Site C Clean Energy Project

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

Task 2a – Peace River Arctic Grayling and Bull Trout Movement Assessment

Task 2d – Site C Fish Movement Assessment

Construction Year 8 (2022)

Kyle Hatch, MSc
LGL Limited

David Robichaud, PhD, RPBio
LGL Limited

Benjamin Cox, MSc
LGL Limited

Steve Crawford, BSc
LGL Limited

24 May 2023

Agreement Numbers 12273 and 14200

Site C Fish Movement Assessment (Mon-1b, Tasks 2a and 2d)

Prepared for:

Nich Burnett
BC Hydro
333 Dunsmuir Street, 13th floor
Vancouver, BC V6B 5R3

Prepared by:

Kyle Hatch, David Robichaud, Benjamin Cox, and Steve Crawford
LGL Limited
9768 Second Street
Sidney, BC V8L 3Y8

24 May 2023

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 staff stationed in Fort St. John that directly helped this project succeed; Justin Krilow, Peter Merth, Matt McGoveran, Jessica Brunet, Laura Young, Jordan Macdonald, Sean Dignan, Arshad Khan, Kaylan McDonald, Sabrina, Penney Bryan Koehler, and Sheri Huff, among others. Thank you also to 4 Evergreen Resources for their staff contributions. We acknowledge this research is being conducted on the traditional territory of Treaty 8 First Nations of Dunne Zaa, Cree and Tse'khene cultural descent. Thanks also to WSP Global, specifically Demitria Burgoon, Dustin Ford and Riley Jellicoe for their support. Finally, thank you to Julio Novoa, Cam McCulloch, Karl English, Lucia Ferreira, Anita Blakley, Steven Roias, Yury Bychkov, and Riley Waytes from LGL Limited for their significant contributions.

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.

This report describes the monitoring data collected during the 2022 field season (1 January 2022 to 31 January 2023) as well as an accompanying analysis that includes all data collected from the ongoing study (1 May 2019 to 31 January 2023). The data collection and analysis are intended to address two components of Mon-1b; the Site C Fish Movement Assessment (Mon-1b, Task 2d) as well as the Peace River Arctic Grayling and Bull Trout Movement Assessment (Mon-1b, Task 2a).

The Site C Fish Movement Assessment (Mon-1b, Task 2d) was implemented 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 designed, deployed, and maintained a fixed radio telemetry array comprised of 28 to 34 fixed-stations per study year along the Peace River and its tributaries. The Peace River Arctic Grayling and Bull Trout Movement Assessment (Mon-1b, Task 2a) was designed to determine the magnitude, direction, and seasonality of Arctic Grayling and Bull Trout movements within the Peace River and its tributaries to help determine the Project's effects on these metrics, and to inform various monitoring programs.

The work was broken into three parts: 1) deployment and maintenance of the fixed-station array, along with the storage and organization of the resulting detection data; 2) fixed wing mobile tracking surveys to augment the data collected by the fixed-station array; and 3) data analysis to begin characterizing the movement patterns of key indicator species.

The array of fixed-stations was designed to encompass the Local Assessment Area from Peace Canyon Dam (RKM 20) to Many Islands, Alberta (RKM 231). Between these locations, fixed-stations were located at the entrance of every major tributary, with Peace River fixed-stations located approximately halfway between each tributary entrance. In all, 34 fixed-stations collected detection data in 2022. Three of which are operated perennially and have been maintained since their installation in 2019. The remaining 31 fixed-stations are operated seasonally and were re-installed for the 2022 season between 6 March and 6 September 2022. Sites deployed within an area of cellular coverage could be contacted remotely to check or change settings, check functionality, and/or download data. All sites were tested for basic operability and 33 fixed-stations were range tested. On average, 50% of transmissions were detected and properly decoded when tags were 291 m away; this metric varied among fixed-stations from 35 to 750 m.

[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.

Furthermore, the average fixed-station detection efficiency for both upstream and downstream movements was 85% in 2022 (range = 44 to 100%).

The 2022 mobile tracking effort focused on Halfway River Bull Trout during peak spawning migrations in September 2022. Two mobile surveys of the Halfway River were conducted over two-day periods[5] by fixed wing aircraft. Antennas were mounted to the aircraft and connected to telemetry receivers in the cabin for each mobile survey. Contrary to 2020 and 2021, no Moberly River mobile surveys were conducted to track spawning Arctic Grayling in 2022. Arctic Grayling spawning behaviour in the Moberly River was instead interpreted using the Moberly River array, comprised of four fixed-stations; Moberly River 1/2/3 and Moberly Lake. Furthermore, no supplemental mobile tracks were conducted during the 2022/2023 winter offseason[6].

The downloaded data files and the post-processed mobile-tracking data files were stored and compiled for inclusion into the Site C Fish Movement Assessment Database. Data were processed to validate the detection records by removing those that were likely false positives and those which resulted from electronic noise. The fixed-station array and mobile tracking efforts collected over 17 million valid detection records that passed the filtering criteria between 1 January 2022 and 31 January 2023. Individual fish tracks were processed for the distances and directions moved, and the seasonality of movement patterns.

Preliminary spawning results identified 38 active[7] adult Bull Trout with spawning behaviours in the Halfway River and its tributaries during the fall spawning period in 2022. Ten Bull Trout were identified to have spawned in the Chowade River, nine in Cypress Creek, five in the upper Halfway River (upstream of the Cameron River), three in the Graham River, one in Fiddes Creek, and one in Needham Creek. The remaining nine were last detected in the lower Halfway River below the confluence to the Cameron River. Additionally, two active adult Arctic Grayling exhibited spawning behaviour in the Moberly River during the Arctic Grayling spawning period from April to June 2022. Both Arctic Grayling individuals were presumed to have moved upstream beyond the inundation zone at RKM 12 to spawn.

Radio-tagged Mountain Whitefish were analyzed to interpret fall (September, October, November) behaviours that may be indicative of spawning or pre-spawning behaviours. There were 47 Mountain Whitefish radio-tagged in September/October 2021 available for this analysis. Of these fish, 18 individuals were detected in fall 2022 with the prominent behaviour (n= 13) being non-migratory (i.e., milling or resident). Four Mountain Whitefish exhibited potential spawn related behaviours by entering and exiting the Pine River in October 2022. Individuals were recording making similar movements in 2020 (n= 1), 2021 (n= 3), and in 2006/2007 (n= 5). The last Mountain Whitefish detected in fall 2022 executed a 75 RKM downstream migration through the Alberta section of the detection array between July and September 2022.

All of the results presented in this report are preliminary. The figures generated to characterize magnitude, seasonality and direction were created to display the capacity of the telemetry detection system (fixed and mobile), facilitate the analysis of large-scale monitoring of movement patterns, and to

---

[5] Halfway River mobile detection flights were conducted on 8 September, 9 September, 18 September, and 19 September 2022.

[6] Supplemental mobile surveys during the off-season were conducted during the 2020/2021 and 2021/2022 winters.

[7] Active refers to a radio-tagged study fish that is not a mortality and possesses a tag that has not yet expired. In terms of spawning, an active study fish is an individual that was tagged before the spawning period began, was detected following release, and was detected during and/or after the spawning period.

support answering specific management questions. The management questions that are presented herein were carefully curated to be at least partially addressable with the data available at the time of writing. Tagged study fish continue to move and be detected. Continued operation of the fixed-station array, and continued mobile tracking, will help further address the management questions outlined herein, as well as those that will be addressed in the future.

Table of Contents

List of Figures

List of Tables

List of Appendices

Introduction

In accordance with Provincial Environmental Assessment Certificate Condition No. 7[8] and Federal Decision Statement Condition Nos. 8.4.3[9] and 8.4.4[10] 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[11]). 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.

This report addresses two interrelated tasks within the Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b); the Site C Fish Movement Assessment (Task 2d) as well as the Peace River Arctic Grayling and Bull Trout Movement Assessment (Task 2a). The Site C Fish Movement Assessment was implemented in 2019 to characterize the magnitude, seasonality, and direction of six key indicator species (Arctic Grayling *Thymallus arcticus*, Bull Trout *Salvelinus confluentus*, Burbot *Lota lota*, Rainbow Trout *Oncorhynchus mykiss*, and Walleye *Sander vitreus*) in the Peace River and its tributaries while the Peace River Arctic Grayling and Bull Trout Movement Assessment expanded on those objectives by focusing on Bull Trout and Arctic Grayling movements within known spawning tributaries.

To achieve the study objectives of both tasks, radio telemetry was employed to catalog fish movements throughout the Peace River and its tributaries. More specifically, study fish were implanted with specialized radio transmitters and were detected by either fixed-station or mobile tracking techniques. Fixed-stations benefit from the capability for continuous operation at important locations which, in turn, provides the basis for addressing the objectives of the Site C Fish Movement Assessment. Mobile tracking, on the other hand, primarily serves to address the Peace River Arctic Grayling and Bull Trout Movement Assessment as well as supplement the underlying telemetry dataset.

The fixed radio telemetry array was designed to span the temporal and spatial extent of the FAHMFP. Temporally, collection of radio telemetry data began in July 2019 (Hatch et al. 2020) with the aim to build on baseline studies that were conducted by the BC Ministry of Environment from 1996-1999 (Burrows et al. 2001, AMEC & LGL 2010b), and by AMEC and LGL from 2005-2009 (AMEC & LGL 2008a,b, 2009, 2010a). The intent is to operate the array in Construction Years 5 to 10[12] followed by Operation Years 1-4, 10-11, 15-16, 20-21, 25-26 and 29-30[13]. Spatially, the extent of the array is meant to coincide with the sampling and tagging of target species by the Peace River Large Fish Indexing Survey (Mon-2, Task 2a). The array was designed to cover 200 river kilometres of the Peace River, including the entrances to major tributaries (Maurice Creek, Lynx Creek, Farrell Creek, Halfway River, Cache Creek, Moberly River, Pine River, Beatton River, Kiskatinaw River, and Pouce Coupe River), as well as to provide additional coverage within important tributaries (Halfway River,

---

[8] 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.

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

[10] 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.

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

[12] 2019 - 2024

[13] 2024-2028, 2034-2035, 2039-2040, 2044-2045, 2049-2050 and 2053-2054, respectively

Moberly River, Chowade River, and Cypress Creek). That said, the array is designed to be flexible, whereby stations can be added, moved, and/or improved as monitoring progresses or study priorities shift.

The Peace River Arctic Grayling and Bull Trout Movement Assessment (Mon-1b, Task 2a) began in 2020 with mobile tracking surveys conducted from a helicopter or fixed wing aircraft. Mon-1b, Task 2a expanded on the fixed station array's coverage area by venturing further into recognized spawning tributaries for Arctic Grayling and Bull Trout. The temporal and spatial extent of the tracking surveys cover known migratory periods (April to June for Arctic Grayling; August to September for Bull Trout) and locations (Moberly River for Arctic Grayling and the Halfway River for Bull Trout). The mobile tracking protocols were modelled after those of the baseline telemetry studies (AMEC & LGL 2008a,b, 2009, 2010a,b), while considering changes to the physical conditions in the study area due to the Project.

Objectives

The objective of the Site C Fish Movement Assessment (Mon-1b, Task 2d) is to collect telemetry data that can characterize 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).

The objective of the Peace River Arctic Grayling and Bull Trout Movement Assessment (Mon-1b, Task 2a) is to perform mobile aerial radio-tracking surveys to determine the magnitude, direction, and seasonality of Arctic Grayling and Bull Trout movements within the Peace River and key spawning tributaries. Data will inform various other components of the FAHMFP but may also be used to inform the operation of the temporary and permanent upstream fish passage facilities, such as the transport and release of these species.

Methods

Study Fish Collection and Tagging

In conjunction with the Peace River Large Fish Indexing Survey (Mon-2, Task 2a) and the Contingent Fish Capture and Transport Program, WSP Global collected, radio-tagged, and released 204 study fish between April and October 2022 (WSP 2023a,b). All radio-tagged study fish were collected by boat electroshocking using methods and settings that were consistent with previous study years (WSP 2023b). Collected study fish were identified to species, weighed in grams, measured for length (most species measured for fork length, FL, but Burbot were measured for total length, TL) in mm, and assigned a life stage (i.e., adult or juvenile[14]) based on their length (Figure 1). Similar to 2019 through 2021, candidate study fish for radio

[14] Categorizing study fish as an adult or juvenile is based on a fork length (FL) cut-off by species; where above the FL cut-off is an adult and under that is a juvenile. For Bull Trout, 250 mm is the FL cut-off between juvenile and adult while 260 and 300 mm are the cut-offs for Rainbow Trout and Arctic Grayling, respectively (Golder Associates 2022).

