Protecting Trout-Bearing Streams of the Sudbury River Watershed
Final Report – September 2014
S. Flint, OARS

Summary:
OARS, Greater Boston Chapter of Trout Unlimited (GBTU), Sudbury Valley Trustees (SVT), the USGS Conte Fish Research Lab, and UMass Amherst collaborated to assess and protect brook trout habitat in the two Sudbury River tributary streams known to have wild brook trout populations. The project goals were to: review current regulatory protections for cold water streams, assess current conditions, identify remediable threats (undersized culverts, bank and streambed erosion, illicit discharges), create a restoration plan, and contribute to longer-term understanding of the effects of climate change on brook trout. Climate change effects were monitored with longer-term stream temperature logging. A project advisory committee assisted in project planning, assessment, and creation of a prioritized management plan based on findings.

Background:
Native Eastern brook trout (*Salvelinus fontinalis*) are a notable keystone species in the northeastern United States, inhabiting flowing, highly oxygenated, cold-water streams. While brook trout are still relatively common in western and central Massachusetts, eastern populations are greatly reduced. Today, the Eastern Brook Trout Joint Venture estimates that geographically isolated populations remain in only about 10% of the subwatersheds in eastern Massachusetts. The survival of these remaining populations is threatened by habitat degradation (e.g. streamflow and temperature changes due to increased watershed development), dams, undersized or inadequate road culverts, non-point source pollution, climate change, and by competition and predation by non-native fish species (including rainbow and brown trout).

The remaining habitat for brook trout in Eastern Massachusetts are the small headwater streams. In addition to being valuable trout habitat, these small streams are the majority of the river miles, they provide the cooler "baseflow" (that is the groundwater flow) to the larger rivers (particularly critical in the summer), they are the rich "edge habitat" between the woods and the streams providing niches for bugs and breeding areas for fish, the streams are some of the last connections between our rapidly disappearing open spaces.

The effects of climate change are likely to increase the stresses already put on headwater streams. These effects include: air and water temperature increases, increased winter/spring storm intensity, increased frequency of summer droughts, and potential invasion of warmer-climate species. Recent studies have shown that the effects of climate change are already being measured both in changes in stream temperatures (Isaak, et.al. 2010) and in the behavior and breeding success of trout (Warren, et.al. 2012). In addition to protecting these small streams and sensitive trout populations from development-associated threats, a better understanding of the effects of climate change is needed. "Basic fish distribution monitoring programs are needed so that anticipated shifts in species distributions can be accurately described in future decades to provide a clearer understanding of how salmonids integrate and respond to changes in thermal conditions" (Isaak, et. al. 2010).

The work already being done to protect streams, streamflow and groundwater protection, low impact development (LID), riparian area protection, and river reconnection efforts, will help streams be resilient to disturbances associated with climate change by: reducing impervious areas, increasing groundwater recharge, reducing and treating stormwater runoff, reconnecting streams with their natural flood plains, protecting flood plains and river-edges from development (Haak et.al. 2010).

Project Goals: The project goals were to: assess current conditions, identify remediable threats (undersized culverts, bank and streambed erosion, illicit discharges), create a restoration plan, and contribute to longer-term understanding of the effects of climate change on brook trout. For practical reasons, the project focused on two brooks, Trout Brook and Cranberry Brook, for detailed habitat and crossings surveys and collected temperature and water quality data on Hop Brook at sites immediately downstream of the confluence of Trout and Hop Brooks.

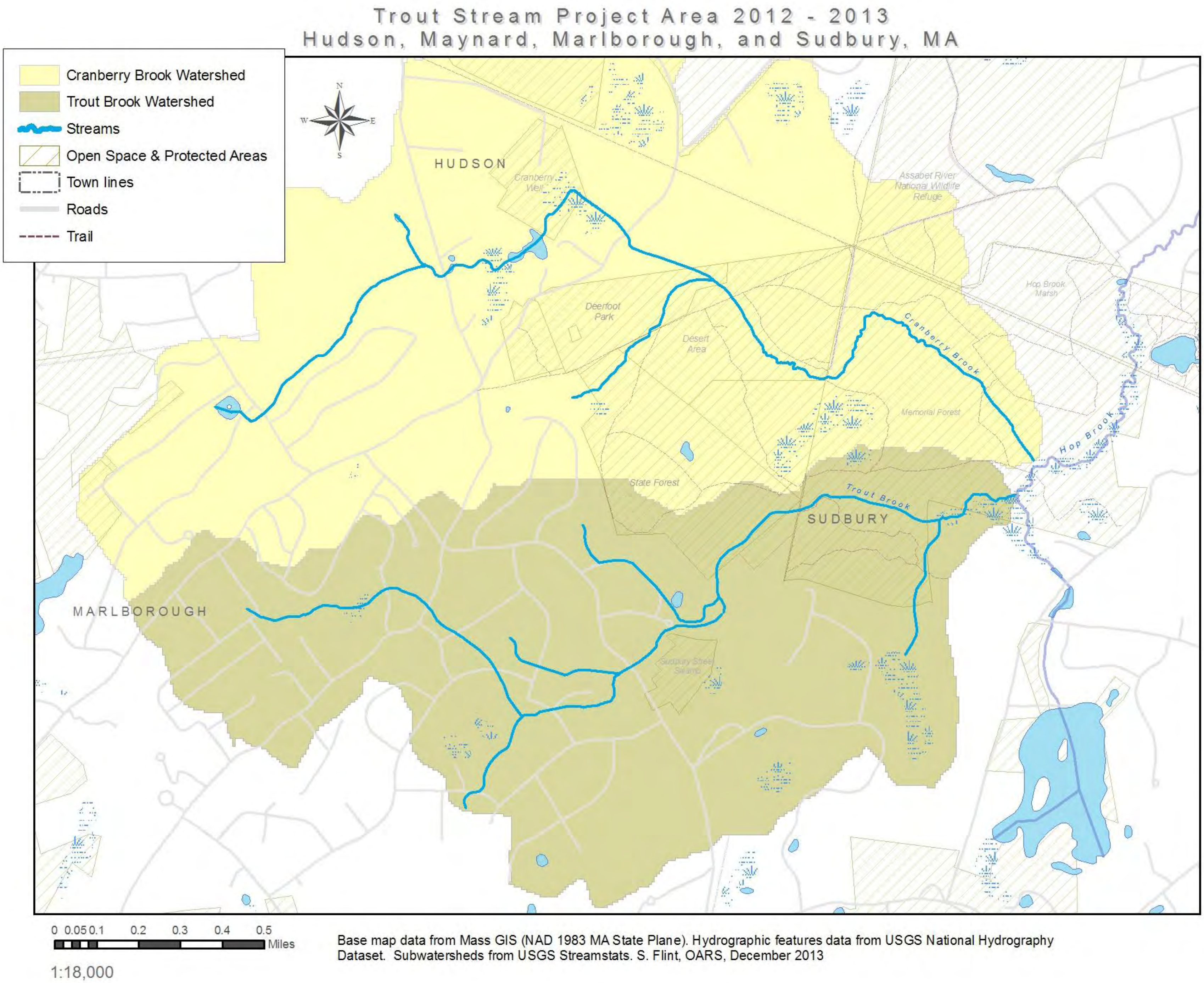
Project partners:
OARS: OARS' mission is to protect, improve, and preserve the Assabet, Sudbury, and Concord rivers, their tributaries and watersheds. We believe that it is vital to raise awareness of the value of and to protect the small, relatively unrecognized streams and that protecting sensitive populations of native brook trout (and other cold-water species) helps ensure protection of the larger ecosystem.
USGS Conte Anadromous Fish Research Center: Ben Letcher's group has been working on understanding of salmonid population dynamics from detailed studies of small areas using tagged individuals, broad-scale studies of untagged trout populations, and DNA studies to examine ancestry, sibling relationships, and population/spatial dynamics. The DNA analysis is being done by Andrew Whiteley of UMass Amherst.
Greater Boston Trout Unlimited: GBTU is interested in the protection and restoration of native brook trout. Greater understanding of trout populations will contribute to TU's ability to protect them.
Sudbury Conservation Commission : The Commission is charged with enforcing the wetlands and river protection acts in Sudbury. They've amended the Town Wetlands Administration bylaw to provide additional protection for cold-water fisheries; this bylaw might be a model for other towns.
Sudbury Valley Trustees: SVT manages Memorial Forest, which is among their priority conservation areas.

Methods:
Advisory Committee: The initial project advisory committee meeting was held October 3, 2012, with 12 attendees representing all of the project partners. The original project plan was revised to (1) include DNA analysis of trout populations from neighboring streams to examine ancestry, sibling relationships, and contribute to a better understanding of population/spatial dynamics, and (2) to include analysis of the conditions in Hop Brook, the stream that both Trout and Cranberry Brook discharge into, to assess the potential use of that stream by trout. The project advisory committee met at the end of the project to review the findings and make management recommendations.

Review of Regulatory Protections for designated cold water fisheries streams. OARS intern, Aaron Bembenek, reviewed the regulatory protections afforded to designated CFRs in Massachusetts (separate report).

Project Location: An overview of the project area is shown in Figure 1. Trout Brook and Cranberry Brook arise in Marlborough, flowing through suburban areas of eastern Marlborough and Hudson (in the case of Cranberry Brook) and then into the protected areas of the Desert Natural Area, Marlborough conservation land, and Memorial Forest. Trout Brook, Cranberry Brook and a small, unnamed tributary to Hop Brook in Memorial Forest were surveyed by Mass Fish and Wildlife in 2011, confirming that sections of the streams are habitat to breeding populations of native brook trout.

