Site C Clean Energy Project

Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b)

Task 2d – Site C Fish Movement Assessment

Construction Year 5 (2019)

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Site C Fish Movement Assessment (Mon-1b, Task 2d)

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27 March 2020 (revised 24 June 2020)

Executive Summary

In accordance with Provincial Environmental Assessment Certificate Condition No. 7[1] and Federal Decision Statement Condition Nos. 8.4.3[2] and 8.4.4[3] for BC Hydro's Site C Clean Energy Project (the Project), BC Hydro has developed the Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP[4]). The Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b) represents one component of the FAHMFP that is designed to monitor the responses, using before and after comparisons, of target Peace River fish populations to the construction and operation of the Project.

The Site C Fish Movement Assessment (Mon-1b, Task 2d) was implemented in 2019 to determine the magnitude, direction and seasonal variability of movements of key indicator species (Arctic Grayling, Bull Trout, Burbot, Rainbow Trout and Walleye) in the Peace River and its tributaries. To achieve these study objectives, LGL deployed a fixed radio telemetry array of 26 receiver stations along the Peace River and its tributaries in 2019. Of these receiver stations, 14 were installed along the Peace River, covering over 200 river kilometers from Peace Canyon Dam to Many Islands, Alberta. Additionally, ten receiver stations were installed at major tributaries of the Peace River (Maurice Creek, Lynx Creek, Farrell Creek, Halfway River, Cache Creek, Moberly River, Pine River, Beatton River, Kiskatinaw River, Pouce Coupe River), and two receiver stations were placed in tributaries of the Halfway River (Chowade River and Cypress Creek). Radio telemetry data collected in 2019 and beyond aims to build on baseline data that was collected by the BC Ministry of Environment from 1996-1999, and by AMEC/LGL from 2005-2009.

Twenty-four receiver stations were installed and operational by 13 July 2019, with the final two stations operational by 31 July 2019. Following a three-month data collection period, 21 stations were demobilized and safely stored in early November 2019 while five stations (Site C Dam, Moberly River, Halfway River, Chowade River and Cypress Creek) were left operating through the winter. The Site C Reservoir Tributaries Fish Population Indexing Survey (Mon-1b, Task 2c) and Peace River Large Fish Indexing Survey (Mon-2, Task 2a) radio-tagged 329 fish between 18 July 2019 and 12 October 2019.

The SRX800 MD-4 is the most sensitive SRX radio receiver that has been manufactured by Lotek Wireless. Sensitivity comes with the benefit of a greater operational range but at the cost of additional noise. Some of this noise came in the form of false-positive detections, which need to be filtered out of the dataset before any meaningful biological analysis can proceed. The unexpectedly high quantity of interference meant that our typical filtering and processing methods were inadequate, and more stringent filters were needed to create a dataset that is robust against error.

Detailed range testing was conducted for all 26 receiver stations to provide insight into the detection probability of individual stations and potential shortfalls. For ease of interpretation, the results from range testing were categorized into one of five general classifications. 'Typical' detection probability curves (n=14) represented the typical result of a receiver with strong and consistent range capabilities. 'Depressed' detection probability curves (n=3) represented receiver stations with a decreased range

[1] The EAC Holder must develop a Fisheries and Aquatic Habitat Monitoring and Follow-up Program to assess the effectiveness of measures to mitigate Project effects on healthy fish populations in the Peace River and tributaries, and, if recommended by a QEP or FLNR, to assess the need to adjust those measures to adequately mitigate the Project's effects.

[2] The plan shall include: an approach to monitor changes to fish and fish habitat baseline conditions in the Local Assessment Area;

[3] The plan shall include: an approach to monitor and evaluate the effectiveness of mitigation or offsetting measures and to verify the accuracy of the predictions made during the environmental assessment on fish and fish habitat.

[4] Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program available at https://www.sitecproject.com/document-library/environmental-management-plans-and-reports.

capacity due to noisier than average environments. ‘Steep’ detection probability curves (n=3) resulted where a physical obstruction (such as a bridge or cliff) created expected range limitations. Six receiver stations (with ‘Atypical’ curves, n=2, or failed tests, n=4) will require retesting before conclusions can be made.

Acknowledgements

The Site C Fish Movement Assessment is funded by the BC Hydro Site C Clean Energy Project. We would like to thank Nich Burnett and Brent Mossop from BC Hydro as well as the BC Hydro Natural Resource Specialists that helped this project succeed; Justin Krilow, Bryan Woodward, Hugh Delorey, Peter Frost, Alysha Parker, and Jacqueline Pizzey, among others. Thank you to 4 Evergreen Resources, specifically Reece Cameron and Herman Davis, for their important contributions. Finally, thank you to Jason Smith, Karl English, Lucia Ferreira, Yury Bychkov and Steve Crawford from LGL Limited for their significant contributions.

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1.0 Introduction

In accordance with Provincial Environmental Assessment Certificate Condition No. 7[5] and Federal Decision Statement Condition Nos. 8.4.3[6] and 8.4.4[7] for BC Hydro's Site C Clean Energy Project (the Project), BC Hydro has developed the Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP[8]). The Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b) represents one component of the FAHMFP that is designed to monitor the responses, using before and after comparisons, of target Peace River fish populations to the construction and operation of the Project.

The Site C Fish Movement Assessment (Mon-1b, Task 2d) was implemented in 2019 to evaluate movement patterns of key indicator species (Arctic Grayling, Bull Trout, Burbot, Rainbow Trout and Walleye) in the Peace River and its tributaries. To achieve these study objectives, LGL deployed a fixed radio telemetry array of 26 receiver stations along the Peace River and its tributaries in 2019.

The array was designed to span the temporal and spatial extent of the FAHMFP. Collection of radio telemetry data began in the summer of 2019 and aims to build on baseline studies that were conducted by the BC Ministry of Environment from 1996-1999 (Burrows et al. 2001, AMEC & LGL 2008, AMEC & LGL 2010), and by AMEC-LGL from 2005-2009 (AMEC & LGL 2008). The intent is to deploy the array in Construction Years 5 to 10[9] followed by Operation Years 1-4, 10-11, 15-16, 20-21, 25-26 and 29-30[10].

The spatial extent of the array coincided with the sampling and tagging of target species by the Peace River Large Fish Indexing Survey (Mon-2, Task 2a). The array covered 200 river kilometers of Peace River, covering the entrances to major tributaries (Maurice Creek, Lynx Creek, Farrell Creek, Halfway River, Cache Creek, Moberly River, Pine River, Beatton River, Kiskatinaw River, Pouce Coupe River), as well as providing coverage within two important tributaries (Chowade River and Cypress Creek).

1.1 Study Objective

The objective of Site C Fish Movement Assessment (Mon-1b, Task 2d) is to collect telemetry data that can determine the magnitude, direction and seasonal variability of movements of key indicator species in the Peace River and its tributaries. Data collected by the Site C Fish Movement Assessment is critical to understanding any changes in fish movement that are associated with the construction and operation of the Project. Telemetry data will also be used to supplement other on-going monitoring programs within the FAHMFP. Such information will help address other fisheries management questions and test hypotheses from the different monitoring programs, such as the Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b), the Peace River Fish Community Monitoring Program (Mon-2) and the Site C Fishway Effectiveness Monitoring Program (Mon-13).

[5] The EAC Holder must develop a Fisheries and Aquatic Habitat Monitoring and Follow-up Program to assess the effectiveness of measures to mitigate Project effects on healthy fish populations in the Peace River and tributaries, and, if recommended by a QEP or FLNR, to assess the need to adjust those measures to adequately mitigate the Project's effects.

[6] The plan shall include: an approach to monitor changes to fish and fish habitat baseline conditions in the Local Assessment Area;

[7] The plan shall include: an approach to monitor and evaluate the effectiveness of mitigation or offsetting measures and to verify the accuracy of the predictions made during the environmental assessment on fish and fish habitat.

[8] Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program available at https://www.sitecproject.com/document-library/environmental-management-plans-and-reports.

[9] 2019 - 2024

[10] 2024-2028, 2034-2035, 2039-2040, 2044-2045, 2049-2050 and 2053-2054, respectively

2.0 Methods

2.1 Equipment and Setup

Radio telemetry stations were comprised of four basic components: the radio receiving equipment, power system, housing, and remote connectivity equipment. Radio receiving equipment was comprised of two or three, three-element YAGI antennas that receive radio signals, which then pass through a coaxial cable to a Lotek ASP-8 switcher, and into the SRX800 MD-4 receiver for coding and storage (Figure 1). Two antennas were the standard with one oriented upstream and the other downstream. A third antenna was added if the station was situated at the confluence of a tributary, where the first two antennas point up and down the Peace River and the third antenna points up the tributary.

The power system provided continuous power to the station through two 80-watt solar panels wired to a 10 amp solar controller that maintained two 100 amp-hour deep cycle AGM batteries (Figure 1). The batteries were then connected to the SRX800 receiver. When the angle of the sun and the hours of daylight were adequate (i.e., generally from spring to fall), the solar setup provided renewable energy to the receiver. During other times of year, the receiver primarily runs off the two deep cycle batteries.

The telemetry station electronics were housed in a custom fabricated aluminum environment box that was sealed and locked during the study period (Figure 1). Station locations that had a sufficient cellular signal were wired to a 4G LTE modem that allowed remote data downloads, receiver maintenance, and power observation (Figure 1).

In most circumstances the environment box was lag-bolted to a large tree with the receiver antennas mounted to the same tree approximately 3 meters above the box (24 stations, Figure 1). In cases in which a suitable tree was not available (two stations), a stand was constructed for the environment box and the antennas were mounted on a mast that was supported by an aluminum tripod.

The angle between two antennas is specific to each site but 120° is the standard. Antennas installed at angles greater than 120° risk reverse detections from the non-intended read direction (e.g. upstream is reading downstream detections from the backside of the antenna), while an angle less than 120° risks overlapping detection zones and can decrease a stations detection range. The solar panels were installed onto a ground-mounted wood stand for setups operating spring to fall and an aluminum stand for stations operating in the winter[11] (Figure 1).

[11] The aluminum solar panel stand allows for panels to be lifted higher to avoid snow and angled more vertically to compensate for the position of the sun in winter.

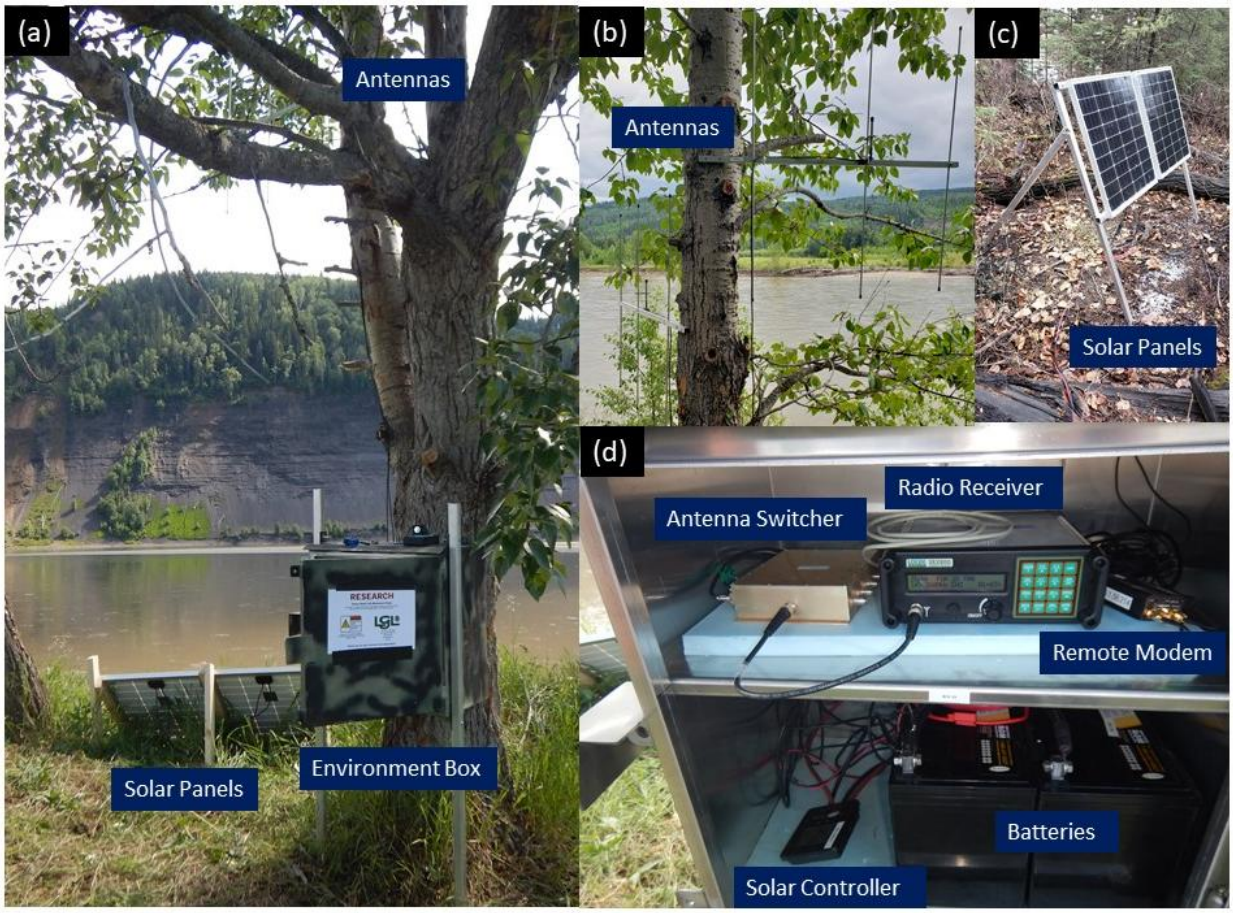

Figure 1. (a) Example fixed radio telemetry station with a view of the antennas, environment box and solar panels. (b) Two, three-element YAGI antennas are mounted to a tree. (c) Two, 80-watt solar panels are mounted to an aluminum stand for deployment during the winter months. (d) View of the inside of an environment box showing the Lotek SRX800 receiver, ASP-8 switcher, LTE remote modem, solar controller and AGM deep cycle batteries.

All stations have a beacon tag positioned on a nearby tree for outage analyses. Beacon tags emitted a coded radio signal once every ten seconds for the first minute of every hour, followed by 59 minutes of radio silence before repeating the sequence. Tags were programmed this way to ensure that outage analyses can proceed with minimal interruption to data collection. At individual stations, observed beacon tag detections are analyzed against expected beacon tag detections to identify when station outages occurred, and data collection ceased.

2.2 Spatial Extent of the Array

In 2019, the fixed radio telemetry array was comprised of 26 stations. Station installations began on 4 July 2019 and the last station was installed on 31 July 2019 (Table 1). Four of the original 30 proposed stations require helicopter use for access and were not deployed in 2019: Halfway River #2, Halfway River #3, Moberly River #2, and Moberly River #3[12]. Five stations deployed in 2019 (Site C Dam, Halfway River #1,

[12] Halfway River #2 and 3, Moberly River #2 and 3 will be deployed in spring 2020.

Moberly River #1, Chowade River and Cypress Creek) were not demobilized in November in order to monitor the movements of radio tagged fish throughout the winter.

The spatial extent of the array was designed to encompass the Local Assessment Area (LAA) (Figure 2), from Peace Canyon Dam (RKM 0) to Many Islands, Alberta (RKM[13] 210). Between these locations, stations were located at the entrance of every major tributary with one mainstem station located approximately halfway between each tributary entrance (Table 1, Figure 2). Deviations from this general format included detection gates[14] created at Peace River #1A/Peace River #1B and Kistkatinaw River/Peace River #3. Detection gates were created to increase detection probability through these corridors. Deploying stations on the left and right banks at Many Islands, for example, will help determine if a radio tagged fish has left the LAA.

