Mousam River Stream Temperature Study

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Maine Rivers

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Introduction

To better understand how dams are affecting habitat conditions in the Mousam River, temperature was monitored continuously in the summer of 2013 at eight locations within the influence of the first five dams. Measurements from these locations were compared to published temperature tolerance levels for brook trout.

Maine is fortunate to be one of the few states in the northeastern United States that can boast of pristine stream and lake habitats that are home to native coldwater fish species. This state is one of the last places in the U.S. where the native eastern brook trout (*Salvelinus fontinalis*) can still be found in a majority of suitable watersheds (Hudy et al. 2008). But the pressures that have pushed these fish to the point of extirpation in other northeastern states are being felt in Maine too. Landscape development and deforestation alter the flow (Armstrong et al. 2010) and temperatures (Nelson & Palmer 2007) in streams. Historical dams fragment and degrade stream habitat (Poff & Hart 2002). Introduced non-native fish such as small mouth bass compete with native species (Bonney 2001).

Figure 1. Old Falls Dam is situated directly upstream of the study reach.

Historical dam building in the Mousam River dates back to 1672 (Hall et al. 2010). The landscape in York County has changed with the progression from forest to farmland in the 1700s and 1800s, and then urban industrial development and forest re-growth in the 1900s. During the 1800s, non-native fish species were first introduced to Maine rivers (Warner 2005), and at some point the Mousam River, though the exact date of introduction is unknown.

Today, the historic habitat alterations of the past are combining with modern river-use pressures and changing climatic conditions to create even less favorable habitat conditions for native fish (Sinokrot et al. 1995). The dams in the Mousam River lack any means of passing fish upstream, and the historical populations of sea-run species have dwindled to remnant populations or disappeared altogether. Stream habitat conditions in the Mousam River have been altered by dam building. Dams create upstream impoundments that increase the surface area of the river, decrease water velocity, and increase surface water temperature (Poff & Hart 2002). Warmer temperatures may result in unsuitable stream water temperatures for brook trout and other native species (Hayes et al. 2006).

Geography and Study Sites

The Mousam River watershed includes 344 miles of stream and a drainage area of 117 square miles in the towns of Acton, Shapleigh, Waterboro, Sanford, Alfred, Lyman, and Kennebunk. There are 14 dams located on the Mousam River. The study area spans approximately 10 miles of the lower Mousam River which includes the first four dams (Figure 2).

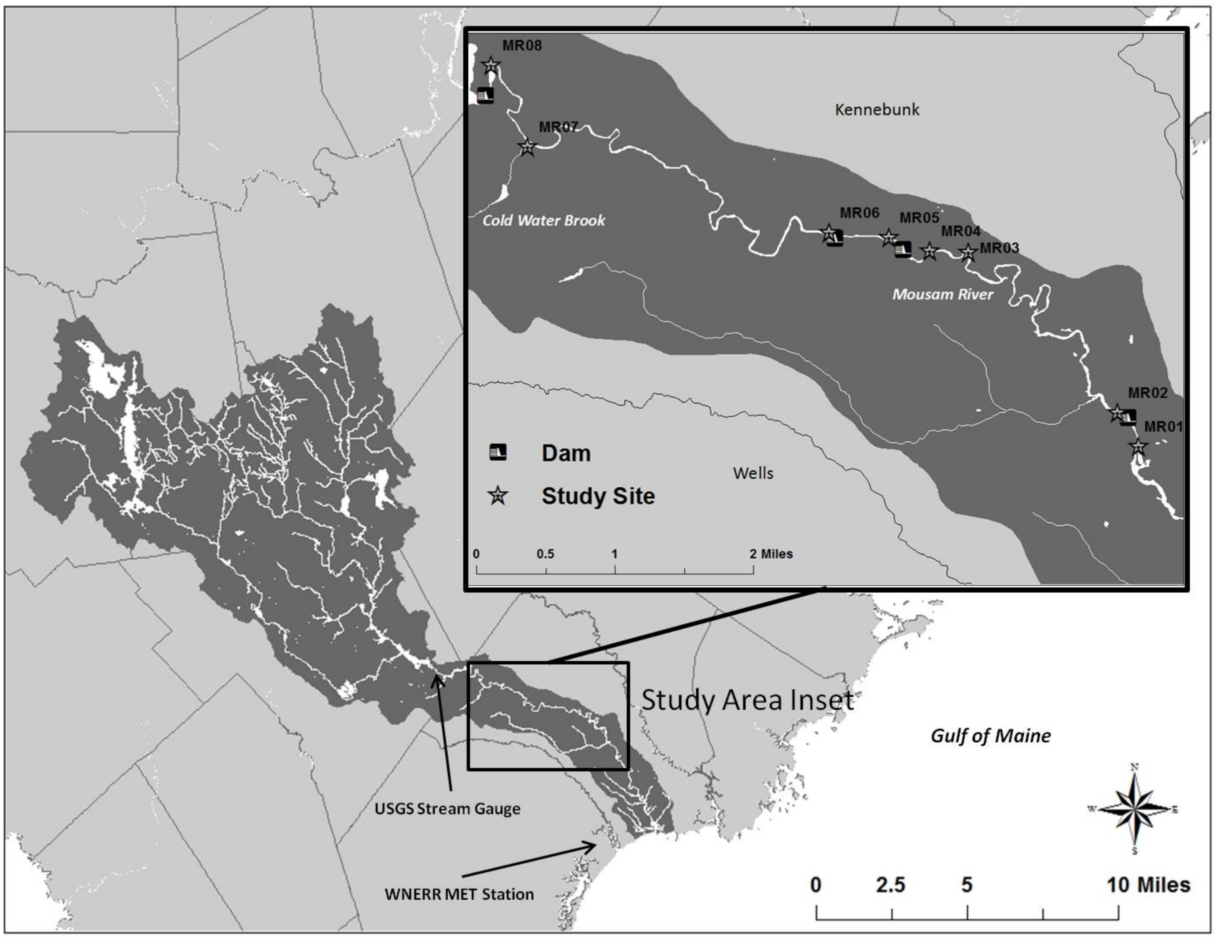

Figure 2. Mousam River temperature study sites are located in the lower river, downstream of the USGS stream gauge and in local proximity to the WNERR meteorological station.

