Characterization of thermal regimes of side channels, alcoves, and ponds on the Willamette River, OR

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Extended Abstract

Introduction

In streams that support habitat for cold-water fishes, water temperature and heat present a challenging water quality issue. Changes in mainstem temperature require subtractions of heat in proportion to discharge and efforts required to bring larger rivers into compliance with regulatory standards may approach or surpass what is feasible in any reasonable regulatory regime. Already, studies have shown that the large heat capacity of water and large flow rates in the main channel of a large river limit the effect of heat transfer mechanisms tending to reduce water temperature, such as shade from riparian vegetation and cool-water inputs from groundwater and the hyporheic zone (Johnson, 2004; Burkholder et al., 2008). However, such heat transfer mechanisms may play significant roles in the heat budgets of secondary channel features, where the volumes and flow rates of water are typically much smaller, channels often much narrower, and the fraction of water surface area shaded by riparian vegetation potentially larger (Figure 1). Such secondary features include alcoves, features that are connected to the main channel only at their downstream end, and side channels, features connected to the main channel at both their upstream and downstream ends. The goal of this study was to characterize thermal regimes in secondary channel features within the modern floodplain of the upper Willamette River.

Study Sites

Data collection took place on the upper Willamette River, a large, gravel-bed river in northwestern Oregon, USA (Figure 2). Concurrent measurements in both secondary channel features and the main channel allowed for characterization of temperatures in the secondary channel features relative to temperatures in the main channel.

Aerial photographs facilitated the identification of off-channel sites grouped within two study reaches along the upper Willamette River: Corvallis (Figure 2b) and Harrisburg (Figure 2c). The selected reaches contained a diversity of secondary channel features, including side channels, alcoves, and beaver ponds. In total, 15 secondary channel features were instrumented. Twelve of the off-channel sites, including one side channel, five alcove, and six beaver ponds, were located in the Harrisburg reach. Three alcoves were located downstream in the Corvallis reach.

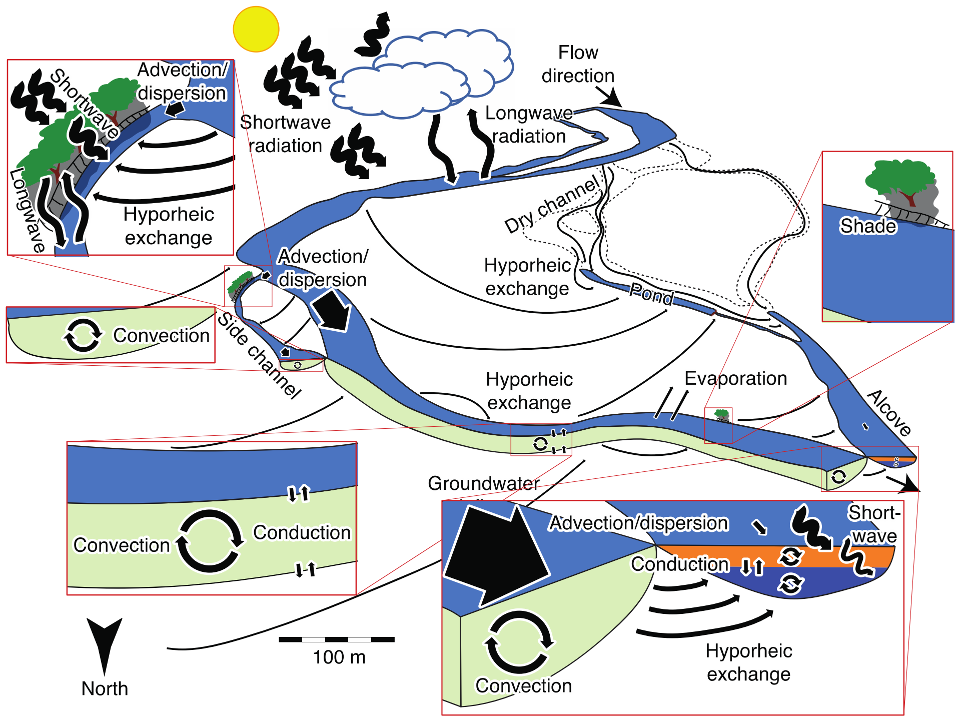

Figure 1. Schematic diagram, based on an oblique aerial photograph of the Willamette River, Oregon, of the heat transfer mechanisms in the main channel, side channels, alcoves, and ponds.