Figure 1: Trout Stream Project Area



Streamstats (USGS) analysis and GIS: The USGS Streamstats web application was used to delineate the sub-basins and determine streamflow statistics for Trout Brook, Cranberry Brook, and Hop Brook (upstream of Surrey Lane). The project data was mapped using ESRI ArcGIS 9.0: sub-watersheds, temperature logging locations, stream habitat survey locations and ratings, water quality sampling locations, crossings (culverts and roads) locations and ratings. Streamflow statistics from Streamstats are shown in Table xx.

Table 1: Streamstats Statistics for Cranberry, Trout, and Hop Brooks

	Stream		
Statistic	Cranberry Brook	Trout Brook	Hop Brook
Drainage area (sq. mi)	1.8	1.36	7.73
Mean Basin Slope (%)	2.04 %	2.08 %	2.82 %
Stratified Drift per Stream Length (sq. mi./mile)	0.32	0.24	0.27
Percent Underlain By Sand And Gravel (percent)	53.04 %	52.49 %	47.97 %
Percent Forest (percent)	43.54 %	21.09 %	42.72 %
Percent Urban	31 %	41 %	27.8%
Percent Impervious	6.31 %	11.8 %	7.83 %
50% Flow Duration [D50] (cfs)[a]	1.74	1.31	7.69
75% Flow Duration [D75] (cfs)	0.66	0.45	3.02
95% Flow Duration [D95] (cfs)	0.19	0.11	1.0
August median flow [AUGD50] (cfs)[b]	0.47	0.3	2.18
Two year 7-day mean low flow [M7D2Y] (cfs)[c]	0.19	0.12	0.99
Ten year 7-day mean low flow [M7D10Y] (cfs)[d]	0.08	0.05	0.46

[a] Flow durations: Streamflow exceeded x% of the time
[b] August streamflow exceeded 50% of the time
[c] 7-Day mean low-flow that occurs on average once in 2 years
[d] 7-Day mean low-flow that occurs on average once in 10 years

Water quality: Water quality sampling (for dissolved oxygen, pH, water temperature, conductivity, total and dissolved phosphorus, nitrates, ammonia, and total suspended solids) was conducted in November, May, and August, in conjunction with OARS' regular river sampling at three sites: Trout Brook, Cranberry Brook, and Hop Brook (the stream into which both Cranberry and Trout Brook discharge). The sampling was conducted in accordance with the "Quality Assurance Project Plan for OARS' Water Quality and Quantity Monitoring Program" (approved May 2013). Water quality data are shown in Appendix A. In general, water quality at the Trout Brook and Cranberry Brook sites was good. Hop Brook was considerably warmer (about 1.5 °C in November and March and 5°C warmer in August) than Trout and Cranberry Brooks and had elevated phosphorus concentrations in the summer. Hop Brook receives the treated discharge from the City of Marlborough's Easterly wastewater treatment facility and is impacted by a series of dams forming four ponds along the brook (Hager, Grist Mill, Carding Mill and Stearns Mill Ponds).

Habitat surveys: The general stream-walk surveys (for habitat conditions, culverts, dams, bridges) were conducted between September 15th and November 15th 2013, by trained volunteers and OARS staff. Thirty-one stream sections, covering about 3.5 miles of stream, were completed on Trout and Cranberry Brooks from their confluences with Hop Brook to dry stream sections upstream of Draper Circle, Marlborough, on Trout Brook and Parmenter Road, Marlborough, on Cranberry Brook.

Table 2: Water Quality Data

Site #	Name	Date	Time	TSS	TP	ortho-P	NO3	NH3	water temp	DO sat	DO	Cond	pH
				mg/L	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*° C*	*%*	*mg/L*	*µS/cm*	*S.U.*
HBS-065	Hop Brook	11/16/2012	10:19:00 AM	1.5	0.03	0.02	1.8	< 0.1	6.21	91.8	11.34	342	7.69
CRN-002	Cranberry Brook	11/16/2012	11:00:00 AM	1.5	< 0.01	< 0.01	0.22	< 0.1	4.69	93.7	12.06	113	7.62
TRT-006	Trout Brook	11/16/2012	11:34:00 AM	1	0.02	< 0.01	0.61	< 0.1	5.67	87.6	10.98	242	7.41
HBS-065	Hop Brook	3/29/2013	11:00:00 AM	1.5	0.01	< 0.01	2.8	< 0.1	6.88	110.8	13.46	494	7.50
CRN-002	Cranberry Brook	3/29/2013	10:39:00 AM	2	< 0.01	< 0.01	0.42	< 0.1	5.42	101.1	12.75	185	6.81
TRT-006	Trout Brook	3/29/2013	10:00:00 AM	1	< 0.01	< 0.01	0.9	< 0.1	6.02	93.0	11.56	209	6.80
HBS-065	Hop Brook	7/22/2013	9:57:00 AM	5.5	0.16	0.09	0.08	< 0.1	23.98	70.5	5.93	746	7.40
CRN-002	Cranberry Brook	7/22/2013	9:30:00 AM	4	0.03	0.02	0.09	< 0.1	18.87	85.5	7.94	169	6.85
TRT-006	Trout Brook	7/22/2013	9:06:00 AM	2.5	0.07	0.06	0.35	< 0.1	20.18	71.8	6.50	318	6.63

Sampling locations: Site Lat/Long (NAD 83 decimal degrees) and description

Hop Brook (HBS-065): 42.372756/-71.467202 Memorial Forest footbridge by Women's Federation , Sudbury, MA

Cranberry Brook (CRN-002): 42.375761/-71.46920 Memorial Forest footbridge on Heron Spur trail, Sudbury, MA

Trout Brook (TRT-006): 42.371489/-71.477922 Memorial Forest footbridge at pipeline pass, Sudbury, MA habitat survey forms were adapted from Massachusetts Riverways Adopt-a-Stream surveys and the EPA Rapid Bioassessment Protocol surveys (a sample form is in Appendix A), to capture habitat information in a simple survey that could be readily conducted by volunteers. Concurrent with the habitat surveys, in-situ water quality measurements were taken. Survey sections were approximately 100 – 300 meters long, aiming to have consistent conditions within each section. Based on the survey parameters and GIS analysis of distance between potential barriers to passage and riparian width, each section was rated as habitat for trout (Appendix B). Parameters included in the rating were: bed material, average riparian width, channel flow status, gradient, sinuosity, presence of large woody debris, undercut banks, overhanging vegetation, bank condition, riparian area vegetation, visible land uses, known presence of fish, stream length between barriers, dissolved oxygen, and pH. Water temperatures from the measurements taken during the habitat surveys were not included in this assessment because they are fall measurements. Further analysis should include summer temperature measurements from the temperature logging. None of the stormwater outfalls observed were flowing; no follow up outfall testing was necessary. Results of the habitat assessments are shown in Figure 6.

In general, the stream quality was good to excellent within the protected areas of Memorial Forest, the Desert Natural Area, and adjoining protected areas. The main difference between the “good” and “excellent” ratings in these protected areas were whether the stream was shaded or running through an open marshy area, where stream temperatures were generally warmer and cover less abundant.

The upstream areas of both Trout and Cranberry Brooks, are in developed areas in Marlborough and Hudson. Sections of the upstream areas of both brooks were dry during the course of these surveys, so ratings are based on physical habitat and not on water quality measurements. Most upstream sections were rated “fair” to “poor” habitat for trout, limited mainly by the number of culverts, the proximity of development, or the presence of an active beaver dam.

Stream crossing assessments: Eighteen stream crossing surveys were conducted by OARS staff and trained volunteers between September 15th and November 15th 2013, and one more surveyed in 2014. The stream continuity methodology developed by the River Continuity Partnership was used to assess culverts and bridge crossings as barriers to fish passage. Assessment data was entered into the River and Stream Continuity Database for rating (http://www.streamcontinuity.org/cdb2/) each crossing as a barrier to fish and animal passage. These crossings will be included in the upcoming Critical Linkages Analysis being conducted by UMass and The Nature Conservancy (http://www.umasscaps.org/applications/critical-linkages.html).

Results of the crossings surveys are shown in Figure 6. The spreadsheet of data is attached (Appendix C). Of the crossings surveyed, ratings were: one “insignificant barrier”; seven “minor barriers”; nine “moderate barriers”; one “significant barrier”; and one “severe barrier.”