Water temperature was monitored at eight sites in lower Mousam River located between the head of tide and Old Falls Dam (Figure 1). Sites were selected to cover a variety of habitat conditions. Three sites were located in impoundments created by the first three dams in the lower Mousam River. Four sites were located in free flowing reaches that occurred downstream of the first four dams in the lower Mousam River. One site was located in Cold Water Brook at the confluence with the Mousam River. Riffle sites were characterized by rocky or gravel substrates with higher stream velocity and turbulent surface water. Run sites were characterized by slower stream velocities and smooth surface water. The amount of shading from riparian vegetative cover varied between sites, and the degree of shading was not quantified for this study. Sites were also selected based on ease of access and distributed at somewhat regular distances along the study reach. Sites were coded "MR" (Mousam River) and a number (01 – 08) with the number increasing from downstream to upstream.

- MR01. This site was located in a free flowing reach of upstream of the head of tide near Rogers Pond. This site was characterized by riffle habitat with moderate riparian cover.

- MR02. This site included a monitoring location at the bottom (MR02B) and the surface (MR02A). The site was located in the impoundment created by Kesslen dam. There was very little riparian cover at this site.

- MR03. This site is located at the upstream end of the Kesslen impoundment. It was characterized by run habitat with abundant riparian cover.

- MR04. This site was located in a free flowing reach downstream of the Twine Mill Dam. The site was characterized by riffle habitat with moderate riparian cover.

- MR05. This site was located in the impoundment created by Twine Mill Dam. This site had no riparian cover.

- MR06. This site was located in the impoundment created by the Dane Perkins Dam. The site had moderate riparian cover.

- MR07. This site was located in a free flowing reach in Cold Water Brook just upstream at the confluence with the Mousam River. This site was characterized by run habitat with abundant riparian cover.

- MR08. This site was located in a free flowing reach located downstream of the Old Falls Dam. The site was characterized by run habitat with moderate riparian cover.

Field Methods

Water temperature was measured at 15-minute intervals continuously from June through October. This period represents the months of warmest water temperature when habitat conditions can negatively affect native fish species. Data loggers were replaced midway through the study to ensure battery life and logger integrity, and to download data. Sites were visited every two weeks to check that loggers were still in place, and to adjust deployment as site conditions warranted (e.g. changes in depth, tampering). Loggers were deployed on June 7th at sites MR03, MR04, MR05, MR06, and MR08. Loggers were deployed on June 10th at sites MR01, MR02, and MR07. All loggers were replaced on August 22nd. Data were downloaded twice, after logger retrieval in August and October.

Onset HOBO Pendant Temperature/Light UA-002-64 data loggers were deployed using rope tied to a buoy and an anchor, which allowed the loggers to be suspended in the water column. The depth at which loggers were deployed was not uniform across sites, but loggers were generally deployed to be suspended in the middle of the water column. Two loggers were deployed at site MR02 (A and B) with A deployed in the middle of the water column and B deployed approximately six inches above the river bottom, and A positioned approximately three feet higher in the water column than B. This stratified deployment at site MR02 was designed to detect the variation between the upper/middle and lower water column in the Kesslen Dam impoundment. Initially, stations were secured to the shore with rope tied to earth anchors, to prevent loggers from being entangled and moved by in-stream debris. Use of shore anchoring was discontinued after several loggers were found to have been dragged to the shore by members of the public. Sites were visited every two weeks, so it was possible to identify suspect data by comparing field visit observations with suspect readings. Loggers found on shore or floating at the water surface were repositioned to the approximate middle of the water column.

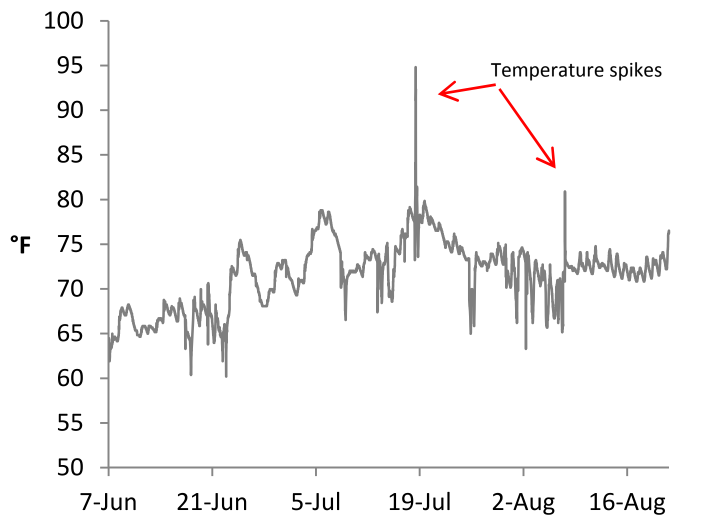

Figure 3. Spikes in temperature indicate out of water data at MR04 prior to Aug 22.

Data Analyses

As previously mentioned, several loggers were found on shore during field visits. This occurred once each at sites MR01, MR02, MR05, and MR06. In addition to the loggers that were pulled to shore, the logger at site MR04 was found out of water in a shallow area during an observed low flow period on August 22nd. The data from this logger during the prior period showed large fluctuations in daily temperature indicating other out of water periods (Figure 3). All suspected out of water data were flagged and were not included in these analyses. The data log from the first deployment at MR03 indicated that the logger reset and discontinued logging after only two weeks of measurements, and no data were available from June 13th to August 22nd. The data log from the second deployment at MR03 ended on September 16th, and no data were available for the rest of the study period. These instrument errors may have been the result of an impact with debris in the stream, and no similar issues were observed with any other loggers. The loggers at MR05, and MR01 that were deployed on August 22nd were lost after September 19th, due to either tampering or entanglement with river debris, and data from that date onward were not retrieved.

