Kenai Thermal Imagery

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11/18/2022

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Executive Summary

• Comments on DEC standards; zone of influence • Notes from Sue for report: format to consider::: highlight what conservation actions are for each property. E.g. we reached out to the city of kenai for their comprehensive plan; sue communicated with DEC about zone of influence and their proposed changes to water temp criteria; mailers •
• Executive summary + 1-2 pages methods, then appendix details actions for spot in each watershed. • Audience::: agency folks, landowners who want details; repository manager; land managers (e.g. CIRI) • E.g.:: ADFG has to bless water science for DNR to use it • outline future steps, how to build on this • e.g., how nice that USFWS has followed our lead

future directions - build relationship w/ USFWS pilot for TIR imagery - commission tool to notify when KPB parcels change hands - which of the 20ish M2S systems would be most valuable to get additional TIR data? o Systems w/ gravel development o Which rivers are zoned for mining? o Are there systems where old gravel extractions need reclaiming? Contact Robert R literature on how material excavation affects groundwater inputs?

—»> read Snyder 2022 http://dx.doi.org/10.1002/ecs2.4265

Snyder et al 2022

1 Introduction

This document contains data and analysis related to the Kenai River Thermal Imagery project. This work is a collaborative effort between three Kenai Peninsula Nonprofits: Cook Inletkeeper, Kachemak Bay Heritage Land Trust, and Kenai Watershed Forum.It is funded by the Alaska Sustainable Salmon Fund (project #53003).

A two-page project summary titled, "Science Based Land Conservation: Cold Water Stepping Stones" is outlined below. A full size version of this information sheet is accessible at the link in the caption below Figure 1.1.

All code used to generate this report is available in the project's GitHub repository at https://github.com/Kenai-Watershed-Forum/kenai_thermal_imagery_v2.

Science-based Land Conservation

Cold Water Stepping Stones

Anticipating the inevitability of climate-related change to freshwater habitats is essential for the management of Alaska's salmon populations, which contribute substantially to global wild salmon production and are exceedingly important to Alaska's ecology, economy, and societal health of Tribal communities.

As water temperatures get warmer in many of Alaska's streams in the years ahead, cold water refugia – areas within a stream which are persistently colder than adjacent areas – will be critical to the survival and persistence of salmon. Deep pools, overhanging vegetation, and undercut banks can be important cold-water habitats; however, stream reaches with groundwater interactions (i.e. springs and seeps) may result in measurably cooler water. Mapping these cold-water stepping stones that are needed for salmon to make their way up and down otherwise warming streams is the first step towards protecting critical salmon habitat in this time of thermal change.

Why is temperature important?

Water temperature affects all phases of the salmon lifecycle, including :

- *timing of migration*
- *survivorship of eggs*
- *respiration*
- *metabolism*
- *availability of O_2*

Warm water temperature induces stress in salmon and makes them more vulnerable to pollution, predation and disease.

For more details, please contact:

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Figure 1.1: Project Summary Sheet, download at https://bit.ly/kenai_tir

2 Project Map

The ArcGIS Online project map may be accessed below or at ArcGIS Online (Click Here: https://arcg.is/0vaueq).

The online map contains layers with the following data:

- Project Watershed Boundaries
- National Hydrography Database (rivers, lakes, streams, etc)
- Anadromous Waters Catalog
  - Streams
  - Lakes
- Kenai Peninsula Borough Parcel Boundaries
- Thermal Imagery Data from NV5 Geospatial consultants report
  - Significant Thermal Features (identified from thermal imagery)
  - Longitudinal Temperature Profiles (main channel temperatures of study streams)
  - Water Temperature Logger Sites

3 Thermal Imagery Data

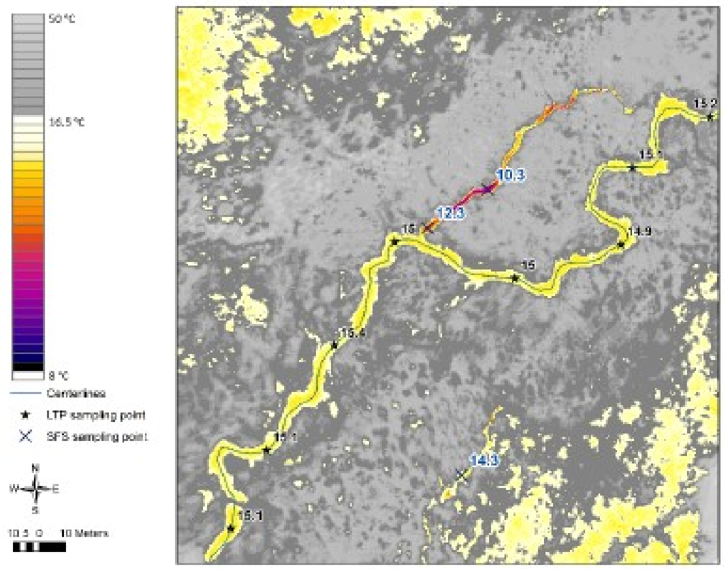

Figure 3.1: Example of airborne thermal infrared imagery showing temperature contrast in a stream. A cold water inflow (purple and blue colors) enters the main channel (yellow color). Figure from NV5 Geospatial consultants report.