Most of the road crossings in the upper sections of Trout Brook, are part of a development done in the 1980’s (between the last USGS scanned topographic map of the section and today; see Figure 7). Some of the development in this section was in violation of the Mass Rivers Protection Act and Wetlands Protection Act (pers. comm. Priscilla Ryder). Four notable crossings in this section (Figure 4) include:

- a 300-ft long culvert at the corner of Harper and Woodcock Lane (fish, likely trout, were observed in the scour hole at the outlet of this culvert)
- a buried section of stream (1200+ feet) under Minehan Lane; the inlet is a vertical concrete box overflow from a small pond
- a 400-ft long culvert under Prendiville Way on a tributary branch of Trout Brook

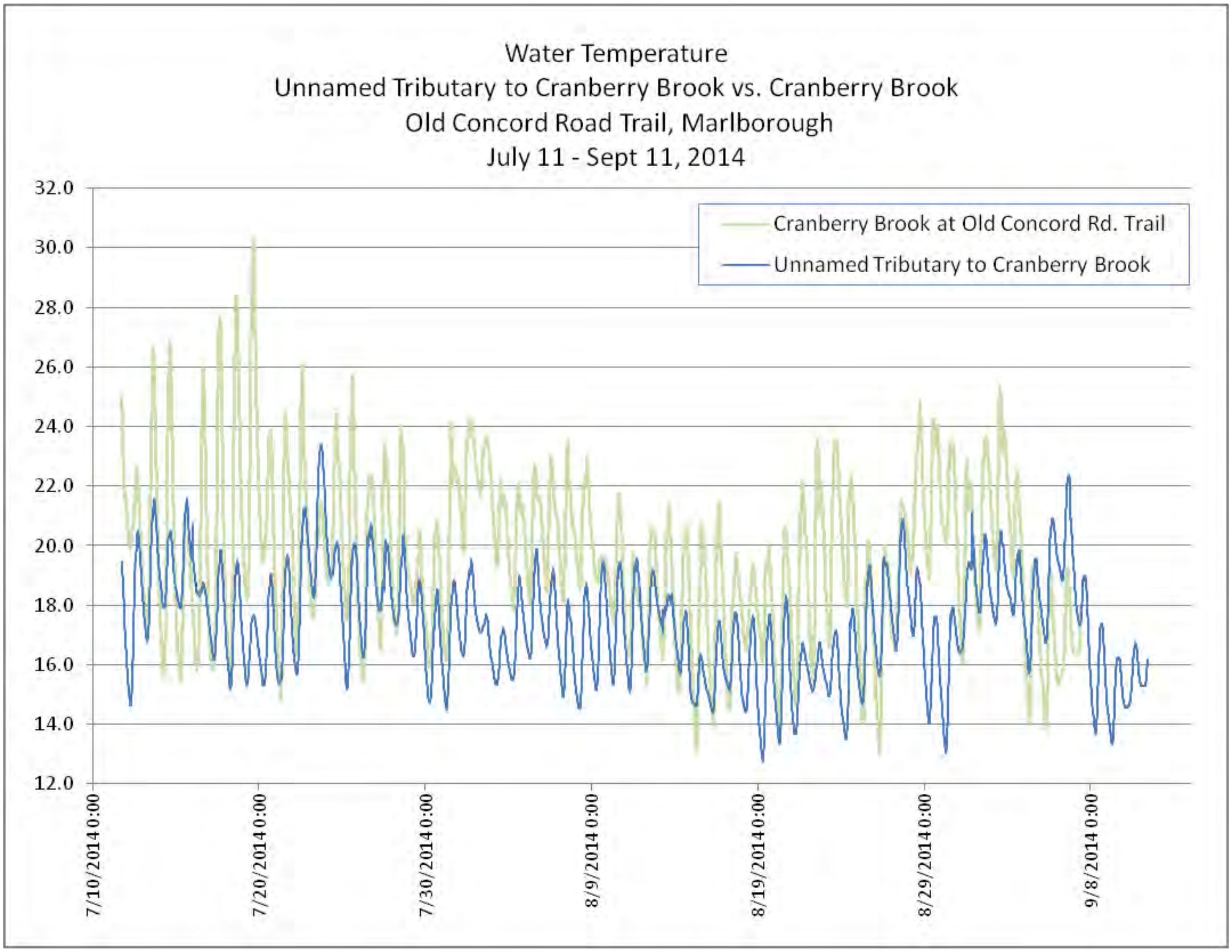
- an old dam forms a 36” drop at the inlet of the culvert under Hemenway Street

The upper section of Cranberry Brook is affected by a large, active beaver impoundment upstream of White Pond Road and is a section that appears to have been used as cranberry bogs. The culvert at White Pond Road, Hudson, has a large scour pool downstream. The section between Parmenter Road and Goodale Street was dry in October and was not surveyed. At the headwater of the stream, between Goodale Street and Vega Road, there is a 350-ft long culvert with a small pond at the inlet.

An unnamed tributary to Cranberry Brook runs from near small parking lot at the junction of Mosher Lane and Concord Road into the Marlborough-Sudbury State Forest (owned by DCR), the Desert Parcel (City of Marlborough). About half way down its course, the brook passes through a small culvert (Figure 2) under Old Concord Road, which is now a walking trail. The culvert is rated a “moderate barrier” to passage. About 18 feet upstream of the culvert is a small (20-inches tall) stone block dam; about 25 ft farther upstream is a second, smaller stone dam. The stream joins Cranberry Brook (a Cold Water Fishery Resource) downstream of White Pond Road and upstream Cranberry Brook’s crossing with Old Concord Road Trail. OARS collected water temperature data in the stream (just upstream of the culvert at Old Concord Road Trail) over the summer of 2014 (data below) that suggest that the stream is an good cold water fishery stream. Figure 3 shows water temperature data from the unnamed tributary compared with data from Cranberry Brook taken just downstream of the confluence of the tributary and Cranberry Brook.

Figure 2: Culvert on unnamed tributary to Cranberry Brook

Figure 3: Water Temperature Data - Summer 2014



Other observations:

- The trail in the "Hop Brook Marsh" conservation area crossing the unnamed tributary to Hop Brook shows signs of erosion from the hillsides and AVT tracks through the stream. Figure 4 looking upstream from below the footbridge.
- A large (4 ft high) pile of grass clippings was found on the upstream side of the culvert at Trout Brook at Graham Path, Marlborough.
- Yard waste and grass clippings were frequently seen at the edges of lawns abutting the streams.
- A patch of *Phragmites* is growing in the beaver impounded section of Cranberry Brook upstream of White Pond Road in Hudson.
- Water quality in the beaver impoundment upstream of White Pond Road is poor for fish (very low dissolved oxygen levels, 3.4%, and low pH 5.68).

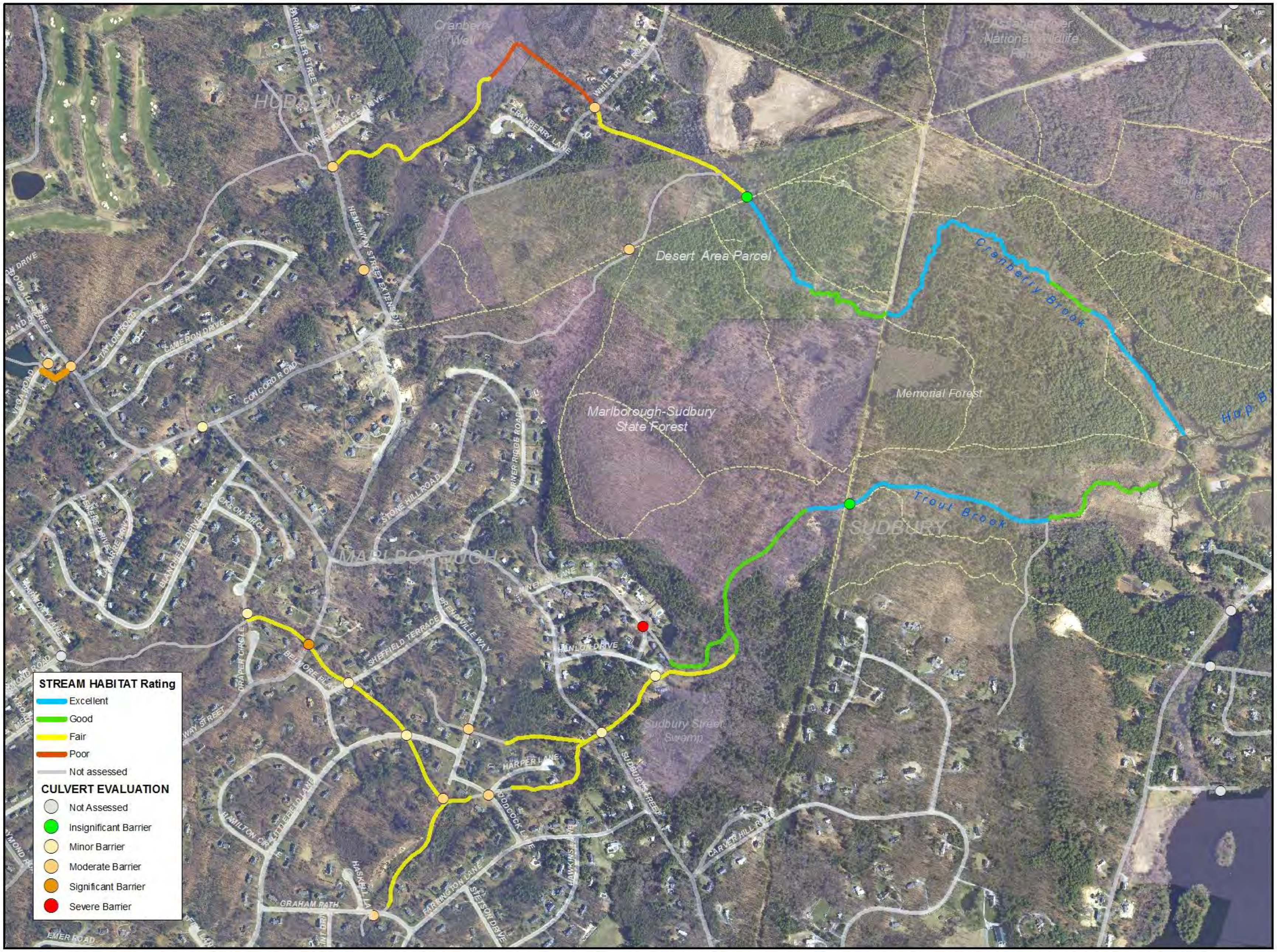
Figure 4: Erosion at unnamed tributary

Phragmites in beaver impoundment.

