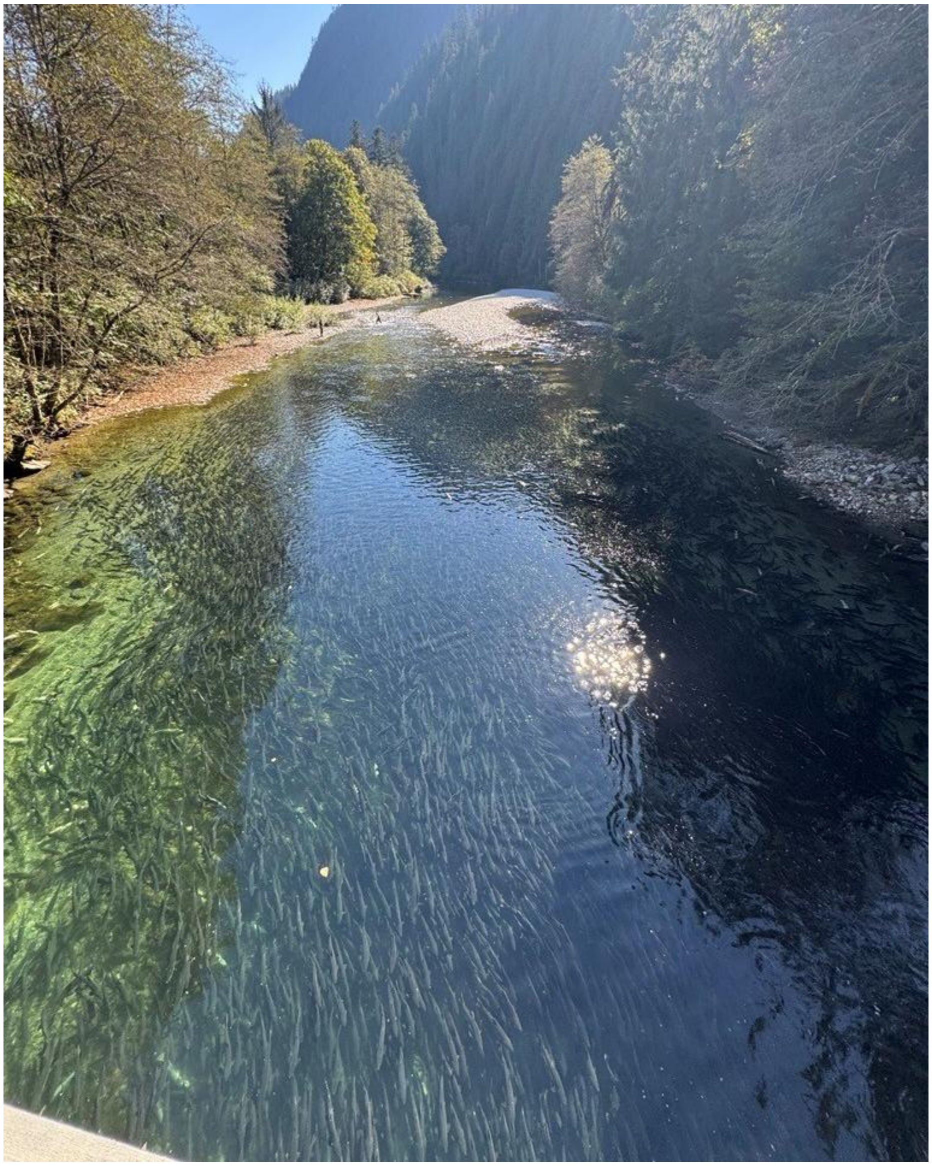
Restoring Balance in xʔəl̓ílwətaʔɬ Waters: Linking Salmon to Habitat and Thermal Regimes in the Indian River Watershed



Haley Crozier[1], Ann-Marie Norris[2], Stephen Healy[3]

[1]Tsleil-Waututh Nation, Treaties, Lands and Resources Department, 3178 Alder Court, North Vancouver, B.C., V7H 2V6
[2]Fisheries and Oceans Canada, Ecosystems Management Branch, Regional Headquarters, 401 Burrard Street, Vancouver, B.C., V6C 3L6
[3]Fisheries and Oceans Canada, Science Branch, Pacific Science Enterprise Centre, 4160 Marine Drive, West Vancouver, B.C., V7V 1N6

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List of Abbreviations:

AFS	Aboriginal Fisheries Strategy
BC	British Columbia
BCMELP	British Columbia Ministry of Environment, Lands, Parks
BCMOECCS	British Columbia Ministry of Environment and Climate Change Strategy
BIESSA	Burrard Inlet Environmental Science and Stewardship Reconciliation Agreement
CABIN	Canadian Aquatic Biomonitoring Network
CPUE	Catch-per-unit effort
CTT	Cutthroat trout
DFO	Fisheries and Oceans Canada
DV	Dolly varden
ECCC	Environment and Climate Change Canada
EPA	Environmental Protection Agency
FHAP	Fish Habitat Assessment Procedure
IRMP	Indian River Monitoring Program
IRW	Indian River Watershed
IRWISP	Indian River Watershed Integrated Stewardship Plan
LOESS	Locally Estimated Scatterplot Smoothing
LWD	Large Woody Debris
RBT	Rainbow trout
TWN	Tsleil-Waututh Nation
USGS	U.S. Geological Survey

Abstract

This report summarizes Tsleil-Waututh Nation and Fisheries and Oceans Canada's collaborative 2024 habitat assessments, juvenile salmonid monitoring, and thermal monitoring within xʔəlí̓lwətaʔɬ/Indian River Watershed (the IRW). The goal of this report was to summarize juvenile salmonid (*Oncorhynchus spp.*) distributions, as well as habitat and temperature regimes and thermal sensitivities among various sites within the IRW. We also paired these multiple datasets to identify any relationships between salmonid abundance, size, and thermal/habitat conditions to help explain how variance in environmental and physical factors influence salmonids in the watershed (including differences among habitat types). Juvenile salmonids were sampled at 23 sites (naturalized channels, restored channels, mainstem sites), temperature was monitored at 21 locations, and detailed habitat assessments were completed in seven side-channels. Linear regression was used to identify relationships between temperature, and habitat conditions, and juvenile salmonid size and abundance.

Natural channels exhibited greater physical variability, habitat heterogeneity (i.e. habitat complexity), and salmonid species diversity than restored channels (i.e human-made). In contrast, restored channels had greater overall densities of salmonids than natural channels. Warmer off-channel and wetland habitats supported mainly larger and higher relative abundance of year 1+ coho (*Oncorhynchus kisutch*), while the colder groundwater-fed channels showed limited juvenile coho occupancy. The greatest coho densities were observed at the Mainstem at 5 K, where large woody debris (LWD) structures likely provided ideal rearing habitat, highlighting the importance of LWD for juvenile fish in the watershed.

Thermal sensitivity analysis showed strong variation among sites, with groundwater-fed channels of 5 K and Wellwood remaining more thermally stable throughout the year, highlighting potential zones of thermal refuge (cooler water, summer; warmer water, winter) for fish. Linear regressions showed significant positive relationships between water temperature and coho and chum size, and between temperature and coho relative abundance, indicating that warmer and more natural off-channel sites may support faster juvenile coho growth rates, and are preferred habitat within the watershed for rearing.

Our findings highlight the importance of habitat heterogeneity, LWD structures, and variable thermal conditions for sustaining juvenile salmonid populations in the IRW. The results support priority restoration actions, including LWD enhancement of the mainstem, protection of groundwater-fed channels (for spawning and thermal refugia), and conservation of productive off-channel wetlands habitats (for rearing and growth), and provide a foundation for adaptive salmonid management in the IRW in a warming climate. These findings align with the goals, objectives, and strategies of the Indian River Watershed Integrated Stewardship Plan (IRWISP), and with Tsleil-Waututh stewardship and values.

Introduction

Tsleil-Waututh Nation Context

Tsleil-Waututh Nation (TWN) are the “People of the Inlet”, and have lived, stewarded, and thrived in the areas of Burrard Inlet, the Fraser Valley, and neighboring waters and valleys since time immemorial (Figure 1; TWN 2022). At the northern end of Indian Arm in Burrard Inlet is the xʔəl̓ílwətaʔɬ/Indian River Watershed (the IRW). The IRW is often considered “the core” of Tsleil-Waututh territory, and holds immense historical, cultural, and economic importance to the Nation. Inlailawatash is the historic Tsleil-Waututh village found where the IRW and the estuary meet. It is also the name of the two Tsleil-Waututh Indian Reserves (IR 4 and 4A), and fee simple lands owned by the Nation (TWN, 2022).

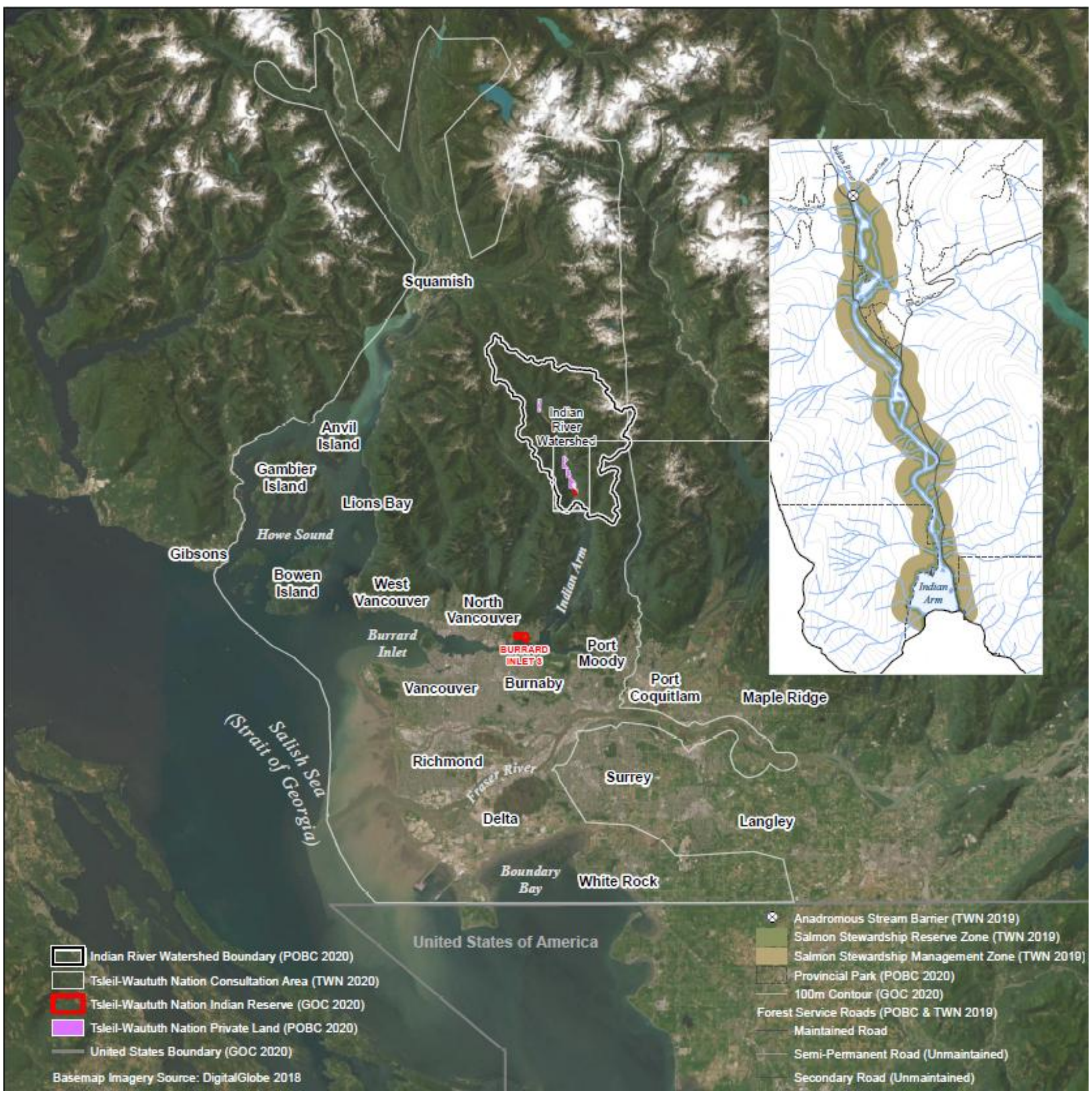

Figure 1: xʔəl̓ílwətaʔɬ/Indian River Watershed regional context and Tsleil-Waututh Nation’s traditional territory. Inlay shows the Indian River Salmon Stewardship and Management Zones as outlined in the Indian River Watershed Integrated Stewardship Plan.

xʔəl̓ílwətaʔɬ/Indian River Watershed:

The IRW is located 30 kilometers northeast of Vancouver and is the southernmost fjord on the west coast of North America (Figure 1; TWN, 2022). It is approximately 219 km^2 (22,000 hectares), and is a glacially formed U-shaped valley, with its headwater found in steep, alpine terrain). The mainstem river flows over 36 km, with an additional 750 km of tributaries. Salmonid species found within the IRW include chum salmon (*Oncorhynchus keta*), coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*), cutthroat trout (*O. clarkiii*), rainbow trout (*O. mykiss*), and dolly varden trout (*Salvelinus malma*). The steep mountains, heavy precipitation and porous valleys of the watershed contribute to poor slope stability. Industrial activity including road construction, and intensive forestry practices increase erosion, and have been identified as major catalysts to future landslides (TWN, 2022). Within the IRW, 15% of slopes are considered unstable, with another 25% of slopes designated as potentially unstable. Unstable slopes lead to landslides occurring on a near yearly basis, occasionally transporting and depositing sediment into areas where salmonids spawn. Negative impacts to fish and fish habitat, as well as environmental stress have been attributed to intensive forestry practices, the installation of a hydroelectric transmission line in 1968, and a natural gas line in 1991. Due to these impacts to the valley, the historically steady hydrology of the watershed has become increasingly unpredictable (TWN, 2022).

TWN Stewardship

Tsleil-Waututh history teaches that the Tsleil-Waututh people accept responsibility for the care of the lands and waters within their traditional territory, leading to ongoing stewardship work within the IRW (TWN, 2022). Stewardship work includes salmonid monitoring carried out under the Aboriginal Fisheries Strategy (AFS) agreement between TWN and the Fisheries and Oceans Canada (DFO), restoration work to improve fish habitat, and the creation and implementation of the Indian River Watershed Integrated Stewardship Plan (IRWISP) that was developed in collaboration with the Province of British Columbia. Further stewardship work and research is also conducted in collaboration with DFO under the Burrard Inlet Environmental Science and Stewardship Reconciliation Agreement (BIESSA; further described below), a Nation-to-Nation Reconciliation Agreement between the Government of Canada and TWN.

Indian River Monitoring Program

Following the AFS Strategy in 2000, TWN established the Indian River Monitoring Program (IRMP). The program was created to protect and restore salmonid populations and their associated habitat within the IRW. The IRMP primarily focuses on chum, coho, and pink salmon, as they are found in much larger numbers than other salmonids in the watershed. The IRMP is focused within the Salmon Stewardship Reserve Zone (Figure 1), which is defined as the southernmost ~10 km of the Indian River that is accessible to anadromous salmon, to where it discharges into the estuary in the Indian Arm (TWN, 2022; Figure 1). Projects within the IRMP include annual juvenile minnow trapping from March through May, adult escapement surveys from July through January, and off-channel habitat assessments in July and August. The present report primarily focuses on the juvenile trapping data and habitat assessments that fall under IRMP.

Restoration Projects

Restoration and enhancement projects began in the IRW in the 1980s to increase off-channel spawning and rearing habitat that had been impacted by extensive logging and infrastructure within the watershed. Jacks and Wellwood Channels were built in 1987, with Brandt North built in 1988, all with a goal of providing spawning habitat for chum and coho, as well as refuge during high flow events. All three side-channels receive high densities of spawning pink and chum, with Jacks typically having the highest density of spawners of all the side-channel sites in the IRW. Additional projects included Counting Towers as rearing and refuge habitat (1988), Beaver Dam as rearing habitat (unknown date), and Forestry Channel as spawning habitat (1999; Figure 2). More recently, TWN in conjunction with DFO's Restoration Center of Expertise implemented several restoration projects including: 8 K Wetland as rearing habitat for coho (2013), Old River Channel for connectivity and spawning (2014), 5 K Channel as spawning and rearing habitat (2016, re-worked 2023), Brandt South to reconnect Brandt North to the mainstem (2022), Elk Slough as rearing habitat (2024), and the installation of large woody debris structures and boulder complexes in the mainstem at the northern end of Old River to increase flow into the side-channel (2024).