Methods

From July through September 2017, Onset Hobo Tidbit v2 data loggers were deployed to measure and record water temperatures (±0.2 °C) at 15-minute intervals. We deployed loggers at near-bed, mid-point, and near-surface depths at three locations along each feature, forming a three-by-three array (Figure 3). We also deployed a single logger at three different well-mixes mainstem locations (Figure 2).

Arrays remained in place at sites from a period of 72 hours to three weeks. Deployment period was effectively arbitrary: we sought to capture at least one diel cycle of temperature in each feature and, ultimately, we averaged data collected at a given site. From August 1 to 3, 2017, a reservoir drawdown increased river stage by 0.5 m at the USGS Harrisburg Gage, and the elevated stage persisted through August. The averaged discharge for the week prior to the drawdown (July 25 through 31, 2017) was 120 m^3/s (4,300 ft^3/s) while the averaged discharge measurements for the week after the drawdown (August 4 through August 10, 2017) equaled 215 m^3/s (7,600 ft^3/s). The change in discharge, and the concomitant increases in water level, allowed data collection at sites before and after the change to cover a wider range of relevant conditions.

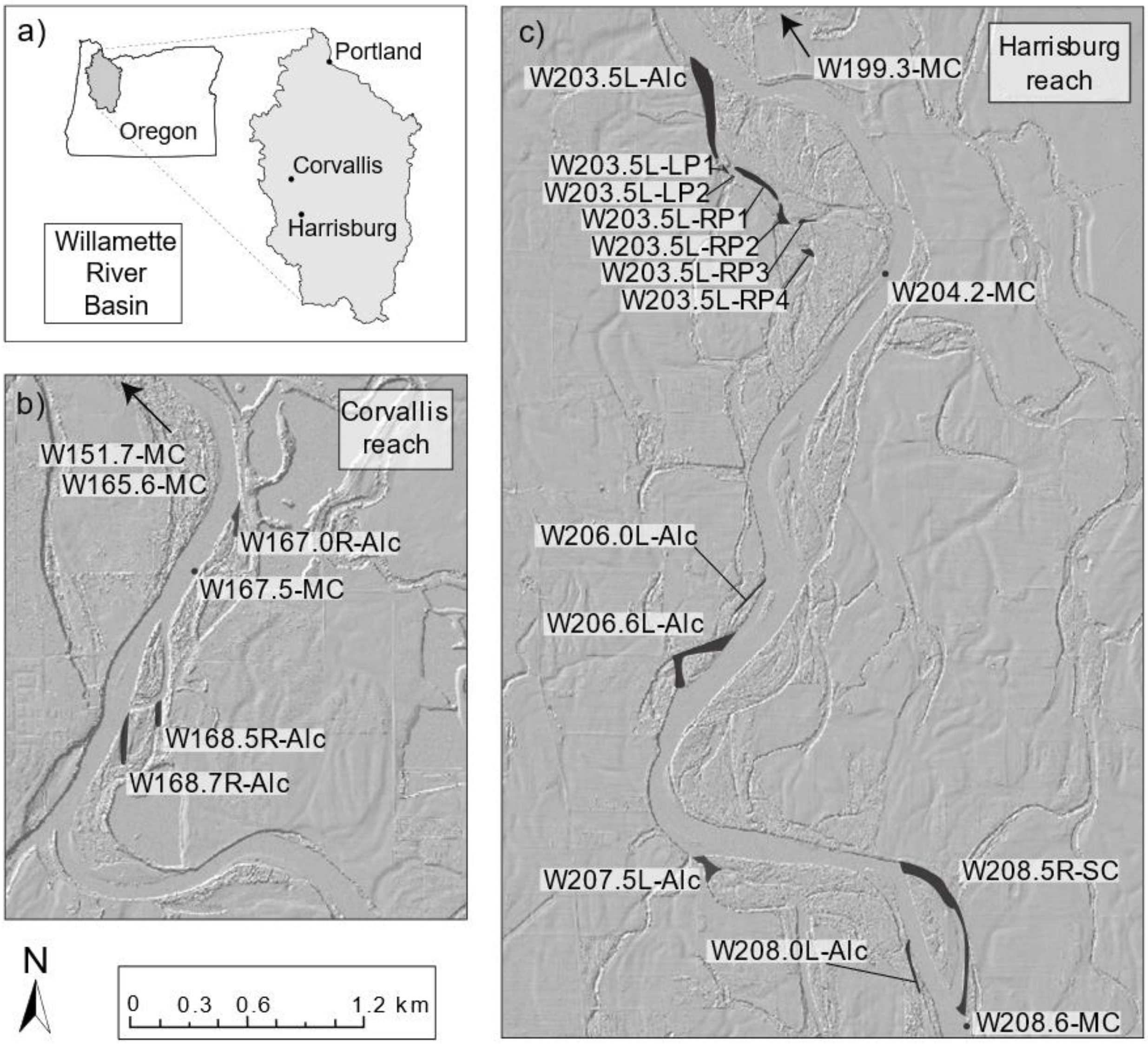

Figure 2. The study area is located in the Willamette River basin (a) and comprises the Harrisburg (b) and Corvallis (c) reaches. Off-channel sites, including eight alcoves, six ponds, and one side channel, are masked in dark gray; mainstem site locations are indicated with dark gray circles; all sites are labeled using the Willamette River Slices framework.

