Appendix 10

Temperature

Temperature Data

Ten Onset HOBO® water level Loggers and three temperature pendant loggers were installed in the Lamprey watershed between 12 April 2006 and 28 April 2006 (Figure 1). Temperature was recorded at 15 minute intervals. Eight of the 13 probes were installed in the mainstem of the Lamprey (five in the Designated River segment), one in the Pawtuckaway River, three in the North River and one in the Little River. The initial attempt to collect the loggers was on 5 October 2006 and, while still considering the period of record in common for all probes, we analyzed data from 1 May 2006 to 30 September 2006, covering 153 days and the entire Rearing and Growth period.

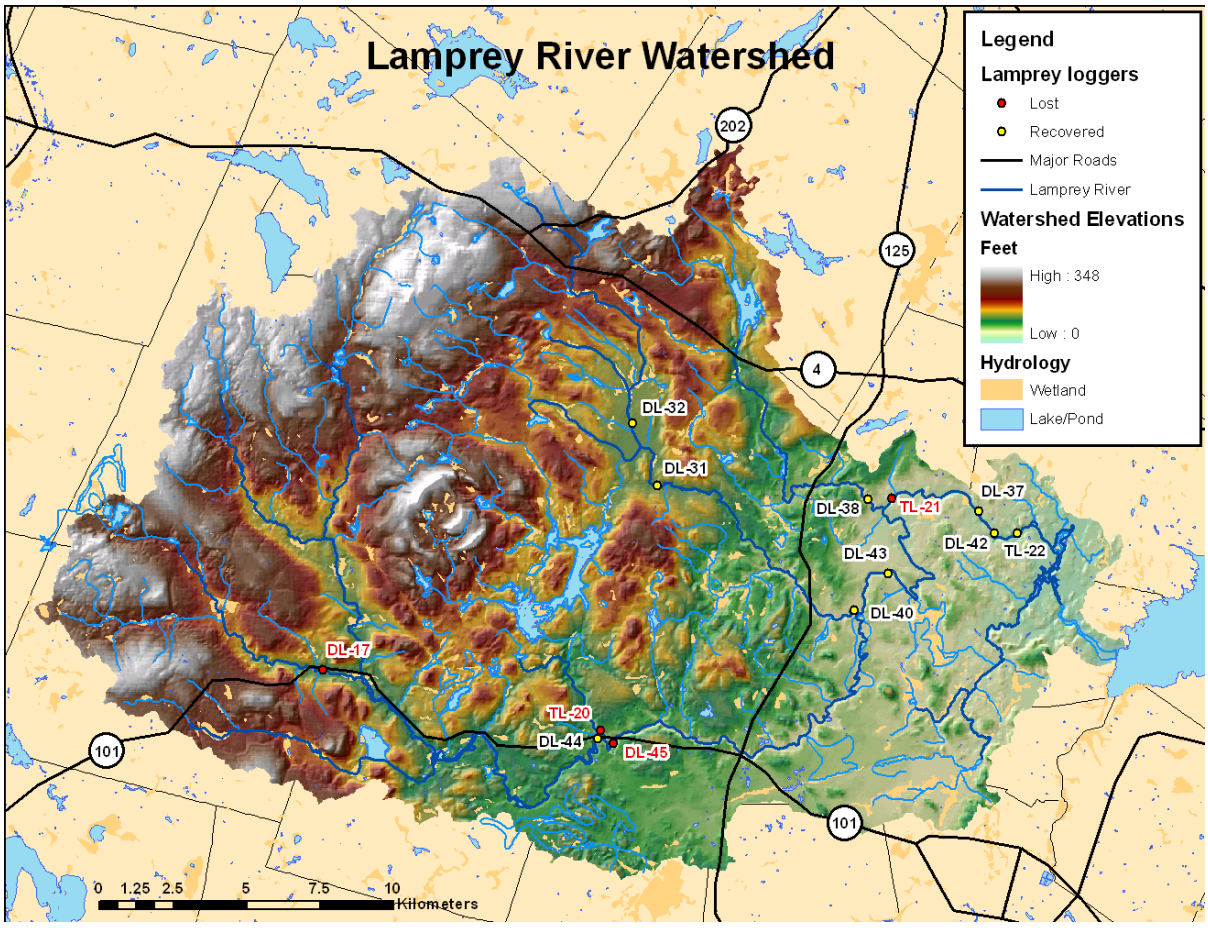


Figure 1. Watershed map of temperature recording probes deployed in the 2006 study season. "DL" refers to probes that record pressure (equivalent of depth) as well as temperature and "TL" refers to probes that only record temperature. Probes labeled in red are those which were lost in the May 2006 flood.

Within thee weeks of installing our probes, the Lamprey suffered what may have been its largest flood of record. The flooding began on May 12th and peaked on May 16th with a recorded discharge of 9100 cfs. As a result of this flood we were unable to recover four temperature loggers (two water level loggers and two temperature pendants). Fortunately, all but one of these instruments was located in the upstream portion of the

designated river, which allowed us to examine some of the observed trends within the study area. However, we are limited in our discussion of influences from the upper watershed. We were fortunate to recover the four probes installed in the North and Little Rivers, the two largest tributaries entering the study reach. After reviewing the data we concluded that it would have been beneficial to install additional probes within the Newmarket impoundment and an additional logger along the designated river to better assess the impacts of individual impoundments on overall temperature trends. These efforts are largely beyond the scope of the project, but often give insight into the dynamic processes and relationships at work throughout the system as well as indicator of sensitive areas or sources of thermal relief.

Data from the recovered probes was downloaded and processed. Because of the variation in date and time of both installation and recovery, we filtered the data into a common period between May 1st and September 31st 2006. A summary of this data can be seen in Table 1.

Table 1. Temperature data for the 2006 season. Distance column is distance upstream of the McCallen Dam in Newmarket. "D US of C" is the distance on that tributary that the loggers are upstream of the confluence with the Lamprey. "Min, Avg, Max" are the average minimum, average, and maximum temperature for the study period. "Pmax" is the highest sustained temperatures recorded during the study period for at least 1 hour.