Figure 5: Beaver impoundment of Cranberry Brook

Figure 6: Habitat and culvert ratings

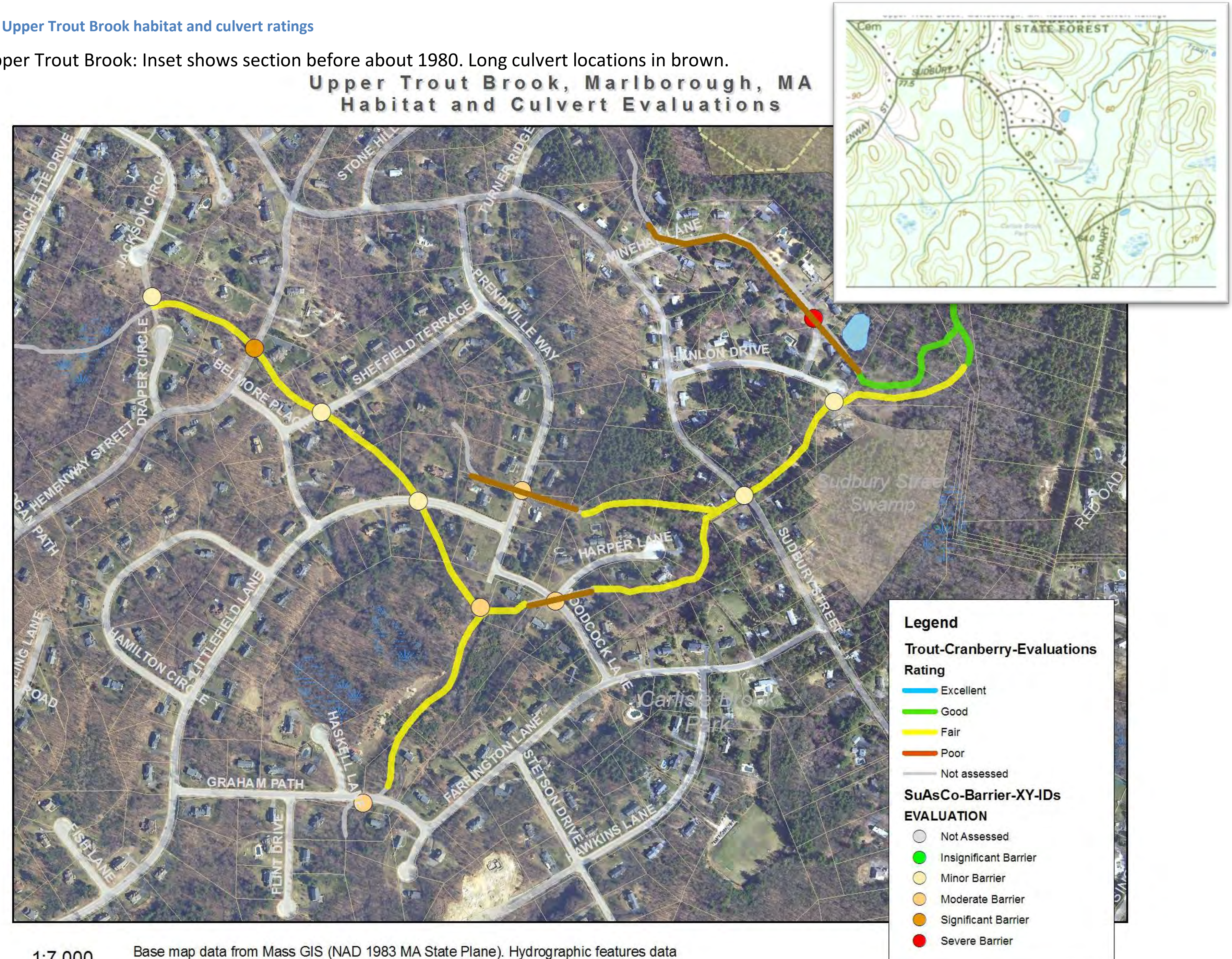
Habitat and Culvert Evaluations - Cranberry & Trout Brooks



1:13,000 Base map data from Mass GIS (NAD 1983 MA State Plane). Hydrographic features data from USGS National Hydrography Dataset. S. Flint, OARS, Sept 2014

Figure 7: Upper Trout Brook habitat and culvert ratings

Upper Trout Brook: Inset shows section before about 1980. Long culvert locations in brown.



1:7,000

Base map data from Mass GIS (NAD 1983 MA State Plane). Hydrographic features data from USGS National Hydrography Dataset. S. Flint, OARS, October 2013

Temperature monitoring: Temperature monitoring was conducted to assess current temperature conditions and contribute to longer-term understanding of the effects of climate change on small trout-bearing streams. The OARS logging protocol was developed based on recommendations from USGS (pers.com. David Armstrong) and Washington State Department of Ecology (2003). Onset TidBit temperature loggers were checked for accuracy before deployment and are installed at nine locations: Hop Brook (2 locations), Cranberry Brook (4 locations), Trout Brook (2 locations), and the unnamed tributary to Hop Brook. To record paired air and water temperatures, four locations had air temperature loggers installed within about 10 feet of the stream temperature logger. Water temperature loggers were installed in mid-channel, about 3-6 inches above the streambed, and deep enough to remain underwater (hopefully) throughout the year. Air temperature loggers were hung about 4 feet off the ground, within about 10 feet of the water temperature logger, on the north side of a tree or in the shade of another structure.

Figure 8: Water temp. logger installation

There are (to date) full records from December 2012 to July 2014 for the locations at Trout Brook (air and water), Cranberry Brook (air and water), and Cranberry Brook (water only). Over the winter loggers were lost from the air temperature logging site at Hop Brook and the unnamed tributary; both were replaced in July 2013. One logger at the second Hop Brook site failed to work and has been replaced (as of November 2013). Loggers at the upstream-most sites on Cranberry Brook and Trout Brook were installed in October 2013. A logger was installed on the unnamed tributary to Cranberry Brook in July 2014. OARS will continue to download the data from these loggers until the batteries stop working (about 5 years). The full records are available in spreadsheet format.

Figure 9: Air temp. logger installation

Figures 10 -13 show: (1) air and water temperature records for Trout Brook over 2013, (2) Trout Brook over the (arguably) hottest week of the summer of 2013, (3) and a three-site comparison of temperatures for Cranberry Brook, an unnamed tributary (labeled "seep") to Hop Brook, and Hop Brook near Surrey Lane (downstream of the confluence of Cranberry Brook with Hop Brook) from July 15 to Sept 15, 2013 (a summer period that is commonly used in analysis of stream temperature data), and (4) the unnamed tributary to Cranberry Brook compared with Cranberry Brook immediately downstream of the confluence of the tributary with Cranberry Brook.

It is worth noting that stream temperatures at the Trout Brook site went about 25°C on eight days over the summer, including five successive days in July 2013. This is the same period of time when a fish kill was observed on the nearby Assabet River in the open sections of the river in Stow, MA. Over the summer (after the logger was re-installed on 7/24/13), the maximum temperature recorded at the unnamed tributary to Hop Brook was 19.4°C.

