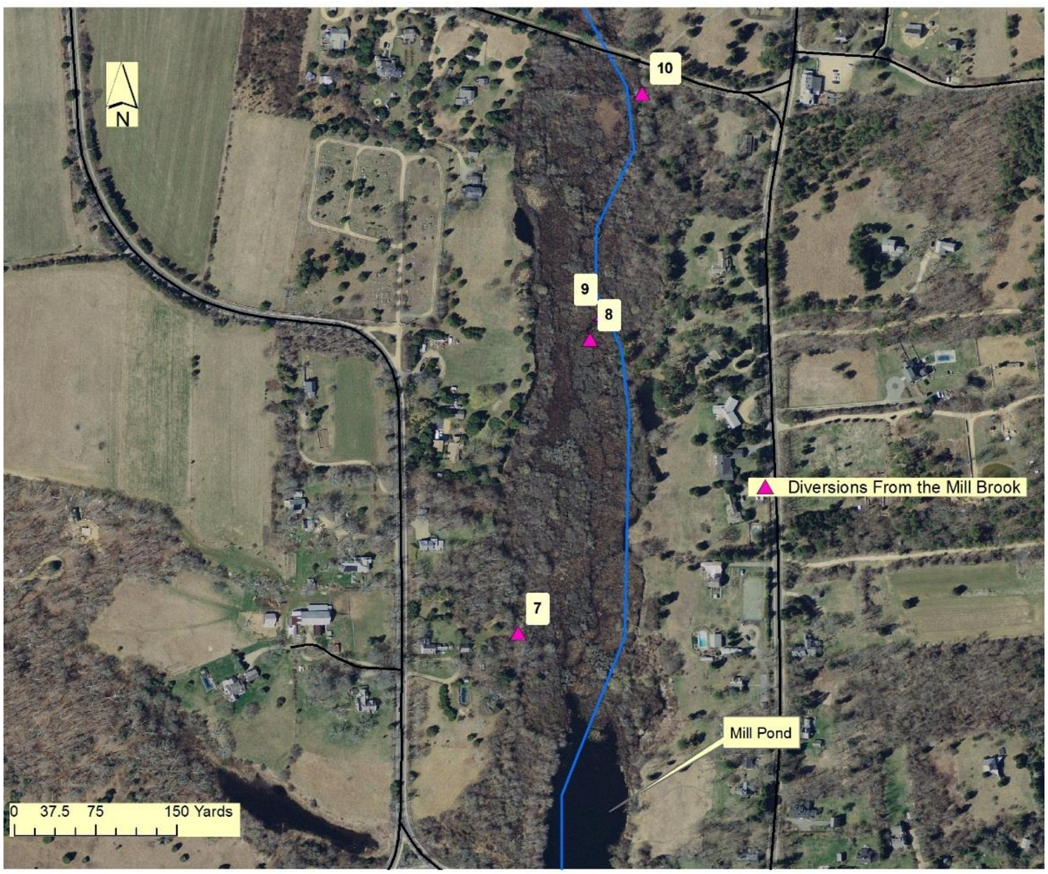


Point 6 – where millrace meets the brook



Groundwater source of the millrace

Figure 4. Showing diversions from the Mill Brook between the Mill Pond and Scotchman's Lane



