CHEHALIS BASIN STRATEGY

THERMAL REFUGIA

Study Goals and Objectives

The overall goal of the Thermal Refugia Project was to identify the spatial distribution of cold-water refuges in the lower mainstem of the Skookumchuck and Newaukum rivers during summer. This work fills a current knowledge gap and is important for species of interest including spring Chinook salmon, who presumably rely on cool thermal refuges to reduce metabolic stress during warm summer months. Thus, results from this study could inform future design and project siting.

Methods / Study Design

To measure the longitudinal temperature profiles in our study area, we employed methods previously developed for the Yakima River by Vaccaro and Maloy (2006). Our approach involved profiling 5-10 km stretches daily using two Solinst Levelogger 5 LTC probes (https://www.solinst.com/products/dataloggers-and-telemetry/3001-levelogger-series/ltc-levelogger/datasheet.php). These probes enabled measurements of temperature, depth, and conductivity (a conservative tracer of groundwater). We conducted these measurements either by towing the probes from a watercraft or by wading, following a Lagrangian framework along the river's central point. One probe was positioned at the streambed, while the other remained at the surface. The tow speed was determined by the streamflow, ensuring that measurements reflected the properties of individual water parcels. The probes have an accuracy criterion of 0.1 °C for temperature and 0.05 µS cm^{-1} for conductivity.

This method allowed us to comprehensively document the longitudinal distribution of temperature in the river, a characteristic that cannot be captured solely through fixed station data. The probes continuously logged data at two second intervals, while a submeter Global Positioning System (GPS) recorded the spatial coordinates. Additionally, we utilized fixed HOBO pendant temperature loggers (UA-001-64K) placed at various locations within the study area. These loggers collected ambient river temperatures during the sampling process and recorded diurnal temperature changes. When selecting the locations for these loggers, we considered three criteria: well-mixed water, shade, and adequate depth to ensure submergence during the low flow period in summer. To secure the loggers, we anchored them using cable or epoxy, and housed them in white perforated plastic vinyl chloride (PVC) enclosures. These enclosures allowed the flowing water to come into contact with the loggers while shielding them from direct sunlight. Finally, we employed a Solinst Barologger to compensate for daily atmospheric pressure fluctuations, thereby ensuring the most accurate determination of water depth changes.

The methodology employed in this study involved the synchronization of various datasets, including profile temperature, ambient river temperature, conductivity, depth, and location data. To achieve this synchronization, the *sqldf* package in R was utilized (R Core Team 2022). Since the

timestamps of the datasets did not align perfectly, a one second buffer was applied to increase the number of aligned data points. This buffer created a time window of one second within which readings from different datasets were considered as matching.

To ensure the quality of the data, logger readings with conductivity levels of 0 µS cm^{-1} were filtered out. Such readings were indicative of the logger not being submerged in water. By applying this filter, only the readings associated with submerged loggers were retained for further analysis.

To visualize the relationship between temperature and location, the temperature and location data were mapped using Esri's Arcpro software. This mapping process facilitated the creation of visual representations that linked temperature readings to specific locations within the river system.

To assess the variation from the ambient river temperature, the temperature recorded by the profiling logger was compared to that of a fixed logger situated in the shade, near the midpoint of the sampled section of the river. This fixed logger served as a representative of the ambient river temperature and the variation was determined by subtracting the temperature recorded by the profiling logger from the ambient river temperature.

Summary of Results

Temperature profiles were conducted for the Mainstem Skookumchuck (Figure 1) and Newaukum (Figure 2) rivers to assess their thermal characteristics during August 2022 and to compare the observed values with thermal tolerances for Chinook salmon (FitzGerald et al. 2022, Table 1). We also compared profiling temperature to ambient river temperature (Figures 3 and 4) and to a fixed temperature logger (Figures 5 and 6). Water temperatures in the Skookumchuck were consistently cooler than those in the Newaukum, providing optimal (10–16 °C) to tolerable conditions (16–21 °C) for Chinook Salmon along most of the river. Conversely, the Newaukum exhibited higher temperatures, rendering some sections intolerable (>21 °C) for holding adult spring Chinook.

