Maximum Daily Stream Temperature in the Queen River Watershed and Mastuxet Brook Summer 2006

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Abstract:
Temperature profile studies of the Queen River in Exeter and South Kingstown, and Mastuxet Brook in Westerly, RI were conducted in the summer of 2006 by the Wood Pawcatuck Watershed Association (WPWA). These projects were undertaken as part of a continuing investigation into brook trout habitat in the Pawcatuck Watershed. WPWA deployed a total of 23 Thermochron iButton temperature loggers in the Queen River, its tributaries, and Mastuxet Brook from July 1 to September 30, 2006. Fifteen iButtons were recovered with usable data, only one from Mastuxet Brook. According to the NOAA website, ambient temperatures for July and August of 2006 were ranked the fifth highest of the last 100 years. All of the stream sites were impacted by the hot weather, with maximum daily stream temperatures at 20^{o} C or above at least 3 or more days during the summer. Seven sites had temperatures above 20^{o} C at least 50% of the time; six of those had temperatures above 23^{o} C for at least 15% of the time. Except for Fisherville Brook, these sites with the warmest continuous readings were just downstream of an impoundment.

In addition, WPWA attempted an in-stream investigation for cold water refugia on two sections of the Queen River using a hand-held YSI data logger. The logger was used to continuously measure temperature as two reaches of the Queen River were traversed mid-stream. There were no significant changes in temperature. It is unlikely that this method would be useful in identifying cold water inputs.

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PUBLISHED BY: Wood-Pawcatuck Watershed Association
December 11, 2006

ACKNOWLEDGEMENT: Funding for this study and publication were made possible by a grant from The Forrest and Frances Lattner Foundation

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Introduction:

The Wood-Pawcatuck Watershed Association (WPWA) continued stream temperature studies in the Pawcatuck Watershed in the summer of 2006, focusing on the Queen River, its tributaries, and Mastuxet Brook. Temperature is one of the critical factors in brook trout habitat (Salvelinus fontinalis) with optimal range below 20^o C (68^o F) (Brett, 1956). In temperatures between 20^o C and 23^o C (73.5^o F), brook trout become stressed and their metabolism is adversely affected. Laboratory test have shown that brook trout can survive in water temperatures of up to 25^o C (77^o F). However, these are under ideal conditions which are not replicated in a natural setting. Stream temperatures above 23.5^o C (75^o F) are believed to cause mortality in native brook trout, especially if they are subjected to them for more than one or two days.

The Queen River watershed was selected because of its pristine nature and important habitat value. Fish sampling done by both Rhode Island Department of Environmental Management (RIDEM) in 1998 (Libby, 2004) and WPWA in 2002 and 2003 (Saila et. al, 2004) confirmed brook trout are abundant throughout the Queen River and its tributaries. This watershed has also been identified as having a high biodiversity of macroinvertebrates, including state listed fresh water mussels (Rathail, personal communication) and dragonflies. According to a five-year Odonata survey conducted by The Nature Conservancy (TNC) and the Rhode Island Natural History Survey, specimens for fifty-four odonata species were collected in the Queen River Watershed (Brown, in prep.). This is comparable to the sixty-six species documented in the Wood River watershed, which is considered to have the highest biodiversity of aquatic macroinvertebrates in the region. The Queen River watershed is about 90% forest and wetlands. Agriculture, recreation (golf courses), commercial, and low to medium residential land use compose the developed portions of the basin. Approximately 10 % of the watershed is protected land, held by TNC and Audubon Society of Rhode Island (ASRI). The State of Rhode Island owns property directly adjacent to the river which was formally a large medical residential facility. With a few exceptions the corridor along the river is primarily forested.

Eleven temperature loggers were installed along the main stem of the Queen River, from just below the headwaters at Dead Swamp in West Greenwich, RI to below the Usquepaug Dam in South Kingstown, RI. An additional eight loggers were installed in seven of the Queen's tributaries, most in Exeter, RI. A total of seventeen loggers were retrieved and fourteen had useable data (MAP 1).

WPWA is investigating the feasibility of wetland and habitat restoration in Mastuxet Brook. This small, two-mile stream is contained entirely in Westerly, RI and drains directly to the Pawcatuck Estuary at Mastuxet Cove. The stream begins in a culvert under Wells Street, off of Rt. 1, a commercial highway. From a visual inspection it appears that wetlands were part of the brook's headwaters on the north side of Wells Street, but they are no longer visible. Immediately downstream from the culvert for about 775 feet there is an inadequate vegetated buffer of less than 20 feet. The stream is intermittent for the first one hundred feet from the