On July 5, 2020, NV5 Geospatial collected thermal infrared imagery from a helicopter-mounted camera for four steams on the Kenai Peninsula in southcentral Alaska. These streams included:

- Kenai River Tributaries
  - Beaver Creek
  - Funny River
  - Moose River
- Kasilof River Tributary
  - Crooked Creek

All streams were flown during the afternoon hours in order to maximize the thermal contrast between the river's water and the banks.

The surveys extend for a total length of 59.1 km of the streams. Flight transects proceeded from the mouth of each stream in an upstream direction. The data were collected to aid the team in identifying the spatial variability in surface temperatures as well as thermal influence of point sources, tributaries, and surface springs.

Specific deliverables generated by NV5 Geospatial from the thermal imagery data include:

- Rasters (map image files; .tif and .jpg formats)
- Shapefiles (longitudinal temperature profiles, stream centerlines, others; .shp format)
- Other supplemental items (coordinates of significant thermal features, maps and figures, and others)

The full technical report from NV5 Geospatial describing detailed methods and interpretation can be accessed at the following link:

The image raster files are of a large size (~3 GB) and may be acquired by contacting staff at Cook Inletkeeper (sue@inletkeeper.org), Kenai Watershed Forum (hydrology@kenaiwatershed.org), or Kachemak Heritage Land Trust (info@kachemaklandtrust.org).

3.1 Parcel data summary

We generated a table in GIS (ArcMap Pro 10.8.1) of parcels in the Kenai Peninsula Borough that intersect with cold-water inputs (e.g. seeps, springs) within the surveyed areas of Beaver Creek, Crooked Creek, Moose River, and Funny River.

Figure @ref(fig:parcel-plot) summarizes the ownership type of these parcels by general category of owner type.

3.2 Ground truth data

On July 7-8, 2021 we visited a subset of sites identified by the NV5 Geospatial Consultants report as cold water features. We visited 12 of 63 total sites. We recorded surface water temperatures of the identified features as well as the adjacent main stem using a using a Hach Sension 5 portable meter. The average time difference between main stem temperature observation and off-channel observation was 13.9 minutes. We created a graphic sketch of the layout of each feature, and recorded site photos.

Field forms, including site sketches, can be accessed at the following link:

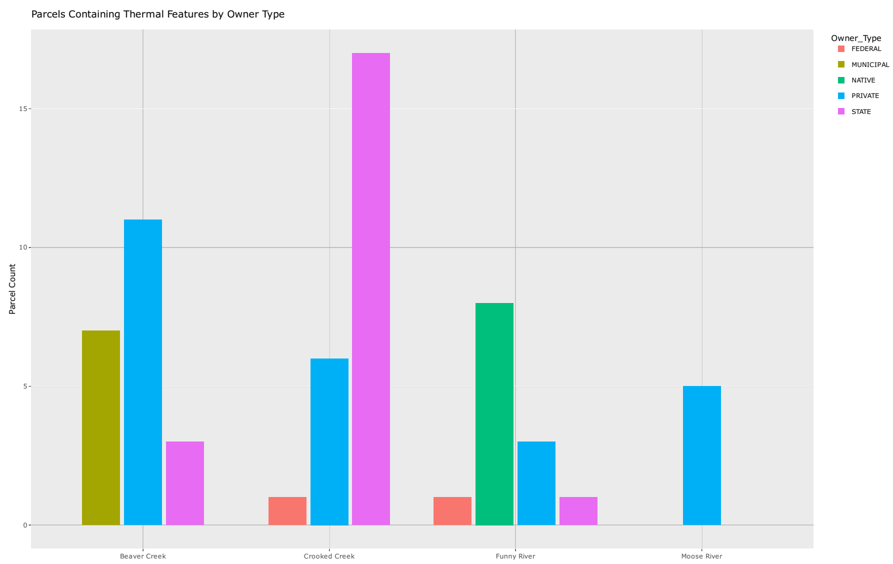

Figure 3.2: Parcel ownership

Figures @ref(fig:gt-obs) through @ref(fig:gt-tir-obs-funny) visualize water temperature data sourced from the significant features in aerial imagery on July 20, 2020 along with ground-truthed measurements from July 7-8, 2021.