In the summer of 2022, we sampled the lower 18 miles of the Skookumchuck River. Temperature measurements ranged from a high of 21.3 °C at the confluence with the Chehalis River to 11.3 °C in the highest sections near the mouth of Johnson Creek at river mile (RM) 18. These temperatures only slightly exceeded the tolerable range for adult Chinook salmon. The highest temperatures in the Skookumchuck River were observed at the confluence with the Chehalis River, likely influenced by the warmer water temperatures in the mainstem.

To assess temperature variations from the ambient river temperature, we compared the profiling logger readings with those of a fixed logger located at RM 11, situated in the shade in mixing water. The largest difference between the Skookumchuck River ambient river temperature and the river profile occurred at RM 4.5, where the profiling logger recorded temperatures of 19.4 °C,

which was 3.7 °C higher than the ambient river temperature of 15.7 °C. This peak was transient and potentially the result of a temporary dewatering of the profiling logger. At the lowest sections of the river, particularly at the confluence (RM 0.01), the profiling logger consistently measured temperatures of 21.3 °C, which was 3.4 °C higher than the ambient river temperature of 17.9 °C. At RM 19, the profiling logger recorded temperatures of 11.3 °C, which was 3.4 °C lower than the ambient river temperature of 14.7 °C.

During our sampling period from August 15–22, 2022 flow rates in the Skookumchuck River ranged from a maximum of 55.1 cubic feet per second (cfs) to a minimum of 44.8 cfs, based on data from the USGS gauge in Bucoda, WA (USGS Station 12026400).

In the Newaukum River, we sampled the lower 12 miles in 2022 and found that temperatures generally approached the upper limit of tolerance for adult Chinook salmon (21 °C), with peak temperatures exceeding their highest thermal thresholds. Interestingly, river temperatures did not follow the expected pattern of cooler temperatures in higher sections. The Newaukum exhibited a patchwork of temperatures ranging from tolerable (17.8 °C located at RM 5) to above the tolerable range (24.4 °C near RM 8).

To assess temperature variations in the Newaukum River, we compared the profile temperature readings with a fixed temperature logger located at RM 4, representing the ambient river temperature. The largest variance from the ambient river temperature in the Newaukum River occurred at the highest and lowest sections of the river. At RM 0.4, the river temperature was 1.8 °C warmer than the ambient river temperature, while at RM 11.6, it was 1.4 °C cooler. Another notable temperature spike was observed at RM 5, where the profiling logger recorded temperatures of 23.5 °C, which was 1.6 °C warmer than the ambient river temperature of 21.6 °C.

Due to issues with the sampling gear, the Newaukum River profile included a wider range of sampling dates than the Skookumchuck River. The upper sections were sampled nearly a month earlier than the lower sections. During this period, the river experienced a substantial decrease in flow, dropping from a maximum of 54.3 cfs on August 8 to 32.2 cfs on September 7 as measured at USGS station 12025000 located at Labree Road bridge in Chehalis, WA. Surprisingly, some of the warmest conditions were observed during the earlier sampling days with higher flow (August 8, 2022, 24.4 °C located at RM 8.5).