ID	Location	Distance		Min	Avg	Max	Pmax
TL_22	Main Stem	4600		18.6	19.2	20.0	27.6
WL_42	Main Stem	5618		18.8	19.3	19.8	27.1
WL_37	Main Stem	6580		18.7	19.3	20.0	27.6
TL_21	Main Stem	10509		X	X	X	X
WL_43	Main Stem	18295		18.4	19.1	19.8	27.9
WL_45	Main Stem	36569		X	X	X	X
WL_44	Main Stem	37641		19.2	20.0	20.9	28.8
WL_17	Main Stem	54085		X	X	X	X
TL_20	Pawtuckaway	37580	D US of C	X	X	X	X
WL_40	North River	20595	129	17.8	18.6	19.5	26.9
WL_31	North River	31179	10584	18.0	18.7	19.4	26.5
WL_32	North River	33963	13368	17.8	18.5	19.4	26.8
WL_38	Little River	11920	880	17.3	17.8	18.5	25.0

Temperatures in the mainstem of the Lamprey River were very similar between each of the study locations, especially from May 1st through July 1st. Water temperatures started out around 12°C and rose to above 15°C on May 6th before dropping steadily during the rains that resulted in the major flood of May 2006 (Figure 2). Temperatures bottomed out at 9°C on May 15th at about the peak discharge of the flood. For the rest of the month, temperatures climbed steadily, peaking at 21°C on June 1st. Temperatures again dropped rapidly during a second, but much less severe flood, in which flows stayed above the 2-year recurrence interval between June 4th and the 13th. Temperatures during this time dropped to around 15°C. As the waters receded, temperatures rose sharply to around 24°C on June 20th. Temperatures rose slowly over the next 45 days, undulating between 21 and 28°C and peaking on both July 19th and August 3rd. River temperatures

cooled steadily over the remainder of the study period, reaching 15°C by September 31st. The loggers, after July 1st, began to have some separation between values, especially in the case of WL-44 which is typically 1°C warmer than the other probes for the remainder of the period, and also in the case of WL-43, which was occasionally as much as 0.5°C cooler than the other probes.

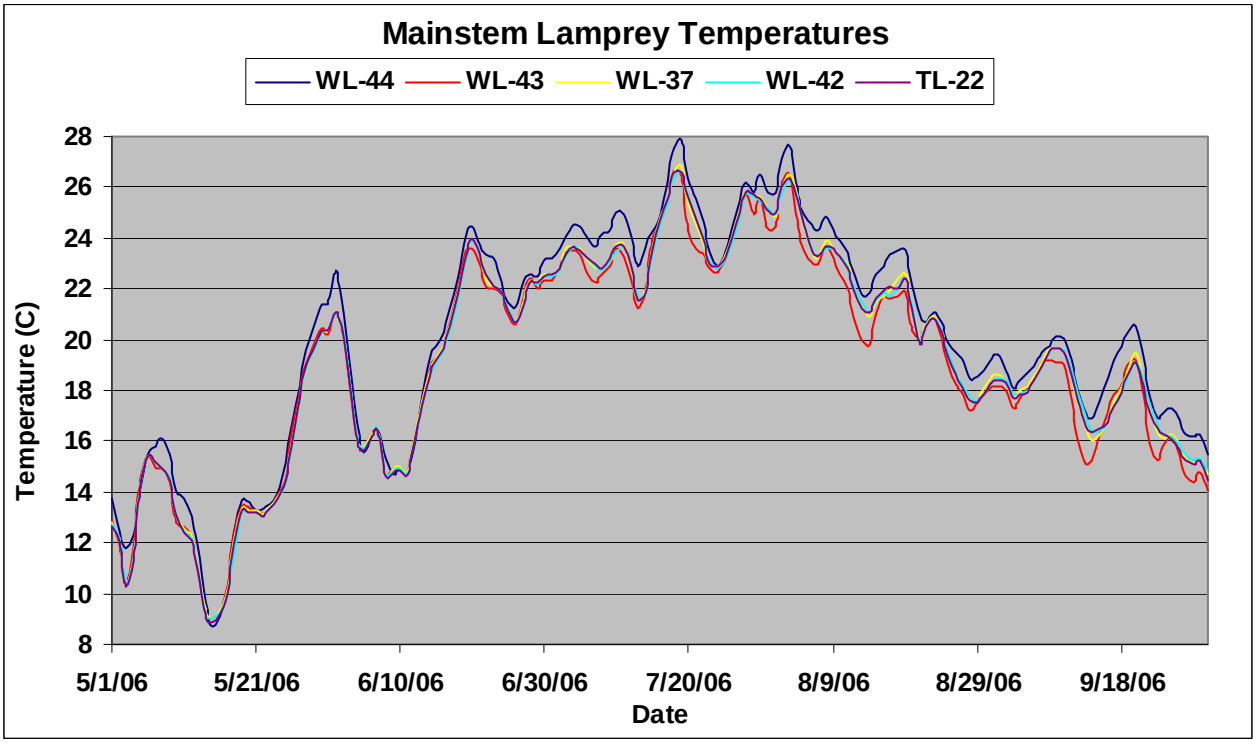


Figure 2. Record of daily average mainstem water temperatures for the period between 1 May 2006 and 30 September 2006.

Temperatures in the two main tributaries of the Lamprey River (North and Little) followed a very similar pattern to the mainstem of the Lamprey, but were generally several degrees cooler, especially after July 1st (Figure 3). Temperatures in the Little River were almost always cooler than those on the North River after July 1st. It is therefore likely that both tributaries would have some cooling effect on the mainstem of the Lamprey River.

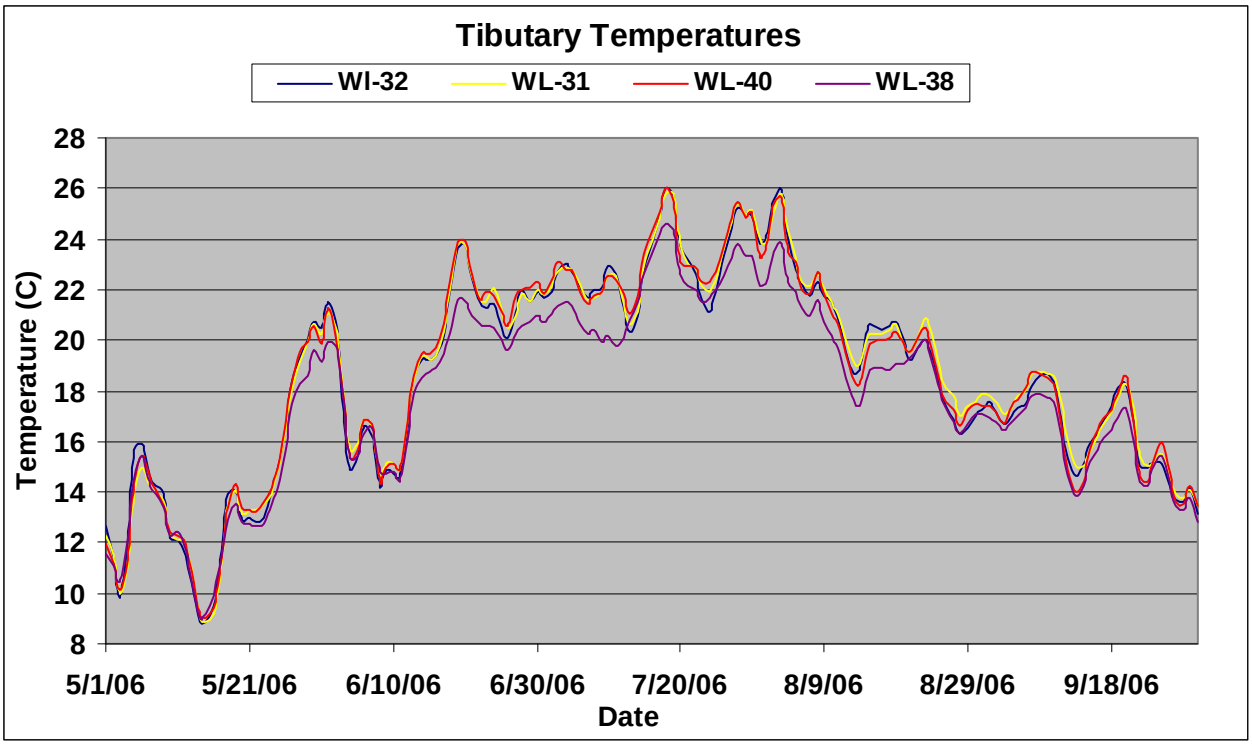


Figure 3. Record of daily average Tributary (North and Little Rivers) water temperatures for the period between 1 May 2006 and 30 September 2006.