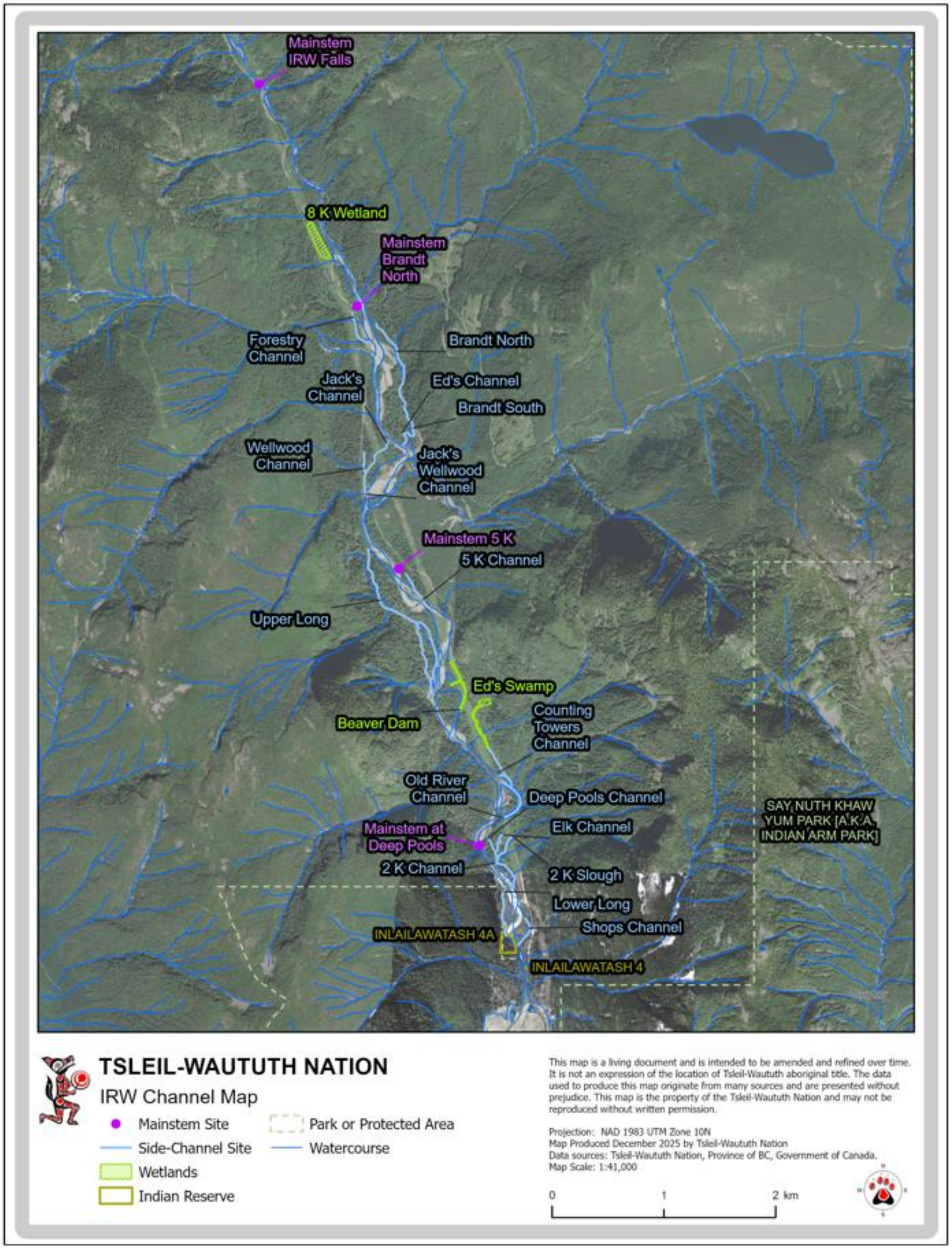

Figure 2: Map of all side-channel and mainstem sites in the Indian River Watershed that had juvenile salmon minnow surveys completed in 2024.

Indian River Integrated Stewardship Plan (IRWISP)

The IRWISP is a watershed-level planning document signed in 2022 that provides a framework for future management direction in the IRW in conjunction with the Province of British Columbia. The plan was 17 years in development, with the original Partnership Agreement signed in 2005 (TWN, n.d.). The IRWISP identifies two key salmonid stewardship goals: restoring watershed integrity through ecological and hydrological health and protecting biodiversity by incorporating its values into all planning and activities. The Salmon Stewardship Management Direction further outlines the objectives of protecting salmon habitat and restoring and enhancing critical habitats within the Salmon Stewardship Area (TWN, 2022). These goals and objectives along with their associated strategies, are being used to guide salmonid stewardship in the IRW.

Burrard Inlet Environmental Science and Stewardship Agreement (BIESSA)

The BIESSA is a Nation-to-Nation Reconciliation Agreement between Canada and TWN, which aims to strengthen coordination and collaboration of science and stewardship activities in Burrard Inlet and the IRW (TWN, 2023). Through the establishment of the BIESSA secretariat, DFO and TWN have been working together on various projects, including environmental monitoring and research in the IRW. This report specifically focuses on data collected using instream temperature loggers deployed throughout the watershed. Other monitoring equipment deployed in the IRW includes depth/temperature loggers, barometric loggers, dissolved oxygen loggers, a rainfall gauge, timelapse cameras, and an automated water sampler to measure suspended sediment, turbidity, and select contaminants (TWN, 2023). The data being collected aids in monitoring the quality of salmonid habitat within the watershed and supplements data collected under the IRMP to gain a fuller understanding of fish and fish habitat in the IRW.

Purpose:

The primary purpose of this report is to provide a comprehensive understanding of juvenile salmonid populations and their habitat in the IRW. Through the inclusion and analysis of multiple datasets collected in 2024, this report aims to provide direction for adaptive management of salmonids in the IRW, including recommendations for restoring and enhancing critical habitat and informing future monitoring as outlined in the Salmonid Stewardship Management Direction section of the IRWISP. Furthermore, it also serves to fulfill the DFO reporting requirements of TWN Scientific License XHAB 46 2024. Understanding how salmonid densities vary among habitat types, what physical features are important, and how temperature influences salmonid distribution and growth will help inform future restoration/preservation priorities and adaptive management in the IRW. As temperatures continue to rise with climate change, cold water refugia and areas better able to buffer warming ambient air temperatures will become increasingly important to maintain resilient salmonid populations into the future.

Methods:

In spring 2024, we conducted juvenile salmon (minnow) trapping at 23 sites (Figure 2), with habitat assessments, flow and temperature data also collected for a subset of these sites (Table 1).

Table 1: Summary of all sites and dates in the Indian River Watershed where minnow trapping was conducted, habitat assessments were completed, and/or had temperature data collected and analyzed in 2024.

Site	Latitude	Longitude	Minnow Survey	Habitat Assessment	Temperature Data
2KChannel	49.481610°	-122.884704°	05-03-2024	N/A	No
2KSlough	49.483660°	-122.885330°	05-01-2024	N/A	Yes
5KChannel	49.504426°	-122.896578°	03-26-2024	07-26-2024	Yes
8KWetland	49.533343°	-122.909196°	03-21-2024	N/A	No
BeaverDam	49.496857°	-122.890628°	03-28-2024	N/A	Yes
Brandt Berm	49.523633°	-122.898667°	N/A	N/A	Yes
BrandtNorth (BrandtUpper)	49.524681°	-122.899861°	04-05-2024	07-24-2024	Yes
BrandtSouth (BrandtRockwall)	49.519696°	-122.897692°	04-05-2024	07-24-2024	Yes
CountingTowerChannel	49.490444°	-122.886858°	04-11-2024	N/A	Yes
DeepPoolsChannel	49.483504°	-122.886963°	05-03-2024	08-07-2024	No
Ed'sChannel	49.516309°	-122.897647°	04-05-2024	N/A	No
Ed'sSwamp	49.495216°	-122.888012°	04-11-2024	N/A	No
ForestryChannel	49.525679°	-122.903806°	04-03-2024	N/A	Yes
JacksChannel	49.514952°	-122.901710°	04-03-2024	N/A	Yes
JackwellwoodChannel	49.512832°	-122.902749°	04-03-2024	N/A	Yes
LowerLong	49.478248°	-122.885566°	04-23-2024	N/A	No
Mainstem4KCorner	49.500733°	-122.892167°	N/A	N/A	Yes
Mainstem5K	49.505706°	-122.898250°	05-10-2024	N/A	Yes
MainstemAboveJacksWellwoo	49.512689°	-122.901892°	N/A	N/A	Yes
MainstematDeepPools	49.483730°	-122.888634°	05-01-2024	N/A	Yes
MainstemBeaverDam	49.494694°	-122.894056°	N/A	N/A	Yes
MainstemBrandtNorth	49.528449°	-122.903692°	05-10-2024	N/A	No
MainstemCountingTowers	49.490700°	-122.888356°	N/A	N/A	Yes
MainstemIRWFalls	49.545149°	-122.915734°	05-10-2024	N/A	No
MainstemLogJam	49.516715°	-122.900289°	N/A	N/A	Yes
MainstemTwinBridges	49.508550°	-122.903017°	N/A	N/A	Yes
OldRiver	49.487151°	-122.883511°	04-23-2024	04-23-2024	Yes
ShopsChannel	49.476682°	-122.882574°	05-03-2024	N/A	No
UpperLong	49.502454°	-122.898218°	04-19-2024	08-16-2024	Yes
WellwoodChannel	49.514706°	-122.902749°	04-03-2024	N/A	Yes

Minnow Trapping

Juvenile minnow trapping was conducted at 23 sites within the IRW (Table 1), including side-channel and mainstem habitat using "gee" minnow traps with ⅛" mesh, baited with approximately 5 g of salmon roe in perforated film canisters (Appendix A, Table A1; BC Ministry of Environment, Lands, Parks [BCMELP], 1997). A total of 377 traps were set over 27 days. The number of traps set per site was standardized to one trap per 24 m of site length. This density of traps was standardized by measuring our longest side-channel site (Upper Long) and dividing it by the maximum number of traps staff could pull from that site in one day with a crew size of three individuals. Traps were placed in areas of slower moving water with cover for fish, including deep pools, woody debris, undercut banks, in vegetation, or under overhanging vegetation. Following a ~24-hour soak, traps were retrieved, and all fish captured were identified by species, enumerated, and a subsample (up to 30 of each species where possible) of fork lengths measured. Fork length was recorded to the nearest 1 mm. After processing, all fish were returned alive to their capture site.

Habitat Assessments:

We completed level 1 habitat assessments at numerous reaches of six side-channels of interest in 2024 (BC MELP, 1997 & BC MELP and DFO, 1996). Side-channels of focus were primarily those that had undergone recent restoration work, or that appeared to have undergone rapid changes in the previous two years as observed by the TWN field crew. Individual reaches were defined as 10 times the average wetted bankfull width (determined by taking and averaging three measurements) or 100 m if the previous value was less than 100 m and being mostly homogenous sections of stream with clear repeating structural characteristics/processes and fish habitat types (BC MELP & DFO, 1996). The exception to these reach lengths occurred within Old River. This site had a large woody debris (LWD) jam installed in July of 2024 immediately upstream of it to attempt to capture more water into the side-channel. To track changes on a fine scale over time, reaches were completed every 100 m for the entirety of the side-channel.

For each reach, a site card was completed (Appendix B, Figure B1). Physical measurements of wetted width, bankfull width, bankfull depth, residual pool depth, and maximum pool depth were recorded using an eslon tape and meter stick. Gradient was measured to the nearest 0.5% using a handheld clinometer. Morphology characterization, habitat quality, cover inventory, feature identification, and water conditions were qualitatively assessed. Water temperature, dissolved oxygen, pH, and conductivity were recorded using a calibrated handheld YSI ProDSS (www.ysi.com). Forestry pins were installed at the north end of each reach to allow for future replication of the surveys.

Flow Data:

We collected flow data in six side-channels using the area-velocity method by measuring stream depth and velocity at ~20 selected intervals at each site (Ahmed & Boyd, 2009). To calculate discharge (m^3/s), an eslon tape stretched across the side-channel was used for distance, and a topset wading rod and flow meter (Hach FH950, www.hach.com) was used to measure water velocity and depth at each interval (Appendix C, Table C1). Elk Channel was the only site where a habitat assessment was completed, but no flow survey was conducted. This was due to discontinuity from the mainstem and a lack of flow within the channel at the time of survey.

Temperature Data:

Between 2022 and 2024, we installed either a HOBO tidbit MX2203 temperature logger or a U20L depth/temperature logger combination logger instream at 21 sites in the IRW which continuously monitored temperatures hourly. Loggers were installed to monitor and describe the fine-scale thermal regimes among sites, and study temperature implications to salmonids, and their habitat use within the watershed. Of the total loggers deployed in the watershed, 14 were deployed in regions with paired minnow trapping (Table 1).

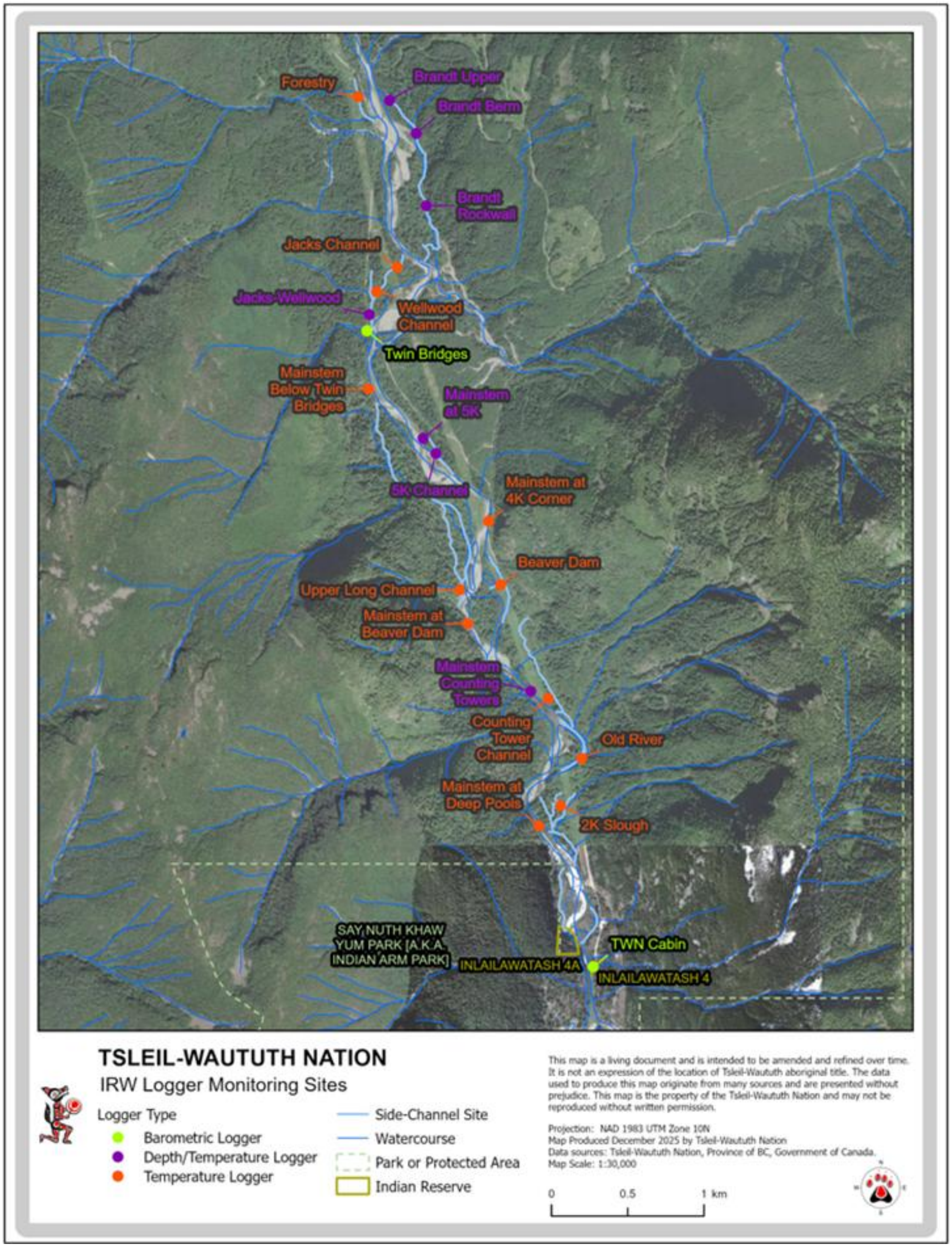

Figure 3: Locations of barometric, temperature, and temperature/depth loggers in the Indian River Watershed. Sites are colored individually based on the logger type deployed.

