Study of Maximum Daily Stream Temperature of Select Streams in the Pawcatuck Watershed, Summer 2005

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Abstract:
During the summer of 2005, WPWA deployed Thermochron iButton temperature loggers on seven low-order streams in the Pawcatuck Watershed-- Queen River, Roaring Brook, Meadow Brook, Taney Brook, Chipuxet River, Chickasheen Brook, and Shunock Brook-- to assess impacts to brook trout habitat from stream temperatures. WPWA undertook this stream temperature study as part of a continuing investigation into brook trout habitat in the Pawcatuck Watershed. Out of 24 temperature loggers initially deployed, 13 were successfully recovered. Average daily air temperatures in the months of July, August and September were some of the hottest on record. All of the stream sites were impacted by the hot weather, with maximum daily stream temperatures above 20^{o} C at least 16% of the time. Nine sites had temperatures above 20^{o} C at least 65% of the time; seven of those had temperatures above 25^{o} C for at least part of the time. Those sites with forested buffers had the coolest temperature readings, while sites below bridges, culverts, or impoundments had the warmest temperature readings.

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Introduction:

Low order streams provide important habitat for many organisms, including native fish and invertebrates. These streams have a number of common characteristics that make them especially important to brook trout (Salvelinus fontinalis): 1) gravely/rocky substrate provides good spawning grounds, 2) canopy cover provides shade, woody debris, and organic matter for invertebrates, 3) changing gradient provides oxygenation and 4) ground water inflow provides cold water during the summer. Alteration to the streams can alter the characteristics that are important for good habitat. Dams and culverts can create reservoirs that warm the water and collect sediment. Roads can add sediment and toxins. Removal of canopy can warm the water, decrease the amount of organic matter available for the food web, decrease available debris for cover, and allow overland runoff to enter the stream, carrying sediment and toxins. Wells near a stream can decrease groundwater flow into the stream, especially during periods of low flow.

Temperature can be a decisive part of any aquatic system with summer being the most critical time of the year for salmonid species. A few degrees one way or another can dictate morbidity and mortality rates. One function of temperature is a control of the amount of dissolved oxygen (DO) the water can retain. In general, the warmer the water, the less DO it can hold at saturation. At 10 degrees C (50^o F), maximum saturation of DO is 11.3 parts per million (ppm), also recorded as mg/L. At 20^o C (68^o F) water can only hold 9.1 ppm of DO and at 25^o C (77^o F) the maximum DO retained is 8.1 ppm. To put this in perspective there are 220,000 ppm of oxygen in the air we breathe, but no more than 12 ppm in water. Even a small decrease in dissolved oxygen can adversely affect certain forms of aquatic life. There may be other factors at work that also decrease the amount of oxygen available to the aquatic inhabitants. Biological processes that remove oxygen, such as decomposition, can be especially harmful when the water is warm and available DO is already low.

Another issue with higher temperatures is increased rate of chemical reactions in the water. Some metals, such as mercury and lead, are normally bound in the sediments. However during certain circumstances, such as highly acidic or anoxic conditions, higher temperatures will accelerate reactions that cause metal compounds to become soluble. Higher water temperatures will also retain more of the metal compound in the water column. Algal blooms are often increased in warm water. These algae blooms can further decrease the oxygen content of a water body during cloudy conditions. The decreased oxygen can cause more acidic conditions which allow more sediment bound elements to convert to soluble compounds and continue the cycle. A number of stressors to the system, such as a high oxygen demand caused by plant decay and the warm water, can quickly set up conditions that will kill or drive out fish and invertebrates.

High water temperatures can make the difference in the animal communities found in streams and rivers. Some species of fish are very susceptible to the changes caused by warm water. They are physiologically adapted to cold water. As soon as the water warms beyond a

certain point, their metabolism alters. WPWA undertook this stream temperature study as part of a continuing investigation into brook trout habitats in the Pawcatuck Watershed. According to a study done by J. R. Cote Brett (1956) brook trout do not grow any larger in water that is greater than 18^{o} C (64.4^{o} F). Above 20^{o} C (68.0^{o} F) they stop feeding and cannot survive for long in water warmer then 23^{o} C (73.4^{o} F). Even under very controlled conditions, including complete saturation with dissolved oxygen, they do not survive beyond 25^{o} C (77^{o} F).