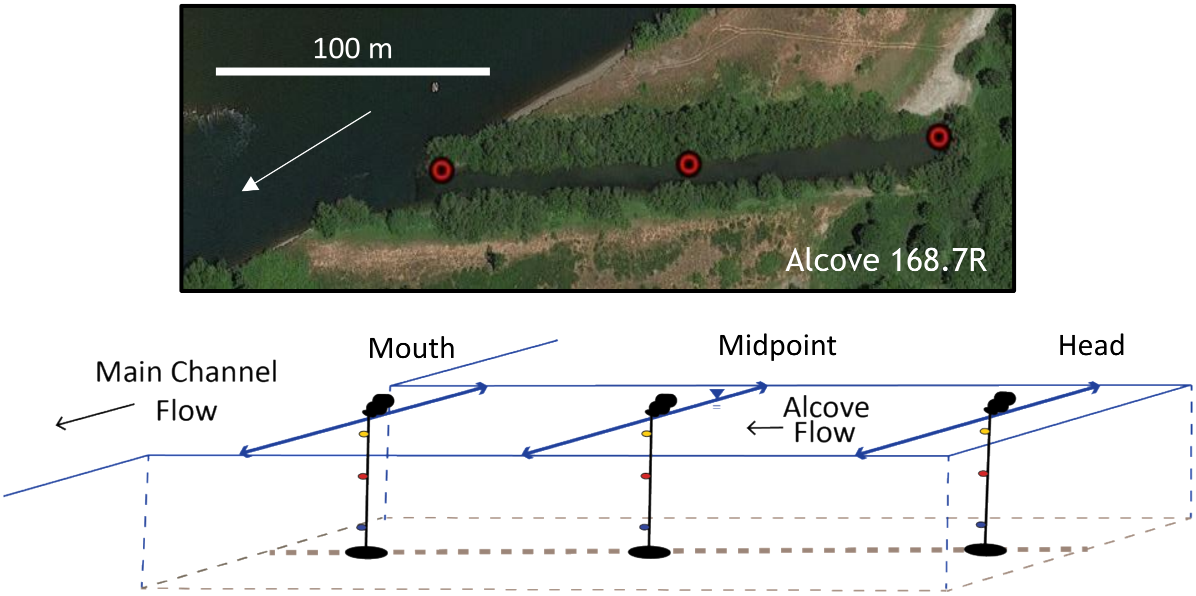

Figure 3. Temperature logger deployment array, with deployment locations at W168.7R-Alc shown as an example of the column placement illustrated in the schematic.

Results

Selected time series shown in Figure 4 illustrate the thermal regimes of several representative sites. A diel cycle of temperature fluctuations is evident at all loggers, but amplitude and phase of fluctuation vary among sites, columns at a site, and, notably, depths within a column.

In the side channel and in the alcoves, daily minimum temperatures occurred in the morning between 08:00 and 09:00. Temperatures tended to peak in the late afternoon to early evening between 15:00 and 18:00. The time of daily maximum temperature varied with depth. For example, the peak temperatures recorded by the top and bottom loggers deployed at the head of W206.0L-Alc were offset by ~9 hours (Figure 4). The time of daily maximum temperature also varied with distance downstream. That is, the daily maximum temperatures at the head, the midpoint, and mouth did not always occur at the same time of day. Compared to secondary channel features, the amplitude of the diel temperature cycle in the main channel is small.

Water temperatures were always coolest near the bed and warmest near the water surface. Near-surface temperatures fluctuated with larger amplitude than near-bed temperatures. At 11 of the apparently stratified sites, water temperatures increased with increasing distance downstream, as at W207.5L-Alc (Figure 4). However, at two stratified sites, W206.0L-Alc and W168.5R-Alc, water temperatures at bottom, middle, and top stations all decreased with increasing distance downstream (Figure 4).