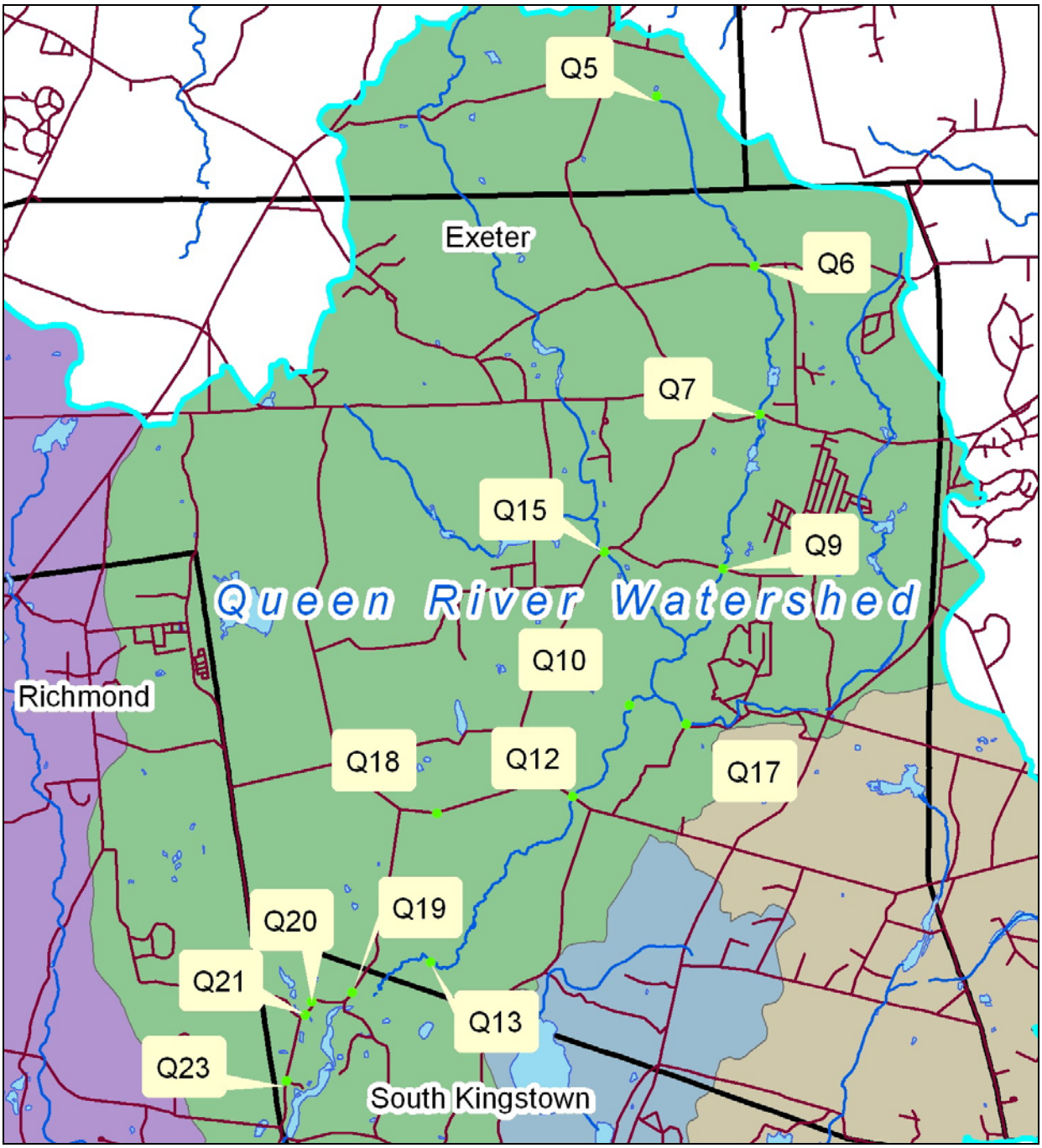
culvert. In this reach Mastuxet Brook is highly impacted by the surrounding land use which consists of two residential buildings on either side and cleared fields that were formerly used for agriculture. This property may be developed into residential buildings in the near future. The stream gains a good buffer further downstream as it traverses two large parcels of protected property. Behind the town-owned Rotary Park there is an area where large boulders and debris were pushed into the stream buffer and the stream itself. About a half mile upstream from the mouth of the brook is a natural ledge cascade with a four foot drop. The last culvert before Mastuxet Brook enters the estuary is under Rt. 1A. There are several boards on the upstream side of the culvert that obstruct the flow of the brook and create a small, one acre reservoir that backs up onto private property.

The Westerly Land Trust (WLT) owns three parcels along the streams upper reach and one parcel in the lower reach. WLT is in the process of negotiating an easement on a small parcel in the lower reach. These acquisitions will be used to help maintain the stream buffer and protect the remaining stream. Outside of the protected areas the stream is surrounded by medium to high density residential and commercial properties. Discounting any land that is already protected, the Mastuxet Brook watershed is at about 90% build out. There remain only five parcels that are undeveloped.

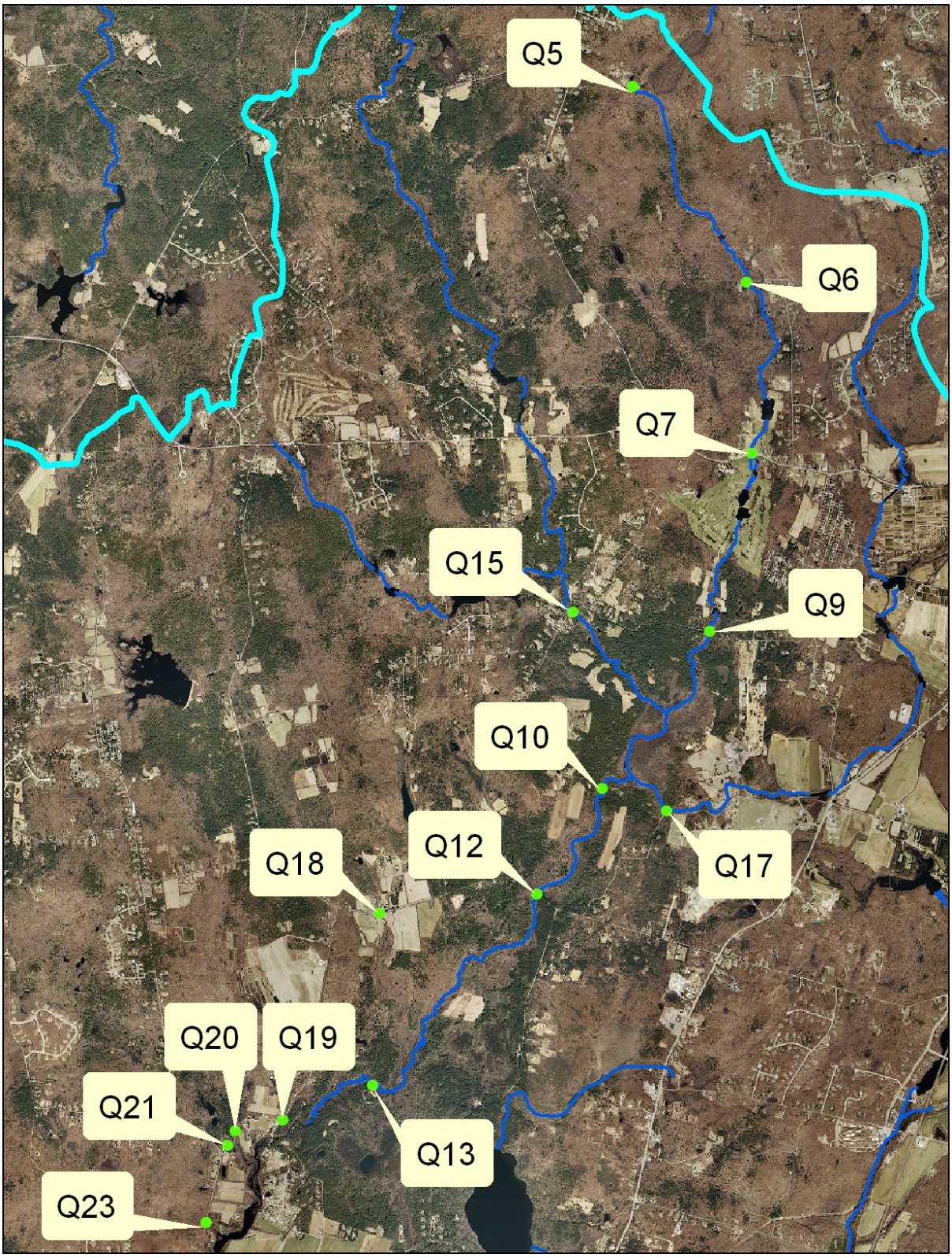
In 1999 RIDEM found four brook trout at one site off Whipple Avenue. This summer WPWA sampled three sites on the stream, but found brook trout at the Whipple Avenue site only. In a brief sampling period, six trout were obtained, indicating that there continues to be a small but viable brook trout population. These trout are isolated from any other breeding populations by the position of the brook in relationship to other streams and by the obstacles found along the lower half of the brook. Brook trout apparently exist in less than a mile stretch of the brook. The long range goals of WPWA and the WLT would be to increase the range of the brook trout in Mastuxet Brook, improve the habitat that is currently used by the trout, and possibly allow trout passage to the estuary.