In the summer of 2006, average river temperatures tended to cool 0.9°C downstream between the probe (DL-44) placed upstream of the designated river at Mary Folsom Blair Park in West Epping and DL-43 placed upstream of Wadleigh Falls in Lee (Figure 4). Average temperatures rose slightly (0.2°C) between Wadleigh Falls and probe WL-37 located at the UNH pumping station in the Wiswall Reservoir. Downstream of the dam average temperatures cooled slightly at both probes (WL-42, TL-22).

Daily Average Maximum and Minimum temperatures were consistently 0.6-0.9°C warmer or cooler than daily average temperatures throughout the study area, with the exception of Probe WL-42 located downstream of the Wiswall Dam. The otherwise consistent pattern suggests the probes were documenting well-mixed surface flow and temperatures and were not overly affected by the location of their placement. The probe downstream of the Wiswall Dam records a slightly different pattern than the others and has a narrower range of recorded temperatures. One possible explanation for this is the proximity to the old mill sluiceway backwater, which was observed to have some groundwater flow contribution. The addition of this ground water source may have resulted in a more consistent temperature.

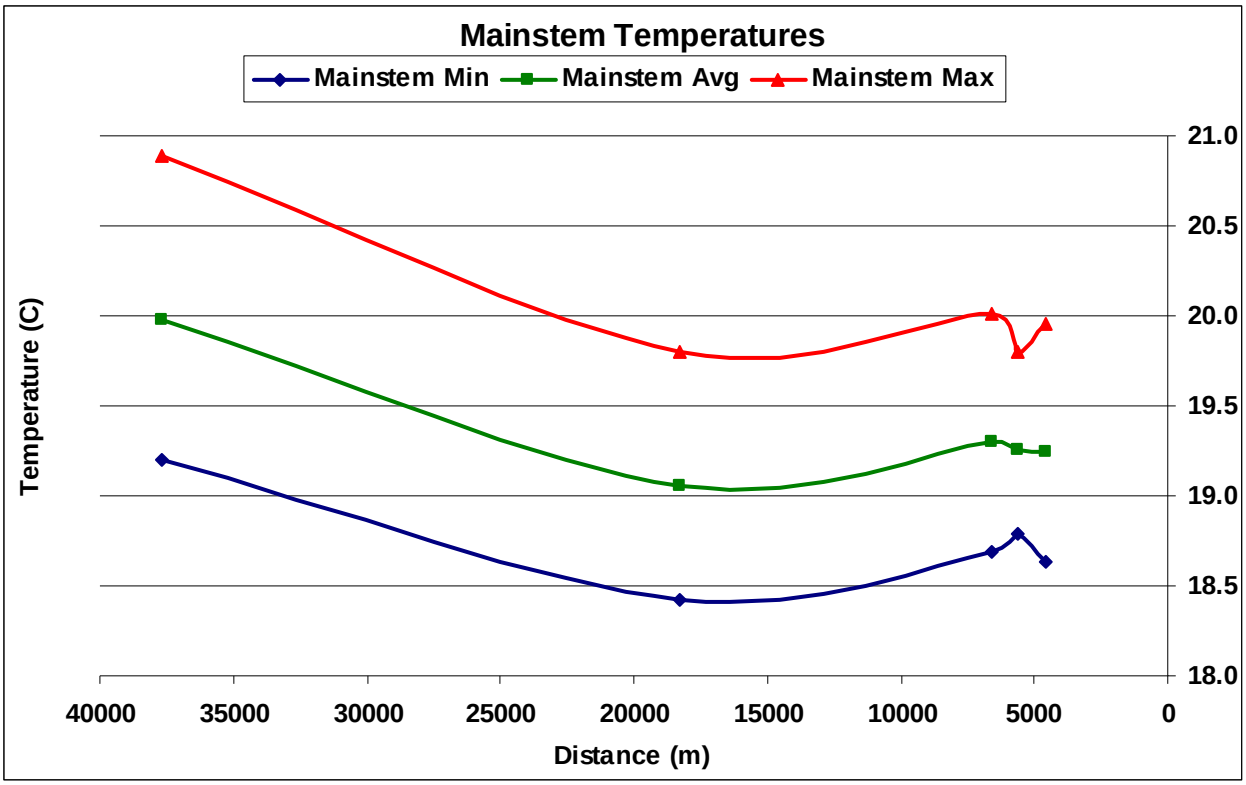


Figure 4. Longitudinal profile of mainstem Lamprey temperatures for average of daily maximum, minimum and average temperatures over the study period.

Average temperatures on the North River change very little over the 13.5 km section we documented in 2006. Average temperatures for the study period are approximately 0.5°C cooler than the Lamprey River at the closest probe located just over 2 km downstream of the confluence (Figure 5). We installed one logger on the Little River approximately 880m upstream of its confluence with the Lamprey. The average temperature for this location during the study period was 1.5°C cooler than the water in the mainstem of the Lamprey. While these are the two largest tributaries on the Lamprey River, and they both appear to contribute water that is cooler than the temperature of the mainstem, it is important to mention that both of these streams are significantly smaller than the Lamprey and may have only minor contributions to the overall mixed temperatures.