Figure 10: Air and water temperatures, Trout Brook, 2013

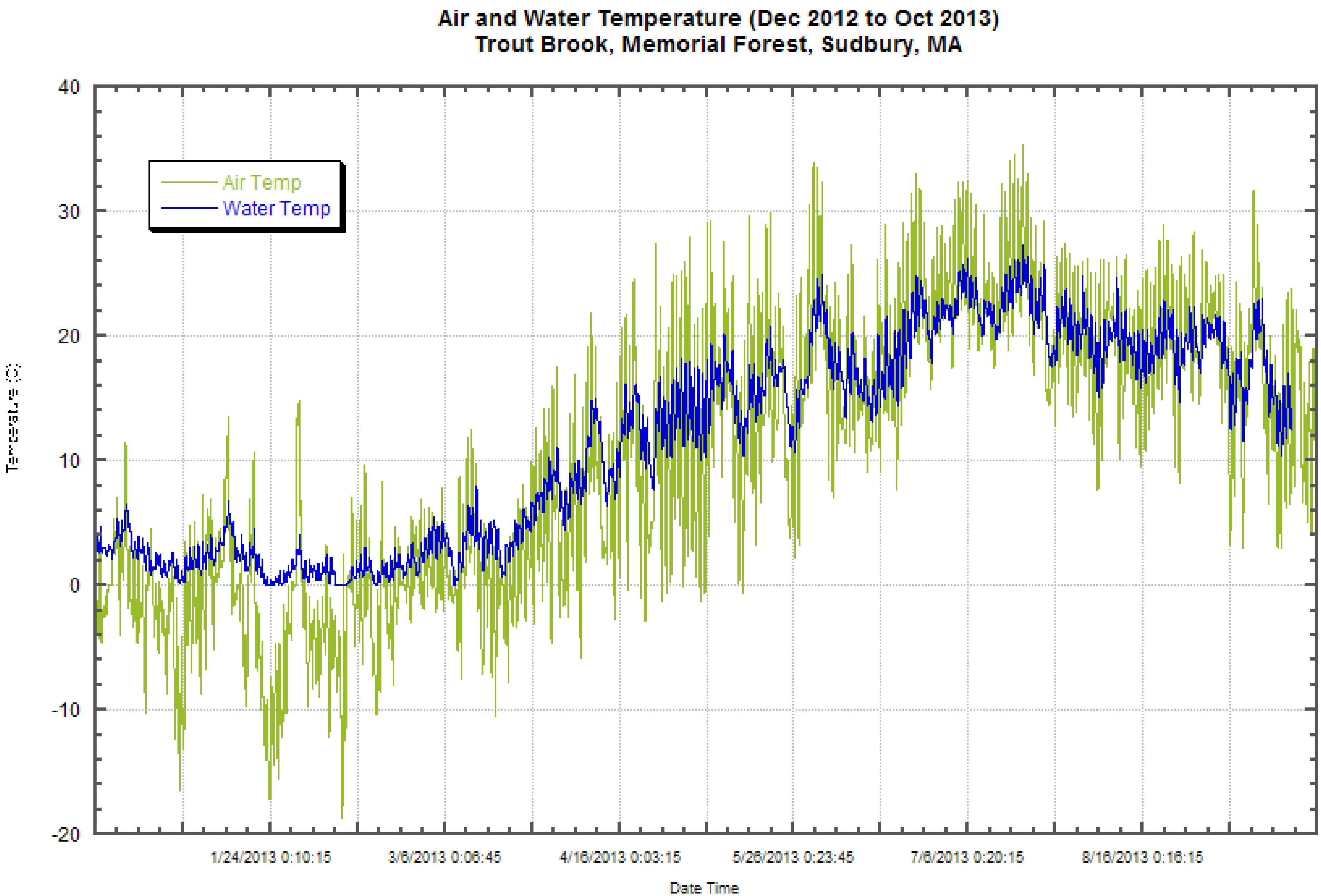


Figure 11: Air and water temps.; three brook comparison, July 15- 21, 2013

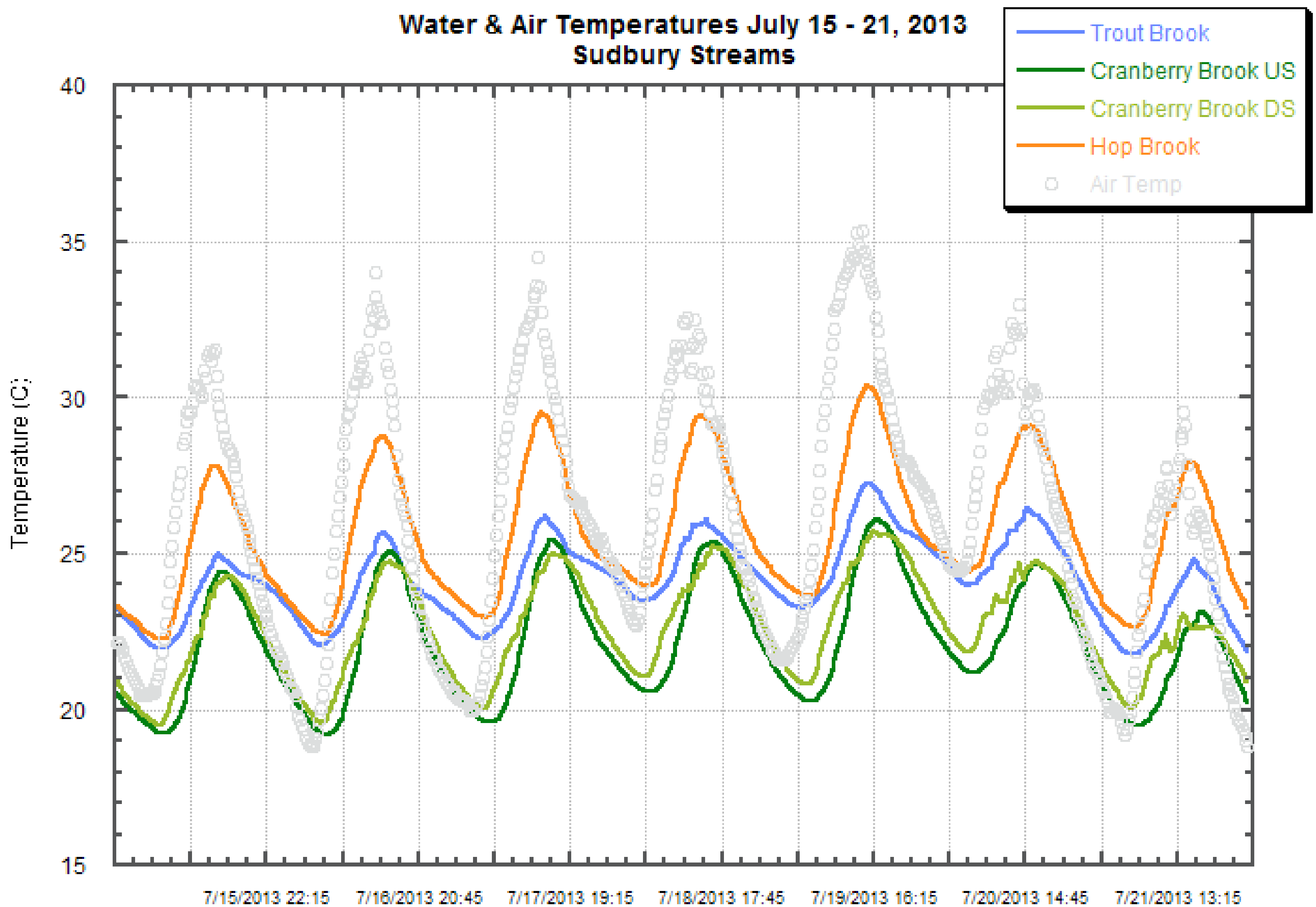


Figure 12: Summer Water Temperatures

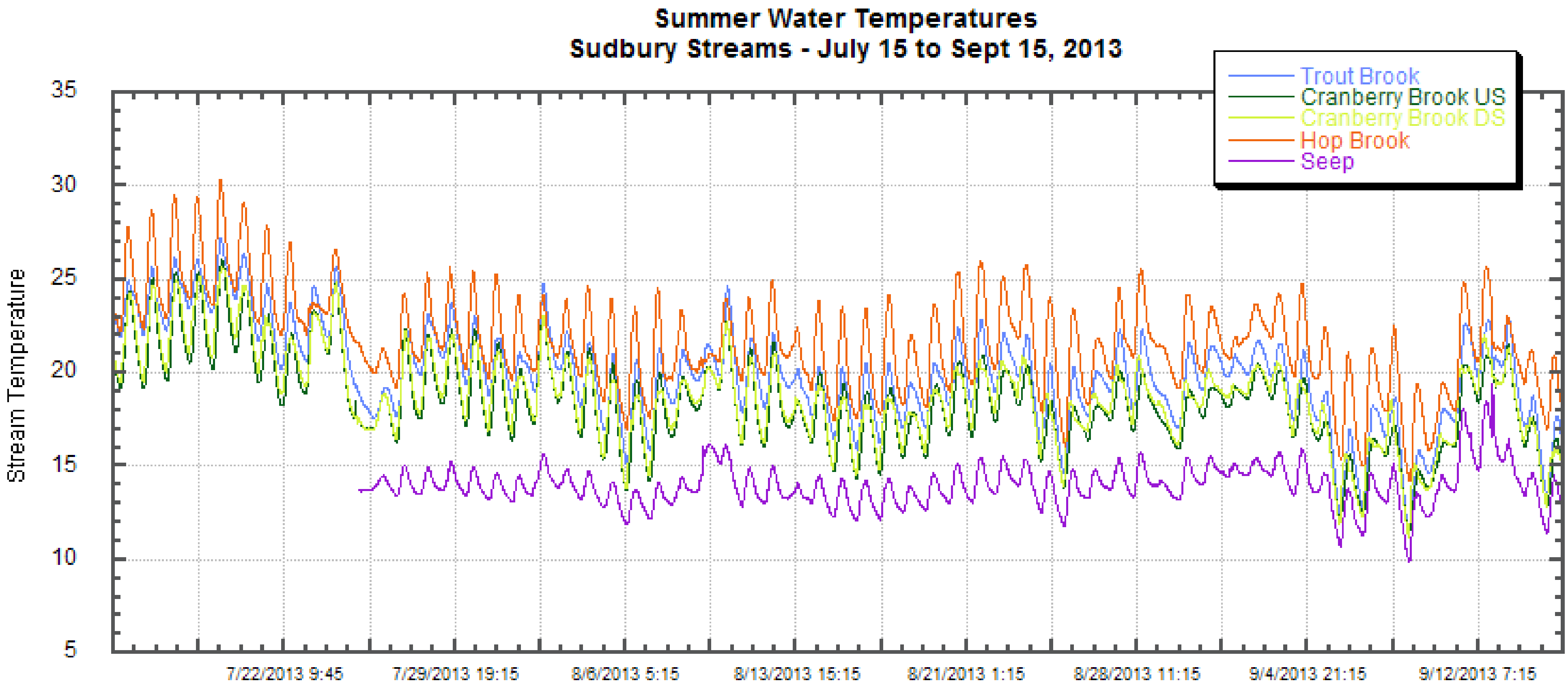
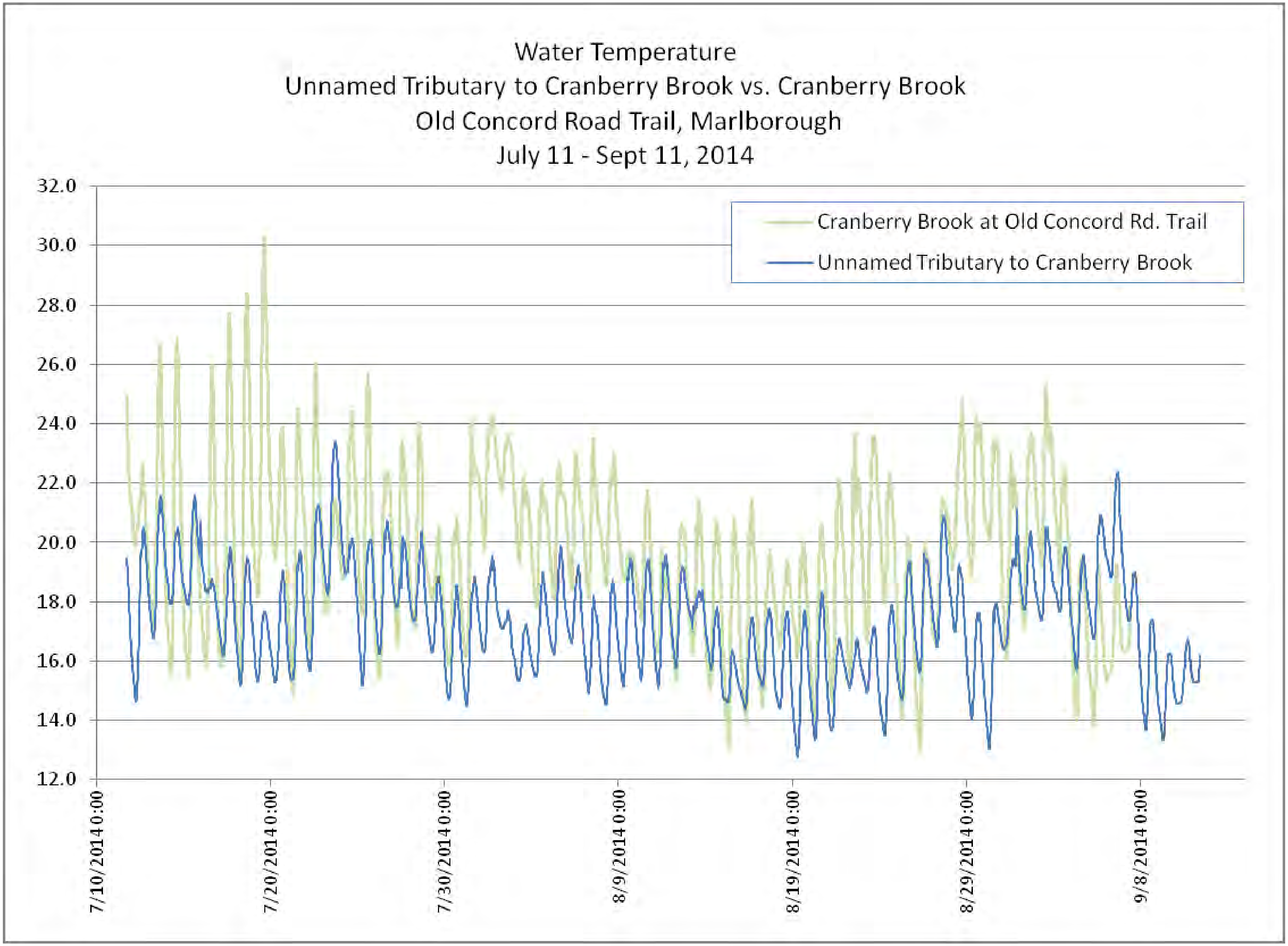


Figure 13: Summer Water Temperatures (UNT Trib and Cranberry Brook)



Trout population genetic analysis:
The original project plan called for fish survey data to be collected and compared with the population data already collected on Trout and Cranberry Brooks. However, it was determined that the data collected by MA Fish and Wildlife did not meet the criteria to be included in the study. Therefore it was decided that Dr. Whitely of UMass would conduct genetic analysis of the isolated trout populations in the unnamed tributary to Hop Brook and in Cranberry Brook. This contributes to ongoing work by UMass and USGS developing a predictive framework for conservation of fragmented populations. Dr. Whiteley's blog describes the work (http://blogs.umass.edu/awhitele/syllabus/): "Genetic data can be used to construct family relationships in the form of pedigrees. Genomic data can be used to identify the precise genes or regions of the genome that are affected by fragmentation. I am currently beginning collaborative work with Ben Letcher (USGS) and Keith Nislow (USFS) to develop a more substantial link between ecology and evolution in a stream fish affected by fragmentation. We will combine a long-term field study of a natural brook trout population with recent advances in genetic and genomic techniques and technologies to gain novel and previously unavailable information on the evolutionary effects of fragmentation on riverine brook trout (*Salvelinus fontinalis*) populations in New England. This evolutionary information, including fitness consequences of key traits and their genomic basis, is essential for conservation and management of fish populations in fragmented landscapes."

In December 2013, Dr. Whitely reported on the genetic analysis (Appendix D). A total of 57 brook trout (*Salvelinus fontinalis*) were examined at eight microsatellite loci from Hop Seep and Cranberry Brook. There were 27 fish from Hop Seep and 30 fish from Cranberry Brook. Of these, there were 13 young-of-the-year (YOY, defined as < 100mm) from Hop Seep and 15 YOY from Cranberry Brook. Several data quality tests revealed no quality issues for the genetic data.

The large proportion of YOY included in the sample could influence results if there were strong full-sibling family structure. The presence of full-siblings in the YOY from both sites was, therefore, tested. The largest family contained seven full-siblings, all from Hop Seep. Thus, of the 13 YOY sampled in Hop Seep, 54% of them appear to belong to one full-sibling family. Other full-sibling families were smaller and less credible, given the small sample size. Additional support for the accuracy of the largest family comes from a clustering program called STRUCTURE. Each individual was assigned to one of two genetic groups. One of these groups consisted entirely of the seven-member full-sibling family (Fig. 1). If population-level structure were present, this method would have allowed us to detect it. Instead, little-to-no population level structure was observed.