#7 – diversion to the Parsonage Pond

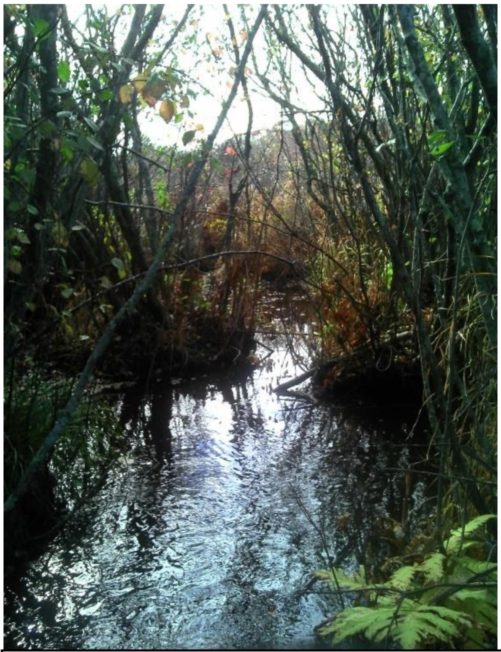
#8 - Diversion to west of book

#9 – Diversion to east of brook

#10 – Beginning of Whiting diversion canal

Photographs from Points on the map in Figure 4.

Point 7 – Beginning of the diversion canal (dry) to the Parsonage Pond



Point 8 – Diversion canal to the West of the brook

Point 9 – Diversion canal to the East of the brook

Point 10 – Beginning of Whiting Diversion canal by Scotchman's bridge

Literature Cited

Lessard, J.L. and D.B. Hayes (2003) Effects of Elevated Water Temperature on Fish and Macroinvertebrate Communities Below Small Dams. River Research and Applications 19:721-732.

Marod, S.M. 1995. The influence of temperature and discharge on movement patterns of brook trout (Salvelinus fontinalis) in the Ford River, Dickinson County, Michigan. M.S. Thesis, Michigan State University, East Lansing, MI.

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Clockwise from left: Sharon Pearson, Cynthia Riggs, Howard Attebery, Laura Murphy, Katie Carlson

Clockwise from left: Laura Murphy, Ken Neagle, Katie Carlson, Emily Goetz, Sharon Pearson

Sharon Pearson and Richard Johnson

Appendix A: Macroinvertebrates Collected and Identified from the Mill Brook Watershed

Common Name	**Life Stage**	**Pollution Score**	**Phylum**	**Class**	**Order**	**Family**	**Genus**	**Species**
fingernail clam	adult	1	Mollusca	Bivalvia	Veneroida	Spaeriidae		
snail 1	adult	1	Mollusca	Gastropoda	Prosobranchia			
snail 2	adult	1	Mollusca	Gastropoda	Prosobranchia			
snail 3	adult	1	Mollusca	Gastropoda	Prosobranchia			
isopod	adult	1	Arthropoda	Crustacea	Isopoda	Asellidae		
Amphipod	adult	1	Arthropoda	Crustacea	Amphipoda	Gammaridae	*Gammarus*	*fasciutus*
Amphipod	adult	1	Arthropoda	Crustacea	Amphipoda	Talitridae	*Hyaella*	*azteca*
Clam shrimp	adult	2	Arthropoda	Branchiopoda				
Riffle beetle	adult	1	Arthropoda	Insecta	Coleoptera	Elmidae		
Riffle beetle	larvae	1	Arthropoda	Insecta	Coleoptera	Elmidae		
Whirligig beetle	adult	1	Arthropoda	Insecta	Coleoptera	Gyrinidae		
Diving beetle	adult	1	Arthropoda	Insecta	Coleoptera	Dytiscidae		
UnID beetle	adult	1	Arthropoda	Insecta	Coleoptera			
Water boatman	adult	1	Arthropoda	Insecta	Heminoptera	Corixidae		
Black fly	larvae	0	Arthropoda	Insecta	Diptera	Simulidae		
Crane fly	larvae	0	Arthropoda	Insecta	Diptera	Tipulidae	*Distera*	*lipulidae*
Water snipe fly	larvae	0	Arthropoda	Insecta	Diptera	Athericidae		
Horse fly	larvae	0	Arthropoda	Insecta	Diptera	Tabanidae		
Soldier Fly	larvae	0	Arthropoda	Insecta	Diptera	Stratiomyidae	*Hermetia*	
Midge	larvae	0	Arthropoda	Insecta	Diptera	Chironomidae		
Phantom crane fly	larvae	0	Arthropoda	Insecta	Diptera	Ptychopteridae		
Stonefly	larvae	2	Arthropoda	Insecta	Plecoptera	Peltoperlidae		
Dobsonfly	larvae	2	Arthropoda	Insecta	Megaloptera	Corydalidae		
Fishfly	larvae	1	Arthropoda	Insecta	Megaloptera	Corydalidae		
Alderfly	larvae	1	Arthropoda	Insecta	Megaloptera	Salidae		
Mayfly	larvae	2	Arthropoda	Insecta	Ephemeroptera	Bactidae		
Dragonfly 1	larvae	1	Arthropoda	Insecta	Odonata	Aeshnidae		
Dragonfly 2	larvae	1	Arthropoda	Insecta	Odonata			
Dragonfly 3	larvae	1	Arthropoda	Insecta	Odonata			
Broad winged Damselfly	larvae	1	Arthropoda	Insecta	Odonata	Calopterygidae		
Narrow winged Damselfly	larvae	1	Arthropoda	Insecta	Odonata	Coenagrionidae		
Damselfly 1	larvae	1	Arthropoda	Insecta	Odonata			
Case building caddis fly	larvae	2	Arthropoda	Insecta	Trichoptera			
Free living caddis fly	larvae	1	Arthropoda	Insecta	Trichoptera	Rhyacophilidae		
Water strider	adult	0	Arthropoda	Insecta	Hemiptera	Gerridae		
Leech	adult	0	Annelida	Hirundinea				
Aquatic earthworm	adult	0	Annelida	Oligochaeta				
Planaria	adult	0	Platyhelminthes	Turbellaria	Tricladia	Planariidae	Planaria	

