Evaluation of Fish Passage at Beaver Dam Analogues with a Focus on Non-Natal Tributary Usage by Juvenile Nechako River Chinook Salmon

Interim Report Prepared for the Nechako Environmental Enhancement Fund

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Abstract

This study was successful in generating novel information about non-natal tributary usage by juvenile Nechako River Chinook salmon and fish passage around beaver dams. Study of fish passage around Beaver Dam Analogues (BDAs) was compromised due to poor conditions in Knight Creek in summer 2025, but knowledge gained about fish passage around beaver dams in Clear Creek should be applicable to BDAs. Preliminary results from water temperature monitoring indicated temperature in Clear Creek (mean: 17.3°C; range: 14.2°C – 20.4°C) and Knight Creek (12.2°C; 11.2°C – 13.7°C) were significantly cooler than the Nechako River mainstem (19.4°C ; 17.9°C – 21.1°C) during the 2025 summer period (Kruskal-Wallis test and post-hoc pairwise Mann-Whitney U-test: $H = 836.8$, $p < 0.001$) (Water Survey of Canada Station 08JC001). Juvenile Chinook were present in both Knight and Clear Creeks when PIT tagging efforts commenced on August 7 and 8, respectively. This result indicated juveniles entered non-natal tributaries in the late spring or early summer period – continued study in 2026 should determine entry timing. The majority of PIT tagged wild-origin juvenile Chinook (59.3%) dispersed from Clear Creek in the late summer and early fall period. The vast majority of hatchery-origin Chinook (99.3%) remained in the system over winter 2025-26. Dispersal of wild-origin Chinook was strongly correlated with decreasing water temperature (R^2=0.87), and other species of salmonids exhibited the same behaviour. Peak dispersal of Chinook occurred on September 20 and dispersal was complete by October 22. There was not a significant size difference between Chinook that dispersed (mean ± SD: 71.3 ± 15.8 mm) versus those that remained or did not survive (68.5 ± 11.5 mm) (Welch's two-sample *t*-test: $t = 1.30$; df =149; $p = 0.19$). Timing of this dispersal in relation to Nechako River water management indicated tributary dysconnectivity may be affecting productivity of Nechako River Chinook by preventing their fall dispersal from disconnected non-natal tributaries and is an issue that requires further investigation. Continued monitoring in 2026 will determine dispersal timing of juveniles that remained in Clear Creek over winter (i.e., whether a spring dispersal occurs and/or whether some Chinook remain in non-natal streams through a second summer), in addition to generating an estimated survival rate for non-natal stream rearing Chinook. Knowledge of the timing of these movements is important to inform Nechako River water management. Daily catch rates indicated abundance of juvenile Chinook decreased upstream of beaver dams in Clear Creek and there was a strong negative correlation between the number of beaver dams and species richness (R^2=0.91). A one-way ANOVA and post-hoc Tukey HSD test found nose-fork length of Chinook captured upstream of beaver dams (mean ± SD: 104.0 ± 38.1 mm; n=7) was significantly greater than those captured downstream of dams (69.1 ± 9.7 mm; n=35; and, 66.4 ± 8.7 mm; n=76) ($F_{2,115} = 29.63$, $p < 0.01$); moreover, there was no significant size difference of Chinook between reaches downstream of beaver dams ($p = 0.54$). Catch rates of rainbow trout increased with increasing distance upstream. There was no significant size difference between rainbow trout upstream or downstream of beaver dams (one-way ANOVA: $F_{3,63} = 1.83$; $p = 0.15$). These results indicate that use of BDAs as a restoration tool may benefit some fish species; however, the use of BDAs in restoration of non-natal stream rearing habitat for juvenile Nechako River Chinook salmon requires careful consideration.

Acknowledgements

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Introduction

Many small tributaries to the Nechako River were historically overlooked as Chinook salmon (*Oncorhynchus tshawytscha*) habitat due to the absence of adult spawners. As such, these small streams were often heavily impacted by human activities such as forestry, ranching/agriculture, and linear development. In recent decades, degradation of these tributaries was exacerbated by widespread changes to the landscape from the mountain pine beetle (*Dendroctonus ponderosae*) epidemic and subsequent wildfire, which in addition to climate change altered the hydrological regime of these small streams. As a result of these changes, many of these streams run dry seasonally and are dysfunctional as fish habitat for much of the year. However, recent environmental-DNA monitoring completed by the Nechako Environment and Water Stewardship Society (NEWSS), the University of Northern British Columbia, and School District 91 has shown that juvenile Chinook continue to utilize many of these streams regardless of their degraded state; in fact, 24 of 32 (75%) streams sampled to date tested positive for Chinook presence (Murray 2025). The tendency of Chinook to enter tributaries indicates that non-natal stream rearing was once a successful life history strategy and therefore tributaries must have been functional year-round. Unfortunately, as a result of the dramatic habitat changes that have occurred, it seems this behaviour might now be a death sentence, as juvenile Chinook are unable to escape when flows recede each summer and perish when streams eventually disappear into the ground until the following spring, when the cycle repeats. This study seeks to improve understanding of non-natal stream rearing behaviour to determine whether this behaviour, in combination with degraded streams and flow management in the Nechako River, might be a factor that is significantly limiting Nechako River Chinook salmon productivity (i.e., via stranding and subsequent mortality of juveniles). Knowledge gained through this study will be used to guide habitat restoration initiatives and Nechako River flow management, with the goal of increasing juvenile Chinook rearing productivity, thus increasing adult spawner abundance of threatened stocks (DU 9; DU 10) in the Nechako River watershed (COSEWIC 2018; DFO 2021).

Additionally, for the reasons described above, NEWSS has constructed a series of Beaver Dam Analogues (BDAs) on several Nechako River tributaries in the vicinity of Vanderhoof, with the objective of retaining water on the landscape to restore riparian habitat for fish and wildlife, while also providing refugia (i.e., ponds) for juvenile Chinook and other fishes during seasonal low-flow periods. While BDAs have shown promise in meeting these objectives, their efficacy as a habitat restoration tool for juvenile Chinook remains uncertain. As such, an additional objective of this study was to assess efficacy of BDAs as a juvenile Chinook habitat restoration strategy. This was accomplished by monitoring fish passage around BDAs and survival rates relative to BDAs, with analogous information also gathered from natural beaver dams. This information will be used to refine and strengthen existing habitat restoration strategies while also providing novel information to develop new, targeted strategies to benefit recovery of threatened Nechako River Chinook salmon.

Methods

Study Area

This study took place in Clear and Knight Creeks, which are direct Nechako River tributaries that flow through the agricultural belt near Vanderhoof, BC. Clear and Knight Creeks meet the Nechako River approximately 14.3 river km upstream (i.e., northwest) and 8.8 river km downstream (i.e., east) of the Burrard Street Bridge in Vanderhoof, respectively (Figure 1). Clear Creek is spring-fed and flows year-round, so it served as the control stream for this study; whereas Knight Creek in its present state is heavily degraded, ephemeral, and subject to intensive restoration efforts by NEWSS, so it served as the test stream for this study (Figure 2). Presence of juvenile Chinook salmon was confirmed in both of these creeks via eDNA and minnow trapping prior to inception of this study.

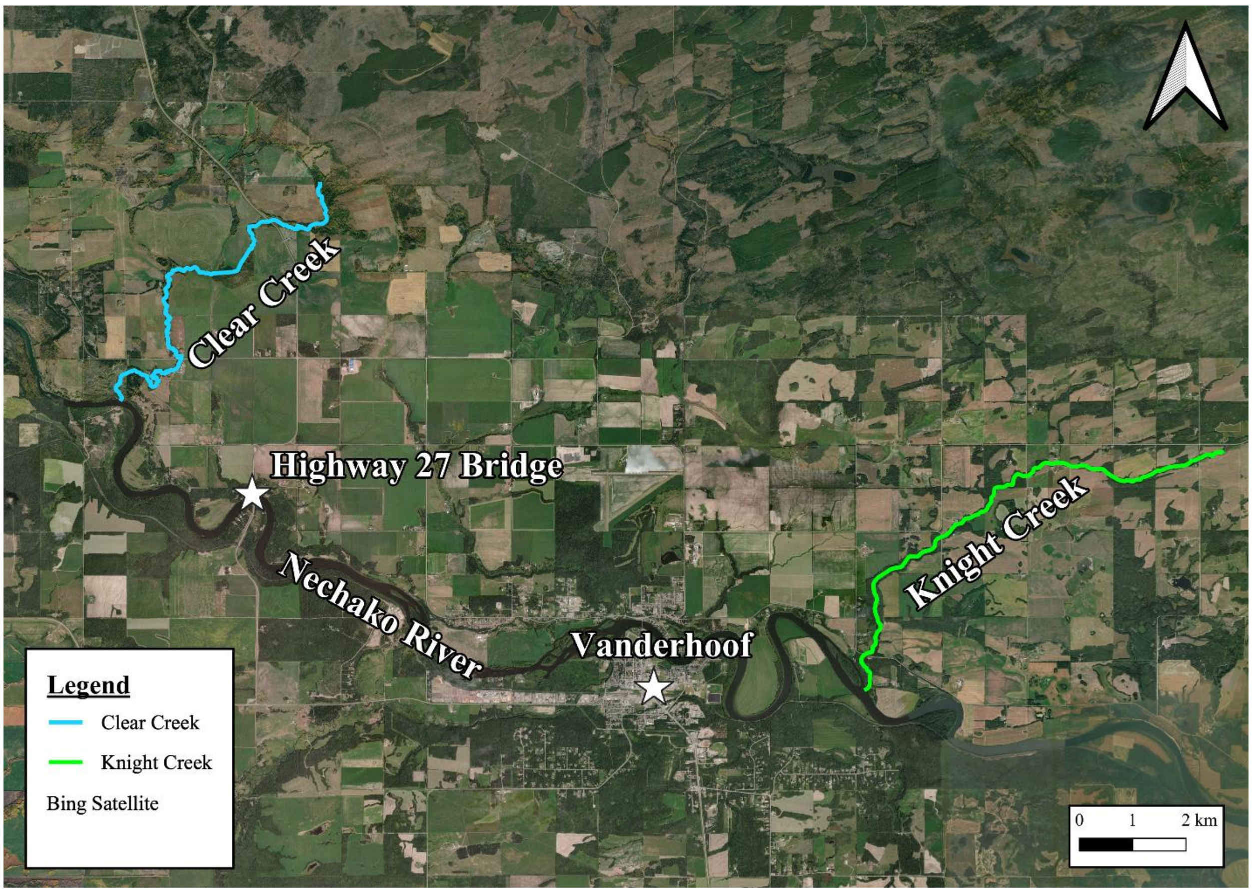


Figure 1: Location of Clear Creek (red line) and Knight Creek (yellow line) relative to Vanderhoof, BC. Bing Satellite image.

Figure 2: Clear Creek (left) in summer 2025 and Knight Creek (right) in fall 2025.

Water Quality and Water Level Monitoring

A HOBO Tidbit MX2203 temperature data logger was deployed to continuously monitor water temperature at each PIT detection site (i.e., six loggers in total). Each logger was fastened to a length of 2x4 lumber with 25 mm #8 wood screws. The 2x4 was positioned vertically with the butt end against the substrate, such that the logger was submerged and approximately 5 cm above the substrate. The 2x4 was fastened in place to the antenna bracket (i.e., see details in "*PIT Monitoring*" section below) with 75 mm #8 wood screws above the surface of the water. This arrangement provided easy access for data downloads because the 2x4 was easily unfastened from the antenna bracket to remove the logger from the water and complete the download.

A HOBO U26-001 dissolved oxygen data logger was deployed at one site in each of Clear and Knight Creeks to continuously monitor dissolved oxygen levels. These loggers were housed in perforated 50 mm diameter ABS housings with end caps that were fastened with ABS cement; one cap was fixed and one was a screw-cap, which provided access for the logger to be inserted or removed. The logger was secured inside the housing with 150 mm cable ties and the end cap screwed shut. The housing was strapped to a length of 2x4 lumber with two stainless steel hose clamps and attached to an antenna bracket in the same fashion as the water level loggers described above.

HOBO U20L-04 water level data loggers were deployed at two sites in each creek: one site near each confluence with the Nechako River to monitor the influence of Nechako River flow; and, an additional site further upstream to evaluate water level exclusive of the Nechako River. Water level loggers were inserted into the same style of housing as the dissolved oxygen loggers described above and the housings were affixed to a 30 cm x 30 cm x 20 cm concrete pier block using stainless steel hose clamps. Each water level logger was placed on the substrate of the stream and the depth of water above the instrument was measured to calibrate the logger position with the actual water depth. Each pier block was tethered to a secure point on the bank with 9 mm galvanized chain. A water level logger was also operated in air to monitor local fluctuation in barometric pressure, which was necessary to calibrate the data. The logger in air was fastened to a nearby tree branch with cable ties.

Tributary Connectivity Monitoring

A GardePro A3S trail camera was positioned at the confluence of each creek with the Nechako River and programmed to capture one photograph per day. This approach provided a means to visually evaluate connectivity of Clear and Knight Creeks with the Nechako River over time under varying flow (Figure 3). These images were correlated with Nechako River discharge data from the Water Survey of Canada (2025) to determine the minimum flow that was required for Knight Creek to remain connected to the Nechako River mainstem.

Figure 3: Trail camera deployed at the confluence of Knight Creek and the Nechako River to create a time lapse photo series that was used to evaluate connectivity of Knight Creek with the Nechako River mainstem over time, summer 2025. An additional trail camera was also deployed for the same purpose at the Clear Creek confluence.

PIT Monitoring

Passive Integrated Transponder (PIT)-based technology was the foundation of fish monitoring activities. Three sites in each creek were instrumented with PIT-detection antenna arrays consisting of two 3 m length Biomark HDPE antennas that spanned the entire stream channel and were positioned approximately 20 m apart (Figure 4). Deployment of dual antennas at each site improved detection efficiency while also providing directionality of fish movement by sequence of detections. Arrays were deployed at strategic locations in each creek, although access to the creeks via private property was somewhat of a constraint and did limit availability of sites. An array was situated near the confluence of each creek with the Nechako River. These sites were the cornerstone of the study as they served as a definitive checkpoint between the closed system of each creek and the open Nechako River mainstem. As such, data collected at these sites were used to quantify residence time within each creek, dispersal timing from each creek, and survival within each creek. The additional arrays that were positioned at upstream locations monitored both upstream and downstream fish movement, which included movement around natural beaver dams (Clear Creek) and BDAs (Knight Creek) (Figure 5; Figure 6). Additionally, multiple arrays complemented one another by providing a basis to estimate detection efficiency at each site.

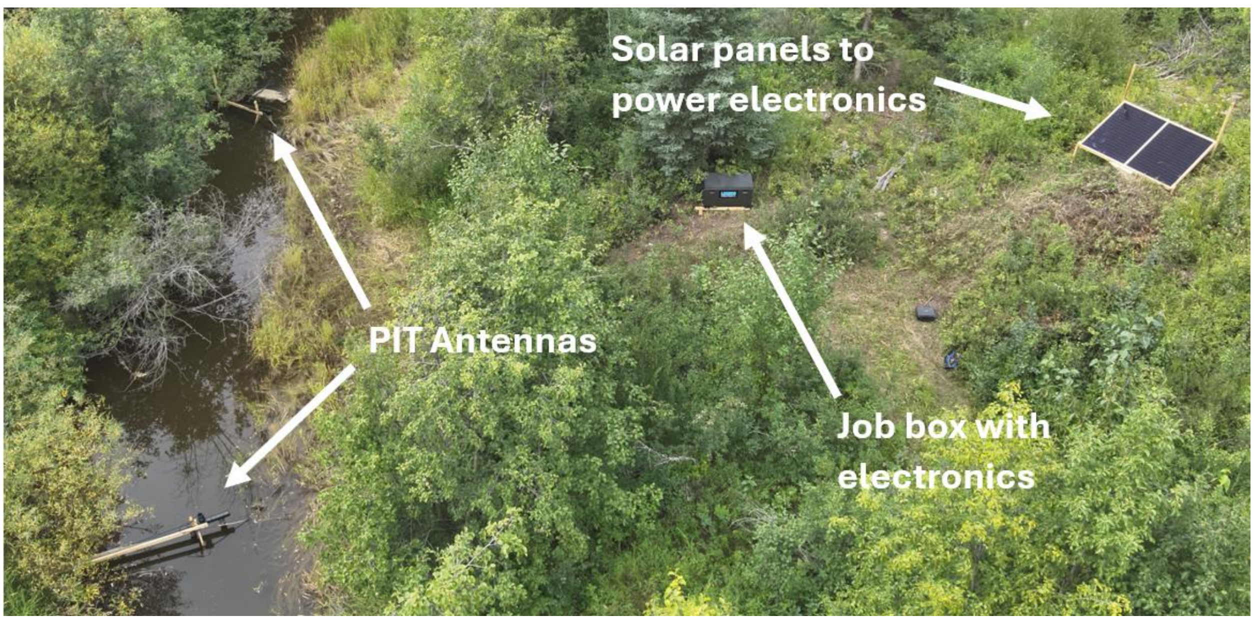


Figure 4: Typical Passive Integrated Transponder detection array setup used for this study. Clear Creek confluence site, July 2025.

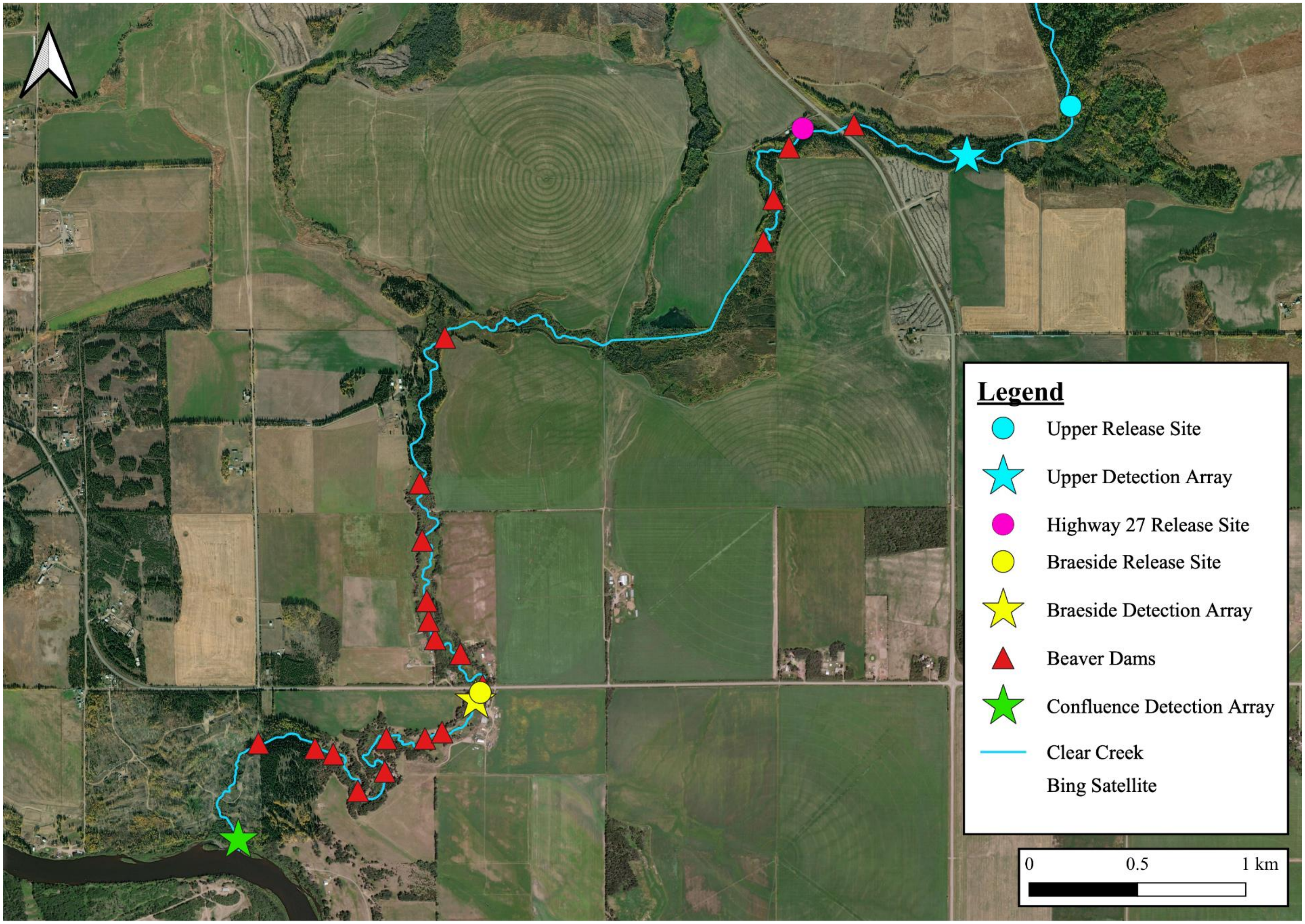


Figure 5: Location of Passive Integrated Transponder detection arrays and natural beaver dams in Clear Creek. Bing Satellite image.