There are two major takeaway points from this analysis: 1) both sites had a surprisingly high amount of within-population genetic diversity. 2) there appears to be genetic connectivity among sites. Isolated populations lose genetic diversity each generation. However, gene flow serves to maintain genetic diversity within sites and minimize genetic divergence between sites. These results suggest that movement between Hop Seep and Cranberry Brook occurs, possibly seasonally when downstream conditions are favorable. While genetic diversity was high in both populations, over half of the YOY in Hop Seep appeared to belong to a single half-sibling family. This could indicate a tendency for inbreeding and successful reproduction by few adults in this site. However, if few adults successfully reproduce each year, heterozygosity would likely not be as high as it is. Yet, heterozygosity tends to be lost slowly, so it would be worth analyzing this population again to see if relatively few adults tend to contribute to subsequent cohorts.

CONCLUSIONS: Management recommendations

- Discuss the trail erosion and AVT use on near the unnamed tributary to Hop Brook with Sudbury Conservation Commission.
- Request Mass Fish and Wildlife electrofishing surveys on:
    - the upper section of Trout Brook between Sudbury Road and Woodcock Lane, Marlborough
    - unnamed tributary to Cranberry Brook off Old Concord Road trail in Marlborough (in the Marlborough-Sudbury State Forest and Desert Area Parcel).
- Start discussions with Marlborough Conservation Commission of possibly remediating culverts:
    - shortening/daylighting the culvert at Woodcock Lane
    - removing or remediating the old dam at Hemenway Road
    - remediating the culvert on the unnamed tributary to Cranberry Brook at Old Concord Road trail
- Start discussions with the Hudson Conservation Commission about remediating the culvert on Cranberry Brook at White Pond Road.
- Conduct outreach around dumping of lawn clippings and yard waste.
- Continue temperature monitoring at current sites and consider adding loggers at other locations.
- Investigate additional protections for Hop Brook as a Cold Water Fishery
- Conduct additional genetic analysis of the trout populations of the “seep” tributary to Hop Brook and Cranberry Brook

References:

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470 MacArthur Blvd., Bourne, MA 02532

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USGS Streamstats Flow Duration Statistics:
http://streamstatsags.cr.usgs.gov/ss_defs/flow_stat_defs.aspx

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COLD WATER STREAMS SURVEY

Fill out a survey sheet about every 200 yards or when the stream characteristics change; e.g. going from open to shaded sections, or from free-flowing to impounded, or impacted by a beaver dam. Take a meter reading at the downstream end of each segment.