Data Analysis:
To study specific salmonid habitat uses and abundances, salmonid species data were summarized by site for lengths and by catch-per-unit-effort (CPUE; as fish/trap hour x 100). Therefore, because traps were standardized based on site size, as well as similar soak times, CPUE for this report can also be considered relative abundance to make comparisons among sites. Species of focus for statistical analyses were coho and chum, as other salmonid sample sizes were low, with presence only at a few sites

To compare size distributions among sites, we created boxplots of fish lengths for each species. For the chum length boxplot, eight data points were removed as their fork length measurements were too large to represent juvenile chum instream (≥ 60 mm; Roegner et al, 2016; Healey et al., 1977) and were likely misidentified coho. To summarize changing instream temperatures (°C) and compare thermal profiles among sites, monthly mean temperatures were calculated. Temporal patterns in water temperature were visualized using locally weighted scatterplot smoothing (LOESS) curves as a function of time to reduce short-term variability (i.e. diurnal max/min) and to allow for improved visual comparisons among sites.

To assess the thermal sensitivities, we ran linear models of average weekly water temperatures as a function of weekly air temperatures (from barometric data loggers; Hilderbrand et al., 2014; Kelleher et al., 2012). One mainstem site was removed from these analyses, so we calculated sensitivity at the remaining 20 sites with sufficient temporal data. The slopes of these linear models can be interpreted as how strongly a site responds to ambient air temperatures, while the R^2 informs how much of the variance of the temperatures in-stream was explained by air temperature alone (Mayer, 2012). Prior to building these linear models, we first removed any values where air temperature was below 0 ºC, as the relationship between air and stream temperatures is known to be non-linear below freezing points (Mayer, 2012; Kelleher et al, 2012).

To assess the association between water temperatures at all our sites (°C) and juvenile salmonids, we regressed relative abundance (i.e. CPUE) and fish lengths as a function of mean water temperatures through the spring months leading up to trapping (i.e. March, April). Preliminary data summary of CPUE suggested that mainstem sites stood out as outliers in linear models (driven particularly by the Mainstem at 5K site); therefore, we only assessed the relationships using data from side- and off-channel sites (n = 10). Beaver Dam was an outlier in the chum temperature~length regression (likely mis-identified coho given the large size > 80 mm), so was removed from analyses. Thus, linear models of length as a function of temperature was only possible for chum and coho at 11 and 13 sites, respectively. All statistical analyses were conducted using R version 4.4.2 (R Core Team, 2025; https://www.R-project.org) statistical software.

Results:

Habitat Assessments

Bankfull width varied between sites, with Upper Long (mean = 20.23 ± 6.3 m), Old River (mean = 16.76 ± 5.22 m), and Brandt South (mean = 12.13 ± 3.73 m) having more than twice the standard deviation of average bankfull channel width at 5 K Channel (mean = 6.22 ± 0.67 m), Brandt North (mean = 8.44 ± 0.66 m), Deep Pools Channel (mean = 13.34 ± 1.81 m), and Elk Channel (mean = 5.41 ± 1.25 m; Figure 4, Table 2). Additionally, Upper Long North and Old River had significant variation between their average bankfull widths among reaches of the same site (Figure 5).

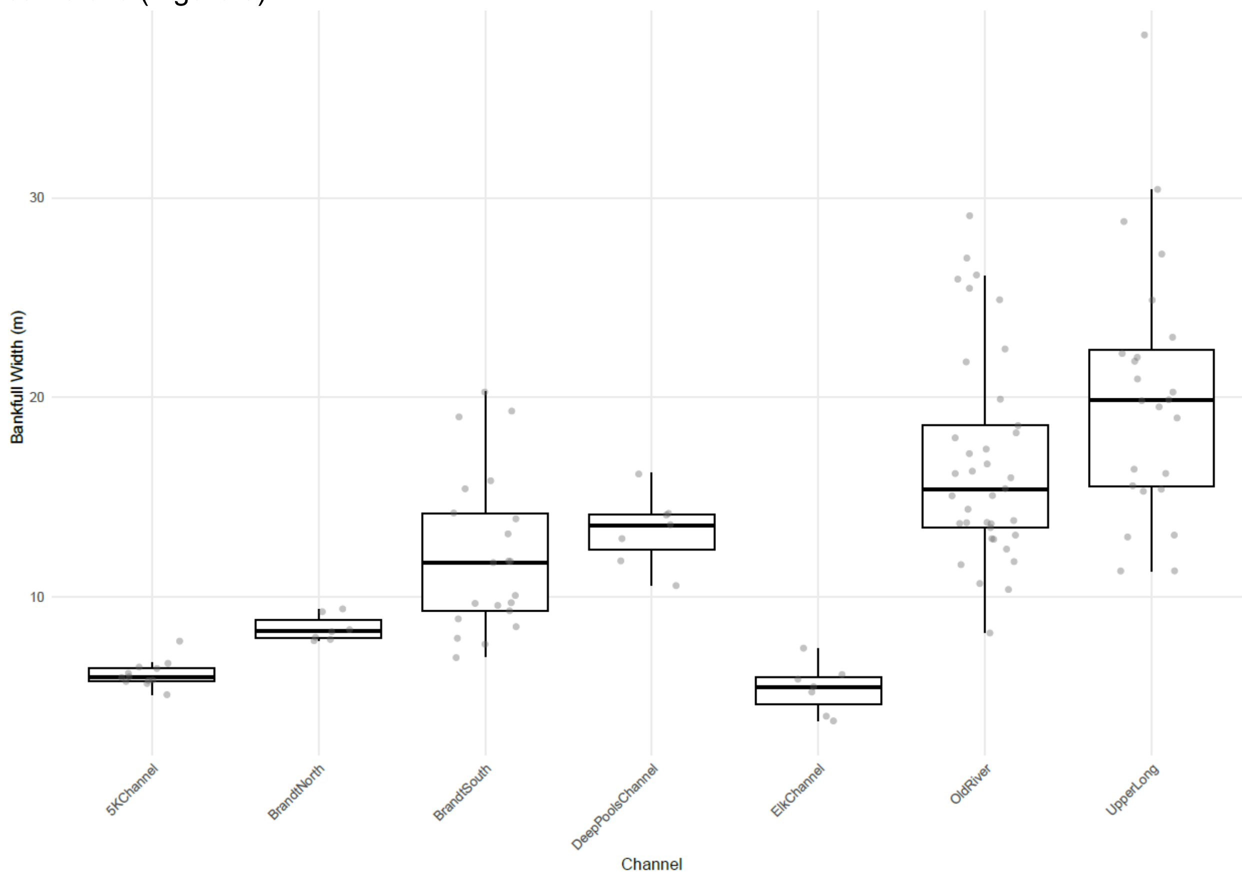

Figure 4: Distribution of bankfull channel widths measured across all transects within each channel in the Indian River Watershed during 2024 habitat assessments. Boxplots summarize individual transect measurements by channel, with boxes representing the interquartile range (25th –75th percentile) and the median shown as a horizontal line. Whiskers extend to 1.5 × the interquartile range, and grey points indicate individual transect measurements.

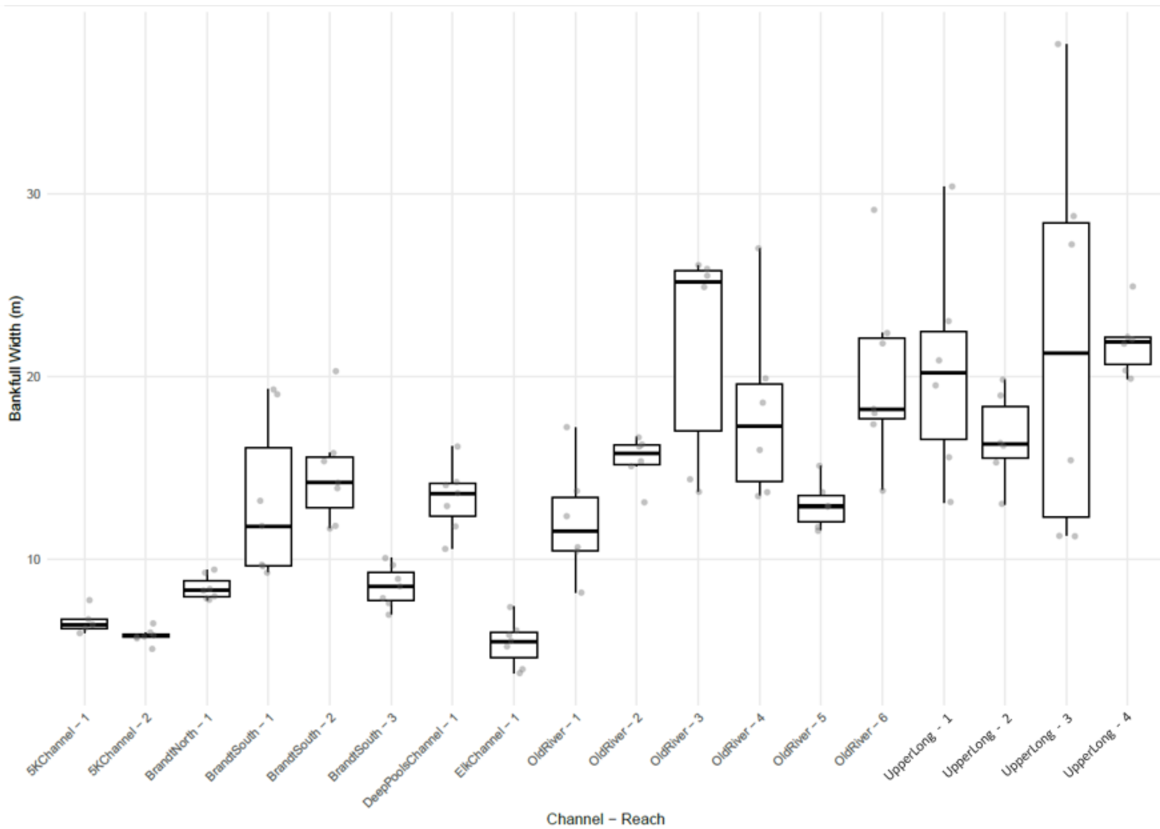

Figure 5: Distribution of bankfull channel widths measured within each channel and individual reach in the Indian River Watershed during 2024 habitat assessments. Boxplots summarize individual transect measurements by channel and reach, with boxes representing the interquartile range (25th –75th percentile) and the median shown as a horizontal line. Whiskers extend to 1.5 × the interquartile range, and grey points indicate individual transect measurements.

For wetted width, Upper Long (mean = 13.57 ± 5.09 m), Deep Pools Channel (mean = 9.30 ± 4.9 m), Old River (mean = 11.13 ± 4.13 m), and Brandt South (mean = 5.76 ± 3.11 m) all had more than twice the standard deviation of wetted width than Elk Channel (mean = 2.81 ±1.21m), 5 K Channel (5.22 ± 0.84 m), and Brandt North (6.77 ± 0.62 m; Figure 6). Additionally, wetted width varied the greatest between reaches in Upper Long and Old River (Figure 7). Additionally, wetted width varied the greatest between reaches in Upper Long and Old River (Figure 7).

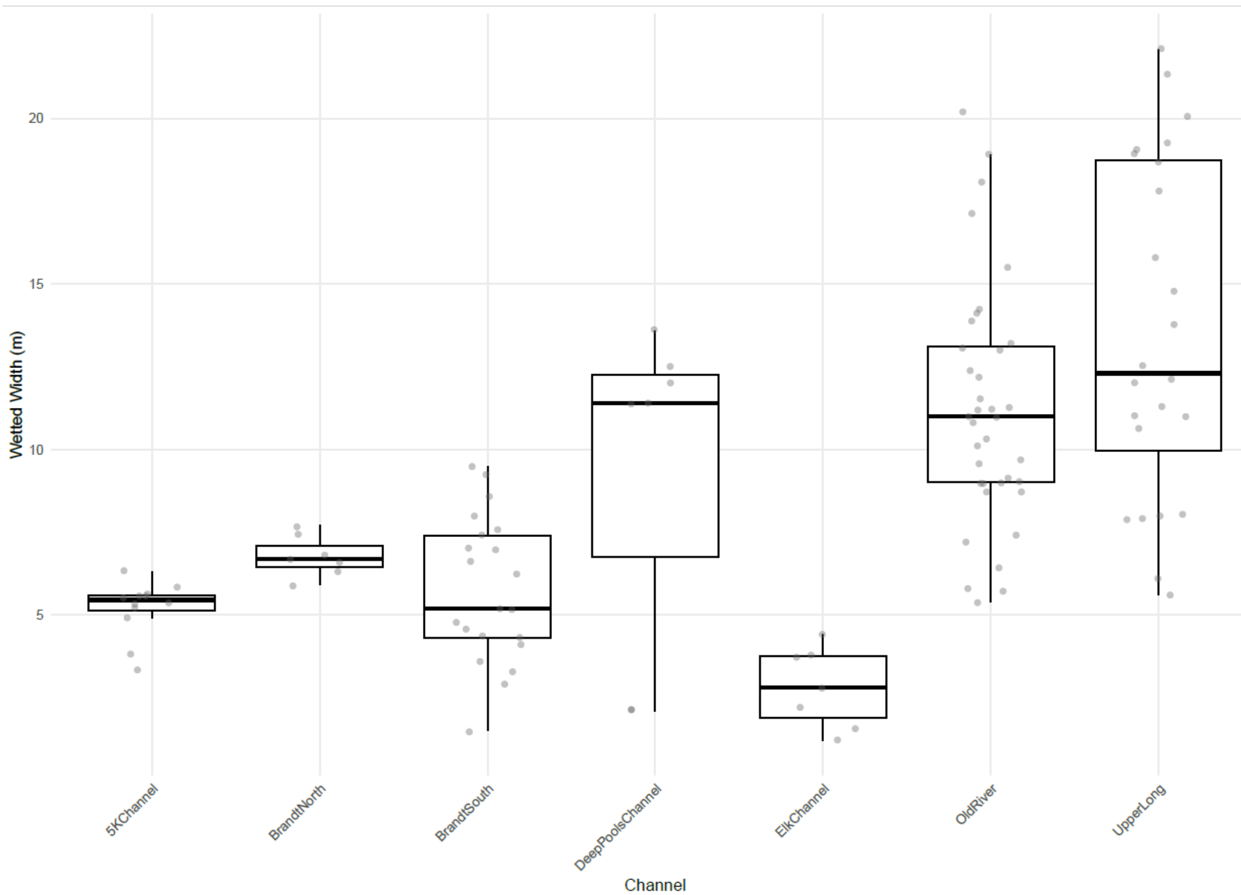

Figure 6: Distribution of wetted channel widths measured across all transects within each channel in the Indian River Watershed during 2024 habitat assessments. Boxplots summarize individual transect measurements by channel, with boxes representing the interquartile range (25th – 75th percentile) and the median shown as a horizontal line. Whiskers extend to 1.5 × the interquartile range, and grey points indicate individual transect measurements.

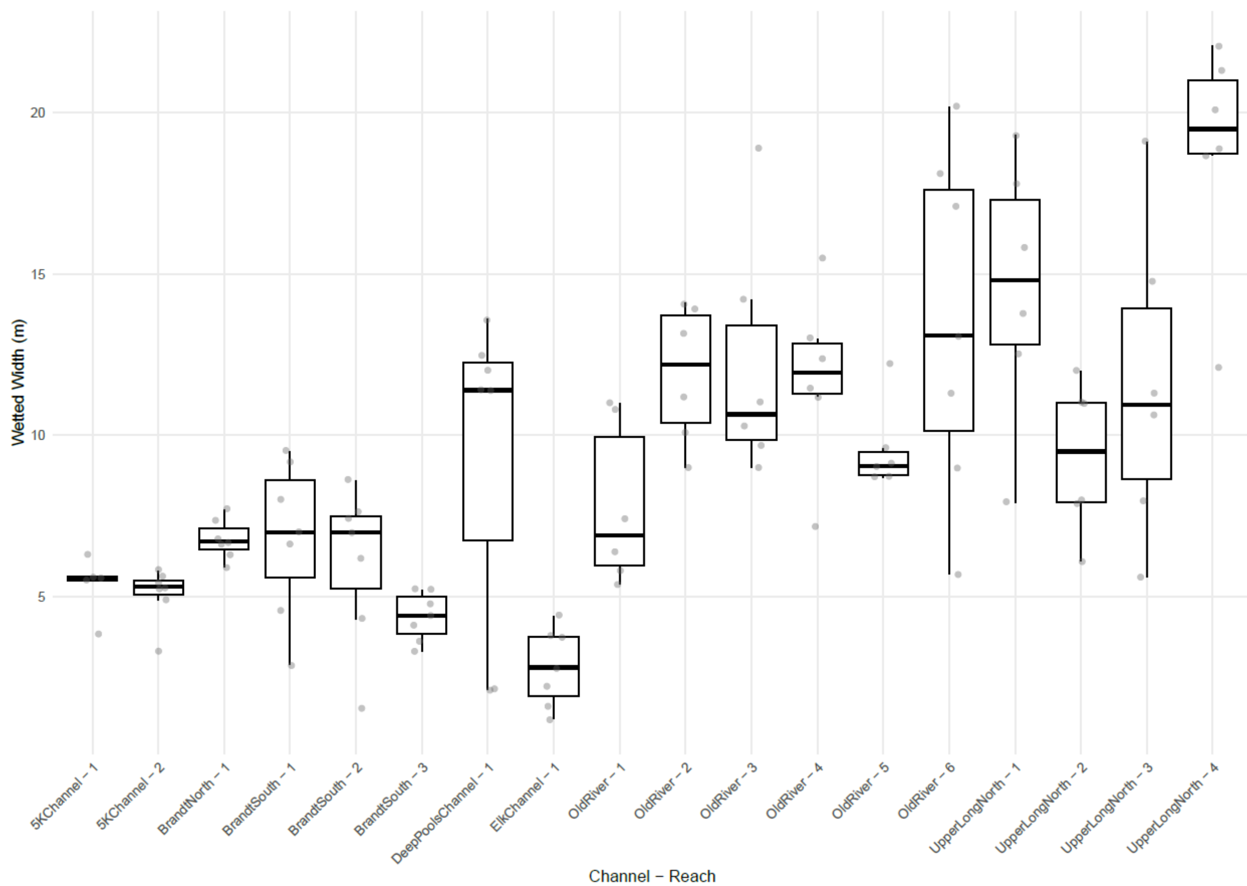

Figure 7: Distribution of wetted channel widths measured within each channel and individual reach in the Indian River Watershed during 2024 habitat assessments. Boxplots summarize individual transect measurements by channel and reach, with boxes representing the interquartile range (25th –75th percentile) and the median shown as a horizontal line. Whiskers extend to 1.5 × the interquartile range, and grey points indicate individual transect measurements.