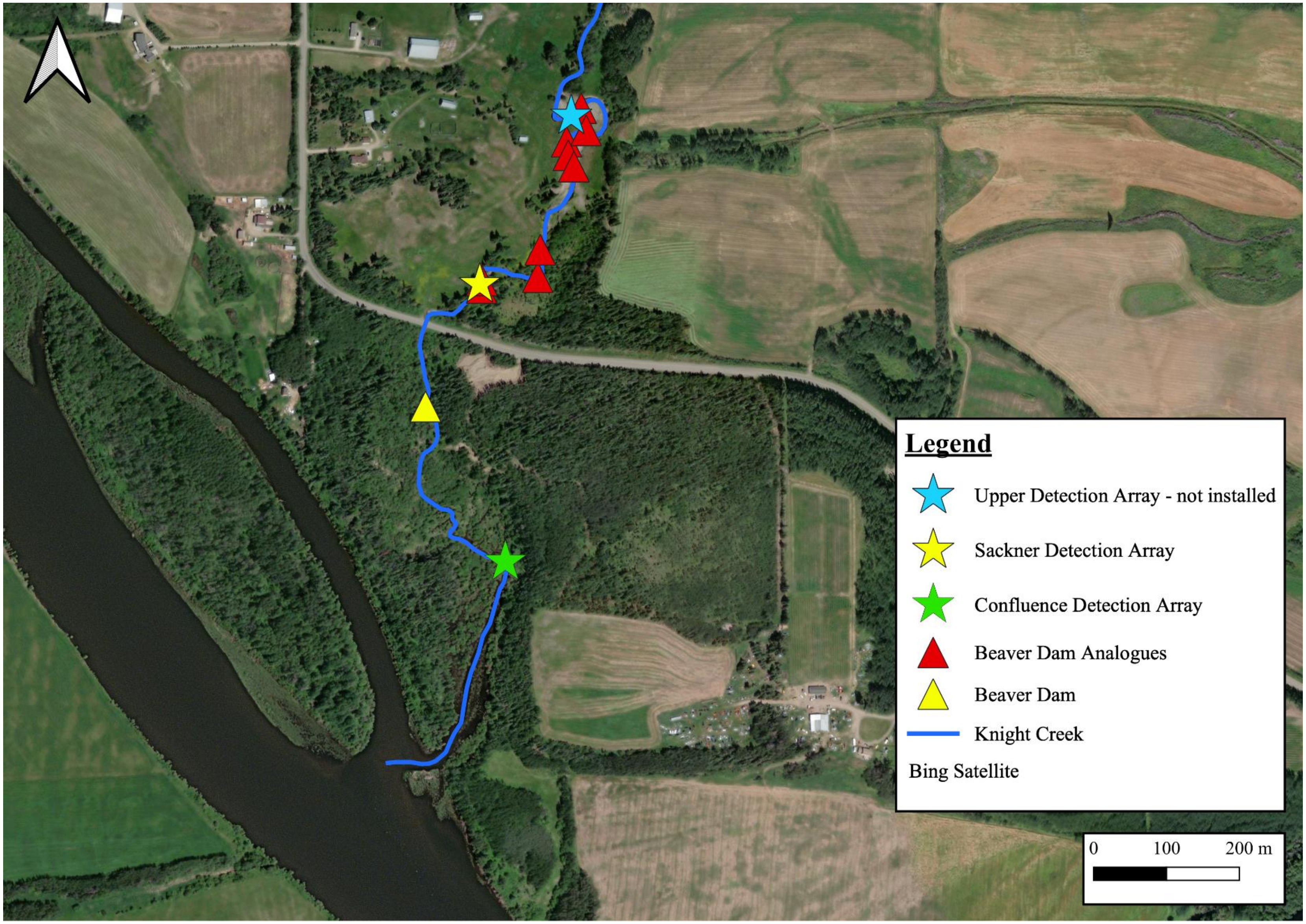


Figure 6: Location of Passive Integrated Transponder detection arrays and Beaver Dam Analogues in Knight Creek. Bing Satellite image.

Mobilization of large woody debris was unlikely in Clear and Knight Creeks due to their relatively small size; as such, damage to the equipment from downstream-drifting debris was not a concern, so each antenna was installed in pass-through orientation (i.e., upright). Pass-through orientation is known to provide better detection efficiency than pass-over orientation (i.e., when antennas are fastened flat to the bottom) (Ohms *et al.* 2023). Each antenna was held upright by a dual A-frame style bracket constructed of 2x4 lumber that was fastened together with 75 mm #8 screws. Two 30 cm x 30 cm x 20 cm concrete pier blocks were fastened to the base of each “A” (i.e., four blocks per antenna) with 10 mm x 450 mm galvanized carriage bolts, fender washers, and nuts. Each antenna was secured to this assembly using multiple heavy-duty 45 cm cable ties. Once each A-frame was constructed and the antenna securely fastened, the entire assembly was moved into position in the stream channel such that the antenna was on the upstream side of the bracket (Figure 7). A rope bridal secured each antenna to an anchor point upstream (i.e., a tree or root mass) to secure the antenna in place in the event of high flow.

Figure 7: PIT detection antenna and bracket at the Clear Creek confluence site, September 2025. Note the algae on the antenna – the top of the algae was the water level during the Summer Temperature Management Program. Rope bridal not shown.

A Biomark IS1001 reader board was dedicated to each antenna, which was connected via a 15 m or 30 m exciter cable (i.e., depending on site characteristics) using Wet-Mate connectors.

Electronics at each site were housed on shore in a 0.6 m x 0.6 m x 1.0 m steel job box. Reader boards were initiated using Biomark Device Manager software on a laptop computer with Bluetooth capability; this software was also used to download detection data and manage reader board storage. Each reader board continuously powered and tuned its antenna while also logging the date, time, and unique tag code of each PIT tagged fish that was detected. Each reader board was equipped with a IS1001 BLE Data Logger that had a capacity of 1,020,000 detections. Reader boards at each site were coupled together with a sync cable, which was necessary to establish an alternating firing sequence such that each antenna could operate without interfering with the other. Each array was powered by dual 100 amp-hour 24V Lithium Blue Smart Batteries connected in parallel that were charged by dual LONGi 400W solar panels through a Victron Energy SmartSolar MPPT 100/50 charge controller (Figure 8).

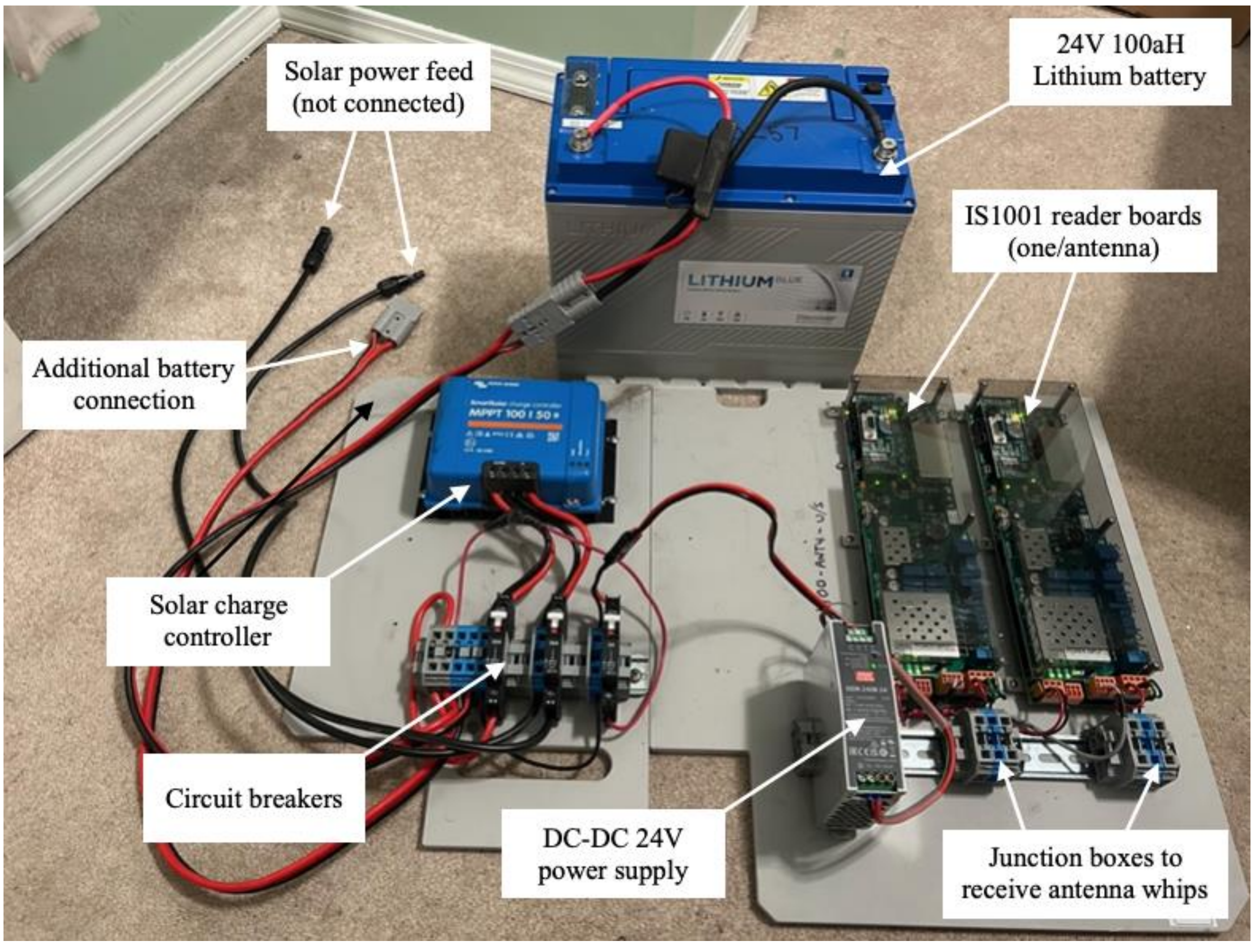


Figure 8: Mockup of electronics assembly used to operate solar powered Passive Integrated Transponder detection arrays. The assembly for each site was housed in a steel job box.

Wild-Origin Fish Capture and PIT Tagging

Fish were captured using a 1.0 m x 3.0 m beach seine with 4 mm stretch mesh or by deploying cylindrical minnow traps baited with wet cat food or salmon roe (Figure 9; Figure 10). Beach seining was generally more effective but fishing locations were limited to larger, slower pools that were free of snags, so minnow trapping was a good alternative to use in and around structures that could not be fished with a seine net. Holding the net open in a semi-circle and causing a commotion upstream of the net by splashing, kicking, and/or smacking the water surface with a stick prior to closing the net to complete the set typically improved catch rates (i.e., by spooking fish downstream and/or out of cover and into the net). Once captured, all fish were transferred to a holding bucket equipped with a portable air pump for oxygenation and held until an appropriate number of fish were captured to warrant a PIT tagging session. Lids were securely fastened to the holding buckets to prevent fish from leaping out of the buckets prior to tagging (Figure 11). When catch volumes were high, several buckets were used to reduce stress by overcrowding. Water temperature was monitored prior to each tagging episode, and tagging did not occur during warm summer periods when water temperature exceeded 17°C and/or when air temperature was exceptionally high (>25°C).

Figure 9: Beach seining at Braeside Road (left) and the lower reaches (right) of Clear Creek, August 2025.

Figure 10: A minnow trap baited with roe. Minnow traps were tethered to the stream bank with a rope to ensure they did not drift downstream and to provide a means of easy recovery from the stream bottom.

Figure 11: Holding bucket equipped with an air pump and air stones for oxygenation and a lid to prevent fish from leaping from the bucket.

An orderly station was set up prior to each tagging session (Figure 12). Vessels were arranged in sequential order beginning with the fish holding bucket, a tub for anaesthetic, an intermediate tub for length measurement, and a recovery bucket. Five-gallon buckets were typically used for holding and recovery, while 30 cm x 45 cm x 15 cm Tupperware totes were used for the anaesthetic bath and measuring tub. When tagging occurred at vehicle-accessible sites a folding table was used, but tagging occurred on an area of flat ground at sites accessed on foot. Shady areas were sought out in sunny weather to mitigate the rate of water temperature increase in vessels while tagging. All vessels were equipped with portable air pumps for oxygenation. A lid was used to partially cover the recovery bucket which provided shade for recovering fish while also preventing revived fish from leaping out of the bucket.

Figure 12: PIT tagging station at Clear Creek, August 2025.

All PIT tagging followed procedures developed by DFO veterinarians. Prior to PIT tag implantation, fish were transferred in small batches (e.g., 10 – 12 individuals at a time) with a dipnet from the holding bucket to an anaesthetic bath consisting of water and Tricaine Methanosulfonate (i.e., TMS or MS-222) in concentrations of approximately 60 mg/L. Two different sized full-duplex B PIT tags were deployed, depending on nose-fork length (NFL) of the individual being tagged: Biomark HPT10 tags (dimensions: 1.3 mm diameter x 10.3 mm length; weight: ~35 mg in air) or Biomark APT12 tags (dimensions: 2.0 mm diameter x 12.5 mm length; weight: ~106 mg in air). Fish with NFL of 47 – 59 mm were implanted with HPT10 tags, while fish ≥60 mm were implanted with APT12 tags (Figure 13). Fish <47 mm were rarely encountered and were released untagged. Once fish were fully anaesthetized (i.e., appeared lifeless and lying sideways or upside-down in the anaesthetic bath), PIT tags were implanted into the body cavity using a single-use pre-loaded needle (Figure 14). All tags were purchased in pre-loaded individual trays to increase efficiency in the field, ensure every needle was sharp, and to provide sterilization between fish. Needles were inserted into Biomark MK 65 (HPT10 tags) or MK25 (APT12 tags) tagging guns by pushing the gun down onto the plastic end of the needle. After a small incision (i.e., approximately the diameter of the tag being applied) was made in the pelvic girdle area of the fish using the tip of the needle, the tag was expelled by squeezing the trigger of the gun, which activated a push rod inside the needle. Care was taken to ensure each tag was inserted at an angle that would allow it to slide easily into the body cavity parallel to the length of the fish, rather than jabbing the tag toward the dorsal area where it might damage the kidney or other organs. A quick and gentle massage of the incision and ventral area was done following the application of each tag to ensure the tag had passed fully through the incision and was properly situated in the cavity of the fish. The empty needle was then expelled from the gun by pulling a secondary trigger and the cycle was repeated with the next individual.

Figure 13: Biomark MK25 Passive Integrated Transponder tagging gun with an APT12 tag. Pencil is shown for scale.

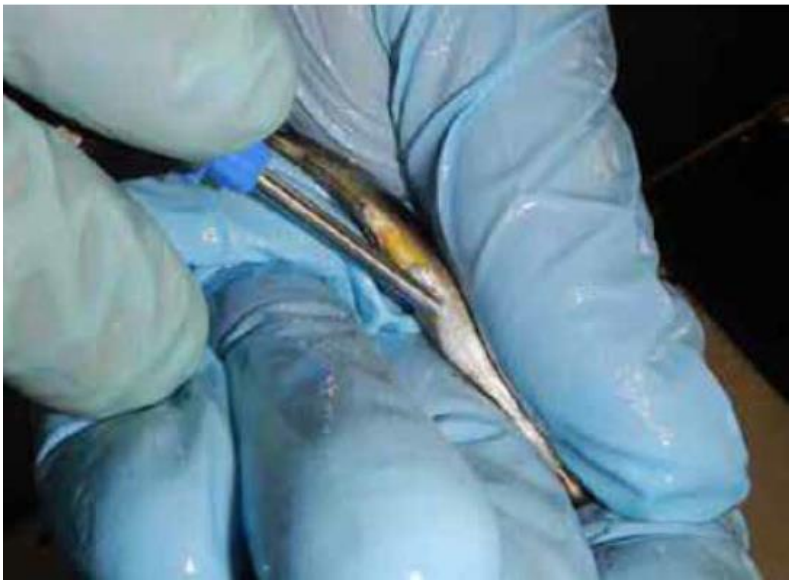


Figure 14: Application of a Passive Integrated Transponder tag (APT12) to a juvenile Chinook salmon at the Cowichan River Hatchery, spring 2015 (Pearce & Damborg 2022).

Following PIT tag application, each fish was passed to an intermediate tub where its NFL was quickly measured with an Aquadynamics 30 cm measuring board and scanned with a Biomark HPR-Lite hand scanner (Figure 15). The NFL and the last four digits of the PIT tag code were recorded on a waterproof paper datasheet along with the species, date and time, and location of capture. Once this process was completed, fish were placed in the recovery bucket. When the anaesthetic had worn off and fish were once again fully vigorous, they were gently released into an area of slack water in the same reach where they were caught (Figure 16).

Figure 15: A newly PIT-tagged wild-origin juvenile Chinook salmon on a measuring board, Clear Creek, September 2025.

Figure 16: Release of PIT-tagged wild-origin juvenile Chinook salmon and other fishes back into Clear Creek, September 2025.

At the end of each field day, tagging data were entered into a digital database by downloading full tag codes from the scanner and associating the codes with the metadata that was collected in the field. Detected tags were then linked with these data to identify the individual fish that was detected, including date of tagging, location of tagging, and NFL at tagging (Table 1).

Table 1: Example of data generated by Passive Integrated Transponder-tagged fish passing the Clear Creek confluence site between August 28 and September 26, 2025. Direction of travel was determined by the sequence at which individuals crossed each antenna.