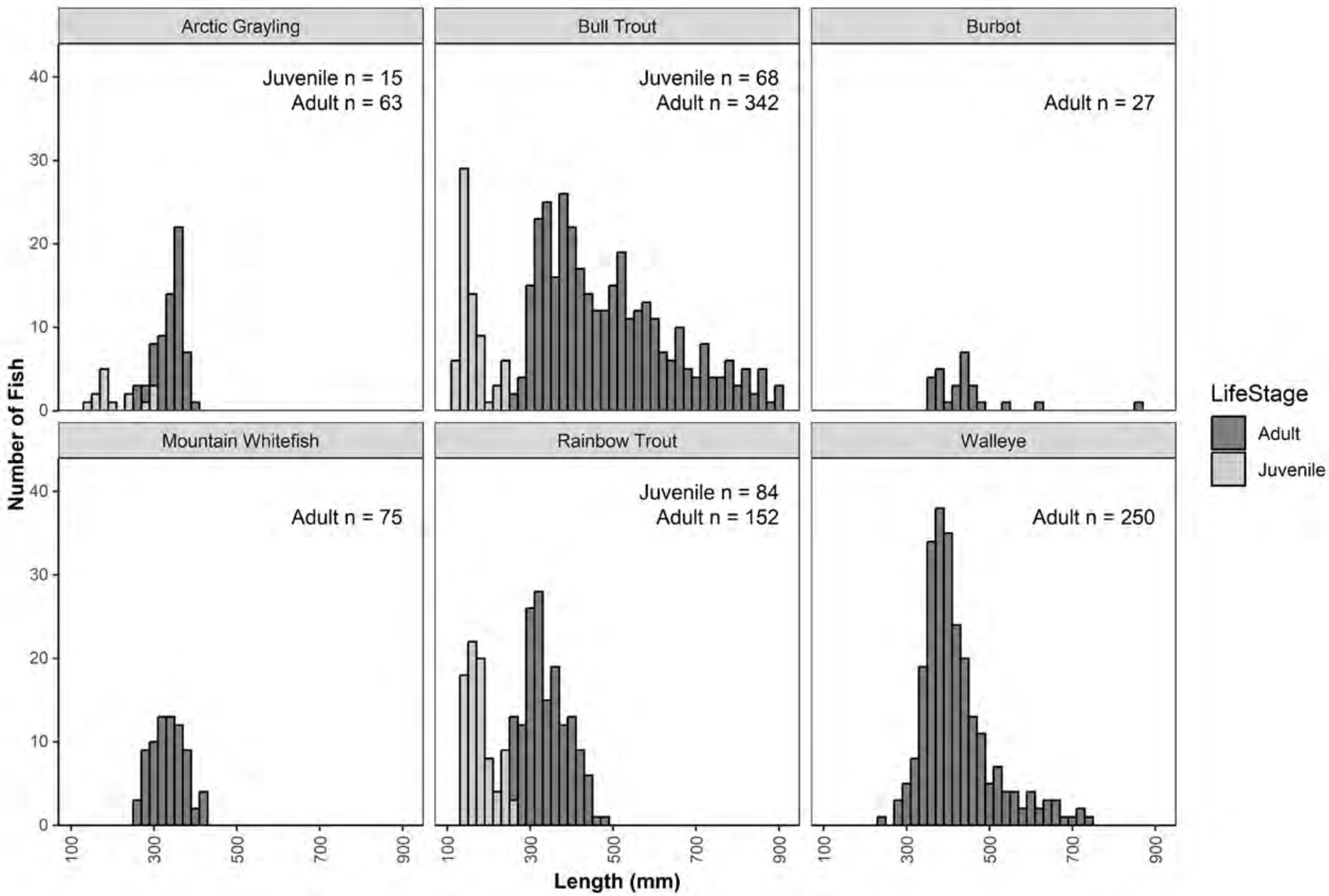


Figure 1. **Histograms of tagged study fish lengths (mm) by species (fork length for most, total length for Burbot) for all study years. Life stage, either juvenile or adult, is denoted by light and dark bars and sample sizes are specified within each species panel.**

Table 1. Lotek Nano radio tag models are listed along with tag weight (grams in air), average burst interval[15] (seconds), expected battery life (days), and the quantities deployed since 2019, by channel.

Tag model	Tag weight (grams)	Avg burst interval (secs)	Expected battery life (days)	Number Deployed				
				2019	2020	2021		2022
				Channel 3	Channel 3	Channel 3	Channel 5	Channel 5
NTF-3-2	0.57	9.5	173	81	91			
NTF-5-2	1.50	9.5	335	12	12			
NTF-6-1	2.50	9.5	493	7	8			
NTF-6-2	4.00	9.5	931	227	168		206	204
NFT-6-2_3s	4.00	3.0	359	2				
NFT-6-2_5s	4.00	5.0	565			58		

tagging were selected based on the health and vigor of the fish following a post-capture holding period; wherein fish that appeared stressed or unhealthy were excluded from contention (WSP 2023b).

Acceptable study fish in 2022 were all tagged by surgically inserting a Lotek Nano NTF-6-2 radio tag (Table 1). The maximum allowable tag burden, defined as the ratio between tag weight and the weight of the study fish, was 2.0% for all tagged fish in 2022 (WSP 2023b), which is a standard that has been consistently referenced in telemetry literature (Jepsen et al. 2005, Smircich and Kelly 2014). For all 2022 tagged fish, the tag burden ranged between 0.05% to 1.63% with a mean of 0.62%.

Prior to 2021, all of the radio tags transmitted at a radio frequency of 149.360 MHz ('Channel 3'). Starting in 2021 and extending into 2022, transmitters of a second frequency (149.400 MHz; or 'Channel 5') have been deployed. The technology used by the radio tag manufacturer (Lotek Wireless[16]) to produce individually-recognizable coded tags only allows for 728 unique IDs and after surpassing that number in 2021, a second frequency was required. All 2022 study fish were radio tagged on Channel 5 with the larger Nano NTF-6-2 radio tag to prioritize a longer expected battery life for all study fish.

Based on the manufacturer's expected battery life estimates for each of the tag models deployed (Table 1), the number of fish that are expected to have had active tags were calculated, by date and species, and are presented in Figure 2. Radio tags were activated using a Lotek tag activator, tag operation was verified, and tag codes were validated using a Lotek SRX800 MD-4 receiver.

Prior to surgery, tags and surgical instruments were disinfected in a 10% Super Germiphene™ solution for 10 minutes before being rinsed with distilled water[17]. Candidate study fish were sedated in an anesthetic bath containing a solution of 50 PPM clove oil and 95% ethanol. Fish were anaesthetized one at time and closely monitored. The degree of sedation was determined by a fish's ability to remain vertical in the anesthetic bath as well as by monitoring the gills for slow and consistent movement. Once anaesthetized, the fish was removed from the anesthetic bath, age and DNA samples were taken, the fish was then

[15] Burst interval refers to the interval of time (in seconds) between radio transmissions. This number is averaged because a range is used to avoid an instance where multiple tags are synced to the same interval. For most tags, the burst interval ranged between 9.197 to 9.799 seconds.

[16] Lotek Wireless Nano Tags: https://www.lotek.com/products/freshwater-nanotag-series/

[17] All surgical instruments were sterilized in an autoclave every evening.

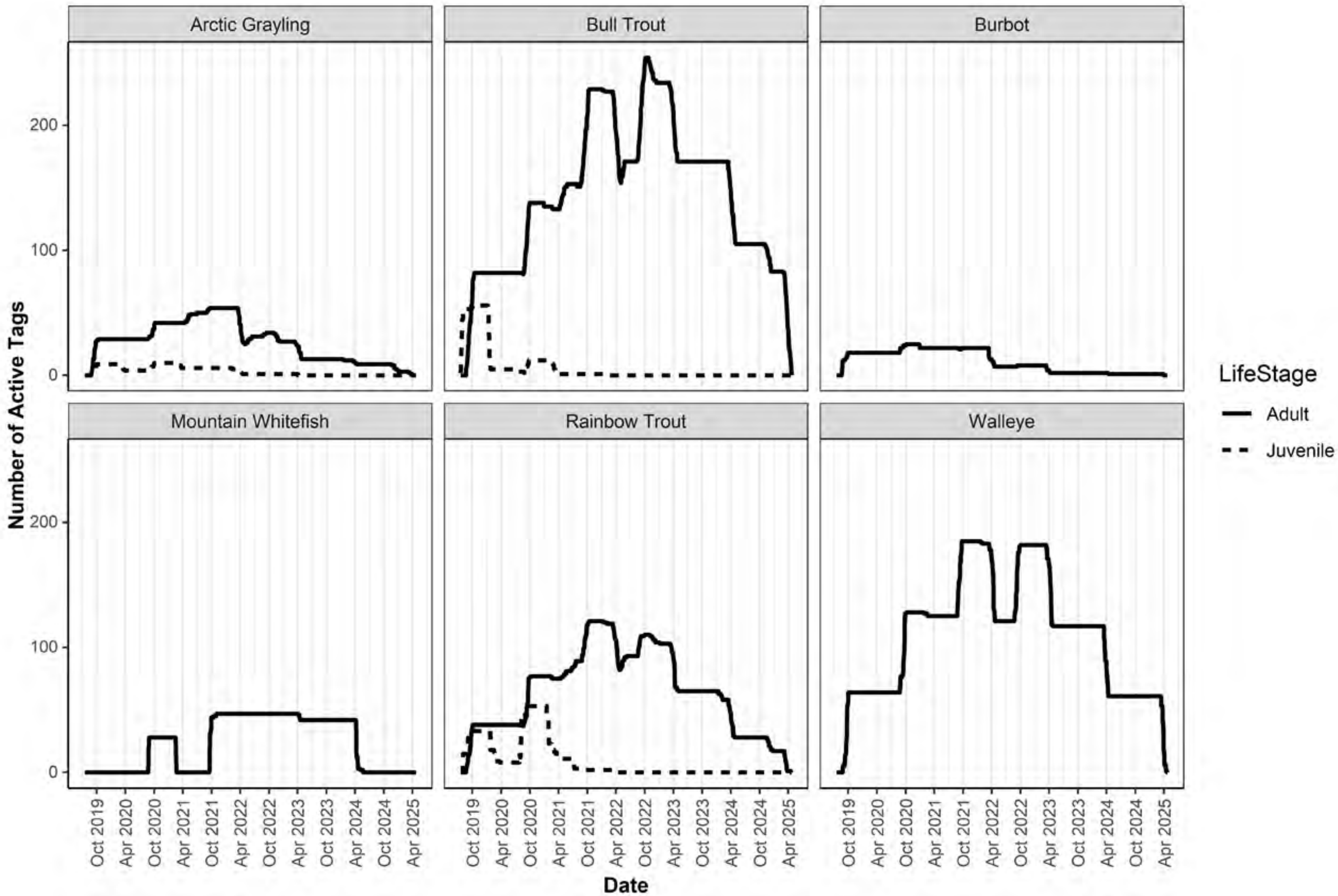


Figure 2. Estimated numbers of active radio tags, by species and date, from 2019 onward. Values are based on the numbers of tags deployed by date, and the manufacturer's battery life estimates for each of their tag models.

weighed, measured, PIT-tagged [18] and then placed ventral side up on a sponge-lined tray in preparation for the surgical tag insertion.

Surgical procedures followed standard methods (e.g., Liedtke and Wargo-Rub 2012). During surgery, a peristaltic pump water system was used to continuously irrigate the fish's gills with fresh river water. Using a #11 scalpel blade an incision of approximately 1.5 times the radio tag diameter was cut through the abdominal wall in a location that was anterior to the cloacal vent, slightly off the mid-line, and posterior to the liver. Using a stainless-steel cannula, the radio tag was inserted through the incision and directed along the body wall toward the fish's caudal fin. Once inserted, the tag was gently seated, with the tag's antenna protruding outside of the fish's body cavity and positioned along the mid-line of the fish. The cannula was removed, and the incision was stitched with two or three stitches[19]. In general, the handling of fish was minimized wherever possible to reduce any latent tagging effects.

Following surgery, the radio-tagged fish was placed in an aerated recovery livewell for a minimum of 10 minutes of monitoring until normal swimming behaviour resumed. Once the tagged fish recovered, the fish was released near the capture location[20]. The exception to this standard was 18 radio tagged Bull Trout that were released at the Halfway River Boat Launch following capture by electrofishing downstream of Site C. Those captured downstream of Site C were collected as part of the Contingent Fish Capture and Transport Program (WSP 2023a).

In total, there were 40 radio tagged study fish that were captured as part of the Contingent Fish Capture and Transport Program. Of which, 22 were collected below Site C and then released into the Site C Forebay, just upstream of Site C. This effort captured and radio-tagged individuals of four different species: Bull Trout (n = 5), Arctic Grayling (n = 6), and Rainbow Trout (n = 11).

An overview map of the study area, including the 2022 fish release locations, by Peace River release sections, is displayed in Figure 3. The numbers of radio-tagged fish released each year (since 2019) are listed by species, age class, tag model, and release river/section in Table 2. Histograms showing the size distributions of study fish are displayed for each of the focal species in Figure 1. Detailed spatial distributions of fish releases are shown using a series of maps in Appendix A.

[18] Passive integrated transponders or PIT tag.

[19] Stitching was by simple surgeon 2-1-1 interrupted stitches using Ethicon Vicryl Plus 5-0 or 4-0 braid sutures depending on the size of the study fish (Ethicon Inc. Somerville, NJ, US)

[20] Fish were released at the approximate halfway point between the upstream and downstream boundaries of the sample site.

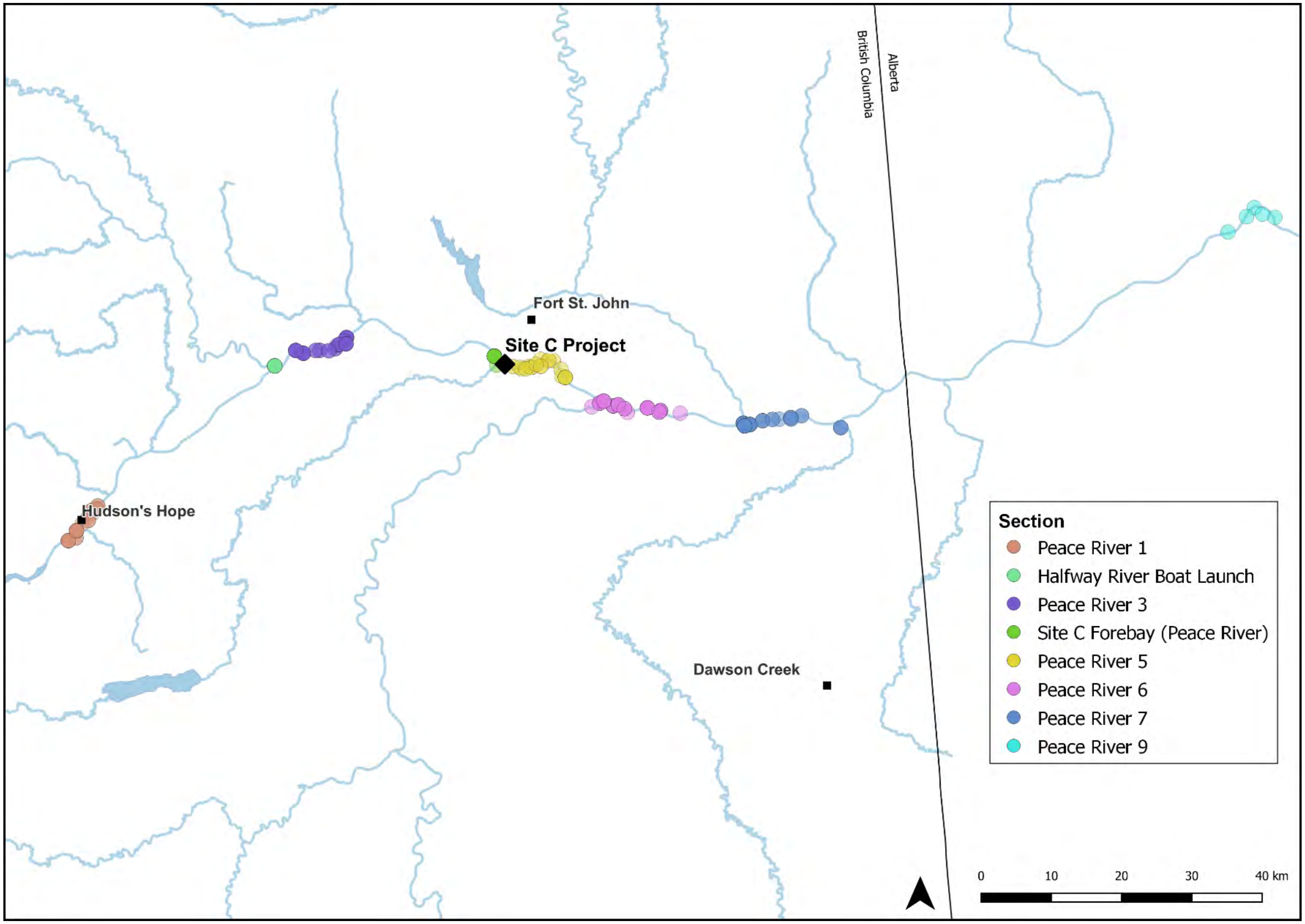


Figure 3. **Map of the Peace River study area showing release locations of radio-tagged study fish in 2022. Site C Forebay (Peace River) also includes fish released at the Moberly Confluence.**

Table 2. Radio-tagged study fish from 2019 through 2022 are listed by species, age class, radio tag model, and release location. Study fish released into the Peace River were separated by section (Figure 3). In most cases, study fish released in a tributary location <1 km from the confluence of the Peace River were counted as a Peace River release for the purpose of this table. Additionally, fish released in sub-tributaries are counted under their primary tributary. For example, fish released in the Chowade River, or Cypress Creek are counted as Halfway River fish.