There are many factors that affect water temperature. One is the amount of vegetation cover over the open water. A high percentage of trees and shrubs along a stream provide more shade to keep the water cool. That is why a 100 to 200 foot buffer of natural vegetation along a stream bank is required by the RI Wetland Regulations. Land use practices, such as golf courses, agricultural fields, or lawns that remove vegetation right down to the stream bank can contribute to warming problems of a stream. The source of the stream water is another factor. Streams that are groundwater recharged in the summer are going to remain much cooler than streams that get their flow primarily from surface water. The ground water stays at approximately 12.8^{o} C (55^{o} F) throughout the year. Problems may arise if groundwater is routinely withdrawn in large quantities near a stream bed, as in the case of irrigation wells. This may result in diverting cool water from that stream. Dams will also warm the water in a stream, behind the impoundment. As water velocity slows and the surface increases, the water will become heated by sunlight and warm air. Water flowing from the impoundment downstream is now much warmer. During our Fish Assemblage Study (2002 to 2003) and Small Dam Study (2004) we characteristically found only warm water fish below almost any size impoundment. In the 2004 study we logged seven sites over seven miles on the Beaver River. The first logger, the farthest upstream, was directly below an 8-foot dam and recorded a high temperature of 24.5^{o} C. Even though the rest of the watershed was heavily forested, it took over 5 miles before the stream temperature moderated to a value of 18^{o} C. Other factors that affect water temperature are the amount of precipitation, water volume, and any discharges into the stream. Discharges from industrial sources may contain water used to cool machinery. As expected this water is much warmer than the normal stream water, and can raise temperatures for quite a way downstream. This is known as thermal pollution.

In the summer of 2005, WPWA conducted a study of water temperatures on some of the low order streams in the Pawcatuck Watershed. For nearly 3 months during the summer, July 1 to September 23, in-situ loggers recorded hourly temperatures. Based on data obtained from the University of RI, Kingston Campus NOAA Weather Observations, the summer of 2005 was far hotter than average, with lower than average rainfall. Maximum daily stream temperatures reflected that fact. Of the thirteen loggers recovered, 7 sites displayed temperatures above 25^{o} C for at least part of the time. Not surprisingly, the sites with the lowest maximum daily temperatures had heavily forested buffers. The sites with the highest temperatures were below bridges, culverts, or impoundments.

Although 24 loggers were installed in seven streams, only 13 were recovered at the end of the summer. It is possible that the other loggers were washed out of the substrate during the heavy rains in late September. A different method of deployment will need to be used for future studies.

Methods and equipment:

The data logger used in this study is a Thermochron iButton, model DS1012L-F51, made by Maxim Integrated Products. These buttons are water proof; 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 3 months. Deployment was from the end of June to the end of September, 2006. To deploy we attached them to a 6 inch heavy metal spike and placed in the substrate of the stream, usually in a relatively deep pool. This method of deployment is not optimum, however, since almost half were not recovered. When very heavy rains feel near the end of September, high flow may have dislodged the loggers from the substrate and carried them downstream.

Twenty-four loggers were deployed in seven streams: Queen River, Roaring Brook, Meadow Brook, Taney Brook, Chipuxet River, Chickasheen Brook, and Shunock Brook. These sites are based on the proposed scenarios that USGS will run for the Pawcatuck Watershed Optimization modeling project being conducted by NRCS. Roaring Brook was selected to establish its suitability as a cold water stream designation. Shunock Brook was selected because it is being evaluated for a fish passage project at the Parke Pond Dam.

For quality control, temperatures were taken manually with a digital thermometer at 10 of the 24 sites and compared with the temperature logger results.