Detection Date	Detection Time	Antenna ID	Tag ID	Direction	Tagging Date	Watershed	Release Site	Capture Method	Tag ID	Species	Origin	NFL @ Tagging
28-Aug-2025	11:18:33	2	985.113008454922	DOWN	21-Aug-2025	Clear Creek	Lower Clear Creek - Confluence	Beach Seine	985.113008454922	CN	W	61
28-Aug-2025	20:26:02	1	985.113008454922	DOWN	21-Aug-2025	Clear Creek	Lower Clear Creek - Confluence	Beach Seine	985.113008454922	CN	W	61
12-Sep-2025	11:36:38	2	989.002032394290	DOWN	21-Aug-2025	Clear Creek	Lower Clear Creek - Confluence	Beach Seine	989.002032394290	CN	W	84
12-Sep-2025	11:38:39	1	989.002032394290	DOWN	21-Aug-2025	Clear Creek	Lower Clear Creek - Confluence	Beach Seine	989.002032394290	CN	W	84
12-Sep-2025	2:54:58	2	989.002032394269	DOWN	21-Aug-2025	Clear Creek	Lower Clear Creek - Confluence	Beach Seine	989.002032394269	CN	W	67
12-Sep-2025	02:55:36	1	989.002032394269	DOWN	21-Aug-2025	Clear Creek	Lower Clear Creek - Confluence	Beach Seine	989.002032394269	CN	W	67
26-Sep-2025	18:54:52	2	989.002032397571	DOWN	23-Aug-2025	Clear Creek	Braeside Road	SCWA Hatchery	989.002032397571	CN	H	75
26-Sep-2025	18:55:25	1	989.002032397571	DOWN	23-Aug-2025	Clear Creek	Braeside Road	SCWA Hatchery	989.002032397571	CN	H	75
26-Sep-2025	18:54:48	2	989.002032394650	DOWN	23-Aug-2025	Clear Creek	Braeside Road	SCWA Hatchery	989.002032394650	CN	H	78
26-Sep-2025	18:55:16	1	989.002032394650	DOWN	23-Aug-2025	Clear Creek	Braeside Road	SCWA Hatchery	989.002032394650	CN	H	78
26-Sep-2025	11:36:38	2	989.002032394302	DOWN	16-Sep-2025	Clear Creek	Lower Clear Creek - Confluence	Beach Seine	989.002032394302	CN	W	87
26-Sep-2025	11:37:53	1	989.002032394302	DOWN	16-Sep-2025	Clear Creek	Lower Clear Creek - Confluence	Beach Seine	989.002032394302	CN	W	87
26-Sep-2025	18:54:51	2	985.113008454697	DOWN	4-Sep-2025	Clear Creek	Braeside Road - Pumphouse	Minnow Trap	985.113008454697	RB	W	49
26-Sep-2025	18:55:24	1	985.113008454697	DOWN	4-Sep-2025	Clear Creek	Braeside Road - Pumphouse	Minnow Trap	985.113008454697	RB	W	49

Fish-Beaver Dam Relationship

The vast majority of fish were captured by beach seine for this study. Beach seine effort was consistent each day and typically consisted of 8 ± 1 sets per day. As such, beach seine catch per day rates were used to evaluate relative abundance of Chinook and species richness by distance upstream. Minnow trapping data were included with beach seine data for evaluation of species richness. Aerial imagery of Clear Creek was captured using a Mavic 3T drone; this imagery was used to determine the number and location of beaver dams.

Hatchery-Origin Chinook PIT Tagging

Hatchery-origin Chinook were also PIT tagged for this study, using the same methods as described above for wild-origin fish. The purpose of PIT tagging hatchery Chinook was to ensure there was a sufficient number of tags deployed in the study area to generate meaningful results in Year 1, while effective methods for capture of wild-origin fish were still being established. Hatchery Chinook were raised at the Spruce City Wildlife Association (SCWA) Hatchery in Prince George from upper Nechako River broodstock. Two-thousand juvenile Chinook were held at the hatchery until they were appropriately sized for application of APT12 tags (i.e., >60 mm NFL). The study design was to release 1,000 of these fish in each creek and distribute them throughout the creek in groups of approximately 200 – 250 fish at a variety of release sites.

Hatchery Chinook were held off food for two days prior to tagging and two days following tagging. All hatchery fish were tagged in a single day by a crew of six people on August 6, 2025, and then held for 17 days until their release on August 23, 2025 (Figure 17). The holding period post-tagging was primarily to evaluate the tagging-related mortality rate and the tag rejection rate, but also to allow the fish time to heal from the tag incision. Furthermore, this process allowed rejected tags and mortalities to be removed from the inventory of fish that were eventually released.

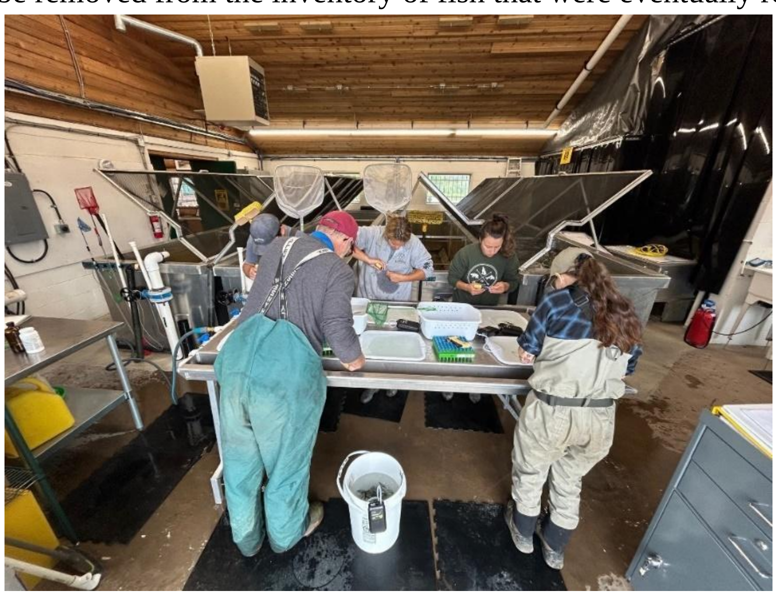


Figure 17: PIT tagging of hatchery-origin Nechako River Chinook salmon at the Spruce City Wildlife Association Hatchery in Prince George, BC, August 6, 2025.

Hatchery Chinook were transported en masse in an aerated transport tank from the SCWA hatchery to Clear and Knight Creeks. At each site, every fish was anaesthetized, scanned, measured for NFL, and the total number was tallied prior to release (Figure 18). These data were recorded on datasheets and linked to full tag codes in the same manner as described for wild fish above. This process was necessary to accurately determine the quantity of individuals released at each site while also creating an inventory of tag codes specific to each site, such that detected or recaptured individuals could be traced back to their release site. Fish were released in batches once the anaesthetic had worn off and they were again fully vigorous. When the desired number of fish for a given site was achieved, the crew proceeded to the next site and the process was repeated.

Figure 18: Inventory and length measurement of PIT tagged hatchery-origin Nechako River Chinook by Spruce City Wildlife Association volunteers prior to their release into Clear Creek, August 23, 2025.

Results

Water Quality and Water Level

Dissolved oxygen and water level loggers were still in situ at the time of this report. As such, results from these data are forthcoming. Temperature loggers were also still in situ at the time of this report; however, some of the loggers had been downloaded periodically during the summer and fall of 2025. These data provided a preliminary glimpse at temperature trends in these creeks relative to the Nechako River mainstem at Vanderhoof (Water Survey of Canada Station 08JC001) (Figure 19).

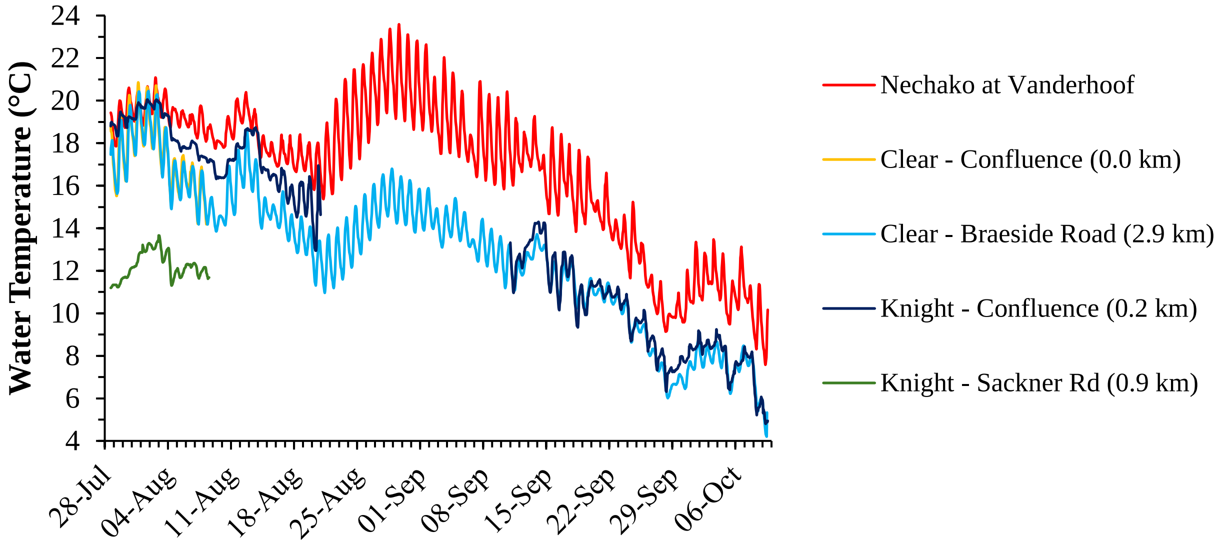


Figure 19: Water temperature at two sites in each of Clear and Knight Creeks compared to the Nechako River mainstem at Vanderhoof (red line; Water Survey of Canada Station 08JC001). Data collected at the Knight Creek confluence (dark blue line) between August 20 and September 11, 2025, were omitted because the logger was dewatered following the Summer Temperature Management Program until it was repositioned on September 11. Loggers at the Clear Creek confluence (orange line) and in Knight Creek at Sackner Road (green line) were last downloaded on August 8, 2025.

A Kruskal–Wallis Test and a post-hoc pairwise Mann–Whitney U-Test were used for a preliminary comparison of water temperature between sites from July 28 to August 8, 2025. The Nechako River was significantly warmer than all other sites (mean: 19.4°C; range: 17.9°C – 21.1°C), while Knight Creek at Sackner Road was significantly colder than all other sites (mean: 12.2°C; range: 11.2°C – 13.7°C) (Water Survey of Canada Station 08JC001) (Figure 20). There was not a significant difference between the Clear Creek sites, but the Knight Creek confluence was significantly warmer than both Clear Creek sites (H = 836.8, p < 0.001).

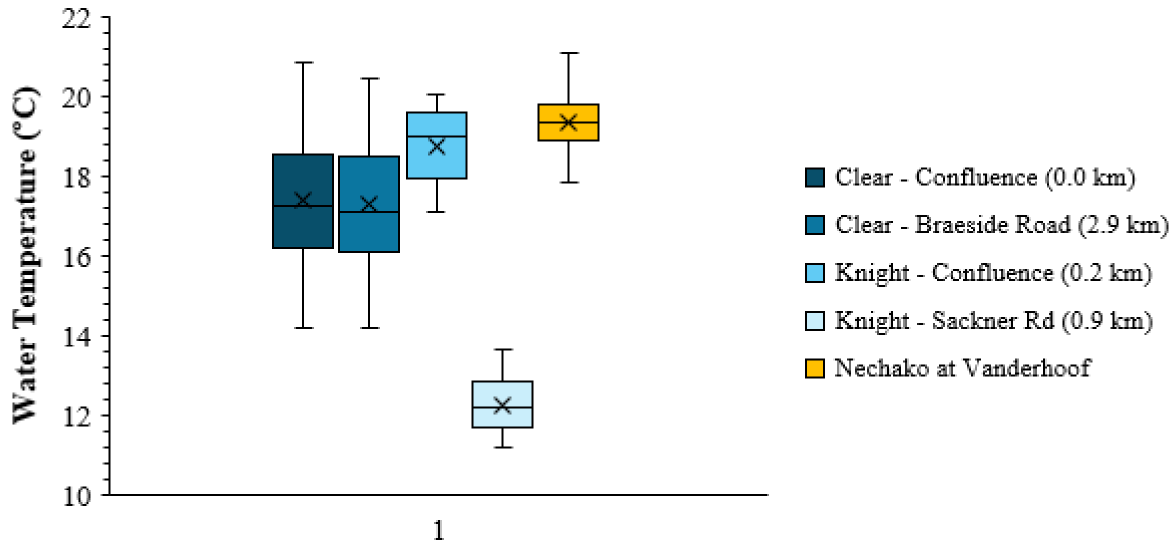


Figure 20: Water temperature at two sites in each of Clear and Knight Creeks and from the Nechako River near Vanderhoof between July 28 and August 8, 2025 (Water Survey of Canada Station 08JC001). The period of this analysis was brief because data had not been retrieved since August 8.

Tributary Connectivity

Clear Creek

Clear Creek remained connected to the Nechako River mainstem for the entirety of the trail camera monitoring period (June 11 to October 2, 2025) (Figure 21).

Figure 21: The confluence of Clear Creek with the Nechako River on June 11, 2025.

Knight Creek

Knight Creek was connected with the Nechako River mainstem when the trail camera was installed on June 11, 2025; however, the creek became disconnected on June 22 (Figure 22). It remained this way until arrival of the Summer Temperature Management Program (STMP) flow on July 18 (Figure 23), but was once again disconnected following the conclusion of the STMP (Figure 24). Correlation of the dates of these photographs with Water Survey of Canada Station 08JC001 data indicated the confluence of Knight Creek was disconnected when Nechako River discharge was less than approximately 85 m^3/s; furthermore, historical flow data suggest the creek was connected throughout the spring to fall period prior to impoundment (Figure 25).

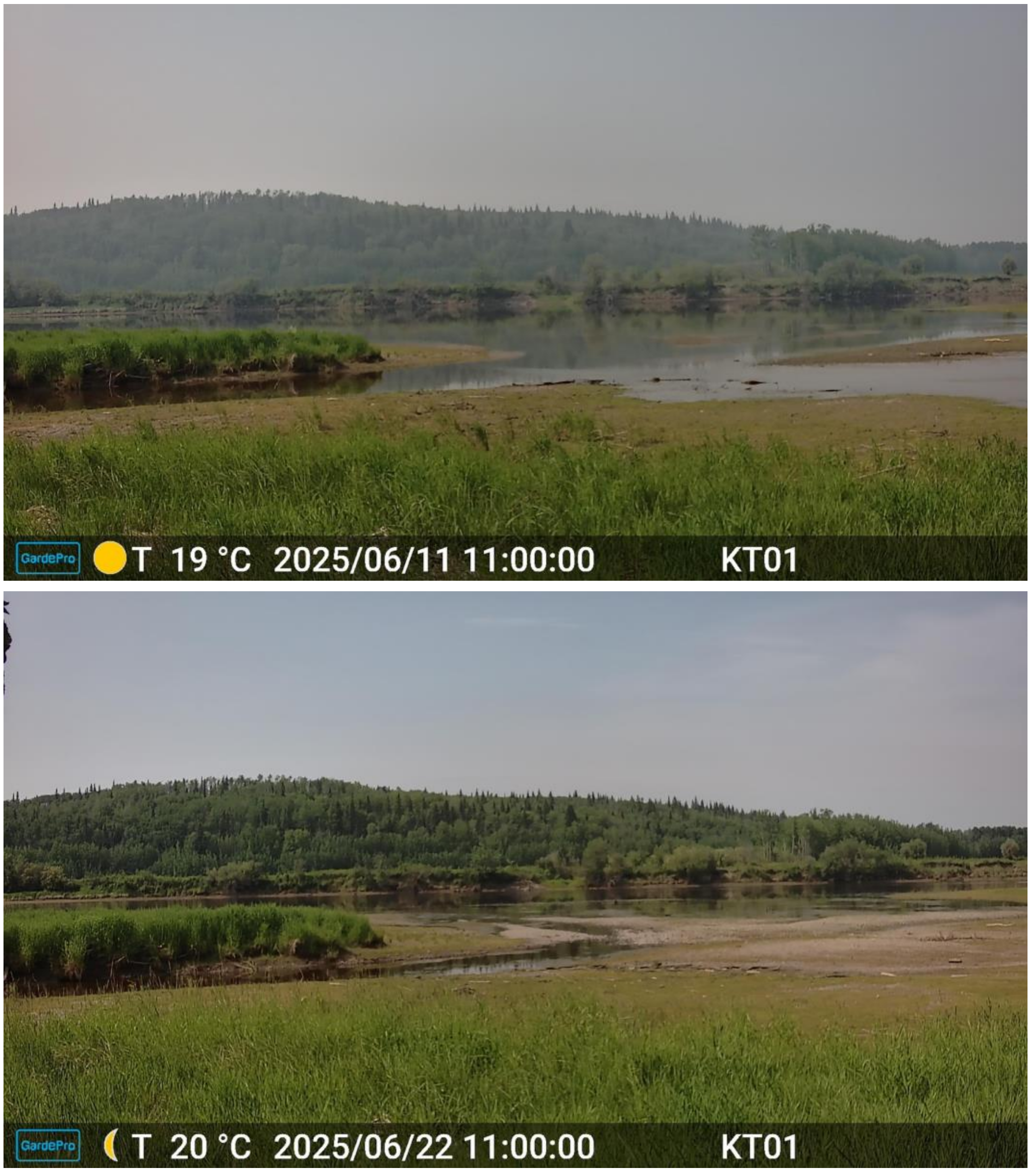


Figure 22: The confluence of Knight Creek with the Nechako River when the trail camera was installed on June 11 (top), and when it became disconnected due to receding flow on June 22, 2025 (bottom).