5 K Channel (Reach 1), Deep Pools Channel, and Elk Channel had a dominant bed material of fines, in contrast, all other reaches had a dominant bed material of gravels. YSI readings during habitat assessments highlighted 5 K Channel as the coldest channel with temperatures of 6.5 °C (Reach 1) and 7.4 °C (Reach 2) differing from all other channels which ranged from 10.2 - 14.8 °C, though measurements were taken across a range of dates (Table 2). Conductivity was also similar across all channels (24.1-29.7 us/cm) except for 5 K Channel (12.9-13.1 us/cm) and Brandt North and South (33.4-38.2 us/cm). Dissolved oxygen ranged between 8.22 and 12.00 mg/L across all channels except for Deep Pools channel, at 4.3 mg/L. The lowest flow sites were 5 K Channel (reach 1; 0.00292 m^3/s), Brandt South (reach 3; 0.0055 m^3/s), Deep Pools Channel (0.02142 m^3/s), 5 K Channel (reach 2; 0.02232 m^3/s), Brandt South (reach 2; 0.03264 m^3/s and reach 1; 0.03296 m^3/s). In contrast, Brandt South had 5 times less flow than Brandt North (0.1582 m^3/s). Flow for all other sites and reaches ranged between 0.13251 – 0.49252 m^3/s (Appendix C, Table C1). The full suite of data collected from habitat assessments is summarized in Appendix B (Table B1); and a subset of the data collected are presented in Table 2.

Table 2: Summary of habitat assessment data collected at seven side-channel sites within the Indian River Watershed during 2024 habitat assessments. *Dissolved oxygen measured in Reach 2 of Old River is an inaccurate reading.

Date Surveyed	Channel	Reach	Mean Bankfull Width (m) (SD)	Mean Wetted Width (m) (SD)	Mean Residual Pool Depth (m) (SD)	Mean Bankfull Riffle Depth(m) (SD)	Crown Closure (%)	Bed Material Dominant/ Subdominant	Temp Celsius	Conductivity	pH	Flow (m^3/sec)	Dissolved Oxygen (mg/L)
2024-07-26	5KChannel	1	6.62 (0.709)	5.36 (0.929)	0.3 (N/A)	0.39 (N/A)	41-70	Fines/Cobble	6.5	12.9	7.74	0.00292	12
2024-07-26	5KChannel	2	5.81 (0.414)	5.07 (0.832)	0.13 (0.058)	0.28 (0.025)	01-20	Gravel/Fines	7.4	13.1	6.53	0.02232	9.04
2024-07-24	BrandtNorth	1	8.44 (0.665)	6.77 (0.616)	0.5 (N/A)	0.50 (N/A)	41-70	Gravel/Cobble	14.6	38.2	6.84	0.15281	8.22
2024-07-25	BrandtSouth	1	13.13 (4.343)	6.83 (0.2402)	0.4 (0.000)	0.50 (0.100)	01-20	Gravel/Cobble	14.4	36.1	6.96	0.032955	10.38
2024-07-24	BrandtSouth	2	14.73 (2.926)	6.09 (2.430)	0.71 (0.566)	0.87 (0.092)	01-20	Gravel/Cobble	13.9	33.4	7.16	0.03264	8.27
2024-07-25	BrandtSouth	3	8.53 (1.124)	4.37 (0.750)	0.6 (0.141)	0.55 (0.071)	01-20	Gravel/Fines	No Data	No Data	No Data	0.0055	No data
2024-08-07	DeepPoolsChannel	1	13.34 (1.809)	9.3 (4.975)	1.35 (0.495)	1.05 (0.495)	41-70	Fines/Gravel	10.2	26.1	6.3	0.02142	4.3
2024-07-18	ElkChannel	1	5.41 (1.246)	2.81 (1.206)	0.63 (0.266)	1.60 (2.081)	41-70	Fines/Fines	14.4	No Data	6.4	No data	No data
2024-08-01	OldRiver	1	12.10 (3.122)	7.8 (2.494)	0.27 (0.115)	0.50 (N/A)	01-20	Gravel/Fines	14.5	24.1	7.81	0.22035	9.32
2024-08-01	OldRiver	2	15.47 (1.303)	11.92 (2.129)	0.4 (N/A)	0.40 (N/A)	01-20	Gravel/Fines	14.8	25.3	6.7	0.27145	95.7%*
2024-08-02	OldRiver	3	21.75 (5.983)	12.18 (3.753)	0.7 (0.424)	0.55 (0.071)	41-70	Gravel/Fines	13.7	25.8	7.9	0.20565	8.45
2024-08-02	OldRiver	4	18.12 (5.502)	11.8 (2.724)	0.9 (0.000)	0.90 (N/A)	41-70	Gravel/Fines	13.8	25.8	7.88	0.1833	9.93
2024-08-06	OldRiver	5	13.00 (1.290)	9.55 (1.340)	0.4 (0.141)	N/A	01-20	Gravel/Fines	12.5	26.3	7.52	0.20835	9.24
2024-08-06	OldRiver	6	20.1 (4.902)	13.5 (5.26)	1.3 (N/A)	0.60 (N/A)	01-20	Gravel/Fines	12.8	25.5	6.82	0.13251	9.08
2024-08-15	UpperLongNorth	1	20.42 (6.069)	14.52 (4.090)	0.87 (0.896)	0.50 (0.200)	21-40	Gravel/Fines	11.9	29.7	6.93	0.4914	9.42
2024-08-15	UpperLongNorth	2	16.62 (2.484)	9.33 (2.322)	0.85 (0.070)	0.70 (0.100)	21-40	Gravel/Fines	13.3	27.7	6.92	0.48306	9.67
2024-08-16	UpperLongNorth	3	22.03 (11.030)	11.57 (4.828)	0.4 (0.000)	0.65 (0.071)	01-20	Gravel/Cobble	11.7	27.2	6.64	0.49252	9.71
2024-08-16	UpperLongNorth	4	21.85 (1.769)	18.87 (3.570)	N/A	N/A	01-20	Gravel/Fines	11.7	24.6	6.84	No data	9.15

Salmonid species and lengths captured at 23 sites during minnow trapping are summarized in Table 3. To divide age classes of coho, age 1+ juvenile coho were identified based on fork lengths > 70 mm, while year 0+ were identified based on fork-length <70 mm, consistent with established Pacific Northwest growth patterns (Hartman and Scrivener, 1990; Bell, 2024). Mainstem IRW Falls had the largest average coho length of 106 ± 11 mm (n = 4). Jackswellwood had the largest average chum length of 40 ± 5 mm (n = 9). Brandt South had the largest average pink length of 32 ± 2 mm (n = 31). Dolly varden (*Salvelinus malma)* were only observed at the Mainstem IRW falls site (n = 6). Cutthroat trout were only caught in 8 K Wetland (n = 54), and Brandt South (n = 1). Rainbow trout were observed in small numbers across the watershed: at Mainstem IRW Falls (n = 3), Mainstem Brandt North (n = 1), Brandt South (n = 1), and 5 K Channel (n = 1). Brandt South had the highest diversity with catches of cutthroat trout (n = 1), rainbow trout (n =1), chum (n = 3), coho (n = 13), and pink (n = 31). Jacks Channel, Upper Long, and Old River were the only three sites with coho, chum, and pink.

Table 3: Summary of length and species for juvenile salmonids caught during minnow surveys in the Indian River Watershed in 2024. Species include coho (*Oncorhynchus kisutch*), chum (*O. keta*), pink (*O. gorbuscha),* rainbow trout (*O. mykiss*; RBT), cutthroat trout (*O. clarkii*; CTT), and dolly varden (*Salvelinus malma*; DV).

Channel	Species	Measured Count	Mean Length (mm)	SD Length	Minimum Length (mm)	Maximum Length (mm)
2KChannel	coho	24	46	22	32	115
2KSlough	coho	15	85	19	41	135
5KChannel	RBT	1	32	N/A	32	32
5KChannel	chum	26	37	4	31	49
5KChannel	coho	8	83	19	39	97
8KWetland	CTT	54	110	23	56	144
8KWetland	coho	64	93	10	71	118
BeaverDam	coho	67	87	12	57	150
BrandtNorth	chum	5	35	3	32	38
BrandtNorth	coho	28	63	13	33	86
BrandtSouth	CTT	1	77	N/A	77	77
BrandtSouth	RBT	1	82	N/A	82	82
BrandtSouth	chum	33	37	3	30	42
BrandtSouth	coho	13	60	19	34	94
BrandtSouth	pink	31	32	2	29	36
CountingTowerChannel	chum	3	35	1	34	36
CountingTowerChannel	coho	62	53	23	29	115
DeepPoolsChannel	coho	18	66	24	34	93
Ed'sChannel	chum	3	30	3	28	34
Ed'sChannel	coho	15	61	6	53	75
Ed'sSwamp	coho	59	87	9	61	103
ForestryChannel	chum	1	36	N/A	36	36
ForestryChannel	coho	23	83	17	50	125
JacksChannel	chum	16	37	3	33	45
JacksChannel	coho	9	44	28	27	95
JacksChannel	pink	1	27	N/A	27	27
JackwellwoodChannel	chum	9	40	5	32	47
JackwellwoodChannel	coho	1	69	N/A	69	69
LowerLong	coho	30	91	14	35	118
Mainstem5K	coho	30	34	2	31	42
MainstemBrandtNorth	RBT	1	79	N/A	79	79
MainstemBrandtNorth	coho	2	99	6	95	103
MainstemIRWFalls	DV	6	94	8	85	105
MainstemIRWFalls	RBT	3	120	27	94	147
MainstemIRWFalls	coho	4	106	11	90	113
MainstematDeepPools	chum	2	33	1	32	33
MainstematDeepPools	coho	5	34	2	32	36
OldRiver	chum	32	31	4	24	38
OldRiver	coho	1	85	N/A	85	85
OldRiver	pink	6	31	2	28	34
ShopsChannel	coho	12	60	28	35	100
UpperLong	chum	39	36	3	25	41
UpperLong	coho	115	54	27	29	118
UpperLong	pink	26	32	2	28	35
WellwoodChannel	chum	4	32	5	25	35

Average coho lengths across all sites was 70 ± 26 mm (n = 575). The largest mean size of 106 ± 11 mm (n = 4) was at the Mainstem IRW Falls site. Mainstem at Deep Pools had the smallest mean size of 34 ± 2 mm (n = 5). Mainstem at 5 K only had year 0 + coho (mean = 34 ± 2 mm, n = 30) (Figure 8). 8 K Wetland, Mainstem Brandt North, Mainstem IRW Falls, and Old River all had only year 1 + coho. In contrast, all other sites had both age classes.

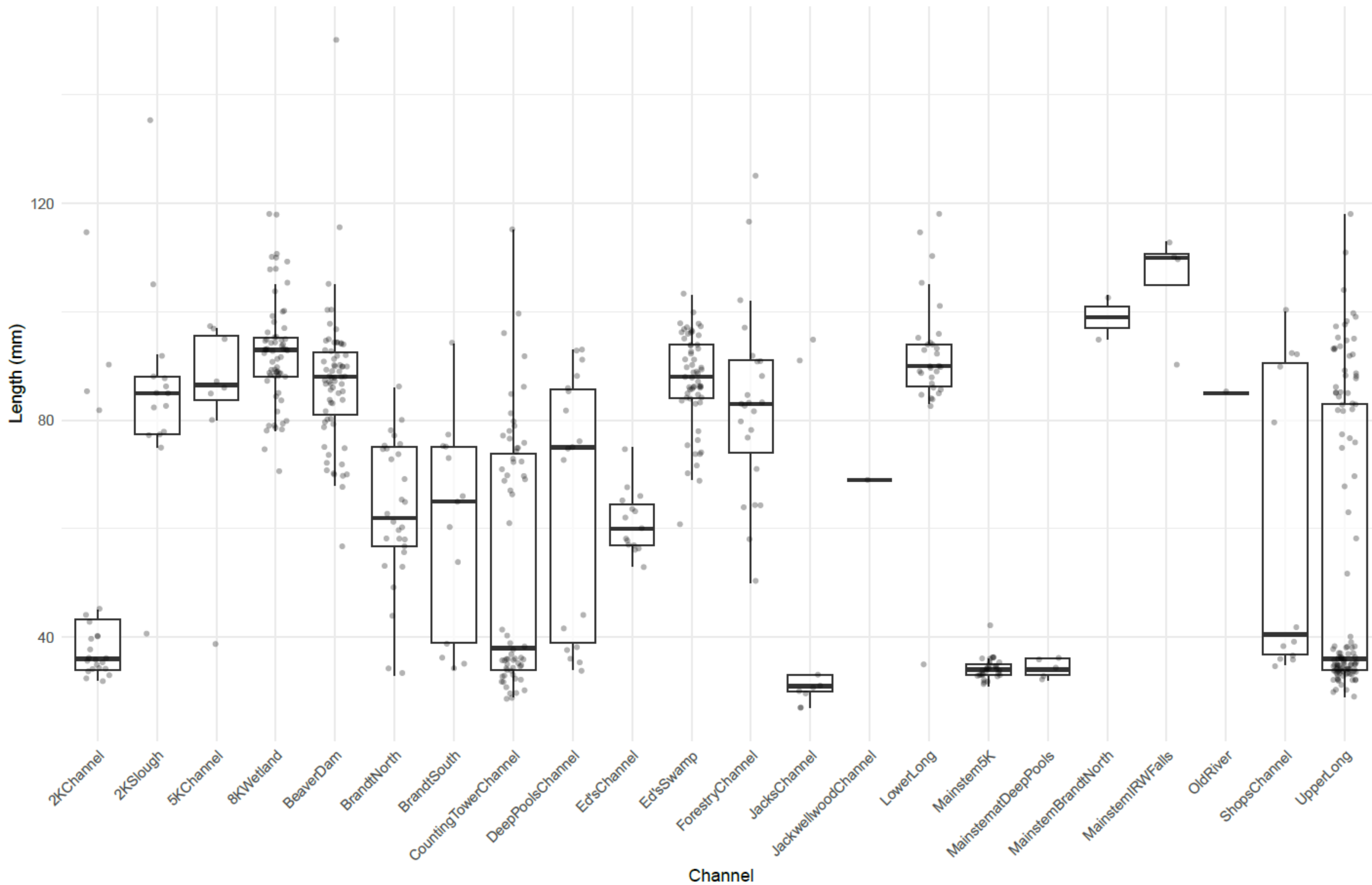

Figure 8: Distribution of juvenile coho fork-lengths (mm) for each site surveyed in the Indian River Watershed in 2024. Boxplots summarize coho lengths for each channel, with boxes representing the interquartile range (25th –75th percentile) and the median shown as a horizontal line. Whiskers extend to 1.5 × the interquartile range, and grey points indicate individual fish measured from 22 minnow trapped sites in the IRW.

Mean chum lengths across all sites was 35 ± 4 mm (n = 173). The smallest mean chum length was 30 ± 3 mm in Ed's Channel (n = 3), and the largest mean chum length was 40-± 5 mm (n = 9) in Jackswellwood Channel (Figure 9).