Most sites showed a notable difference between the last reading of the first deployment and the first reading of the last deployment, which were within at least one hour of each other at all sites. Potential differences in calibration might have accounted for small increases or decreases in readings between first deployment and second deployment data. To rule out the influence of differences in calibrations between loggers a test deployment was conducted in the laboratory. Loggers were set to measure

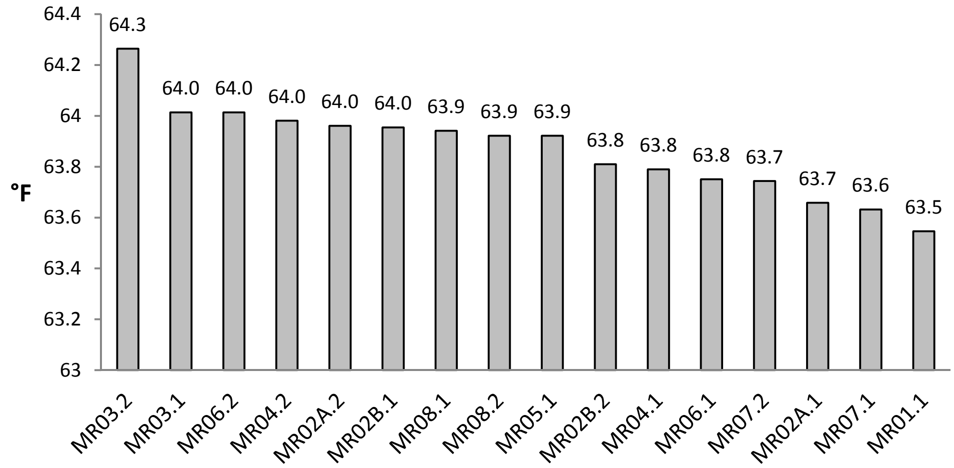

Figure 4. Temperature logger calibration test shows calibration within accuracy range of ±.85°F

temperature every 15 minutes over a six hour period in the same location. The mean temperature was calculated for each logger, and values were compared to determine if the range exceeded the accuracy specified by the manufacturer. This test showed that the logger readings varied by a maximum of 0.8 °F (Figure 4). This value is close to the specified accuracy range for the Hobo 002-AU temp/light logger (±0.85 °F). Based on this test we determined that differences in logger calibrations did not significantly contribute to the discrepancy between first and second logger deployments. The more likely explanation for the difference between first and second deployments is a modification of the deployment location. At the start of the second deployment, loggers were placed as close to the original location as possible, however the deployment method was not precise enough to avoid changes in depth from the first to the second deployment. A thermally stratified water column could have resulted in significant and abrupt changes in water temperature from one deployment to the next. The data show some evidence of this, where some sites exhibited as much as a 5 °F change within one 30-minute period. This was particularly noticeable at site MR07, where the confluence of water from Cold Water Brook and the Mousam River resulted in a greater stratification of water temperatures (Figure 5).

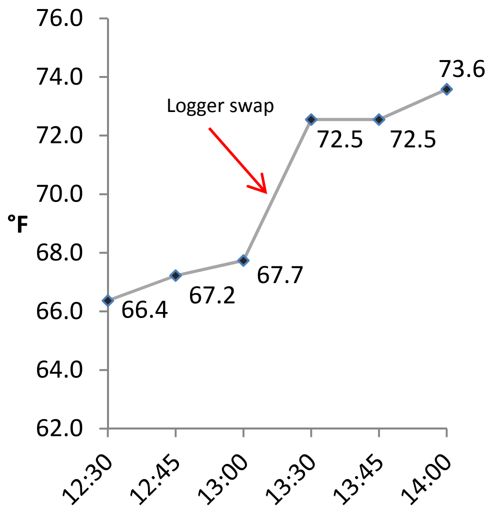

Figure 5. An abrupt increase of 4.8 °F indicates a change in MR07 logger location relative to colder water inputs from the adjacent tributary.

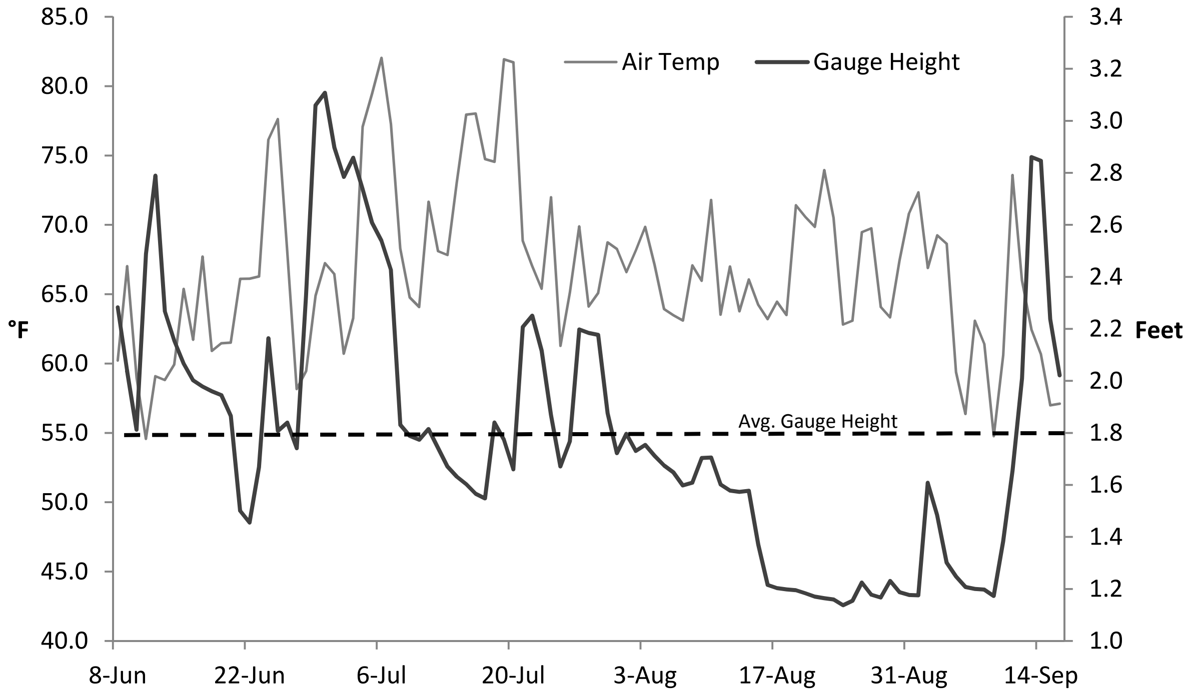

Figure 6. Stream flow was below the summer time average during periods of extended peak air temperatures in July and August.