Stream Name: ___________________________________**Town:** _________________________

Date: _________________________ **Observers:** _________________________________

Today's weather: ***clear*** ***light rain*** ***rain*** ***heavy rain***

Air Temperature: _________________ **Time:** __________________

GPS format (circle one): Decimal degrees Degrees, minutes, seconds

Segment upstream end (GPS coord): ________________________ **/** _______________________

Segment downstream end (GPS coord): ________________________ **/** _______________________

Instream characteristics for segment

What is **the stream bottom** made of? (*mark from 1=most typical to 6=least typical)*

____Organic debris (leaves, twigs) _____ Gravel (1/4 - 2")

____Silt (mud) _____Cobbles (2 -10")

____Sand (1/16" to 1/4") _____Boulders (> 10")

Water Color? Clear Cloudy Tea Milky Muddy Other _____________

Water Quality Impacts

Oily sheen or smell Fishy odor or fish kill

Sewage: smell, milky color, toilet paper Foam or scum *(describe. Does a stick break it up?)*

Typical Water Depth (in feet): ____________________

How much of the channel is covered with water (bottom of bank to bottom of bank)

Optimal	Suboptimal	Marginal	Poor
Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills more than 75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25 – 75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.

Streamflow: Fast Slight Almost still

Gradient: Low Moderate Steep

Sinuosity: Straight Meandering Braided Channelized

Characterized by: Step pools Riffles/pools Riffle/runs Run

Is stream flow **blocked** by: Trees Trash / Large objects Beaver dam Other _____________

Reach Habitat

Large woody material Abundant Moderate Sparse None

Small organic material Abundant Moderate Sparse None

Undercut banks Abundant Moderate Sparse None

Overhanging vegetation Abundant Moderate Sparse None

Aquatic vegetation Abundant Moderate Sparse None

Are there areas covered with algae? Streambed Around pipes Rocks

Pg. 2: Stream Name________________________________ Date ________________________

Alterations

Dams, Culverts, and Outfalls

___ **Dam** (GPS location __________________ /______________________)

Dam height (from downstream stream channel to top of spillway) <3 ft 3 – 6 ft > 6 ft

Construction: rock masonry wood concrete earthen

Current use of dam: hydropower flood control recreation water supply unknown

Problems evident: leaks cracks holes erosion plant growth

___ **Culvert/Bridge** (GPS location ____________________ /____________________) ***Fill out separate data sheet!***

___ **Outfall** (GPS location ______________________ /______________________) ***Fill out separate data sheet!***

____ **Beaver dam** (GPS location ______________________ /______________________)

Evidence of recent activity? ____

Runoff: Do you see runoff from any of the following? *(circle. *If run-off is significant locate on map.)*

Animal pasture Parking lots Sewage outfall Roads

Bridges Construction Plowed fields Lawns Other____________

Riparian Area and Land Use

Stream bank integrity? Intact Erosion in some areas Erosion in many areas

Collapsed in some areas Collapsed in many areas Channelized or stabilized

Stream bank cover? *LEFT and RIGHT BANK as looking downstream*

Left Bank: Eroding Moss Trees/Shrubs Exposed Roots Grass/Flowers

Loosestrife/Phragmites Riprap/channelized Shrubs/brambles Wetlands/marsh

Right Bank: Eroding Moss Trees/Shrubs Exposed Roots Grass/Flowers

Loosestrife/Phragmites Riprap/channelized Shrubs/brambles Wetlands/marsh

Other invasive species present?_______________________________________

Is there a **vegetated riparian** area beyond the stream bank? If yes, indicate condition.

Left Bank: Shrubs/grasses mowed pasture/meadow Forested/trees Park with few trees Lawn

Right Bank: Shrubs/grasses mowed pasture/meadow Forested/trees Park with few trees Lawn

If riparian area is **not vegetated**, please describe condition: (i.e. parking lot, pavement, roadway, buildings)

Left Bank:____

Right Bank:____

Pg. 3: Stream Name________________________________ Date ________________________

Riparian Area and Land Use (continued)

What are the land uses **visible** from the river? (*checkmark all that apply & circle the dominant land use type*)

___ Industrial ___ Parking lots ___ Golf courses

___ Commercial ___ Roads ___ Protected/conservation land

___ Agricultural ___ Landfills ___ Undeveloped/unprotected land

___ Residential ___ Railroads ___ Wastewater treatment plants

___ Park/ ball fields ___ Junkyards ___ Wooded areas ____Other *(describe)*

WILDLIFE / HABITAT

Aquatic Species

Do you see fish or evidence of fish? (describe)____

Estimate number ______________ *If possible, describe species & size.*___________________________

Evidence of fish? (i.e. nests) _______________________________

Other forms of aquatic life? *(circle, identify species if known*)

Aquatic insects Turtles Frogs Salamander Snail Mussels Snakes Clams

Other________________________

Evidence of aquatic species? (i.e. eggs, tracks) ________________________

METER READINGS

Take readings about every 200 yards or when the stream characteristics change; e.g. going from open to shaded sections, or from free-flowing to impounded, or impacted by a beaver dam.

GPS location of reading ______________________________ / __________________________

Position in stream: Lft/Ctr/Rt	Reading Dpth (ft)	Temp (°C)	Sp Cond (μS/cm)	Cond (μS/cm)	DO %	DO (mg/L)	pH

Appendix B

Habitat Survey Ratings (0 to 5): scores totaled for each stream section surveyed (habitat survey data will be attached in a spreadsheet).

INSTREAM CHARACTERISTICS

Bed Material

Boulder/Cobble/Gravel	5
Cobble/Gravel/Sand	4
Sand/Silt	2
Sand/Silt/Organic	1
Organic/Clay	0

Average Riparian Width

>30	5
10 to 30	3
2 to 10	2
>2	0

Channel Flow Status

Optimal	5
Suboptimal	3
Marginal	2
Poor	0

Gradient

Steep	5
Moderate	3
Low	1

Sinuosity

Meandering/Braided	5
Straight	3
Channelized	1

Large Woody Debris (

Abundant	5
Moderate	3
Sparse	1
None	0

Undercut Banks

Abundant	5
Moderate	3
Sparse	1
None	0

Overhanging Vegetation

Abundant	5
Moderate	3
Sparse	1
None	0

Bank Condition

Intact	5
Erosion in some areas	4
Erosion in many areas	3
Collapsing in some areas	1
Collapsing in many areas	0

RIPARIAN AREAS

Riparian area (within 10 meters)

Forested/trees	5
Shrubs/grasses	3
Wetlands/marsh	0

Visible Landuses

Protected	5
Fields	4
Residential (lawns)	3
Farm fields	3
Paved	0
Industrial	0

Length between crossings/culverts/barriers

>1000 m	5
500 - 1000 m	4
250 - 500	3
100 - 250	2
<100 m	1

FISH

Fish Present

yes	5
unknown	1
no	0

WATER QUALITY

Dissolved Oxygen (mg/L)

>8 mg/L	5
6-8 mg/L	4
5-6 mg/L	3
3-5 mg/L	2
0-3 mg/L	0

Summer water temps

11 to 16	5
16 - 20	4
20 - 24	3
over 24	0

pH

6.5 to 8.0	5
4.0-6.5 or 8.0 -9.0	3
<4.0 or >9.0	0

OVER ALL RATING DESCRIPTION

55-65	EXCELLENT
45-54	GOOD
25-44	FAIR
<25	POOR

Appendix C

Culvert Survey Results (results can be viewed on the Stream Continuity database at http://www.streamcontinuity.org/cdb2/search_crossings.cfm by searching coordinator "Sue Flint")

Stream Name	Road Name	Type	Evaluation	Crossing Span	Structure Length (ft)	Aquatic Score	Longitude	Latitude
Cranberry Brook	outlet: Goodale St inlet: Vega Rd.	Single Culvert	Moderate barrier	Severe Constriction	353	0.557	-71.50296	42.37484
Cranberry Brook	Parmenter Road	Single Culvert	Moderate barrier	Severe Constriction	32	0.604	-71.49446	42.37966
Cranberry Brook	Hemenway Street	Single Culvert	Moderate barrier	Mild Constriction	37	0.637	-71.49377	42.3771
Cranberry Brook	Concord Road	Single Culvert	Minor barrier	Mild Constriction	45	0.709	-71.49844	42.37333
Cranberry Brook	White Pond Road	Single Culvert	Moderate barrier	Severe Constriction	37	0.535	-71.48633	42.38103
Trout Brook	Draper Circle	Single Culvert	Minor barrier	Spans Bank to bank	60	0.810	-71.49727	42.36895
Trout Brook	Hemenway Street	Single Culvert	Significant barrier	Mild Constriction	55	0.467	-71.49561	42.3682
Trout Brook	Sheffield Terrace	Multiple Culverts	Minor barrier	Mild Constriction	54	0.768	-71.49416	42.36736
Trout Brook	Littlefield Lane	Single Culvert	Minor barrier	Mild Constriction	60	0.728	-71.49217	42.3658
Trout Brook	Woodcock Lane	Single Culvert	Moderate barrier	Severe Constriction	40	0.638	-71.49097	42.36443
Trout Brook	Harper Circle	Single Culvert	Moderate barrier	Severe Constriction	300	0.593	-71.48855	42.36463
Trout Brook	Sudbury Street	Single Culvert	Minor barrier	Mild Constriction	48	0.840	-71.48588	42.36601
Trout Brook	Hanlon Drive	Multiple Culverts	Minor barrier	Mild Constriction	21	0.845	-71.48413	42.36739
Trout Brook	pipeline trail in Memorial Forest	Footbridge	Insignificant barrier	Spans channel & banks	3.5	0.976	-71.47777	42.37154
UNK tributary to Trout Brook	Graham Path	Single Culvert	Moderate barrier	Severe Constriction	68	0.635	-71.49327	42.36158
UNK tributary to Trout Brook	Prendiville Way	Single Culvert	Moderate barrier	Severe Constriction	418	0.661	-71.49021	42.366083
UNK tributary to Trout Brook	Minehan Lane	Single Culvert	Severe barrier	Mild Constriction	nr	0.1	-71.48378	42.3679
UNK tributrary to Cranberry Brook	Old Concord Road Trail	Single Culvert	Moderate barrier	Severe Constriction	42	0.525	-71.48464	42.37756