Year	Species	Age Class	Tag Model	Peace River Section 1	Halfway River Boat Launch	Peace River Section 3	Upstream of Site C	Peace River Section 5	Peace River Section 6	Peace River Section 7	Peace River Section 9	Maurice Creek	Farrell Creek	Halfway River	Pine River	Beatton River	Kiskatinaw River	Total
2019	Arctic Grayling	Adult	NTF-6-2			20		4	4	1								**29**
2019	Arctic Grayling	Juvenile	NTF-6-2						3	2								**5**
2019	Arctic Grayling	Juvenile	NTF-3-2					3	1									**4**
2020	Arctic Grayling	Adult	NTF-6-2			12		1										**13**
2020	Arctic Grayling	Juvenile	NTF-6-2			1												**1**
2020	Arctic Grayling	Juvenile	NTF-6-1			1												**1**
2020	Arctic Grayling	Juvenile	NTF-3-2			2		1	1									**4**
2021	Arctic Grayling	Adult	NTF-6-2				1	1		2								**4**
2021	Arctic Grayling	Adult	NFT-6-2_5s				7	1										**8**
2022	Arctic Grayling	Adult	NTF-6-2	1		2	6											**9**
2019	Bull Trout	Adult	NTF-6-2	25		25		13	10	4	1							**78**
2019	Bull Trout	Adult	NFT-6-2_3s	1														**1**
2019	Bull Trout	Adult	NTF-6-1	2					1									**3**
2019	Bull Trout	Juvenile	NTF-5-2					1	2					2				**5**
2019	Bull Trout	Juvenile	NTF-3-2											51				**51**
2020	Bull Trout	Adult	NTF-6-2	12		17		11	6	1	4							**51**
2020	Bull Trout	Adult	NTF-6-1	1				1										**2**
2020	Bull Trout	Adult	NTF-5-2			2												**2**
2020	Bull Trout	Adult	NTF-3-2	2														**2**
2020	Bull Trout	Juvenile	NTF-6-1						1									**1**
2020	Bull Trout	Juvenile	NTF-3-2	4		1		3	2		1							**11**
2021	Bull Trout	Adult	NFT-6-2	12		21	1	17	7	5	1				1		1	**66**
2021	Bull Trout	Adult	NFT-6-2_5s	2	17	5	6	1	1									**32**
2022	Bull Trout	Adult	NFT-6-2	15	18	27	5	16	11	10	3							**105**
2019	Burbot	Adult	NTF-6-2			1		1		5	8							**15**
2019	Burbot	Adult	NTF-6-1						3									**3**
2020	Burbot	Adult	NTF-6-2					2		2	2							**6**
2020	Burbot	Adult	NTF-5-2	1														**1**
2021	Burbot	Adult	NFT-6-2														1	**1**
2022	Burbot	Adult	NFT-6-2								1							**1**
2020	Mountain Whitefish	Adult	NTF-3-2					19	5	4								**28**
2021	Mountain Whitefish	Adult	NFT-6-2				3	23	14						2			**42**
2021	Mountain Whitefish	Adult	NFT-6-2_5s				4	1										**5**
2019	Rainbow Trout	Adult	NTF-6-2	17		15		5										**37**
2019	Rainbow Trout	Adult	NTF-6-2_3s	1														**1**
2019	Rainbow Trout	Juvenile	NTF-6-2			2												**2**
2019	Rainbow Trout	Juvenile	NTF-5-2	2		1		1	2									**6**
2019	Rainbow Trout	Juvenile	NTF-3-2	7		2				1			15					**25**
2020	Rainbow Trout	Adult	NTF-6-2	19		16		1										**36**
2020	Rainbow Trout	Adult	NTF-6-1	1				1										**2**
2020	Rainbow Trout	Adult	NTF-3-2	2														**2**
2020	Rainbow Trout	Juvenile	NTF-5-2			1						7	1					**9**
2020	Rainbow Trout	Juvenile	NTF-3-2	9		1			1	1		20	10					**42**
2021	Rainbow Trout	Adult	NFT-6-2	15		9	7	4		1							1	**37**
2021	Rainbow Trout	Adult	NFT-6-2_5s			1	8											**9**
2022	Rainbow Trout	Adult	NFT-6-2	9		5	11	3										**28**
2019	Walleye	Adult	NTF-6-2			2		1	11	48								**62**
2019	Walleye	Adult	NTF-6-1					1										**1**
2019	Walleye	Adult	NTF-5-2							1								**1**
2020	Walleye	Adult	NTF-6-2	2		13		8	11	17	10							**61**
2020	Walleye	Adult	NTF-6-1						1		1							**2**
2020	Walleye	Adult	NTF-3-2					2										**2**
2021	Walleye	Adult	NFT-6-2					3	18	17					5	12	1	**56**
2021	Walleye	Adult	NFT-6-2_5s					1	1							2		**4**
2022	Walleye	Adult	NFT-6-2						29	31	1							**61**
Total				**162**	**35**	**205**	**59**	**151**	**146**	**153**	**33**	**27**	**26**	**53**	**8**	**14**	**4**	**1076**

Fixed-Station Telemetry

Radio telemetry fixed-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 a SRX800 or SRX1200 (hereafter SRX) receiver for coding and storage (Figure 4). 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 pointed up and down the Peace River and the third antenna pointed 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 4). The batteries were then connected to the SRX receiver. When the angle of the sun and the hours of

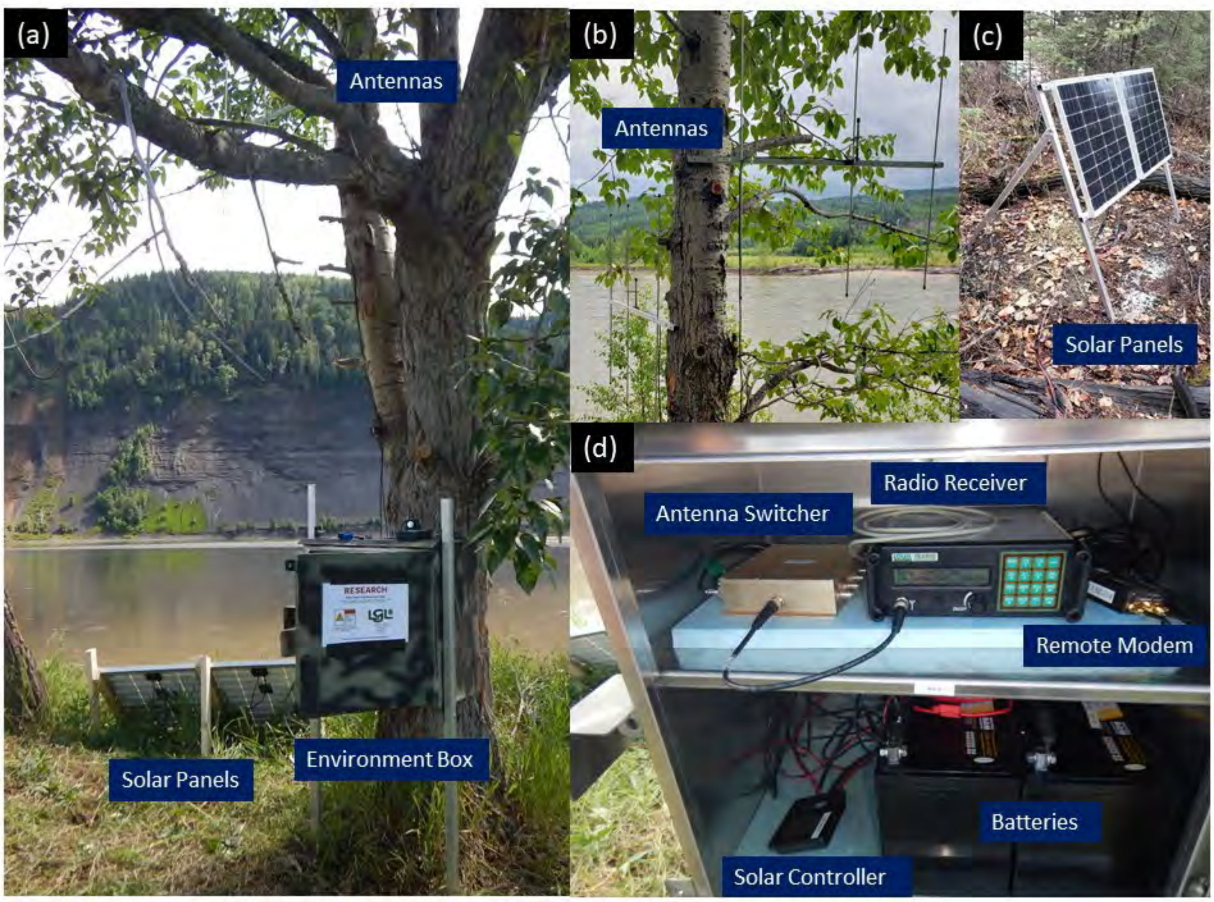


Figure 4. Example of a fixed radio telemetry station. (a) View of the antennas, environment box, and solar panels. (b) Two, three-element YAGI antennas are mounted to a tree. (c) Two, 80-watt solar panels mounted to an aluminum stand for deployment during the winter months. (d) View of the inside of an environment box showing the Lotek SRX800 receiver, ASP-8 switcher, LTE remote modem, solar controller, and AGM deep cycle batteries.

daylight were adequate (i.e., generally from April to October), the solar setup provided renewable energy to the receiver. During the remainder of the year, the receiver ran primarily off the two deep cycle batteries which required a battery swap approximately every three weeks during routine maintenance. 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[21] (Figure 4).

The telemetry station electronics were housed in a custom fabricated aluminum environment box that was sealed and locked during the study period (Figure 4). 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 4).

In most circumstances the environment box was lag-bolted to a large tree with the receiver antennas mounted to the same tree approximately 2 to 4 m above the box (Figure 4). In cases where a suitable tree was not available, a stand was constructed for the environment box with the antennas mounted on a mast that was supported by an aluminum tripod (Table 3).

The angle between two antennas was specific to each site but 120° was the standard. Antennas installed at angles greater than 120° risked collecting 'reverse detections' from the non-intended read direction (e.g., upstream antenna reading downstream detections from the backside of the antenna), while an angle less than 120° risked overlapping detection zones and could decrease a fixed-station's detection range.

Stations were programmed to scan two frequencies over each individual antenna. The receivers scanned one channel for 10 seconds per antenna, flip to the other channel for 10 seconds per antenna, and then flip back to repeat the cycle.

Temporal and Spatial Extent of the Array

The spatial extent of the array was designed to encompass the Local Assessment Area (LAA) (Figure 5), from Peace Canyon Dam (RKM[22] 20) to Many Islands, Alberta (RKM 231). Between these locations, stations were located at the entrance of every major tributary with one Peace River station located approximately halfway between each tributary entrance (Table 3, Figure 5). Deviations from this general format included detection gates[23] created at Peace River #1A/Peace River #1B and Kiskatinaw 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 (Peace River #1A/Peace River #1B), for example, should help determine if a radio-tagged study fish has left the LAA. Furthermore, seven fixed-stations were installed within the Moberly River and Halfway River drainage systems (referenced as 'Tributary Upstream' in Table 3 and Figure 5) along with three fixed-stations installed in the 108R Offset Side Channel (referenced as 'Side Channel' in Table 3 and Figure 5).

---

[21] The aluminum solar stand lifts the panels higher to avoid snow accumulation and creates a more vertical orientation to compensate for the position of the sun in winter.

[22] RKM or river kilometres in the Peace River are calculated as the distance (in kilometres) from the tailrace of WAC Bennet Dam.

[23] A detection gate is comprised of two receivers, one placed on either riverbank, to increase detection probability.