Four temperature loggers were installed along the length of Mastuxet Brook. Unfortunately, only two of the temperature loggers were retrieved and one of those was unreadable. Therefore data was obtained from only the fourth logger, which had been installed at the mouth of the stream just after an impounded culvert.

Another part of the temperature study this year was an experiment to see if pockets of cold water refugia could be found from in-stream testing. This was done by walking midstream in two reaches of the Queen River with a handheld YSI data logger recording temperature readings every five minutes. The goal was to see if significant decrease in temperature could be determined, possibly indicating ground water seeping into the stream surface water at that point. About 5000 feet where covered in the two sections and no significant temperature differences were observed.



MAP 1A Queen River sites



MAP 1B Queen River Sites with Land Use

Methods and equipment:

The temperature data logger used in this study is a Thermochron iButton, model DS1012L-F51, made by Maxim Integrated Products. These buttons are waterproof; can measure temperatures between -30^{o} C to $+70^{o}$ C; can be set to record at intervals as low as every minute; and can log up to 2048 temperature measurements. According to the manufacturer, they are accurate to within +/- 1^{o} C. iButtons are also economical, costing under $15 each.

For our purposes the loggers were set at an interval of one hour and logged continuously for just under three months. Logging began July 1 and ended September 30, 2006. The iButtons were retrieved late September into early October. Data from July 1 to September 18, or 80 complete 24-hour periods, were used for this report. For deployment the loggers were attached to various lengths of rebar which had been cut with a point. The rebar was hammered into the substrate of the stream, usually in a relatively deep pool.

Quality control checks were done using a manual digital thermometer at twelve of the twenty-three sites at least once during the deployment period, with the date and hour noted. These readings were compared with the temperature readings downloaded from the loggers for the same date and hour. In a paired t-test, there were no significant differences between the readings. Therefore, the results of the loggers are accepted as accurate within 1^{o} C, as stated by the manufacturer.

The test for cold water refugia was conducted using a YSI 600QS set to record temperature every 5 minutes. Temperature accuracy is rated at $\pm$ 1^{o} C by the manufacturer. No other quality control check was performed for temperature at this time.

Results:

QUEEN RIVER TEMPERATURE STUDY

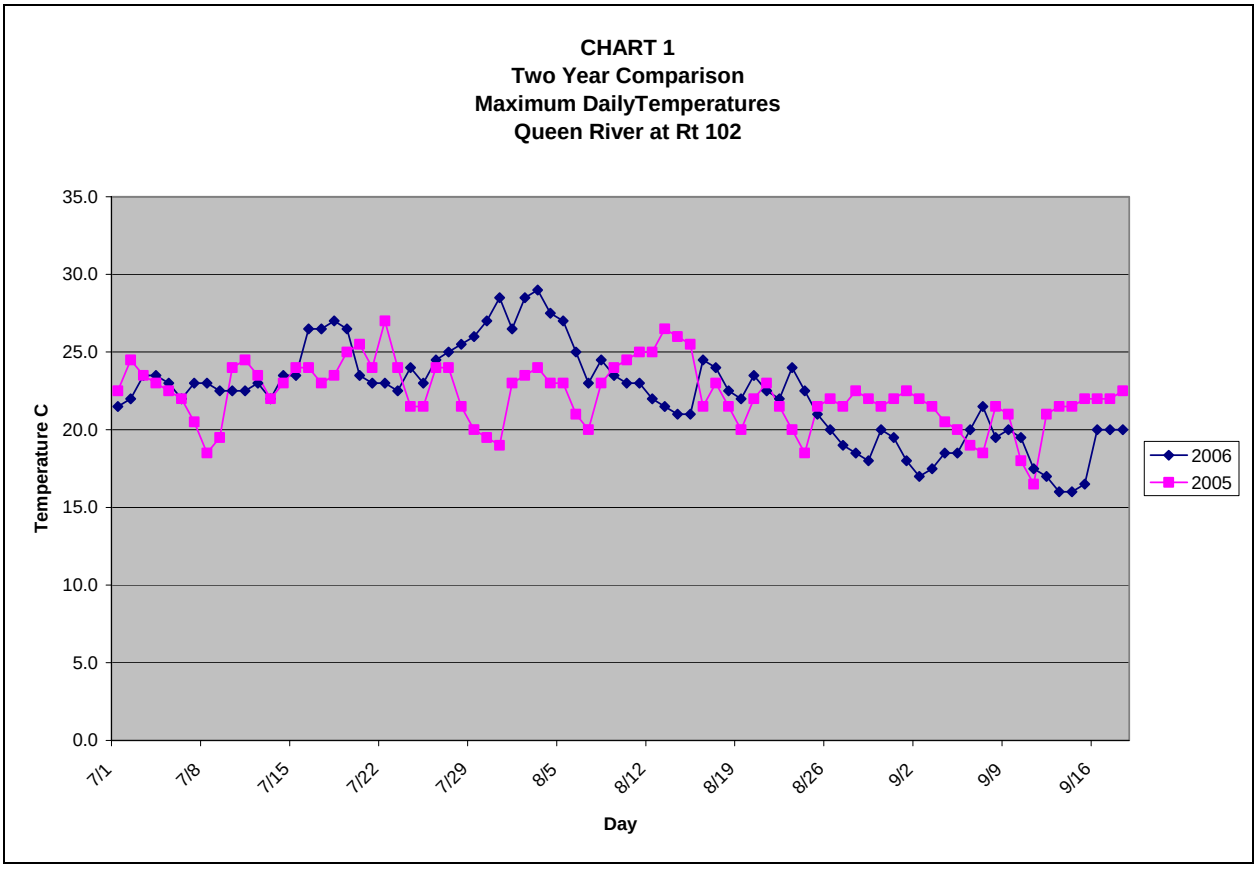
Out of the nineteen temperature loggers that WPWA installed in the Queen River Watershed, seventeen were retrieved from the streams. The other two were believed to be dislodged from the stream bed and lost downstream. Data was recovered from fourteen of the retrieved loggers; seven from sites on the Queen River and seven from sites on tributaries to the Queen. The sites, their locations, and results are listed in TABLE 1. and identified on the maps below.

TABLE 1.

Temp Logger #	River	Site	Percent Days w/ Temps ≥20°C	Percent Days w/ Temps >23°C	Percent Days w/ Temps >25°C
M1	Mastuxet Brook	DS culvert, Winnepaug/ Rt. 1A intersection	72%	23%	7%
Q5	Queen	Headwaters DS Dead Swamp, off Hopkin's Hill Road	14%	0%	0%
Q6	Queen	DS culvert, Stony Lane	50%	8%	0%
Q7	Queen	US culvert, Rt. 102	80%	35%	19%
Q9	Queen	DS bridge at William Reynolds Rd	79%	34%	17%
Q10	Queen	Queen River Preserve, US Sandy Bridge Rd.	46%	2%	0%
Q12	Queen	DS bridge at Mail Road	48%	2%	0%
Q13	Queen	ASRI Eppley Property, near caretakers house	34%	1%	0%
Q15	Fisherville Brook	DS bridge on Liberty Church Rd.	67%	15%	2%
Q17	Queen's Fort Brook	Near entrance Queen River Preserve, N of Sandy Road	4%	0%	0%
Q18	Locke Brook	DS bridge at Mail Road	30%	2%	0%
Q19	Rake Factory Brook	DS culvert at Glen Rock Rd.	64%	31%	14%
Q20	Sherman Brook	US bridge at Glen Rock Rd.	21%	0%	0%
Q21	Glen Rock Brook	US bridge at Glen Rock Rd.	76%	42%	24%
Q23	Unnamed Brook	DS culvert at Glen Rock Rd.	9%	0%	0%