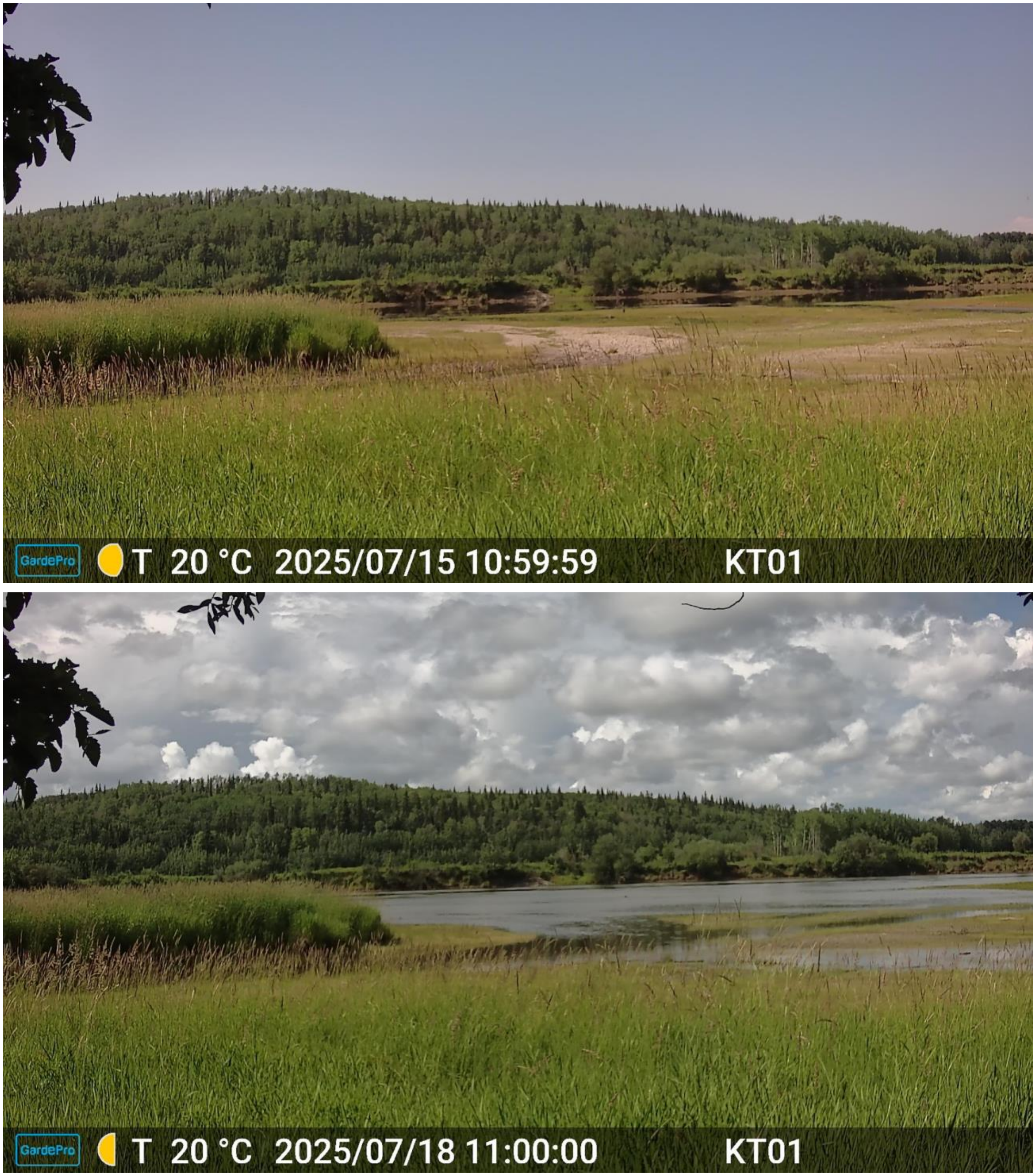


Figure 23: The confluence of Knight Creek with the Nechako River on July 15 (top), prior to arrival of Summer Temperature Management Program flow on July 18, 2025 (bottom).

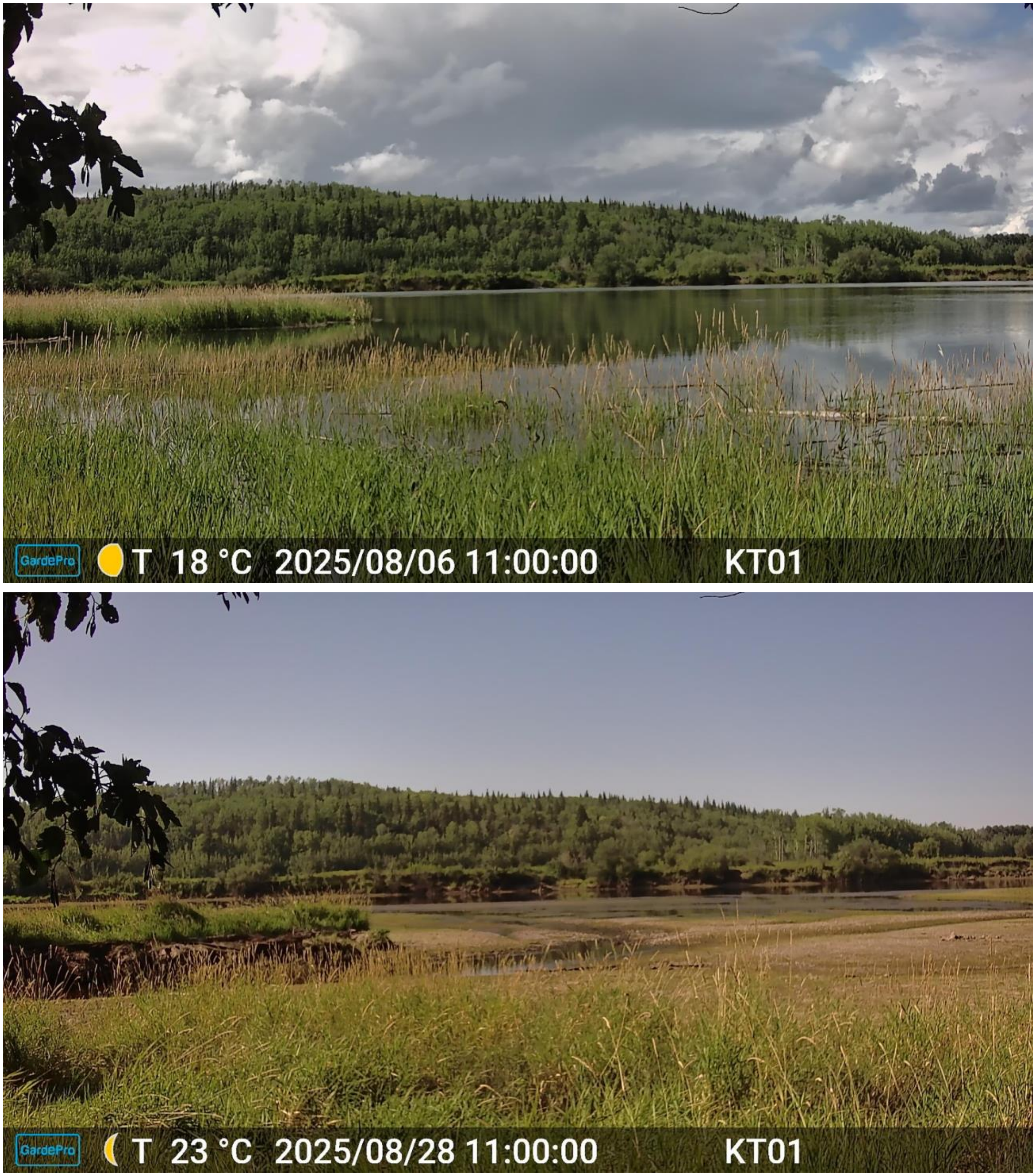


Figure 24: The confluence of Knight Creek with the Nechako River during peak Summer Temperature Management Program flow on August 6 (320 m^3/s; top) and following conclusion of the program on August 28, 2025 (85 m^3/s; bottom) (Water Survey of Canada Station 08JC001).

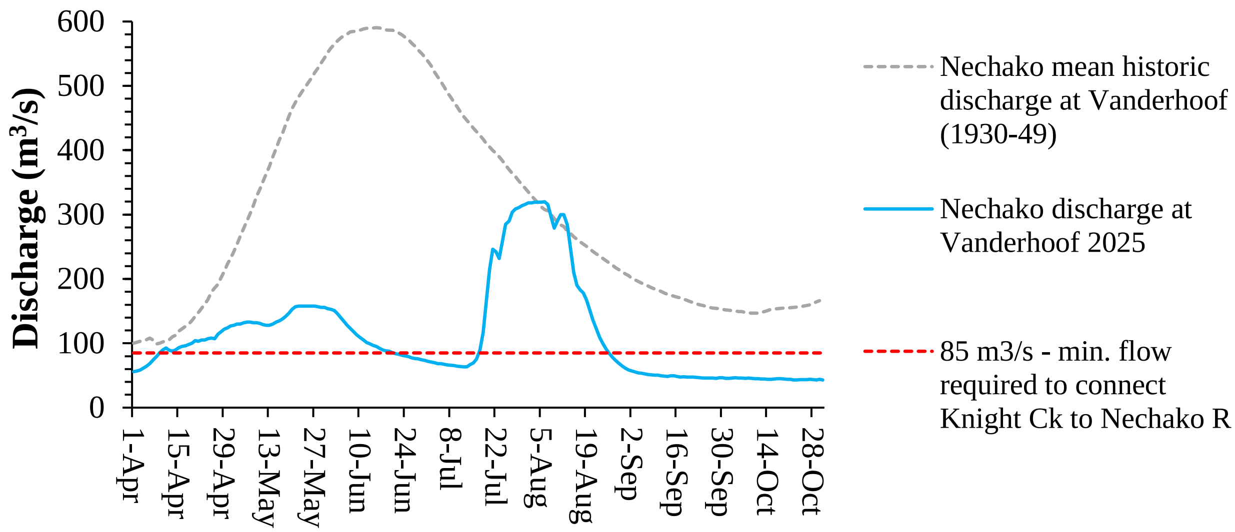


Figure 25: Historical Nechako River discharge (grey dashed line) versus 2025 discharge (blue solid line). The red dashed line indicates the estimated discharge threshold at which Knight Creek becomes disconnected from the Nechako River mainstem. Historical discharge was estimated by summing mean Nechako River discharge measured at Fort Fraser (1930–1949) with mean Nautley River discharge (1950–2024), because historical Nechako flow measurements were collected upstream of the Nautley–Nechako confluence. In contrast, 2025 discharge data were collected at Vanderhoof (blue solid line) and include contributions from both rivers.

PIT Monitoring

PIT Tag Implantation Efficacy

All PIT tags deployed in wild-origin fish in 2025 were implanted by DFO Restoration Biologist Stewart Pearce, RPBio. Stewart gained extensive experience in PIT tagging through stock assessment projects on Vancouver Island from 2017 to 2022. Of the 400 hatchery Chinook Stewart PIT tagged specifically for this study, there was one mortality (0.25%) and five tag rejections (1.25%), so 394 of 400 tags (98.5%) were implanted effectively. As such, it was assumed that the rate of tagging-related mortality and/or tag rejections in wild-origin fish was insignificant and did not influence study results.

PIT Tag Deployment in Wild-Origin Fish – Clear Creek

The PIT-related equipment required for this project is patented and such equipment is manufactured by very few companies – none of which are located in Canada. For this reason, all of the PIT equipment for this project was obtained from Biomark Inc., which is headquartered in Boise, ID. Complications with the Canada Border Services Agency were encountered when importing the equipment from Boise, which delayed the arrival of the shipment and therefore delayed commencement of field activities. A start date of July 1 was desired, however PIT tagging did not commence in Clear Creek until August 8, 2025.

A total of 343 wild-origin fish from nine species were PIT tagged in Clear Creek, which included Chinook salmon (*Oncorhynchus tshawytscha*), rainbow trout (*O. mykiss*), mountain whitefish (*Prosopium williamsoni*), bull trout (*Salvelinus confluentus*), northern pikeminnow (*Ptychocheilus oregonensis*), longnose sucker (*Catostomus catostomus*), redside shiner (*Richardsonius balteatus*), longnose dace (*Rhinichthys cataractae*), and peamouth chub (*Mylocheilus caurinus*). All salmonids that were captured were PIT tagged, while a subsample of other species captured (~10%) were also tagged to broaden knowledge of overall fish usage in Nechako River tributaries in addition to fish passage at BDAs and/or natural beaver dams. Table 2 provides a summary of PIT tag deployments by species, while Figure 2 shows temporal distribution of tags by species.

Table 2: Summary of Passive Integrated Transponder tag deployments by species in Clear Creek, August 8 to September 16, 2025. All salmonids were tagged, while just a subsample of other species were tagged. As such, these numbers represent the total number of salmonids captured but only a portion of other species.

Species	PIT Tag Deployments	Recaptures
Chinook Salmon	162	17
Rainbow Trout	67	5
Mountain Whitefish	13	0
Bull Trout	1	0
Northern Pikeminnow	33	0
Longnose Sucker	31	0
Redside Shiner	30	0
Longnose Dace	4	0
Peamouth Chub	2	0
Total	343	22

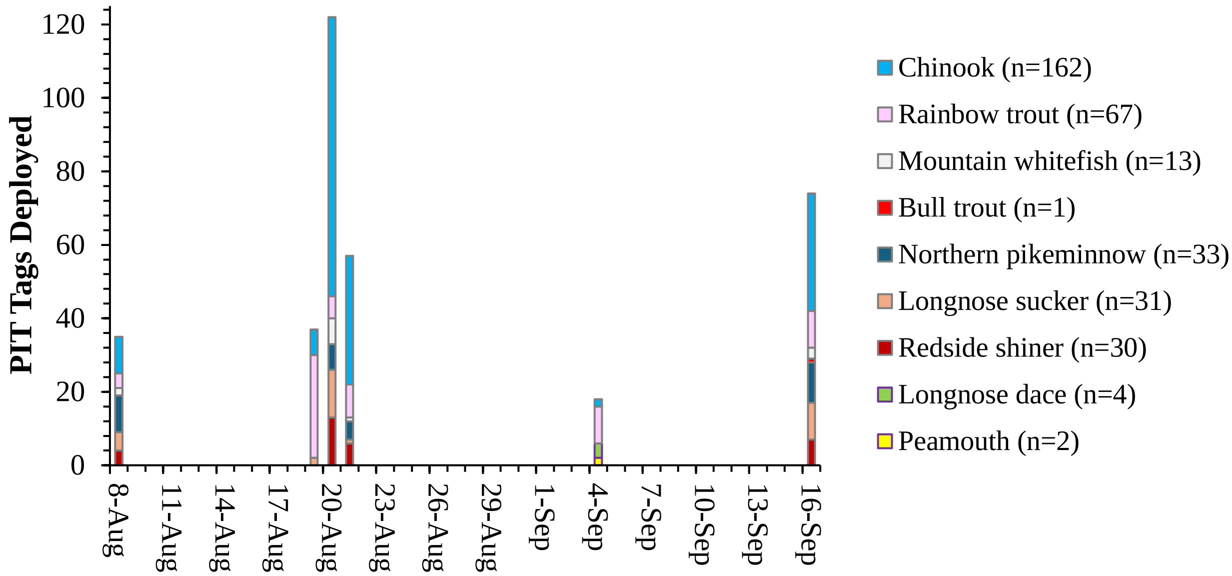


Figure 26: Temporal distribution of PIT tags deployed in 343 wild-origin fish from nine species captured in Clear Creek between August 8 and September 16, 2025.

PIT tagging occurred over five days in five reaches of Clear Creek between August 8 and September 16, 2025. Beach seining was substantially more effective than minnow trapping, with 94 percent of tags deployed from beach seine capture. Landowners denied access to a large section of Clear Creek between Braeside Road (river km 3.0) and just downstream of Highway 27 (river km 9.0). As such, tagging efforts were constrained to areas downstream of Braeside Road or upstream of Highway 27. The majority of PIT tag deployments occurred in the lowermost reaches: river km 0.0 – 0.2 (Confluence Reach) and river km 0.4 – 0.5 (Lower Reach). Additional deployments occurred at river km 1.6 – 1.8 km (Braeside Pumphouse Reach) and river km 3.8 – 3.0 (Braeside Reach); and, upstream of Highway 27 at river km 9.8 – 10.6 (Upper Reach) (Figure 27).

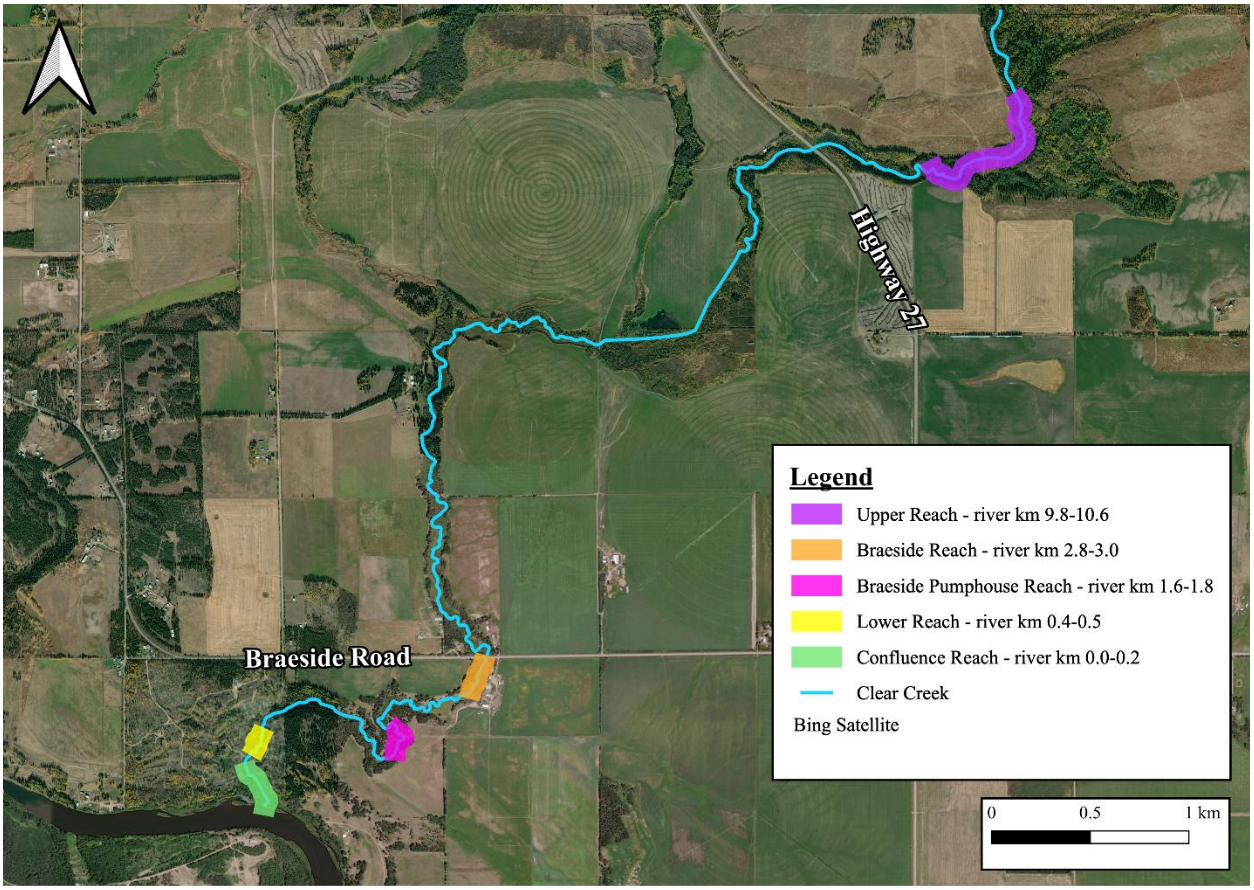


Figure 27: Reaches of Clear Creek where PIT tagging occurred from August 8 to September 16, 2025. Access to much of the creek was constrained by landowner permission, so reaches were primarily selected by accessibility. Bing Satellite image.