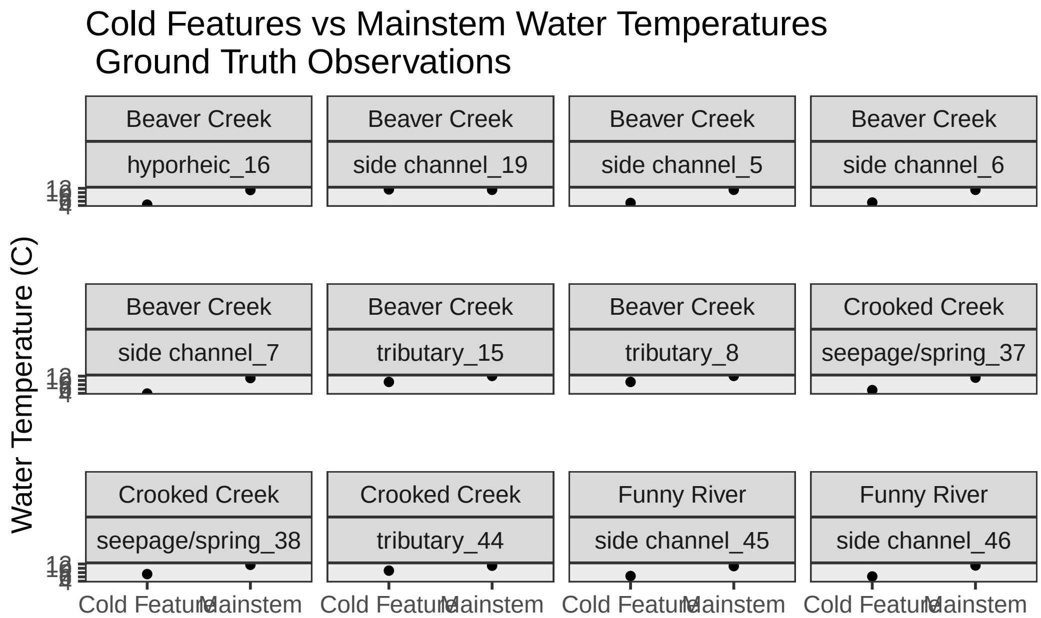

Figure 3.3: Cold Feature vs. Mainstem, ground truth observations water temperature data.

3.3 Collaborative Assessment

Researchers with participating organizations used data from several sources to assess conservation strategies within each study watershed, and recorded their notes on a shared platform. These collective notes are being used internally to inform strategy for outreach approaches with local property owners.

Data sources used to assess parcel-specific conservation strategies include:

- Custom maps for each significant thermal feature, including information about the parcel or parcels that it occupies
- Information about individual thermal features from the NV5 Geospatial Consultants Report, including mean value and contrast with the main stem
- The ArcGIS Online project map

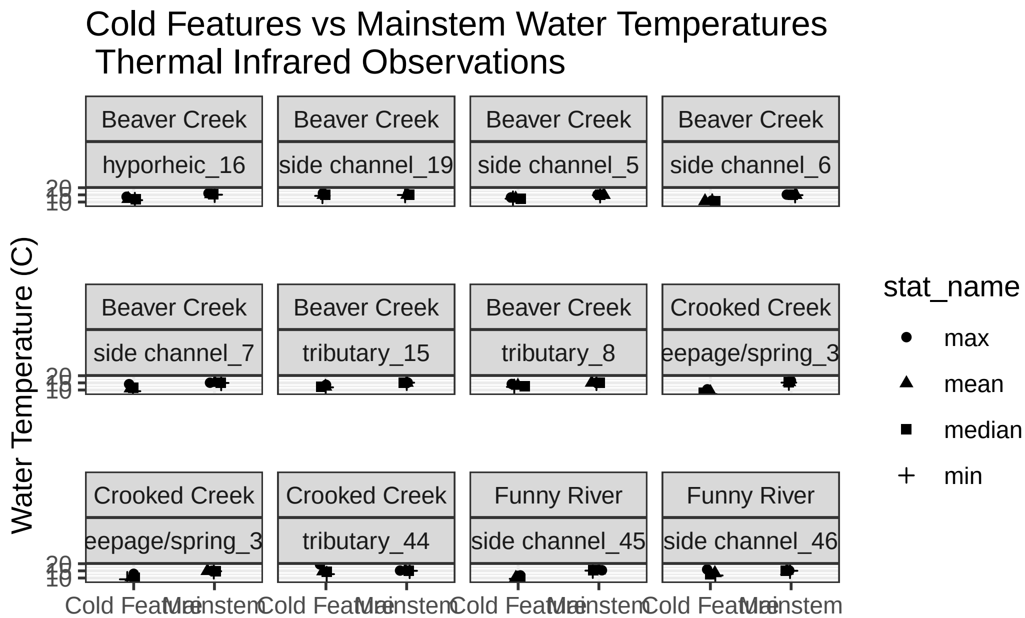

Figure 3.4: Cold Feature vs. Mainstem, thermal infrared water temperature data.