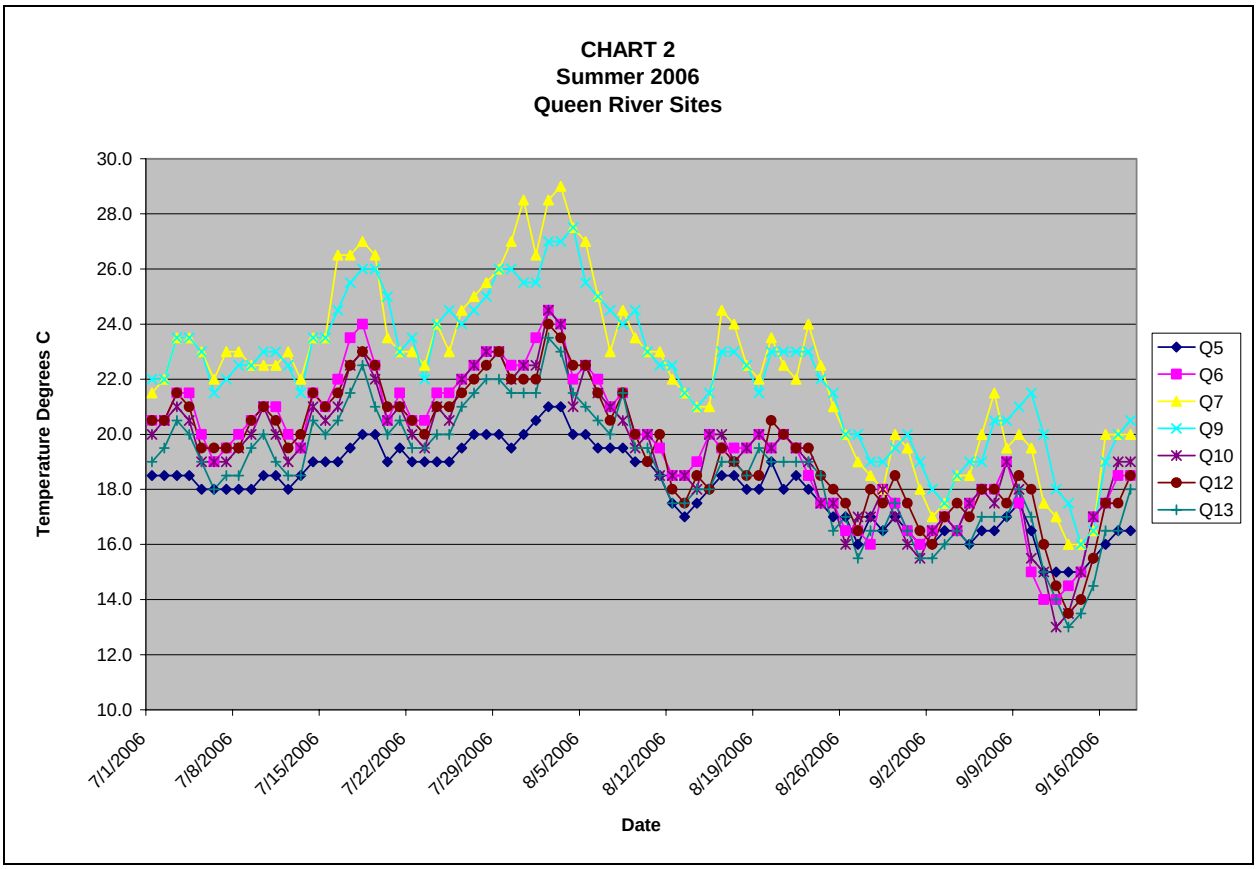
The only site that was logged in both 2005 and 2006 was on the Queen River at Rt. 102. This site is just above a culvert and about ¼ mile below a small reservoir called Edwards Pond. Land use on either side of the stream for this stretch is primarily mowed open fields. There is a marginal vegetated stream buffer upstream to the reservoir of about ten feet on either side. This is only 10% of the 100 feet of vegetated buffer required by the State of Rhode Island Wetland Regulations for a stream less than ten feet average width. Both the warming effect of the reservoir and the lack of vegetated cover contribute to a very warm stream temperature in this

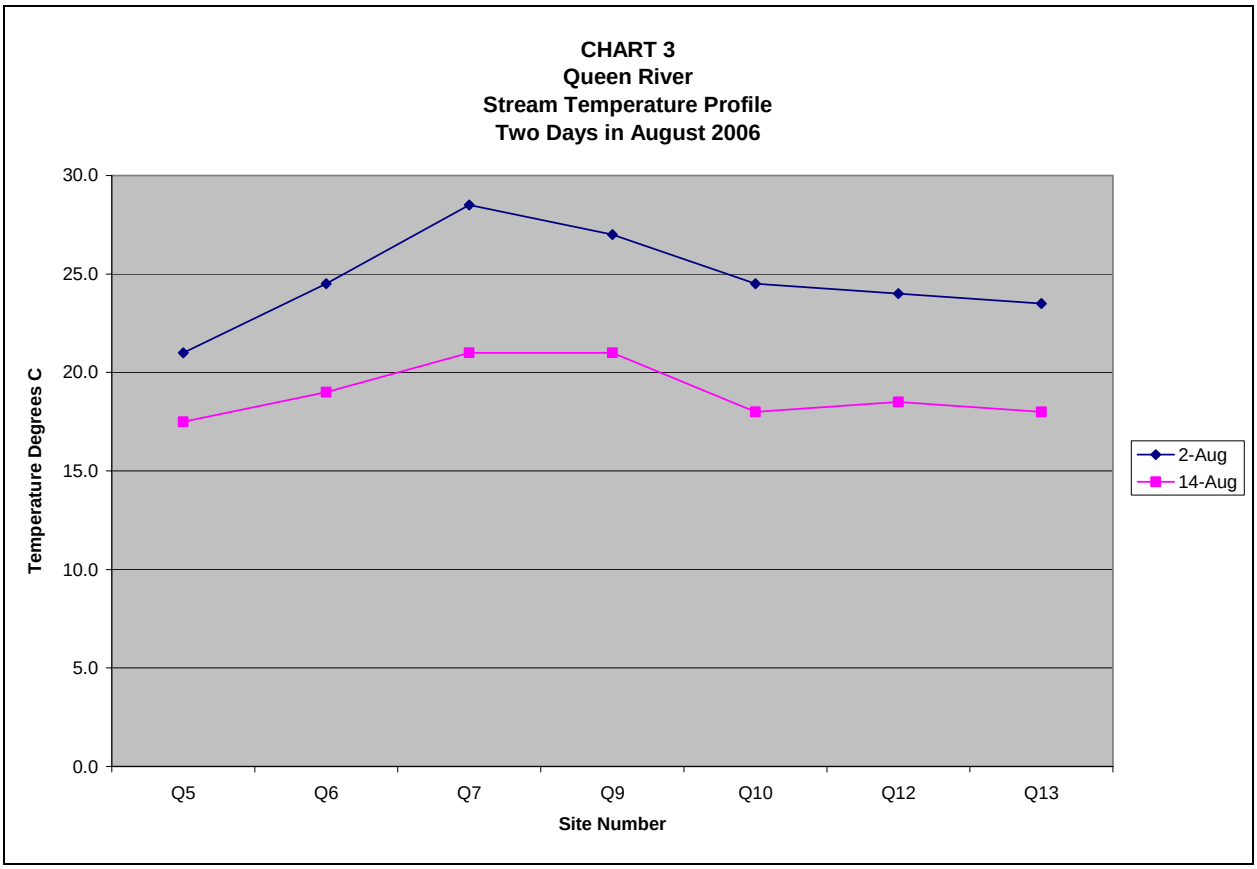
reach. In 2005 the daily maximum stream temperature reached 20° C or above on 68 days or 85% percent of the study period. Daily maximum reached 23.5° C or above 31% of the time and 25° C or above 10% of the time. At the same site in 2006 there were very similar results. A daily maximum stream temperature of or greater than 20° C was reached 80% of the time, 23.5° C or above 35% of the time, and 25° C or above 19% per cent of the time. Moreover, from July 15 to August 11 the daily minimum temperatures do not go below 20° C. CHART 1 shows a comparison of the maximum daily temperature range for both 2005 and 2006. The temperature range is very similar. In a paired t-test there were no significant differences between the two years.