Six stations were to be placed in tributaries upstream of the Peace River (Table 1, Figure 2). Cypress Creek and Chowade River were the only two upstream tributary stations installed in 2019. The remaining four stations, Moberly River #2 and 3 and Halfway River #2 and 3, were not installed in 2019 due to logistic constraints and will therefore be installed in the spring of 2020.

Table 1. Station names, types, numbers, installation and demobilization dates, and current status (as of January 2020).

Station Name	Access	Station Type	Station #	Installation Date	Demobilization Date	Modem	Status
Peace River #1A	Boat	Peace River	1	9 July 2019	4 November 2019	no	Inactive - Stored
Peace River #1B	Boat	Peace River	2	9 July 2019	4 November 2019	no	Inactive - Stored
Peace River #2	Boat	Peace River	3	12 July 2019	4 November 2019	no	Inactive - Stored
Pouce Coupe River	Boat	Tributary Entrance	4	8 July 2019	1 November 2019	no	Inactive - Stored
Peace River #3	Boat	Peace River	5	8 July 2019	5 November 2019	no	Inactive - Stored
Kiskatinaw River	Boat	Tributary Entrance	6	13 July 2019	5 November 2019	no	Inactive - Stored
Beatton River	Boat	Tributary Entrance	7	13 July 2019	5 November 2019	no	Inactive - Stored
Peace River #4	Truck	Peace River	8	12 July 2019	6 November 2019	no	Inactive - Stored
Pine River	Boat	Tributary Entrance	9	7 July 2019	5 November 2019	no	Inactive - Stored
Peace River #5	Boat	Peace River	10	7 July 2019	5 November 2019	no	Inactive - Stored
Site C Dam	Truck	Peace River	11	11 July 2019	-	yes	Active
Moberly River #1	Truck	Tributary Entrance	12	11 July 2019	-	yes	Active
Moberly River #2	Helicopter	Tributary Upstream	13	-	-	-	Inactive - Stored
Moberly River #3	Helicopter	Tributary Upstream	14	-	-	-	Inactive - Stored
Peace River #6	Boat	Peace River	15	10 July 2019	5 November 2019	yes	Inactive - Stored
Peace River #7	Truck	Peace River	16	6 July 2019	7 November 2019	yes	Inactive - Stored
Cache Creek	Truck	Tributary Entrance	17	4 July 2019	6 November 2019	yes	Inactive - Stored
Peace River #8	Truck	Peace River	18	6 July 2019	3 November 2019	yes	Inactive - Stored
Halfway River #1	Truck	Tributary Entrance	19	8 July 2019	-	yes	Active
Halfway River #2	Helicopter	Tributary Upstream	20	-	-	-	Inactive - Stored
Halfway River #3	Helicopter	Tributary Upstream	21	-	-	-	Inactive - Stored
Peace River #9	Truck	Peace River	22	8 July 2019	3 November 2019	yes	Inactive - Stored
Farrell Creek	Truck	Tributary Entrance	23	13 July 2019	2 November 2019	yes	Inactive - Stored
Peace River #10	Truck	Peace River	24	13 July 2019	2 November 2019	yes	Inactive - Stored
Lynx Creek	Truck	Tributary Entrance	25	11 July 2019	2 November 2019	yes	Inactive - Stored
Peace River #11	Truck	Peace River	26	11 July 2019	7 November 2019	yes	Inactive - Stored
Maurice Creek	Truck	Tributary Entrance	27	10 July 2019	2 November 2019	yes	Inactive - Stored
Peace Canyon Dam	Truck	Peace River	28	10 July 2019	2 November 2019	yes	Inactive - Stored
Chowade River	Truck	Tributary Upstream	29	31 July 2019	-	no	Active
Cypress Creek	Truck	Tributary Upstream	30	30 July 2019	-	no	Active

[13] RKM or river kilometers are calculated as the distance (in kilometers) from the tailrace of Peace Canyon Dam.
[14] A detection gate is comprised of two receivers, one placed on either riverbank, to increase detection probability.

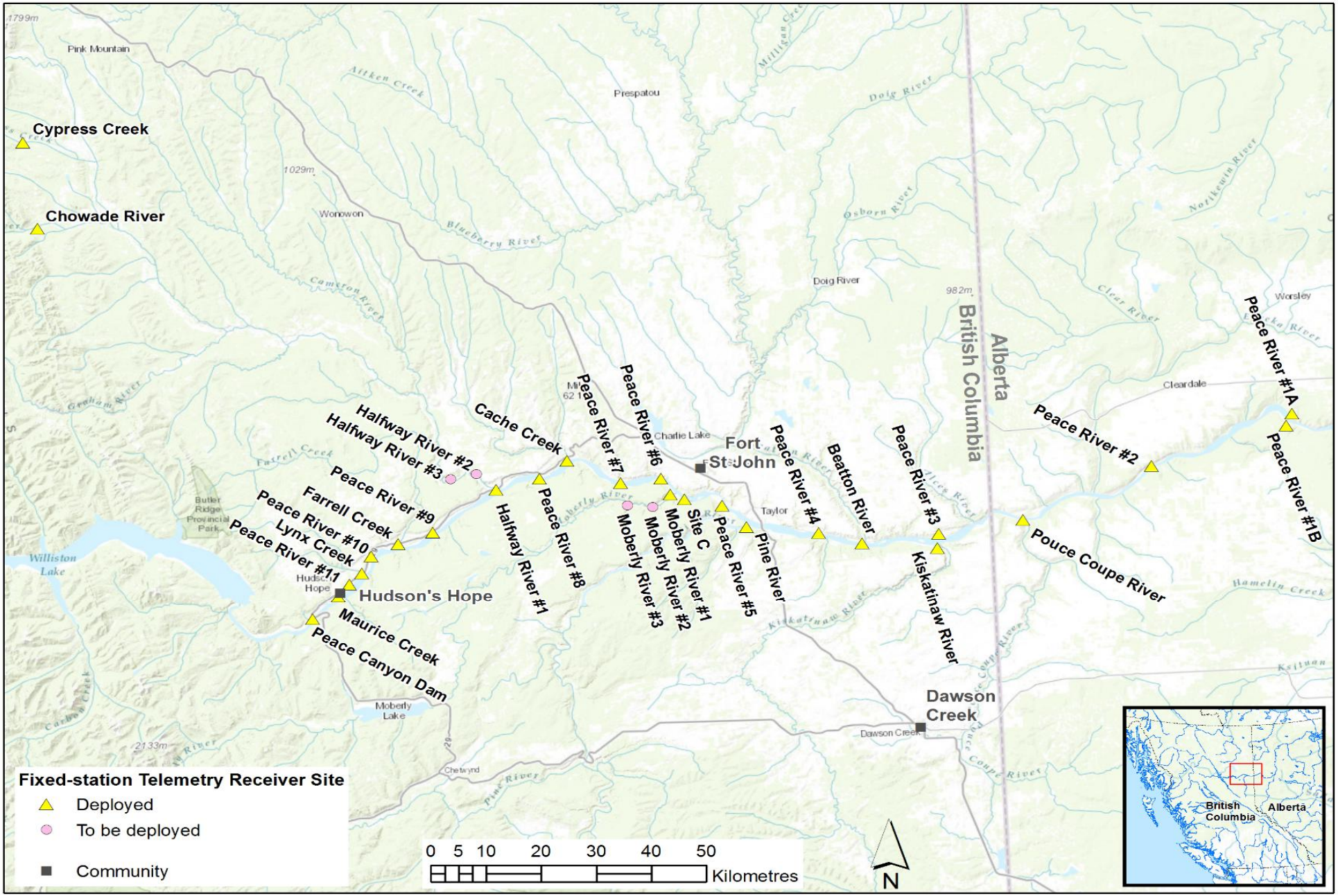

Figure 2. Location of fixed radio telemetry stations for the Site C Fish Movement Assessment. Stations that were deployed in 2019 are shown as yellow triangles. Four of the 30 originally proposed stations (pink circles) will be deployed in spring 2020.

2.3 Study Fish Collection and Tagging

As part of the Site C Reservoir Tributaries Fish Population Indexing Survey (Mon-1b, Task 2c) and Peace River Large Fish Indexing Survey (Mon-2, Task 2a), Golder Associates collected and radio tagged 329 study fish between July and October, 2019. All radio tagged study fish were collected by backpack or boat electrofishing before being surgically inserted with a Lotek Nano radio tag[15]. Table 2 lists radio tagged study fish by species, age class and release river or tributary. For additional details and methods into study fish collection, handling, tagging and release please refer to the Mon-1b, Task 2c and Mon-2, Task 2a 2019 annual reports.

Table 2. Radio tagged study fish are listed by species, age class and release river or tributary. All collection, handling and tagging was conducted by Golder Associates as part of the Site C Reservoir Tributaries Fish Population Indexing Survey (Mon-1b, Task 2c) and the Peace River Large Fish Indexing Survey (Mon-2, Task2a).

Species	Age class	Peace River	Farrell Creek	Chowade River	Cypress Creek	Fiddes Creek	Total
Arctic Grayling	Adult	32					32
Arctic Grayling	Immature	6					6
Bull Trout	Adult	75					75
Bull Trout	Immature	10		12	26	15	63
Rainbow Trout	Adult	40					40
Rainbow Trout	Immature	16	15				31
Burbot	Adult	18					18
Walleye	Adult	63					63
Walleye	Immature	1					1
Total		261	15	12	26	15	329

2.4 Testing

The power system, radio equipment, and remote connection systems were all tested for basic functionality before the release of any study fish. The radio equipment was tested to ensure tag signals were being coded as expected and the antenna angles were correctly oriented. Power systems were tested for capacity and confirmation of power generation. Lastly, each station with a remote modem was logged into using an off-site computer to confirm proper operation.

Beyond basic functionality testing, each receiver station was range tested. The most common range testing approach was a series of upstream to downstream tag drag drifts from a jet boat. To begin a range test drift, the jet boat was positioned approximately 800 meters upstream of the station, active test tags were deployed, and the boat was powered down to allow a drift with the flow of the river. Each range test drift ended approximately 800 meters downstream of the station following a cease in detections; after which, these procedures were repeated. The test tags consisted of a low-power tag (Lotek NanoTag Model NTF-3-2) and a high-power tag (Lotek NanoTag Model NTF-6-4)[16] deployed to a depth of 1 meter for all tests. During each test, the boat had an onboard GPS unit set to high-frequency tracking, which continuously collected spatial and temporal data points as the boat and test tags drifted through the

[15] Tag model per study fish was dependent on the size of the fish. Lotek NanoTag Models used in 2019 are listed from small to large; NTF-3-2, NTF-5-2, NTF-6-1, and NTF-6-2.

[16] The Nano NTF-3-2 was the smallest of the radio tags implanted in 2019 and therefore represents the low power tag, while the Nano NTF-6-4 was the largest, representing the high power tag.

detection area. Other range testing approaches used the same base methodology but without the jet boat and either tracked by foot or radio-controlled boat in shallow environments.

GPS tracking data were temporally correlated to detection records and then grouped into 50 m bins for analysis and plotting. Detection probabilities were calculated within each 50 m bin as the quotient of the observed quantity of detections divided by the expected quantity. For each station, the detection probabilities were plotted against the distance from the receiver and fit with a logistic regression curve to graphically display detection range (Figure 3). The fitted logistic equation parameters were used to calculate the distances in which detection probability was 95%, 50% and 5%. As is standard practice in acoustic and radio telemetry studies, the detection probability at these mentioned values as well as the shape of the curve were used to interpret the detection range for each station (Kessel et al. 2014).

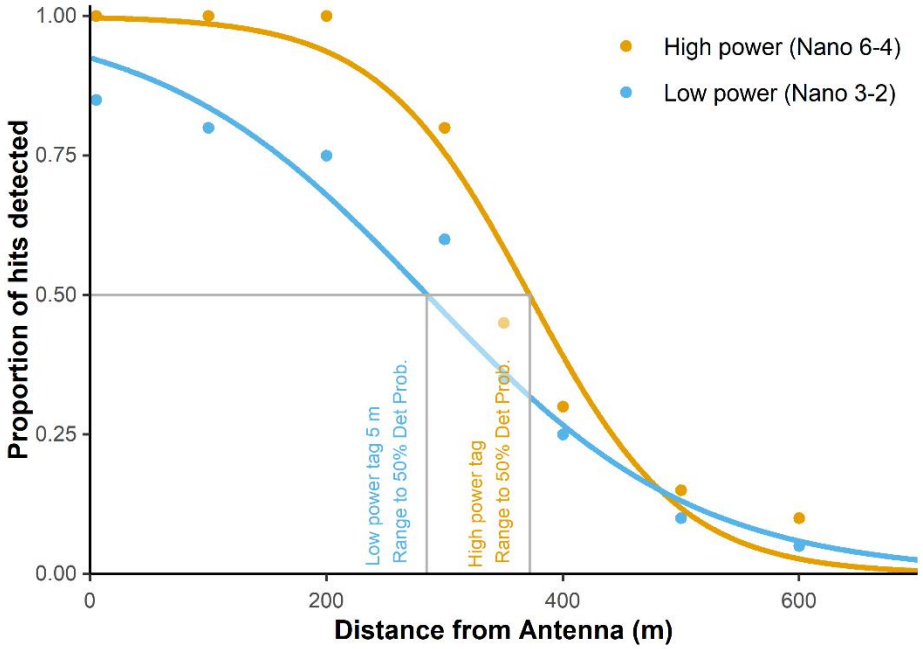

Figure 3. Example of a detection probability curve generated from range testing data.

2.5 Download and Maintenance

Standard receiver maintenance requires an on-site visit in which the data are downloaded, notes of functionality are recorded and the equipment is inspected for damage and/or malfunction. Data were downloaded using SRX800 Host software on a field laptop before being uploaded to the cloud when a Wi-Fi connection was re-established.

Field logs were maintained throughout the field season, and key indicators of the systems operational performance were recorded. These indicators included: current voltage, remaining percent battery capacity, solar amp hours collected, and remaining data storage. Appendix A provides detailed records of all station field visits before demobilization in November 2019.

There were three situations in which a station needed remote or physical maintenance: equipment malfunction, loss of power, or a full memory bank. Beacon tag detection records were used to evaluate a station's functionality over the course of the study period. The moment a beacon tag is no longer logged

helps identify when an outage begins and ends. To guarantee that every receiver station was operating and collecting data as expected, field visits occurred cyclically every three to four weeks (Table 3). Any sites with a cellular modem connection were remotely checked weekly.

Table 3. Field schedule in 2019.

Start Date	End Date	Work Completed
27 June 2019	14 July 2019	Station Installations 1
30 July 2019	31 July 2019	Station Installations 2
1 August 2019	7 August 2019	Download/Testing/Maintenance 1
29 August 2019	2 September 2019	Download/Testing/Maintenance 2
18 September 2019	23 September 2019	Download/Testing/Maintenance 3
1 November 2019	3 November 2019	Download/Testing/Maintenance 4
3 November 2019	8 November 2019	Station Demobilization
9 November 2019	Present	Winter Maintenance

2.6 Data Management

The downloaded data files have been stored and compiled for inclusion into the Site C Fish Movement Assessment Database. The Site C Fish Movement Assessment Database is a SQL-Server relational database comprised of multiple data tables stored on a local network. Data are retrieved and queried using Microsoft Access as the front-end to the database. All data tables are carefully keyed and organized for easy and comprehensive querying.

Beyond data storage, the data need to be processed to validate individual detection records. The SRX800 receiver is a sensitive radio receiver which can boost a receiver's detection range but at the cost of additional noise and false-positive detections. A false-positive detection occurs when a receiver codes a signal and incorrectly assigns it to a fish from which it did not originate.