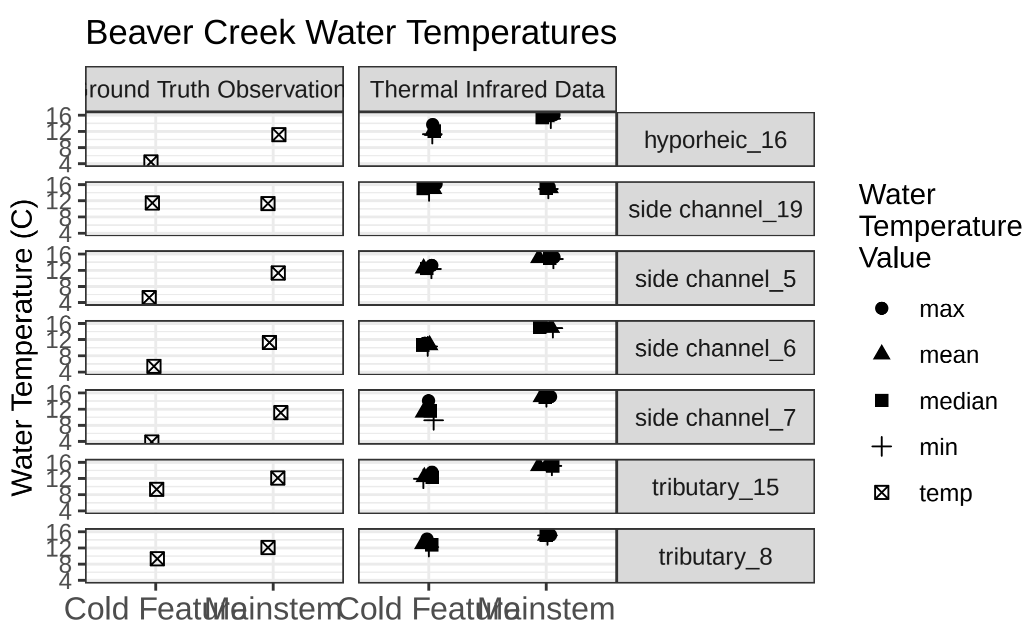

Figure 3.5: Beaver Creek water temperatures, ground truth and thermal infrared imagery observations.

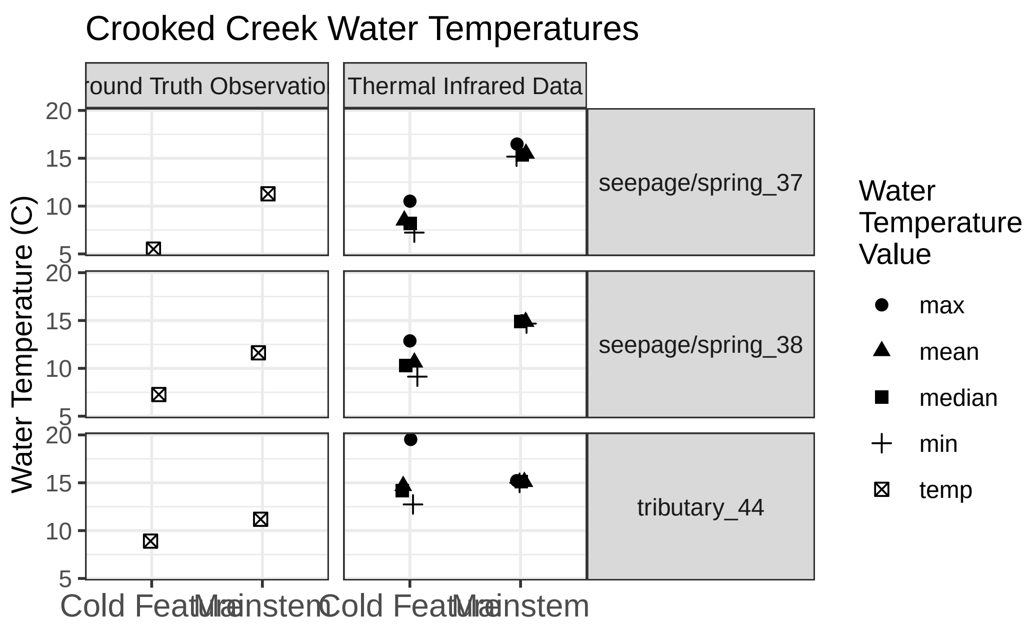

Figure 3.6: Beaver Creek water temperatures, ground truth and thermal infrared imagery observations.