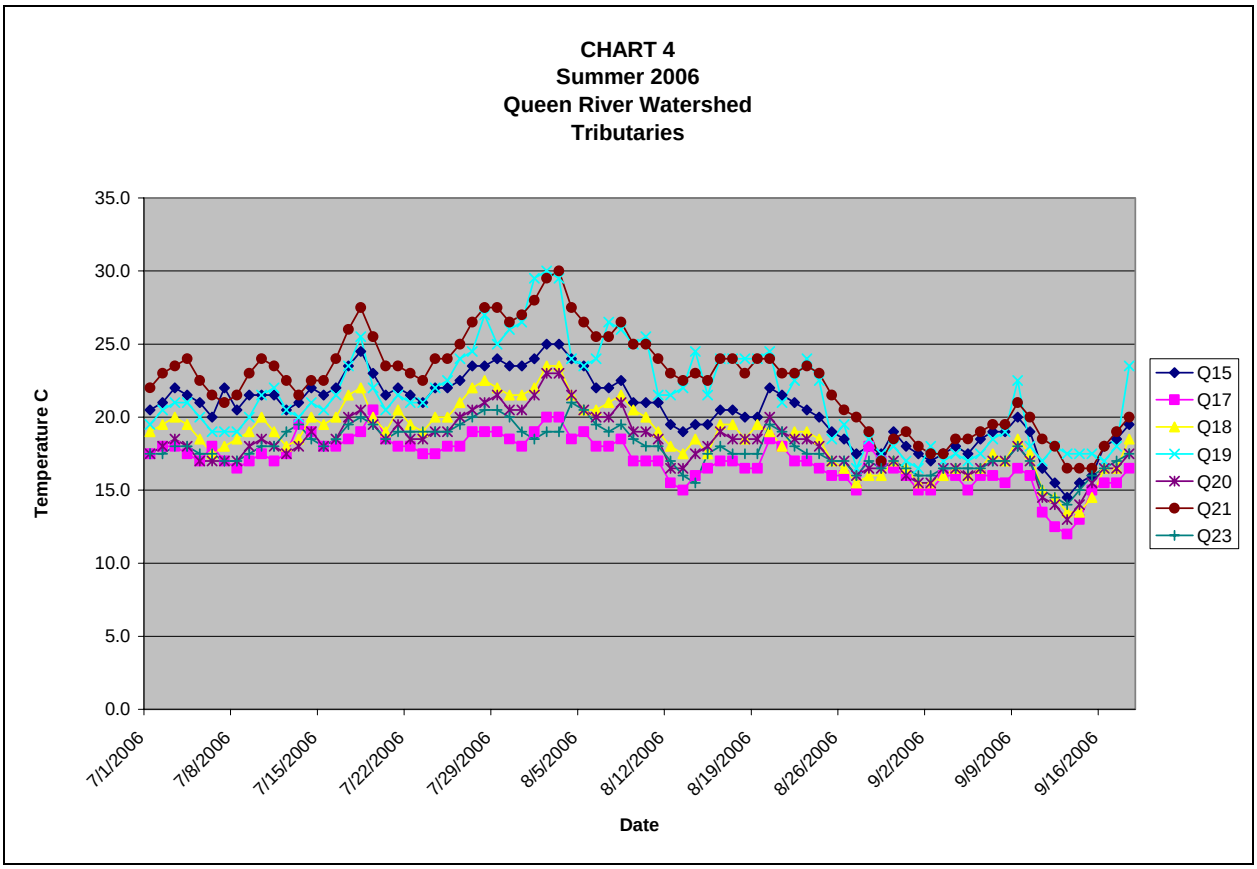
Due to all the impoundments in the upper Queen River, the temperature profile is unusual. CHART 2 shows the daily maximum stream temperature for all seven sites in the main stem of Queen River. The profile for the stream, from the Headwaters below Dead Swamp (Q5) to the site at the ASRI Epply Property, which is just above the Glen Rock Reservoir (Q13) is shown in CHART 3 for two days in August. August 2 was the hottest day of the summer with a high of 34.9° C (94.8° F). An expected stream profile would show cooler headwaters and a gradual warming during the course of the river as it gets wider and increases in volume. In this profile it is clear that while the headwaters are cooler, it is the middle of the river that is the warmest. The same profile can be seen for August 14, which was a much cooler day. The warmest sites on the Queen River are Rt. 102 (Q7) and the next site which is 1.5 miles

downstream on Williams Reynolds Road (Q9). Both these sites are below impoundments. Between these sites, the stream flows for about 0.8 miles through a golf course that includes three impounded irrigation ponds. There is little or no vegetated buffer on this section of the Queen River. In contrast, the three downstream sites, Sandy Road (Q10), Mail Road (Q12), and the ASRI Marion Epply Property (Q13), are sections of the river that cross well forested areas, mostly in protected open space. The Epply site was 5^{o} C cooler on August 2 than the Rt. 102 site (23.5^{o} C versus 28.5^{o} C). This is still within the mortality range for brook trout but it is believed that there are pockets of cooler water refugia that the fish were able to access.





The tributaries of the Queen River also showed a range of temperatures during the summer of 2006. Generally, tributaries are expected to contribute cooler water to a river system. However, two of the contributing streams to the Queen River, Glen Rock Brook (Q21) and Rake Factory Brook (Q19), had very warm stream temperatures, as high as 30^{o} C (86^{o} F) on August 2. Glen Rock Brook is below an impoundment, so the high temperatures are not unexpected. However, the measurements for Rake Factory Brook were taken about two miles downstream of any impoundment. The high stream temperatures may have been caused by very low water levels in the brook during the middle of the summer. As seen in CHART 4, the temperature levels in Rake Factory Brook fluctuate more than the other streams. This brook has run dry in previous summers.