The filtering process developed for the Site C Fish Movement Assessment includes five steps:

- Removal of duplicate records[17];
- Removal of records that do not match the list of released tag codes and frequencies;
- Removal of detections that *do* match the list of released tag codes, but which occurred prior to the release of the fish;
- Pulse rate filtration; and
- Detection frequency filtration.

Since the Lotek NanoTags were programmed to transmit at a certain pulse rate (e.g., one transmission per 9.8 seconds), we were able to use the expected timing of transmissions to filter out detections that were recorded outside of the expected cycle. For example, two detections separated by 5 seconds would be rejected if the tag had a pulse rate of 9.8 seconds. Following this, we applied a detection frequency filter. The detection frequency filter rejected any detection if it is not part of a set of three or more during a ten-minute window. Random noise events that lead to false-positive detections are more likely to occur

[17] Duplicate records occur when a station's databanks are not cleared after downloading. The next subsequent download will include newly collected detections as well as the detections recorded from the last cycle.

as singular events (or events separated by more than 10 minutes), or with timing other than that of the manufacturer's programmed pulse rate.

Another validation step that will be performed before data analysis is an examination of detection histories for each individual study fish to locate any red-flag patterns. These patterns include detection sequences with multiple subsequent missed receiver stations along a movement pattern.

3.0 Results

3.1 Data Collection

3.1.1 Radio Telemetry Operations

The array collected over 7 million valid detection records that passed the filtering criteria between 4 July 2019 and 7 November 2019 (Table 4). Every station collected valid detection data except for Peace Canyon Dam and Cypress Creek (Table 4). Data collection proceeded beyond 7 November 2019 at five stations (Site C Dam, Moberly River #1, Halfway River #1, Cypress Creek and Chowade River), however data processing was limited to the November demobilization for all stations detailed herein. Appendix B presents an overview of the relative quantities of validated detections for each receiver station (Figures B1 to B4). Further, the frequency of false-positive detections is displayed in Figures B5 to B8, along with noise signal detections per receiver station (Code 999) (Figures B9 to B12).

Table 4. Counts of valid detection records and unique codes (individual study fish) detected at each receiver station.

Station Name	Valid Count	Unique Codes
Peace River 1A & 1B	14,955	23
Peace River 2	28,965	30
Pouce Coupe River	125,028	26
Kiskatinaw River & Peace River 3	265,552	44
Beatton River	1,342,069	45
Peace River 4	851,264	45
Pine River	11,113	6
Peace River 5	62,253	26
Site C Dam	419,144	29
Moberly River 1	63,935	17
Peace River 6	7,656	25
Peace River 7	391,142	27
Cache Creek	75,304	20
Peace River 8	1,241,479	49
Halfway River 1	6,488	8
Peace River 9	5,545	8
Farrell Creek	55,803	12
Peace River 10	47,692	17
Lynx Creek	505,418	19
Peace River 11	1,723,045	46
Maurice Creek	375,549	29
Peace Canyon Dam	0	0
Chowade River	34,600	4
Cypress Creek	0	0

Table 5 lists the six outages that occurred in 2019. The first outage from Peace River #10 followed a routine station download. During the maintenance cycle, the power cable, connecting the receiver to the power system, was jostled causing a disconnection. When the SRX800 is disconnected from external power it continues to operate on local battery power; therefore, the unit appeared functioning when the crew departed but the receiver failed approximately 24 hours later. Peace River #1A underwent a short outage from a wildlife disturbance that flipped over the solar panels, eventually causing a power loss. Both outages from Peace River #10 and Peace River #1A occurred early in the season and were resolved before 80% of tagged fish were released into the Peace River.

The outages from Peace River #1B, Beatton River and Site C Dam all occurred late in the field season and were the result of power loss from reduced solar generation that seasonally begins in the fall (Table 5). Further, Peace River #1B, Beatton River and Site C Dam all have an obstructed south facing view which does not permit optimal power generation. Peace River #11, on the other hand, collected a significant quantity of data in the final month of operation that filled its data storage bank.

The outages on Peace River #11, Peace River #1B and Beatton River all overlapped with scheduled demobilization and therefore acted as a virtual demobilization, which is defined as a situation where a station remains physically setup but is no longer collecting data. Site C Dam, on the other hand, was revisited on 3 November 2019 and batteries were replaced to prepare the station for continued operation throughout the winter.

Table 5. Outage start date, end date, days offline and notes are listed for all stations that experienced an outage in 2019. Further dissections into outages are displayed in beacon tag detection plots in Appendix B, Figures B13 to B16.

Station Name	Outage Start	Outage End	Days Offline	Note
Peace River #10	5 August 2019	28 August 2019	24	SRX Unplugged
Peace River #1A	26 August 2019	29 August 2019	4	Wildlife Disturbance
Peace River #11	17 October 2019	1 November 2019	15	SRX storage full/Demob
Site C Dam	25 October 2019	3 November 2019	9	Low Light Conditions
Peace River #1B	29 October 2019	1 November 2019	3	Low Light Conditions/Demob
Beatton River	29 October 2019	1 November 2019	3	Low Light Conditions/Demob

3.1.2 Range Testing

Range test results were categorized into five classifications for ease of interpretation. The five classifications include four general types of curve ('Typical', 'Steep', 'Depressed', and 'Atypical' detection probability curves) and failed tests.

A Typical detection probability curve (Figures 4 and 5, n=14) was recognized as the standard classification as it followed the expected logistic regression shape, similar to Figure 3 and identified from the literature (Kessel et al. 2014). The Typical detection curve displayed 80-100% detection probability at <50 meters, 45-65% at 400-500 meters, and 15-25% at >600 meters (Table 4). A Steep detection probability curve, on the other hand, was classified by 90-100% detection at <50 meters followed by a more aggressive decrease in detection probabilities (Figure 6, n=3). A Depressed detection probability curve displays values that are lower than a typical trend (Figure 6, n=3), due to a noisy environment during the test, in which intermittent periods of interference at the station decreased the receiver station's ability to code transmissions.

Table 6. Range test methods, results and notes by station name.

Station Name	Test Method	Result Category	Notes
Peace River #1A	Jet Boat	Typical Efficiency Curve	
Peace River #1B	Jet Boat	Typical Efficiency Curve	Missing <200m data
Peace River #2	Jet Boat	Failed Test	Insufficient Data
Pouce Coupe River	Boat/Foot	Steep Efficiency Curve	Cliff wall obstruction
Peace River #3	Jet Boat	Typical Efficiency Curve	
Kiskatinaw River	Boat/RC	Depressed Efficiency Curve	Noisy during test
Beatton River	Boat/RC	Failed Test	Insufficient Data
Peace River #4	Jet Boat	Typical Efficiency Curve	
Pine River	Jet Boat	Typical Efficiency Curve	
Peace River #5	Jet Boat	Typical Efficiency Curve	
Site C Dam	Jet Boat	Failed Test	Insufficient Data
Moberly River #1	Foot	Typical Efficiency Curve	Missing >400m data
Peace River #6	Jet Boat	Typical Efficiency Curve	
Peace River #7	Jet Boat	Depressed Efficiency Curve	Noisy and missing <200m data
Cache Creek	Foot	Atypical Efficiency Curve	Retest suggested
Peace River #8	Jet Boat	Atypical Efficiency Curve	Flat Low-Power efficiency
Halfway River #1	Boat/Foot	Typical Efficiency Curve	
Peace River #9	Jet Boat	Typical Efficiency Curve	
Farrell Creek	Foot	Steep Efficiency Curve	Bridge obstruction
Peace River #10	Jet Boat	Typical Efficiency Curve	
Lynx Creek	Foot	Steep Efficiency Curve	Bridge obstruction
Peace River #11	Jet Boat	Typical Efficiency Curve	Missing <200m data
Maurice Creek	Jet Boat	Depressed Efficiency Curve	Noisy during test
Peace Canyon Dam	Foot	Failed Test	Insufficient Data
Chowade River	Foot	Typical Efficiency Curve	No high-power tag tested
Cypress Creek	Foot	Typical Efficiency Curve	No high-power tag tested

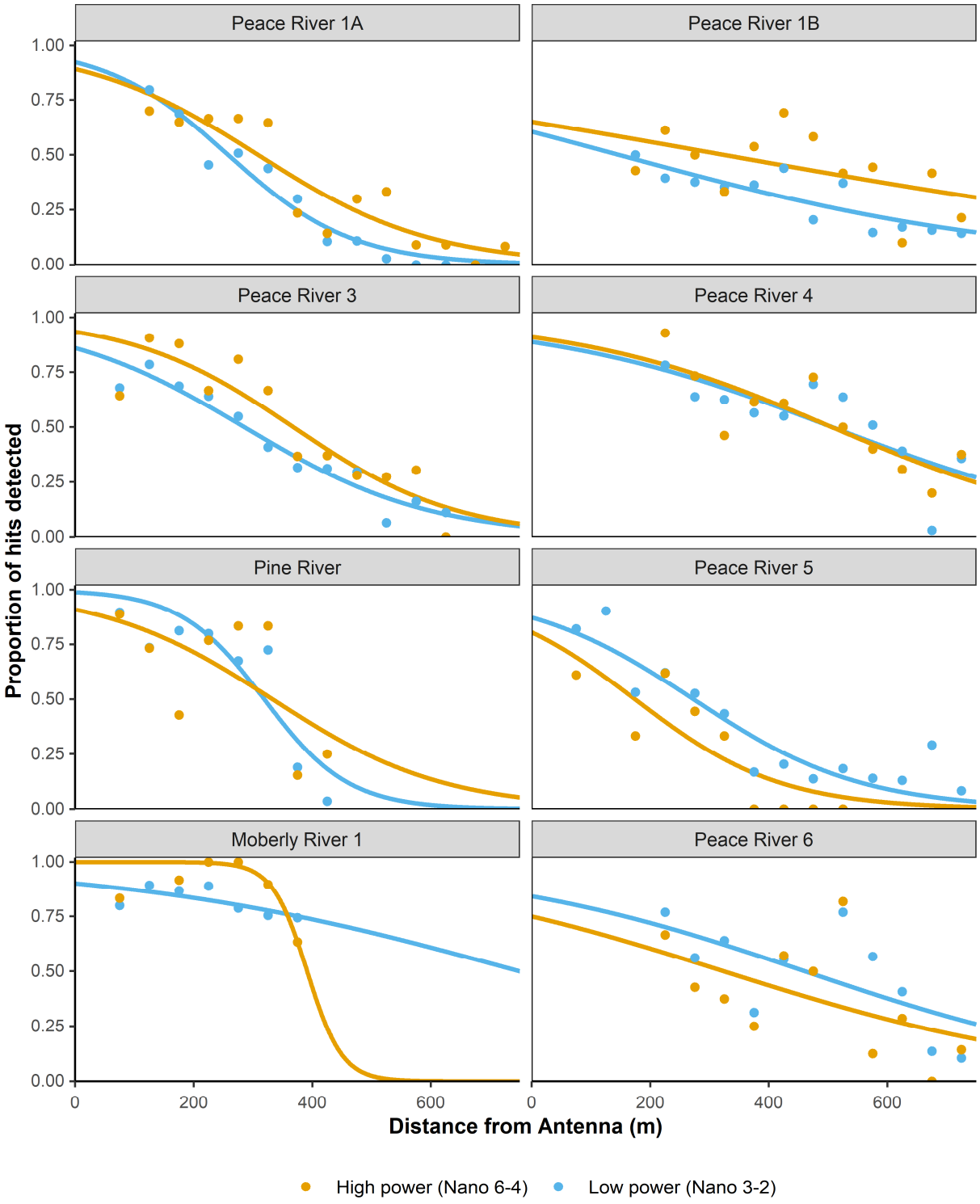

Figure 4. Set of range test results for stations with a Typical Detection Probability curve.

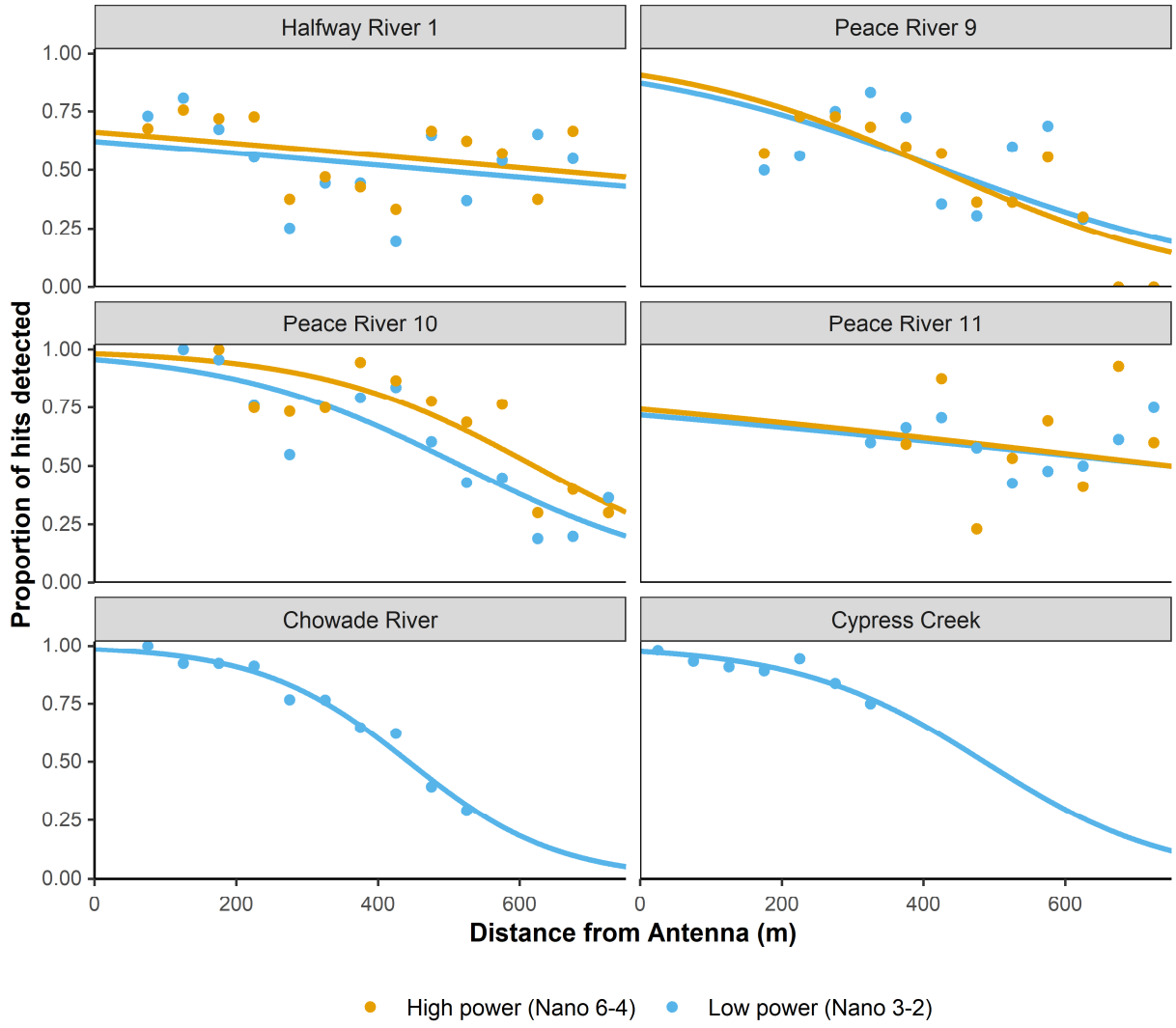

Figure 5. Set of range test results for stations with a Typical Detection Probability curve.

There were two stations that exhibited Atypical detection curves: Cache Creek and Peace River #8 (Figure 6, n=2). The low-power curve on Peace River #8 follows an unexpectedly flat trend, while Cache Creek shows a flattened and depressed efficiency curve. The final classification is a failed test (n=4), in which insufficient data were collected and detection efficiency curves were not constructed.