Project collaborators may access the Thermal Imagery Database Google Sheet using the link below:

Link: Thermal Imagery Collaborative Assessment

An example map is shown in figure @ref(fig:example-map).

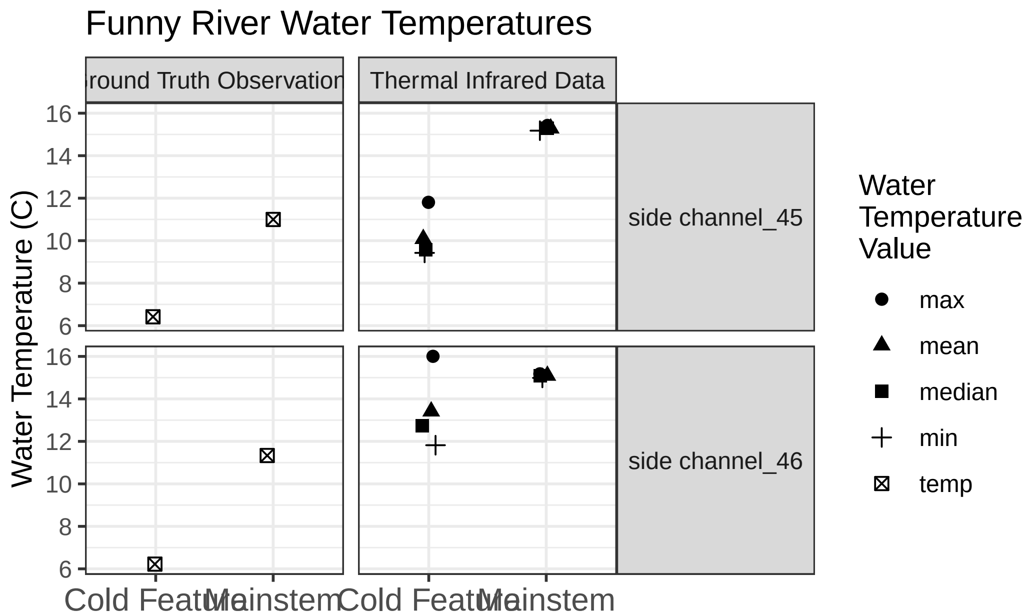

Figure 3.7: Funny River water temperatures, ground truth and thermal infrared imagery observations.

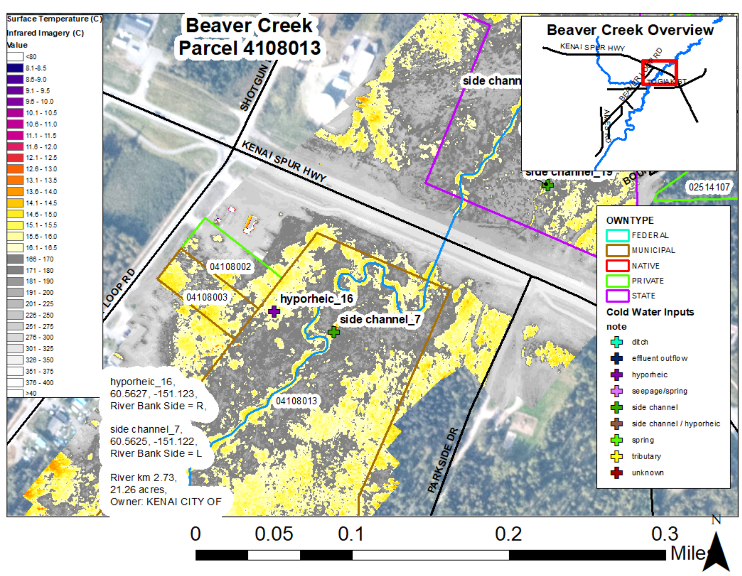

Figure 3.8: Example of airborne thermal infrared imagery map with parcel overlay

4 Water Temperature Loggers

In order to supplement aerial thermal infrared imagery and cold-feature ground truthing data, we deployed water temperature loggers in the lower reach of each study stream to collect continuous time series of water temperature. We used Onset HOBO Temp Pro V2 loggers, deployed and maintained according to standards published in Mauger et al. 2015.

This section executes methods to visualize and perform basic quality checks on continuous temperature loggers deployed in the study streams. All data files (.csv) used in these analyses can be downloaded from this project's GitHub repository.

4.1 Map

See the Project Map section of this report for locations of water temperature logger sites. The ArcGIS Online layer titled, "Water Temperature Logger Sites" displays these locations.