Stream flow and air temperature are factors that influence water temperature. Water-level measurements from the USGS flow gauge on the Mousam River (USGS 2013) located upstream of the study sites were correlated with air temperature readings at the WNERR meteorological station (NOAA 2013). Discharge data (cubic feet per second) were not available from the USGS stream gauge for the entire study period so gauge height (depth in feet) was used instead. The average gauge height during the study period was 1.8 feet. Air temperatures during periods of below average flow were 1.1 °F higher than during average and above average flows. This is likely because several periods of below average flow occurred during periods of peak temperature in July and August (Figure 6).

Our analyses evaluated habitat conditions at each site based on published optimum temperature levels for native brook trout. In developing habitat suitability criteria for brook trout the U.S. Geological Survey identified a range of optimum temperatures for brook trout, gathered from the available literature at the time. They established upper tolerance levels of around 77 °F for short exposure times, and an optimum temperature range of 51.8-60.8 °F (Raleigh 1982). While the short duration upper tolerance values are of concern for fish in the wild, research indicates that sub-lethal temperatures experienced in the wild may be a more significant limiting factor on brook trout distribution (Wehrly et al. 2007). The optimum growth temperature range defines those temperatures at which a fish is best able to grow. Growth rate is a determining factor in a fishes ability to achieve an adequate size for effectively carrying out its life history, including activities such as establishing territory, feeding, escaping predation, and reproducing (Robinson et al. 2010). Temperatures that exceed the optimal range inhibit growth by inducing thermal stress in brook trout that results in reduced metabolism and feeding. In laboratory studies, sustained temperatures above the optimum growth limit of 60.8 °F (but below upper

Table 1. Data availability varies at each study site.

Site	Available Data
MR01	Jun 11 - 13, Jun 19 - Aug 22
MR02	Jun 11 - 18, Jun 21 - Oct 27
MR03	Jun 8 - 12, Aug 23 - Sep 15
MR04	Jun 8 -19, Aug 9 - Oct 20
MR05	Jun 8 - Aug 21
MR06	Jun 8 - Aug 2, Aug 9 - Oct 27
MR07	Jun 11 - Oct 20
MR08	Jun 8 - Oct 20

tolerance limits) have been shown to decrease growth rates for both sustained and oscillating temperature over acute (1-4 day) and chronic (8-24 day) periods, with a limit of positive growth at approximately 73.4 °F (Chadwick 2014).

Temperature data from our study sites were compared with published observations to determine if habitat conditions at the study sites exceeded optimal ranges for acute and chronic periods. The daily mean and max temperatures were calculated for each study site. Our analyses refer to the above values of 60.8 °F optimal growth limit, and 73.4 °F positive growth limit.

Results

Due to the constraints in the data outlined in the data discussion, water temperature readings were not available from all sites at all times of the study due to tampering and equipment loss. As a result data are not continuous for all sites (Table 1). Data were omitted from the analyses for days when an entire 24-hour period of readings was not available (e.g. the day first day of deployment, or day of retrieval).

There were 67 days of water temperature measurements for site MR01. Daily average water temperature exceeded the optimal and positive growth limits on 67 (100%) and 23 (34%) days respectively (Figure 7).

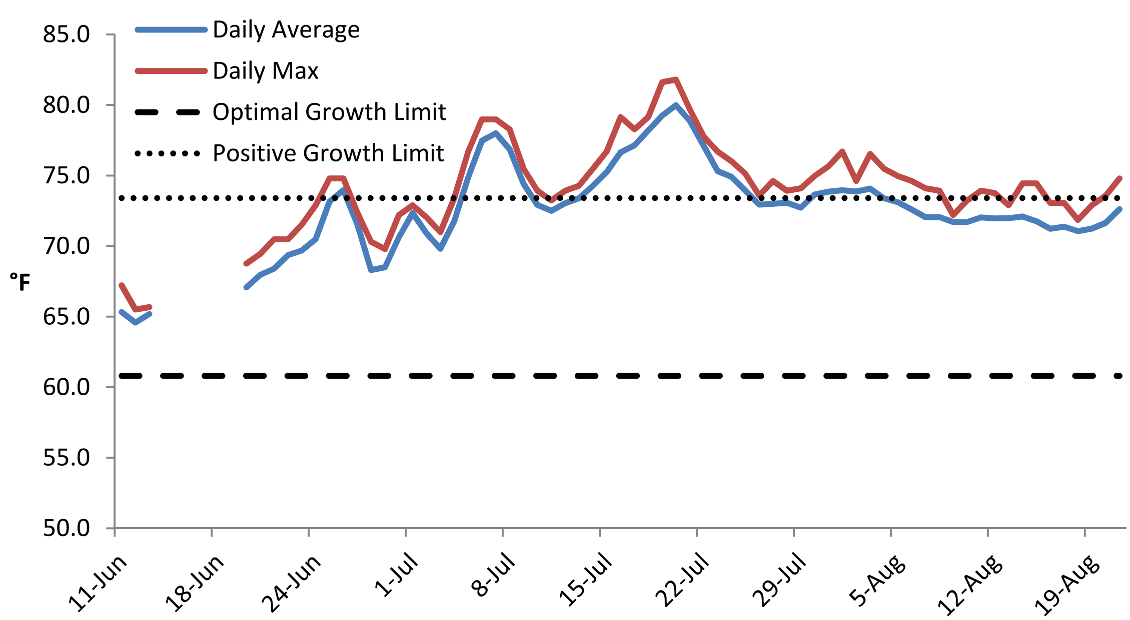

Figure 7. Daily average and maximum water temperatures at site MR01 were plotted against the optimum growth limit (60.8 °F) and positive growth limit (73.4 °F) for brook trout.