The relative detection probabilities of the low power (Nano NTF-3-2) versus the high power (Nano NTF-6-4) tags across the receiver stations yielded differences that were minimal.

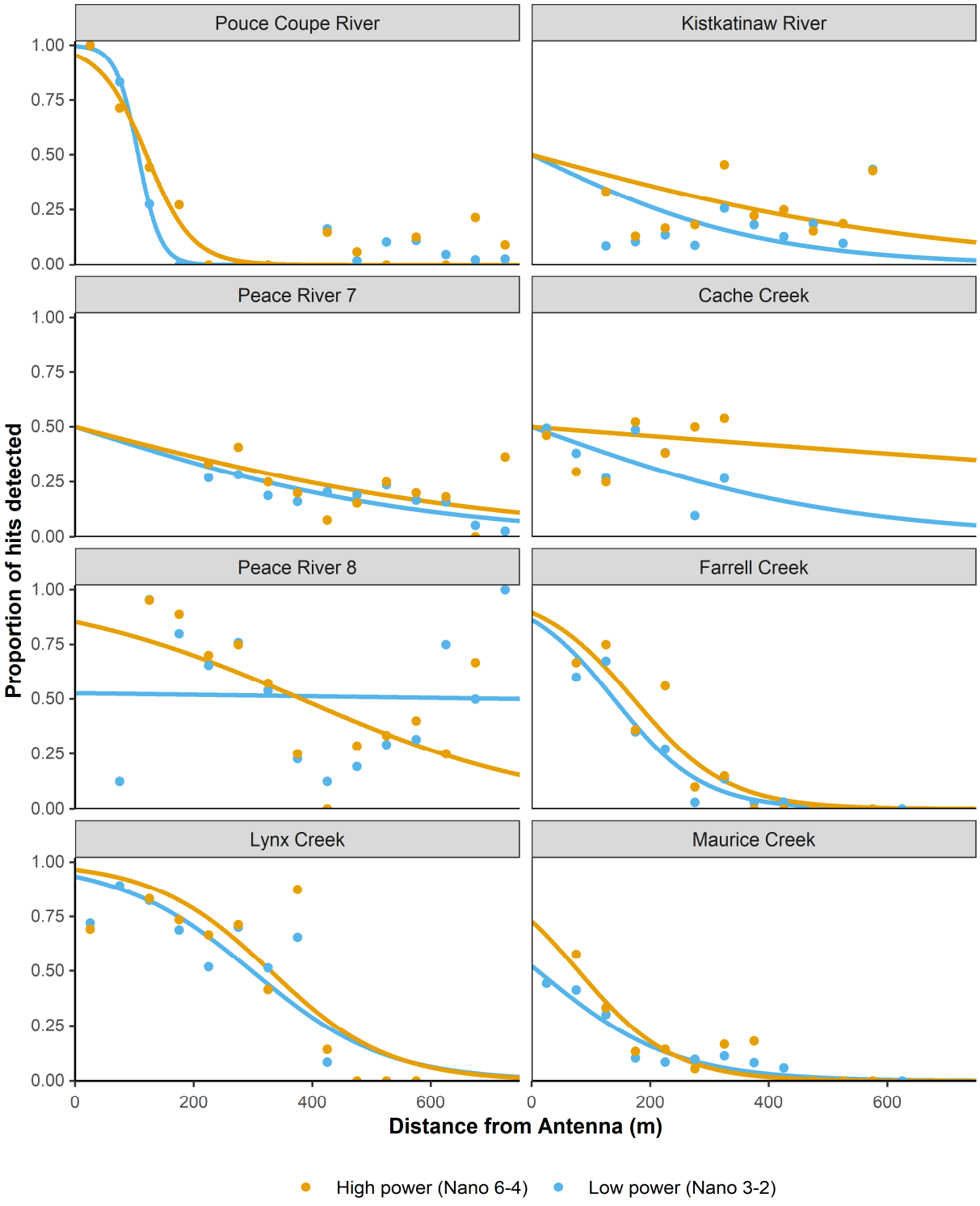

Figure 6. Range test results for stations with steep (Pouce Coupe River, Farrell Creek, Lynx Creek), depressed (Kiskatinaw River, Peace River #7, Maurice Creek), and atypical detection probability curves (Cache Creek, Peace River #8).

3.2 Data Management

3.2.1 Data Organization

The downloaded data files have been stored and compiled for inclusion into the Site C Fish Movement Assessment Database. The Site C Fish Movement Assessment Database is a SQL-Server relational database comprised of multiple data tables stored on a local network. Data are retrieved and queried using Microsoft Access as the front-end to the database. All data tables are carefully keyed and organized for easy and comprehensive querying. Figure 7 is a visual representation of the database, displaying how each of the tables relate to each other, while Table 7 describes each table with text.

3.2.2 Data Requests

To date, no requests have been submitted for any of the telemetry data from the Site C Fish Movement Assessment Database. A system is in place to accept data requests and record the request information into the SQL Server database (Table 7). Metadata about each request includes: the request date, fulfillment date, organization name, fulfiller name, requesters name, and requesters contact information.

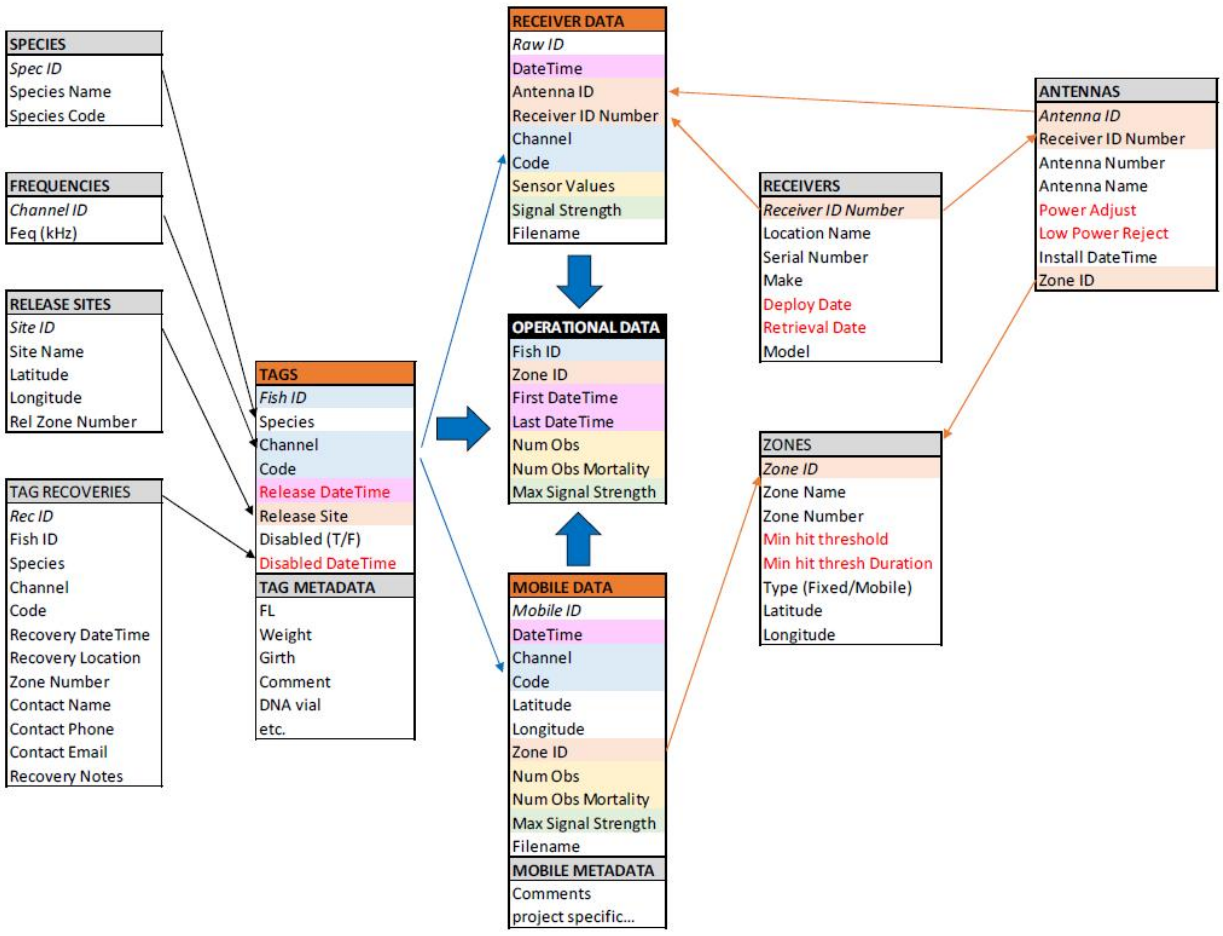

Figure 7. Visual representation of the database, displaying how each of the tables relate to each other.

Table 7. An outline of table names and table contents for the SQL server database.

Table Name	Table Contents	Notes
Species	Key to species codes	
Frequencies	Frequency, channel and code for all tags received	
Release Sites	Release locations	
Tag Recoveries	A detailed account of tags recovered	
Tags	Tagged fish characteristics and release data	
Antennas	Antenna orientation per station	
Receivers	Station locations as well as deploy/demob dates	
Zones	River zones geographically seperated for analysis	
Receiver Data	Processed detection data from fixed receiver sites	
Mobile Data	Processed detection data from mobile telemetry	
Operational Data	All processed detection data and fish attributes for analysis	
DataRequests	Record of data requests	not displayed in figure 7
DetRadio_FilesImported	Record of SRX800 detection files imported	not displayed in figure 7
EquipmentFunctionality	List of equipment inventory and status	not displayed in figure 7
DownTime	Station outages with date ranges and notes	not displayed in figure 7
StationDeployments	Station deployment locations and notes	not displayed in figure 7
StationEquipment	Equipment inventory per station	not displayed in figure 7

4.0 Discussion

The objective of Site C Fish Movement Assessment (Mon-1b, Task 2d) is to collect telemetry data that can determine the magnitude, direction and seasonal variability of movements of key indicator species in the Peace River and its tributaries. Between 4 July 2019 to 7 November 2019, the fixed radio telemetry array collected over 7 million validated and filtered detection records from the 329 radio tagged and released study fish.

Interruptions in data collection occurred at five stations in 2019, accounting for only 1% of the total hours in data collected. The outage caused from unplugging of the SRX800 was an early season error that did not reoccur. Additionally, wildlife disturbances were reduced by repositioning the panels into less-frequented spaces and concealing any cables. The remaining four sites that experienced power and data capacity issues in the fall will be avoided in coming years with more frequent visits, especially when solar windows begin to diminish, and data heavy stations are identified.

Range testing was an expansive effort in 2019, which provided insight into the functionality of the individual receiver stations. Range tests that resulted in Typical efficiency curves (14 of 26 stations) were interpreted as having strong and consistent range capabilities. Detection probabilities of 50% at 400-500 meters and a max range of >700 m is the expected outcome. Stations with a Steep efficiency curve (3 of 26 stations) were accepted given that the range limitations were caused by physical obstructions. Additionally, these stations were at tributary entrances which require less range capabilities than a station in the Peace River.

Stations that documented a Depressed efficiency curve (3 of 26 stations) had range limitations due to a noisy environment during testing. A noisy environment is prone to periods of intermittent interference that hampers a receiver station's ability to detect and code incoming signals. These stations also experienced an increase in intermittent interference outside of range testing, supporting the conclusion that these stations experience periods of range limiting noise during normal operation. Following range tests at these stations, receiver settings[18] were actively monitored and adjusted in-season to account for the increased interference to improve efficiency. Although these stations have a depressed detection curve relative to other stations, their detection probabilities remain sufficient for achieving the study objectives.

Atypical detection curves (2 of 26 stations) and failed tests (4 of 26 stations) signify that these tests need to be repeated. The Atypical curves show that these stations are functioning but have failed to create an interpretable detection curve for any number of reasons, including intermittent interference and/or insufficient data. Failed tests occurred on the Beatton River, Peace Canyon Dam, Peace River #2 and Site C Dam due to insufficient data collected. Regardless of the missing range test data, Beatton River, Peace River #2 and Site C Dam consistently collected valid detection data throughout the field season (Appendix B).

[18] Gains (a measure of a receiver's sensitivity) were reduced and a signal strength deviation filter was added.

5.0 References

AMEC Earth & Environmental and LGL Ltd. 2010. Peace River Fisheries Investigation, Peace River and Pine River Radio Telemetry Study 2009. Report prepared for BC Hydro Vancouver, BC.

AMEC Earth & Environmental and LGL Ltd. 2010. Analysis and Assessment of the Ministry of Environment's Peace River Bull Trout and Arctic Grayling Radio Telemetry Database 1996 to 1999. Report prepared for BC Hydro Vancouver, BC.

AMEC Earth & Environmental and LGL Ltd. 2008. Movements of radio-tagged Bull Trout and Arctic Grayling in the upper Peace River system, 1996 to 1999. Report prepared for BC Hydro Vancouver, BC.

Burrows J., T. Euchner and N. Baccante. 2001. Bull Trout movement patterns: Halfway River and Peace River progress. Bull Trout II Conference Proceedings: 153-157.

Kessel S. T., S. J. Cooke, M.R. Heupel, N.E. Hussey, C.A. Simfendorfer, S. Vagle and A. T. Fisk. 2014. A review of detection range testing in aquatic passive acoustic telemetry studies. Reviews in Fish Biology and Fisheries (24): 99–218.

6.0 Appendix A

Field Station Log Records - 2019

Table A1. Battery voltage, battery percent capacity, amp hours collected, detection data collected, station visitor initials and station notes are listed per station name and the date visited.