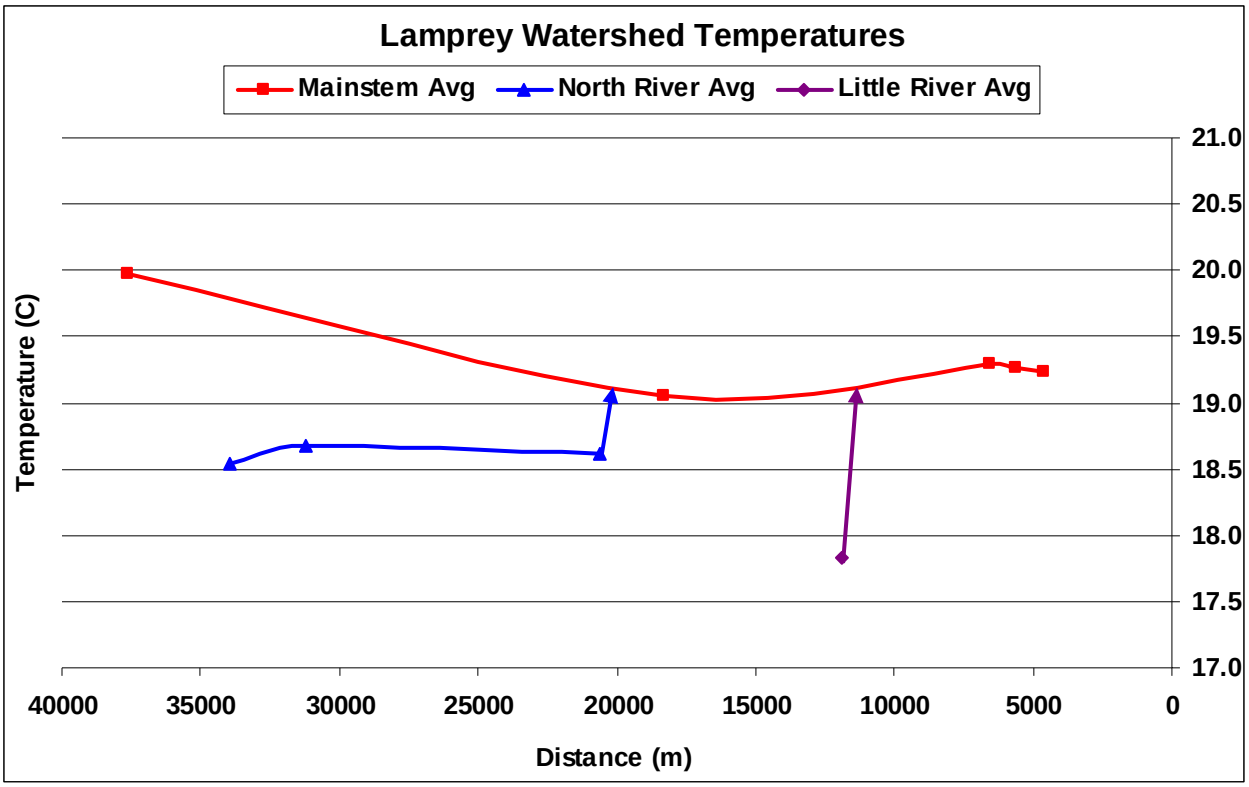


Figure 5. Longitudinal profile of mainstem Lamprey average temperatures along with temperatures recorded on the two main tributaries to the study reach. Arrow represents tributaries confluence with the Lamprey River.

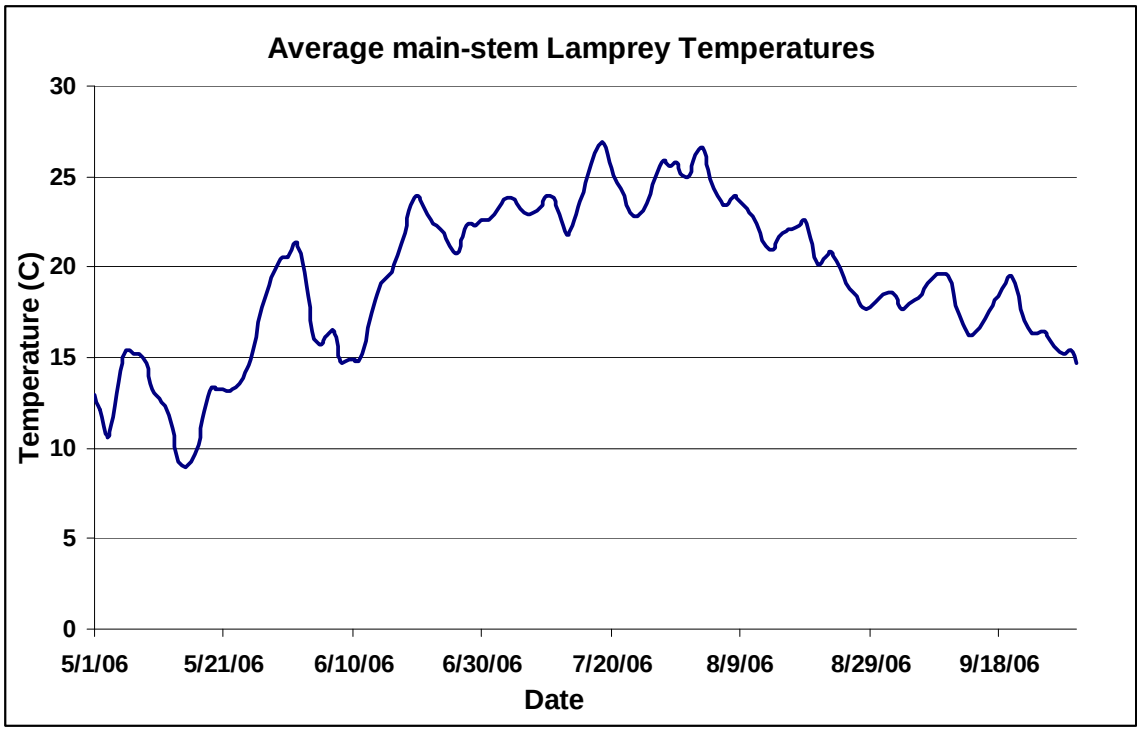
The trend of decreasing temperatures downstream from our starting location to a low value from which temperatures begin to rise is reminiscent of the temperature analysis on the Souhegan River. In that project, we concluded that the man-made impoundments had a significant influence on downstream river temperatures, especially those located in the headwaters. In the Lamprey River, our first study probe (WL-44) located upstream of the designated river is immediately downstream of Bunker Pond, our probe further upstream on the North Branch River was lost in the flooding. This location is immediately upstream of the confluence of the Pawtuckaway River and seems to indicate that there is some warming of the upstream sections of the Lamprey by the pond or other impoundments further upstream. The loss of our loggers in the Pawtuckaway River and downstream of the confluence limits our ability to assess the influence of the Pawtuckaway's temperature on that on the mainstem Lamprey. We can speculate, however, that the contribution is either similar, or cooler than the water temperatures observed at WL-44 because of the lower downstream temperatures. We find that the average water temperature for the river has cooled by 1°C by the time we reach the first logger in the designated river just upstream of Wadleigh Falls. The combination of potential temperature readjustment over the 19 km relatively un-impounded stretch between WL-44 and WL-43, and the confluence of the cool North River indicate that sections 1 and 2 are most likely the coolest areas on the lower Lamprey River. Downstream of DL-43 the Lamprey encounters several natural and one large man-made

impoundment before our next logger located at the UNH pumping station. The pumping station is located approximately 800 m upstream of the Wiswall Dam, well within the impounded area. At this location we see a slight rise in average study period temperatures by 0.25°C. Downstream of WL-37 we have two loggers placed approximately 1 km apart. These two probes recorded successively cooler average study period temperatures, although it is important to mention that these changes are relatively minor. The impoundments on the Lamprey River appear to have an effect on the temperature profile, however, not to the same degree as was documented on the Souhegan River. On the Lamprey River there are many small natural impoundments caused by bedrock outcrops, and two man-made impoundments behind intact dams in the designated river. All of these, except for the Newmarket impoundment, are relatively narrow, partially shaded pools, which are confined by the steep banks of the incised river at those locations. In fact for the most part the impoundments are less than twice the width of free flowing sections of river adjacent to them. This differs from the Souhegan River where the impoundments are many times the width of the free flowing sections and therefore lack the shading necessary to balance the "solar panel" effect of the flat shallow pools. Unfortunately, we were unable to document the temperatures on the Newmarket impoundment but, since the tidal zone begins immediately downstream of the McCallen Dam there are no effects of temperature on the fresh water system downstream. The effect of elevated river temperature on an estuary system is beyond the scope of this discussion. While the Lamprey is likely to be slightly warmer than the Souhegan River it is not believed to historically host native cold water fish, and therefore, the warm temperatures downstream of impoundments are of less concern. However, the cooler tributaries of the system may have been more suitable for populations of cold water-dependant species and maintaining their integrity may be important to the Lamprey as sources of thermal relief during drought conditions.