Water temperatures were nearly uniform with depth at two sites, W208.5R-SC and W206.6L-Alc (Figure 4). At both sites, near-bed temperature measurements were within 0.5 °C of near-surface temperature measurements. Only one local exception was observed at the most downstream section of the deep side channel reach at low stage (Figure 4).

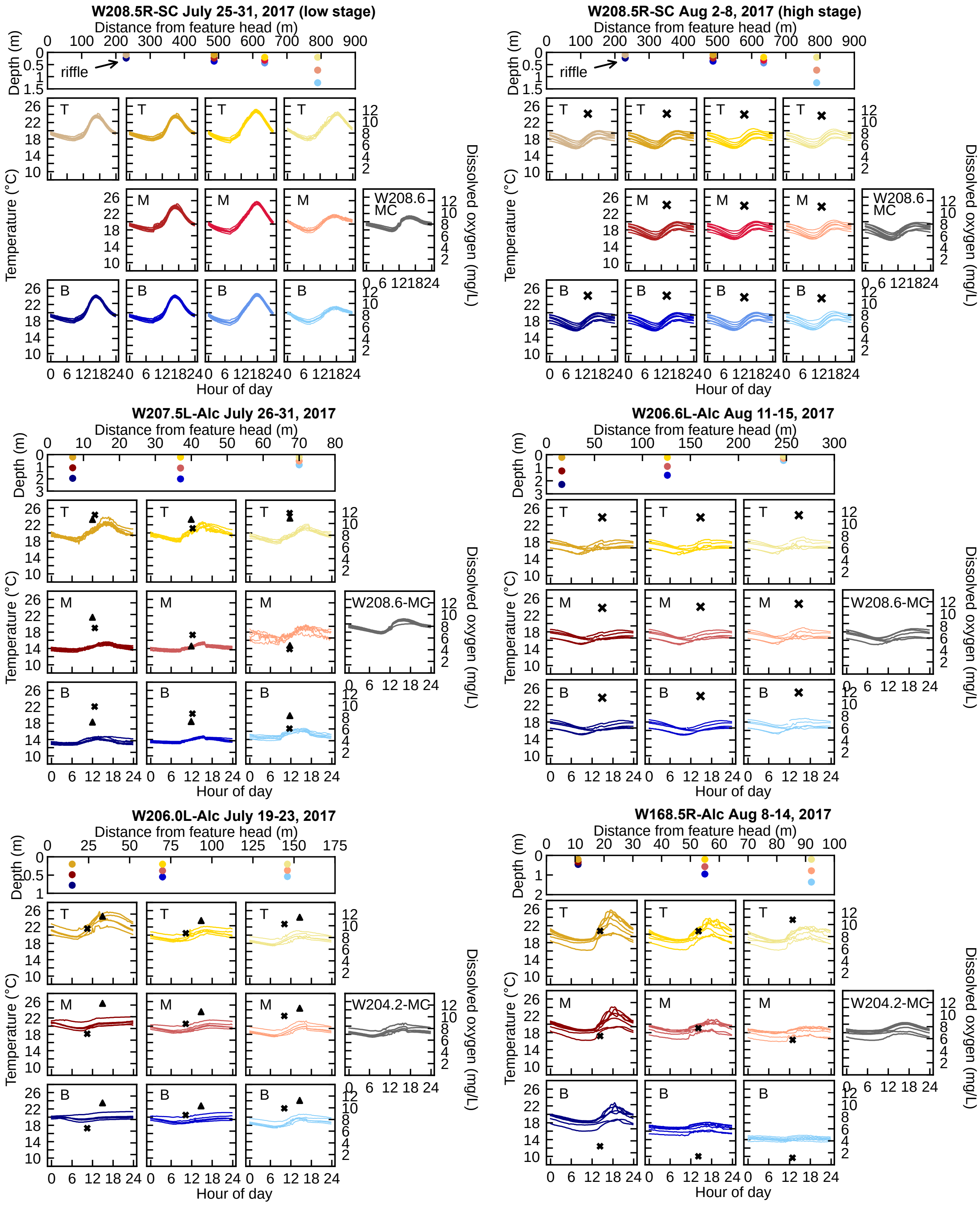

Figure 4. Water temperature (lines, left-hand y-axis) and dissolved oxygen (“x” or triangle, right-hand y-axis) vs. hour of day (x-axis), grouped by site and time period (site name and month/day of 2017 in group title), for up to 7 diel cycles each, for the side channel and four alcoves. In each grouping, each graph corresponds to one station at the site, plus one graph for the same days at the mainstem site indicated on the graph (B = bottom, M = middle, T = top;). Depths of stations at each site are shown as well, plotted by distance from feature head.

References

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