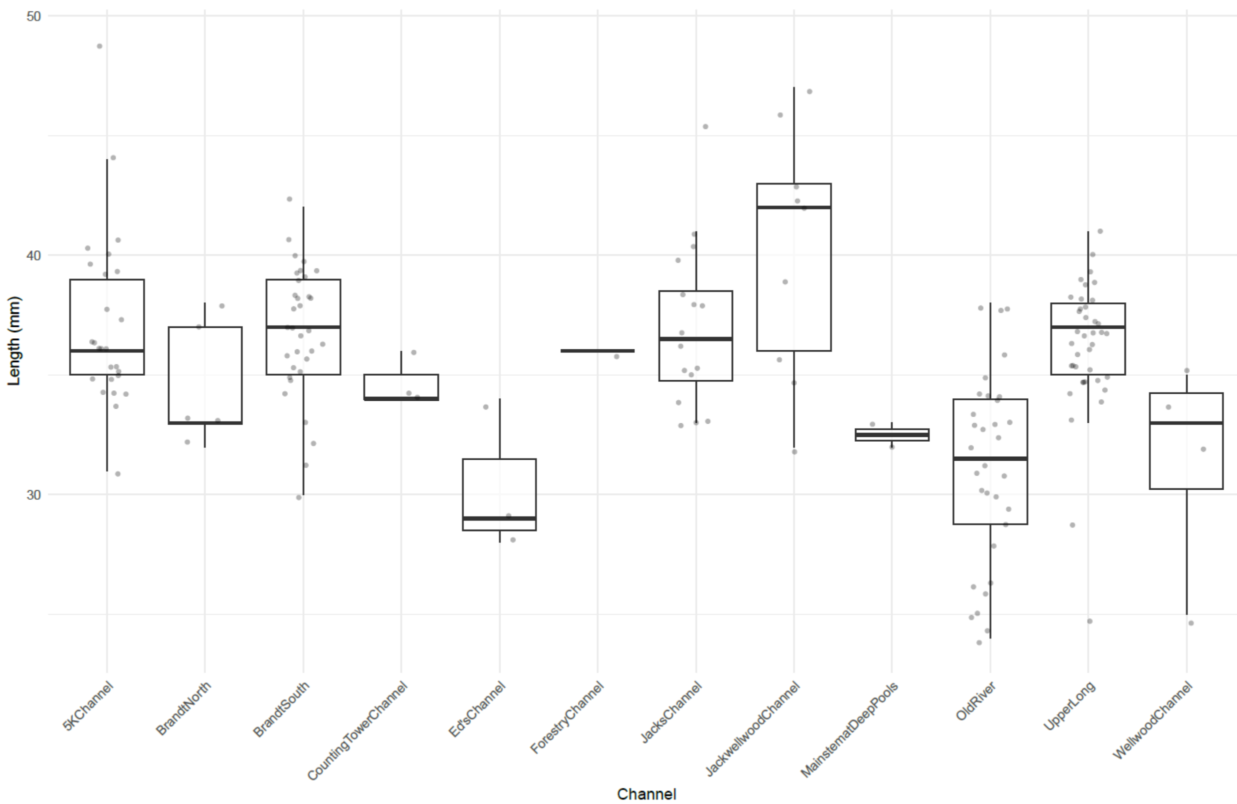

Figure 9: Distribution of juvenile chum fork-lengths (mm) for each site surveyed in the Indian River Watershed in 2024. Boxplots summarize chum lengths for each channel, with boxes representing the interquartile range (25th – 75th percentile) and the median shown as a horizontal line. Whiskers extend to 1.5 × the interquartile range, and grey points indicate individual fish measured.

Coho were caught in 22 of 23 sites (96%), and chum were caught at 12 of 23 sites (52%). Mean coho relative abundance (or CPUE: fish/trap/hour*100) across all sites was 10 ± 12 (n = 22). Coho were caught in all sites except Wellwood, with the lowest relative abundance being 0.2 in Old River, and the highest relative abundance being 53 at the Mainstem at 5 K. Average chum relative abundance across sites where chum were caught was 5 ± 57 (n = 12). Chum were not caught in 2 K Channel, 2 K Slough, 8 K Wetland, Beaver Dam, Deep Pools Channel, Ed's Swamp, Lower Long, Mainstem at 5 K, Mainstem Brandt North, Mainstem IRW Falls, and Shops Channel. The lowest relative abundance where chum were caught was 3 in Forestry Channel, and the highest relative abundance was 206 in Brandt South (Figure 10).

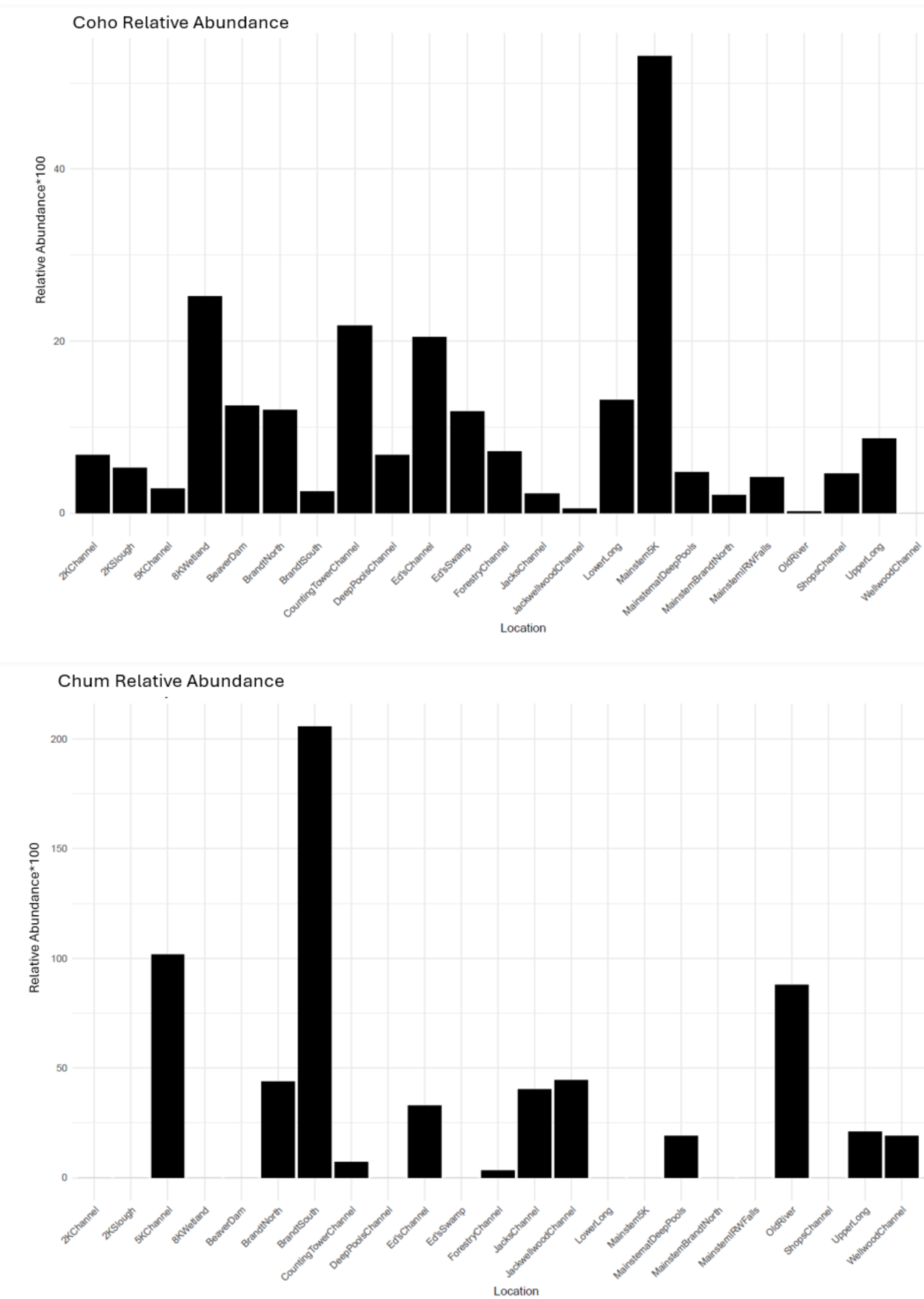

Figure 10: Bar plots for relative abundance (or CPUE; fish/trap/hourx100) for coho (top) and chum (bottom) salmon for 23 minnow trapped sites in 2024 in the Indian River Watershed.

When comparing thermal profiles among sites in the IRW, 5 K Channel maintained the most consistent temperature year-round of all the sites, while Beaver Dam had the greatest variation in temperature (Figure 11). Beaver Dam was the warmest site for most of the year, whereas Wellwood Channel was the coolest site for most of the year. For most sites, the lowest temperatures were in the second half of January. The exceptions to this occurred with Wellwood Channel and Jackswellwood (lowest temperatures in early May), and 5 K Channel (early July). The mainstem had little variation in their temperatures throughout the year among sites in contrast to side-channels which exhibited more variability among sites. Temperature differences among sites were greatest during the spring and summer (~May through August), with the lowest in the winter (though data were incomplete through Nov and Dec). The highest instream temperatures occurred between July and the end of October, with the exceptions being those suspected of having higher groundwater influence, including 5 K Channel (highest temperatures in January and March), Wellwood Channel (September to October), and Jackswellwood (October).

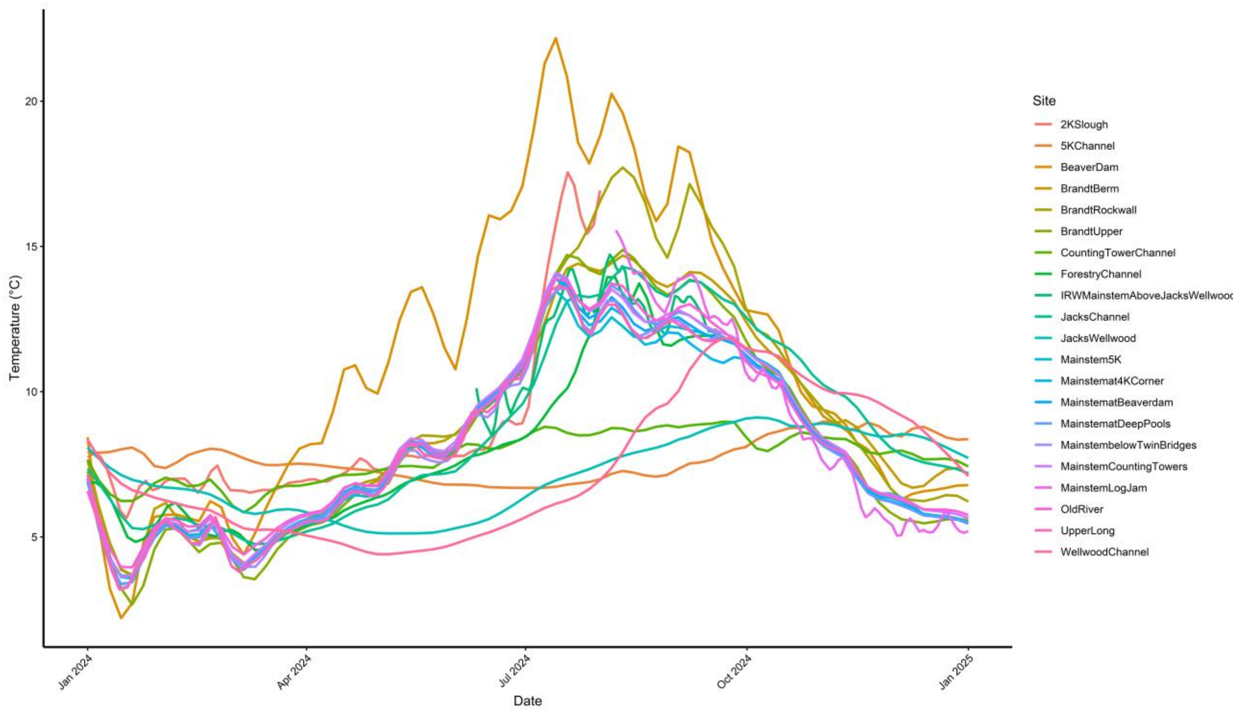

Figure 11: Temperature trends (°C) across 21 sites in the Indian River Watershed across 2024. Data were fit with a locally-weighted regression (LOESS) smoothing function to remove some of the daily diurnal 'noise' in the data to improve visual comparisons among groups.

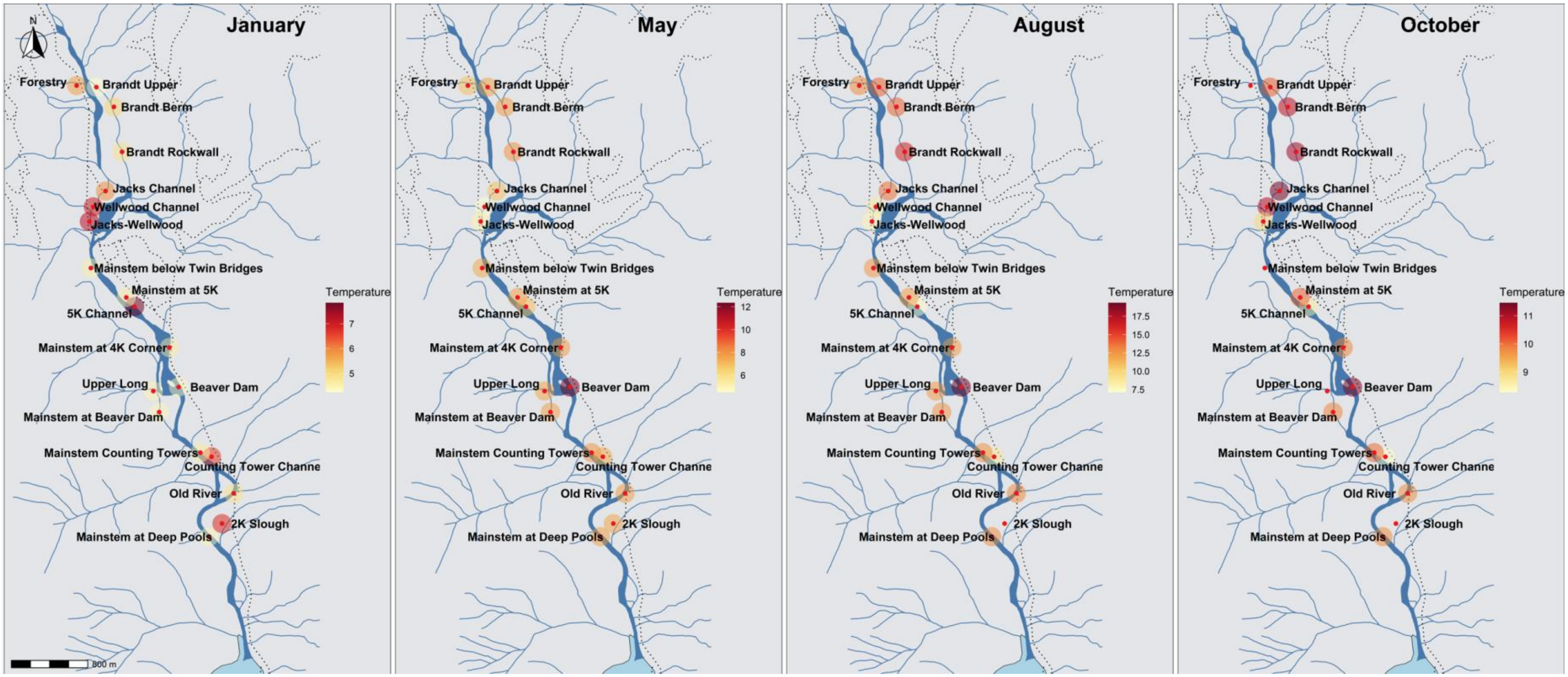

Figure 12: Thermal heatmaps for 19 sites within the Indian River Watershed across four representative months from each season (January = Winter, May = Spring, August = Summer, October = Fall), highlighting fine-scale and intra-annual variance in thermal profiles among sites in 2024. Points represent locations where a data logger was deployed, with colored circles highlighting monthly average temperatures for each site (darker = warmer; lighter = cooler). Blue lines depict the river or tributaries, and dashed lines indicate roads. Sites with a point but no shaded circle indicate missing data.

The mean slope from thermal sensitivity models across all sites was 0.39 ± 0.23 (Table 4). The highest sensitivity site (i.e. where water temperature was most affected by air temperature) was Beaver Dam (slope = 0.85, R^2 = 0.88), with the lowest sensitivity sites being 5 K Channel (slope = -0.06, R^2 = 0.05), Wellwood Channel (slope = -0.01, R^2 = 0.00), and Jackswellwood (slope = 0.05, R^2 = 0.03) where water temperature showed essentially no relationship to air temperature (Figure 13; Table 4).