Raw Temperature Data

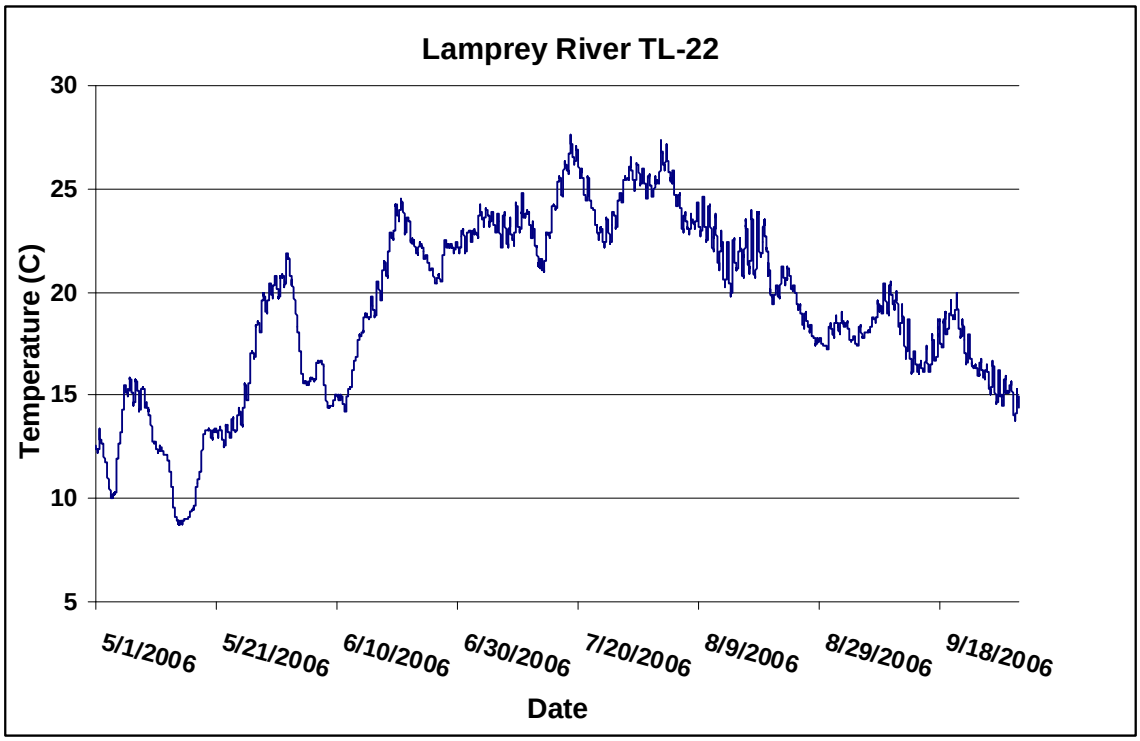
Thirteen Hobo® temperature probes (3 temperature pendant, 10 water-level loggers) were installed throughout the Lamprey River watershed. Eight of these loggers were installed in the mainstem of the Lamprey, 5 within the designated reach. Five additional loggers were installed on three tributaries to the Lamprey; 2 of those enter within tributaries, and the 4 loggers placed within them, enter within the designated reach. Data recovered from these probes form the basis of our study period (May 1st, 2006 – September 30, 2006). Average daily temperature data was calculated for each probe and then averaged with other probes collecting data on that day. Four probes were lost during the flooding that took place around May 16th 2006. Figure 6 presents a river average temperature for the mainstem Lamprey River during the study period.

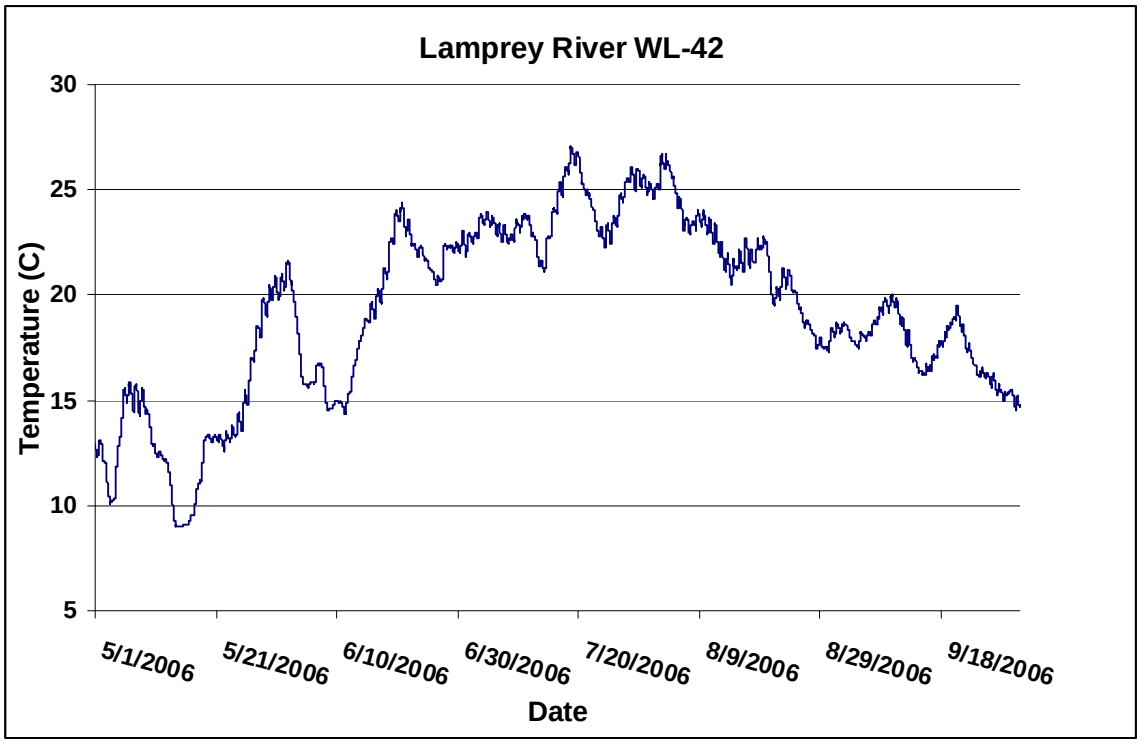
Figure 6: Summary of average Souhegan River temperature data from all available probes during the period of study.