Table 3. **Station names, types, numbers, installation and demobilization dates, and status (as of January 2023). Twelve stations, deployed or maintained as part of Mon-13 (Site C Fishway Effectiveness Monitoring Program), are named with a prefix "INS". *Red* demobilization date refers to stations left operating with a low-voltage cut-off and the date value is when the station went dormant for the off-season. *Red* modem refer to four stations that didn't have an operational modem in 2022 but will in 2023.**

Station Name	Access	Station Type	Station #	Installation Date	Demobilization Date	Modem	Operation	Antenna Count / Location
Peace River 1A	Boat	Peace River	1	24 Apr 2022	24 Oct 2022	No	Seasonal	2 / tree
Peace River 1B	Boat	Peace River	2	24 Apr 2022	24 Oct 2022	No	Seasonal	2 / tree
Peace River 2	Boat	Peace River	3	24 Apr 2022	*7 Dec 2022*	No	Seasonal	2 / tree
Pouce Coupe River	Boat	Tributary Entrance	4	24 Apr 2022	24 Oct 2022	No	Seasonal	3 / tree
Peace River 3	Boat	Peace River	5	25 Apr 2022	24 Oct 2022	No	Seasonal	2 / tree
Kiskatinaw River	Boat	Tributary Entrance	6	25 Apr 2022	24 Oct 2022	No	Seasonal	3 / tree
Beatton River	Boat	Tributary Entrance	7	25 Apr 2022	24 Oct 2022	No	Seasonal	3 / tree
Peace River 4	Truck	Peace River	8	8 Mar 2022	*13 Dec 2022*	No	Seasonal	2 / tripod
Pine River	Boat	Tributary Entrance	9	25 Apr 2022	23 Oct 2022	No	Seasonal	2 / tree
Peace River 5	Boat	Peace River	10	25 Apr 2022	23 Oct 2022	No	Seasonal	2 / tree
West Side Channel	Boat	Side Channel	50	5 Sep 2022	23 Oct 2022	*No*	Seasonal	2 / tree
East Side Channel	Boat	Side Channel	51	6 Sep 2022	23 Oct 2022	*No*	Seasonal	2 / tree
South Side Channel	Boat	Side Channel	52	6 Sep 2022	23 Oct 2022	*No*	Seasonal	2 / tree
Site C Dam	Truck	Peace River	11	11 Jul 2019	-	Yes	Perennial	2 / tree
INS Mainstem 2	Truck	Peace River	33	1 Aug 2020	-	-	Perennial	2
INS Approach Zone A	Truck	Peace River	34	2 Aug 2020	-	-	Perennial	1
INS Approach Zone B	Truck	Peace River	35	3 Aug 2020	-	-	Perennial	1
INS Cofferdam	Truck	Peace River	36	3 Aug 2020	-	-	Perennial	2
INS Diversion Tunnel	Boat	Peace River	37	4 Apr 2021	-	-	Perennial	2 / tree
INS Entrance Aerial	Truck	Peace River	38	15 Sep 2020	-	-	Perennial	1
INS Entrance Dipole	Boat	Peace River	39	18 Mar 2022	1 Nov 2022	-	Seasonal	2 / tree
INS Entrance Pool Dipole	Boat	Peace River	40	18 Mar 2022	1 Nov 2022	-	Seasonal	2 / tree
INS Turning Basin	Boat	Peace River	41	18 Mar 2022	1 Nov 2022	-	Seasonal	2 / tripod
INS Cell 8	Boat	Peace River	42	18 Mar 2022	1 Nov 2022	-	Seasonal	2
INS Vee-Trap	Boat	Peace River	43	18 Mar 2022	1 Nov 2022	-	Seasonal	1
INS Diversion Tunnel Inlet	Boat	Peace River	46	28 Mar 2021	-	-	Perennial	1
Moberly River 1	Truck	Tributary Entrance	12	11 Jul 2019	-	Yes	Perennial	2 / tree
Moberly River 2	Helicopter	Tributary Upstream	13	6 Mar 2022	21 Oct 2022	No	Seasonal	2 / tree
Moberly River 3	Helicopter	Tributary Upstream	14	6 Mar 2022	21 Oct 2022	No	Seasonal	2 / tree
Moberly Lake	Truck	Tributary Upstream	47	7 Mar 2022	3 Sep 2022	Yes	Seasonal	2 / tree
Peace River 6	Truck	Peace River	15	26 Apr 2022	*19 Dec 2022*	Yes	Seasonal	2 / tree
Peace River 7	Truck	Peace River	16	26 Apr 2022	25 Oct 2022	Yes	Seasonal	2 / tree
Cache Creek	Truck	Tributary Entrance	17	28 Apr 2022	10 Sep 2022	*No*	Seasonal	2 / tree
Peace River 8	Truck	Peace River	18	8 Mar 2022	*8 Dec 2022*	Yes	Seasonal	2 / tripod
Halfway River 1	Truck	Tributary Entrance	19	8 Jul 2019	-	Yes	Perennial	2 / tree
Halfway River 2	Helicopter	Tributary Upstream	20	23 Apr 2022	21 Oct 2022	No	Seasonal	2 / tree
Halfway River 3	Helicopter	Tributary Upstream	21	6 Mar 2022	21 Oct 2022	No	Seasonal	2 / tree
Chowade River	Truck	Tributary Upstream	29	29 Jul 2022	4 Oct 2022	No	Seasonal	3 / tree
Cypress Creek	Truck	Tributary Upstream	30	3 Aug 2022	5 Oct 2022	No	Seasonal	2 / tree
Peace River 9	Truck	Peace River	22	8 Mar 2022	22 Oct 2022	Yes	Seasonal	2 / tree
Farrell Creek	Truck	Tributary Entrance	44	5 Mar 2022	3 Sep 2022	Yes	Seasonal	1
Peace River 10	Truck	Peace River	24	7 Mar 2022	22 Oct 2022	Yes	Seasonal	2 / tree
Peace River 11	Truck	Peace River	26	7 Mar 2022	*2 Dec 2022*	Yes	Seasonal	2 / tree
Maurice Creek	Truck	Tributary Entrance	31	8 Mar 2022	22 Oct 2022	Yes	Seasonal	2 / tree
Peace Canyon Dam	Truck	Peace River	45	5 Mar 2022	22 Oct 2022	Yes	Seasonal	2

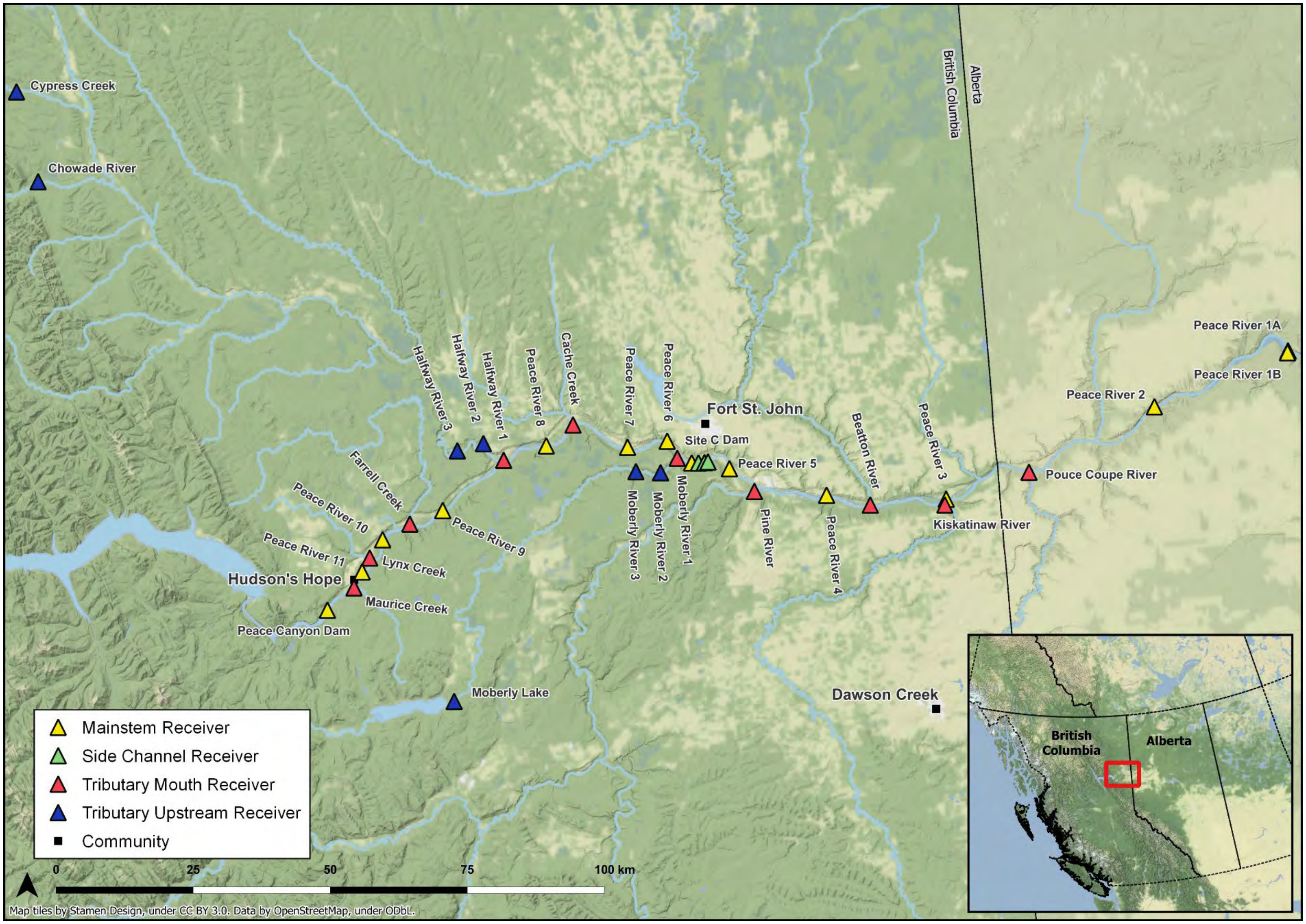


Figure 5. Locations of the 34 fixed radio telemetry stations operated for the Site C Fish Movement Assessment in 2022. Twelve additional stations that are not shown on this map were deployed or maintained by InStream Fisheries Research as part of Mon-13 (Site C Fishway Effectiveness Monitoring Program). 'Side Channel Receiver' refers to three receivers that are operated in the 108R Side Channel downstream of Site C.

In 2022, 34 fixed radio telemetry stations were deployed and maintained by LGL Limited. These included four stations that were not operated in 2021 (Table 3): Lynx Creek (a station that was operated in 2019-2020 but not in 2021[24], which was re-deployed in 2022) and three new stations that were installed in September 2022 on the 108R Side Channel located downstream of Site C Dam for the Site C Offset Effectiveness Monitoring Program[25] (Figure 6). In addition to the 34 LGL receivers, there were twelve fixed-stations operated as part of Mon-13 (Site C Fishway Effectiveness Monitoring Program), whose maintenance was managed by InStream Fisheries Research.

Figure 6. Locations of the three 108R Side Channel receivers deployed in 2022 (yellow triangles). Blue triangles denote the stations installed at Site C Dam. Refer to Whelan et al. (2023) for more information on the Site C Offset Effectiveness Monitoring Program.

The temporal extent of the array spanned from 5 March to 24 October 2022 for the seasonally operated fixed-stations; with the remaining fixed-stations staying active and operated perennially (Table 3). Redeployment timing of the seasonal fixed-stations varied by site, depending on access (e.g., the install of the Chowade River and Cypress Creek stations were delayed because snow limited access; Table 3). In 2022, five stations were left operating past demobilization with a low voltage cut-off (Table 3). During the

[24] Due to bridge construction efforts and the lack of available receivers, Lynx Creek was not operated in 2021. Lynx was re-installed for the 2022 field season on 28 April 2022.

[25] Refer to Whelan et al. (2023) for more information on the Site C Offset Effectiveness Monitoring Program.

reduced solar conditions in winter, the setup was designed to disconnect from the system load (SRX and modem) after falling below a threshold voltage (11.1V) and remain dormant until conditions improved in February or March to repower and reconnect the system at 12.2V.

Testing

The power system, radio equipment, and remote connection systems were all tested for basic functionality upon deployment. The radio equipment was tested to ensure tag signals were being coded at expected ranges and the antenna angles were correctly oriented. Power systems were tested for capacity and confirmation of power generation. Lastly, each station equipped with a cellular modem was logged into using an off-site computer to confirm remote accessibility.

Beyond basic functionality testing, range testing was conducted for 33 fixed-stations operated in 2022. 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 m upstream of the fixed-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 m downstream of the fixed-station, after which, these procedures were repeated. Test tags were programmed to transmit more frequently (every 3 seconds) and deployed to a depth of 1 m 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 detection area. Other range testing approaches used the same base methodology but without the jet boat and either tracked by foot or a radio-controlled boat in shallow environments.

GPS tracking data were run through GIS scripts to calculate, from moment to moment, the distance of the test tags from the antennas in question. The GPS data were then temporally correlated to detection records and 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. It was necessary to use proportions of expected quantities, rather than success/failure for every individual transmission, because channel and antenna switching receiver functions often meant that not all transmissions were expected to be detected. 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. The fitted logistic equation parameters were used to calculate the distances in which detection probability was at a certain level (e.g., 50%). As is standard practice in acoustic and radio telemetry studies, the distance at 50% detection probability and the steepness of the curve were used to interpret the detection range for each station (Kessel et al. 2014).

Range test data were also used to create detection probability maps for each receiver station. Track data for each range test were split into 30-second segments, and the midpoint of each 30-second segment was used to represent the location of the test tags during that 30-second interval. The expected quantity of detections for each tag in each 30-second interval was determined based on the tag's characteristics (i.e., frequency, pulse rate) and the receiver's configuration (i.e., accounting for antenna and channel switching). Kriging was used to interpolate the observed proportion of detections over the area covered by the range test. The proportion of detections were logit transformed prior to fitting. For intervals where the proportion of observed detections was equal to 0 or 1, values were fixed at 0.001 and 0.999 respectively, restricting the transformed data to logit values between -6.9 and 6.9. Variograms for each receiver were fit in R (R Core Team 2021) using autoKrige in the automap package (Hiemstra et al. 2009), which automatically selects the best fit from several variogram models given the data. Predicted rasters were then back-transformed to the probability scale for plotting.

Table 4. Fixed-station deployment, maintenance, and demobilization field schedule in 2022.

Start Date	End Date	Work Completed
overwinter	2 March 2022	Winter Maintenance
3 March 2022	10 March 2022	Station Installations 1
20 April 2022	30 April 2022	Station Installations 2
27 May 2022	5 June 2022	Download/Testing/Maintenance 1
27 June 2022	4 July 2022	Download/Testing/Maintenance 2
23 July 2022	30 July 2022	Download/Testing/Maintenance 3
2 September 2022	11 September 2022	Download/Testing/Maintenance 4
20 October 2022	28 October 2022	Station Demobilization 1
29 October 2022	overwinter	Winter Maintenance

Download and Maintenance

Standard fixed-station maintenance required a monthly on-site visit in which the data were downloaded, notes were recorded about functionality, and the equipment was inspected for damage and/or malfunction. Data were downloaded using SRX800/SRX1200 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.

There are three situations in which a station needs remote or physical maintenance: equipment malfunction, loss of power, or a full memory bank. The receivers normally record an internal battery voltage check hourly, and a conspicuous loss of these checks from the data would be an indication that the fixed-station was not functional. Moreover, the beacon tag detection records (should be detected six times in the first minute of each hour when scanning one frequency) could be used to evaluate whether the fixed-station was properly scanning and to assess antenna and wiring integrity. The timing when battery check records stopped, or when a beacon tag was no longer being recorded, was used to identify when an outage began. To guarantee that every fixed station was operating and collecting data as expected, field visits occurred cyclically every three to four weeks (Table 4).