Station Name	Date Visited	Voltage	Battery%	Amp Hours	Data Collected (KB)	Initials	Notes
Peace River #1A	9 July 2019	13.4	100%	0	0	KH/HD	install
Peace River #1A	2 August 2019	12.4	70%	78	800	RC/KH	
Peace River #1A	30 August 2019	5.8	0%	139	2,000	RC/KH	dead - solar flipped
Peace River #1A	22 September 2019	13.4	100%	293	500	RC/KH	
Peace River #1A	4 November 2019	11.7	35%	422	3,400	RC/KH/SC	demob
Peace River #1B	9 July 2019	13.1	100%	0	0	KH/HD	install
Peace River #1B	2 August 2019	12.8	88%	0	100	RC/KH	solar controller switched
Peace River #1B	30 August 2019	12.8	90%	152	3,000	RC/KH	
Peace River #1B	22 September 2019	12.3	73%	242	800	RC/KH	settings changed
Peace River #1B	4 November 2019	0.0	0%	-	300	RC/KH/SC	dead & demob
Peace River #2	11 September 2019	12.9	100%	0	0	JS/RC	install
Peace River #2	2 August 2019	13.8	100%	174	800	KH/HD	
Peace River #2	30 August 2019	13.7	100%	347	1,300	RC/KH	
Peace River #2	22 September 2019	13.7	100%	488	400	RC/KH	
Peace River #2	4 November 2019	13.5	100%	734	700	RC/KH/SC	demob
Pouce Coupe River	8 July 2019	12.9	100%	0	0	JS/RC	install
Pouce Coupe River	2 August 2019	12.7	85%	114	200	KH/HD	
Pouce Coupe River	30 August 2019	11.7	33%	212	1,200	RC/KH	battery swap
Pouce Coupe River	22 September 2019	12.1	52%	324	1,100	RC/KH	battery swap
Pouce Coupe River	4 November 2019	0.0	0%	-	2,000	RC/KH/SC	dead & demob
Peace River #3	8 July 2019	12.9	100%	0	0	JS/RC	install
Peace River #3	3 August 2019	13.8	100%	188	100	RC/KGH	
Peace River #3	31 August 2019	14.7	100%	357	100	RC/KH	
Peace River #3	22 September 2019	13.7	100%	494	600	RC/KH	
Peace River #3	5 November 2019	12.9	100%	736	2,600	RC/KH/SC	demob
Kiskatinaw River	13 July 2019	14.2	100%	0	0	KH/HD	install
Kiskatinaw River	3 August 2019	13.9	100%	145	900	KH/RH	
Kiskatinaw River	31 August 2019	13.8	100%	302	1,200	RC/KH	
Kiskatinaw River	22 September 2019	13.7	100%	428	500	RC/KH	
Kiskatinaw River	5 November 2019	12.8	88%	649	1,000	RC/KH/SC	demob
Beatton River	13 July 2019	13.5	100%	0	0	KH/HD	install
Beatton River	3 August 2019	13.5	90%	120	100	KH/RH	
Beatton River	31 August 2019	14.6	100%	334	300	RC/KH	
Beatton River	23 September 2019	12.7	82%	442	1,700	RC/KH	
Beatton River	5 November 2019	0.0	0%	-	15,500	RC/KH/SC	demob/dead/low data
Peace River #4	12 July 2019	14.0	100%	0	0	KH/HD	install
Peace River #4	5 August 2019	13.5	100%	173	400	RC/KH	station moved
Peace River #4	29 August 2019	13.8	100%	318	300	RC/KH	
Peace River #4	20 September 2019	13.4	100%	450	2,400	RC/KH	
Peace River #4	5 November 2019	14.0	100%	715	10,800	RC/KH/SC	demob
Pine River	7 July 2019	13.7	100%	0	0	KH/HD	install
Pine River	3 August 2019	13.7	100%	188	700	RC/KH	
Pine River	31 August 2019	13.8	100%	349	1,000	RC/KH	
Pine River	23 September 2019	13.8	100%	483	600	RC/KH	
Pine River	5 November 2019	13.1	100%	719	800	RC/KH/SC	demob
Peace River #5	7 July 2019	13.7	100%	0	0	KH/HD/RC	demob
Peace River #5	14 July 2019	13.7	100%	105	100	KH/HD/RC	test
Peace River #5	3 August 2019	13.6	100%	202	300	RC/KH	
Peace River #5	31 August 2019	13.7	100%	373	300	RC/KH	
Peace River #5	23 September 2019	14.0	100%	516	300	RC/KH	
Peace River #5	5 November 2019	12.8	90%	745	1,200	RC/KH/SC	install

Table A2. Battery voltage, battery percent capacity, amp hours collected, detection data collected, station visitor initials and station notes are listed per station name and the date visited.

Station Name	Date Visited	Voltage	Battery%	Amp Hours	Data Collected (KB)	Initials	Notes
Site C Dam	11 July 2019	13.2	100%	0	0	RC/KH	install
Site C Dam	7 August 2019	13.2	100%	229	500	RC/KH	
Site C Dam	2 September 2019	13.3	100%	-	200	RC/KH	
Site C Dam	21 September 2019	13.0	90%	559	1,300	RC/KH	
Site C Dam	3 November 2019	13.1	90%	700	4,400	RC/KH/SC	demob
Moberly River #1	11 July 2019	14.3	100%	0	0	RC/KH	
Moberly River #1	7 August 2019	14.5	100%	241	600	RC/KH	
Moberly River #1	2 September 2019	13.9	100%	495	600	RC/KH	
Moberly River #1	21 September 2019	14.3	100%	597	300	RC/KH	
Moberly River #1	3 November 2019	12.9	100%	922	1,300	RC/KH/SC	demob
Peace River #6	10 July 2019	12.9	100%	0	0	JS/RC	install
Peace River #6	3 August 2019	13.7	100%	224	1,200	RC/KH	
Peace River #6	31 August 2019	13.7	100%	446	1,000	RC/KH	
Peace River #6	23 September 2019	13.7	100%	627	400	RC/KH	
Peace River #6	5 November 2019	13.7	100%	-	600	RC/KH/SC	demob
Peace River #7	16 July 2019	13.7	100%	0	0	JS/KH	install
Peace River #7	5 August 2019	13.7	100%	268	800	RC/KH	
Peace River #7	29 August 2019	13.8	100%	469	400	RC/KH	
Peace River #7	21 September 2019	13.8	100%	653	400	RC/KH	
Peace River #7	7 November 2019	13.7	90%	1001	4,800	RC/KH/SC	demob
Cache Creek	4 July 2019	14.4	100%	0	0	JS/KH	install
Cache Creek	4 August 2019	13.5	100%	247	100	RC/KH	
Cache Creek	29 August 2019	13.5	100%	525	300	RC/KH	
Cache Creek	20 September 2019	13.0	100%	711	200	RC/KH	
Cache Creek	6 November 2019	13.2	100%	-	1,500	RC/KH/SC	demob
Peace River #8	6 July 2019	13.9	100%	0	0	JS/KH	install
Peace River #8	4 August 2019	13.7	100%	256	100	RC/KH	
Peace River #8	29 August 2019	13.8	100%	457	600	RC/KH	
Peace River #8	21 September 2019	13.7	100%	638	3,600	RC/KH	
Peace River #8	3 November 2019	13.1	100%	971	14,500	RC/KH/SC	demob
Halfway River #1	8 July 2019	12.9	100%	0	0	RC/KH	install
Halfway River #1	4 August 2019	13.6	100%	247	900	RC/KH	
Halfway River #1	29 August 2019	13.9	100%	453	1,200	RC/KH	
Halfway River #1	21 September 2019	13.3	100%	629	400	RC/KH	
Halfway River #1	3 November 2019	12.9	90%	826	1,800	RC/KH/SC	demob
Peace River #9	8 July 2019	13.2	100%	0	0	KH	install
Peace River #9	4 August 2019	13.7	100%	259	900	RC/KH	
Peace River #9	29 August 2019	13.8	100%	467	1,300	RC/KH	
Peace River #9	20 September 2019	13.7	100%	649	1,400	RC/KH	changed settings
Peace River #9	3 November 2019	13.0	100%	1000	1,500	RC/KH/SC	demob
Farrell Creek	13 July 2019	13.0	100%	0	0	JS/RC	install
Farrell Creek	4 August 2019	13.7	100%	159	500	RC/KH	
Farrell Creek	29 August 2019	13.5	100%	342	500	RC/KH	
Farrell Creek	20 September 2019	13.7	100%	499	1,400	RC/KH	changed settings
Farrell Creek	2 November 2019	13.0	90%	797	1,800	RC/KH/SC	demob

Table A3. Battery voltage, battery percent capacity, amp hours collected, detection data collected, station visitor initials and station notes are listed per station name and the date visited.

Station Name	Date Visited	Voltage	Battery%	Amp Hours	Data Collected (KB)	Initials	Notes
Peace River #10	13 July 2019	13.0	100%	0	0	JS/RC	install
Peace River #10	4 August 2019	13.5	100%	161	100	RC/KH	
Peace River #10	29 August 2019	13.8	100%	211	100	RC/KH	SRX unplugged
Peace River #10	20 September 2019	13.8	100%	369	1,200	RC/KH	
Peace River #10	2 November 2019	14.7	100%	701	3,600	RC/KH/SC	demob
Lynx Creek	12 July 2019	13.0	100%	0	0	JS/RC	install
Lynx Creek	6 August 2019	13.5	100%	180	100	RC/KH	
Lynx Creek	29 August 2019	14.0	100%	360	200	RC/KH	
Lynx Creek	20 September 2019	13.6	100%	527	2,200	RC/KH	
Lynx Creek	2 November 2019	12.6	80%	806	4,300	RC/KH/SC	demob
Peace River #11	13 July 2019	13.0	100%	0	0	JS/RC	install
Peace River #11	6 August 2019	13.5	100%	212	200	RC/KH	
Peace River #11	29 August 2019	13.9	100%	399	1,700	RC/KH	
Peace River #11	20 September 2019	13.7	100%	569	8,200	RC/KH	
Peace River #11	7 November 2019	12.6	81%	914	16,000	RC/KH/SC	demob & data full
Maurice Creek	10 July 2019	13.8	100%	0	0	KH/HD	install
Maurice Creek	6 August 2019	13.7	100%	238	1,100	RC/KH	
Maurice Creek	29 August 2019	13.9	100%	425	1,000	RC/KH	
Maurice Creek	20 September 2019	13.8	100%	593	2,400	RC/KH	
Maurice Creek	2 November 2019	12.5	74%	876	4,300	RC/KH/SC	demob
Peace Canyon Dam	10 July 2019	14.3	100%	0	0	KH/HD	
Peace Canyon Dam	6 August 2019	14.2	100%	242	2,900	RC/KH	
Peace Canyon Dam	29 August 2019	14.3	100%	429	2,700	RC/KH	
Peace Canyon Dam	20 September 2019	13.0	90%	548	2,200	RC/KH	
Peace Canyon Dam	2 November 2019	12.8	90%	929	500	RC/KH/SC	
Chowade River	31 July 2019	13.7	-	-	0	KH	install
Chowade River	7 August 2019	13.8	-	-	200	JB	
Chowade River	13 August 2019	13.7	-	-	200	AP	
Chowade River	28 August 2019	13.8	-	-	200	LJW/SL	
Chowade River	7 September 2019	13.8	-	-	200	AP/LJ	
Chowade River	11 September 2019	13.9	-	-	200	CTM/LJW	
Chowade River	25 September 2019	13.6	-	-	200	AP	
Chowade River	3 October 2019	13.4	-	-	200	LJ	
Chowade River	24 October 2019	13.1	-	-	200	AR/LJ	
Chowade River	17 November 2019	12.9	-	-	200	KC/LJW	
Chowade River	12 December 2019	12.3	-	-	200	KC/LJW	battery swap
Chowade River	19 December 2019	12.6	-	-	200	LJ/AP	battery swap
Chowade River	21 December 2020	12.1	-	-	200	LJ/CM	battery swap
Cypress Cr	30 July 2019	13.5	-	-	0	KH	install
Cypress Cr	1 August 2019	13.8	-	-	200	LJ	
Cypress Cr	6 August 2019	13.6	-	-	200	LJ	
Cypress Cr	22 August 2019	13.9	-	-	200	MC/AR	
Cypress Cr	29 August 2019	13.4	-	-	200	LJW/SL	
Cypress Cr	12 September 2019	13.8	-	-	200	CM/LJ	
Cypress Cr	30 September 2019	13.9	-	-	200	MC/AR	
Cypress Cr	23 October 2019	13.7	-	-	200	LJ/AR	
Cypress Cr	13 November 2019	13.6	-	-	200	LJ/KC	
Cypress Cr	2 December 2019	12.8	-	-	200	LJ/KC	
Cypress Cr	19 December 2019	13.8	-	-	200	AR/LJ	
Cypress Cr	2 January 2020	12.7	-	-	200	LJ/CM	panels covered w/ snow

7.0 Appendix B

Valid, Noise, False-Positive and Beacon Detection by Date and Receiver

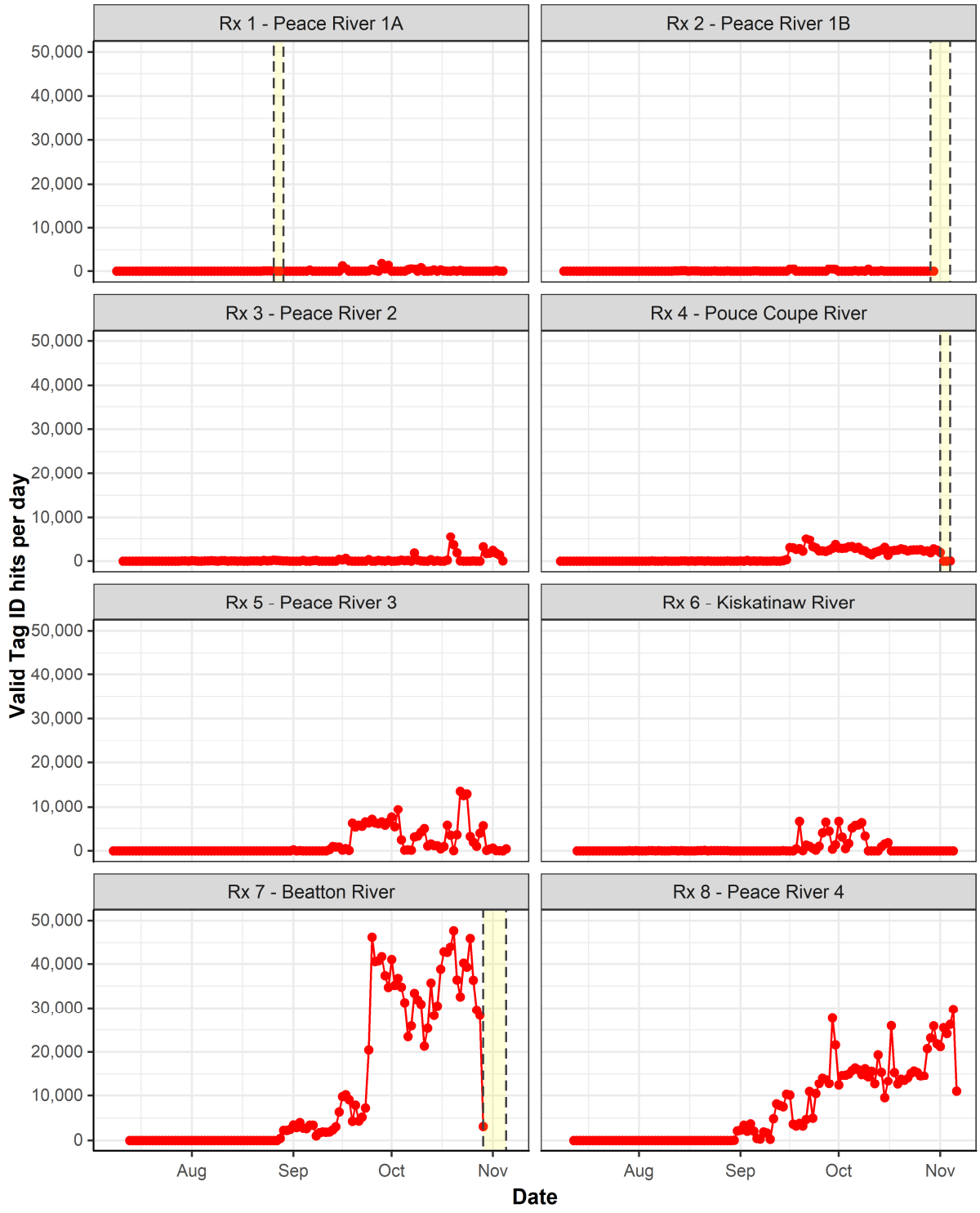

Figure B1. Validated detection signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