Appendix B1: Mill Brook Watershed Macroinvertebrate Data by Site and Season

Site	Sub-Site	Month	number of organisms	diversity score	H20 quality score
Fisher	above	June	8	10	11
	above	Aug.	14	16	12
	below	June	11	14	12
	below	Aug.	18	20	13
Crocker	above	June	7	8	5
	above	Aug.	8	10	6
	below	June	13	16	13
	below	Aug.	8	9	5
Priesters	above	June	14	15	13
	above	Aug.	12	15	10
	below	June	15	23	13
	below	Aug.	10	14	8
Alberts	above	June	12	14	10
	above	Aug.			
	below	June	13	19	11
	below	Aug.			
Wascosims		June	13	17	13
		Aug.	15	19	11

Appendix B2: Macroinvertebrate Species Abundance by Site and Season, part 1

Site	Above/below	June/Aug	clam	snail 1	snail 2	snail 3	isopod	Gammaris amphipod	Tallid amphipod	Clam shrimp	Riffle beetle	Whirligig beetle	Diving beetle	Unknown beetle	Water boatman
Fisher	Above	June						C			R				
	Above	Aug.					A	S			R				
	Below	June	C								S	R		R	R
	Below	Aug.	C			S	C	R			S				
Crocker	Above	June	S				S	C							
	Above	Aug.	C			R	A	S							
	Below	June	A	R							R	R			R
	Below	Aug.	C				R	R		R					
Priesters	Above	June		S	R	R	R	A			S	R			
	Above	Aug.	C	S	R		S	C							
	Below	June	A	C			S	C			C				R
	Below	Aug.	A	A				S			A				
Alberts	Above	June	C				R	R			R	S			
	Above	Aug.													
	Below	June	A	A				A			S	S	R	R	R
	Below	Aug.													
Wascosims		June	S				C	C			S				
		Aug.	S			R	C	S			S		R		
feeder brook		June	A	S		A	A	A	R				R		
		Aug.	A			A	A	C			R	S	R		
Witch Brook		Aug.	R	R			S	S			S				