Mobile Telemetry

Mobile tracking (Table 5, Appendix D) was employed to expand on the detection coverage provided by the fixed-station array and to meet the core objectives of the Peace River Arctic Grayling and Bull Trout Movement Assessment (Mon-1b, Task 2a). In 2022, mobile surveys were designed to track Bull Trout in the Halfway River watershed in September to identify probable spawning locations and describe the timing of movement immediately prior to and following spawning. The approach was to conduct two multi-day flight surveys[26] centered around peak Bull Trout spawning as per the guidance of the Peace

Table 5. Mobile tracking survey dates, locations tracked, and vessels used in 2022.

Date	Task / Areas Covered	Vessel
8 September 2022	Bull Trout tracking in the Halfway, Survey 1, Day 1	Fixed-wing
9 September 2022	Bull Trout tracking in the Halfway, Survey 1, Day 2	Fixed-wing
18 September 2022	Bull Trout tracking in the Halfway, Survey 2, Day 1	Fixed-wing
19 September 2022	Bull Trout tracking in the Halfway, Survey 2, Day 2	Fixed-wing

River Bull Trout Spawning Assessment (Mon-1b, Task 2b). Two surveys of the Halfway River and its upper tributaries were conducted in September taking four overflights to complete (Table 5; Appendix D, Figure D1).

Mobile surveys were also conducted for spring spawning Walleye in the Beatton River (Appendix D, Figure D2) as part of the Walleye Spawning and Rearing Use Survey (Mon-2, Task2e) and are reported separately in Robichaud et al. (2023). Also, a receiver was used to scan opportunistically for tagged fish whenever the Halfway River boat ramp was visited to detect any tags that may have been shed by fish released at this location (n =17).

Bull Trout mobile tracking flights were conducted by fixed wing aircraft (Table 5). Fixed wing flight speeds and altitude remained consistent across surveys at 100-160 km/h and 150-215 m above the river. A two-element Yagi antenna was mounted on each wing of the aircraft. Shielded coaxial cable (RG-58) was used to connect the antennas to two SRX800-MD receivers in the cabin, where each receiver scanned only one of the two transmitter frequencies (i.e., 149.360 and 149.400 MHz). Specifically, the signal from the port and starboard antennas were merged and the combined feed was split and fed into each of the receivers. A GPS signal was fed directly into the SRX800 receivers (producing geo-referenced detection data), and a handheld GPS unit was run to store a complete track of the survey route. Receiver clocks were synchronized with the GPS units prior to each flight. The approximate position and identity of each detected radio tag (tagged fish) was recorded manually on a datasheet by the field crew, as a backup to the electronic systems. Prior to the first survey, a test tag was used to qualitatively confirm detection range at altitude, and test receiver gain settings.

The SRX800 receivers and GPS units were downloaded after each day, and the data were sent electronically to the office staff for processing. Detections from each day were filtered to remove noise, and erroneous detections from codes that were not associated with active tags. Then, the highest-powered detection of each unique tag was selected, and the timestamp and geographic coordinates of that detection were used to represent that fish’s location during the time of the flight survey. Thus, at the end of each flight, each unique tag appeared once in the resulting datafile, on a line containing its ID (frequency, code, species), a timestamp, latitude, longitude, and power reading associated with the highest power detection event, as well as the number of times it was detected during the flight.

[26] Two or more days of flying was required to completely cover the areas of interest.

The geo-referenced data were processed using a Python script in ArcGIS that assigned each detection to a 'mobile tracking zone' (Figure 7), and outputted the name of the river/creek in which the detection was located, and a RKM reading. RKM readings were specific to each river or creek in the study area and were a measure of the distance of the detection location from the river's mouth or confluence to the next order stream (e.g., a detection recorded 25 km upstream the Halfway River from the confluence to the Peace River was given a value of 25 RKM). The exception being RKM readings in the Peace River, which

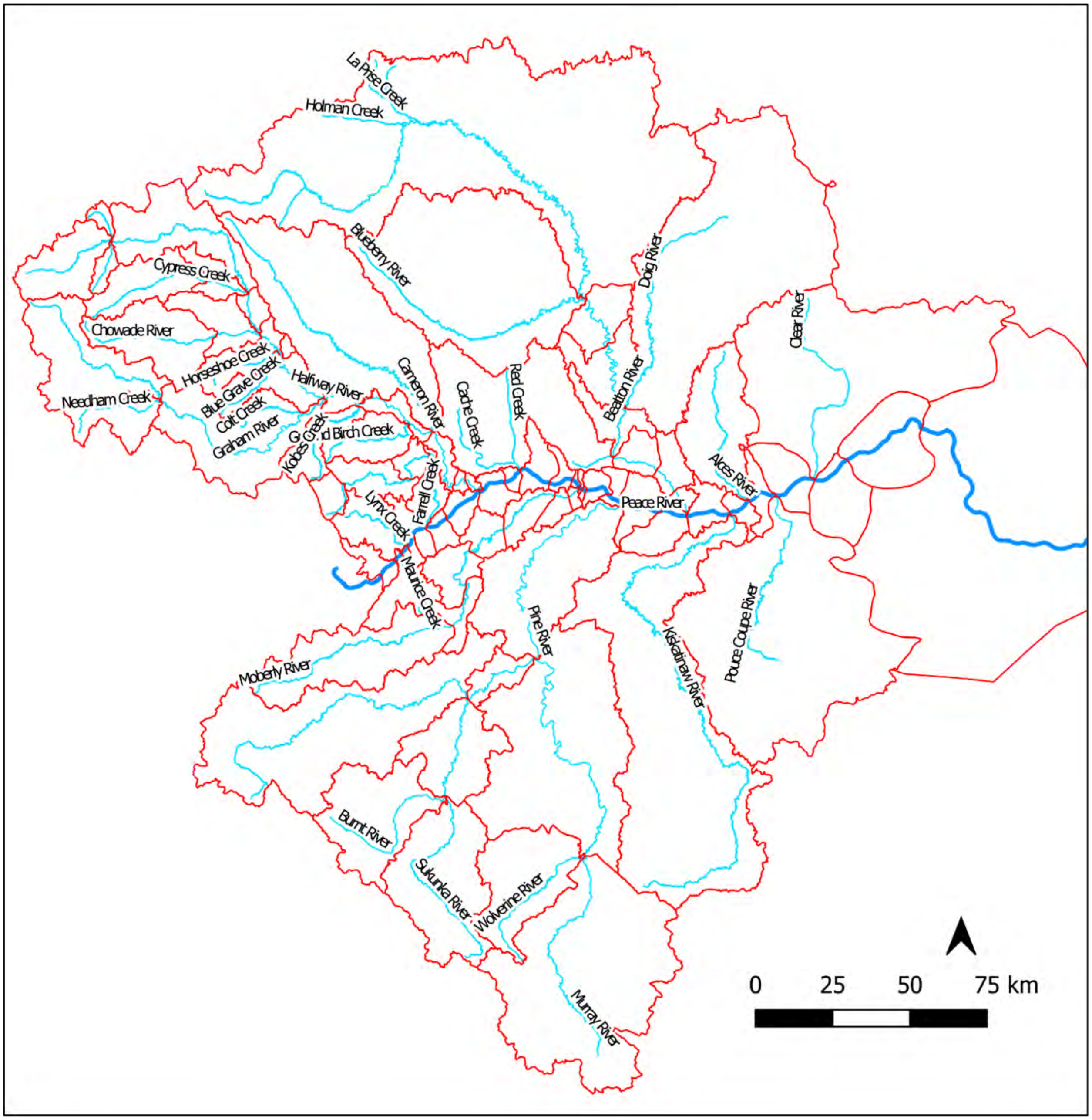


Figure 7. **Mobile tracking zones (polygons with red borders) overlain on the Peace River (dark bold blue) and its major tributaries (lighter blue). Zones were defined by watershed boundaries, and the positions of the fixed-station receivers.**

were defined as the distance downstream from WAC Bennett Dam (RKM 0). Lastly, the post-processed data were uploaded into the Site C Fish Movement Assessment Database and were processed further (see proceeding section) using R (R Core Team 2021) and Telemetry Manager (English et al. 2012).

When processing mobile telemetry data in general, we did not assume that detections within 0.5 km of the mouth of a tributary were committed to continuing upstream. This is because many of these detections could theoretically be of fish that are actually in the Peace River mainstem yet appear to be within a tributary as a result of the position of the aircraft, the timing of tag transmissions relative to the motion of the aircraft, or, to a lesser extent, the sampling error of the GPS device (which typically had better than 50 m accuracy). As such, the mobile-tracking zones (Figure 7) associated with tributary areas were set to start 0.5 km from their junction with the larger river to which they join.

Data Management and Processing

The downloaded data files and the post-processed mobile-tracking data files were 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 (or R, if preferred) as the front-end to the database. All data tables are carefully keyed and organized for easy and comprehensive querying. A visual representation of the database, displaying how each of the tables relate to each other, is provided in Figure C1 (in Appendix C). Table C1 describes each table with text.

A system is in place to accept data requests from other contractors and record the request information into the SQL Server database. To date, there have been nine requests for data from the Site C Fish Movement Assessment Database; all of which have been fulfilled and are summarized in Table C2. Metadata about each request include: the request date, fulfillment date, organization name, fulfiller name, requesters name, and requesters contact information (Table C2). Other than formal requests, though, the data have been processed and analyzed by LGL staff both in-season, in response to requests from BC Hydro, and as part of the annual reporting tasks.

Data processing begins with the validation of individual detection records. The SRX800 and SRX1200 receivers are particularly sensitive radio receivers which benefit from boosted detection ranges 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[27];
- 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 or after its removal;
- Pulse rate filtration;
- Detection frequency filtration; and
- Examination of individual detection histories.

[27] Duplicate records occur when a fixed-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 previous cycle(s).

Since the Lotek NanoTags were programmed to transmit at a certain pulse rate (e.g., one transmission every 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, an approach used more commonly in acoustic telemetry or JSATS[28] (Beeman and Perry 2012). 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 that rejected any detection if it was not part of a set of three or more within a ten-minute window. Random noise events that lead to false-positive detections are more likely to occur 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 was an examination of detection histories for each individual study fish to locate any 'red-flag' patterns. These patterns can include detection sequences in which a study fish moves between geographically distinct fixed-stations (i.e., >100 m) in a matter of seconds or in situations where a study fish may have been missed by too many fixed-stations along a supposed movement route.

Data Analysis

Specific analytical methods follow in the subsequent sections. In all cases in which statistical analyses occurred, including the calculation of 95% confidence bounds, we assumed an alpha level of 0.05 (Zar 1984).

Detection Efficiency

Detection efficiency is defined as the proportion of study fish detected while passing a fixed-station. This is different from detection probability which is defined as the probability of detecting a radio tag's transmission at a particular distance from an antenna. Detection efficiency is a *post-hoc* metric derived from actual study fish's movements while detection probability is generated during range testing with test tags. Where applicable, both metrics were used in conjunction to evaluate a fixed-station's effectiveness at detecting radio-tagged study fish (Adams et al. 2012, Kessel et al. 2014).

Detection efficiency analyses were conducted for all fixed-stations and separated by movement direction (i.e., upstream or downstream) that had at least one complete and known passage event (i.e., a valid detection upstream and downstream of the analyzed fixed-station). The metric was calculated by dividing the quantity of study fish detected during fixed-station passage by the total quantity of study fish known to have passed that fixed-station. The total quantity of study fish that passed a fixed-station was defined as the count of fish whose sequential detection history showed detections both upstream and downstream of the analyzed fixed-station. Asymptotic 95% confidence intervals were calculated using the binomial error distribution (Zar 1984).

Spans in which a fixed-station outage was known to have occurred were not included in the detection efficiency analysis. The underlying goal was to estimate the proportion of study fish detected while a fixed-station was actively collecting data.

Detection efficiencies were also calculated *post-hoc* for Halfway River (Bull Trout) mobile tracking efforts (Appendix D, Figure D1). Prior detection records at fixed-stations were used to determine where study fish were assumed to be located during each mobile track (Appendix D). If a fish was assumed present

---

[28] Juvenile Salmon Acoustic Telemetry System, or JSATS, is a high frequency acoustic telemetry approach that can create large quantities of noise and false-positive detection data.

during a particular mobile track this was referred to as a possible detection event[29]. The resulting detection efficiency was calculated as a proportion of the possible detection events that were detected during that track. This calculation assumes that a possible detection event is in fact possible, and the study fish has not exited the spatial expanse of the mobile tracking route without our knowledge.

Magnitude, Seasonality and Direction

The detection data (both mobile and fixed-station) were geo-referenced and then processed using a Python script in ArcGIS that assigned each detection to a river kilometer (RKM). Next, the detection data were reorganized into a movement-focused format in which each data row represented a recorded movement, such that the change in time and distance moved between each successive detection could be calculated for each individual study fish. For each movement, the direction was defined by whether it was oriented as upstream or downstream.

Among the core objectives of the Site C Fish Movement Assessment (Mon-1b, Task 2d) is to conduct large scale, region-wide analyses of the telemetry data to determine the magnitude, direction, and seasonal variability of fish movements in the Peace River and its tributaries. To address this objective, figures were produced for each study species that display average monthly movement distances, as well as figures that show monthly tributary entrance and exit behaviours.

Movement distances (in RKM) were categorized, averaged, and then plotted with 95% confidence intervals (Zar 1984)[30]. Mean movement distances were categorized by species, river, direction, and month. Data collected from 2019 through 2022 were included in this analysis to create a region-wide representation of fish movements designed to grow with each successive data collection season until the establishment of the Site C Reservoir. Movements in the Peace River were analyzed and displayed for all six indicator species[31], while movements specific to Peace River tributaries were analysed for Bull Trout, Arctic Grayling and Walleye for movements in the Halfway River, Moberly River and Beatton River, respectively. The tributaries and respective species analyzed were based on known or expected behaviours in those tributaries (i.e., spawning) as well as the availability of detection data from mobile tracking efforts and/or upstream tributary fixed-stations.

For month-scale analyses of movement, each observed displacement event was assigned to a month based on halfway-point between the timestamps of the two start and end detection events. Since the accuracy of this method declines as the duration between the two detection events increases, a threshold of <45 days between detection events was used to filter movements.