Appendix D PICTURES

Pictures:

Culvert at Harper Lane and Woodcock Lane, Marlborough

Inlet

View upstream

Outlet

View Downstream

Appendix D PICTURES

Culvert at Minehan Road

Outlet

View downstream

Upstream pond and inlet

Appendix D PICTURES

Old dam and pond at Hemenway Street, Marlborough
Dam spillway/ culvert inlet

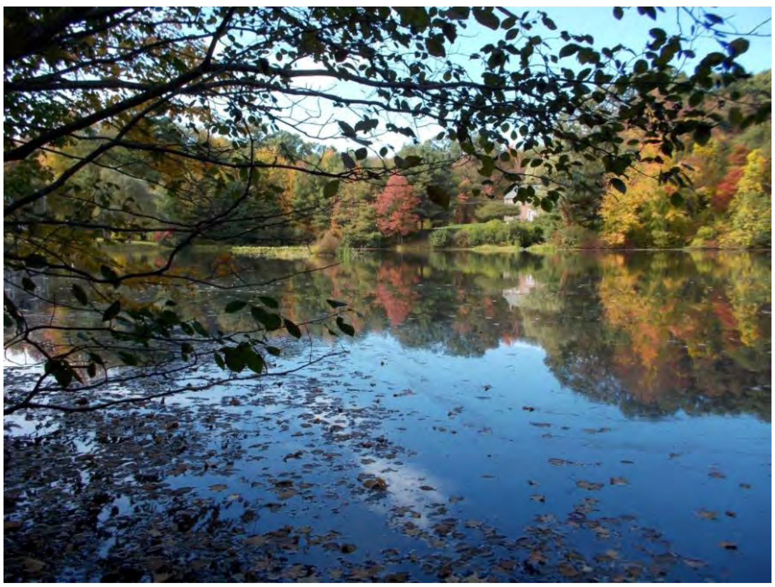
Culvert outlet

Upstream view (pond)

Appendix D PICTURES

Culvert at Vega and Goodale Roads, Marlborough

Inlet



Upstream view

Outlet

Appendix D PICTURES
Culvert at White Pond Road, Hudson
Inlet

Outlet

Downstream scour pool

View upstream towards beaver dam

Outlet

Conservation genetic analysis of brook trout from Sudbury Massachusetts

Andrew Whiteley, UMass Amherst Conservation Genetics Lab
December 22, 2013

We examined a total of 57 brook trout (*Salvelinus fontinalis*) at eight microsatellite loci from Hop Seep and Cranberry Brook in Sudbury, Massachusetts. There were 27 fish from Hop Seep and 30 fish from Cranberry Brook. Of these, there were 13 young-of-the-year (YOY, defined as < 100mm) from Hop Seep and 15 YOY from Cranberry Brook. We performed several data quality tests that revealed no quality issues for the genetic data. The large proportion of YOY included in the sample could influence results if there were strong full-sibling family structure. We therefore tested for the presence of full-siblings in the YOY from both sites. The largest family contained seven full-siblings, all from Hop Seep. Thus, of the 13 YOY sampled in Hop Seep, 54% of them appear to belong to one full-sibling family. Other full-sibling families were smaller and less credible, given the small sample size. Additional support for the accuracy of the largest family comes from a clustering program called STRUCTURE. Each individual was assigned to one of two genetic groups. One of these groups consisted entirely of the seven-member full-sibling family (Fig. 1). If population-level structure were present, this method would have allowed us to detect it. Instead, we observed little-to-no population level structure.

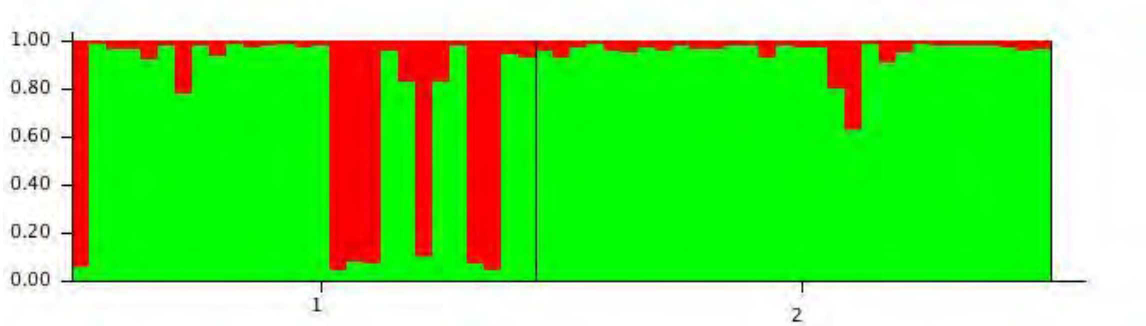


Fig. 1. Results from STRUCTURE analysis of Hop Seep and Cranberry Brook, Sudbury, MA. Each vertical bar represents the genetic assignment for one individual. Hop Seep is site 1, Cranberry Brook is site 2. A black vertical bar separates the two sites. Individuals assigning to group 1 are in red, those assigning to group 2 are in green. Partial genome assignments are possible. The seven individuals for which the majority of the genome assigns to group 1 (in red) belong to one full-sibling family from Hop Seep.

Subsequent analyses were performed with all over-yearlings and one sibling per full-sibling family. Removal of all but one full-sibling minimizes bias from including family groups. Samples sizes became N = 21 for Hop Seep and N = 29 for Cranberry Brook. Genetic diversity was high in both sites (Table 1). We compared genetic variation for the two Sudbury sites to representative brook trout from other regions. We have examined a series of brook trout in Virginian Appalachian Mountain streams at the same genetic markers. Shown in Table 1 are the sites with highest (DV-a) and lowest (DN-a) genetic diversity from Whiteley et al. (2013). The Sudbury sites have similar heterozygosity but half the allelic diversity as DV-a from Virginia. The Sudbury sites have higher heterozygosity and greater allelic diversity than DN-a from Virginia. DN-a is among brook trout populations with the least genetic diversity examined at the UMass Conservation Genetics Lab to date. The Sudbury sites also have similar amounts of genetic diversity as western Massachusetts sites that are part of our long-term brook trout study conducted by the USGS Conte Lab, USFS, and UMass Amherst (Table 1). We show genetic diversity for representative samples of the mainstem West Brook and a small connected tributary (Mitchell Brook; Table 1).

Table 1. Summary of genetic diversity within sites. H_S is mean within-population heterozygosity. A_O is mean number of observed alleles. *AR* is allelic richness, the number of alleles standardized for sample size. Shown for comparison are two populations from Virginia, collected in 2010, with the most and least genetic diversity from Whiteley et al. (2013). Also shown are two sites from within our long-term brook trout study in West Brook in western Massachusetts (Whately, MA). Mitchell Brook is a tributary of the West Brook mainstem. Results are a subset from 2004 but are representative of the populations.

Site	*N*	H_S	A_O	*AR*
		Sudbury sites		
Hop Seep	21	0.712	5.0	5.0
Cranberry Bk	29	0.669	5.5	5.4
		Virginia comparison		
DV-a (most gen. var.)	379	0.780	10.9	8.2
DN-a (least gen. var.)	46	0.565	3.4	3.48
		West Brook (MA) comparison		
West Brook mainstem	60	0.630	7.1	7.1
Mitchell Brook	66	0.600	5.1	5.1

There was very little evidence of genetic divergence between Hop Seep and Cranberry Brook. A standard measure of genetic differentiation is F_{ST}. F_{ST} provides a measure of allele frequency divergence between populations and ranges from zero to 1. F_{ST} was 0.013 and the 95% confidence interval contained zero (95% CI: -0.001 – 0.024). We can also directly test for significant allele frequency divergence. Results of this test revealed significant divergence ($P = 0.006$). Together, these results suggest that there is some genetic divergence between the two sites, but it is slight. It is not unusual to observe F_{ST} values between 0.15 and 0.30 at this spatial scale elsewhere in the brook trout native range.

There are two major takeaway points from this analysis: 1) both Sudbury sites had a surprisingly high amount of within-population genetic diversity. 2) there appears to be genetic connectivity among sites. Isolated populations lose genetic diversity each generation. However, gene flow serves to maintain genetic diversity within sites and minimize genetic divergence between sites. These results suggest that movement between Hop Seep and Cranberry Brook occurs, possibly seasonally when downstream conditions are favorable. While genetic diversity was high in both populations, over half of the YOY in Hop Seep appeared to belong to a single half-sibling family. This could indicate a tendency for inbreeding and successful reproduction by few adults in this site. However, if few adults successfully reproduce each year, heterozygosity would likely not be as high as it is. Yet, heterozygosity tends to be lost slowly, so it would be worth analyzing this population again to see if relatively few adults tend to contribute to subsequent cohorts.

Literature Cited

Whiteley, A. R., J. A. Coombs, M. Hudy, Z. Robinson, A. R. Colton, K. H. Nislow, and B. H. Letcher. 2013. Fragmentation and patch size shape genetic structure of brook trout populations. Canadian Journal of Fisheries and Aquatic Sciences 70:678-688.