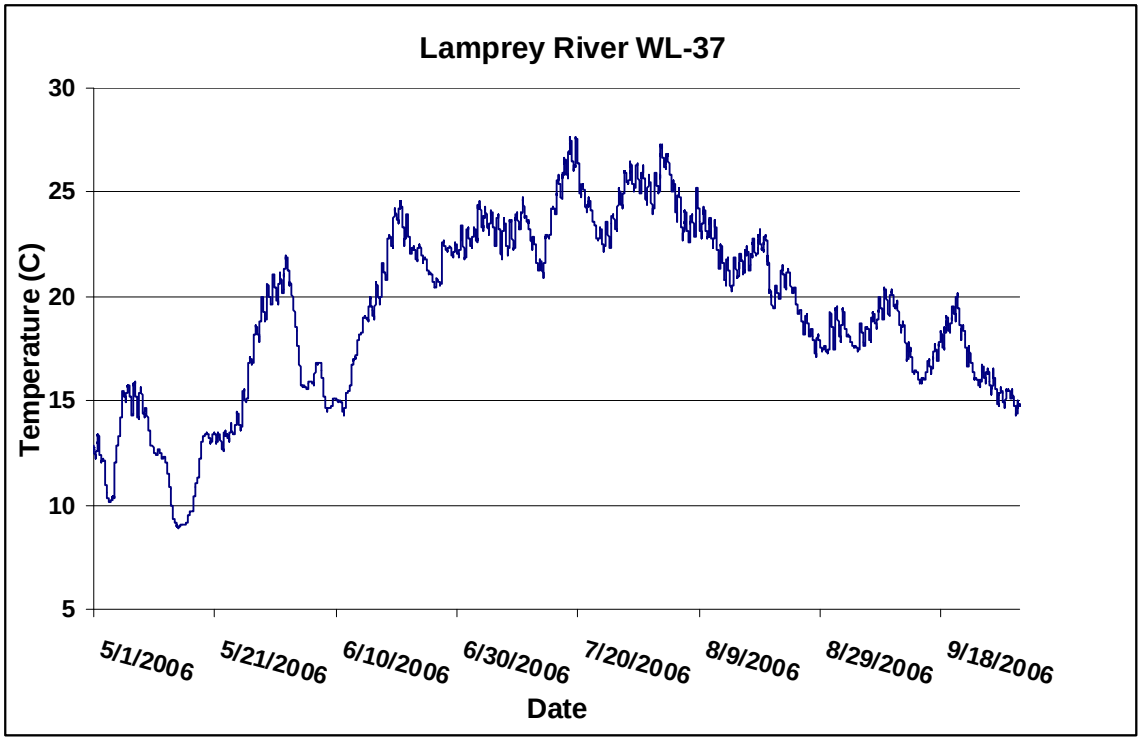


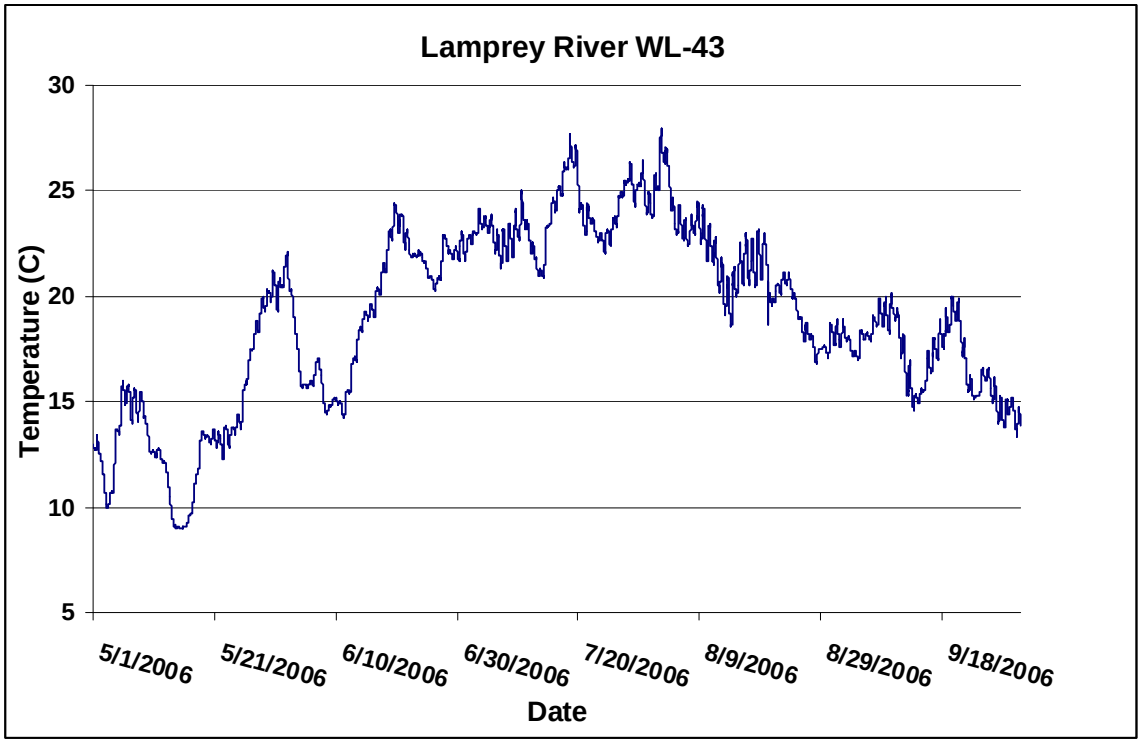
The graphs below (Figure 7) show raw data obtained for each of the nine surviving long-term temperature probes installed in the Lamprey River. Temperatures were recorded in 15-minute intervals at each site.

Figure 7: Raw temperature data for each temperature probe in the Lamprey River recovered during the study period.






Lamprey River WL-37
Temperature (C)
30
25
20
15
10
5
5/1/2006
5/21/2006
6/10/2006
6/30/2006
7/20/2006
8/9/2006
8/29/2006
9/18/2006
Date