Seasonal fish movements were further explored by analyzing monthly tributary entrance and exit behaviours. Ten fixed-stations were placed at or near tributary entrances (one station per tributary entrance, Table 3). Each tributary entrance fixed-station was equipped with an antenna that was pointed upstream of that tributary along with one (or two) antennas that pointed downstream (or into the Peace River). The sequence of detections on each antenna orientation was analyzed to enumerate monthly tributary entrance and exit behaviours by species. For this analysis, three uncontested[32] detections on the

[29] The term detection event is used due to the possibility of a single study fish being detectable across multiple mobile tracking flights.

[30] Categorized monthly movement distances for all six species were normally distributed.

[31] Bull Trout, Arctic Grayling, Walleye, Rainbow Trout, Mountain Whitefish and Burbot.

[32] The fixed-station receiver switches to other available antennas every ten seconds. An uncontested detection string refers to a string of detections recorded on only one antenna within the 10 seconds the receiver scanned that frequency.

upstream antenna meant the study fish was located upstream of that tributary fixed-station, with the opposite true for three uncontested detections on the downstream antenna(s). Any movement from downstream to upstream was identified as an entrance behaviour while any movement from upstream to downstream was an exit behaviour. Some individual study fish repeatedly entered and exited a tributary within a matter of days, which, if left uncorrected, would skew the resulting count towards species and fixed-stations that were more likely to capture this behavioural pattern. Therefore, to create a visualization that was standardized across species, tributaries, and years, individual study fish were limited to three tributary interactions per month[33]. This approach was independently validated by using upstream detection data (fixed-station and mobile) from the Halfway River and Moberly River to confirm that entry and exit behaviours were identified as expected.

The monthly movement analyses are a means to condense and visualize the available telemetry data with the underlying purpose of displaying large scale movement patterns that can be leveraged to interpret the capacity of the array and monitor fish movement as the Project progresses. This approach helps condense a large amount of movement data into a standardized format for all six indicator species. That said, the approach has some limitations that should be stated.

The telemetry system does not possess the capacity for universal and ubiquitous detection. This means that specific and/or granular movements made by study fish have the potential to be overlooked. This includes, but is not limited to, movements that may occur between fixed-stations, outside of the detection array (Figure 5), or movements that occur during the non-operating period between November and March. This can limit biological interpretations when portions of a study area are more thoroughly combed for detectable study fish than others. For example, the detection coverage of the Halfway River is not the same every month of the year. Mobile tracking in the Halfway River is designed to capture Bull Trout spawning behaviour in September (Appendix D, Figure D1) and the Halfway River #2 and Halfway River #3 fixed-stations are not operated from December through February (Table 3).

Spawn Timing and Distribution

In accordance with the underlying objectives of Mon-1b, Task 2a (Peace River Arctic Grayling and Bull Trout Movement Assessment), Bull Trout and Arctic Grayling spawning behaviours were analyzed in 2022. Previous research has identified the Halfway River as the primary spawning tributary for Peace River Bull Trout[34] and the Moberly River as the primary spawning tributary for Peace River Arctic Grayling[35] (Geraldes & Taylor 2022).

---

[33] Most of the study fish with this behaviour started and ended the analyzed month in the same location, i.e., above or below the tributary, and were assigned two interactions (one exit and entry). However, some of study fish with numerous detections in a single month ended the month in a different location than they began. These fish were assigned three interactions to account for their final location (i.e., entry/exit/entry or exit/entry/exit).

[34] Genetic analysis of Peace River Bull Trout samples collected between 2016 and 2020 estimated that 94% of individuals originated from the Halfway River and its tributaries whereas 4% originated from the Pine River with the remaining 3% undetermined (Geraldes & Taylor 2022). Furthermore, otolith and fin ray microchemistry analysis of Peace River sampled Bull Trout confirmed this trend with the majority of individuals originating from the Halfway River while the minority originated from the Pine and Moberly rivers (Mainstream Aquatics 2012, TrichAnalytics 2020)

[35] Genetic analysis of Peace River Arctic Grayling samples collected between 2018 and 2020 estimated that 86% of individuals originated from the Moberly River whereas 7% originated from the Pine River, <1% from the Halfway River and the remaining 7% undetermined (Geraldes & Taylor 2022). Otolith and fin ray microchemistry validate this finding, and consistently found that the majority of Arctic Grayling sampled near Site C originate from the Moberly River with lesser proportions originating from the Halfway, Pine, or Beatton rivers (Mainstream Aquatics 2012, TrichAnalytics 2020).

In cooperation with this base knowledge, fixed-stations were deployed and operated on the Moberly and Halfway rivers (Figure 5) during each spawning period to capture upstream movements that are indicative of spawning. Additionally, mobile tracking surveys were conducted across the Halfway River drainage during the 2022 Bull Trout spawning period. Mobile tracking surveys to target spawning Arctic Grayling in the Moberly River were not conducted in 2022 as in previous years (Hatch et al. 2020, 2021).

Individual Bull Trout and Arctic Grayling detection histories were manually analyzed in conjunction with prior knowledge regarding spawn timing[36] to identify entry and exit timing, as well as upstream and downstream movements. In 2022, approximate spawn locations were only estimated for Halfway River Bull Trout due to the additional geospatial information from the Halfway River mobile tracking survey (Table 5).

For Halfway River Bull Trout, it was assumed that a spawning study fish would follow a generalized paradigm in which the individual enters the tributary system, migrates upstream to the desired spawning location, and then resides in this spawning location before migrating back downstream and eventually exiting the tributary. A modification to this paradigm includes any individuals that potentially residualize or die in their spawning tributary either before or after a potential spawning event. In which case, spawning location would be based on the identification of any pre- or post-spawn behaviours along with the application of any prior knowledge of peak spawn timing.

[36] Bull Trout spawn in the fall with spawner activity peaking during the month of September (Putt et al. 2020), while Arctic Grayling spawn in the spring during the months of May and June (Nelson and Paetz 1992, Mainstream Aquatics 2012).

Table 6. Counts of valid detection records and unique codes (individual study fish) detected at each receiver from 1 Jan 2022 to 31 Jan 2023.[37]

Station #	Station Name	Valid Count	Unique Codes
1 & 2	Peace River 1 (1A & 1B)	56,178	42
3	Peace River 2	3,571	48
4	Pouce Coupe River	135,167	24
5 & 6	Peace River 3 (& Kiskatinaw River)	1,330,619	91
7	Beatton River	826,792	83
8	Peace River 4	3,513,631	149
9	Pine River	32,116	57
10 & 32	Peace River 5 (& INS Mainstem 1)	33,801	100
50	West Side Channel	7,738	32
51	East Side Channel	339	4
52	South Side Channel	581,171	39
11 & 33-41	Site C Dam (all recievers)	7,012,511	125
12	Moberly River 1	26,345	12
13	Moberly River 2	2,470	6
14	Moberly River 3	2,698	5
15	Peace River 6	295,177	48
16	Peace River 7	253,891	59
17	Cache Creek	2,599	1
18	Peace River 8	507,465	78
19	Halfway River 1	192,105	69
20	Halfway River 2	40,816	59
21	Halfway River 3	13,691	42
29	Chowade River	808	5
30	Cypress Creek	5,218	5
22	Peace River 9	16,175	42
23	Farrell Creek	7,157	8
24	Peace River 10	659,574	41
26	Peace River 11	1,480,960	55
31	Maurice Creek	28,055	16
28	Peace Canyon Dam	151,979	8
47	Moberly Lake	0	0

Results

Data Collection

The fixed-station array and mobile tracking effort collected over 17 million valid detection records that passed the filtering criteria between 1 January 2022 and 31 January 2023 (Table 6). Starting in January 2022, data collection occurred solely at the three fixed-stations that were operated overwinter (Site C Dam, Moberly River 1, and Halfway River 1), while the remainder of the array[38] was seasonally operated between March and November 2022. Appendix B presents an overview of the relative quantities of validated detections for each fixed-station (Figure B1). Further, the frequency of noise signal detections (Code 999) per fixed-station is displayed in Figure B2, and the frequency of false-positive detections is shown in Figure B3.

The fixed-station array was online 99% of the time between the 2022 installation and demobilization dates for each respective receiver (Table 4, Table 7). The remaining 1.1% was the result of minor receiver-specific interruptions (Table 7), with relatively notable interruptions occurring at Moberly River 2 (the

[37] Note that some stations are grouped together to create a detection gate that can detect passing fish from both sides of the river (i.e., Peace River 1 and Peace River 3). Similarly, Site C Dam is a group of overlapping fixed-stations including the single fixed-station operated by LGL Limited as well as the twelve fixed-stations operated by Instream Fisheries Research in 2022.

[38] Including all fixed-stations left dormant over winter with a low-voltage cutoff awaiting better solar conditions.

environmental box fell off its tree), Cache Creek (animal disturbance that disconnected the system), and Site C Dam (low light and low temperature winter operating conditions).

Fixed-Station Range Testing

An objective of Mon-1b, Task 2d is to range test every fixed-station annually to assess and quantitatively evaluate functionality. As such, wherever possible, all fixed-station antennas were tested individually to create detection probability maps (Figure 8) and logistic detection probability curves (Appendix F). Additionally, all stations were also tested for basic range functionality[39] on deployment and were analyzed *post-hoc* to determine detection efficiency.

Among the 34 fixed-stations operating in 2022, all but one fixed-station (Pine River) were tested (Table 8). Range test detection probability maps were created for each tested station to better visualize the expected detection zones (Figure 8). An ideal detection probability map would display a gradient across the tested area that builds from high detection probabilities near the station (80-100%, shown as green) to moderate probabilities (60%-80% as light green, 40-60% as yellow, and 20%-40% as orange) all the way to zero detection probability further away from the station (0-20%, shown as red). Most fixed-stations displayed this ideal detection probability map (n=16) including Peace River 2/5/7, Moberly River 1/2/3, Halfway River 2, Pouce Coupe River, Kiskatinaw River, Chowade River, Farrell Creek, Lynx Creek, Peace Canyon Dam, East Side Channel and the West Side Channel.

Several fixed-station range tests produced detection probability maps with sufficient detection area, but which were missing the 'no detection' (red) zones at the edges of the tested area (Figure 8). Eight stations made up this category including Peace River 1/4/6/8/9/10, Halfway River 1 and the South Side Channel. This occurred when most or all of the test was conducted within a positive detection area and that area sufficiently covered the river. These stations are operating within expected parameters.

[39] Basic range functionality was qualitatively tested by carrying a test tag to ~250 m upstream and downstream of an antenna and then validating detections.

Table 7. Outage start date, end date, days offline, and notes for all fixed-stations that experienced an outage from 1 Jan 2022 to 31 Jan 2023. Further dissections into outages are displayed in beacon tag detection plots in Appendix B (Figure B4)

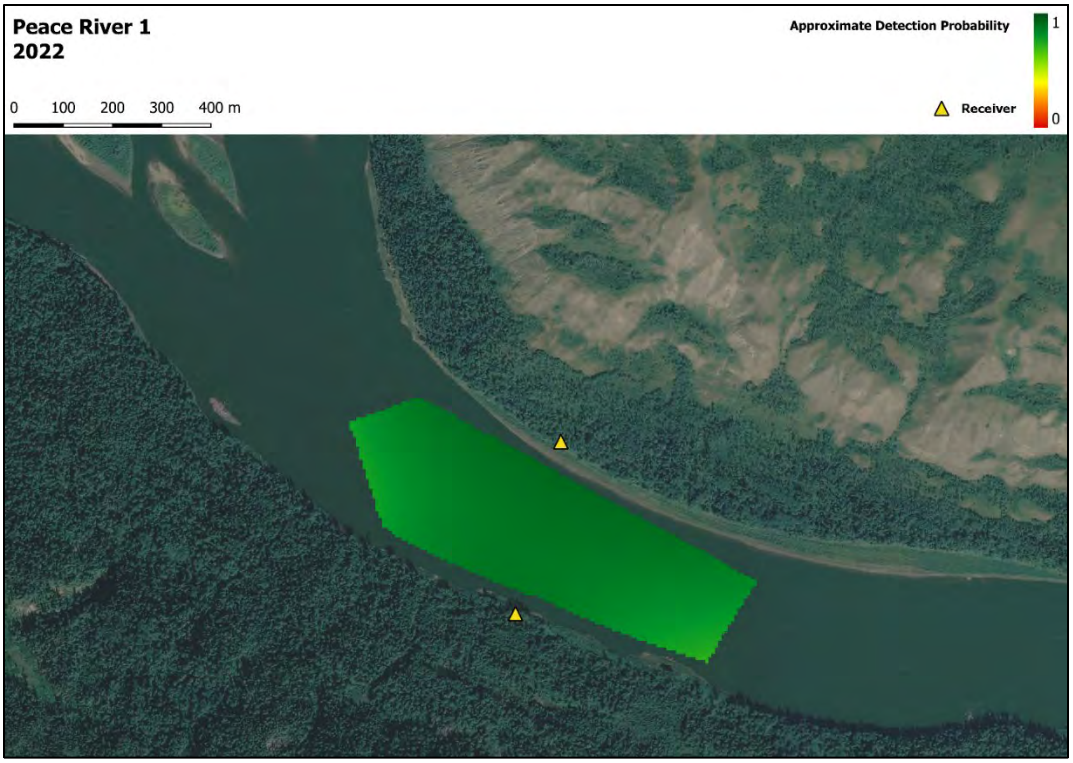
Study Year	Station Name	Outage Start	Outage End	Days Offline	Note
2022	INS Approach Zone B	2 January 2022	13 January 2022	11	Low Light Conditions / Cold weather
2022	INS Mainstem 2	3 January 2022	11 January 2022	6	Low Light Conditions / Cold weather
2022	INS Entrance Aerial	4 January 2022	11 January 2022	7	Low Light Conditions / Cold weather
2022	INS Approach Zone A	5 January 2022	11 January 2022	5	Low Light Conditions / Cold weather
2022	INS Diversion Tunnel	6 January 2022	11 January 2022	5	Low Light Conditions / Cold weather
2022	INS Diversion Tunnel Inlet	7 January 2022	11 January 2022	4	Low Light Conditions / Cold weather
2022	Halfway River 1	2 March 2022	5 March 2022	3	Low Light Conditions / Cold weather
2022	Farrell Creek (2021)	9 April 2022	15 April 2022	6	Low Light Conditions / Cold weather
2022	Lynx Creek	14 May 2022	31 May 2022	17	Not operational
2022	INS Turning Basin	25 May 2022	2 June 2022	8	Not operational
2022	INS Vee-Trap	25 May 2022	2 June 2022	8	Not operational
2022	Peace River 9	27 May 2022	31 May 2022	5	Not operational
2022	INS Cell 8	21 June 2022	27 June 2022	6	Not operational
2022	Moberly River 2	9 July 2022	21 October 2022	104	Box fell off tree
2022	Cache Creek	10 July 2022	10 September 2022	63	Animal Activity
2022	Moberly Lake	6 August 2022	3 September 2022	28	Designed for summertime
2022	Farrell Creek (2021)	29 August 2022	3 September 2022	5	Low Light Conditions
2022	Peace River 1B	2 September 2022	7 September 2022	5	Low Light Conditions
2022	Beatton River	7 September 2022	24 October 2022	47	Cabling came unplugged
2022	Peace River 1B	26 September 2022	24 October 2022	23	Low Light Conditions
2022	Peace Canyon Dam (2021)	28 September 2022	22 October 2022	24	Low Light Conditions
2022	Peace River 1A	19 October 2022	24 October 2022	5	Low Light Conditions
2022	Site C Dam	27 October 2022	5 November 2022	9	Blown Fuse
2022	Halfway River 1	10 December 2022	14 December 2022	4	Low Light Conditions / Cold weather
2022	Site C Dam	12 December 2022	26 January 2023	41	Low Light Conditions / Cold weather
2022	INS Diversion Tunnel Inlet	20 December 2022	21 January 2023	30	Not operational
2022	INS Mainstem 2	21 December 2022	18 January 2023	19	Not operational
2022	INS Approach Zone B	23 December 2022	21 January 2023	31	Not operational
2022	INS Diversion Tunnel	23 December 2022	18 January 2023	26	Not operational
2022	Moberly River 1	24 December 2022	8 January 2023	13	Low Light Conditions / Cold weather
2022	INS Approach Zone A	24 December 2022	18 January 2023	24	Not operational
2022	INS Entrance Aerial	24 December 2022	18 January 2023	25	Not operational
2022	Halfway River 1	27 December 2022	29 December 2022	2	Low Light Conditions / Cold weather
2022	Halfway River 1	1 January 2023	6 January 2023	5	Low Light Conditions / Cold weather
2022	Moberly River 1	12 January 2023	19 January 2023	7	Low Light Conditions / Cold weather
2022	Halfway River 1	13 January 2023	19 January 2023	5	Low Light Conditions / Cold weather