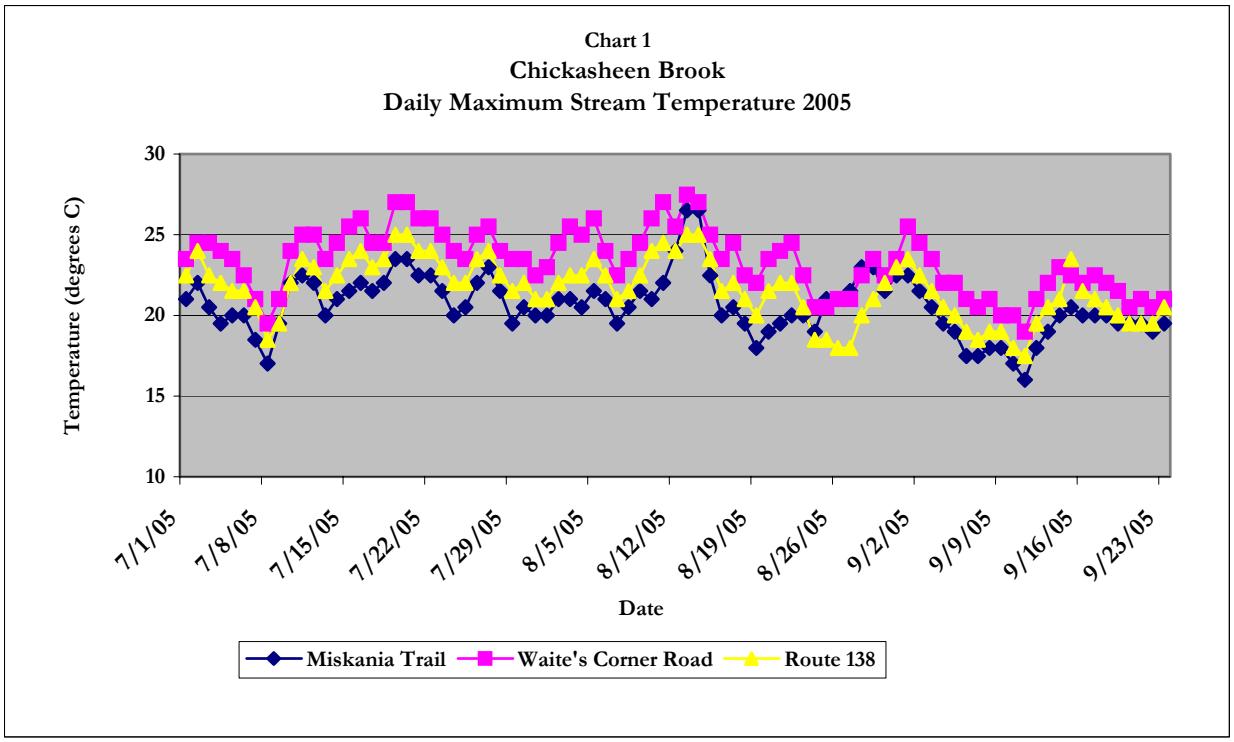
Results:

Mean daily air temperatures in RI for the summer of 2005 were much higher than average. According to NOAA Climate Data, out of the last 100 years, July, August, and September ranked 91, 100, and 99 respectively for average daily temperatures. In fact, 2005 had the hottest August since records were kept starting in 1895. Average daily air temperatures from the University of RI, Kingston station were somewhat cooler, but still well above average. At the same time, precipitation was far less than average for July and September and slightly more than average for August. Overall, the summer season was ranked 35, with 100 being the wettest year. These statistics were reflected in the conditions of the first order streams that WPWA monitored last year. 2005 was not actually considered a drought year because of higher than average spring precipitation which recharged ground water reserves. Nonetheless, by the beginning of August sections of many first order streams were dry or nearly so. Streams observed by WPWA staff in this condition included Parris Brook and Roaring Brook in Arcadia Management Area, Woody Hill Brook and Dawley Brook in Hopkinton, Meadow Brook in Richmond, and Sherman Brook in Exeter. It has been noted in the past that these streams tend to be dry in a below average rainfall year. The maximum daily stream temperatures were also high for all study sites. Nine sites had stream temperatures above 20^{o} C at least 65% of the time. All of the sites had stream temperatures above 20^{o} C at least 16% of the time.