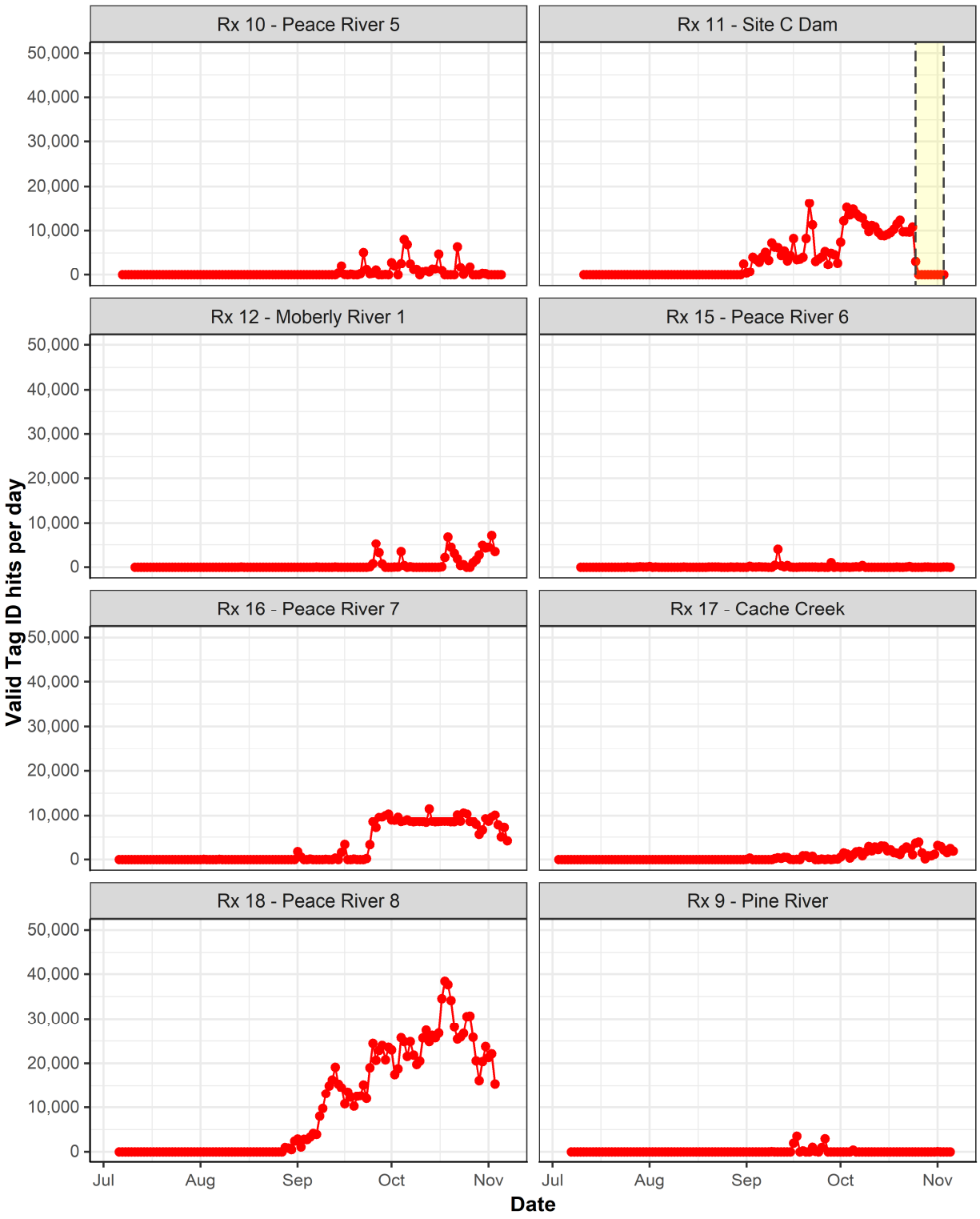

Figure B2. Validated detection signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

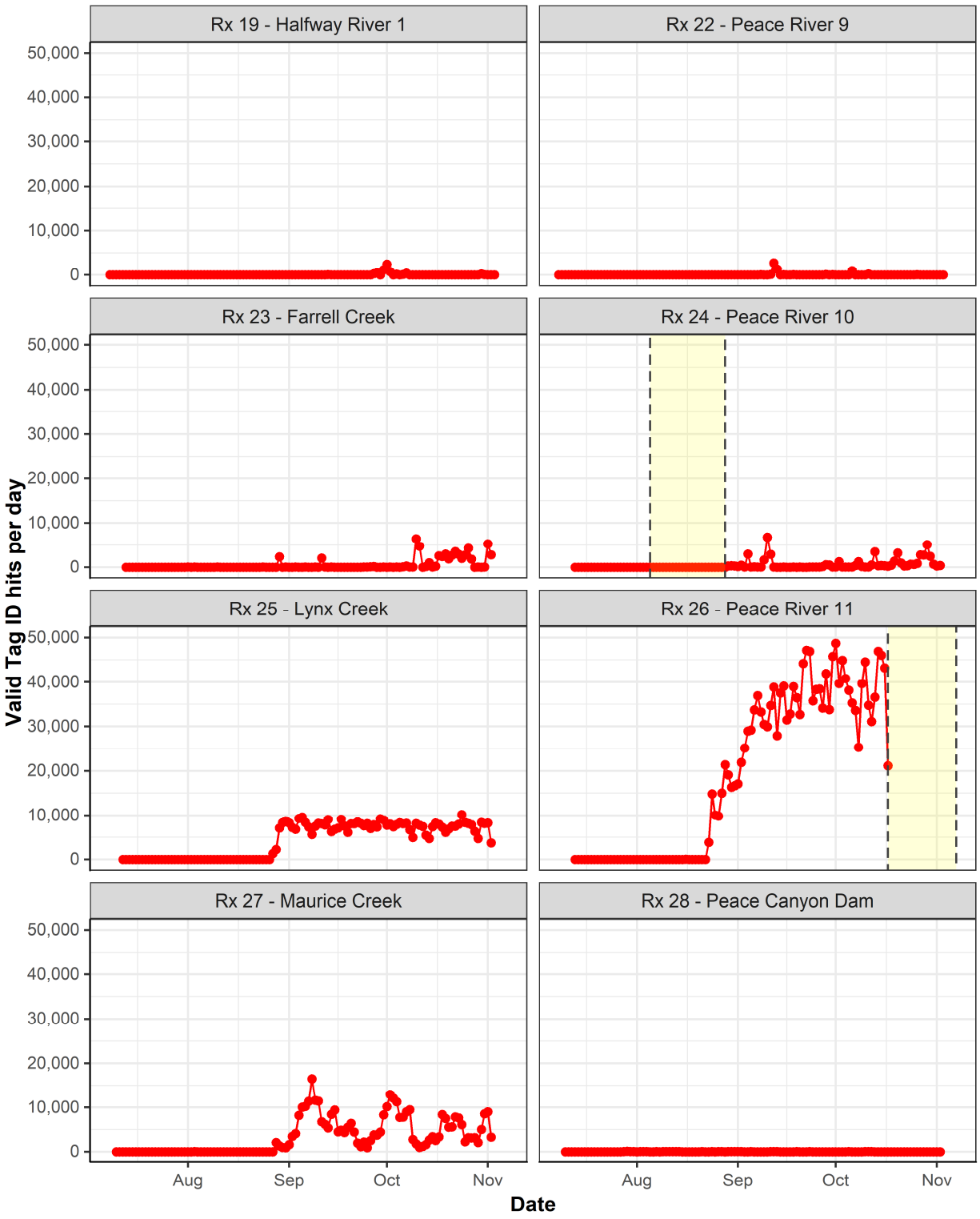

Figure B3. Validated detection signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

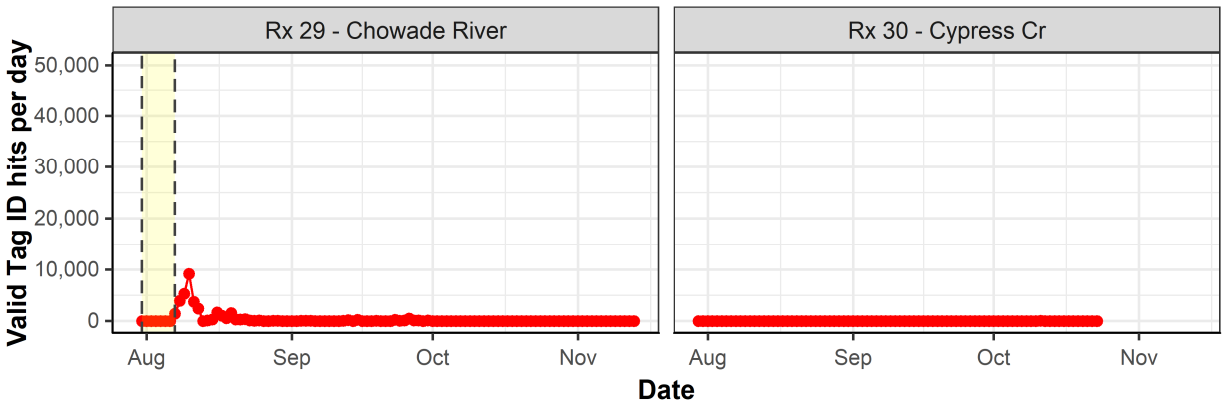

Figure B4. Validated detection signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

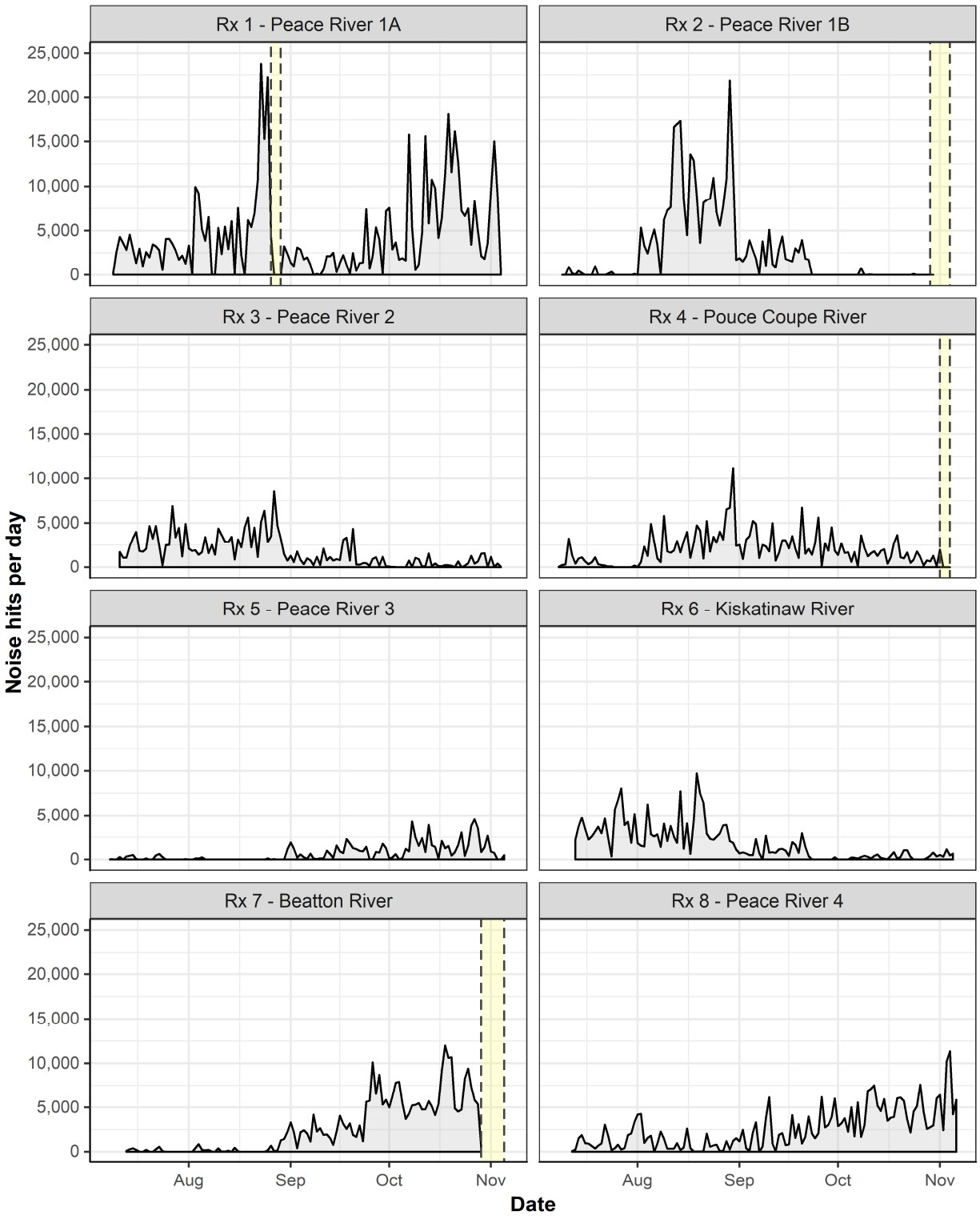

Figure B5. Noise (Code 999) signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

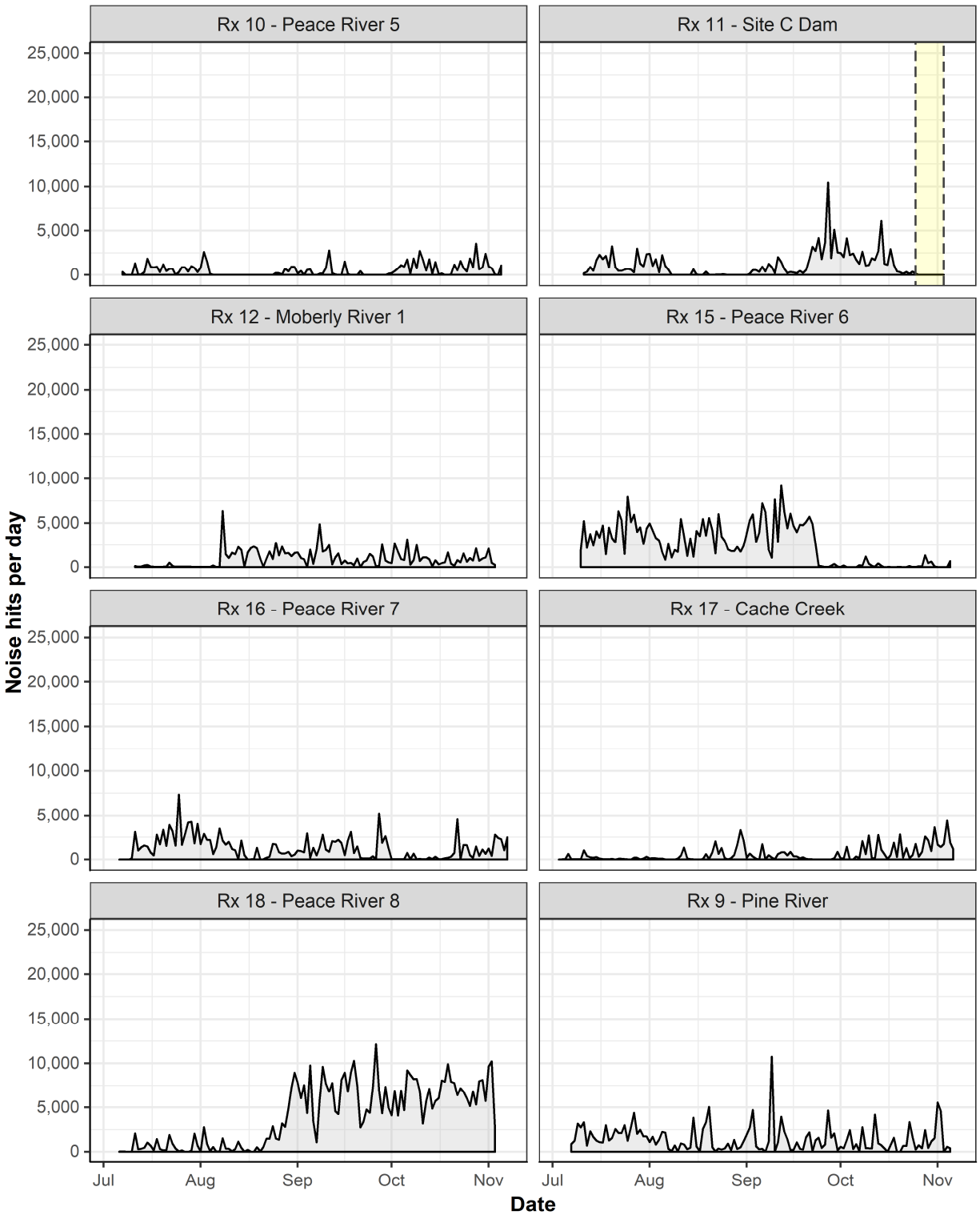

Figure B6. Noise (Code 999) signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