There were 137 days of water temperature measurements for site MR02A. Daily average water temperature exceeded the optimal and positive growth limits on 114 (83%) and 43 (31%) days respectively (Figure 8).

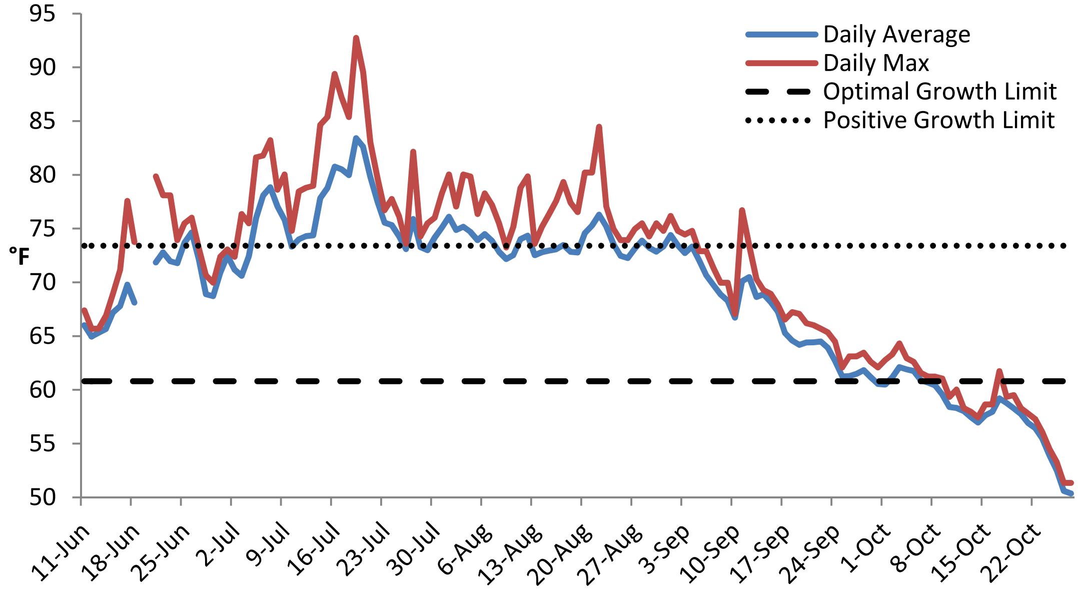

Figure 8. Daily average and maximum water temperatures at site MR02A were plotted against the optimum growth limit (60.8 °F) and positive growth limit (73.4 °F) for brook trout.

There were 137 days of water temperature measurements for site MR02B. Daily average water temperature exceeded the optimal and positive growth limits on 114 (78%) and 24 (17%) days respectively (Figure 9).

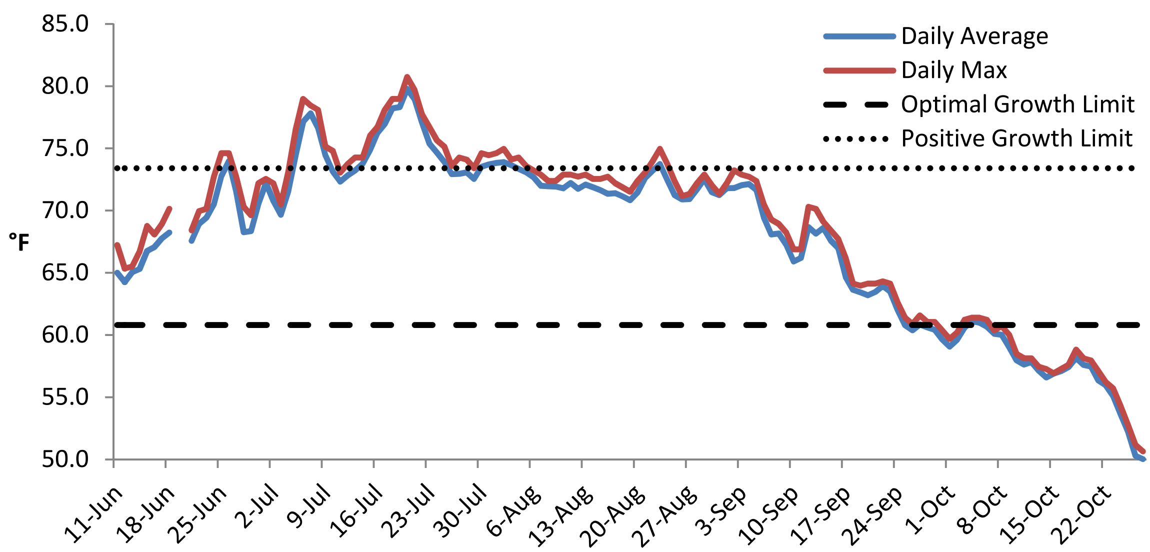

Figure 9. Daily average and maximum water temperatures at site MR02B were plotted against the optimum growth limit (60.8 °F) and positive growth limit (73.4 °F) for brook trout.

There were 29 days of water temperature measurements for site MR03. Daily average water temperature exceeded the optimal and positive growth limits on 29 (100%) and 5 (17%) days respectively (Figure 10).

