Using Stream Temperature Data to Assess Restoration, Stewart River, MN

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Introduction:

- Monitoring stream restoration projects is critical to accessing project success and guiding future efforts.
- Temperature data are easy and inexpensive to collect.
- Temperature data are biologically relevant, as it drives processes at every biological scale.
- This study assessed stream temperature in the restored reach relative to an upstream reference station and changes in stream temperature within the restored reach of the river.
- Temporal variability in the relationship between air and stream temperature does not allow for direct comparison of pre- versus post-restoration data, so we developed a variable to account for daily variability and compared the air-water temperature among years.

Background:

- The Stewart River is a coldwater stream managed by the MNDNR for Brook, Brown, and Rainbow trout.
- Groundwater inputs to North Shore streams are limited but potentially important to maintaining cool water temperatures optimal to stream trout.
- Lateral channel migration and flooding degraded the stream channel, resulting in tree loss and reduced shading. Additional trees were removed to facilitate restoration activities.
- A restoration project with the goals of reconnecting the stream with the floodplain and raising the groundwater table to increase groundwater capacity was completed in 2015.
- Maintaining cool stream temperatures optimal to trout was a high priority of the project.
- Increasing groundwater capacity would help maintain cool stream temperatures during summer months.

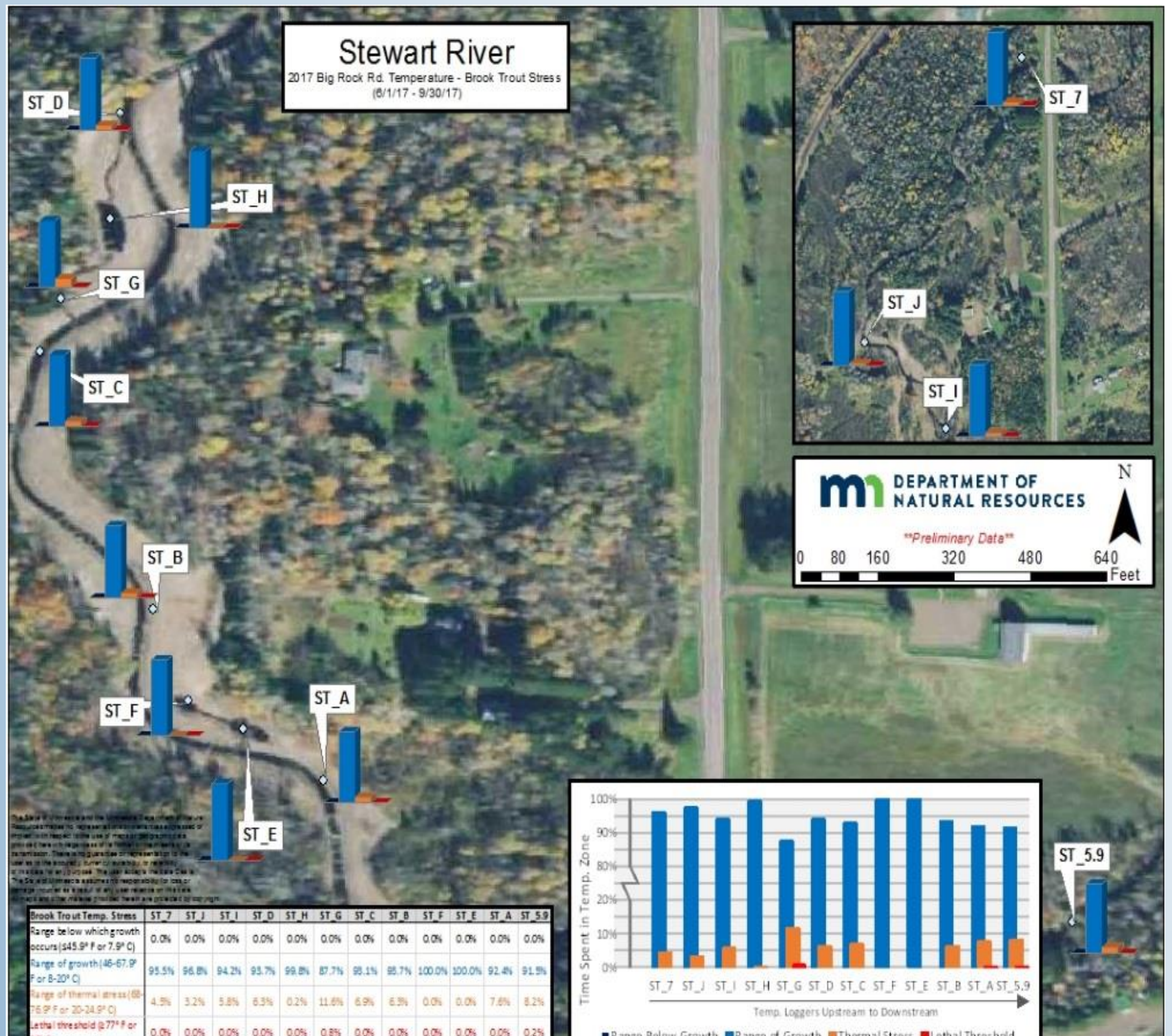

Figure 1: Locations of temperature monitoring stations. Data were collected inconsistently among years and stations, limiting the analyses we could perform. Data related to optimal temperatures for Brook Trout are presented in the table and graph at the bottom of the map.

How did stream temperatures in the restored reach relate to temperatures at a reference station among years?

- Mean daily stream temperature at multiple stations within the restored reach were compared to those at an upstream reference station (ST_7) both pre- and post-restoration.
- To account for daily variability related to weather, discharge, and shading, so we created a daily variability variable.

$$T_{ST\_7} = T_{air} + \varepsilon_{daily}$$

- We compared mean daily temperatures between the reference station and four stations within the restored reach. We included a year effect to compare the relationship before and after the restoration activity.