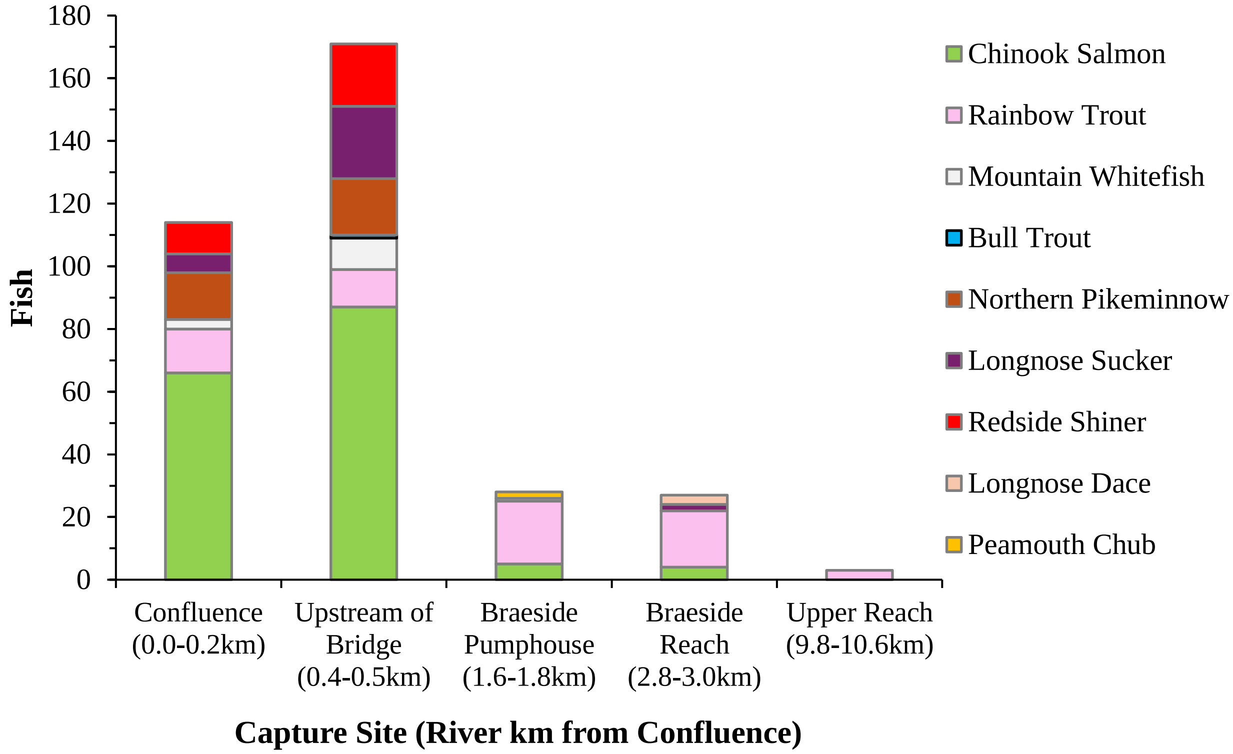


Figure 28: Summary of Passive Integrated Transponder tag deployments by species and site in Clear Creek, August 8 to September 16, 2025. All salmonids that were captured were PIT tagged, but only a portion of other fish species were PIT tagged (~10%); as such, the number of PIT tags deployed in non-salmonids does not reflect total abundance. Distances in brackets on the x-axis represent the distance and extent of each reach from the confluence with the Nechako River.

Fish-Beaver Dam Relationship

Chinook salmon were encountered as far upstream as the outlet of the Braeside Road culvert (river km 3.0). Rainbow trout were encountered throughout the system. As shown in Figure 5 (above) there were 20 active beaver dams in summer 2025. The downstream-most beaver dam was located approximately 700 river meters upstream of the confluence with the Nechako River. Chinook catch per day by beach seine and species richness were greatest downstream of this dam (river km 0.0 – 0.2 and 0.4 – 0.5). Chinook catch per day and species richness were negatively correlated with distance upstream (Chinook catch/day: R^2=0.56; species richness: R^2=0.88) (Figure 29; Figure 30). There was a strong negative correlation between species richness and number of beaver dams (R^2=0.91) (Figure 31). However, catch per day of rainbow trout was the inverse of Chinook and increased with distance upstream (R^2=0.99) (Appendix II).

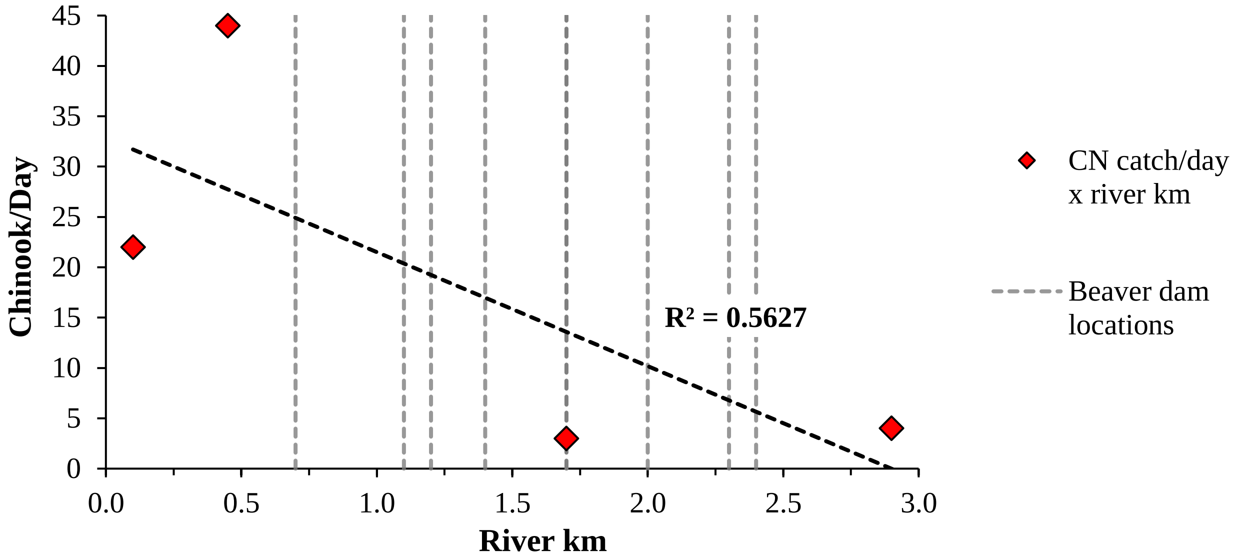


Figure 29: Chinook catch per day by river kilometer (red diamonds) in Clear Creek by beach seine. Vertical grey dashed lines represent natural beaver dam locations by river kilometer in summer 2025. Beach seining was not attempted upstream of Braeside Road (river km 3.0), so distance on the x-axis was reduced for clarity.

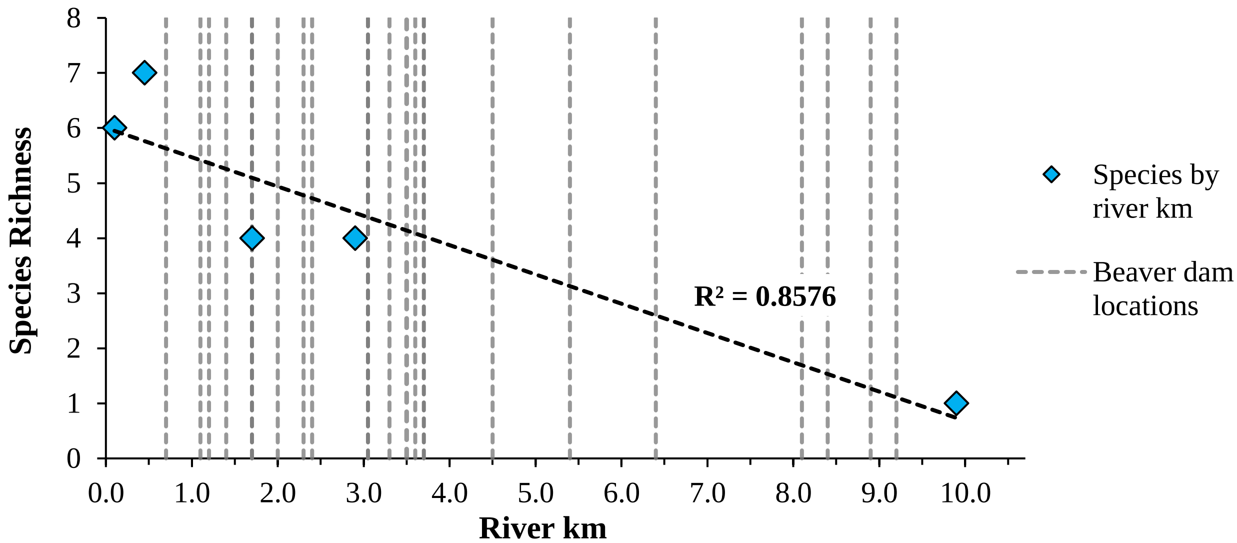


Figure 30: Species richness by river kilometer (blue diamonds) in Clear Creek. Vertical grey dashed lines represent natural beaver dam locations by river kilometer in summer 2025. Fish were captured by beach seine or minnow trap.

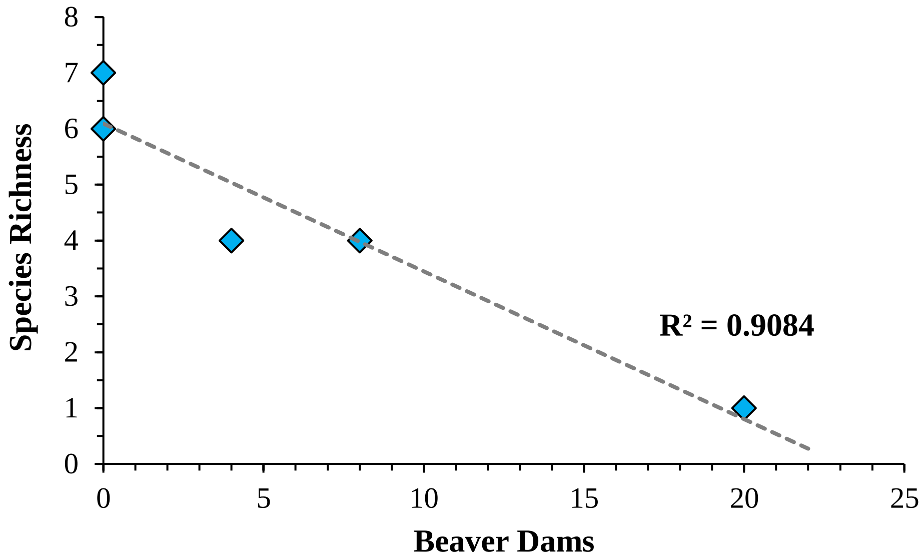


Figure 31: Species richness versus number of beaver dams (blue diamonds) in Clear Creek.

PIT Tag Deployment in Wild-Origin Fish – Knight Creek

As discussed in the section above, arrival of PIT-related equipment was delayed due to issues with importing the equipment from Idaho. Some prospecting for capture sites was conducted in the confluence area and lower reaches of Knight Creek using a beach seine on July 30 (i.e., during the Summer Temperature Management Program). Redside shiner and northern pikeminnow were very abundant throughout this area at that time, however no salmonids were encountered. Furthermore, water temperature was 19.1°C on July 30, which was above the DFO veterinarian-specified threshold of 17.0°C for PIT tagging. As such, PIT tagging was not attempted in the Confluence Reach (river km 0.0 – 0.5) of Knight Creek in 2025.

PIT tagging in Knight Creek commenced in the reaches upstream and downstream of Sackner Road (river km 0.8) on August 7, 2025. Three fish species were encountered, including Chinook salmon, rainbow trout, and longnose sucker. NEWSS salvaged 384 Chinook in addition to 1,000 other fishes in this area in August 2024. However, in 2025, only six Chinook and one rainbow trout were captured in the Upper Sackner Reach (river km 0.8 – 1.2), while 19 Chinook and 17 longnose suckers were captured around the culvert under the road (river km 0.8). No Chinook were encountered in Lower Sackner Reach (river km 0.6 – 0.8) (Figure 32). Most of Knight Creek was subsurface at this time and all fish captured were stranded in isolated pools.

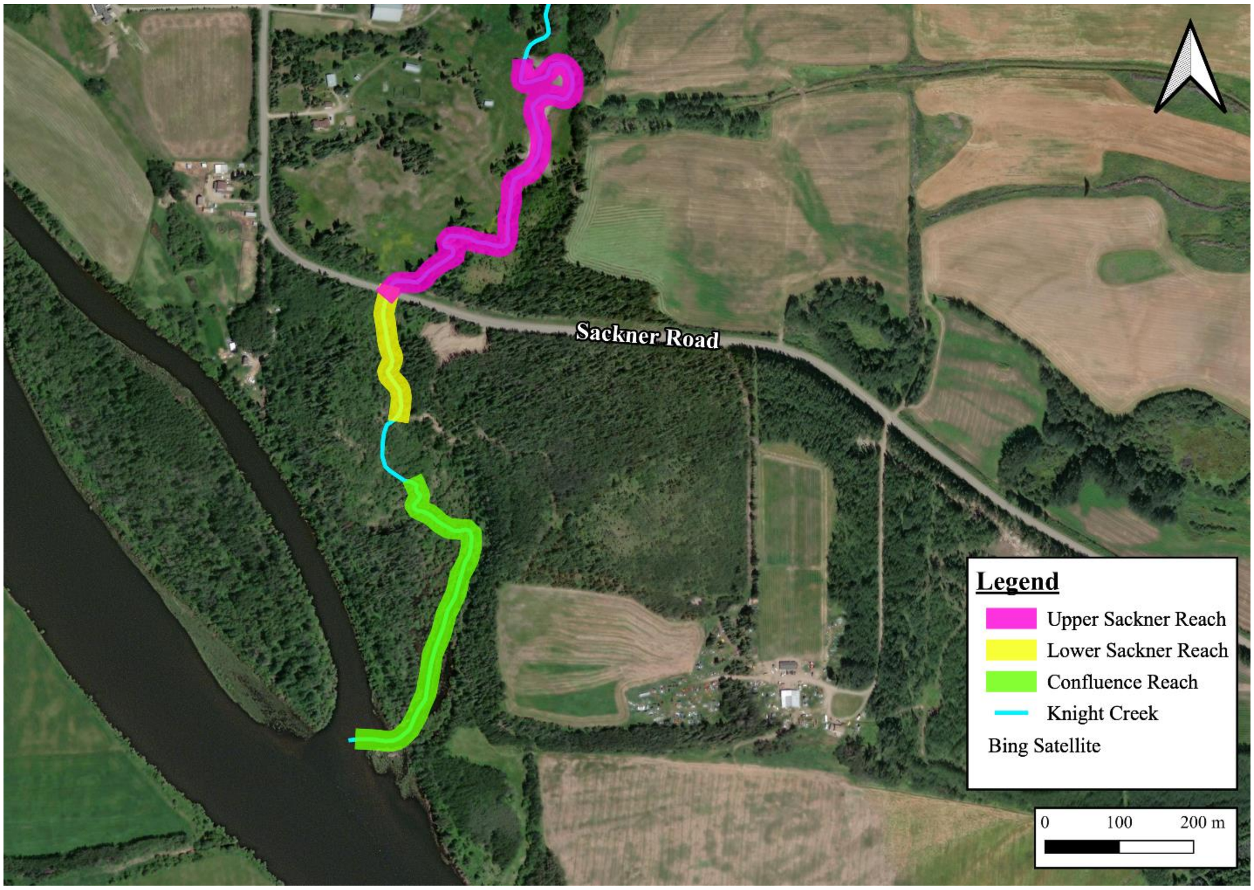


Figure 32: Reaches of Knight Creek that were accessible for PIT tagging. PIT tagging occurred at Upper and Lower Sackner Reaches on August 7, 2025. Bing Satellite image.

Water temperature was 12.0°C prior to commencement of tagging operations; however, 100 percent of salmonids (25 Chinook salmon; 1 rainbow trout) and 2 of 17 longnose suckers did not survive the PIT tagging process. Following the discovery that the fish were not recovering from the anaesthetic, water quality was again measured with a YSI probe and it was discovered that dissolved oxygen concentrations (DO) in the pools the fish were captured from was less than 3.0 mg/L, which is far below the optimal 8.0 mg/L threshold for salmonids and stress in salmonids increases when DO falls below 6.0 mg/L (Carter 2005; Carter 2008). For this reason, PIT tagging was suspended at these reaches of Knight Creek until conditions improved, which did not occur in 2025 before winter . Following this unfortunate episode, DO concentrations were considered in addition to water temperature during PIT tagging operations.

PIT Tagged Hatchery-Origin Chinook – Clear Creek

A total of 1,488 hatchery-origin PIT tagged Chinook were released into Clear Creek at three sites on August 23, 2025. Four-hundred eighty-nine Chinook were released in the Upper Reach (river km 10.6), 495 Chinook were released at the Highway 27 crossing (river km 9.0), and 504 Chinook were released at the Braeside Road crossing (river km 3.0) (Figure 33).

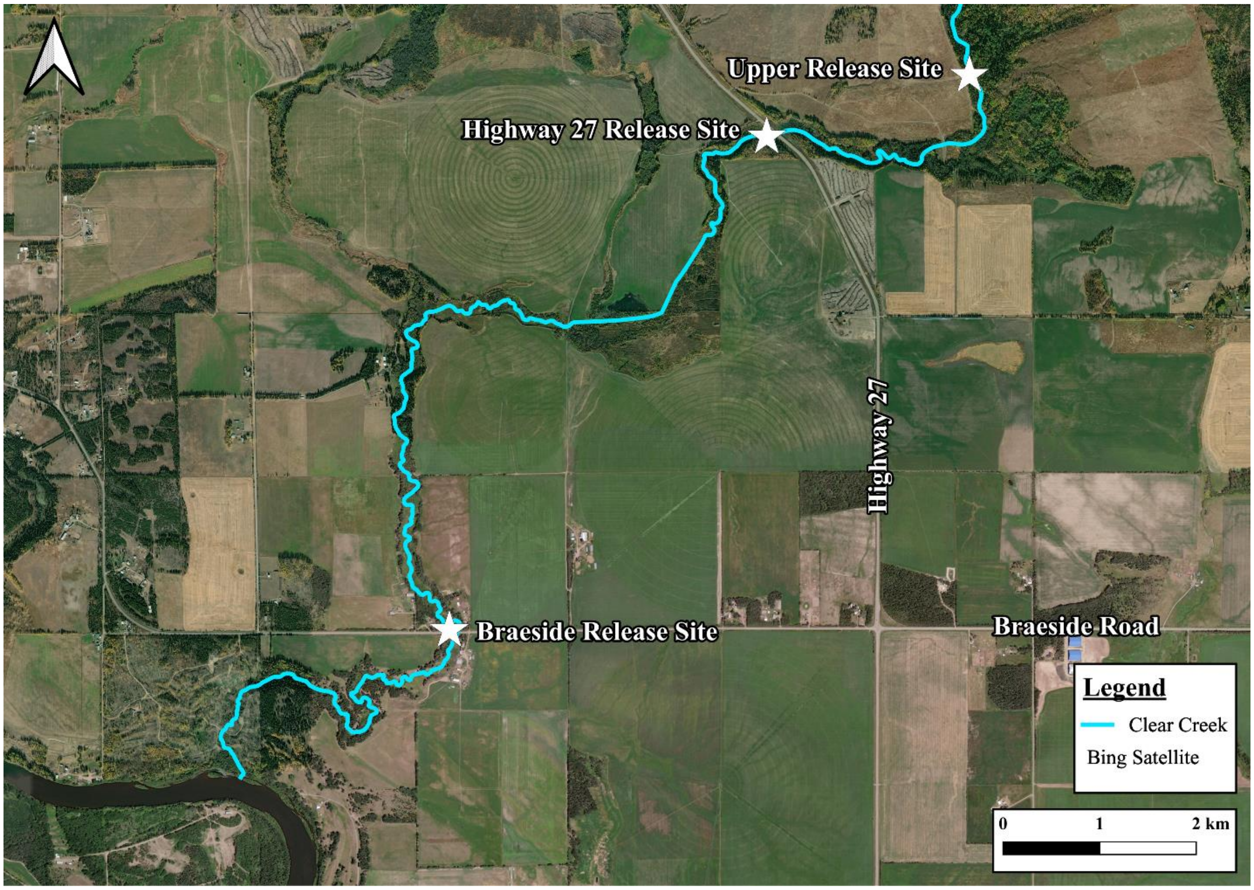


Figure 33: Release sites of hatchery-origin Chinook into Clear Creek on August 23, 2025. Bing Satellite image.