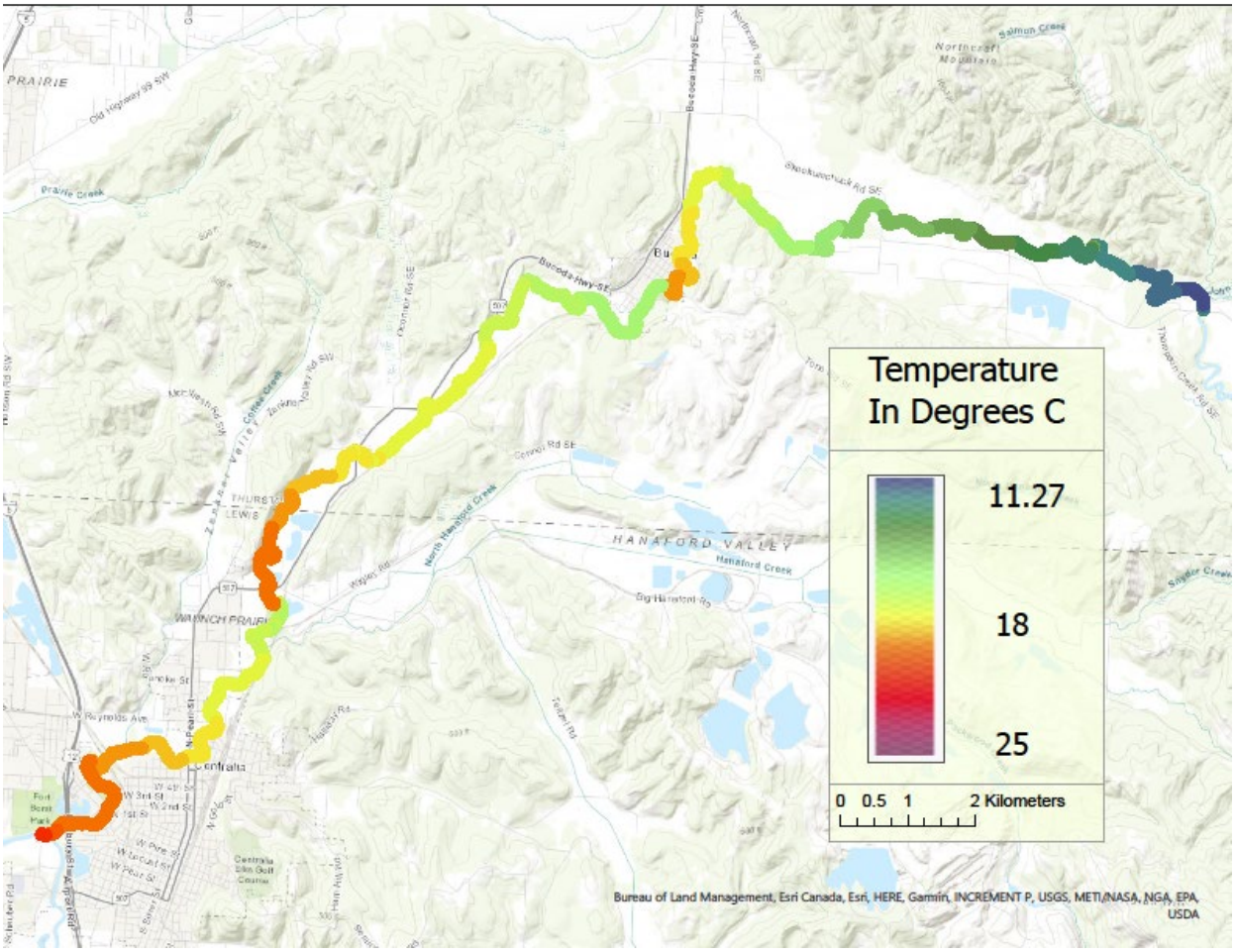

Figure 1. *Skookumchuck River Thermal Profile.*

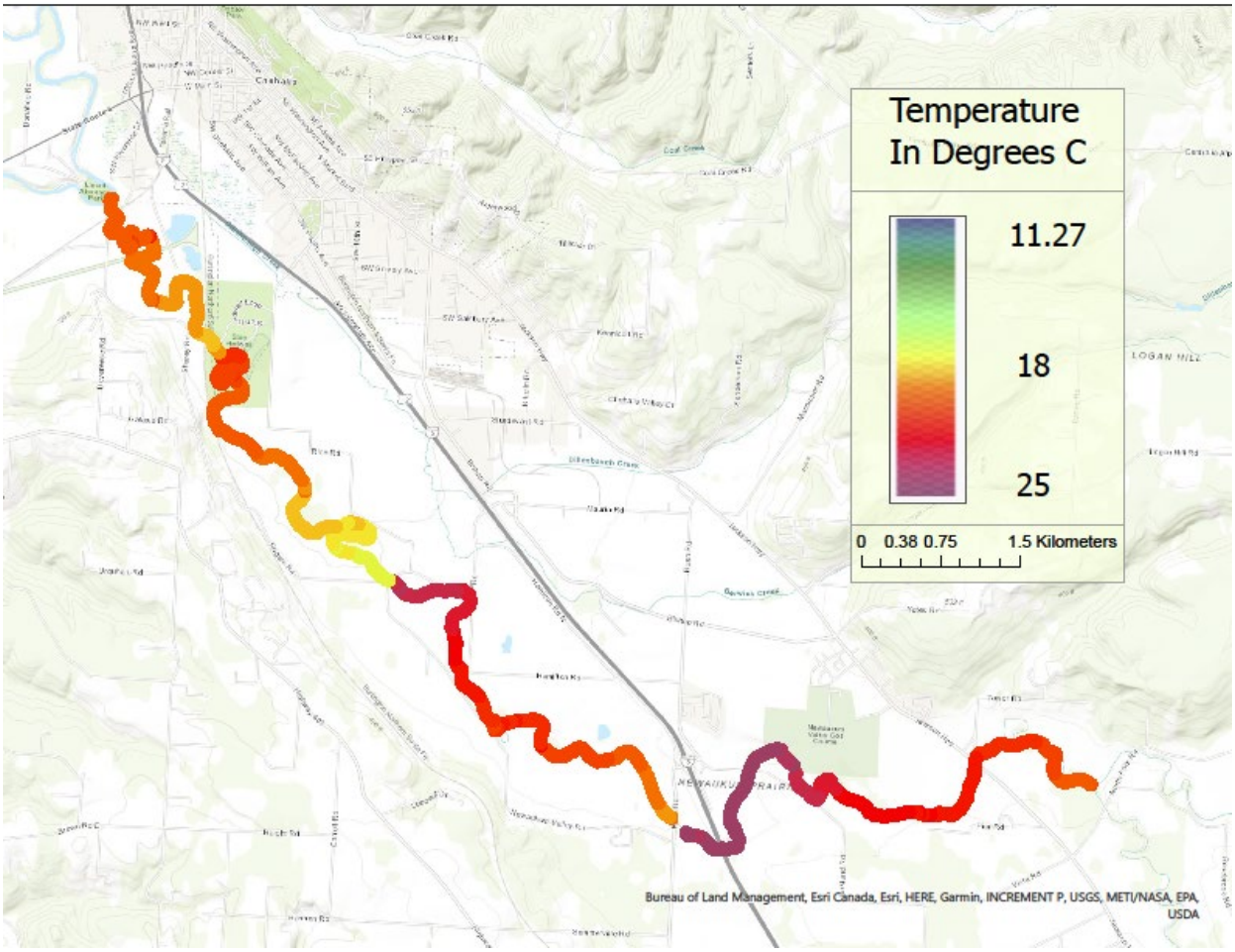

Figure 2. *Newaukum River Thermal Profile.*

Table 1. *Chinook salmon thermal thresholds. modified from (FitzGerald et al. 2022).*

Chinook Salmon	Thermal Threshold (Degrees Celsius)			
Life Stage	Tolerable	Optimal	Tolerable	Intolerable
Adult Migration	<10	10-20	20-21	>21
Holding	<10	10-16	16-21	>21
Spawning	<13	13-16	16-19	>19
Incubation	<9	9-13	13-17	>17
Rearing	<13	13-20	20-24	>24
Juvenile Outmigration	<15	15-20	20-24	>24
Smoltification	<10	10-19	19-24	>24