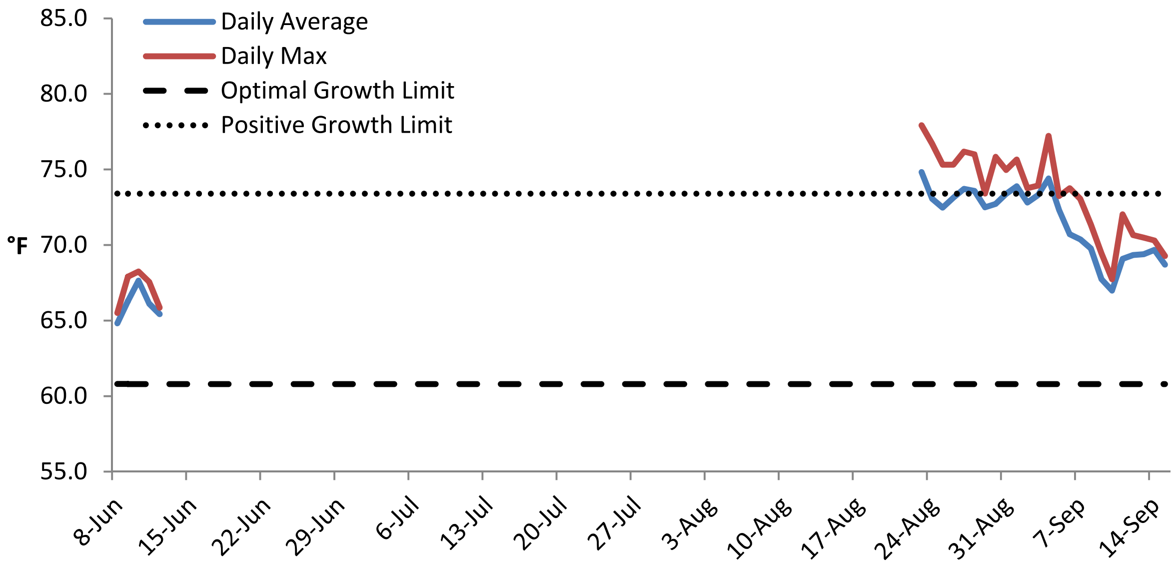

Figure 10. Daily average and maximum water temperatures at site MR03 were plotted against the optimum growth limit (60.8 °F) and positive growth limit (73.4 °F) for brook trout.

There were 85 days of water temperature measurements for site MR04. Daily average water temperature exceeded the optimal and positive growth limits on 71 (84%) and 3 (4%) days respectively (Figure 11).

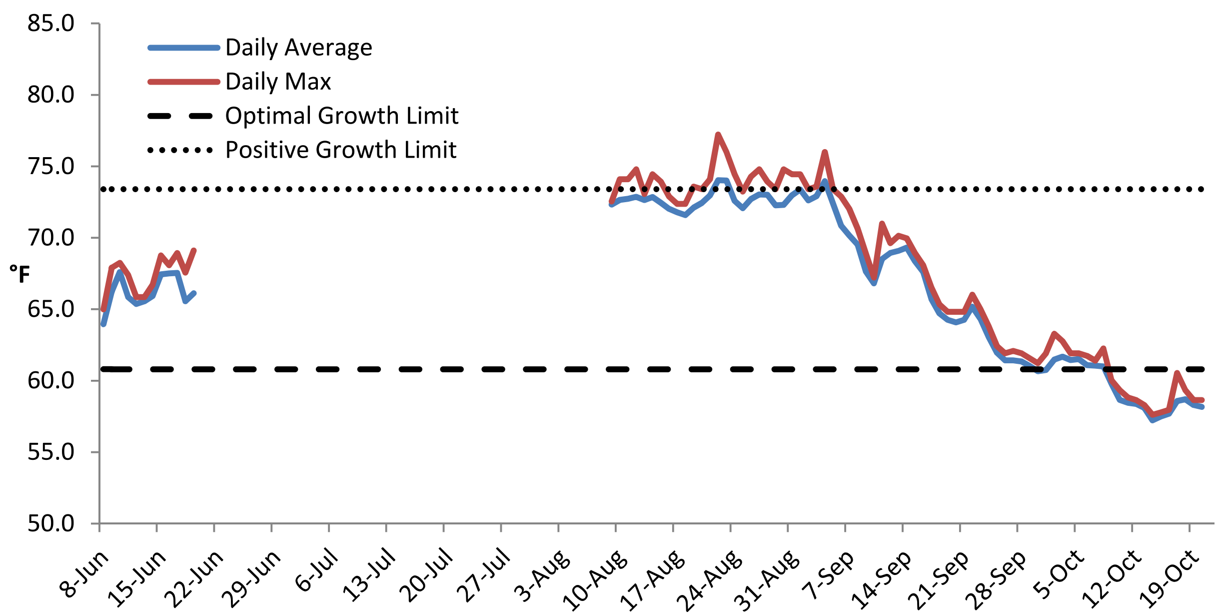

Figure 11. Daily average and maximum water temperatures at site MR01 were plotted against the optimum growth limit (60.8 °F) and positive growth limit (73.4 °F) for brook trout.

There were 75 days of water temperature measurements for site MR05. Daily average water temperature exceeded the optimal and positive growth limits on 75 (100%) and 37 (49%) days respectively (Figure 12).