PIT Tagged Hatchery-Origin Chinook – Knight Creek

The original intent of this study was to release 1,000 hatchery-origin PIT tagged Chinook into each of Clear and Knight Creeks. However, conditions in Knight Creek were poor in summer 2025 due to localized impacts in addition to a persistent regional drought. Discharge in Knight Creek was nil by August and the watercourse was reduced to a series of isolated pools, many of which had poor dissolved oxygen concentrations (typically < 3.0 mg/L). As such, a larger portion of PIT tagged hatchery-origin Chinook were released into Clear Creek (n=1,488) than Knight Creek (n=489). A large pond with reasonable dissolved oxygen concentration (7.9 mg/L) was found at the Gudbranson Road crossing, so Chinook were released into this pond with the objective of assessing overwinter survival and outmigration success from such an isolated pond the following spring (i.e., to simulate conditions stranded Chinook might encounter in a BDA pond). The release into Knight Creek also occurred on August 23 (i.e., same day as Clear Creek releases) (Figure 34).

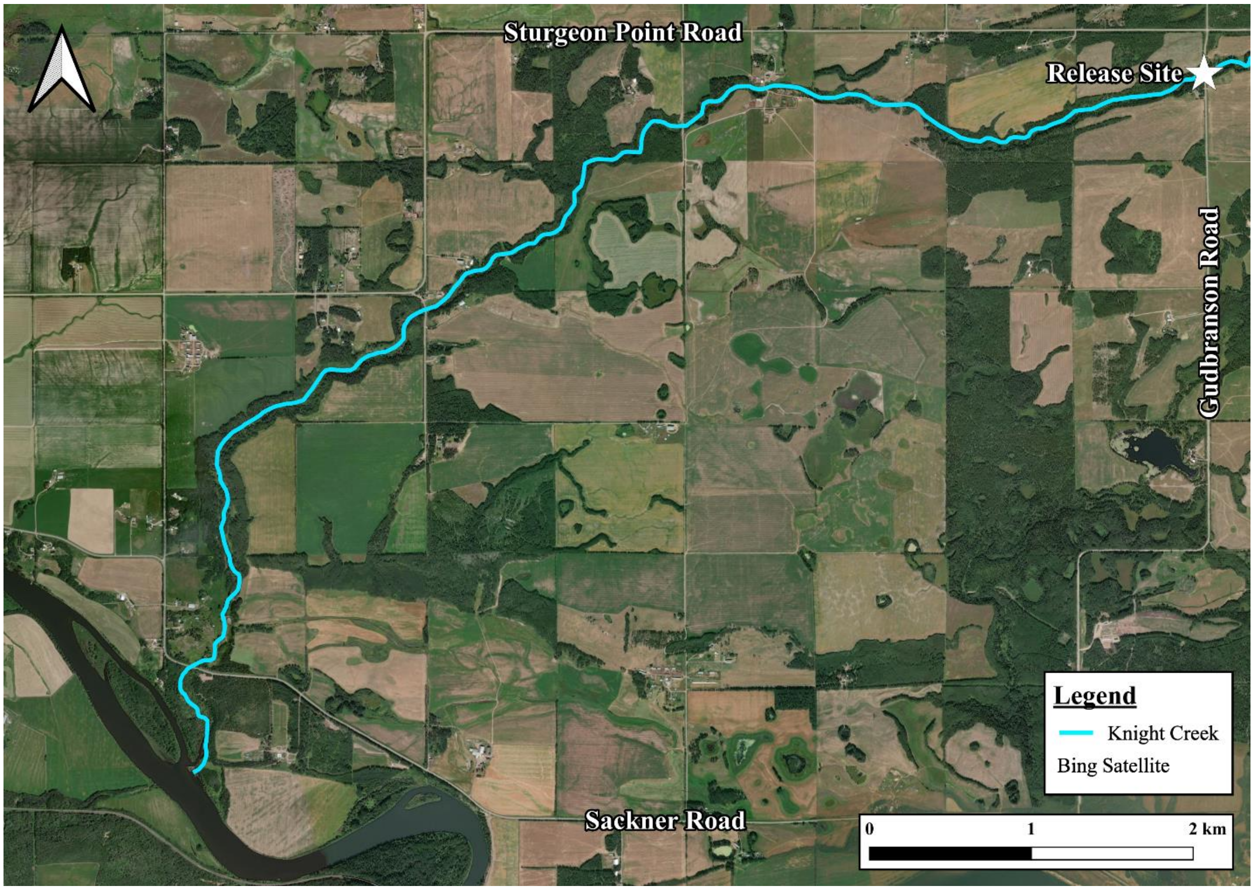


Figure 34: Release site of hatchery-origin Chinook salmon into Knight Creek on August 23, 2025. Bing Satellite image.

Salmonid Size

Nose-fork length (NFL) of Chinook salmon in Clear Creek was smaller than all other salmonids encountered (mean ± SD: 70.3 ± 14.4 mm; n=162). Mountain whitefish (76.2 ± 6.4 mm; n=13), rainbow trout (119.7 ± 73.1 mm; n=67), and bull trout (296.0 mm; n=1) were larger than Chinook on average (Appendix II).

Mean NFL of juvenile Chinook captured between August 19 – 21 differed significantly among reaches (one-way ANOVA: $F_{2,115} = 29.63$, $p < 0.01$). Post-hoc comparisons using Tukey's HSD test indicated that fish at Braeside Pumphouse Reach and Braeside Reach (river km 1.6–1.8 & 2.8–3.0) were significantly larger (mean ± SD: 104.0 ± 38.1 mm; n=7) than those at both the Confluence Reach (river km 0.0–0.2; 69.1 ± 9.7 mm; n=35; $p < 0.01$) and the Lower Reach (river km 0.4–0.5; 66.4 ± 8.7 mm; n=76; $p < 0.01$). No significant difference in Chinook size was detected between the Confluence Reach and Lower Reach ($p = 0.54$) (Figure 35). Only fish that were PIT tagged between August 19 – 21 were used for this particular analysis to reduce the influence of growth over time on this result.

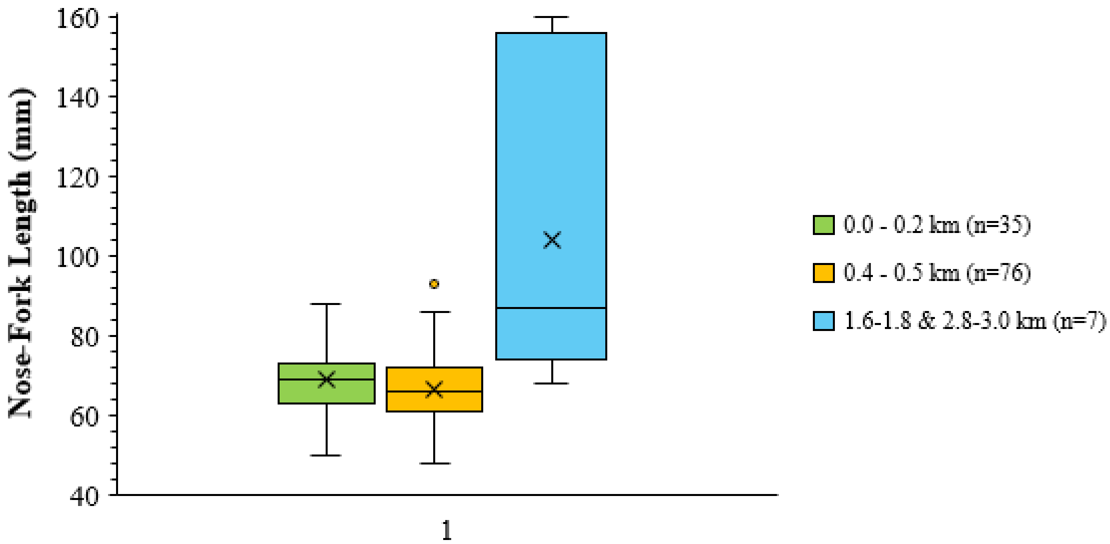


Figure 35: Nose-fork length (mm) of Chinook salmon captured and PIT tagged in three reaches of Clear Creek between August 19 and 21, 2025: river km 0.0 – 0.2 (green; n=35), 0.4 – 0.5 (orange; n=75), and 1.6 – 1.8 & 2.8 – 3.0 (blue; n=7). Fish captured on other dates were excluded from this analysis to reduce the influence of growth over time on this result.

Chinook salmon captured in the lower reaches of Knight Creek (river km 0.8 – 1.2) on August 7 were significantly larger (mean ± SD: 65.8 ± 7.7 mm; n = 25) than Chinook captured in the lower reaches of Clear Creek (river km 0.0 – 0.3 and 0.5 – 0.6) on August 8 (58.1 ± 7.3 mm; n = 10) (Welch's two-sample *t*-test: $t = -2.77$; df =18; $p = 0.01$) (Figure 36). Chinook captured in Clear Creek at later dates were excluded from this analysis to reduce the influence of growth over time on this result.

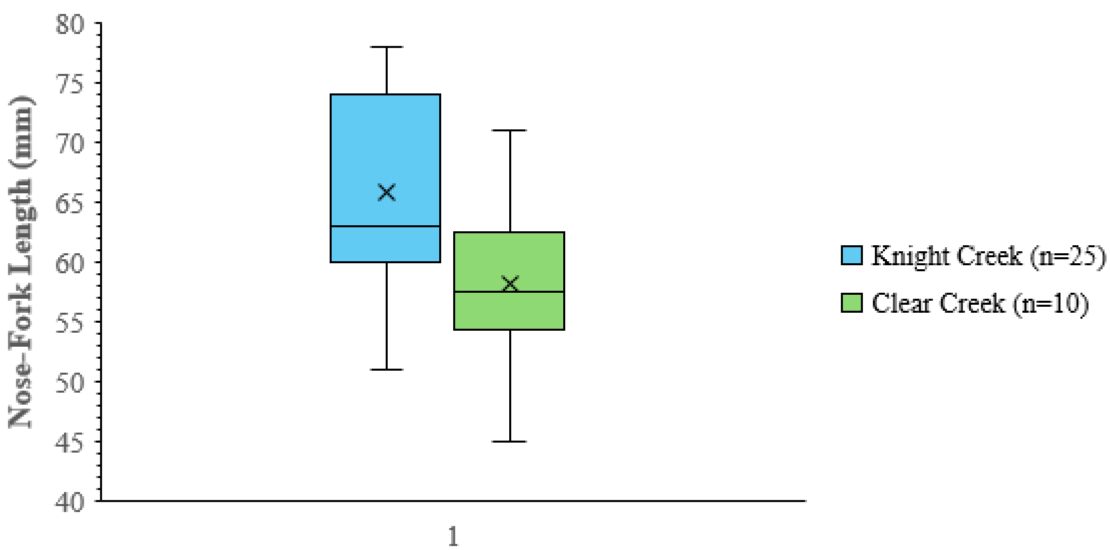


Figure 36: Nose-fork length (mm) of Chinook salmon captured and PIT tagged in lower reaches of Knight Creek (river km 0.8 – 1.2; n = 25) on August 7 (blue) versus the lower reaches of Clear Creek (river km 0.0 – 0.2 and 0.4 – 0.5; n = 10) on August 8 (green).

Nose-fork length of rainbow trout ranged from 149.3 ± 83.1 mm (mean ± SD; n=12) in the Lower Reach (river km 0.4 – 0.5) to 96.7 ± 10.5 mm (n=3) in the Upper Reach (river km 9.9 – 10.6). Rainbow trout did not differ significantly in size between any of the capture sites (one-way ANOVA: $F_{3,63} = 1.83$; $p = 0.15$) (Appendix II).

PIT Tag Detections

Clear Creek – Confluence Detection Array (river km 0.0)

The confluence site was monitored continuously from July 28 to December 16, 2025. The array functioned without any technical issues between July 28 and November 28. However, after November 28, monitoring was intermittent due to reduced solar charging capacity as a result of shorter daylight period and/or periodic snowfall that obscured the solar panels. Based on these results, it is expected that the array should function continuously again after early February 2026 (i.e., when daylight is again sufficient for solar charging to meet power demand).

Between August 8 and October 22, 104 of 162 PIT tagged wild-origin Chinook (64.2%) were detected at the confluence site. Some of these Chinook milled about the site for a brief period of time, but eventually 87 fish were conclusively detected moving downstream and therefore were assumed to have dispersed from Clear Creek. The direction of travel of an additional 14 Chinook was inconclusive, but nine of these fish were last detected on the downstream-most antenna, so it was assumed that they also dispersed from the system. Five Chinook were last detected on the uppermost of the two antennas at the site, which suggested they remained in the system, while an additional three Chinook were last detected moving back upstream past the site. In total, these detection data indicated 66 of 162 wild-origin Chinook (40.7%) overwintered in Clear Creek or did not survive, whereas 96 of 162 wild-origin Chinook (59.3%) dispersed to the Nechako River mainstem. Ten of 504 hatchery-origin Chinook (1.9%) from Braeside Road were detected moving downstream past the confluence site; none of these fish were detected moving back upstream. No other hatchery-origin Chinook were detected at the confluence site, which indicated that 1,478 of 1,488 hatchery-origin Chinook (99.3%) overwintered in Clear Creek or did not survive. Peak downstream movement occurred on September 20. The absence of detections between October 23 and December 16 indicated dispersal of juveniles from Clear Creek was complete by October 22 (Figure 37; Figure 38).

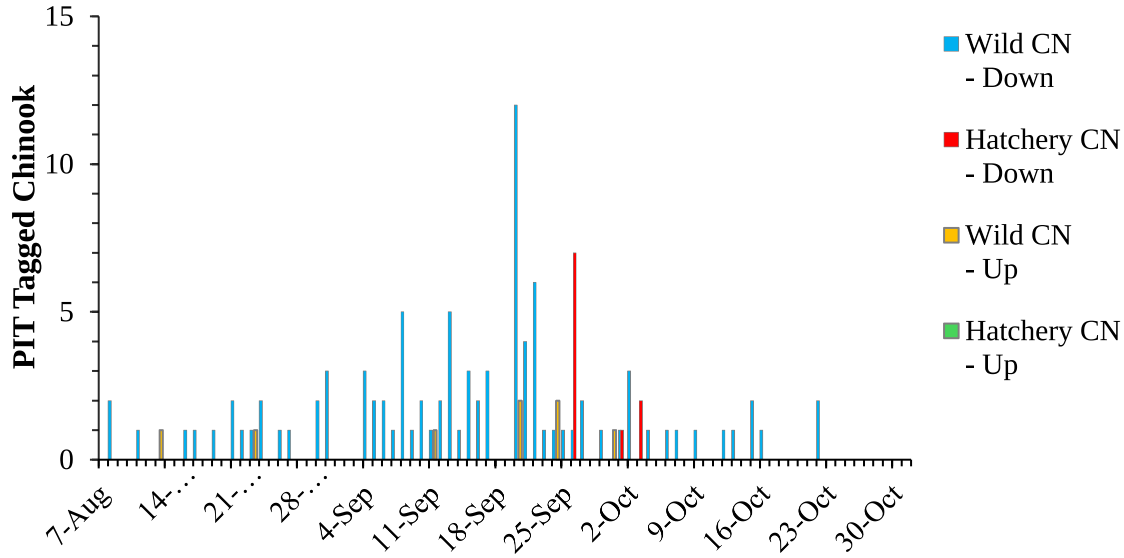


Figure 37: Daily detections of PIT tagged wild-origin and hatchery-origin Chinook salmon at the Clear Creek confluence site from August 8 to October 31, 2025. Monitoring continued through December 16; however, no detections occurred after October 31, so the date range shown was reduced for clarity.

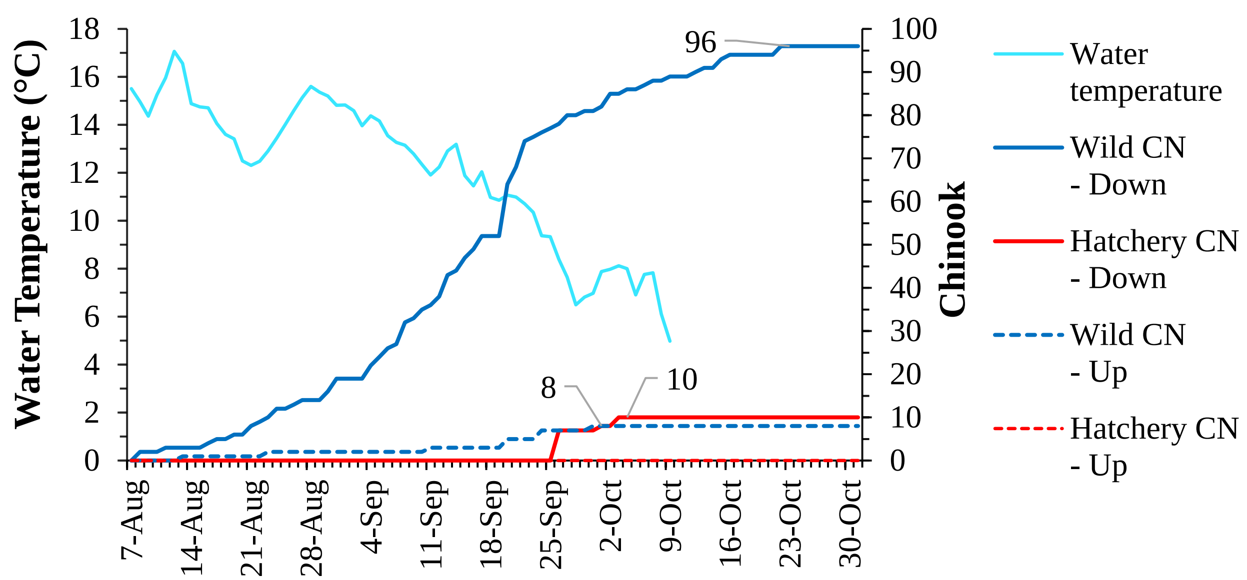


Figure 38: Cumulative detections of PIT tagged Chinook salmon at the Clear Creek confluence site from August 8 to October 31, 2025, in relation to water temperature (bright blue line). Downstream-bound wild-origin and hatchery-origin juvenile Chinook are represented by solid dark blue and red lines, respectively, while upstream-bound wild-origin and hatchery-origin juvenile Chinook are represented by dashed dark blue and red lines, respectively. Monitoring continued through December 16; however, no detections occurred after October 31, so the date range shown was reduced for clarity.

Chinook dispersal from Clear Creek was strongly correlated with decreasing water temperature (R^2=0.87) (Figure 39).