Appendix B2: Macroinvertebrate Species Abundance by Site and Season, part 2

Site	Above/below	June/Aug	Black fly	Crane fly	Water snipe fly	Horse fly	Soldier fly	midge	stonefly	Dobson fly	fishfly	alderfly	mayfly	leech	Aquatic earthworm	Caddis fly	planaria
Fisher	Above	June							R				C	R		S	
	Above	Aug.		R		R		C	R		R		S	S	S	S	R
	Below	June		R				A	R				R		R	C	
	Below	Aug.						R	R		R		S	R	S	S	R
Crocker	Above	June						S	R					R			R
	Above	Aug.													R	R	R
	Below	June	R					C	R		R		C	R		S	
	Below	Aug.						R								S	S
Priesters	Above	June						S		R			S	R	S	S	
	Above	Aug.						S					R		R	C	
	Below	June		R				C	R				S	A	R	A	A
	Below	Aug.						R					S	S		A	S
Alberts	Above	June												R	R	A	R
	Above	Aug.															
	Below	June						C			C			R		C	
	Below	Aug.															
Wascosims		June		R				A	S	S			R	R		A	R
		Aug.			R			A	C			R		R	R	S	R
feeder brook		June	R				R	C	S				S	S	A	S	R
		Aug.						C					R	C	C	R	R
Witch Brook		Aug.						S				R		S	A	S	

Appendix B2: Macroinvertebrate Species Abundance by Site and Season, part 3

Site	Above/below	June/Aug	Phantom crane fly	Water strider	Calopterygidae damselfly	Coenagrionidae damselfly	Unknown damselfly	Aeshnidae dragonfly	Unknown dragonfly	copepod	Free living caddis fly
Fisher	Above	June	R				R				
	Above	F		R			R				
	B	June									
	B	F	R	S			R		R		
Crocker	Above	June									
	Above	Aug.	S								
	B	June							R		
	B	Aug.								R	
Priesters	Above	June						S			
	Above	Aug.			R		R			R	
	B	June		S							
	B	Aug.		R							
Alberts	Above	June		R			R		R		
	Above	Aug.									
	B	June				R					
	B	Aug.									
Wascosims		June		R							
		Aug.	C								
feeder brook		June						R			
		Aug.		R		R	R	S	S	S	
Witch Brook		Aug.									A

Appendix C: Physical Characteristics of the Mill Brook Watershed Sampling Sites

Site	June Visit	August Visit	Stream Width	Bottom Description	June Temp	Aug Temp	June pH	Aug. pH	June O2	Aug O2	June Conductivity	June cond. corrected	Aug. cond. Corrected	H2O Quality Score
Waskosim's	6/3/2015	8/14/2015	6 feet	mud sand gravel	57	62	6.2	6.2	8.4	9.6	91.3	110.6	108.8	13
Fisher above	6/3/2015	8/6/2015	8 feet	mud sand	55	62	6.1	6.4	7.1	7.9	76.1	99.4	108.5	11
Fisher below	6/3/2015	8/6/2015	15 feet	sand gravel cobbles	60	76	6.5	6.6	8.3	6	82.2	100.3	66.5	12
Crocker above	6/10/2015	8/27/2015	45 feet	mud	69	66			5.7	6.1	87.5	96.7	95	5
Crocker below	6/10/2015	8/26/2015	35 feet	mud sand gravel	72	76	6.4	6.6	5.7	7.1	84.8	96.4	94.3	13
Priester above	6/17/2015	8/26/2015	20 feet	sand	69	74	6.4	6.6	7.3	7.3	84.9	93.1	94.8	13
Priester below	6/17/2015	8/26/2015	15 feet	sand gravel cobbles	68	71	6.6	6.6	7.5	7.5	79.3	87.6	86.7	13
Alberts above	6/13/2015		15 feet	mud gravel	71		6.5		6.8		94.2	101.4		10
Alberts below	6/13/2015		15 feet	mud sand	71		6.5		7.4		94.6	101.8		11
Feeder Br.	6/24/2015		6 feet	sand gravel cobbles	61		6		4.9		73.7	89		
Witch Brook		8/27/2015	5 feet	mud sand		65			5.2	5.2	85.2	97.4		