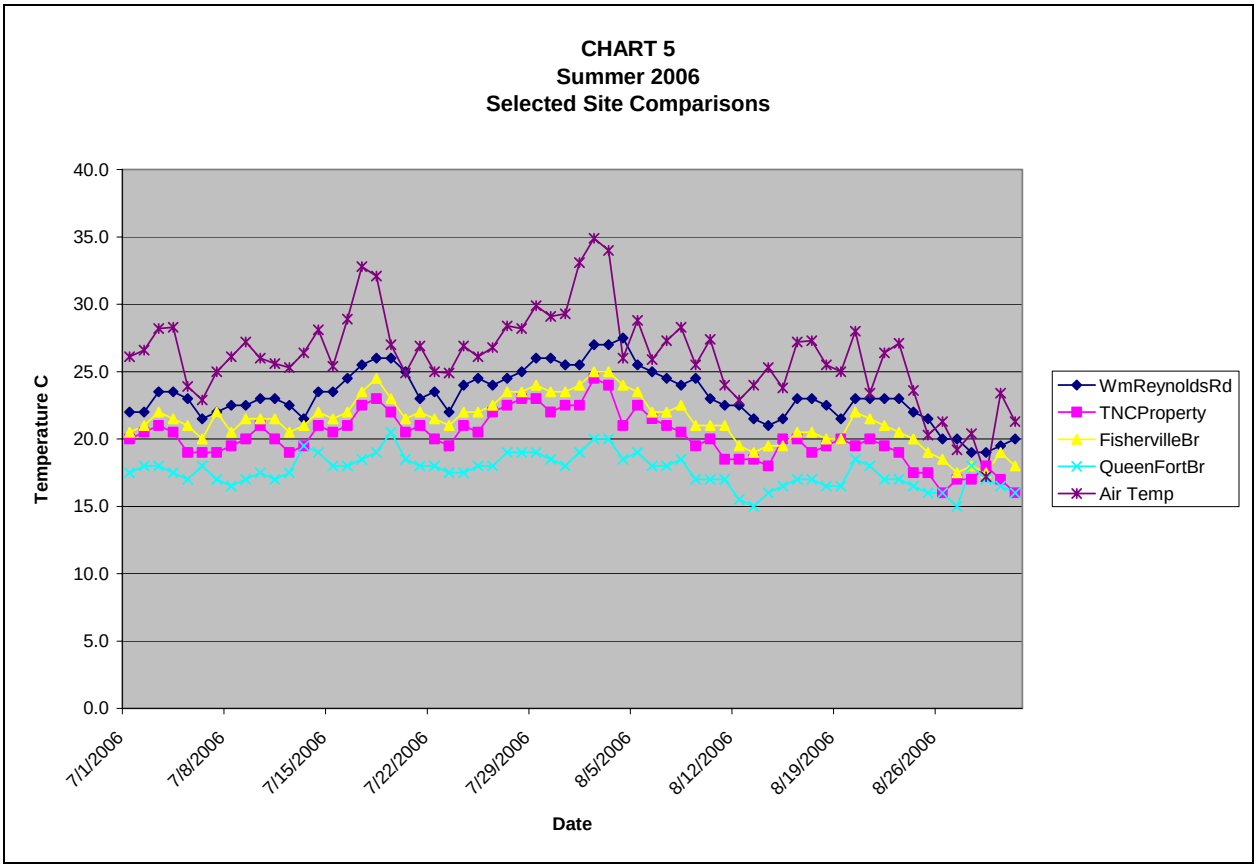


The coolest temperatures were measured in Queens Fort Brook (Q17). The measurements were taken 0.35 miles upstream from where the brook enters the Queen River on an important TNC property, the Queen River Preserve. The cold, contributing waters of Queen Fort Brook helps keep this section of the Queen River cooler in the warmest part of the summer. Measurements taken on the Queen River at Sandy Bridge (Q10), 0.3 miles downstream of the confluence, show a distinct moderation of temperature from Williams Reynolds Road (Q9). The Sandy Bridge site experienced temperatures in the critical range above 20^{o} C for 37 days with only two of those days above 23.0^{o} C. In comparison Williams Reynolds Road had sixty-three days in the critical range with twenty-seven days above 23.0^{o} C and fourteen days above 25.0^{o} C. However, Queens Fort Brook may experience problems in a dryer summer. Part of the brook runs just south of agricultural fields near the entrance to the State of RI property. There is a section of the brook that has been excavated for an irrigation pond. In August of 2002 WPWA staff noticed that downstream of the irrigation pond the brook was completely dry, apparently as a result of water withdrawals from the pond. Since 2006 had record rainfall for the summer, agricultural irrigation was minimal. However, in a dry year the withdrawal of irrigation water from Queens Fort Brook may prevent cooler water from reaching the Queen River.

Another small contributing tributary, an unnamed brook entering from the west into the Glen Rock Reservoir, had very cool temperatures with only seven days or 9% in the critical range above 20^{o} C. The highest reading on this brook of 21^{o} C was for only one day.

Unfortunately, the small volume of water contributed by this brook probably has little effect on the warm waters of the reservoir.