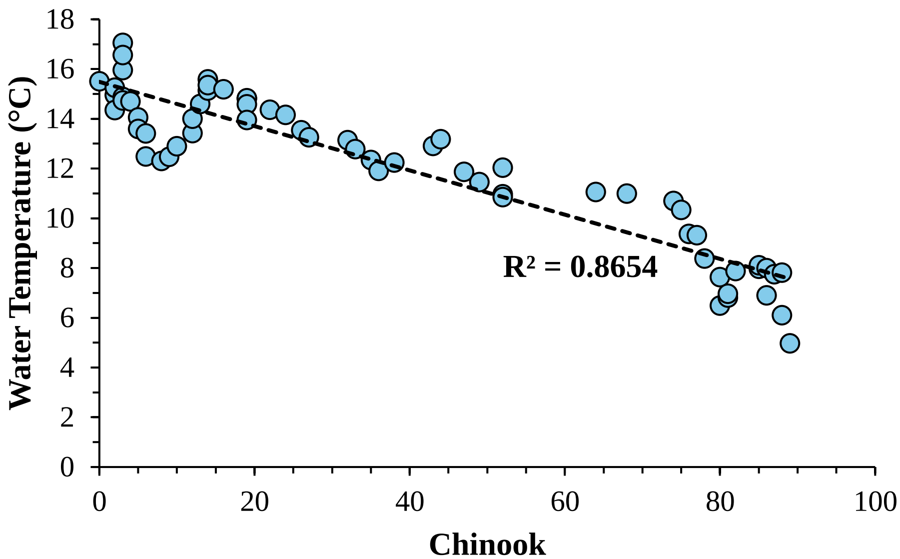


Figure 39: Correlation analysis between the number of PIT tagged juvenile Chinook that were detected moving downstream past the detection array at the Clear Creek confluence versus water temperature in Clear Creek.

Of the 104 wild-origin Chinook that were detected at the Confluence Detection Array, 52 (50.0%) were tagged in the Confluence Reach (river km 0.0 – 0.2), 49 (47.1%) were tagged in the Lower Reach (river km 0.4 – 0.5), one (1.0%) was tagged at the Braeside Pumphouse Reach (river km 1.6 – 1.8), and two (1.9%) were tagged at the Braeside Reach (river km 2.8 – 3.0). The proportion of Chinook that dispersed from Clear Creek relative to the number PIT tagged in each reach is shown in Figure 40.

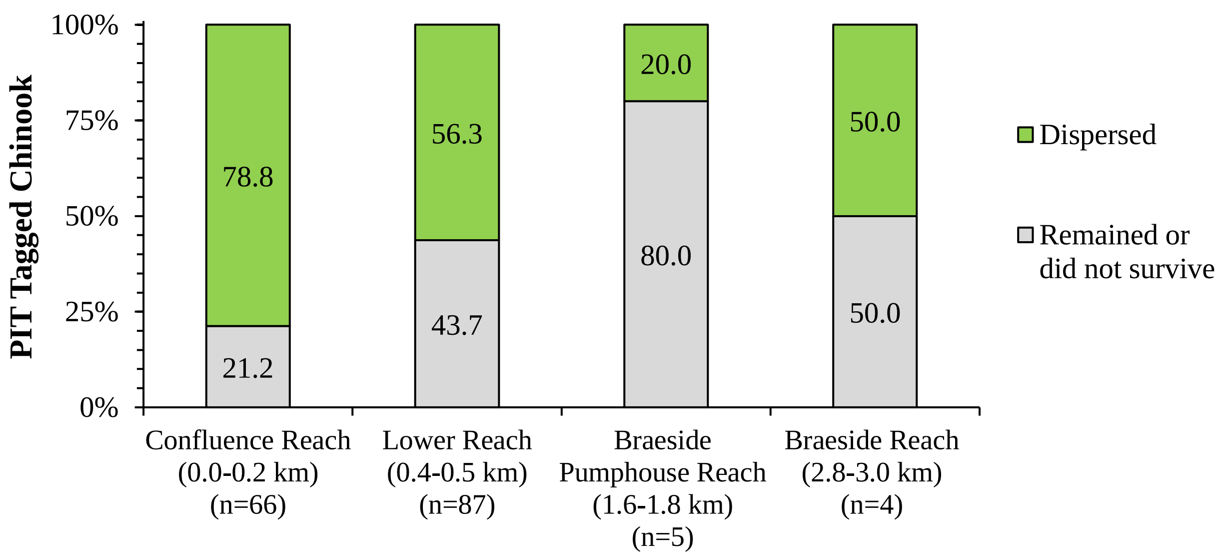


Figure 40: Proportion of PIT tagged wild-origin Chinook salmon that dispersed from Clear Creek, relative to the location where they were tagged.

Wild-origin Chinook spent an average of 20.3 days (range: 0 – 63 days) in Clear Creek after being PIT tagged before they dispersed to the Nechako River mainstem. Chinook that were PIT tagged in the Confluence Reach (river km 0.0 – 0.2) remained for the shortest period of time after being tagged (18.4 days; range: 0 – 60 days), while Chinook that were PIT tagged in the Lower Reach (river km 0.4 – 0.5), Braeside Pumphouse Reach (river km 1.6 – 1.8), and Braeside Reach (river km 2.8 – 3.0), remained for an average of 22.0 days (range: 1 – 63 days), 27.0 days (range: 0 days), and 24.5 days (range: 16 – 33 days) after being PIT tagged, respectively (Figure 41).

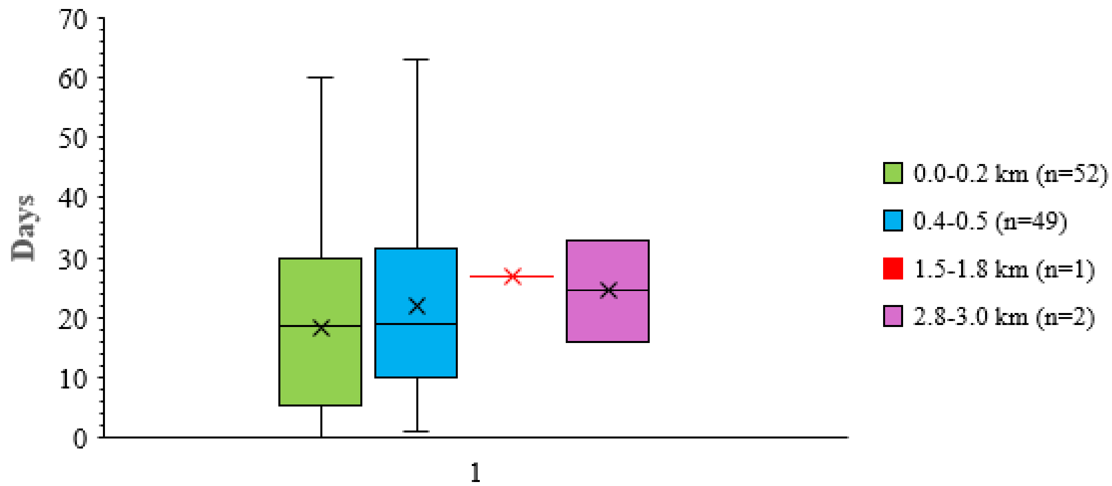


Figure 41: Duration (days) that wild-origin juvenile Chinook salmon remained in Clear Creek after they were PIT tagged, relative to the location where they were tagged.

There was not a significant size difference between juvenile Chinook that dispersed from Clear Creek (mean ± SD: 71.3 ± 15.8 mm; n=96) and those that remained or did not survive (68.5 ± 11.5 mm; n=58) (Welch's two-sample *t*-test: $t = 1.30$; df =149; $p = 0.19$) (Figure 42).

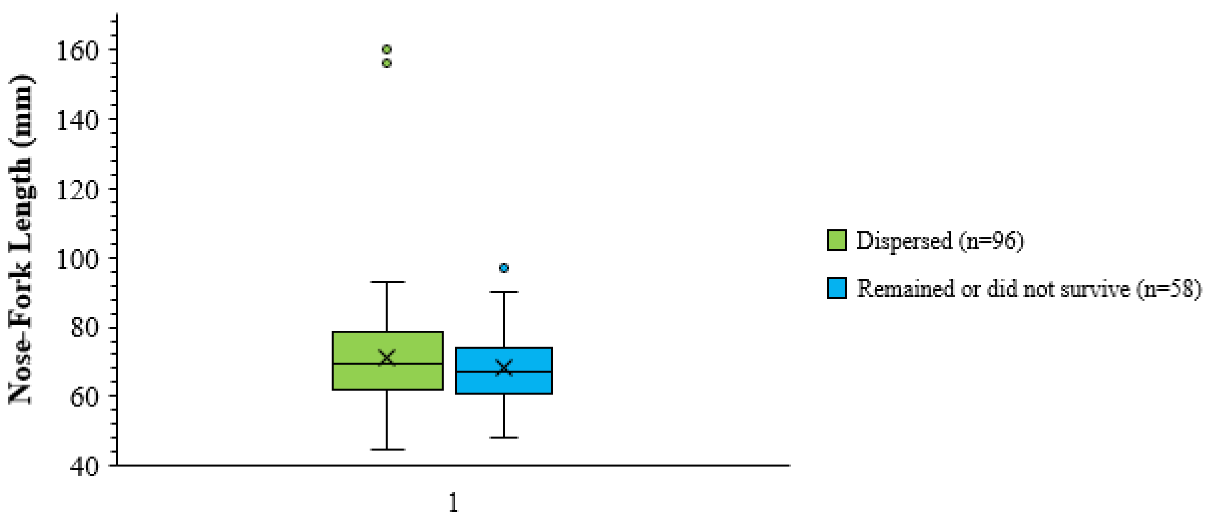


Figure 42: Nose-fork length (mm) of PIT tagged juvenile Chinook salmon that dispersed from Clear Creek (green; n=96) versus those that remained in Clear Creek or did not survive (blue; n=58).

Three salmonid species were PIT tagged in Clear Creek in addition to Chinook salmon. Downstream movement of these fish was similar in timing to Chinook salmon and also correlated to decreasing water temperature (R^2=0.89). Seventeen of 67 rainbow trout (25.4%), 8 of 13 mountain whitefish (61.5%), 1 of 1 bull trout (100%) were detected at the Confluence Detection Array as they dispersed from Clear Creek (Figure 43). Rainbow trout were the only species that were detected moving after October 22 – two individuals moved downstream past the site on November 21 and 23. Rainbow trout were also the only one of these species detected moving back upstream; three individuals were detected travelling upstream past the Confluence Site on August 21, September 7, and October 1.

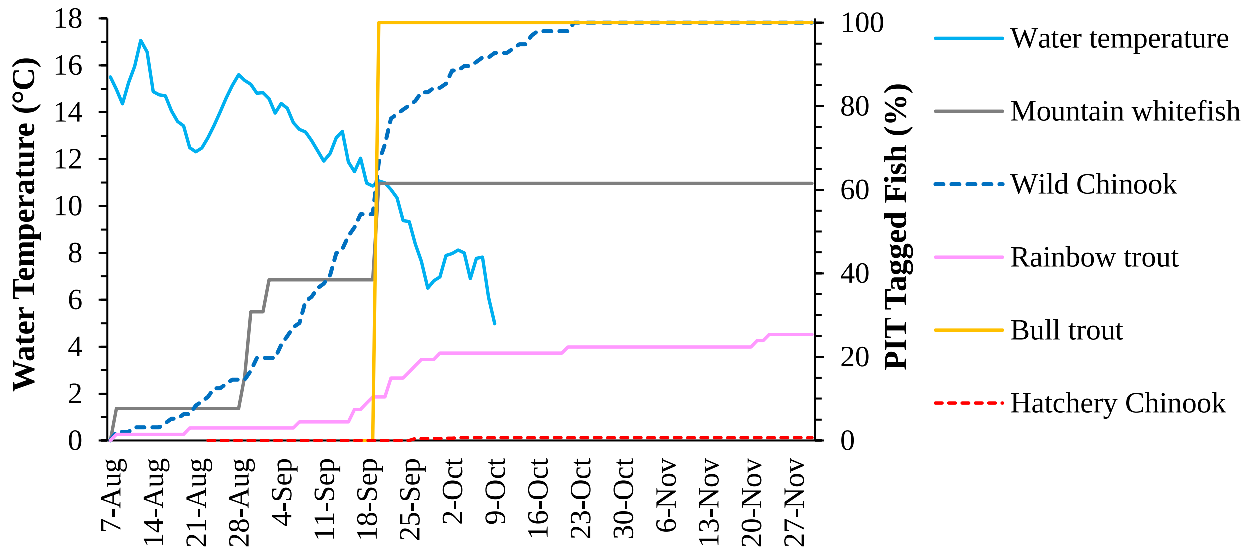


Figure 43: Cumulative proportion of all PIT tagged salmonids that dispersed from Clear Creek between August 8 and November 30, 2025, in relation to water temperature (solid blue line). Three species of salmonids were tagged in addition to Chinook salmon (blue and red dashed lines): Bull trout (orange solid line), mountain whitefish (grey solid line), and rainbow trout (pink solid line). Monitoring continued through December 16; however, no detections occurred after November 23, so the date range shown was reduced for clarity.

Clear Creek – Braeside Detection Array (river km 2.9)

The Braeside Detection Array functioned nearly continuously from July 30 to December 16. As with the Confluence Detection Array, shorter daylight hours and obscuration of the solar panels by snow affected performance starting in late November. A technical glitch occurred on September 19, when a 12V battery that was mislabeled by the manufacturer as 24V (i.e., the appropriate voltage for the PIT detection system) was added to the system to boost capacity of the power reserve in preparation for decreased solar charging output as a result of shorter daylight period. The system operated normally at first, but then crashed due to insufficient voltage and remained off until the next site visit on October 1. As such, no data were collected during this period. Furthermore, the entire system was wiped out by a torrent of water that rushed through the site when a beaver dam in the Braeside Road culvert just upstream (<100 m from the detection array) was breached by highway maintenance crews, sometime during this same period. This torrent of water blew the antennas out of position and swamped the electronics. Fortunately, due to the power outage from the battery mishap, the damage to the electronics was minimal because there was no power to the system when the event occurred.

Despite these mishaps, the Braeside Detection Array operated continuously for 77 of 89 days (87% of the time period) before decreased daylight period and snowfall affected performance due to reduced solar charging output. During this period, the only fish detected at this site were fish that were tagged within the Braeside Reach and/or hatchery-origin Chinook that were released at the site – no PIT tagged fish of any species from reaches downstream or upstream of the site were detected. Hatchery Chinook were actually a nuisance – many individuals did not disperse far and loitered around the antennas which caused a massive accumulation of redundant detections that exceeded the memory capacity of the reader boards and caused the oldest detections to be overwritten when the memory storage was exceeded. This issue was rectified by setting the reader boards to ignore redundant tag codes over a specified period of time; 30 minutes was selected and worked well to reduce the rate of memory consumption.

Clear Creek – Upper Detection Array (river km 10.0)

The Upper Detection Array functioned continuously from August 12 until December 16, with the exception of the same solar charging-related issues as the other sites that started to occur in late November (i.e., discussed in previous sections). No PIT tagged fish of any species from reaches downstream were detected at the site. Hatchery-origin Chinook that were released approximately 0.6 km upstream were quick to disperse downstream past the site, with the first fish arriving at the site approximately 10 hours after their release. Similar to the Braeside Detection Array however, many of these hatchery Chinook loitered around the two antennas, which caused the same memory capacity issues as the Braeside site until the reader board settings were adjusted (i.e., see details in "*Braeside Detection Array*" section above).

Knight Creek

By the time PIT detection arrays were installed in Knight Creek, flow was nil and the creek was reduced to a series of isolated pools. As such, these arrays were not operated and there were no detection data to report for 2025. These arrays will be operated beginning in early March 2026, to monitor dispersal of hatchery-origin Chinook that were released in a pond at Gudbranson Road.

Chinook Dispersal Timing and Nechako River Flow Management

Dispersal of Chinook from Clear Creek began August 8 and concluded October 22; peak dispersal occurred on September 20. Knight Creek was disconnected from the Nechako River mainstem on August 28, when Nechako River discharge declined to less than 85 m^3/s. It was assumed that dispersal timing of juvenile Chinook from Clear Creek was representative of Chinook in other non-natal rearing tributaries in the Nechako River watershed. As such, timing of dispersal indicated that fewer than 15 percent of juvenile Chinook could have dispersed from Knight Creek, due to dysconnectivity of the creek with the Nechako River mainstem as a result of flow management, whereas pre-impoundment flow data indicated that Knight Creek remained connected throughout the dispersal period (Figure 44).

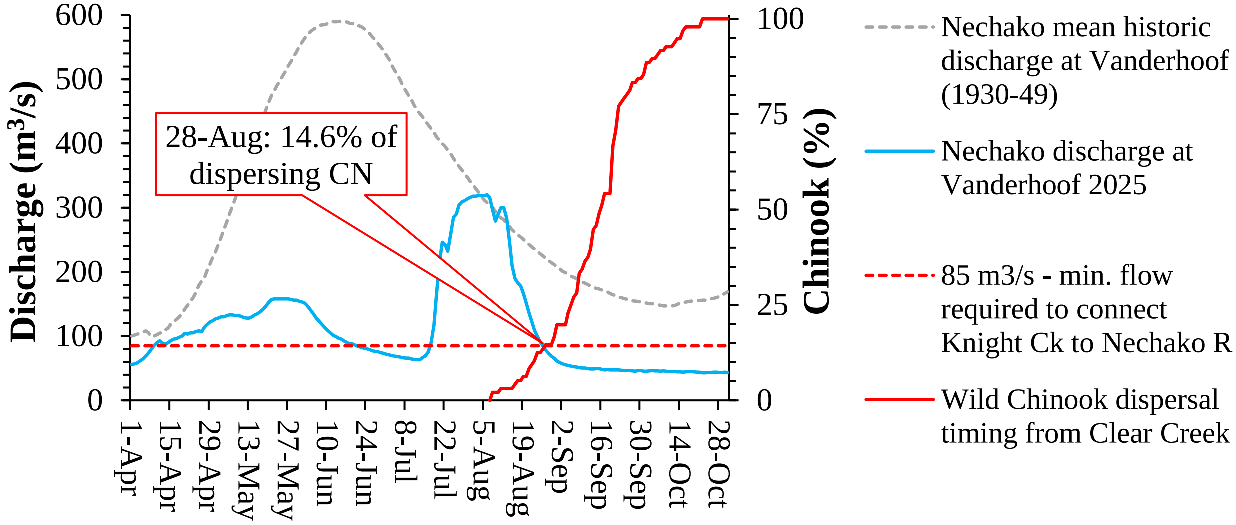


Figure 44: Dispersal timing of juvenile Chinook salmon from Clear Creek (solid red line) relative to the connectivity threshold of Knight Creek (85 m^3/s; dashed red line) and Nechako River flow in 2025 (blue solid line). Grey dashed line represents mean discharge prior to impoundment (Water Survey of Canada 2025).

Discussion

Clear Creek remained connected to the Nechako River mainstem throughout the 2025 summer and fall period due to consistent, spring-fed flow and the channel morphology at the Clear Creek-Nechako River confluence. These attributes resulted in Clear Creek being an optimal control site for this study. Beavers were far more active in the Clear Creek watershed than previously believed, so there was less unobstructed channel length than was desired; however, beaver dams in Clear Creek became an inadvertent surrogate for the study of fish passage around Beaver Dam Analogues (BDAs), because persistent drought continued to plague the region and rendered Knight Creek dysfunctional by August 2025, such that passage at BDAs could not be studied as intended.