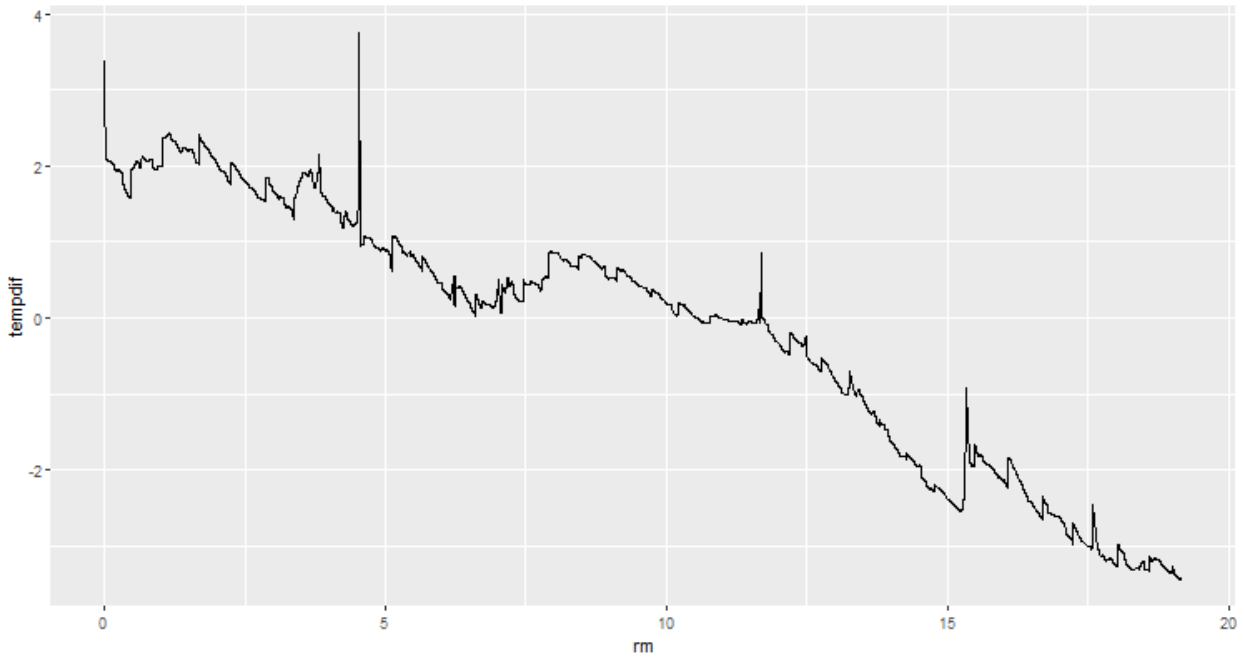

Figure 3. *Skookumchuck River temperature difference in degrees Celsius between the profiling logger and the ambient river temperature. The x axis is river miles while the y access is the temperature difference in degrees C.*

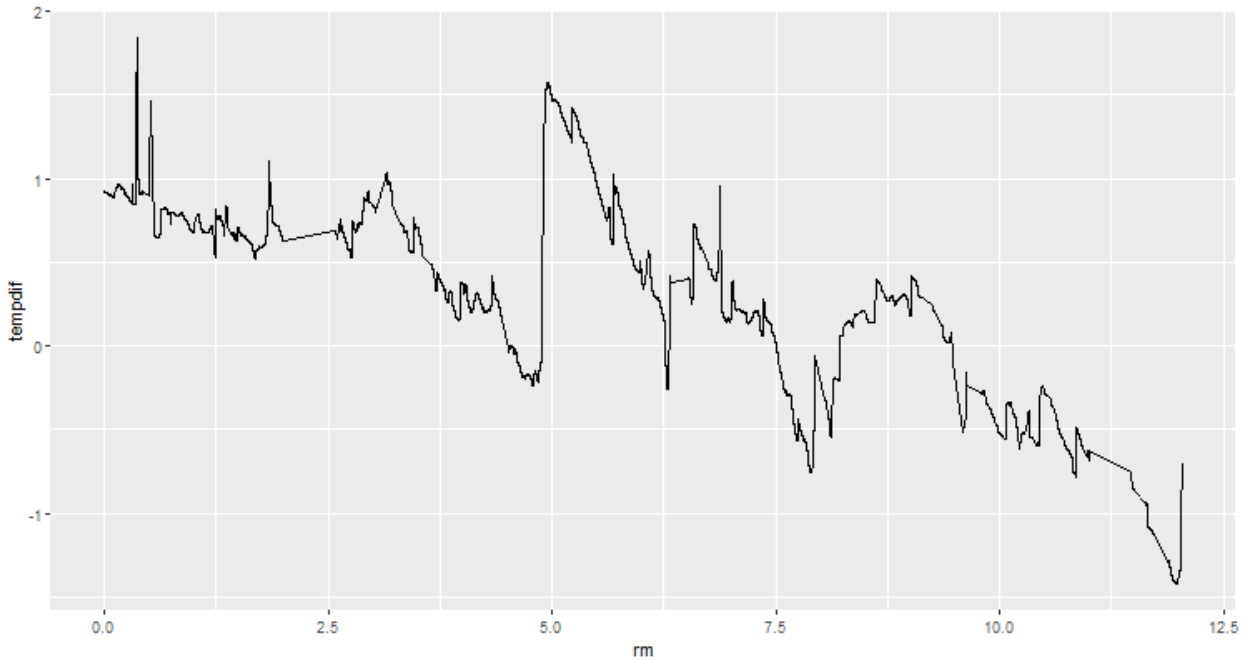

Figure 4. *Newaukum River temperature difference in degrees Celsius between the profiling logger and the ambient river temperature. The x axis is river miles while the y access is the temperature difference in degrees C.*