There were three fixed-stations (Peace River 3, Moberly Lake, and Halfway River 3) where the test did not cover a sufficient area to effectively interpret the fixed-station range (Figure 8). These tests were successful in that the fixed-station was detecting in expected areas, however the extent of that detectable range was not identifiable. At Halfway River 3, the range tested area did not include a critical section of the primary channel, opposite to the receiver.

Table 8. Completion of a successful range test by study year (Yes, No, Not Tested or NA/-) as well as the approximate minimum distance from the fixed-station antennas to the range test area (i.e., the river or creek).

Fixed-Station Name	Successful Range Test 2019	2020	2021	2022	Minimum Distance from Antenna to Testing Area (m)
Peace River #1A	Yes	Yes	Yes	Yes	75
Peace River #1B	Yes	Yes	Yes	Yes	75
Peace River #2	No	Yes	Yes	Yes	50
Pouce Coupe River	Yes	Yes	Yes	Yes	250
Peace River #3	Yes	Yes	Yes	No	50
Kiskatinaw River	Yes	Yes	No	Yes	175
Beatton River	No	*Not Tested*	No	No	200
Peace River #4	Yes	*Not Tested*	Yes	Yes	250
Pine River	Yes	Yes	Yes	*Not Tested*	75
Peace River #5	Yes	Yes	Yes	Yes	125
West Side Channel	-	-	-	Yes	25
East Side Channel	-	-	-	Yes	25
South Side Channel	-	-	-	Yes	25
Site C Dam	*Not Tested*	*Not Tested*	Yes	Yes	75
Moberly River #1	Yes	*Not Tested*	Yes	Yes	175
Moberly River #2	-	*Not Tested*	Yes	Yes	75
Moberly River #3	-	*Not Tested*	Yes	Yes	50
Moberly Lake	-	-	Yes	No	15
Peace River #6	Yes	Yes	Yes	Yes	75
Peace River #7	Yes	*Not Tested*	Yes	Yes	150
Cache Creek	Yes	*Not Tested*	Yes	No	25
Peace River #8	Yes	*Not Tested*	Yes	Yes	75
Halfway River #1	Yes	*Not Tested*	Yes	Yes	50
Halfway River #2	-	*Not Tested*	No	Yes	100
Halfway River #3	-	*Not Tested*	Yes	Yes	75
Chowade River	Yes	*Not Tested*	*Not Tested*	Yes	50
Cypress Creek	Yes	*Not Tested*	*Not Tested*	No	50
Peace River #9	Yes	*Not Tested*	Yes	Yes	125
Farrell Creek	Yes	*Not Tested*	Yes	Yes	75
Peace River #10	Yes	*Not Tested*	Yes	Yes	75
Lynx Creek	Yes	*Not Tested*	-	Yes	50
Peace River #11	Yes	*Not Tested*	Yes	Yes	250
Maurice Creek	Yes	*Not Tested*	Yes	Yes	50
Peace Canyon Dam	No	*Not Tested*	No	Yes	100

Non-conforming or 'spotty' detection probability maps resulted from the range tests at Beatton River, Cache Creek, Peace River 11, Maurice Creek, and Cypress Creek stations (Figure 8). The low detection probability areas from the Maurice Creek detection map were likely due to shadowing caused by the temporary bridge just downstream of the station, as well as high flow conditions during the test which potentially created unexpected results. The Cache and Cypress creek fixed-stations were both operational but performed sub-optimally during the range test for unknown reasons. Both fixed-stations will receive a systemic refresh for the 2023 field season and detection capabilities will be reassessed. Both Peace River 11 and Beatton River are fixed-station receivers where numerous tagged study fish reside for much of the year. These additional tags in the detection area likely created collisions (i.e., when numerous tags of the same frequency are in the same location, their overlapping transmissions can interfere with a receivers ability to decode each of the unique signals) which lower detection probabilities and create odd detection patterns.



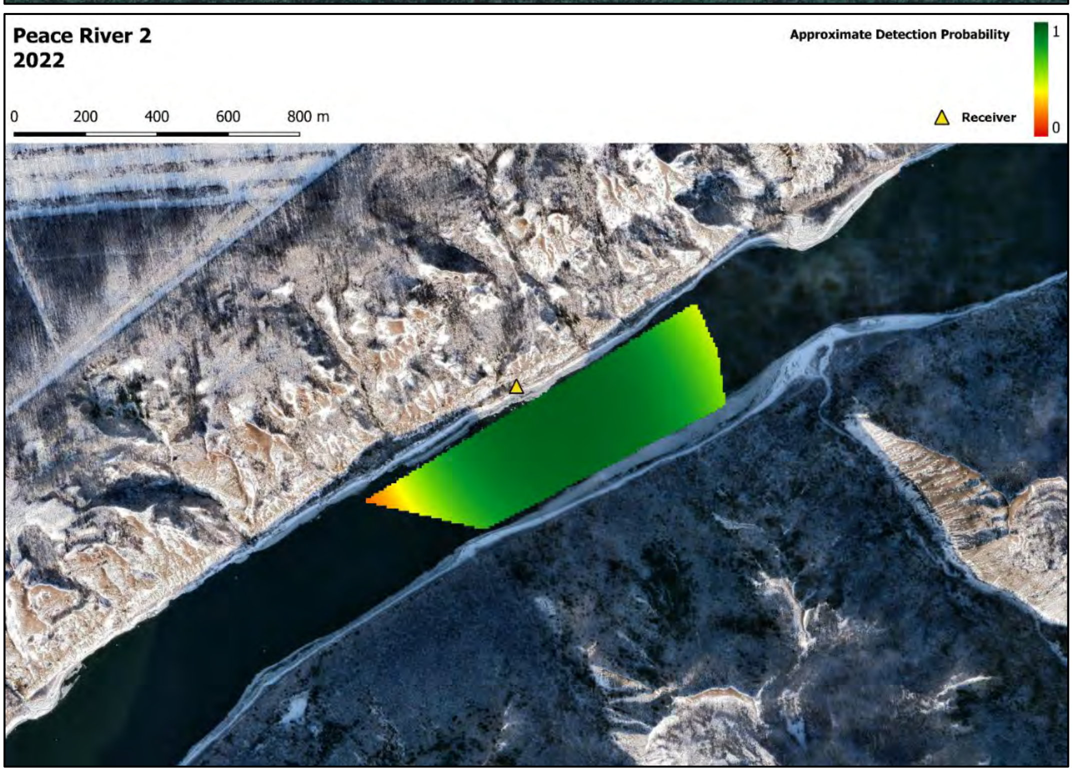


Figure 8. Range test detection probability maps for Peace River 1 and 2. Figure continues on the subsequent 15 pages.

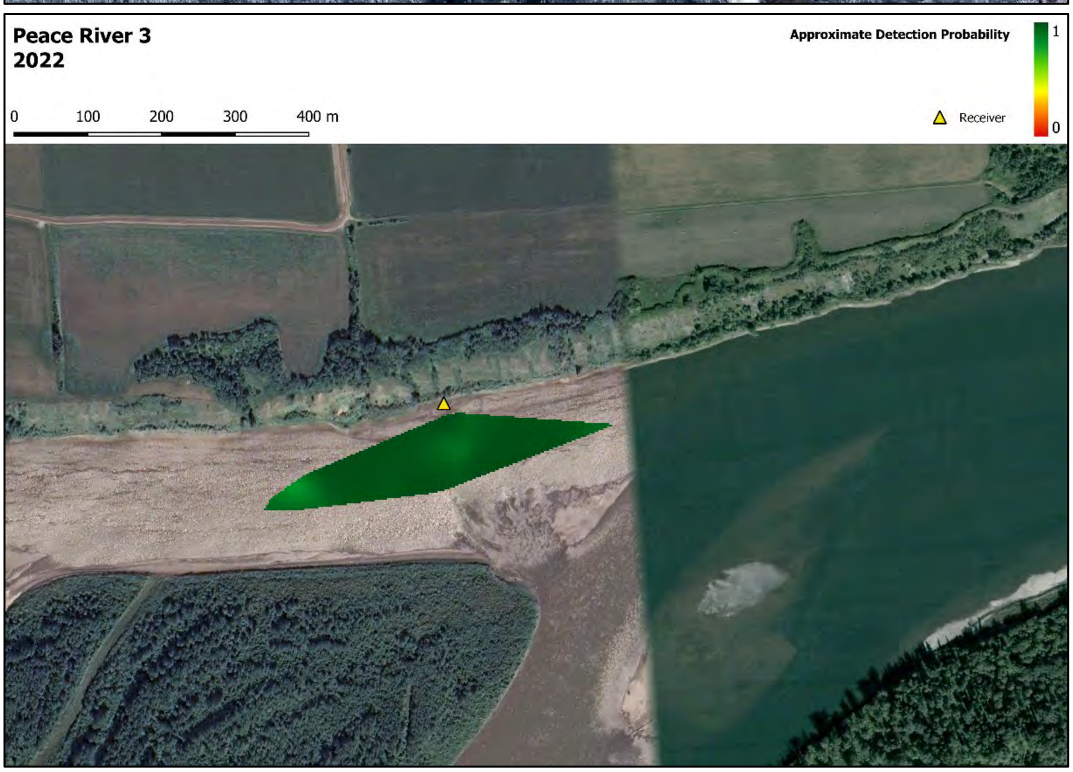
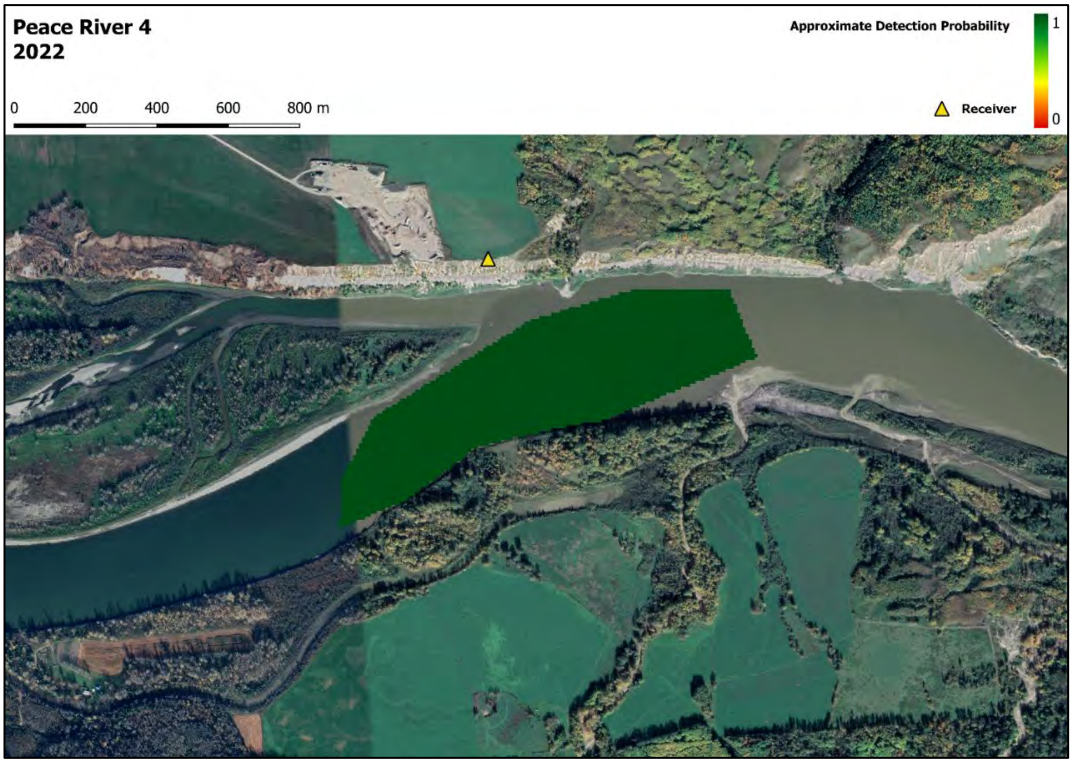


Figure 8 continued (Part 2 of 16).

Figure 8 continued (Part 3 of 16).