4.2 Logger Data QA/QC

Data retrieved from the field was subjected to a basic quality assurance process before being incorporated into the analysis dataset. We visually inspected each water temperature time series and excluded data indicative of pre/post deployment or exposure. Figures Figure 4.1 and Figure 4.2 provide a visual example of water temperature time series prior to and post quality assurance processes.

4.2.1 Additional data preparation

The following sections describe additional details on data preparation specific to each water temperature logger site.

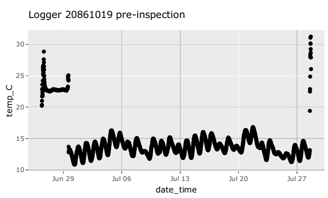

Figure 4.1: Example of water temperature time series prior to quality assurance process

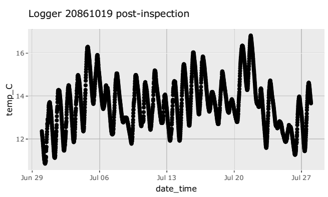

Figure 4.2: Example of water temperature time series after quality assurance inspection

4.2.1.1 Beaver Creek

Loggers at the Beaver Creek logger site were deployed in early summer 2020. As part of a separate research project, Alaska Center for Conservation Science (University of Alaska Anchorage) established a logger site several hundred meters upstream also in Summer 2020.

We examined if data from the two sites are similar enough to use as a proxy for each other when data observations are missing. Time series from both sites are shown in figure Figure 4.3, and simultaneous values from both sites are presented in figure Figure 4.4.

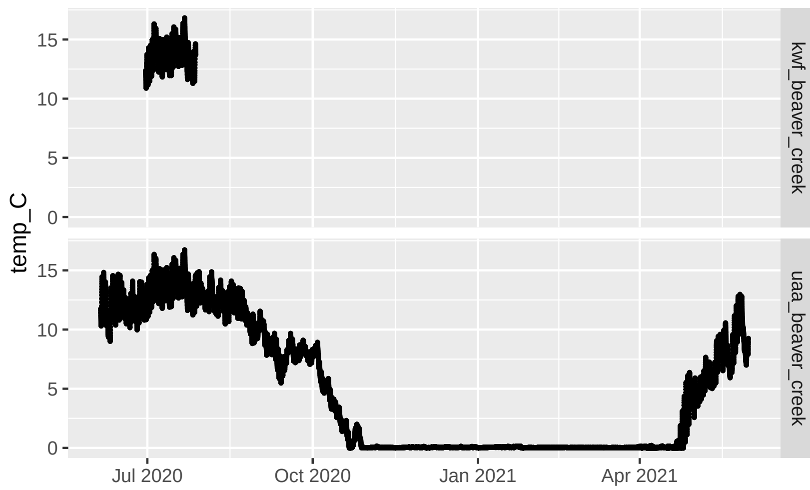

Figure 4.3: Water temperature time series from Lower Beaver Creek at two nearby sites.

The average absolute difference in temperature between the two logger sites in Beaver Creek is 0.06 ± 0.05 C (mean ± sd). For most applications, a substitution of data from either of these sites in Lower Beaver Creek will still accurately represent water temperature.

4.2.1.2 Lower Crooked Creek

Lower Crooked Creek has two adjacent water temperature monitoring locations within 20 m of each other. Further details on these two sites are described below, and figure @ref(fig:cc-map) shows locations of the two sites.

4.2.1.2.1 Lower Crooked Creek Real-time temperature monitoring site

Cook Inletkeeper maintains a site installed by Beaded Stream that records air and water temperature data in real-time and streams these data live at https://inletkeeper.org/our-wo

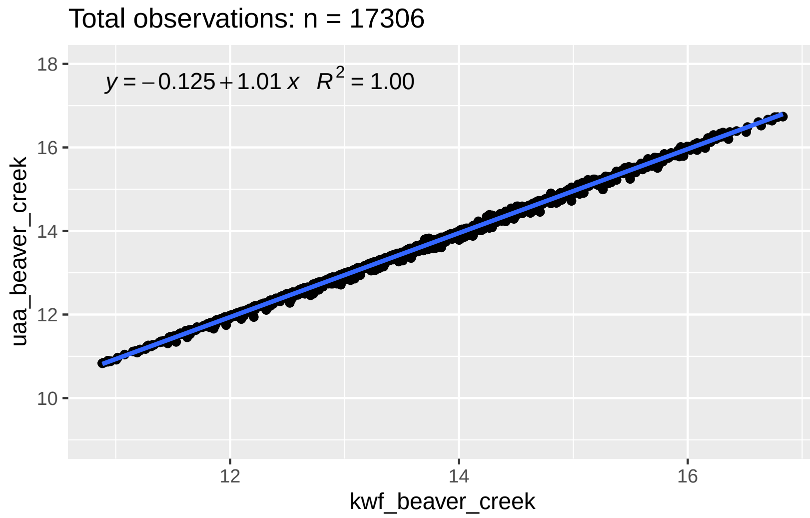

Figure 4.4: Regression of simultaneous water temperature observations from two nearby sites in Beaver Creek.