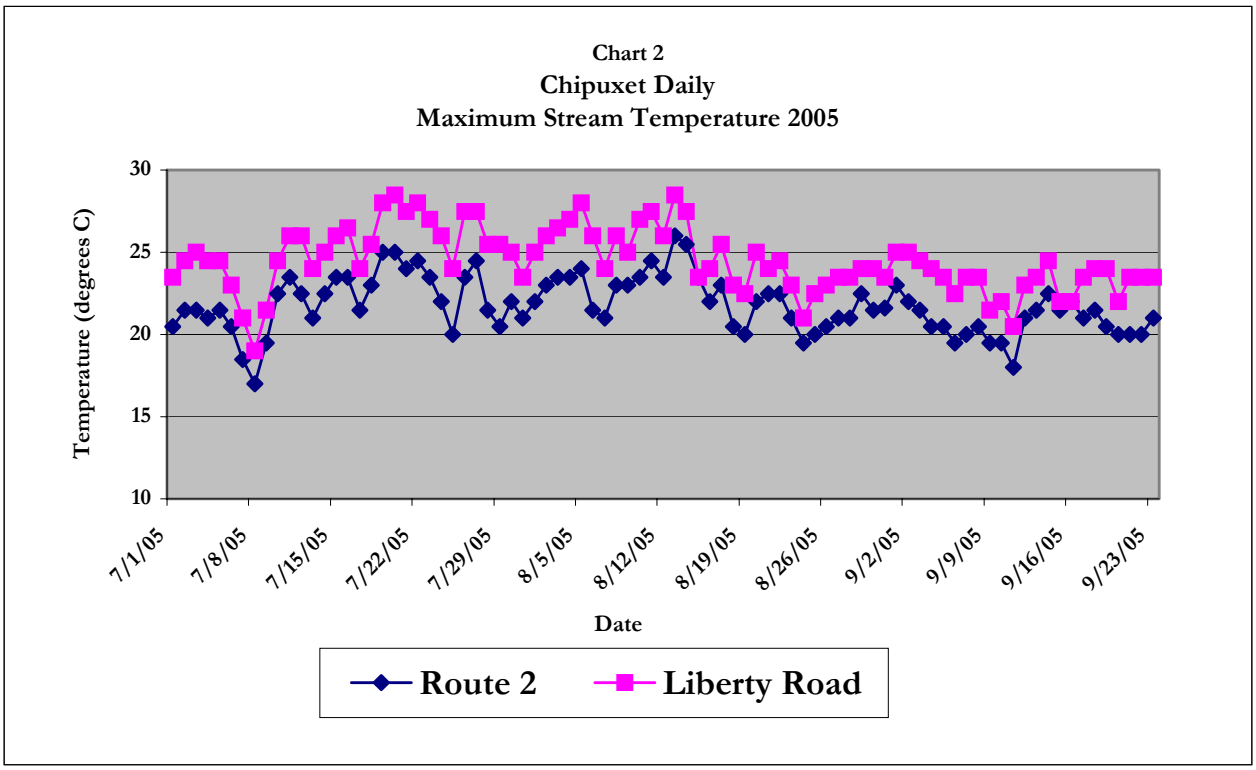
Because only half of the loggers were recovered, quality control checks could be correlated with only 3 sites. However, in a paired t-test, there was no significant difference

between the two temperatures. Therefore, the results of the loggers are accepted as accurate within 1 ^{o} C.

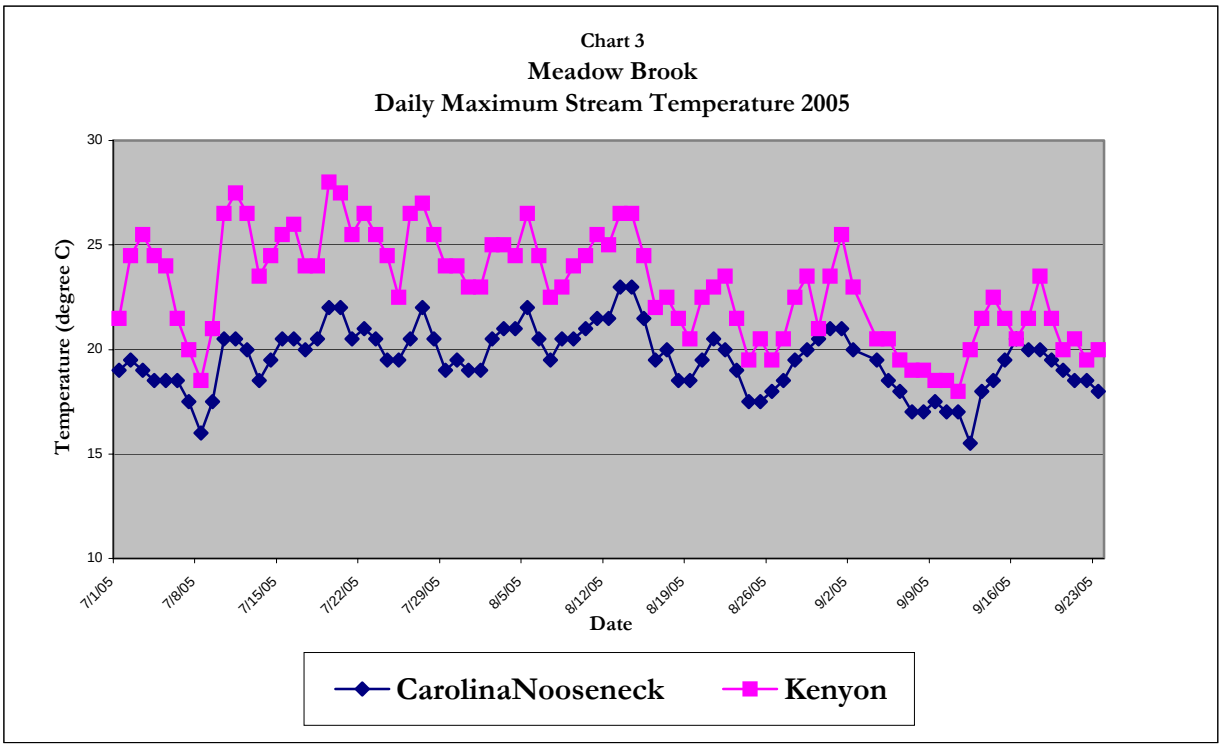
Chickasheen Brook (Chart 1) in Exeter and South Kingstown had warm temperatures at all three sites recorded. The first site, at Miskania Trail, is below a small impoundment which is itself downstream of Bear Swamp. While this site is in a heavily forested area, it still had 58 days (68%) with maximum stream temperatures above 20^{o} C. The next site downstream at Waite's Corner Road had 83 days (98%) above 20^{o} C. This part of the stream drains from Barber and Yawgoo Ponds. Both ponds have had problems with excess phosphorus and algal blooms last summer. Immediately downstream, below Rt. 138, the third site had 72 days (85%) with stream temperatures above 20^{o} C. No brook trout have been found in Chickasheen Brook (Libby, 2004; Saila et. al, 2004).