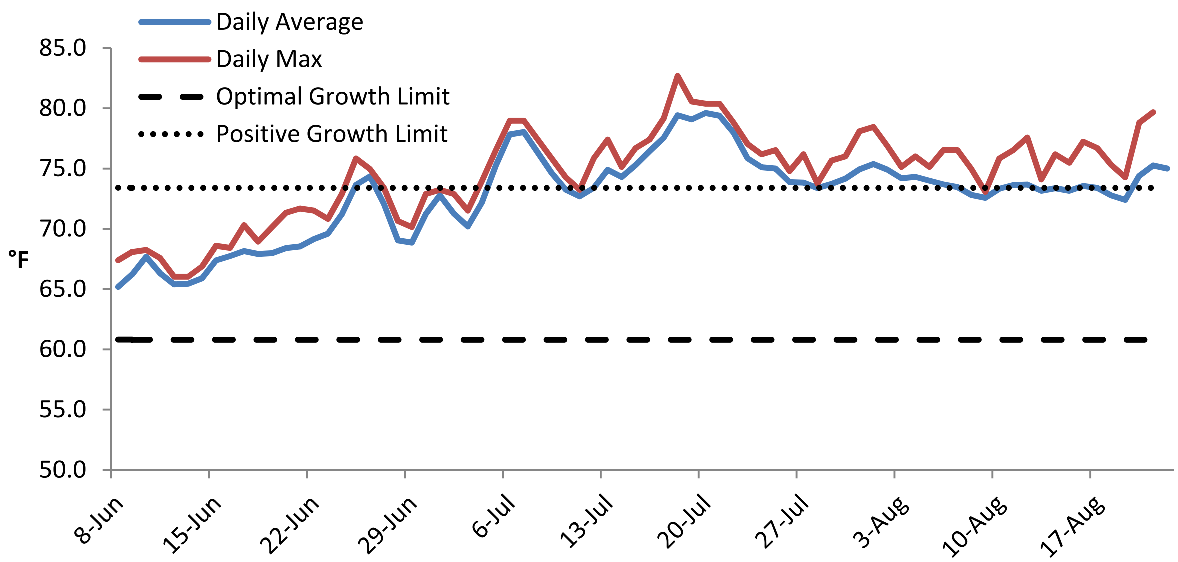

Figure 12. Daily average and maximum water temperatures at site MR05 were plotted against the optimum growth limit (60.8 °F) and positive growth limit (73.4 °F) for brook trout.

There were 136 days of water temperature measurements for site MR06. Daily average water temperature exceeded the optimal and positive growth limits on 116 (85%) and 40 (29%) days respectively (Figure 13).

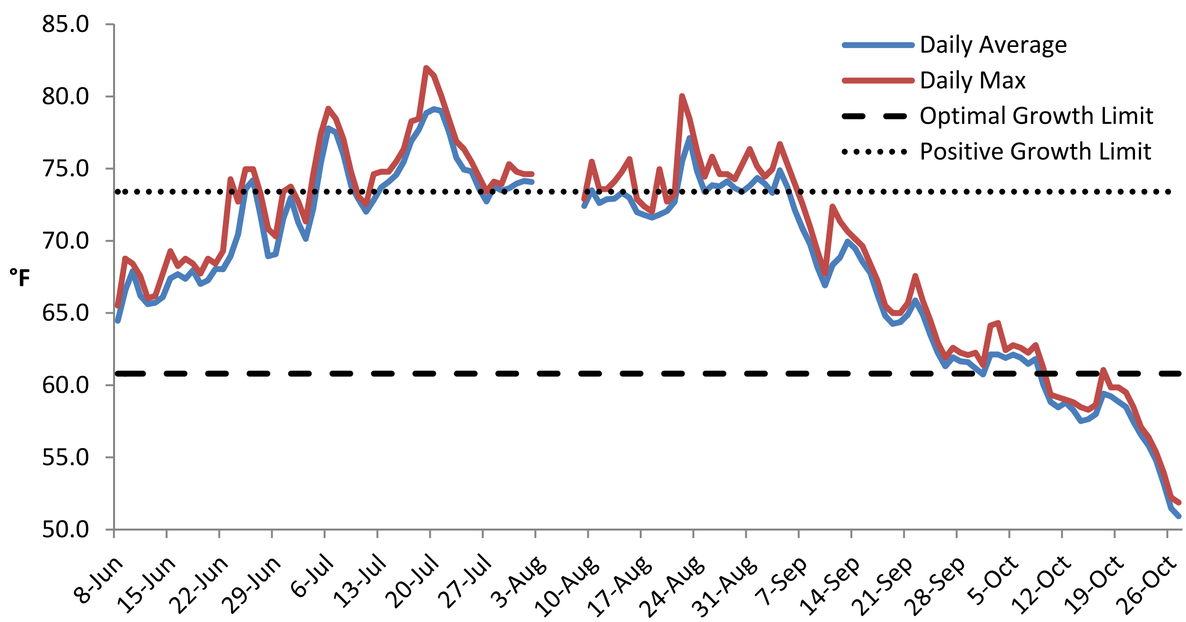

Figure 13. Daily average and maximum water temperatures at site MR06 were plotted against the optimum growth limit (60.8 °F) and positive growth limit (73.4 °F) for brook trout.

There were 132 days of water temperature measurements for site MR07. Daily average water temperature exceeded the optimal and positive growth limits on 72 (54%) and 1 (1%) days respectively (Figure 14).

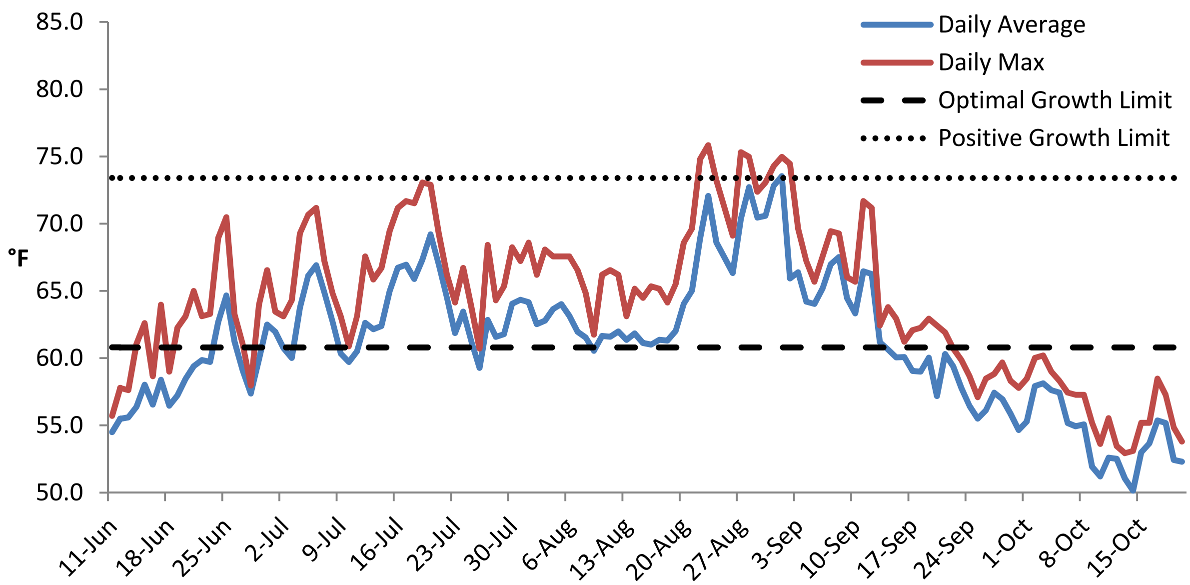

Figure 14. Daily average and maximum water temperatures at site MR07 were plotted against the optimum growth limit (60.8 °F) and positive growth limit (73.4 °F) for brook trout.