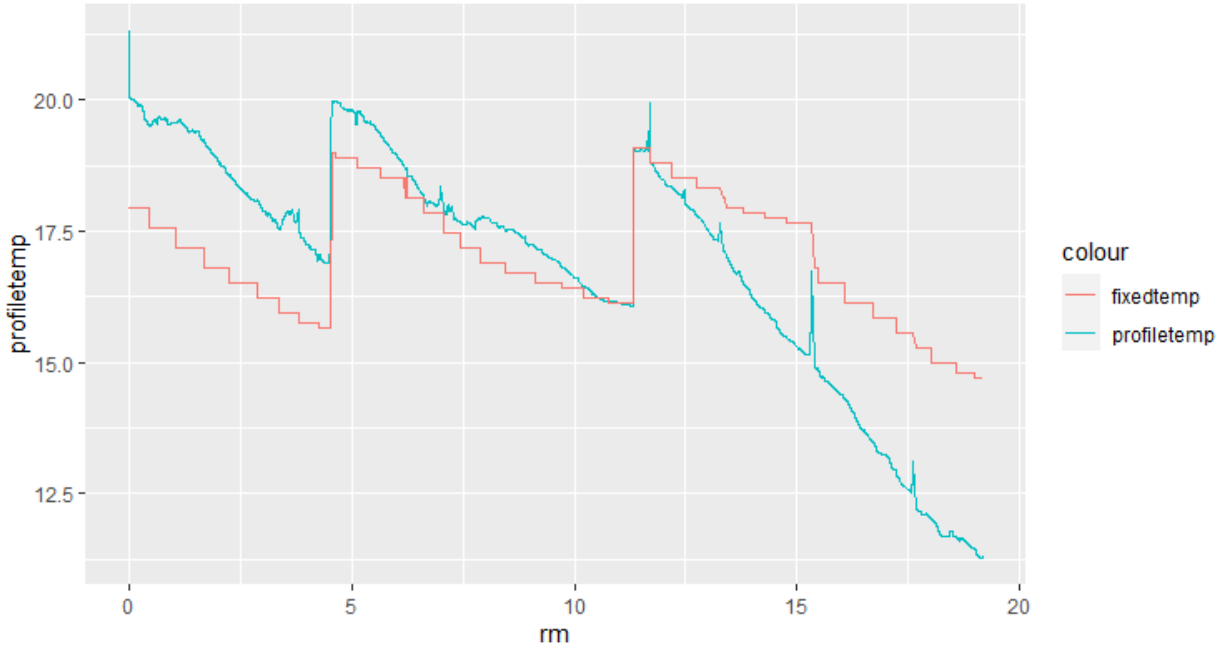

Figure 5. *Skookumchuck River temperature profile and fixed temperature logger. The orange line is the fixed temperature logger, and the blue is the profiling logger. The x axis is river miles, and the y axis is temperature in degrees C.*