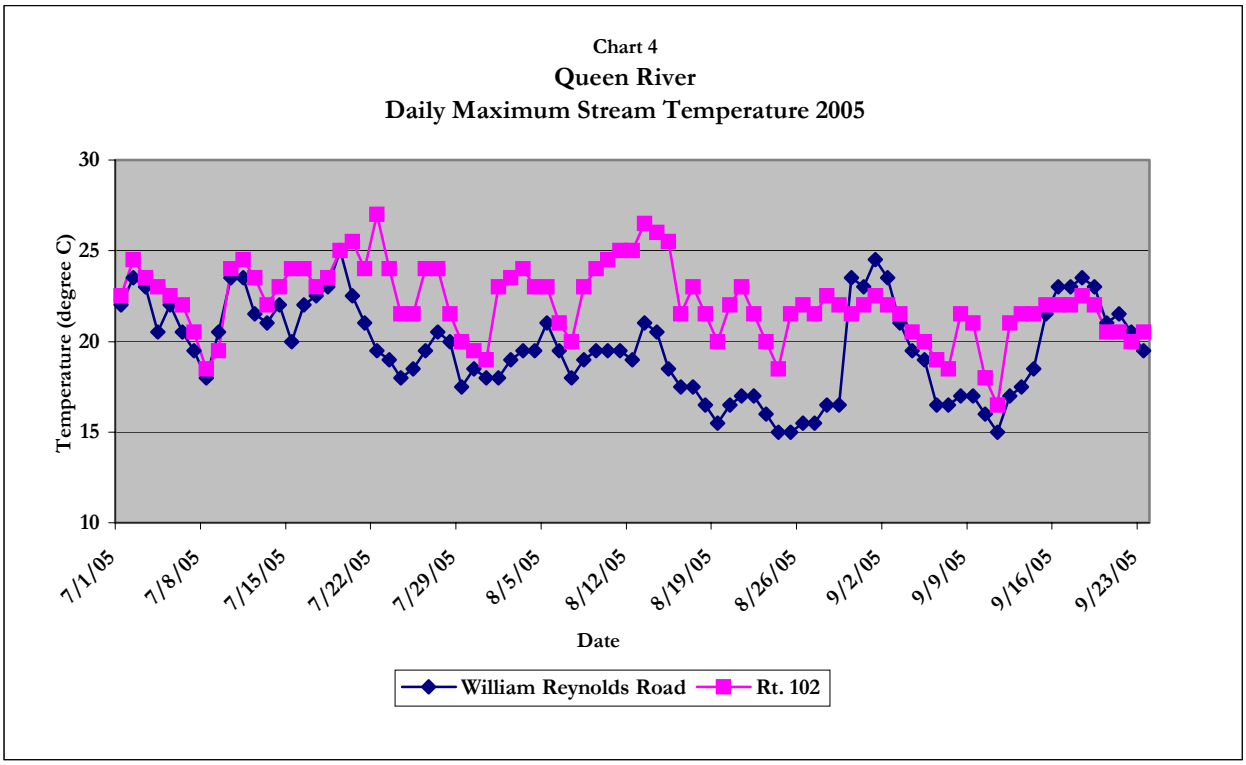
The ***Chipuxet River*** (Chart 2) is subject to water withdrawals for agricultural purposes in its upper reaches. The first logger was placed at Rt. 2, which is close to the start of the stream. The second logger was at Liberty Road, about 2 miles below a reservoir and pumps used to irrigate turf fields. Both sites had very high water temperatures, but the second site (99% of days with stream temperatures above 20^{o} C) was significantly higher than the first (85% of days above 20^{o} C). However, brook trout have been found at the Liberty Road site in the past (Libby, 2004).