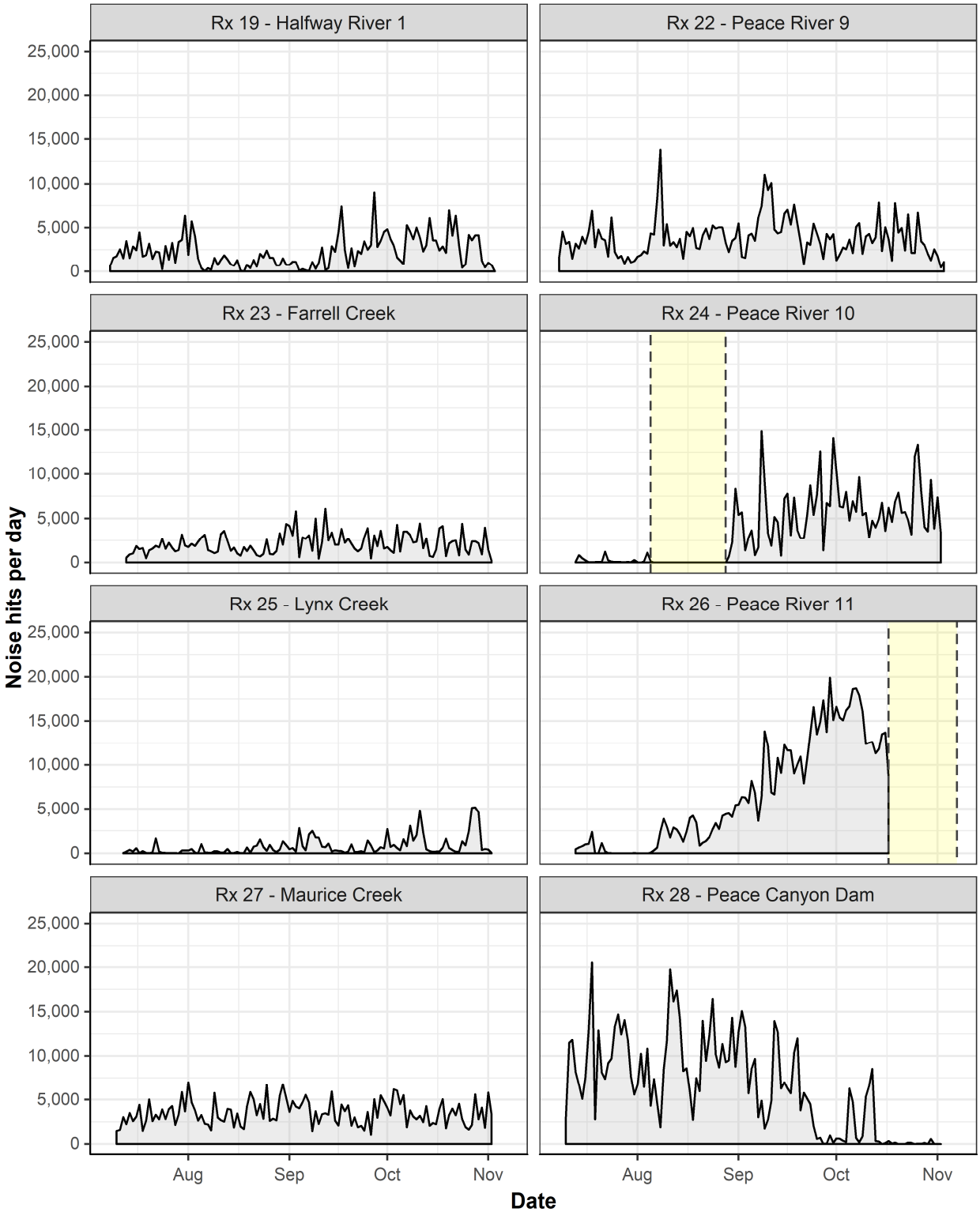

Figure B7. Noise (Code 999) signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

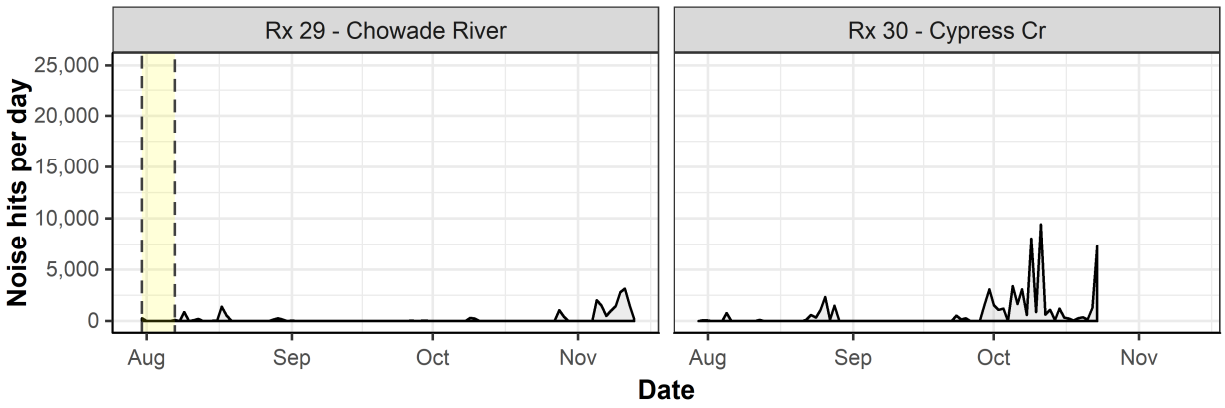

Figure B8. Noise (Code 999) signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

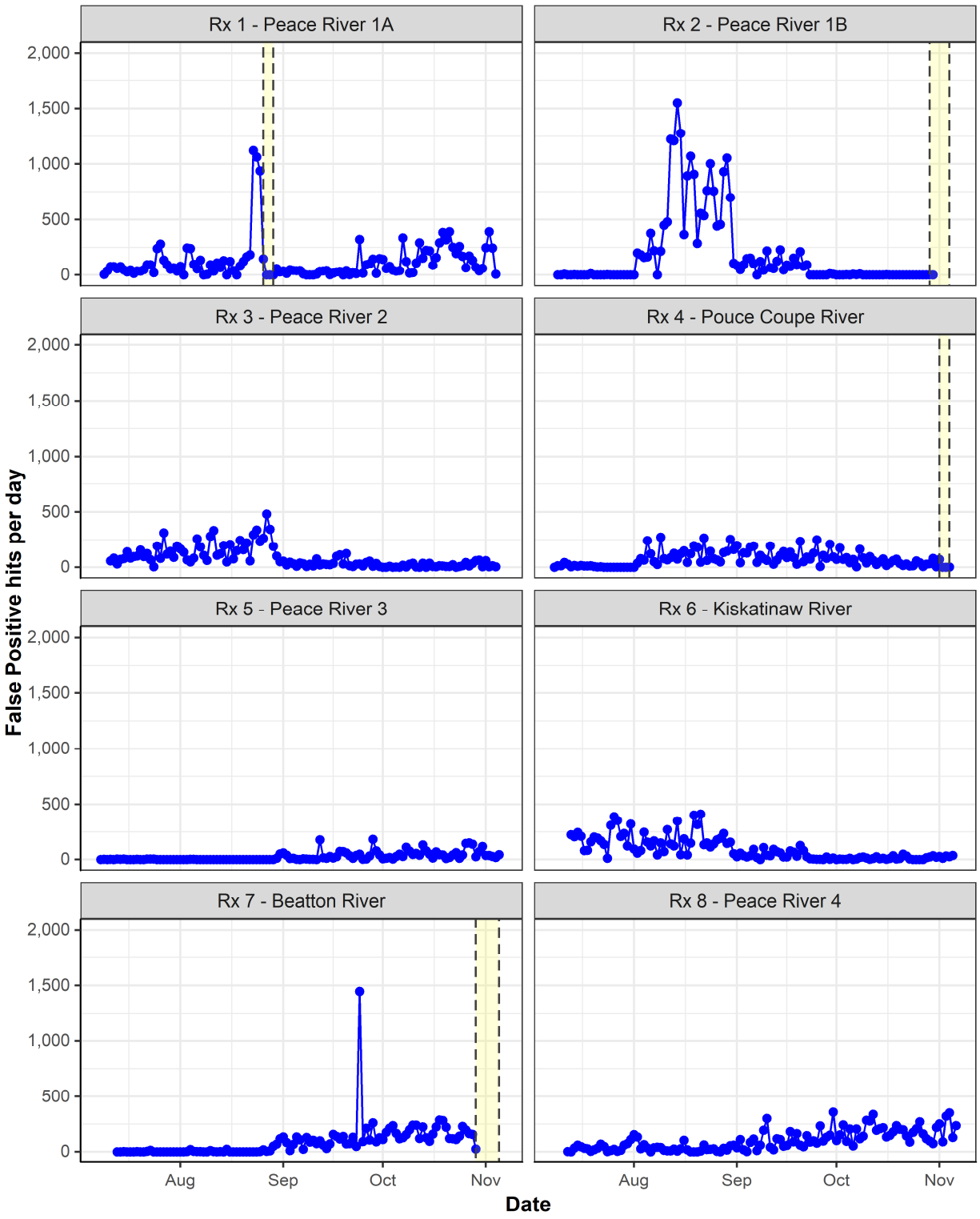

Figure B9. False positive signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

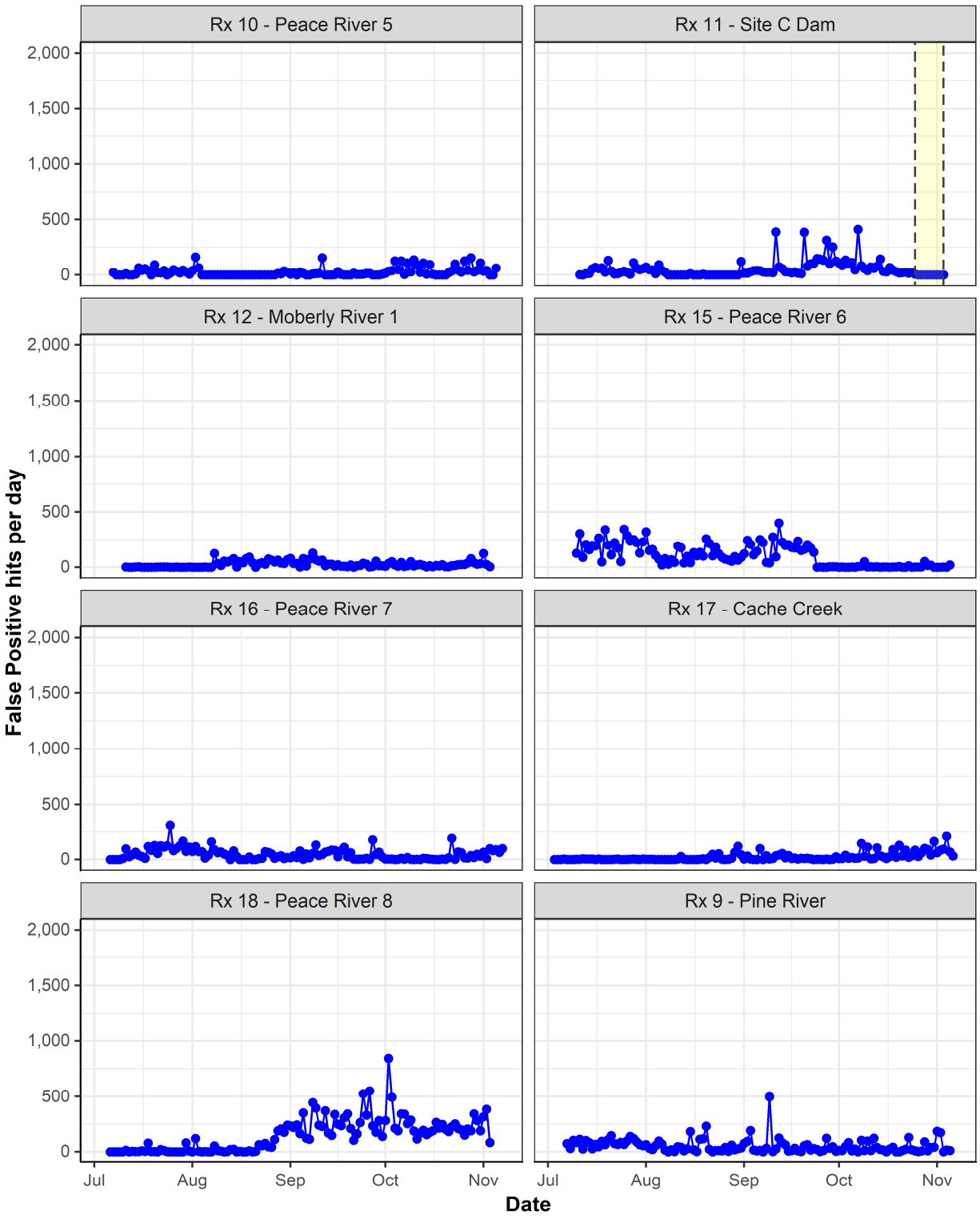

Figure B10. False positive signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

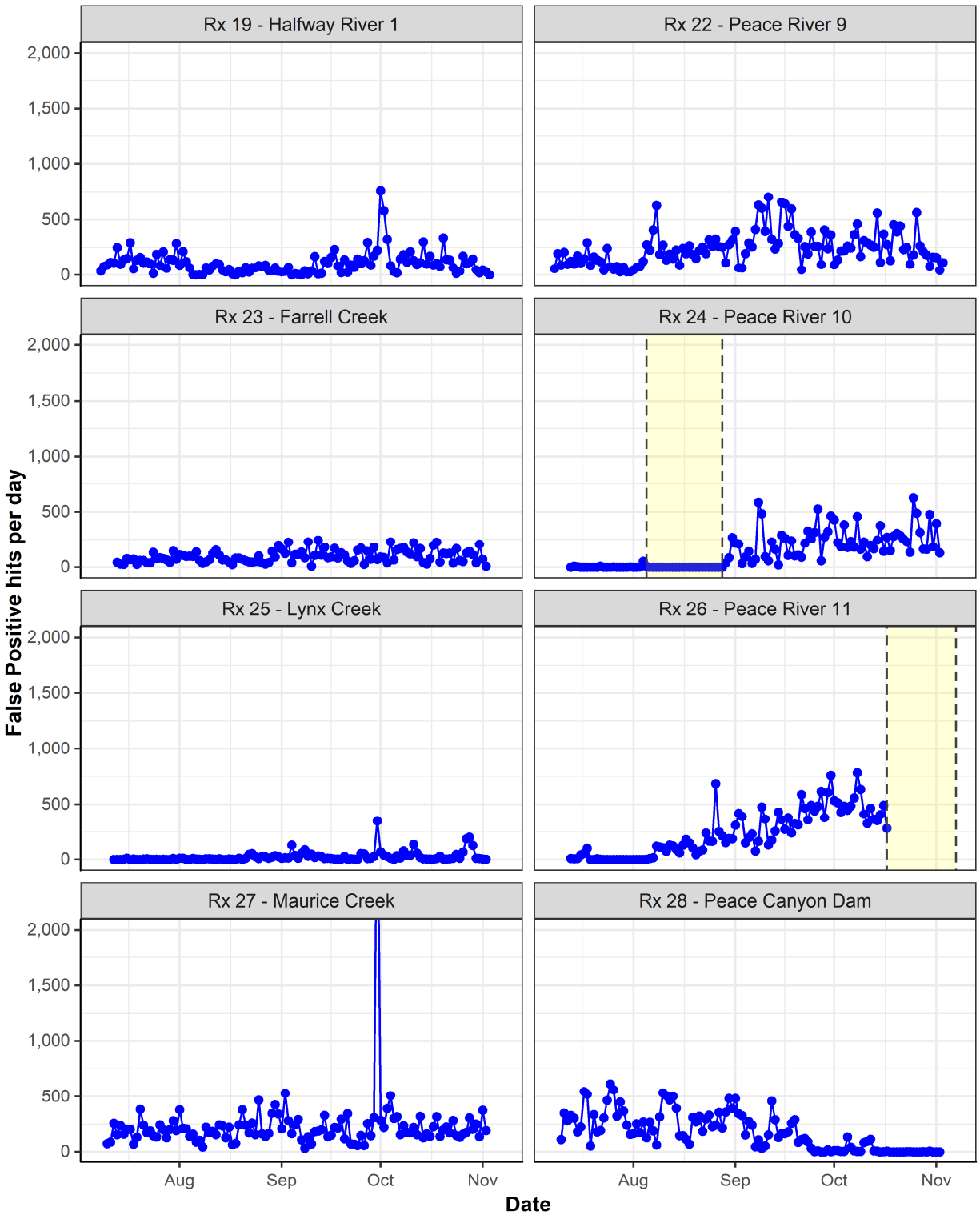

Figure B11. False positive signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