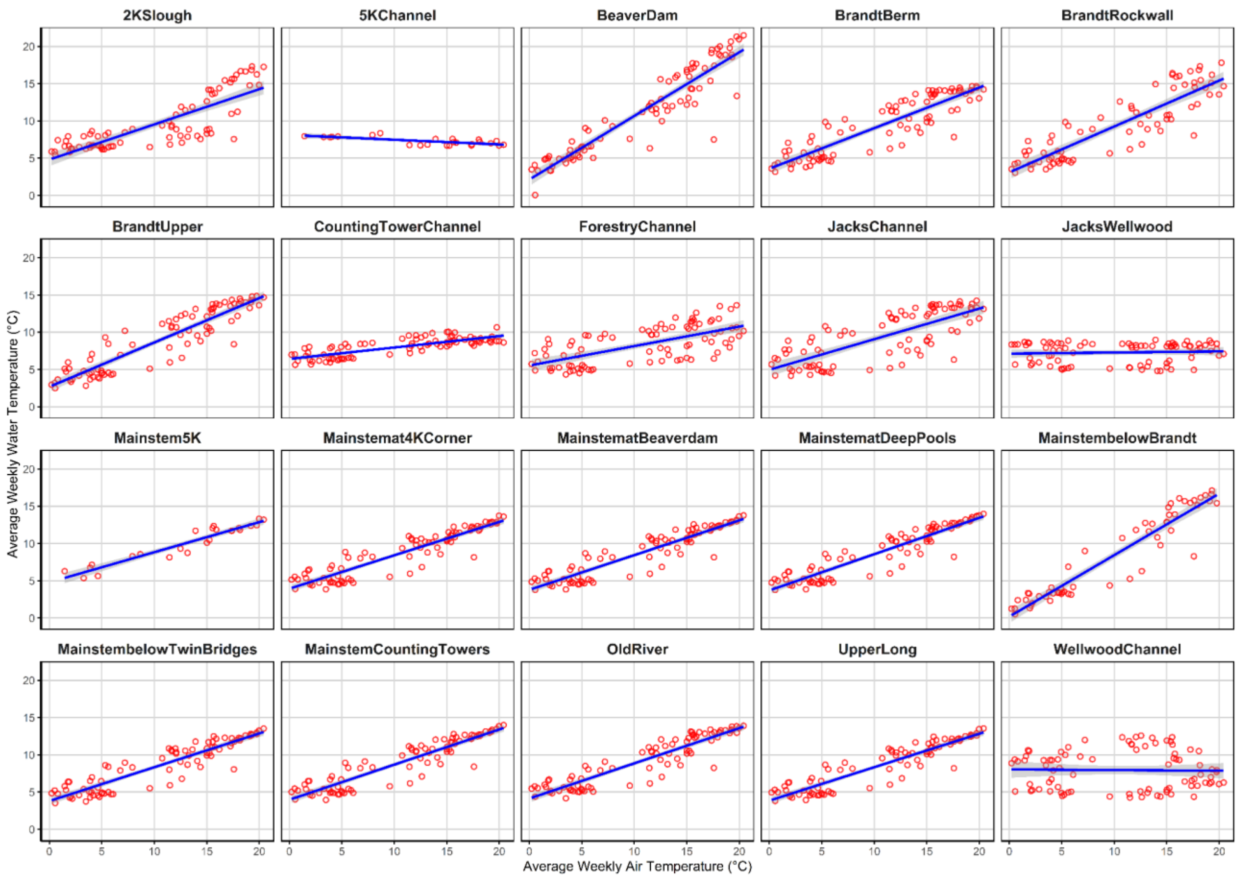

Figure 13: Thermal sensitivity for 20 of the sites within the Indian River Watershed calculated using linear regression to analyze the relationship between weekly mean air and water temperatures (°C). Sensitivity is quantified by the slope of the model, with fit assessed using R-squared (R^2; summarized in Table 4).

Table 4: Thermal sensitivity regression model slopes and corresponding R-squared (R^2) for 20 sites within the Indian River Watershed.

Site	Sensitivity (model slope)	R-Squared
2KSlough	0.47	0.68
5KChannel	-0.06	0.50
BeaverDam	0.85	0.88
BrandtBerm	0.54	0.80
BrandtRockwall	0.62	0.78
BrandtUpper	0.60	0.84
CountingTowerChannel	0.15	0.62
ForestryChannel	0.26	0.43
JacksChannel	0.41	0.59
JacksWellwood	0.01	0.00
Mainstem5K	0.40	0.91
MainstemCountingTowers	0.47	0.86
MainstemDeepPools	0.26	0.83
Mainstemat4KCorner	0.45	0.85
MainstematBeaverdam	0.47	0.86
MainstematDeepPools	0.49	0.87
MainstembelowTwinBridges	0.45	0.84
OldRiver	0.47	0.85
UpperLong	0.45	0.86
WellwoodChannel	-0.01	0.00

When assessing fish size as a function of temperatures, we found significant relationships between chum ($p = 0.043$, $R^2 = 0.31$) and coho ($p = 0.047$, $R^2 = 0.25$) lengths (mm) relative to average water temperature (°C) in March (Figure 14), but not for April (coho: $p = 0.126$, $R^2 = 0.20$; chum: $p = 0.196$, $R^2 = 0.16$).

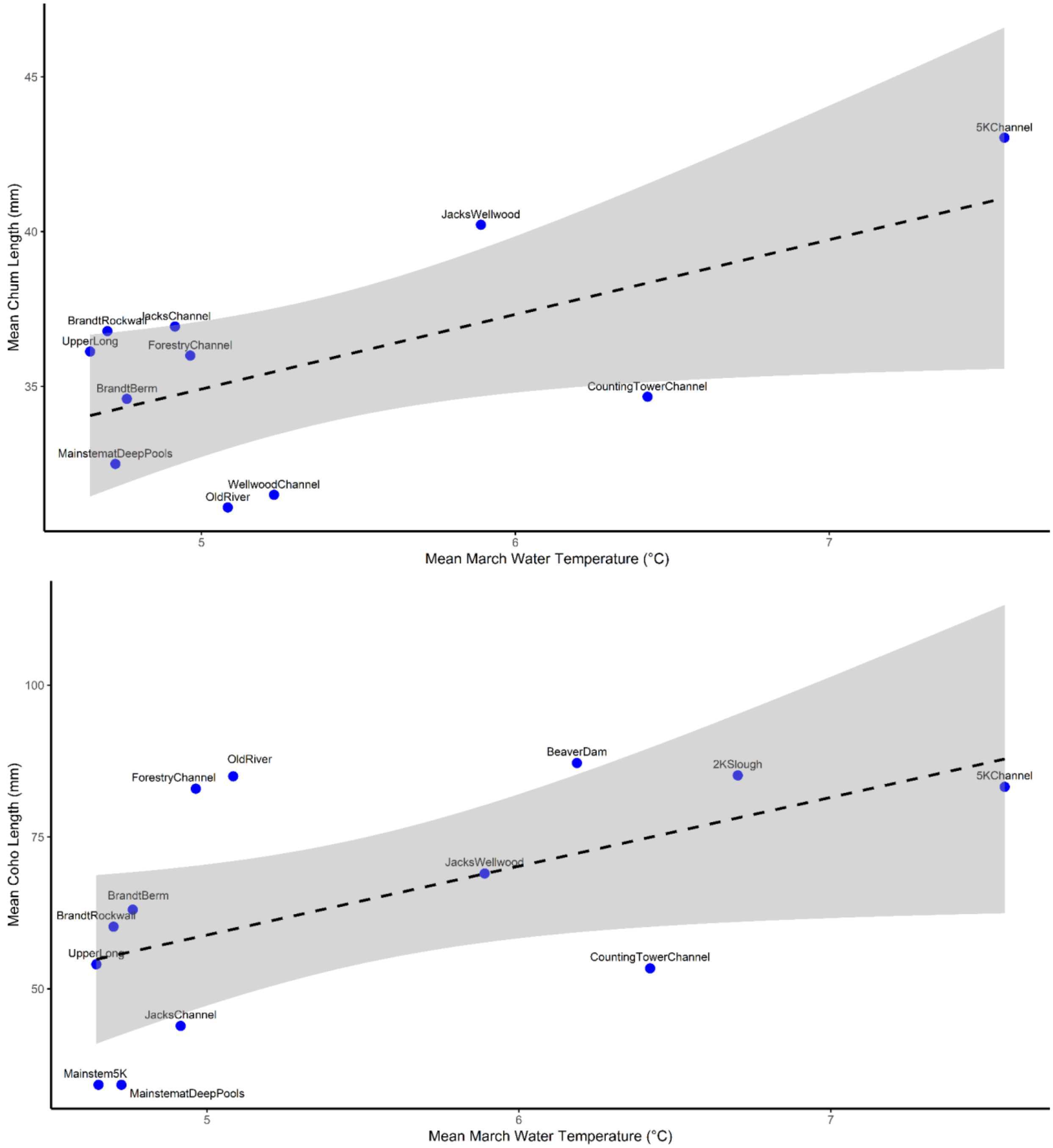

Figure 14: Relationships between average chum (top) and coho (bottom) fork-lengths (mm) in 2024 as a function of mean water temperature (°C) in March across several minnow trapping sites where fish were captured in the Indian River Watershed using linear regression. Dashed line is the model fit, while the 95% confidence intervals are shown as the grey shaded region for each species.

A significant relationship between coho relative abundance and mean water temperatures (°C) was observed in April (Figure 15), with higher coho relative abundance in warmer channels ($p = 0.047$, $R^2 = 0.35$). No significant relationship between chum relative abundance and mean water temperature was observed in April ($p = 0.422$; $R^2 = 0.07$).

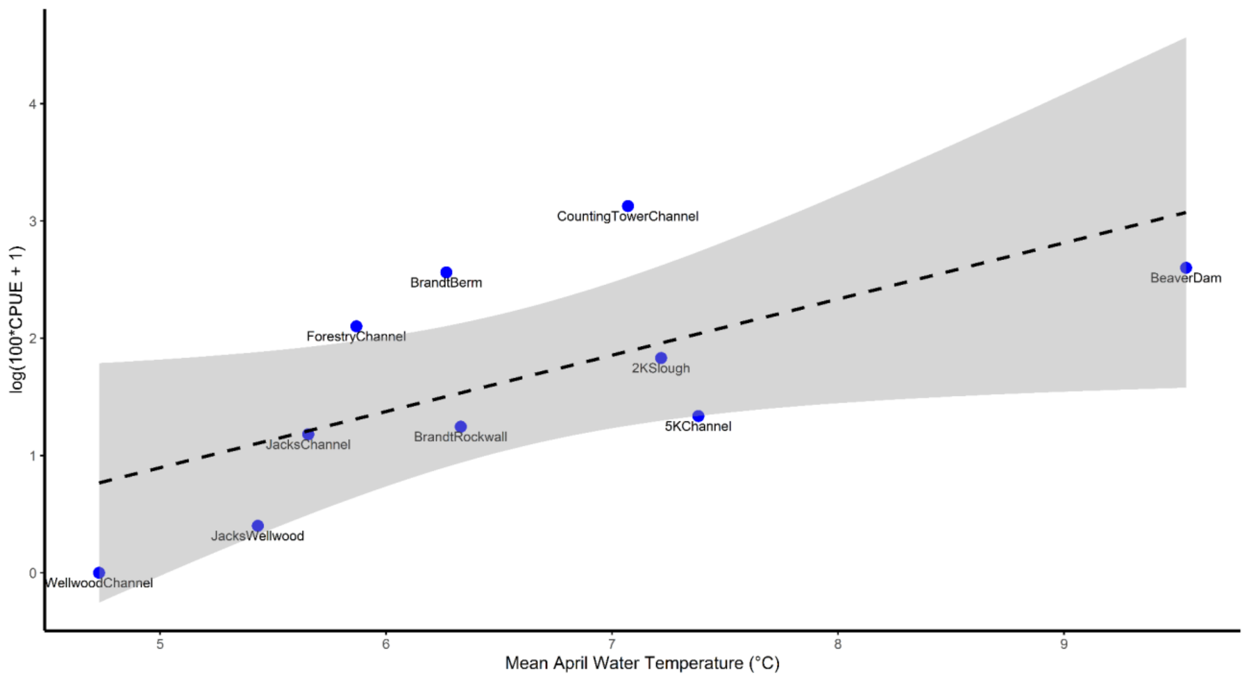

Figure 15: Relationship between relative abundance (CPUE) for coho compared to mean water temperature (°C) in April 2024 across several off-mainstem sites in the Indian River Watershed using linear regression including 95 % confidence intervals. Dashed line is the model fit, while the 95% confidence intervals are shown as the grey shaded region.

Discussion:

This report is the first to integrate multiple datasets from within the IRW to gain a greater understanding of current physical and environmental conditions, and study the implications for salmonids within the watershed. For past surveys, habitat data were only collected to monitor channel changes, and minnow data were collected to supplement spawner data. Our 2024 monitoring work in the IRW included physical assessments of fish habitat, measurements of water quality and chemistry, juvenile salmonid surveys to determine sizes and distribution, and paired temperature data collection at multiple sites. Juvenile salmonid surveys were completed at 23 sites, temperature trends were outlined for 21 sites, thermal sensitivity was modelled for 20 sites, habitat assessments and water quality and chemistry were completed in seven side-channel sites, and discharge calculations were completed for six of those sites. Furthermore, juvenile fish data were put in context with thermal metrics to gain some insight into how temperatures are influencing salmonids (e.g. growth, habitat use) in the early spring. Below, we summarize the findings from each aspect of this work, put it in context with literature, and make specific recommendations for improved monitoring, management, and future restoration works activities.

Temperature

Instream temperature monitoring began in 2022 in the IRW, allowing for the observation of hourly year-round temperatures at a fine-scale (i.e. temporally and geographically). Summarized data from 2024 suggest that highest instream temperatures occurred between July and the end of October (at most sites due to the influence of higher ambient air temperatures) and typically remained below levels thought to be of thermal concern for most species of salmonid (~20 °C; Jonsson, 2023). In contrast, the lowest instream temperatures were in the second half of January (when ambient air temperatures are at their coolest). These low instream January temperatures (below < 4 – 5°C) may slow egg development and delay emergence (Sandercock, 1991; McCullough, 1999), while the increase of instream temperature in February (>5°C) provided the optimal instream temperature for egg incubation (5 - 12°C; U.S. Environmental Protection Agency [EPA], 2001a; British Columbia Ministry of Environment and Climate Change Strategy [BCMOECCS], 2023). Optimal juvenile salmonid growth occurs between 10–15 °C (BCMOECCS, 2023), with all sites except Beaver Dam below this range until June. Up until this time, salmonids will exhibit lower metabolism and food consumption, leading to slower growth rates (McCullough, 1999). In contrast, salmonids (specifically coho) within Beaver Dam had two more months of optimal growth conditions than all other sites, as this site reached 10°C in early April. Beaver Dam was also the only site to reach temperatures that would be considered of thermal concern for salmonids (>20 °C in July and August; Jonsson, 2023). Overall, all sites within the IRW were near or within the generally accepted temperature range for salmonids of all life stages year-round (5–17 °C; McCullough 1999; U.S. EPA, 2001a)

These data have also helped highlight which areas within the watershed are composed of higher proportions of groundwater versus surface water and may thus be important habitat for thermal refugia. For example, for several sites we observed the coolest temperatures occurring in May (Wellwood Channel and Jackswellwood) and July (5 K Channel) and tended to show relatively stable temperatures throughout the year. Furthermore, thermal sensitivity was lowest at these sites, showing almost no linear relationship between ambient air temperature and water temperature, likely indicating a significant influence by groundwater at these sites. These low summer temperatures in groundwater-fed side-channels are likely due to snowmelt travelling through the subsurface before entering the channels (Sheibley et al., 2024) which can buffer instream temperature fluctuations from changes to ambient air temperature (Caissie, 2006; Fisher et al., 2007; Kiffney et al., 2003; Kaandorp et al., 2019). 5 K Channel also had significant shade cover (41-70% crown closure) in Reach 1, further buffering temperatures by reducing UV exposure.