$$T_{\iota} = T_{air} + \varepsilon_{daily} + year + \varepsilon_{\iota}$$

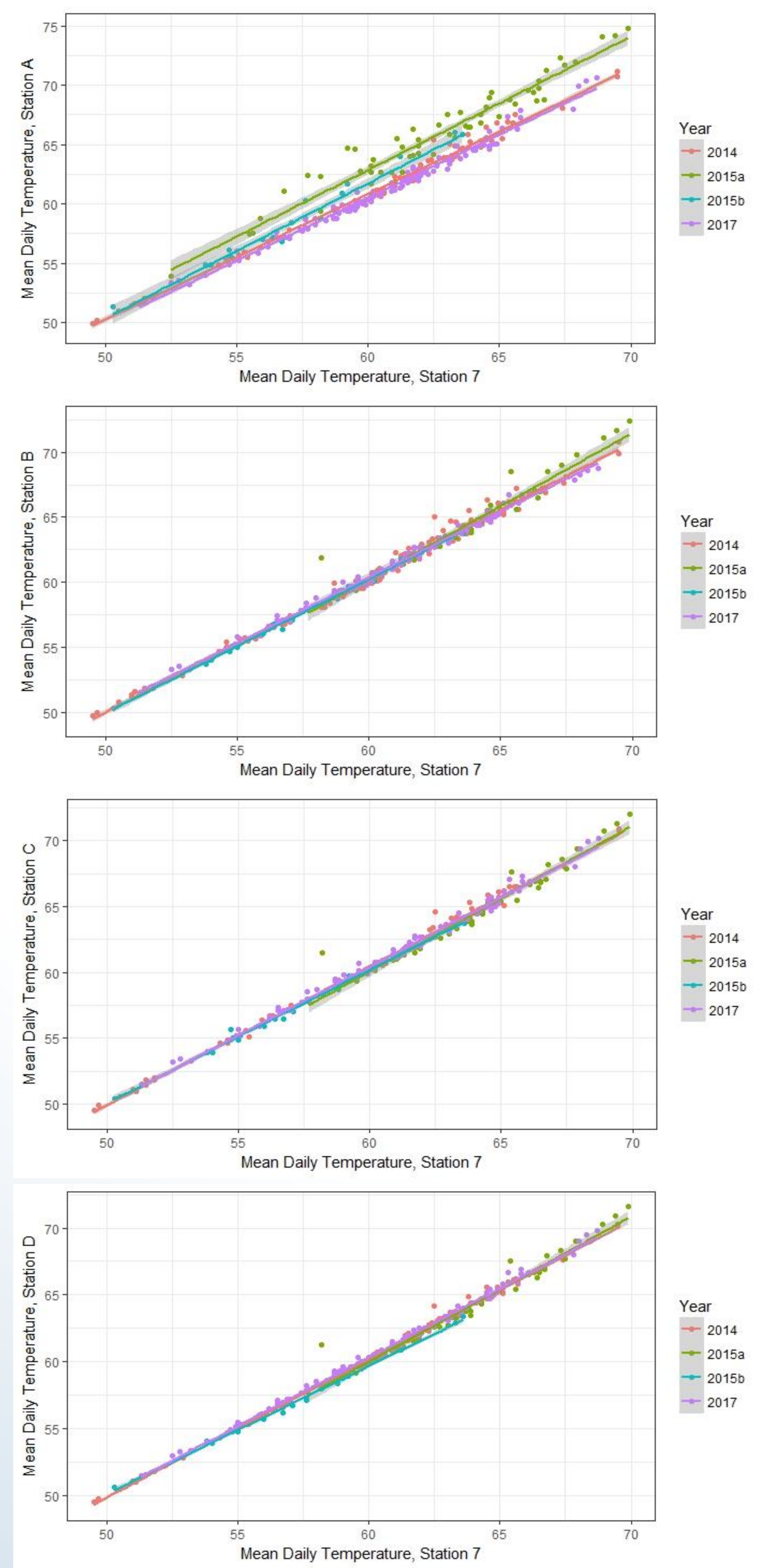

Figure 2: Mean daily temperature at the reference station (°F, Station 7) versus monitoring stations within the restored reach (°F). Data are color coded for year. 2014 and 2015a are pre-restoration data. 2015b and 2017 are post-restoration data.

- The differences between stream temperature at the reference station and monitoring stations varied spatially and temporally Figure 2).
- The relationship between temperature at the downstream-most station (A) and water temperature at the monitoring station was significantly different from 2014 all years ($p<0.05$). That effect was variable.
- There was no year effect for stations B and C.
- Temperatures at Station D was different post-restoration than in 2014. That difference varied by year (Table 1).

*Table 1: Results of a linear model at individual monitoring stations. * denote $p<0.05$. A Bonferroni correction for multiple comparisons was made. Temperature is in units of °F.*

Station	T_{air}	ε_{daily}	2015 pre-	2015 post-	2017
A	0.52*	1.05*	2.15*	0.67*	-0.36*
B	0.50*	1.04*	0.23	-0.11	0.003
C	0.51*	1.03*	-0.23	-0.24	-0.09
D	0.50*	1.03*	0.02	-0.31*	0.13*

How much did water temperature change within the restored reach?

- We used a one-sample Wilcoxon test to compare mean daily temperatures within the restored reach, including between side channels and the nearest upstream station on the main channel.