Lamprey River WL-43
Temperature (C)
30
25
20
15
10
5
5/1/2006
5/21/2006
6/10/2006
6/30/2006
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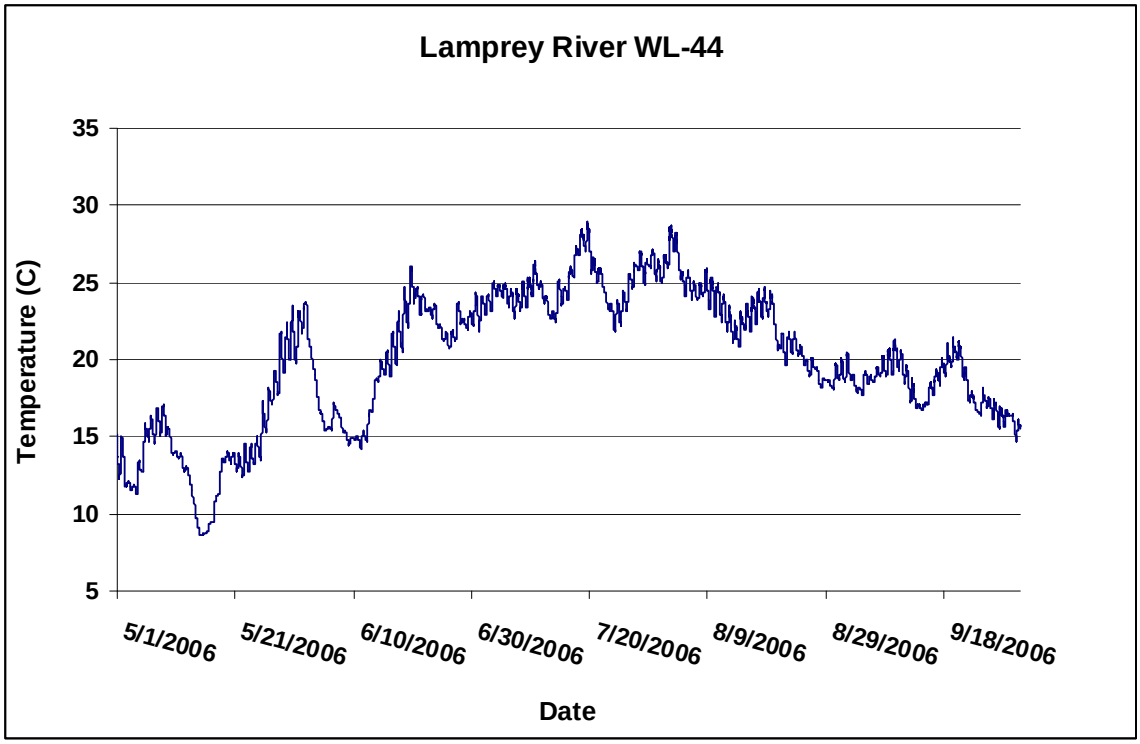
8/9/2006
8/29/2006
9/18/2006
Date


Lamprey River WL-44
Temperature (C)
35
30
25
20
15
10
5
5/1/2006
5/21/2006
6/10/2006
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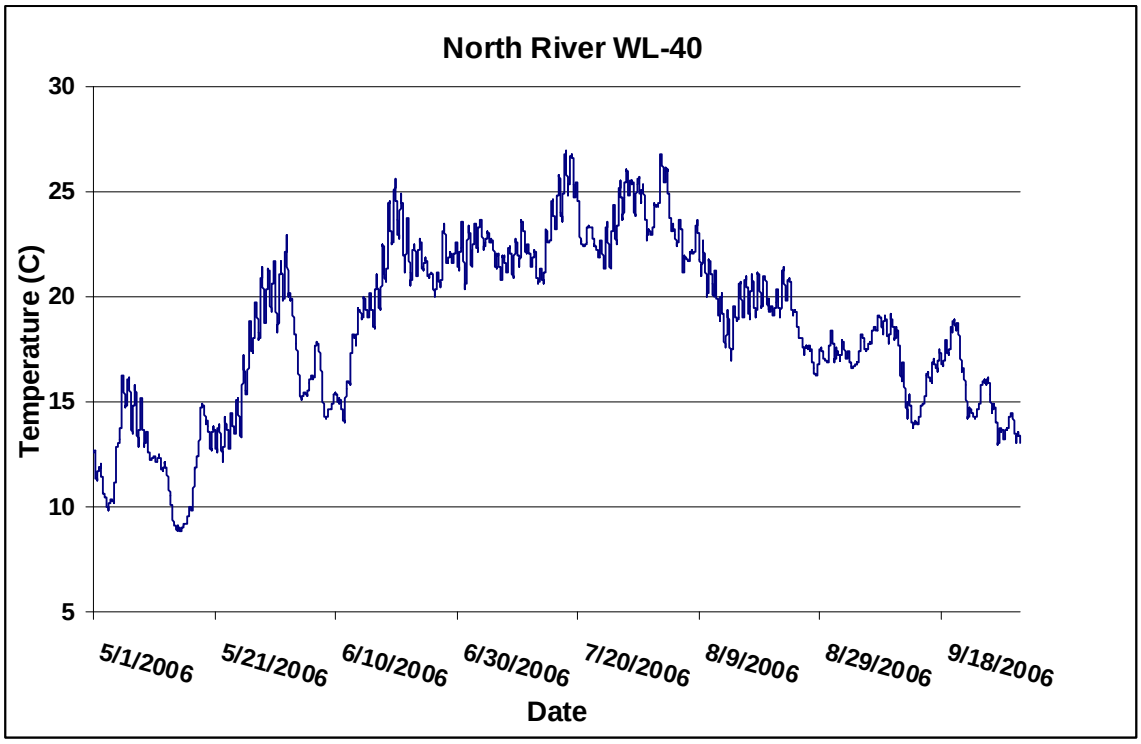
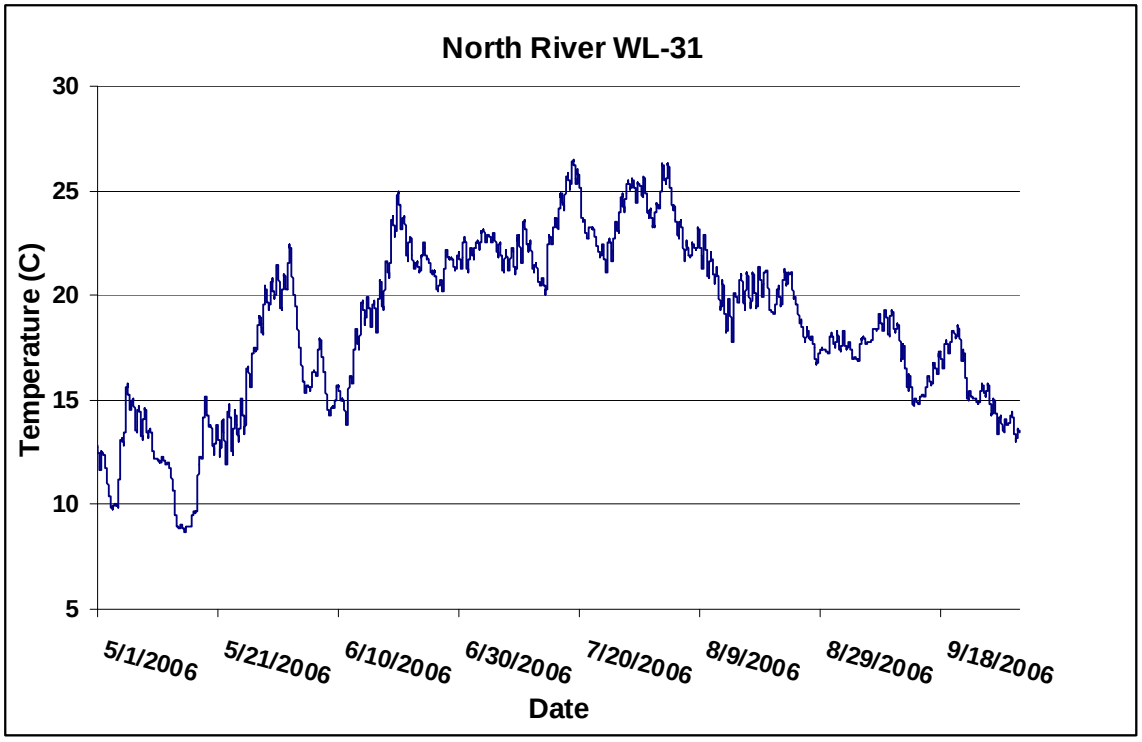
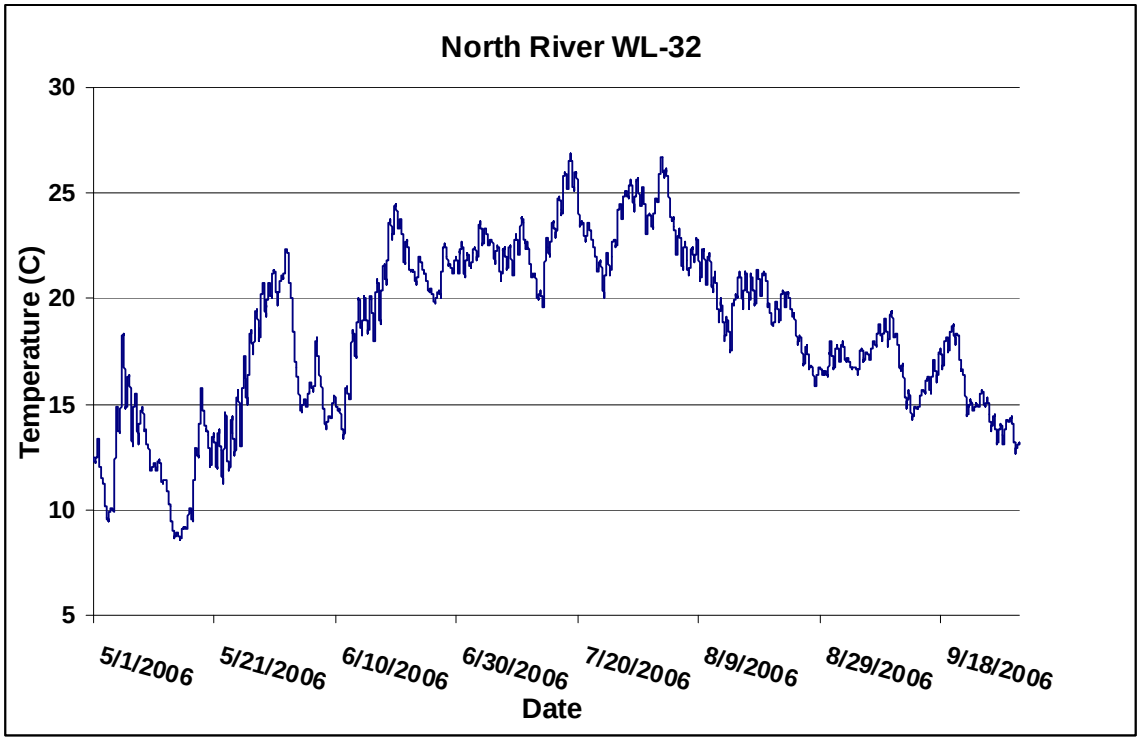
8/9/2006
8/29/2006
9/18/2006
Date