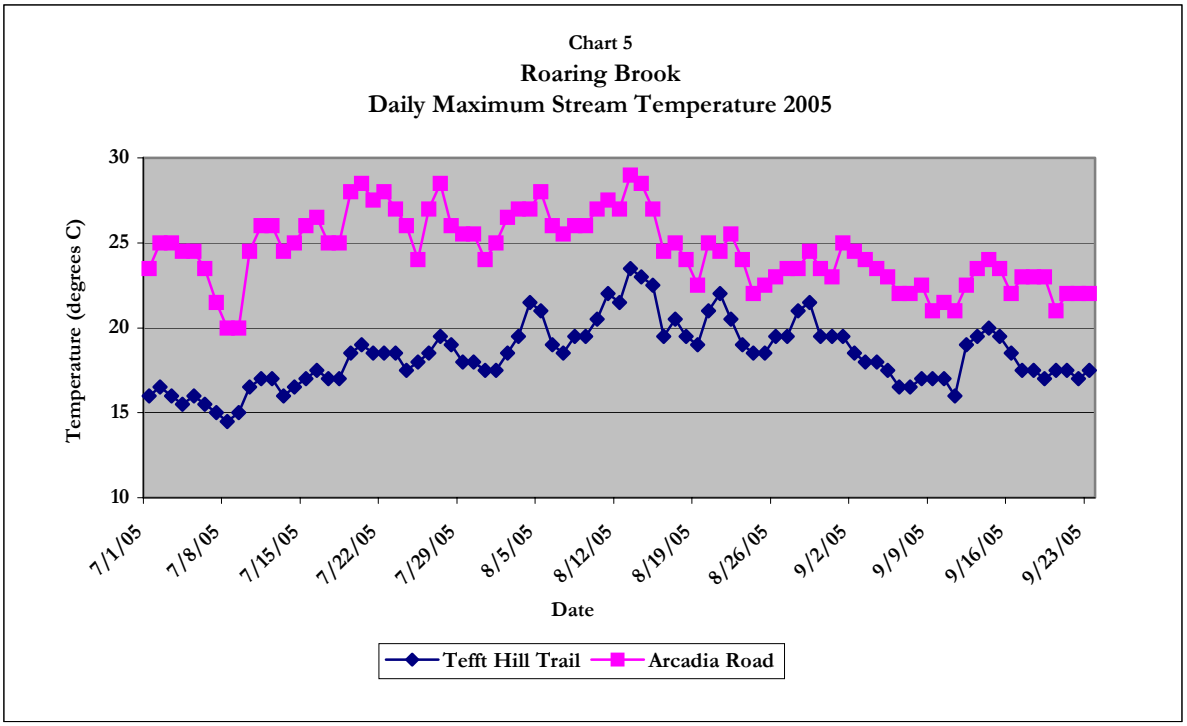
Meadow Brook (Chart 3) in Richmond has an unusual pattern to the stream flow. It rises out of swamps and wet meadows, then flows under Rt. 138 and across a golf course where the stream buffer has been totally removed. During the summer months, its top reaches flow, then dry at the wet meadows and through the golf course. Downstream of the golf course it flows through a forested area and into the Carolina Management Area. At the lower reaches it crosses between turf and agricultural fields before draining into wetlands at the top of Meadowbrook Pond. Where it flows between the fields it has a significant native vegetative buffer of 200 to 400 feet width. The first logger site at Carolina Nooseneck Road was in the upper reaches where flow was maintained all summer. Even so, almost half of the days recorded (45%) had maximum stream temperatures above 20^{o} C. The second site at Kenyon Hill Trail was below the golf course and forested area, before the stream enters the Carolina Management Area. All but 10 days (88%) had temperatures above 20^{o} C. It was unfortunate that we were unable to recover the logger from the lower reaches. This area is good brook trout habitat (Libby, 2004; Saila et. al, 2004), and the stream temperature may recover to acceptable values for brook trout before entering the pond.