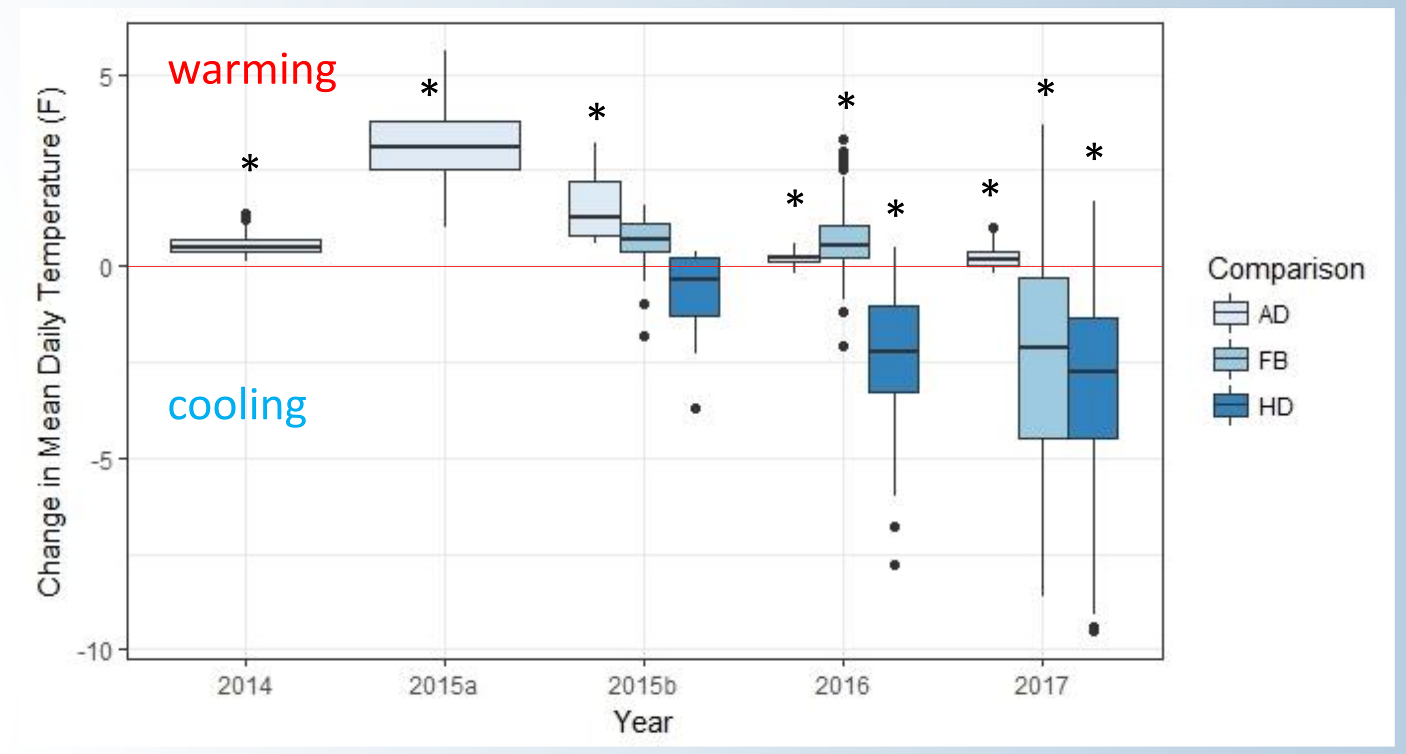

*Figure 3: Box plots of changes in water temperature (°F) from upstream to downstream between multiple stations. Comparison AD is between Stations A and D. Comparison FB is between Stations F and B. Comparison HD is between Stations H and D. * indicates that $p<0.05$. 2015a=data collected pre-restoration in 2015, while 2015b=data collected post-restoration in 2015. Corrections were made for multiple comparisons.*

- Temperatures consistently increased within the restored reach from Station A to Station D (Figure 3). The amount of increase in water temperatures varied among years.
- Temperature changes between side channels both increased and decreased between Station B and Station F.
- Water temperature at Station H was consistently cooler than temperatures in the main channel upstream of the pool.

Conclusions:

- Relationships between temperatures in the reference and restored reach varied spatially and temporally. The temperature in the restored reach was both cooler and warmer than the temperatures at the reference station, depending on the year.
- There are potential sources of energy gains and losses within the restored reach that were not consistent among years. These are likely related to weather and discharge.
- Temperatures in the side channels, constructed to provide additional habitat, differed from those in the mainstem. Cooler temperatures in the pools at times indicate that there were periodic groundwater inputs to the system.
- Increases to stream temperatures post-restoration from tree removal may have been mitigated by groundwater inputs.

Future Considerations:

- Efforts of future restoration projects should weigh the costs/benefits of tree removal, restoration (including increased groundwater capacity), and their effects on stream temperature in this region, given the limited input of cool groundwater.
- This study emphasizes the importance of long-term monitoring, thoughtful study design and collecting consistent data (pre- and post-) to understanding the success of projects.