North River WL-40
Temperature (C)
30
25
20
15
10
5
5/1/2006
5/21/2006
6/10/2006
6/30/2006
7/20/2006
8/9/2006
8/29/2006
9/18/2006
Date


North River WL-31
30
25
20
15
10
5
Temperature (C)
5/1/2006
5/21/2006
6/10/2006
6/30/2006
7/20/2006
8/9/2006
8/29/2006
9/18/2006
Date


North River WL-32
30
25
20
15
10
5
Temperature (C)
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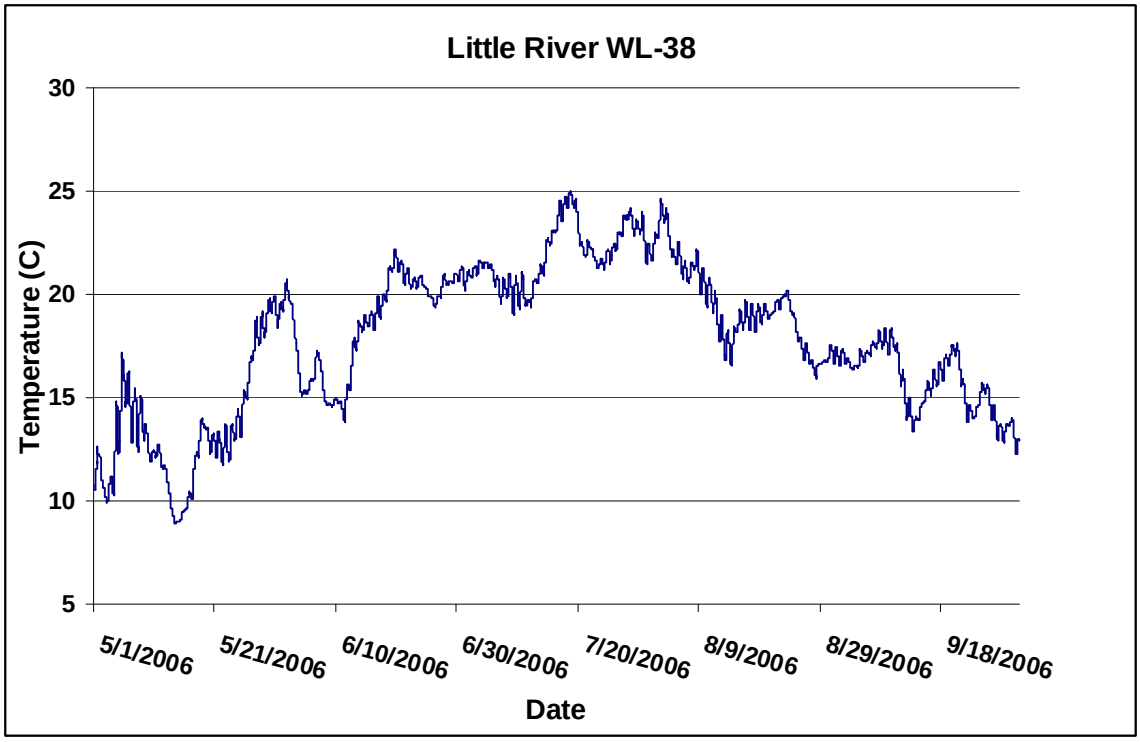
5/21/2006
6/10/2006
6/30/2006
7/20/2006
8/9/2006
8/29/2006
9/18/2006
Date


Little River WL-38
30
25
20
15
10
5
Temperature (C)
5/1/2006
5/21/2006
6/10/2006
6/30/2006
7/20/2006
8/9/2006
8/29/2006
9/18/2006
Date