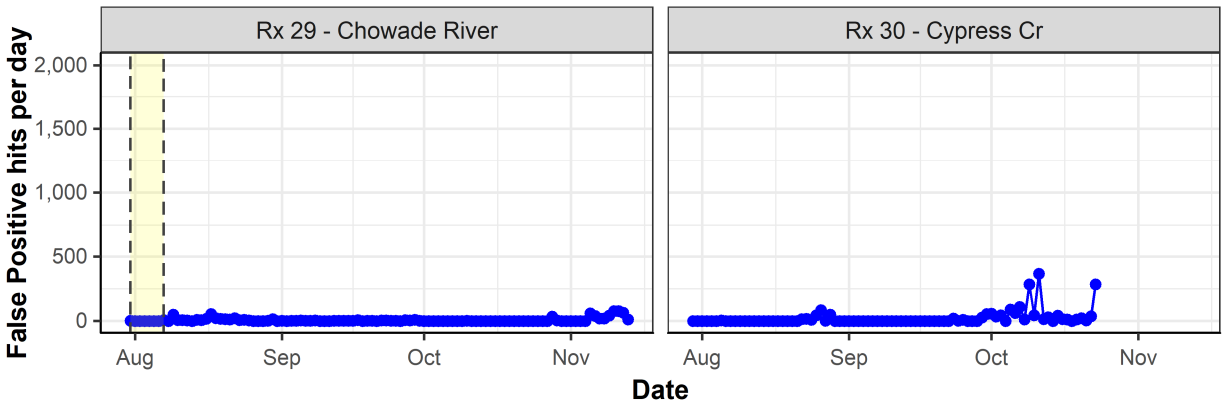

Figure B12. False positive signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

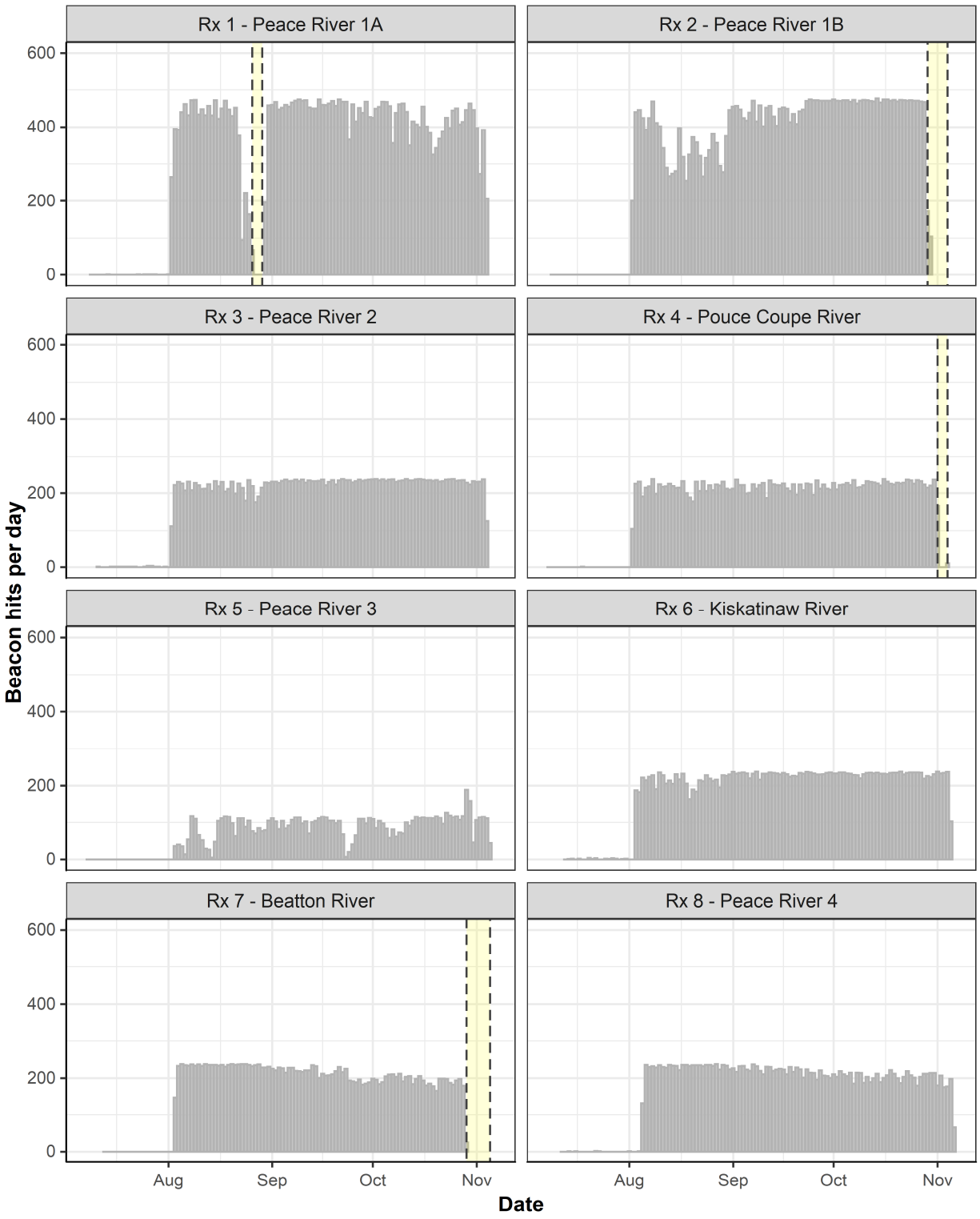

Figure B13. Beacon tag signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

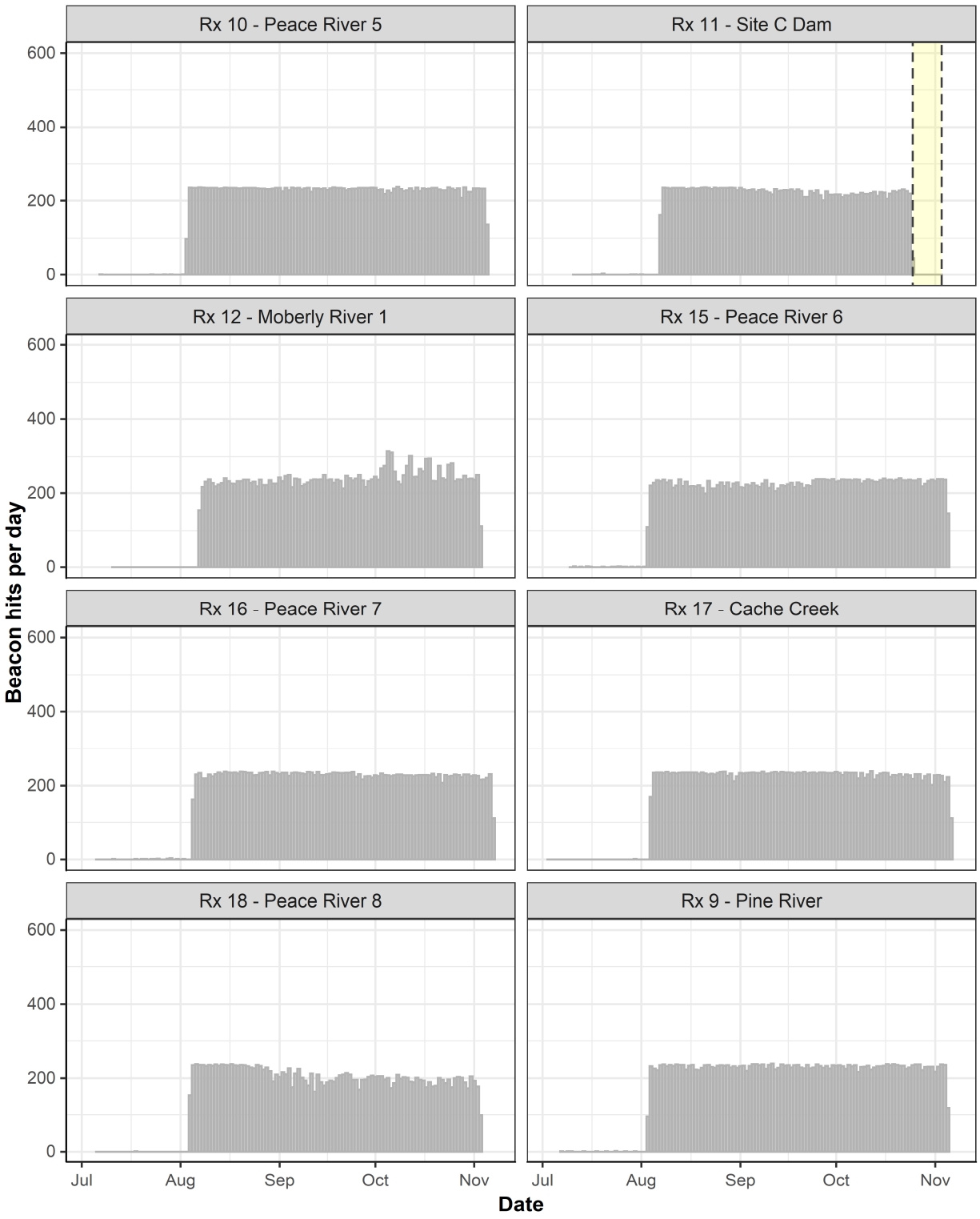

Figure B14. Beacon tag signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

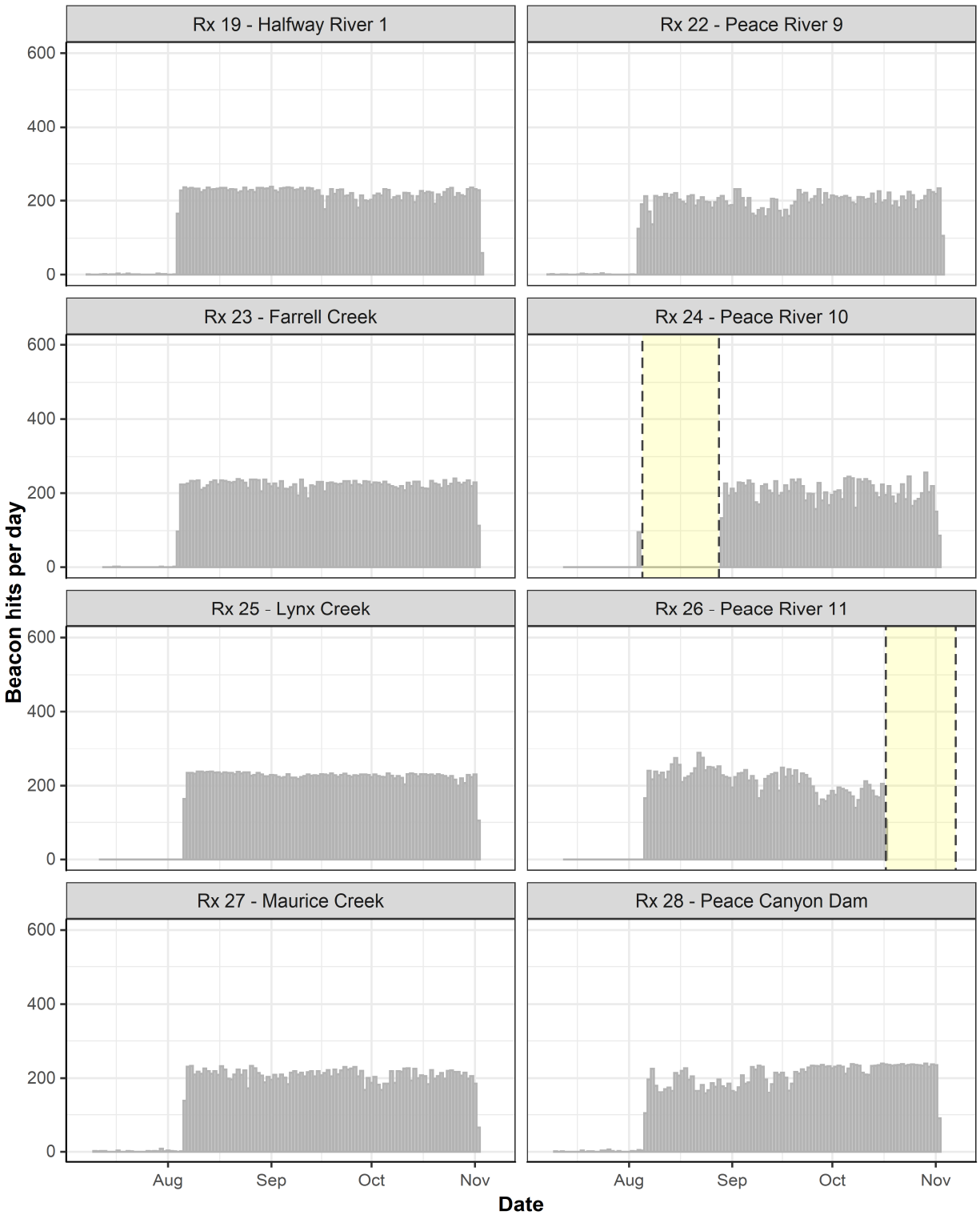

Figure B15. Beacon tag signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.

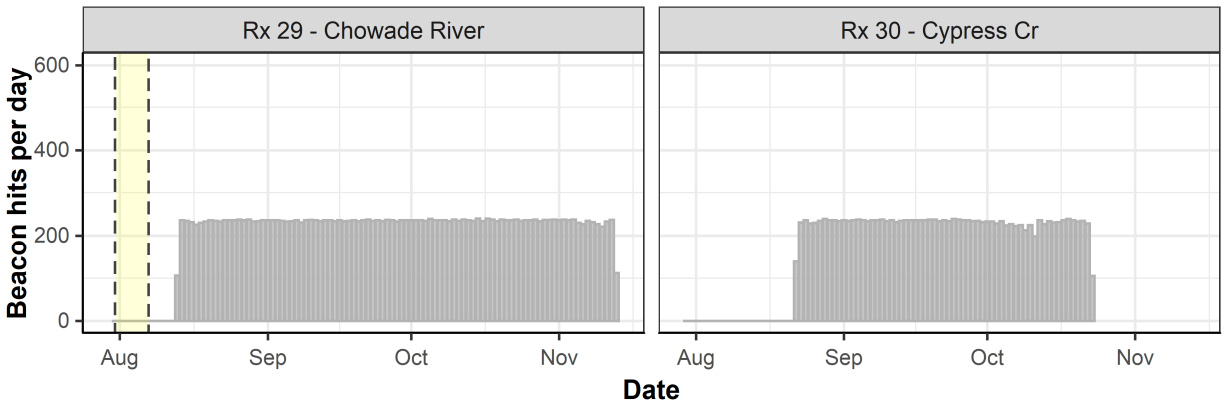

Figure B16. Beacon tag signals by station organized into hits per day in 2019. The spaces highlighted with a yellow rectangle signify periods in which receiver outages had occurred and data collection did not proceed.