Thermal sensitivities elsewhere varied greatly, representing a range of water temperature responses to air temperature across a relatively fine geographic scale. Thermal sensitivity was highest in the off-channel Beaver Dam site, likely due to the standing-water nature and lack of shading via crown closure at this site (right under a hydro line 'right of way' where vegetation is routinely cleared), which allows for more direct sunlight, and thus heating potential (U.S. EPA, 2001b). Low-growing vegetation that doesn't require clearing and could overhang the channel could be planted in future to increase riparian shading at this site. Similar physical and thermal conditions are found in 8 K Wetland and Ed's Swamp, which are also likely not influenced by the cooling effects of groundwater. In contrast to the more groundwater-dominated sites, these low-flow, off-channel 'wetland-type' habitats were dominated by year 1+ coho.
While we didn't see a positive relationship in all models of fish size and abundance with respect to temperature, we observed significant positive relationships between water temperature and

chum and coho lengths in March, and between water temperature and coho relative abundances in April. Juvenile coho can be strongly associated with wetland habitat and exhibit larger body sizes and quicker growth relative to fish rearing in mainstem and tributary habitats as a result of warmer spring temperatures, increased prey availability, and the low-velocity refuge conditions found in these sites (Lusardi et al., 2019). Additionally, juvenile coho rearing in off-channel ponds tend to be larger than those overwintering in small groundwater channels and runoff tributaries (Lestelle, 2007), similar to what was seen in the present study. Previous studies have also found that juvenile coho are most abundant in beaver pond habitats during winter (Nickelsonet al., 1992), with 8 K Wetland, Beaver Dam, and Ed's Swamp all being influenced by beaver activity. Larger salmonid body sizes and higher coho relative abundance in warmer channels suggest increased food availability and more favorable rearing conditions, reinforcing the importance of off-channel wetland habitats for juvenile coho rearing, growth, and abundance (Lusardi et al., 2019).

Jackswellwood is fed by both Jacks Channel and Wellwood Channel, with Wellwood contributing to cooler and more stable water temperatures. However, minnow trapping results from Wellwood and Jackswellwood Channels showed little or no use by juvenile coho. Wellwood Channel is the coldest site year-round, only exceeding 10°C after September (Figure 7). These profiles are lower than optimal rearing temperatures for coho juveniles (~10-15°C; Richter & Kolmes, 2005), and may be resulting in coho leaving to find warmer temperatures elsewhere in the watershed. The persistently low temperatures may explain the limited use of Wellwood, as well as the reduced use of Jackswellwood due to the thermal influence of Wellwood.

While juvenile coho may not be present in these channels during the spring, these cooler groundwater influenced habitat can provide important thermal stability for the watershed, and may still be acting as thermal refugia for juvenile salmonids and other life-stages (e.g. adult spawners) at other times of the year. This is further supported by the observation that all three of these channels support the highest densities of chum spawners in the IRW year after year. These important groundwater and upwelling zones provide conditions that are unique from mainstem flow, likely contributing to the observed use of these habitats by spawning chum. Groundwater fed and upwelling sites are often preferred spawning areas for chum due to the cool, stable thermal regimes and good intragravel exchange, which enhance egg survival and development (Geist et al., 2002; Burril et al., 2010). Instream temperatures in these channels from October through February ranged between approximately 5 – 10 °C, which is within the optimal range for salmonid egg incubation (U.S. EPA, 2001a; BCMOECCS, 2023). To further assess whether instream conditions at these sites are influencing egg survivability, egg survival studies are recommended within these channels.

Together, the lack of use by juvenile coho and the high use by spawning chum highlight a trade-off among habitat types, where cooler groundwater-fed channels may be suboptimal for juvenile coho growth, but provide ideal conditions for spawning and thermal refuge. These findings showcase the importance of preserving groundwater fed habitats in a warming climate, while also highlighting the importance of having varied habitat types to meet the needs of all salmonid life stages.

<u>LWD and Salmonid Use</u>

The Mainstem at 5 K had the highest relative abundance of coho, more than double that of all other sites. It was also an outlier with the temperature-relative abundance relationship trend, as it was a cooler site with high relative abundance. The unexpectedly high concentration of coho at this site may be a result of several naturally deposited LWD structures found here. These structures have scoured out several deep pools, which have provided cover and refugia for juvenile coho (Giannico, 2000). Additionally, organic material in these structures can increase the availability of food for juvenile coho (Nielsen 1992).

Due to past historic intensive logging practices in the IRW, there is a shortage of these LWD structures within the mainstem. The mainstem Indian River has extensive unvegetated gravel bars, long and straight riffles and glides, extensive bank erosion, and low pool frequency. Additionally, the IRW has been impacted by two severe drought events in the summers of 2023 and 2024, during which a ~100m section of the mainstem dried up when flows went subsurface. Rivers with low volumes of LWD typically exhibit simplified channel morphology, reduced pool frequency and sediment storage, and altered sediment movement and hydraulics (Lininger & Hilton, 2022; Mellina & Hinch, 2009). LWD plays a critical role in moderating stream hydrology by increasing hydraulic roughness and enhancing the retention of water and sediment within stream channels, thereby slowing conveyance and promoting flow heterogeneity. Gurnell et al. (2002) demonstrated that LWD is a key control on channel hydraulics and form, influencing how water moves through the channel and how sediment is routed and stored. Stable accumulations of LWD can impound flow, raise bed-surface elevation, and increase water retention within channels, reinforcing its role in shaping channel morphology and hydraulic processes (Gurnell et al., 2002; Bisson et al., 1987). According to the U.S. National Marine Fisheries Service (n.d.), LWD depletion after logging can persist for centuries, while Reid (1998) notes that full recovery of LWD inputs may require 100–200 years.

Several studies demonstrate that LWD plays a critical role in both juvenile coho salmon habitat quality and stream hydrologic function. In stream reaches supplemented with LWD, significantly higher densities of juvenile coho salmon were supported than in reaches lacking added wood, with juvenile densities increasing in areas containing greater volumes of LWD (Gonzalez et al., 2017). Similarly, Quinn and Peterson (1996) reported that the installation of LWD structures can increase overwinter survival of juvenile coho salmon, potentially leading to higher smolt production and increased adult returns. Beyond direct biological benefits, field studies have shown that LWD installation alters channel hydraulics by increasing pool frequency and depth, reducing flow velocities, and enhancing sediment retention, thereby increasing hydraulic complexity and water residence time (Hilderbrand et al., 1997; Shield et al., 2001; Grabowski et al., 2019). These hydrologic and geomorphic responses contribute to improved habitat stability and resilience during high and low-flow conditions. One of the core objectives of the IRWISP is to restore and enhance critical salmonid habitats through increased LWD volumes and the creation of off-channel and side-channel habitats, alongside efforts to improve overall hydrological health within the watershed. In this context, the documented ecological and hydraulic benefits of LWD, combined with observed high juvenile coho densities in the Indian River mainstem near the 5 km mark, reinforce the need to prioritize LWD installation within the mainstem Indian River. However, our current approach to making linkages between juvenile salmonid abundances, habitat use, and identifying key regions for restoration on the mainstem are still limited, as habitat and LWD surveys are not currently conducted on the mainstem. Beginning to conduct these surveys on the mainstem could inform future restoration, and areas of concern with increasing drought events. This active LWD restoration is particularly important given that natural wood recruitment processes are unlikely to recover for several decades.

Habitat

For over 10 years, TWN has been conducting Level 1 habitat assessments in the IRW, with 2024 being the first year reaches were standardized and marked for future repetition. Our assessments highlighted significant differences between human-made and naturally formed channels. The human-made channels of Brandt North, 5 K Channel, and Brandt South (Reach 3) had much less variability in their bankfull and wetted widths, likely due to the rock armored walls that were installed along the bank edges to prevent changes to the channel widths (Szarek-Gwiazda, 2023), which can result in less channel sinuosity, undercut banks, and lower habitat heterogeneity (Schmetterling et al 2001; Reid & Church 2015). In contrast, the naturally formed channels of Brandt South (Reaches 1 and 2), Deep Pools Channel, Elk Channel (pre-2024 restoration work), Old River and Upper Long had much more variation in their bankfull and wetted widths (Lane, 1957), and greater complexity overall. Upper Long North and Old River also had significant variation in their bankfull and wetted widths between individual reaches. This is likely caused by the mainstem influence that is exhibited on these side-channels, with areas of deposition and scour affecting the morphology of the channels (Lane, 1957). High flow events further exacerbate these changes throughout the channels over time. The flow loss from Brandt North to Brandt South (five times less flow) is indicative of surface water infiltrating the subsurface and contributing to groundwater recharge. Water loss such as this is characterized by downstream decreases in flow as water moves vertically into the streambed and adjacent groundwater sources (Barlow, 2012).

Channels with greater habitat complexity, including Brandt South (Reaches 1 and 2), Deep Pools Channel, and Upper Long supported both year 0+ and year 1+ coho. These more complex sites were characterized by varying flows and depths, meanders, deep pools, and multiple cover types, creating diverse microhabitats that can be used and occupied by different coho age classes. Increased habitat heterogeneity can better allow multiple age classes to co-exist, as these variations in depth, velocity, and structure influence the distribution and use of off-channel features (Glova, 2000). Additionally, the availability and distribution of food and structural cover such as that provided by woody debris and deep pools, affect habitat selection by juvenile coho, supporting overlapping distributions of different age and size classes in complex channels (Giannico, 2000).

In addition to varying age classes of coho, Brandt South also had the highest relative abundance of chum of all sites, with twice that of the second highest site for abundance (5 K

Channel). It is assumed that the relative abundance in Brandt South could be due to the high density of chum spawners in this channel that were observed by the TWN field crew in the fall of 2023. 5 K Channel was also observed to have a high density of chum spawners but has an overall smaller size, so may not be able to support as high densities of juveniles.

The Mainstem IRW Falls had the largest average coho length, with all individuals measuring > 70 mm which is indicative of the 1+ year age class of coho (Sethi et al., 2017 and Bell, 2024), however sample size at this site was small. This site is one of the largest pools in the upper half of the anadromous habitat in the IRW, fed by a waterfall that acts as an upstream fish barrier. Larger body sizes observed here may be the result of several interacting factors. First, the waterfall may deliver plentiful food in the form of invertebrates and organic material being washed downstream, thus increasing prey availability for juveniles (Lusardi, Hammock, Jeffres, Dahlgren, & Kiernan, 2019). Second, lower densities of juvenile salmonids can reduce interspecific competition for food resources, leading to greater per-capita food availability (Hartman & Scrivener, 1990). Finally, the deep pool morphology of this site provided abundant cover and complexity, with further coverage provided by the aerated water entering the pool from the falls (Giannico, 2000).

In contrast to the Mainstem IRW falls pool, the downstream large pool sites of Mainstem at Deep Pools and Mainstem at 5 K supported the smallest average coho size, representing primarily the 0 + age class. These downstream pool reaches supported higher overall densities of juvenile salmonids, resulting in greater competition for food and space, leading to density dependence. These densities could limit growth rates, particularly when compared to fish occupying low-competition refuge habitats farther upstream where food may be more accessible. Pool frequency is widely recognized as an indicator of habitat complexity and quality in salmonid habitat, as pools provide critical low-velocity refuge and rearing habitat (McIntosh et al., 2000). However, the relatively low pool frequency observed in the IRW suggests that these habitats are likely limited, potentially concentrating juvenile salmonids into fewer available pool habitats, increasing competition within these locations (McIntosh et al., 2000). To further understand pool frequency within the IRW, we recommend pool frequency surveys be conducted on the mainstem river.

Dolly Varden were only observed at the Mainstem IRW Falls site. In the past, large numbers of Dolly Varden have been observed in side-channel habitats upstream of the anadromous salmonid barrier (TWN, unpublished data). Individuals caught at the Mainstem IRW Falls site may have been swept over the barrier during high flow events. Rainbow trout were also observed at Mainstem IRW Falls, whereas no trout were detected in other mainstem sites. In contrast, substantially higher densities have been observed upstream of the anadromous barrier during past surveys (TWN, unpublished data). Higher densities of trout found above the anadromous barrier are likely due to a lack of competition with juvenile coho, which are absent from these upstream habitats (Fausch & White, 1986).

8 K Wetland was the only site that supported substantial populations of both juvenile coho and cutthroat trout. Off-channel wetland and floodplain habitat such as 8 K Wetland, Beaver Dam,

and Ed's Swamp provided important refuge and rearing habitat for juvenile coho during high flows, as these areas often support higher densities, enhanced growth, and increased survival compared with other habitat types (Jeffries et al., 2006). Juvenile coho that redistribute into these areas during high flow periods often remain through winter, benefiting from the low-velocity refuge conditions that these habitats provide (Rodgers et al., 1987). 8 K wetland was also the only location where cutthroat trout were caught. The high cutthroat trout densities here were likely related to the complex, low-gradient habitat it provided. The site contains many deep (>1 m) rearing ponds connected by slow-moving narrow channels (<1 m wide), with abundant large woody debris. Combined, these features create diverse cover, low velocity refuge, and productive foraging areas that are well-suited to supporting high densities of cutthroat trout (Pearson Ecological, n.d.).

In Lower Long, all coho were > 80 mm other than a single individual. Lower Long is a tidally influenced channel in its lower half and is therefore likely brackish for part of the tidal cycle. These larger coho were likely undergoing smoltification and preparing for outmigration, which commonly occurs within this size range (Sandercock, 1991). In addition, salinity tolerance in juvenile coho is strongly size-dependent, with individuals below 70-80 mm exhibiting reduced survival in brackish conditions, (Weisbart, 1968), which likely explains the near absence of smaller coho at this site. Brackish environments such as Lower Long provide important transition environments where juvenile coho can physiologically prepare to enter the marine environment. During smoltification, increases in gill Na^+/K^+-ATPase activity enable the regulation of ions in saline environments, allowing individuals to gradually adjust from freshwater to saltwater environments (McCormick, 1993). The use of Lower Long by larger juveniles is consistent with this transitional life stage, where individuals occupy brackish or estuarine habitat prior to full outmigration.

Further Recommendations

Based on this report and synthesis of our current work in the IRW, we note some areas where further work and/or research could be conducted in addition to the recommendations made above (also see: Table 5).

The Level 1 FHAP surveys have provided valuable qualitative, and some quantitative information about the sites surveyed but are missing some critical pieces to better understand salmonid habitat quality. To supplement these surveys in future, it is recommended that LWD measurement and pool frequency surveys be conducted as described by BC MELP & DFO (1996). Both surveys provide methods and diagnostic tables for determining if LWD quantities and pool frequency within a channel are high enough to create ideal salmonid habitat. Both LWD and pools provide cover, and complex habitat for juvenile salmonids.

Spawning gravel surveys or Wolman pebble counts are also recommended to determine the quantity and quality of the spawning gravels at each site. Salmonids select gravel and pebble substrates of specific size ranges that allow redd excavation and provide interstitial flow for oxygenated water to incubating eggs (Bjornn & Reiser, 1991), and fine sediment within these gravels can reduce embryo survival by limiting water movement through the redd (U.S.

Geological Survey, 2024; Kondolf & Wolman, 1993). Wolman pebble counts are used to quantitatively describe the surface substrate size distribution in potential spawning habitat, providing an objective measurement of gravel suitability for salmonid spawning, and aiding in monitoring of habitat restoration effectiveness. We also recommend conducting invertebrate surveys using the Canadian Aquatic Biomonitoring Network (CABIN) protocols (Environment and Climate Change Canada [ECCC], 2012), as invertebrate surveys can provide an indicator of overall ecosystem health, as well as quantifying food availability for juvenile salmonids (ECCC, 2018).

Because of our lack of understanding of trout populations within the IRW, we recommend additional monitoring work to better understand their populations. Fedorenko and Shepherd (1984) found that between 1971 and 1982, the IRW had an average escapement of 110 steelhead trout. In the winter of 2018, the TWN field crew observed ~75 adult steelhead holding in a single pool (TWN, unpublished data). In subsequent years, steelhead have been sporadically observed. One of the strategies in the IRWISP includes the “assessment of steelhead and other resident trout species”. Unfortunately, current survey methods (minnow trapping and visual stock assessment) do not provide much information on *O. mykiss* populations. To help fill the knowledge gaps on resident trout and steelhead within the IRW, it is recommended that snorkel surveys for steelhead redds and resident trout observations be implemented in the future.

In addition to the recommended monitoring work, further restoration activities are also recommended. To aid in restoring the hydrology of the IRW, the previously mentioned installation of many LWD complexes to compensate for the lack of LWD inputs is recommended. Additionally, to address the extensive and unstable unvegetated gravel bars within the IRW, high-density willow staking is recommended on elevated bars to aid in their revegetation. Willow staking and other live plant bioengineering techniques help stabilize bare gravel bars by binding sediment with roots, increasing surface roughness to slow water velocities, and promoting deposition of fine sediments and organic materials that support vegetation establishment (Polster, 2002; U.S. Department of Agriculture Natural Resources Conservation Service, 2007). As the willow cuttings grow, their root networks reduce erosion and initiate successional riparian vegetation, gradually turning bare gravel bars into more stable vegetated habitats (Polster, 2002). Finally, to protect the floodplain from upslope impacts such as landslides, hillslope stabilization and decommissioning of old logging roads is recommended.