The reason that juvenile Chinook salmon are attracted to tributary streams of the Nechako River for rearing is not totally obvious, but there are several possibilities. Temperature refugia (i.e., cooler water during summer), food availability, and cover from predation may all be reasons driving this behaviour. Whatever the reasons, non-natal stream rearing appears to have provided a selective advantage historically, which is why juvenile Chinook continue this behaviour despite the degraded condition of many Nechako River tributaries today. Results at the time of this report were incomplete – forthcoming results of monitoring at Clear and Knight Creeks will continue to generate valuable information about non-natal tributary usage by juvenile Chinook, including whether survival rates vary between functional and degraded creeks, or between reaches within these creeks themselves (e.g., upstream or downstream of BDAs or beaver dams). Gathering this information is a necessary step to inform restoration strategies, particularly with respect to implementation of BDAs. Qualification of non-natal rearing tributaries and quantification of juvenile Chinook within these tributaries is also needed across the Nechako River watershed to better understand whether stranding and subsequent mortality in degraded and/or seasonally disconnected streams is impacting survival of a significant portion of the juvenile population and therefore limiting productivity of the Nechako River Chinook salmon population overall.

Fishing success and species richness declined with increasing distance upstream, which indicated that beaver dams were an impediment to upstream passage of fish, including juvenile Chinook. Furthermore, Chinook captured upstream of beaver dams were larger-bodied. This trend was evident in Knight Creek as well, because there was a beaver dam downstream of the reach where the fish were captured. Whether beaver dams were a selective size barrier (i.e., only larger-bodied fish were capable of ascending dams) or whether juvenile Chinook upstream of dams benefited from reduced competition and therefore grew at a faster rate was unknown. Increasing the frequency of fishing effort in 2026 and the number of capture locations spatially, in addition to continued monitoring of fish movement via PIT tag detections, will continue to improve understanding of fish-beaver dam relationships; this information should also be applicable to BDAs. These interim results pose several questions for habitat restoration and Nechako River Chinook recovery with respect to beaver dams and Chinook productivity, which likely can be answered in future years with continued study. These questions include but are not limited to: are beaver dams in non-natal tributaries limiting Chinook rearing productivity by limiting the amount of available non-natal stream rearing habitat, thereby limiting carrying capacity of these streams? Or, are beaver dams necessary to keep at least some amount of tributary channels wetted throughout the year? Although preliminary results show Chinook are less abundant upstream of dams, might beaver dams provide a competitive advantage for these fish by providing them the space and resources to grow larger prior to their outmigration to sea? And, what is the best angle of approach from a restoration standpoint: more beavers and BDAs, fewer beavers and beaver dams, or a mix depending on site characteristics? A glaring paradox also exists with respect to ephemeral streams: if there are no beavers or BDAs to retain water, they are dysfunctional as fish habitat; with that in mind, should installation of BDAs in such streams carry on without regard for fish passage because without BDAs there will be no fish regardless? Whatever the case, restoration should focus on the option that results in greatest juvenile Chinook output, which ultimately should result in increased adult spawner recruitment. Answering such questions and developing such targeted restoration strategies is not out of reach – it is absolutely possible by monitoring PIT tagged Chinook when they return as adults through installation of PIT detection arrays in the Nechako River mainstem.

Rainbow trout were the exception to the fish passage-beaver dam relationship. Abundance of rainbow trout actually increased with distance upstream and their size was consistent between reaches. Fewer rainbows dispersed from Clear Creek in the fall compared to Chinook. These results indicated that the majority of rainbow trout were full-time residents of tributaries and have adapted well to coexisting with beavers. These results are important because they highlight the fact that the presence of certain salmonids upstream of beaver dams does not necessarily mean these areas are accessible to all salmonids.

Results of fish passage around beaver dams in Clear Creek pose a paradox with respect to fish habitat and BDAs as a restoration tool for Chinook salmon habitat restoration. In the case of Knight Creek, fish habitat will not exist without functioning BDAs and/or beaver dams to retain water. There are a myriad of benefits to retaining water on the landscape – results to date already show that rainbow trout is a species that is poised to benefit from BDAs. However, benefits of BDAs for juvenile Chinook are less apparent because beaver dams appear to substantially restrict passage of Chinook to areas upstream. As such, implementation of BDAs needs to be carefully strategized for them to be a viable habitat restoration option for Chinook salmon. Perhaps extensive BDA implementation in headwater areas would benefit Chinook by slowing the movement of water from the landscape while leaving lower tributary reaches accessible; or, perhaps purposefully prohibiting Chinook entry to dysfunctional tributaries by constructing large, impassible BDAs in the lowermost reaches should be considered to reduce risk of stranding-related mortality (i.e., force the fish to go elsewhere to have a better chance at survival). Alternatively, integration of fish passage systems with BDAs might be necessary (i.e., fish ladders or similar devices), but long-term maintenance and operation of such structures is a concern. In its current condition, Knight Creek appears to be killing Chinook on an annual basis due to stranding, either through physical drying of the stream bed and/or through extremely low dissolved oxygen concentration in most of the isolated pools after flow recedes. Some form of mitigation needs to occur at Knight Creek to reduce stranding-related mortality until the stream is restored. Restoration is a process that will take time and BDAs are a necessary tool for restoration, but how BDAs are implemented with respect to juvenile Chinook requires careful consideration.

Movements of juvenile Chinook salmon are known to be highly synchronous and influenced by temperature (Sykes *et al.* 2009). As such, it is reasonable to assume that dispersal of juvenile Chinook from non-natal rearing tributaries, particularly within the Nechako River watershed (i.e., fish belonging to the same population), are similarly timed. Results of this study to date have shown that the majority of juvenile Chinook in Clear Creek dispersed in the fall. Timing of this dispersal in relation to disconnection of Knight Creek from the Nechako River mainstem as a result of managed flow was alarming. This discovery suggests that water management in the Nechako River could be restricting or outright prohibiting fall dispersal of juvenile Chinook from many non-natal rearing streams. Due to the timeline of this study thus far, the survival rate of juvenile Chinook that overwinter in non-natal rearing streams has not yet been determined, but if overwintering survival is low in many tributaries and fall dispersal from these tributaries is restricted, this phenomenon may be an additional factor that is limiting Nechako River Chinook productivity. For this reason, it is paramount that the confluences of all known Chinook non-natal rearing streams be assessed for connectivity to determine the magnitude of this potential problem and to design mitigation strategies if/where necessary. This potential problem is not an issue for Clear Creek (i.e., it is functional and remains connected year-round), but we cannot assume Clear Creek is the norm; based on results from Knight Creek, we must assume this problem exists at other tributaries throughout the Nechako River watershed until proven otherwise.

Conclusion and Recommendations

Knowledge gaps regarding non-natal tributary use by juvenile Chinook salmon and fish passage at beaver dams and/or Beaver Dam Analogues (BDAs) have contributed to uncertainty in habitat restoration strategies aimed at recovering Nechako River Chinook salmon. The goal of this study was therefore to address these gaps and to generate information needed to optimize habitat restoration by developing strategies specifically tailored to benefit juvenile Chinook salmon. These strategies are also expected to provide broader ecological benefits through recovery of riparian habitat along heavily degraded streams. To date, this study has begun to address these knowledge gaps and has generated novel information on non-natal tributary use by juvenile Chinook salmon in the Nechako River watershed, as well as direct evidence of fish passage at beaver dams. Assessment of fish passage at BDAs was limited due to poor environmental conditions in Knight Creek during summer 2025; however, results observed at beaver dams are expected to be broadly applicable to BDAs.

Study results indicate that juvenile Chinook were present in non-natal tributaries from at least July through December, although most individuals present during summer dispersed to the Nechako River mainstem by late October. Upstream passage of juvenile Chinook at beaver dams appeared limited, and Chinook captured upstream of beaver dams were significantly larger than those found in unobstructed reaches downstream. An unanticipated result of this study was that fall dispersal timing of juvenile Chinook from non-natal tributaries may coincide poorly with Nechako River flow management, potentially increasing the risk of stranding due to tributary disconnection. Collectively, these findings provide important context for habitat restoration planning in non-natal tributaries, including the application of BDAs, and may also inform flow management in the Nechako River. While additional study is required to validate these findings, results to date provide a strong foundation for improving the effectiveness of habitat restoration efforts, including BDA implementation, with the goal of increasing juvenile rearing productivity and ultimately adult Chinook spawner abundance in the Nechako River.

Recommendations for 2026-27 include:

- Continued monitoring of tributaries to assess behaviour and fate of remaining PIT tagged Chinook (i.e., both hatchery and wild-origin fish), including:
    - Timing of dispersal – monitor whether overwintering Chinook in Clear Creek disperse in spring and/or fall to inform Nechako River flow management;

  - Survival – assess number of Chinook in Clear Creek that dispersed versus those that were not detected to generate a baseline for comparison of survival in degraded creeks;
  - Movement – assess whether Chinook move upstream of beaver dams in their second year during spring freshet, and whether any fish that dispersed in fall 2025 return for a second summer of rearing in 2026, or whether they enter alternative tributaries (e.g., Knight Creek) to improve understanding of fish passage at beaver dams/BDAs and expand knowledge of non-natal tributary usage; and,
  - Movement – assess the ability of hatchery-origin Chinook to move downstream past numerous beaver dams in Clear Creek, and beaver dams and BDAs in Knight Creek to continue to improve understanding of fish passage at beaver dams and BDAs;
- Replicate PIT tagging efforts in Clear Creek to strengthen and/or broaden 2025 study results and continue to expand knowledge of non-natal tributary usage to inform habitat restoration in degraded streams;
- Expand PIT tagging efforts to Knight Creek (as originally intended) to provide comparative results about Chinook behaviour and survival in degraded streams and to provide a baseline to measure efficacy of restoration efforts;
  - Focus PIT tagging efforts earlier in the season when Knight Creek still has flow (i.e., prior to mid-July);
- Operate a fence-type trap in the spring that is oriented to capture upstream-bound juveniles as they enter Clear and Knight Creeks
  - Generate information on entry timing to tributaries;
  - PIT tag if size permits to improve understanding of residence time within non-natal rearing tributaries; and,
- Operate a fence-type trap in late summer and early fall that is oriented to capture downstream-bound juveniles as the disperse from Clear and Knight Creeks
  - Estimate the mark rate of the population (i.e., proportion of all juvenile Chinook that were PIT tagged). This mark rate can be used with mark-recapture modelling to expand the unmarked proportion by the total number of detected individuals that dispersed to formulate an estimate of abundance within each creek.
  - This method could be replicated in any creek where restoration works are occurring to assess change in abundance in addition to survival rate.

Literature Cited

Carter K. 2005. The effects of dissolved oxygen on steelhead trout, coho salmon, and Chinook salmon biology and function by life stage. North Coast Region, California Regional Water Quality Control Board. 29 p. Available from: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/shasta_river/060707/29appendixbetheeffectsofdissolvedoxygenonsteelheadtroutcohosalmonandchinooksalmonbiologyandfunction.pdf

Carter K. 2008. Effects of temperature, dissolved oxygen/total dissolved gas, ammonia, and pH on salmonids: implications for California's North Coast TMDLs. California Regional Water Quality Control Board, North Coast Region. Available from: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/klamath_river/

COSEWIC. 2018. COSEWIC assessment and status report on the Chinook Salmon Oncorhynchus tshawytscha, Designatable Units in Southern British Columbia (Part One – Designatable Units with no or low levels of artificial releases in the last 12 years), in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxxi + 283 pp. Available from: http://www.registrelepsararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1

DFO. 2021. Recovery Potential Assessment for 11 designatable units of Fraser River chinook salmon, *Oncorhynchus tshawytscha*, part 2: elements 12 to 22. Canadian Science Advisory Secretariat Science Advisory Report 2021/030.

Ohms, H.A., J.V. Tranquilli, G. Brooks, and D.A. Boughton. 2023. Flexible-pass-through antennas for half-duplex passive integrated transponder tags in medium to large rivers used to study size-selective reservoir passage. North American Journal of Fisheries Management 43(3): 687–694. Available from: https://doi.org/10.1002/nafm.10884

Pearce, S., K. Pellett, J. Damborg. 2020. Cowichan Chinook enumeration methodology change. Technical Report prepared for the Pacific Salmon Commission Southern Endowment Fund, Year 3 of 5. 38 pp plus Appendix.

Water Survey of Canada. 2025. Real Time Hydrometric Data: Nautley River near Fort Fraser (Station 08JB003). Available from: https://wateroffice.ec.gc.ca/search/real_time_results_e.html?search_type=station_name&station_name=nautley&operating_agency=all&gross_drainage_operator=%3E&gross_drainage_area=&effective_drainage_operator=%3E&effective_drainage_area=

Water Survey of Canada. 2025. Historical Hydrometric Data: Nechako River near Fort Fraser (Station 08JA001). Available from: https://wateroffice.ec.gc.ca/search/historical_results_e.html?search_type=station_name&station_name=nechako&start_year=1850&end_year=2026&minimum_years=&operating_agency=all&gross_drainage_operator=%3E&gross_drainage_area=&effective_drainage_operator=%3E&effective_drainage_area=

Water Survey of Canada. 2025. Real Time Hydrometric Data: Nechako River at Vanderhoof (Station 08JC001). Available from: https://wateroffice.ec.gc.ca/search/real_time_results_e.html?search_type=station_name&station_name=nechako&operating_agency=all&gross_drainage_operator=%3E&gross_drainage_area=&effective_drainage_operator=%3E&effective_drainage_area=

Appendix I

A 160 mm nose-fork length rainbow trout between 160 mm (top) and 156 mm (bottom) juvenile Chinook salmon. These fish were captured at the outlet of the Braeside Road culvert in Clear Creek in August 2025 (river km 3.0). Both of these Chinook were detected leaving Clear Creek in September 2025.

Bull trout captured in Clear Creek approximately 500 river meters upstream of the confluence with the Nechako River on September 16, 2025. This fish departed Clear Creek four days after it was tagged.

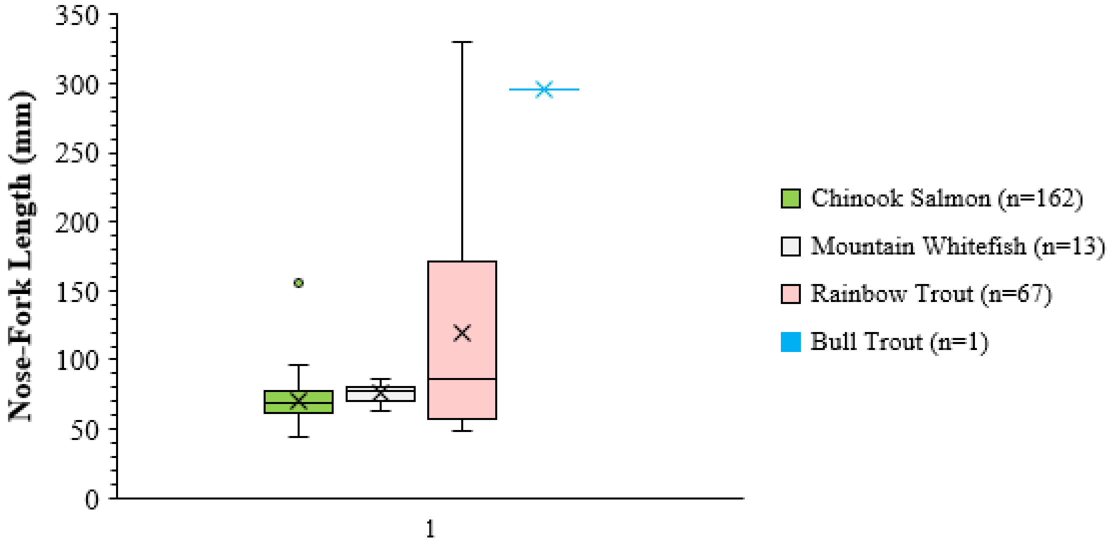
Rainbow trout captured in Clear Creek in September 2025.

Mountain whitefish captured in the lower reaches of Clear Creek, September 2025.

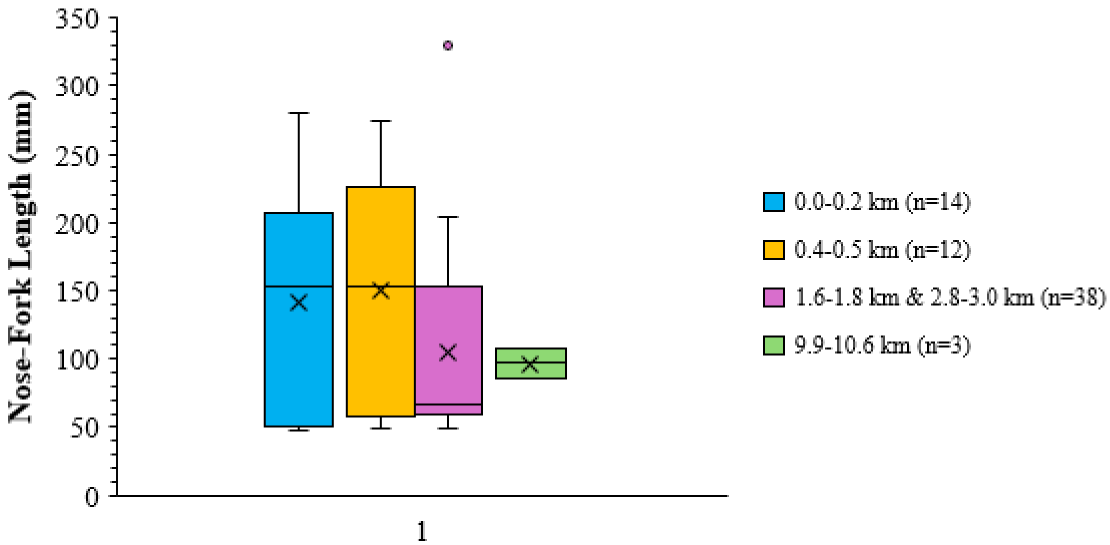
Anaesthetized Chinook fry prior to PIT tagging. Air stone was removed for picture clarity.

Appendix II

Nose-fork length (mm) of salmonids that were captured and PIT-tagged in Clear Creek between August 8 and September 16, 2025, which included Chinook salmon (green; n=162), mountain whitefish (light grey; n=13), rainbow trout (pink; n=67), and bull trout (blue; n=1).



Nose-fork length (mm) of rainbow trout captured and PIT tagged in three reaches of Clear Creek between August 8 and September 16, 2025: river km 0.0 – 0.2 (Confluence Reach; green; n=14), 0.5 – 0.6 km (Lower Reach; orange; n=12), 1.6 – 1.8 km and 2.8 – 3.0 km (Braeside Pumphouse Reach and Braeside Reach, combined; blue; n=38), and 9.9 – 10.6 km (Upper Reach) (purple; n=3).



Rainbow trout catch per day by river kilometer (pink diamonds) in Clear Creek by beach seine. Vertical grey dashed lines represent natural beaver dam locations by river kilometer in summer 2025. Beach seining was not attempted upstream of Braeside Road (river km 3.0), so distance on the x-axis was reduced for clarity.