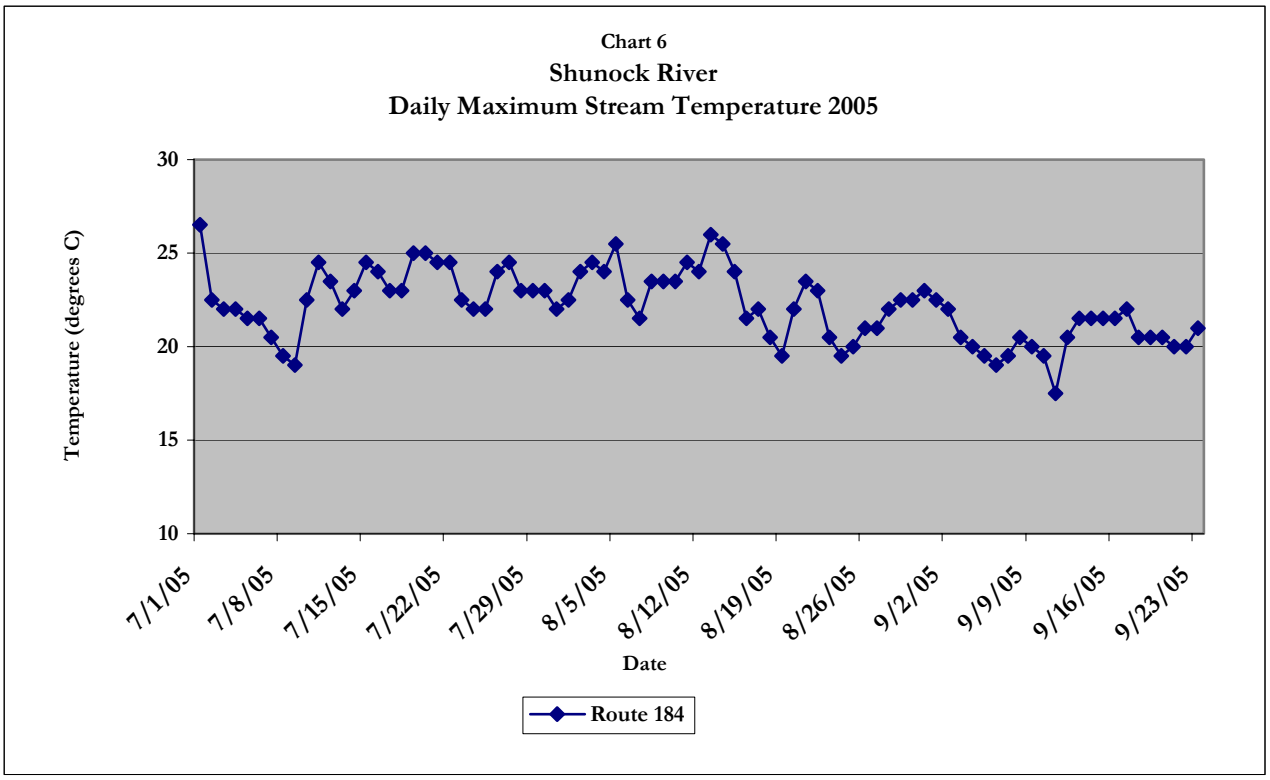
Only two sites on the ***Queen River*** (Chart 4) were recorded, one at Rt. 102 near the Exeter Country Club and the second on private property approximately one mile downstream from the first site. The first site was below a small reservoir and traveled through an open field with very little buffer area (20 to 50 feet). Temperatures at this site were higher than the downstream site, with 84% of the daily maximum stream temperatures above 20° C. The downstream site, at private property north of William Henry Road, made significant recovery, with only 41% of days of above 20° C. This may be due to the heavy forest canopy at the site as well as ground water influence. The lower site is considered to be acceptable brook trout habitat (Saila et. al, 2004).