<u>Conclusion:</u>
This report integrated multiple datasets collected within xʔəl̓ílwətaʔɬ/Indian River Watershed (IRW) to better understand how habitat conditions, temperature regimes, and hydrological processes influence juvenile salmonid distribution, growth, and habitat use. Throughout the watershed, we observed clear relationships between habitat type, thermal regime, and salmonid life stage, highlighting the importance of maintaining a diversity of habitat conditions to support salmon populations throughout their life cycle.

Instream temperature monitoring showed that many channel temperatures trended with ambient air temperatures. Warmer, low velocity off-channel and wetland habitats supported higher relative abundances and larger body sizes of juvenile coho, indicating the importance of these sites for rearing and growth. In contrast, groundwater fed channels including Jacks, Wellwood, Jackswellwood, and 5 K exhibited low thermal sensitivity and greater thermal stability, indicating a large contribution of groundwater inputs. These channels showed limited use by juvenile coho during the spring but supported high densities of spawning chum in the fall. This highlights the importance of these cooler channels in providing stable thermal conditions year-round, cold water refugia in the summer, and the ideal spawning habitat and incubation habitat they provide in the fall and winter. Mainstem habitats with LWD supported the highest densities of juvenile coho, reinforcing the importance of habitat complexity for rearing. Trout were observed in low numbers at most sites, except for at 8 K Wetland, which is ideal trout habitat. Low trout numbers at most locations are likely influenced by competition with juvenile coho, as trout densities had been observed to be much higher above the anadromous barrier where coho are absent. Together, these findings all demonstrate that different habitat types within the IRW provide complementary ecological functions, each supporting different species and life stages at varying times of the year and in different areas.

Furthermore, we synthesized the findings of habitat assessments, juvenile salmonid monitoring, and thermal monitoring and provide recommendations for future monitoring, restoration, and habitat protection efforts within the watershed (Table 5). Recommendations include prioritizing LWD placement in the mainstem to create pools and improve rearing habitat, protecting groundwater fed channels that provide spawning habitat and thermal refugia, and conserving off channel wetland habitats that support rearing juvenile salmonids and their growth. Additional monitoring efforts including expanded habitat assessments in the mainstem and continued temperature monitoring would further bolster our understanding of watershed processes and improve adaptive management in the future.

While this study provided valuable information on salmonid habitat use and environmental conditions within the IRW, several limitations should be considered. Data was collected over a single year, with not all datasets overlapping across sites, limiting the ability to directly compare all variables. In addition, temperature loggers were deployed at single locations within each channel, which would not fully capture fine-scale spatial variability. Future work that incorporates multi-year datasets, greater spatial coverage, and more integrated sampling would improve the strength of these findings.

Overall, this work supports the goals and objectives outlined in the IRWISP and reflects TWN stewardship, values, goals, and priorities. Through identifying key habitat functions and areas of importance for different salmonid life stages, this report contributes to the ongoing efforts to protect and restore the ecological integrity of the watershed. Maintaining habitat diversity, and protecting thermal refugia, while improving critical rearing and spawning habitats will be essential for sustaining a resilient salmonid population in the IRW in a changing climate.

Table 5: Recommendations for future monitoring and restoration work in the Indian River Watershed.

Table of Recommendations for future monitoring and restoration work in the IRW
Habitat Assessments 1. Conduct LWD and pool frequency surveys to further characterize salmonid habitat quality. 2. Conduct spawning gravel surveys or Wolman pebble counts to determine the quality and quantity of spawning gravel among sites. Compare to TWN spawner data. 3. Conduct invertebrate surveys using CABIN protocols to determine ecosystem health and food availability for juvenile salmonids.
Juvenile Salmonids 4. Consider a small-scale mark-recapture study for juveniles to calculate relative abundance by site and between habitat types. 5. Conduct egg survivability studies at targeted sites including Jacks, Wellwood, and Jackswellwood.
Restoration and Preservation 6. Installation of LWD complexes within the mainstem IRW to compensate for the lack of LWD input due to historic logging activities. 7. Mainstem bar stabilization and re-vegetation work using willow stakes. 8. Hillslope stabilization to reduce impacts from landslide activity. 9. Preservation and protection of key habitats including wetland habitats for juvenile rearing and growth, and groundwater fed habitats for spawning adults and thermal refugia.
Trout Surveys 10. Snorkel surveys for resident trout, and redd surveys for steelhead to better understand trout populations.
Future Data Analysis 11. Analyzing minnow trapping data in comparison with TWN juvenile salmon beach seine outmigration data or adult stock assessment data to track survival from juvenile to outmigration, to spawner life stages.

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Appendices:

Appendix A: 2024 IRW Minnow trapping data summary.

Table A1: Summary of minnow trapping data for all sites and species in the Indian River Watershed in 2024 including number of traps, number of each species measured along with total catches, and catch-per-unit-effort (CPUE; relative abundance).

Location	No. Traps	Trap Hours	Coho Measured	Coho Bulk Count	Coho Total	Chum Measured	Chum Bulk	Chum Total	Pink Measured	Pink Bulk	Pink Total	RBT Measured	RBT Bulk	RBT Total	CTT Measured	CTT Bulk	CTT Total	DV Measured	DV Bulk	DV Total
BeaverDam	27	633.22	68	11	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CountingTowerChannel	17	426.13	62	31	93	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0
UpperLong	80	1,919.10	114	52	166	39	1	40	2	2	4	0	0	0	0	0	0	0	0	0
8KWetland	33	814.42	64	141	205	0	0	0	0	0	0	0	0	0	54	0	54	0	0	0
OldRiver	25	581.25	1	0	1	32	19	51	6	0	6	0	0	0	0	0	0	0	0	0
LowerLong	18	418.5	30	25	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ShopsChannel	10	282.83	12	1	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2KChannel	14	358.17	24	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DeepPoolsChannel	10	265.83	18	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2KSlough	11	286	15	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MainstematDeepPools	4	104.67	5	0	5	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
MainstemIRWFalls	4	96	4	0	4	0	0	0	0	0	0	3	0	3	0	0	0	6	0	6
MainstemBrandtNorth	4	96	2	0	2	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Mainstem5K	4	96	30	21	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BrandtSouth	23	525.17	13	0	13	33	75	108	30	99	129	1	0	1	1	0	1	0	0	0
Ed'sChannel	5	122.08	15	10	25	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0
BrandtNorth	11	250.8	28	2	30	5	6	11	0	0	0	0	0	0	0	0	0	0	0	0
JacksChannel	16	398.4	9	0	9	16	0	16	1	0	1	0	0	0	0	0	0	0	0	0
JackwellwoodChannel	8	202.67	1	0	1	9	0	9	0	0	0	0	0	0	0	0	0	0	0	0
WellwoodChannel	8	209.33	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0
ForestryChannel	13	320.23	23	0	23	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
5KChannel	12	285	8	0	8	29	0	29	0	0	0	1	0	1	0	0	0	0	0	0
Ed'sSwamp	10	245.17	29	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A2: Summary of minnow trapping relative abundances (CPUE) for coho and chum by site based on trap hours and number of traps for each site in the Indian River Watershed in 2024.

Location	No.Traps	Trap Hours	CohoCPUE*100	ChumCPUE*100	PinkCPUE*100	RBTCPUE*100	CTTCPUE*100	DVCPUE*100
BeaverDam	27	633.22	12	0	0	0	0	0
CountingTowerChannel	17	426.13	22	7	0	0	0	0
UpperLong	80	1,919.10	9	21	0	0	0	0
8KWetland	33	814.42	25	0	0	0	7	0
OldRiver	25	581.25	0	88	1	0	0	0
LowerLong	18	418.5	13	0	0	0	0	0
ShopsChannel	10	282.83	5	0	0	0	0	0
2KChannel	14	358.17	7	0	0	0	0	0
DeepPoolsChannel	10	265.83	7	0	0	0	0	0
2KSlough	11	286	5	0	0	0	0	0
MainstematDeepPools	4	104.67	5	19	0	0	0	0
MainstemIRWFalls	4	96	4	0	0	3	0	6
MainstemBrandtNorth	4	96	2	0	0	1	0	0
Mainstem5K	4	96	53	0	0	0	0	0
BrandtSouth	23	525.17	2	206	25	0	0	0
Ed'sChannel	5	122.08	20	33	0	0	0	0
BrandtNorth	11	250.8	12	44	0	0	0	0
JacksChannel	16	398.4	2	40	0	0	0	0
JackwellwoodChannel	8	202.67	0	44	0	0	0	0
WellwoodChannel	8	209.33	0	19	0	0	0	0
ForestryChannel	13	320.23	7	3	0	0	0	0
5KChannel	12	285	3	102	0	0	0	0
Ed'sSwamp	10	245.17	12	0	0	0	0	0

Appendix B: Habitat assessment site card.

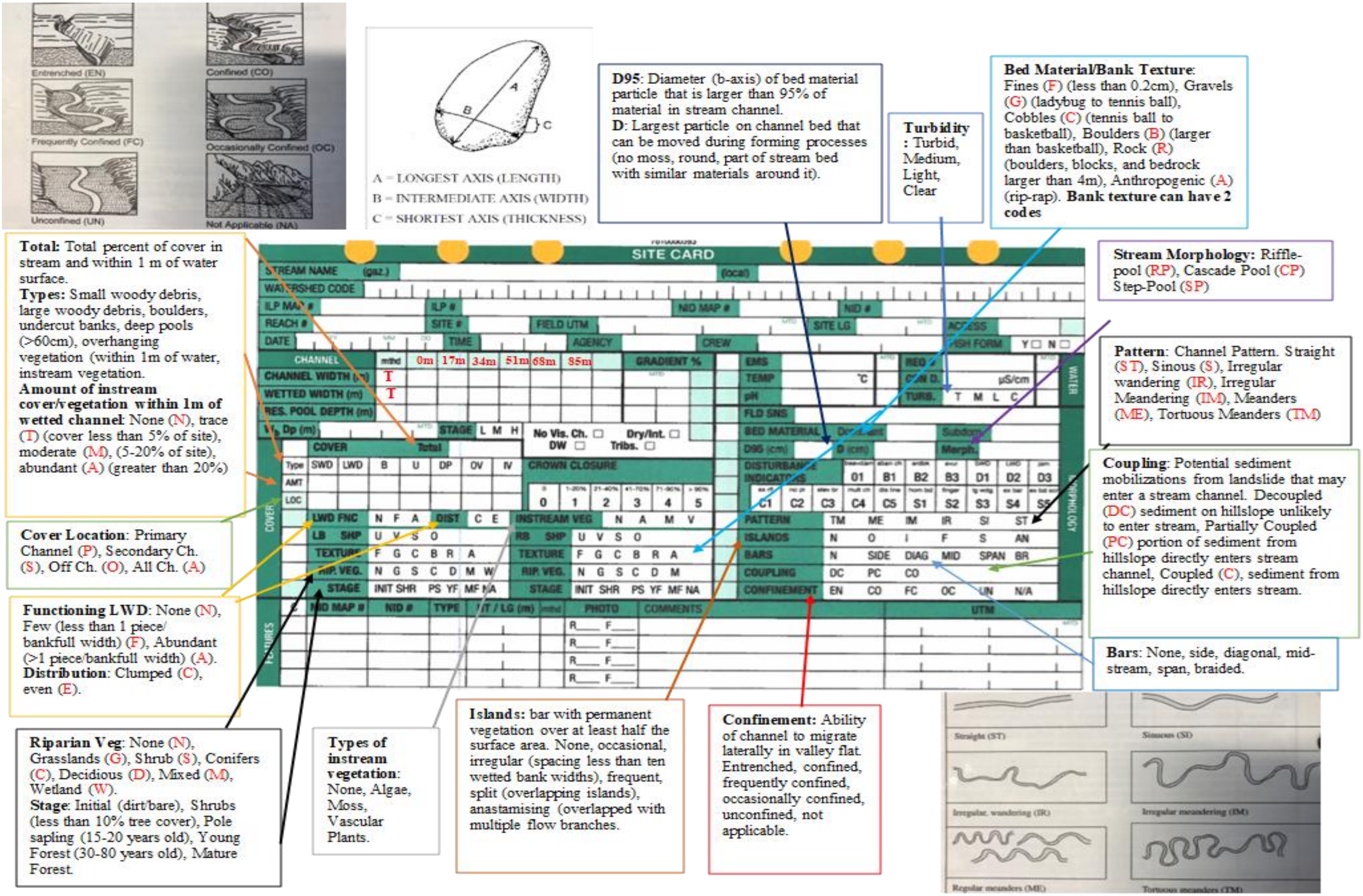

Figure B16: Level 1 Fish Habitat Assessment Procedure (FHAP) site card with explanatory boxes used to collect data for habitat assessments in the Indian River Watershed.

Table B1: Flow measurements and dates for each location and individual channel reach where flow surveys were conducted in the Indian River watershed in 2024.

Location	Date	Time	Flow (m^3/sec)
Brandt North	24-Jul-24	11:34	0.15
Brandt South Reach 1	25-Jul-24	11:41	0.03
Brandt South Reach 2	25-Jul-24	13:10	0.03
Brandt South Reach 3	25-Jul-24	NA	0.01
5K Reach 1	26-Jul-24	11:08	0.00
5K Reach 2	26-Jul-24	12:06	0.02
Old River Reach 1	01-Aug-24	11:40	0.22
Old River Reach 2	01-Aug-24	11:44	0.27
Old River Reach 3	01-Aug-24	12:10	0.21
Old River Reach 4	02-Aug-24	12:30	0.18
Old River Reach 5	02-Aug-24	13:40	0.21
Old River Reach 6	02-Aug-24	NA	0.13
Deep Pools	07-Aug-24	11:00	0.02
Upper Long Reach 1	13-Aug-24	11:50	0.49
Upper Long Reach 2	15-Aug-24	13:57	0.48

Appendix C: IRW logger information.

Table C1: Details for all environmental data loggers deployed in the Indian River watershed including logger type, model, serial number, deployment date and time, and location coordinates.

Location	Deployment No.	Logger Manufacturer	Logger Type	Model	Serial	Deploy Date	Deploy Time	Latitude	Longitude
MainstematDeepPools	2	Onset	Temperature	MX2203	21306954	2022-08-22	13:31	49.482750	-122.887633
CountingTowerChannel	2	Onset	Temperature	MX2203	20754021	2022-08-23	10:28	49.490268	-122.886765
MainstematBeaverdam	2	Onset	Temperature	MX2203	20754019	2022-08-23	11:37	49.494694	-122.894056
Mainstemat4KCorner	2	Onset	Temperature	MX2203	21413947	2022-08-18	15:05	49.500733	-122.892167
UpperLong	2	Onset	Temperature	MX2203	21306935	2022-08-23	11:59	49.496700	-122.894767
WellwoodChannel	3	Onset	Temperature	MX2203	21306619	2022-08-16	15:30	49.514303	-122.902278
JacksChannel	2	Onset	Temperature	MX2203	21306268	2022-08-18	13:55	49.515740	-122.900412
BrandtBerm	2	Onset	Depth/Temperature	U20L	20810592	2022-08-16	13:50	49.523633	-122.898667
2KSlough	2	Onset	Temperature	MX2203	21306607	2022-08-22	13:01	49.483930	-122.885673
OldRiver	2	Onset	Temperature	MX2203	21306926	2022-08-22	14:06	49.486733	-122.883783
ForestryChannel	2	Onset	Temperature	MX2203	21306938	2022-08-22	10:47	49.525797	-122.903933
MainstembelowTwinBridges	2	Onset	Temperature	MX2203	21306948	2022-08-18	14:32	49.508550	-122.903017
BeaverDam	2	Onset	Temperature	MX2203	21306934	2022-08-23	11:04	49.496978	-122.891078
Jackswellwood	1	Onset	Depth/Temperature	U20L	21285250	2022-08-16	15:00	49.512938	-122.902944
BrandtRockwall	1	Onset	Depth/Temperature	U20L	20810597	2022-09-01	12:45	49.519367	-122.897767
Baro Logger North Twin Bridges	2	Onset	Depth/Temperature	U20L	21060371	2022-08-16	13:30	49.511983	-122.903150
Baro Logger Cabin	1	Onset	Depth/Temperature	U20L	21060389	2024-05-29	10:40	49.474433	-122.882750
BrandtUpper	1	Onset	Depth/Temperature	U20L	21285253	2022-09-01	14:20	49.525567	-122.901083
MainstemCountingTowers	1	Onset	Depth/Temperature	U20L	20810595	2022-09-07	12:30	49.490700	-122.888356
5KChannel	1	Onset	Depth/Temperature	U20L	21060366	2023-10-31	11:45	49.504732	-122.896931
Mainstem5K	1	Onset	Depth/Temperature	U20L	21060386	2023-10-31	11:58	49.505631	-122.898078