There were 135 days of water temperature measurements for site MR08. Daily average water temperature exceeded the optimal and positive growth limits on 123 (91%) and 55 (41%) days respectively (Figure 15).

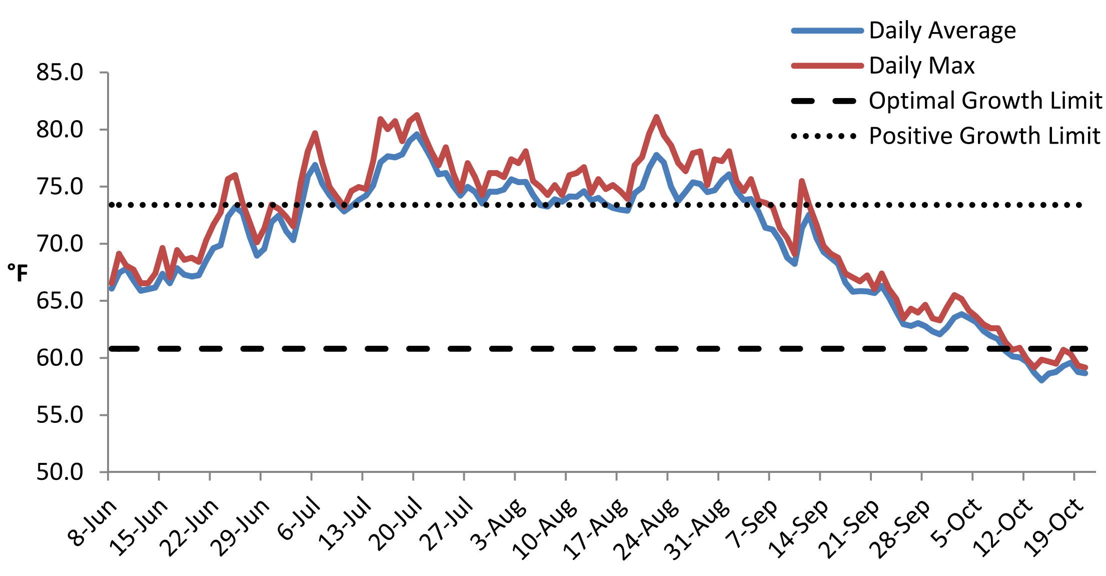

Figure 15. Daily average and maximum water temperatures at site MR08 were plotted against the optimum growth limit (60.8 °F) and positive growth limit (73.4 °F) for brook trout.

Conclusions

All sites experienced extended chronic periods with water temperatures exceeding the optimal growth limit for brook trout. All main stem Mousam River sites recorded daily averages above the optimal growth limit on 78% or more of the study days. The exception was MR07, the tributary site on Cold Water Brook, where daily average temperatures exceeded the optimal growth limit on 54% of study days, however even at this site daily maximum temperature exceeded the optimum growth limit on 73% of study days.

The data show that habitat conditions in the lower Mousam River likely limit the growth and survival of native brook trout during periods of high temperature in the summer. While lethal temperatures were recorded infrequently, temperatures exceeded the optimal growth limit for brook trout most of the time. When temperatures exceed this limit, fish growth slows as conditions become increasingly stressful. The stress related to high water temperature can exacerbate the effects of other environmental stressors such as predation or low dissolved oxygen levels and in turn lead to increased mortality. Additionally, periods of low flow during periods of high air temperature can further exacerbate these stressful habitat conditions.

In contrast to the Mousam River, Cold Water Brook seems to provide measurably better habitat conditions for native brook trout. This highlights the importance of access to tributary streams that provide refuge from increased summer time water temperatures.

Table 2. Impounded and free flowing reaches both experienced high daily average water temperatures.

Habitat Type	Site ID	# Days Exceeding Optimal Limit	% Days Exceeding Optimal Limit	# Days Exceeding Growth Limit	% Days Exceeding Growth Limit	Total # Days
Free Flowing Sites	MR08	123	91%	55	41%	135
	MR07	72	54%	1	1%	132
	MR04	71	84%	3	4%	85
	MR01	67	100%	23	34%	67
	MR03	29	100%	5	17%	29
Impounded Sites	MR06	116	85%	40	29%	136
	MR02A	114	83%	43	31%	137
	MR02B	114	78%	24	24%	137
	MR05	75	100%	37	49%	75

The extent that the lower Mousam River dams influence river water temperature is not made clear by the results of this study, given that the impounded and free flowing reaches alike experienced significant periods of unfavorable in-stream conditions (Table 2.) This likely speaks to the fact that the impoundments in the lower Mousam River are in close proximity to each other may not provide adequate time for the river water to cool as it moves downstream. Additionally, two large impoundments upstream of the study reach are likely responsible for increasing the water temperature before it ever reaches the lower river. Additional data are needed on river conditions upstream of all of the impoundments to provide a clearer picture of the extent of their effect on river temperature. The data support this possibility, with the worst conditions observed at MR08, a free flowing reach downstream of the fourth and fifth dams at Old Falls and Estes Lake respectively.

However, it can be inferred based on the literature that the lower Mousam dams do influence downstream habitat conditions. At the present these conditions are prohibitive for native brook trout. The effects of climate change are likely to further exacerbate the warming of waters in the Mousam River, with air temperature in Maine predicted to increase by as much as 11° in the summer (Whitman et al. 2013). With water temperatures already routinely exceeding optimal growth conditions for brook trout, it is likely that water temperatures will begin to approach lethal limits for native brook trout much more frequently.

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