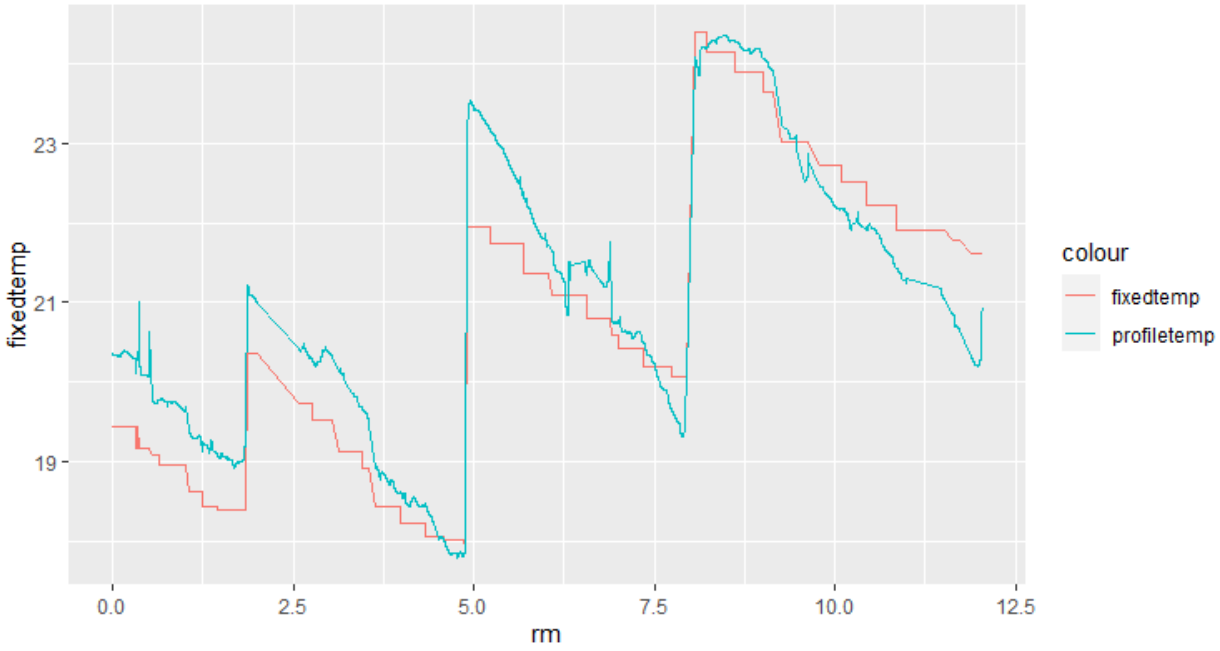

Figure 6. *Newaukum River temperature profile and fixed temperature logger. The orange line is the fixed temperature logger, and the blue is the profiling logger. The x axis is river miles, and the y axis is temperature in degrees C.*

Discussion

We found that temperatures were consistently cooler in the Skookumchuck River (range 12.1 °C to 21.3 °C) than the Newaukum River (range 17.8 °C to 24.4 °C) in summer 2022. The coolest temperatures in the Skookumchuck River were identified furthest upstream at RM 18 near the confluence with Johnson Creek and the warmest temperatures at the confluence with the Chehalis River. The temperature profiles in the Skookumchuck River were characterized as optimal (10-16 °C) or tolerable (16-21 °C) for holding adult spring Chinook. By contrast, temperatures in the Newaukum River exhibited a mosaic ranging from 17.8 °C to 24.4 °C, with much of the lower mainstem in the vicinity of I-5 characterized as intolerable (>21 °C) for holding adult Chinook salmon.

Results from this work could inform conservation and help identify areas for on-the-ground restoration techniques aimed to cool river temperature. However, critical data gaps remain, including temperature profiles of major tributaries (e.g., North, Middle, and South forks of the Newaukum River) and habitat use by holding adult spring Chinook. This study was funded for just one year under the ASRP Monitoring and Adaptive Management Plan, therefore it is unlikely that the results will provide meaningful time-series information to the five-year science-policy feedback loop unless monitoring continues. However, the collected dataset lends itself well to further analysis examining thermal conditions on a finer spatial scale (i.e., thermal refuges associated with tributary confluences). The information provided has relevance to spring Chinook salmon, a species of interest guiding prioritization and sequencing of ASRP activities.

Adaptive Management

Results from the summer temperature profiles of the mainstem Skookumchuck and Newaukum rivers could inform the ASRP Steering Committee decisions about protection/restoration projects and guidance to sponsors looking to develop habitat projects aimed to reduce stream temperature. However, because this work was only funded for one year, it will not contribute to the long-term status and trends monitoring in the Chehalis Basin nor the five-year adaptive management science/policy feedback loop. The Steering Committee could use this information about summer temperature profiles in the mainstem Skookumchuck and Newaukum rivers for project scoping and conservation actions, particularly with respect to holding adult spring Chinook salmon. For the Skookumchuck River, where discussions about the fate of the Trans Alta dam are ongoing, this information, and particularly the observed increasing downstream gradient of stream temperature below Johnson Creek, provides context about the river's thermal profile in response to release of impounded water behind the dam during the warmest part of the year.

References

FitzGerald, A. M., Boughton, D. A., Fuller, J., John, S. N., Martin, B. T., Harrison, L. R., and Mantua, N. J. (2022) Physical and biological constraints on the capacity for life-history expression of anadromous salmonids: An Eel River, California, case study. Canadian Journal of Fisheries and Aquatic Sciences, 79(7): 1023–1041. https://doi.org/10.1139/cjfas-2021-0229

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Vaccaro, J. J. and Maloy, K. J. (2006) A thermal profile method to identify potential ground-water discharge areas and preferred salmonid habitats for long river reaches: U.S. Geological Survey Scientific Investigations Report 2006-5136, 16 p.