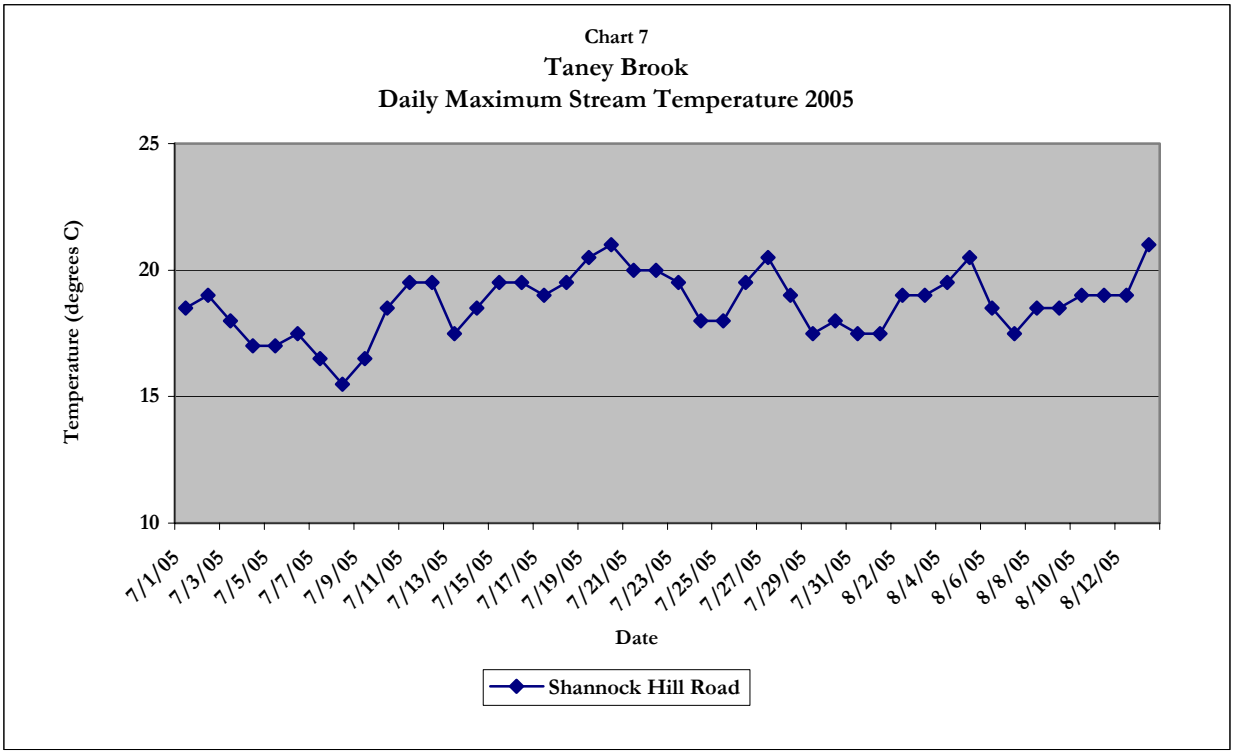
Roaring Brook (Chart 5) demonstrated the most diversity in stream temperatures between two sites. The site at Tefft Hill Trail is in a heavily forested area of the Arcadia Management Area. It is at least 4 miles downstream of a dam at Boone Lake, in Exeter. Out of 85 days recorded, only 14 days had maximum stream temperatures above 20° C (16%). The second site, below Arcadia Road, is less than one mile downstream of the first. There are, however, 2 small impoundments between the two sites, which create 2 small reservoirs; approximately 3 acres at the upper impoundment and less than 1 acre at the lower impoundment. In addition, the site sits about 100 yards below a road, with little vegetation cover from the road. As a result of these factors, all of the 85 days recorded had maximum stream temperatures above 20° C (100%). In our Fish Assemblage Study of 2003, brook trout were numerous at the Tefft Hill Trail site, while none were found below Browning Mill Pond.



Shunock River (Chart 6) in North Stonington, CT had only one logger recovered, near the intersection of Rtes. 49 and 184. This site is approximately 10 miles below the impoundment at Parke Pond. The daily maximum stream temperatures at this site were also high, with 84% above 20^{o} C. This is surprising because most of this reach is in a well forested area. The CT DEP also stocks this site with several species of trout for recreational fishing and it contains native brook trout as well (Hagstrom et. al., 1995). However, the Shunock River flows through several miles of wetlands which end about one mile upstream of the temperature logger.



Taney Brook (Chart 7) at Shannock Hill Road in Richmond had one logger that only recorded for 44 days. This small, relatively undeveloped watershed had the coolest temperatures, only 14% of the daily maximum stream temperatures above 20° C. Taney Brook is known to contain brook trout.



Conclusions:

During a hot summer like 2005, stream temperatures increase, putting low order streams under stress. If other habitat stressors are added to that then these low order streams may not be able to support some forms of native aquatic life. Adequate buffers appear to be a significant contribution to maintaining lower water temperatures. Another concern is water withdrawals from or near low order streams. It was difficult to place loggers at appropriate sites to draw any correlation between groundwater or stream water withdrawals and stream warming. However, with warm air temperatures and low precipitation, it is clear that groundwater influences stream habitats. Groundwater provides both flow and cool water. If water withdrawals divert groundwater from the streams during hot weather, then aquatic life may be left with no refugia and mortality may result.

Further studies will focus on the feasibility of identifying pockets of refugia for salmonid species by locating sources of groundwater flow into streams.

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