Figure 4.5: Lower Crooked Creek temperature monitoring sites

rk/healthy-habitat/real-time-temperature-sites/crooked-creek/. Water and air temperature data has been recorded and streamed from this site at hourly intervals since summer 2017.

Temperature data from this location can be downloaded as a csv file directly from the above Inletkeeper web link. However, ***as of 2022-12-01 there is an error with the publicly available csv file***. The publicly available csv file has incorrect time stamps after 12/31/2019. Beaded Stream staff is aware of the error, and says the remedy will require an in-person visit to the field. In the mean time, contact Beaded Stream staff to request access to most current data.

The data with correct time stamps from 2017-08-15 though 2021-10-26, obtained directly from the internal Beaded Stream dashboard, is also available for download at this link from GitHub: **Download Lower Crooked Creek Realtime Temperature Data**.

4.2.1.2.2 Lower Crooked Creek HOBO TempPro V2 logger site

A pair of HOBO Temp Pro V2 loggers are installed at a location 20 m upstream from the real-time temperature logger site. Water temperature is recorded at 15 minute intervals.

During a site visit on 7/28/2021, we discovered that this pair of loggers potentially resided within a small, previously unidentified cold water plume incoming from the river-left bank. (On the ArcGIS Online project map, this feature is identified as "tributary_44." It was unclear if the local cold water seep was influencing the loggers in way such that they would not represent main channel temperature.

In order to determine if HOBO logger data prior to 7/28/2021 is influenced by the cold seep, we performed the following steps:

1. *Relocated loggers.* On 7/28/2021, we modified logger deployment such that one logger was directly upstream of the cold water seep, and one remained in its original location within the seep.
2. *Compared temperature data upstream vs. downstream of the seep.* We observed consistently cooler temperatures in the downstream logger, with an average absolute difference of 1.47 $\pm$ 0.30 °C (mean $\pm$ sd). Figure @ref(fig:cc-plots) displays time series from both loggers as well as the difference values where simultaneous data from both locations exists.

From these data we observe that the small cold water tributary consistently affected main stem temperature where the loggers recorded temperature. Temperature contrast was much less apparent in cooler months, after approximately September 1st, 2021. Thus, the data from these HOBO loggers prior to 7/28/2021 in the location downstream of the small cold water tributary should not be considered representative of main channel Crook Creek temperatures.

We reviewed all paper field forms from the lower Crooked Creek site from 2015 - present (link here) to determine the time extent that HOBO loggers may have been influenced by the cold water tributary. These notes suggest that the period extended from from 5/31/2019 - 7/28/2021. Prior to 5/31/2019 there is not evidence on file that can confirm whether or not the loggers were deployed within the cold water plume.

One possible explanation for why technicians failed to observe the cold water seep when they installed the HOBO loggers in Summer 2019 is that high discharge level in the Crooked Creek main channel temporarily masked the localized effect of cold water input. These results highlight the value of regular site visits to re-verify that the site is well-mixed, or checking temperatures beyond the minimum of five observations across a transect.

Additionally, these results exemplify the role of cold water inputs in maintaining thermal refugia for salmonids in watersheds such as Crooked Creek. Note in figure Figure 4.6 that water temperature within the cold water plume in the main channel was often 1.5 °C cooler than the non-influenced location. Temperature differentials of this nature help allow salmonids to access a diverse portfolio of thermal environments important to functions throughout their life cycle such as migration, metabolism, and foraging.