Fisherville Brook showed warmer than expected temperatures. Fifty-four days or 67 % of the study period had a maximum daily stream reading of 20° C or greater, 15% of the study period had temperatures of 23.5° C or above, and 3% or two days had readings of 25° C or above. It is difficult to determine all the factors that are contributing to the warming of this stream. Most of the watershed for this stream is in well forested areas. Sodom Brook drains from two impounded ponds with the last impoundment only 0.3 miles from where it enters Fisherville Brook. The study site is 0.3 miles below this confluence. There are additional impoundments on the mainstem of Fisherville Brook just north of Rt. 102, about 1.7 miles upstream of the study site. The warmer water from the impoundments may have contributed to the readings taken on Fisherville Brook. CHART 5 shows a comparison of the temperatures from Williams Reynolds Road and Sandy Bridge, which is about two miles apart and the two tributaries that enter the Queen Rive between these sites, Fisherville Brook and Queens Fort Brook. Fisherville Brook enters the Queen .9 miles below Williams Reynolds Road and Queen Fort Brook enters at 1.5 miles.



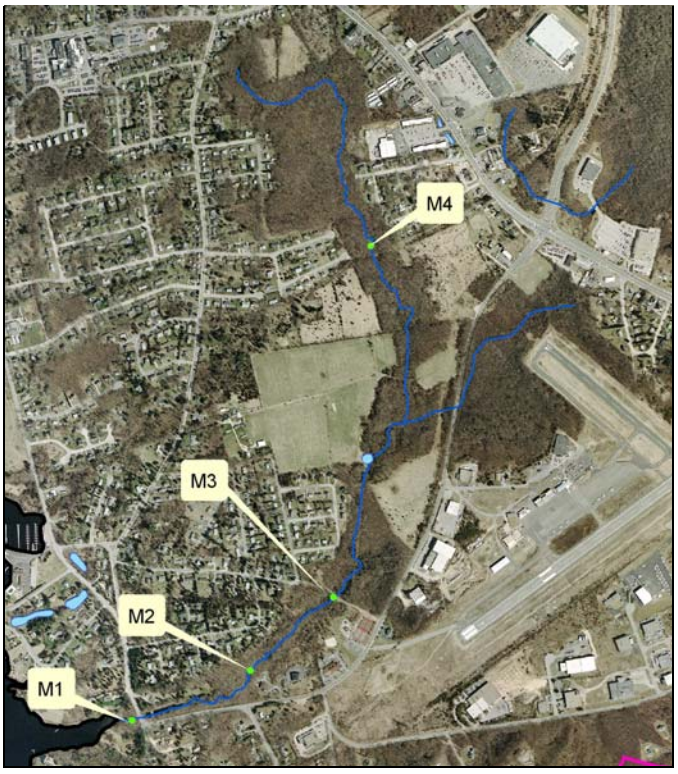
The other two tributaries, Locke Brook (Q18) and Sherman Brook (Q20) had similar temperature ranges to each other, with twenty-four and seventeen days respectively above 20° C. Locke Brook only had two out those days above 23.0° C and Sherman Brook had none. Both of

these streams were sampled during WPWA's Fish Assemblage Study (Saila et. al, 2004) and found to contain significant populations of brook trout. However, Sherman Brook runs dry in a low rainfall year, possibly due to agricultural withdrawals from upstream.

Another aspect of the 2006 temperature studies was to see if it were possible to easily identify pockets of cold water refugia in a stream by taking continuous temperature readings while walking mid stream. Two sections of the Queen River where used for this purpose. The first test was done on TNC Queens River Preserve and included about 2500 feet that started just downstream of Bear Swamp and the confluence with Queens Fort Brook. The second section, also approximately 2500 feet in length, started just below Williams Reynolds Road and extended into property owned by ASRI. Results from these tests did not reveal any significant differences in temperature along the reach, and were therefore inconclusive.

MASTUXET BROOK

Four temperature loggers were installed in Mastuxet Brook to try to determine what sections of the brook had stream temperatures cold enough to support brook trout. MAP 2 shows the sites. Only two of the loggers were recovered and only one of these had data that was readable. The recovered logger, M1, was from the site that was near the mouth of the brook, just below an impounded culvert. Not unexpectedly the readings from this site showed very warm water. From July 8 through August 25 the maximum daily stream temperature was always above 20^{o} C with 25 of those days at or above 23.0^{o} C. The data from this one site does not provide the information needed to make a judgment about the rest of the brook, which is known to have a viable brook trout population in at least the upper mile. Therefore no conclusions can be drawn from this study and it will need to be repeated in the summer of 2007.



MAP 2 Mastuxet Brook Sites

Conclusions:

During a summer with consistently warm temperatures many of the reaches on the Queen River and its tributaries experience maximum daily stream temperatures that exceed even marginal temperature ranges for brook trout. The US Geological Survey (USGS) did a similar study in the summer of 2000 (Armstrong and Parker, 2003) which included several of the same sites in the Queen River Watershed with equivalent results. According to their report "the stream temperatures in the Queen River headwaters were marginal for brook trout in the summer of 2000." Impoundments make a major contribution to reducing the quality of cold water fisheries in the Queen River. Besides fragmenting the available habitat and isolating fish populations impoundments warm the water in both the upstream reservoir and downstream flow.

Because brook trout are still present in this watershed in adequate numbers to maintain populations, they must be able to locate cold water refugia in order to survive the warmest summer temperatures. WPWA attempted to find in-stream refugia by taking continuous temperature readings while walking mid-stream. This method did not yield sufficient data to make any determinations about the location of colder water pockets. While some fish may take refuge in deep pools in the main stem of the Queen, others are likely to use the colder tributaries. However, some of the tributaries are adversely impacted by impoundments. Other tributaries that do contain colder water are subject to water withdrawals. This is limiting the amount of available habitat for the trout in hot summers. Adding other stressors to this system, such as increased water withdrawals for agriculture or housing development may significantly impact the viability of the brook trout population in the Queen River watershed.

A change in the system that affects brook trout indicates that other organisms could be affected as well. These would be organisms that also rely on clean, cold running water. For instance, there is already anecdotal information that certain species of fresh water mussels in the Queen River have declined over the past decade. (Hartenstine, personal communication). One species, Margaritifera margaritifera, relies on brook trout for their larval stage. Their decline may be due to many factors, but they are most likely related to the change in habitat quality. A decrease of brook trout habitat means a change for many other species associated with brook trout.

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