Appendix D1: Plant List from sampling sites along the Mill Brook Watershed, part 1

Plant name	Latin name	Waskosim"s Rock	Below Fisher	Above Crocker	Below Crocker	Above Priester	Below Priester	Unnamed Feeder Brook	Witch Brook
Red maple	Acer rubrum	X	X	X	X	X	X	X	X
Willow species	Salix sp.		X						
Beetlebung	Nyssa sylvatica			X		X	X	X	
Black oak	Quercus velutina				X				
White oak	Quercus alba	X							
Beech	Fagus grandifolia	X			X	X	X	X	
American holly	Ilex opaca					X			
Sassafras	Sassafras albidum	X						X	
Hickory species	Carya sp.							X	
Pignut hickory	Carya glabra	X							
Sweet pepperbush	Clethra alnifolia	X	X	X	X	X	X	X	X
Winterberry	Ilex verticellata	X	X	X	X				
Swamp azalea	Rhododendren viscosum	X	X	X	X	X	X		X
Smooth alder	Alnus serrulata		X						X
Speckled alder	Alnus incana				X	X			
Poison sumac	Toxicodendron vernix		X						
Rose	Rosa palustris (?)		X						
Male berry	Lyonia ligustrina		X						
Highbush blueberry	Vaccinium corymbosum		X	X	X	X	X		
Multiflora rose*	Rosa multiflora			X				X	X
Arrowwood	Viburnum dentatum	X					X		
Dangleberry	Gaylussacia frondosa								
Common elderberry	Sambucus canadensis						X		X
Chokeberry species	Aronia sp.						X		
Greenbrier	Smilax rotundifolia		X	X	X		X		
Dewberry	Rubus hispidus	X	X	X	X	X			X
Virginia creeper	Parthenocissus tricuspidata	X	X				X	X	X
Wild grape	Vitis labrusca		X				X		
* NON-NATIVE INVASIVE SPECIES									

Appendix D1: Plant List from sampling sites along the Mill Brook Watershed, part 2

Plant name	Latin name	Waskosim"s Rock	Below Fisher	Above Crocker	Below Crocker	Above Priester	Below Priester	Unnamed Feeder Brook	Witch Brook
Skunk cabbage	*Symplocarpus foetidus*	X	X				X	X	X
Canada mayflower	*Mianthemum canadense*	X	X	X	X	X	X	X	X
Jewel weed	*Impatiens capensis*		X	X	X			X	X
Violet	*Viola species*		X						X
Poison ivy	*Toxicodendron*	X	X		X		X		
Starflower	*Trientalis borealis*								
Cardinal flower	*Lobelia cardinalis*			X					X
Goldenrod	*Solidago rugosa*			X					
Phragmites*	*Phragmites australis*			X					
Wild sarsaparilla	*Aralia nudicaulis*	X		X	X			X	
Cutleaf water horehound	*Lycopus americanus*			X				X	X
Dock species	*Rumex sp.*								X
Wintergreen	*Gaultheria procumbens*	X							
Dotted knotweed	*Persicaria punctata*	X							
Pylaei's rush	*Juncus pylaei*			X					
Swan's sedge	*Carex swanii*				X				
Swamp sedge	*Carex intumescens*								X
Sedge species	*Carex Sp.*			X					X
Sallow sedge	*Carex lurida*								X
Marsh fern	*Thelypteris palustris*		X						
Sensitive fern	*Onoclea sensibilis*	X							X
Cinnamon fern	*Osmunda cinnamomea*	X	X			X		X	X
Fern species	Fern sp.			X					X
Small fern	Fern sp.				X				
Fern species	*Dryopteris sp.*					X			
Duckweed	*Lemma minor*								

* NON-NATIVE INVASIVE SPECIES