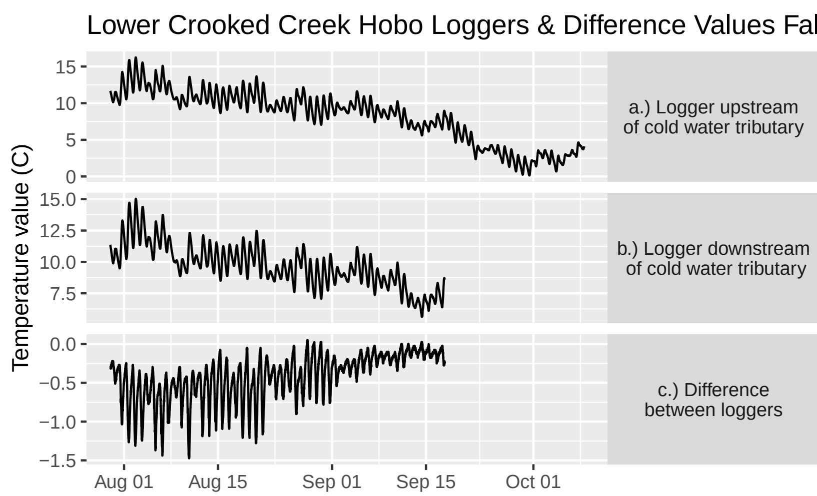

Figure 4.6: Water temperature time series from Lower Crooked Creek at two nearby loggers (~5 m apart). a.) Upstream of a small coldwater tributary, b.) downstream of small coldwater tributary, c.) difference values between the loggers. Note different y-axis ranges.

4.2.2 Extent of water temperature time series

Figure Figure 4.7 displays temporal extent of currently available water temperature at each site

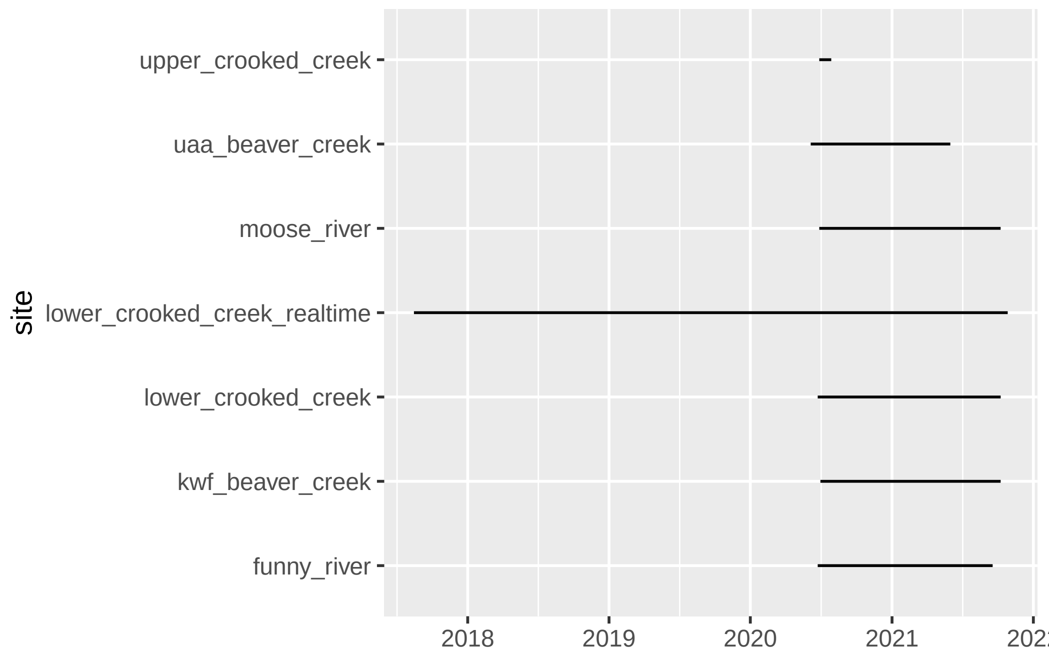

Figure 4.7: Temporal extent of water temperature logger data

5 Applications

We applied our findings of where cold-water inputs were located towards education and outreach opportunities in the Central Kenai Peninsula region.

We used the thermal features map layer generated from this project as a tool to help generate comments on a local land management plan. We commented on the City of Kenai 2021 Land Management Plan, which highlighted a number of parcels in the Beaver Creek corridor, and recommended parcel-specific actions (e.g. retain, sell, re-zone).

We created a separate map showing parcels highlighted in the plan, with management status available in a point and click format. The parcels were superimposed on a several layers highlighting ecological values such as wetlands and anadromous streams, as well as the thermal features identified in this project. Methods are described in a separate stand-alone document at https://rpubs.com/kwf/867931.

Access the City of Kenai Land Management Plan Comments Map here: https://arcg.is/1Oq9Kq.

Access PDFs of submitted Public Comments below:

5.1 Landowner Outreach

5.1.1 Letter

We composed a letter addressed to landowners whose property contains cold water features that flow in to one of our study streams. This letter describes the nature of the project and the value of cold water features to salmon habitat. Landowners are invited to contact the researchers if they would like more information about their specific property.

A draft version of the letter to landowners may be accessed below:

5.1.2 Postcard

We designed and mailed a post card to landowners whose property contains cold water features that flow in to one of our study streams. The postcard notifies landowners that their specific parcels are of high conservation value, and encourages them contact project scientists to learn more about best practices.

A PDF proof version of the postcard may be accessed below:

6 Summary

In summary, this book has no content whatsoever.

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References