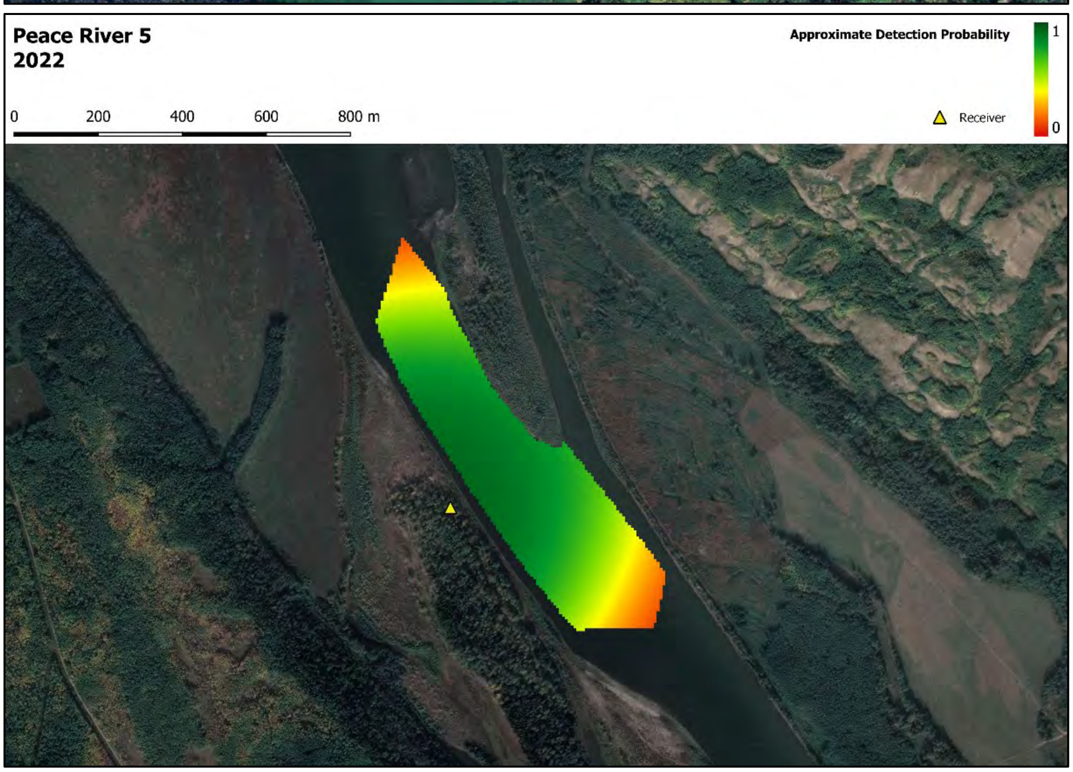
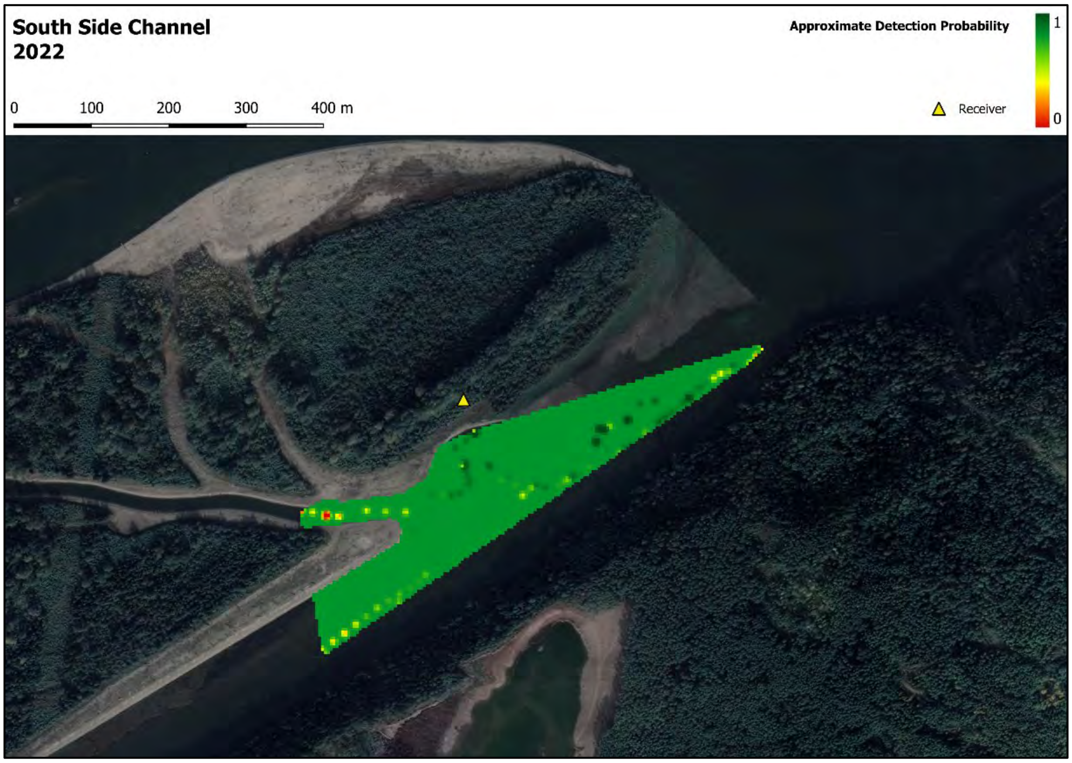


Figure 8 continued (Part 4 of 16).

Figure 8 continued (Part 5 of 16).



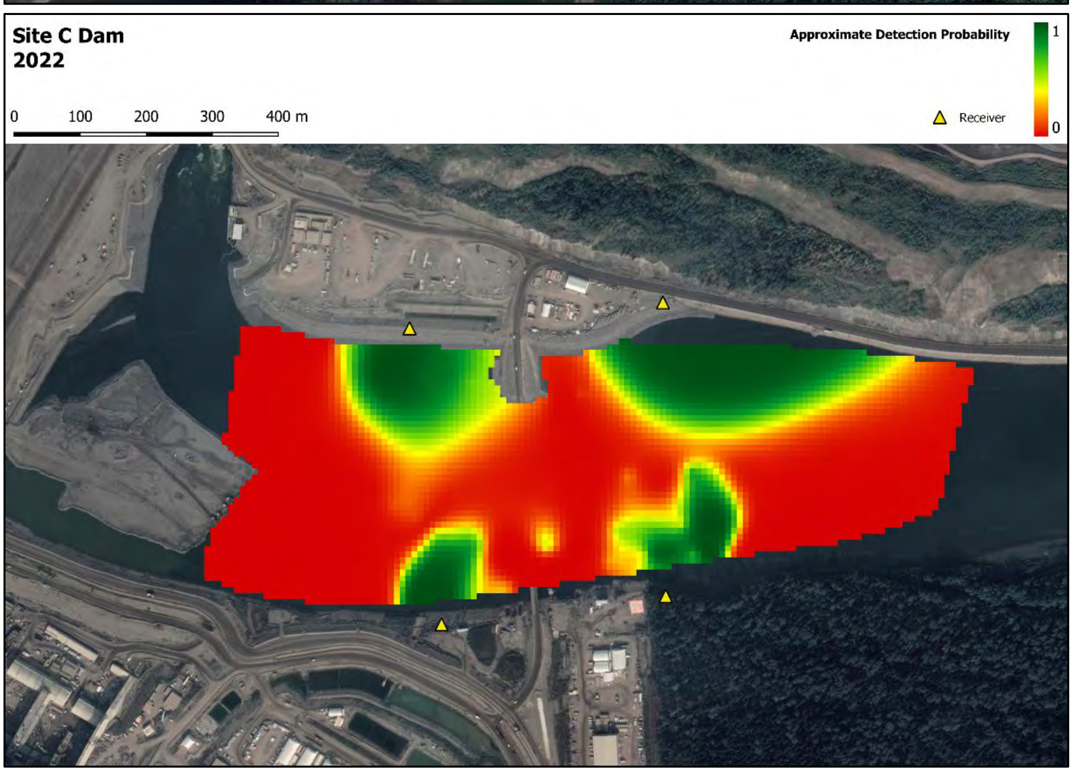


Figure 8 continued (Part 6 of 16).

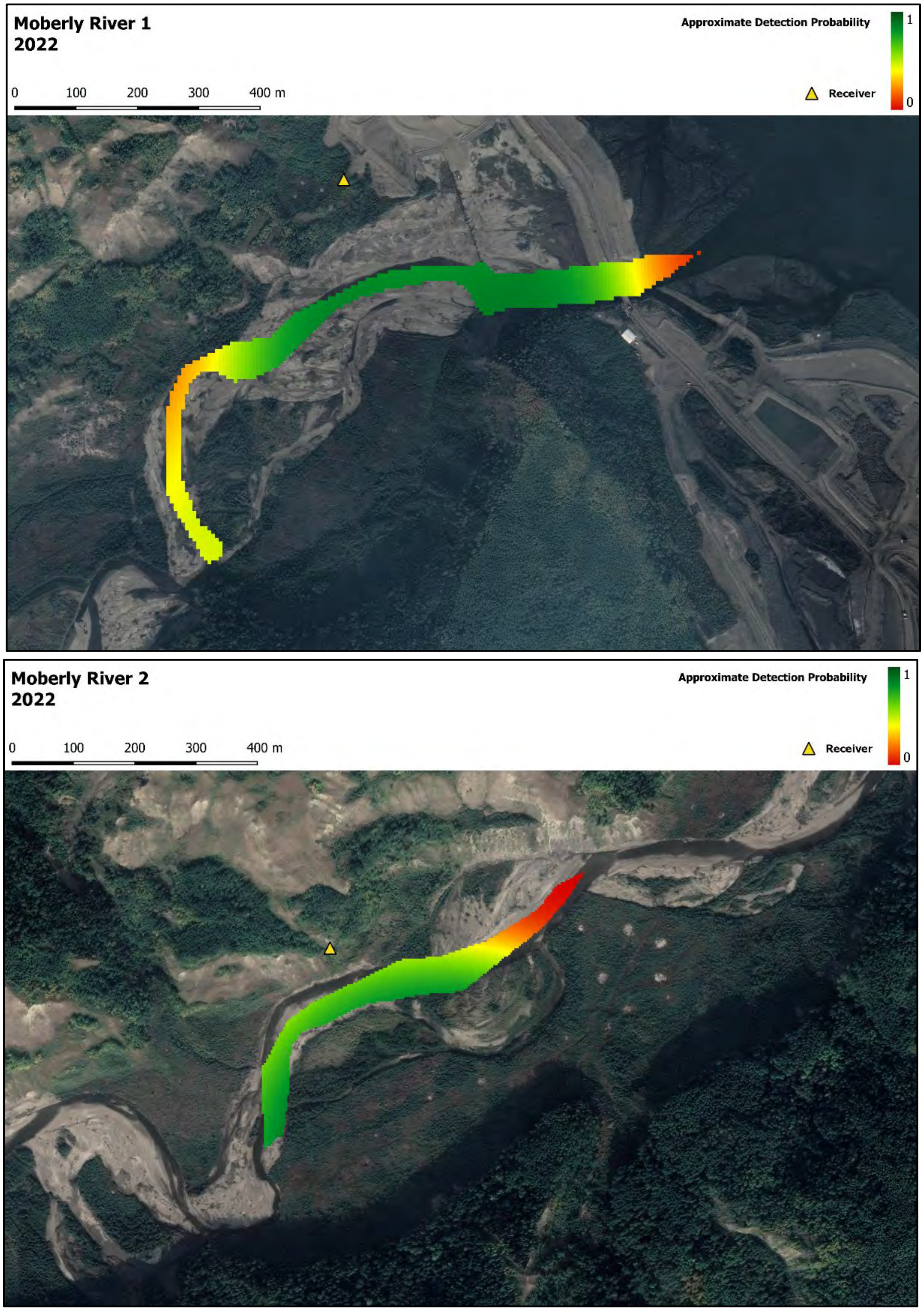
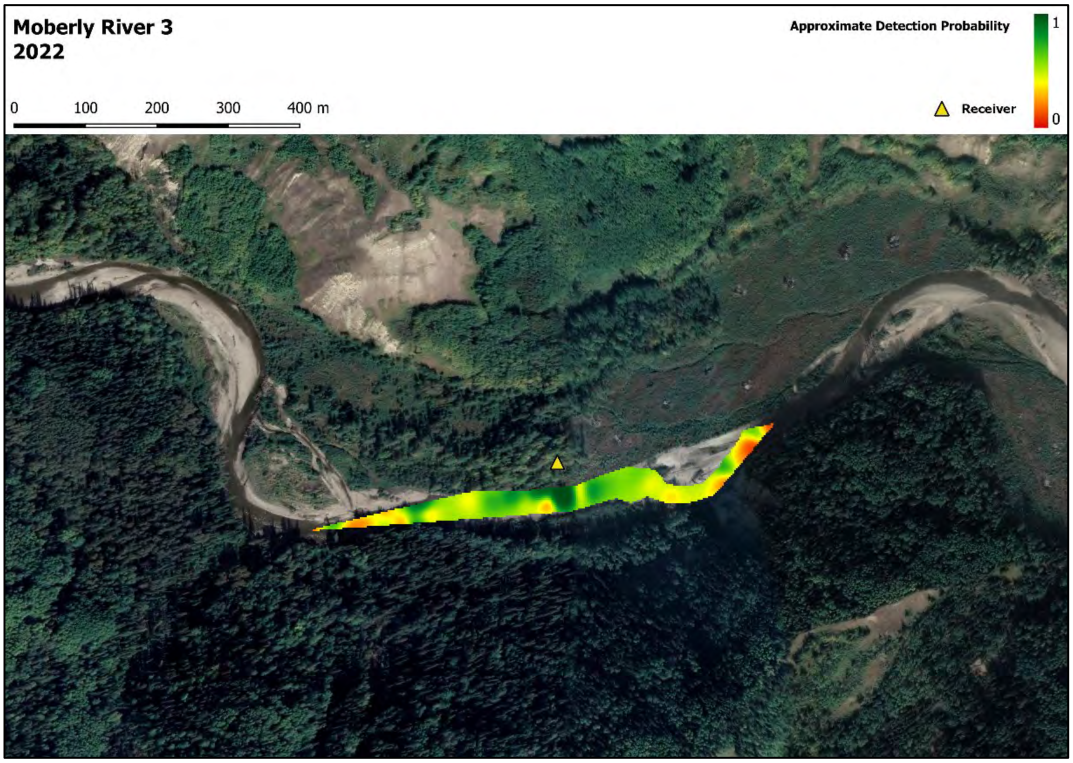


Figure 8 continued (Part 7 of 16).



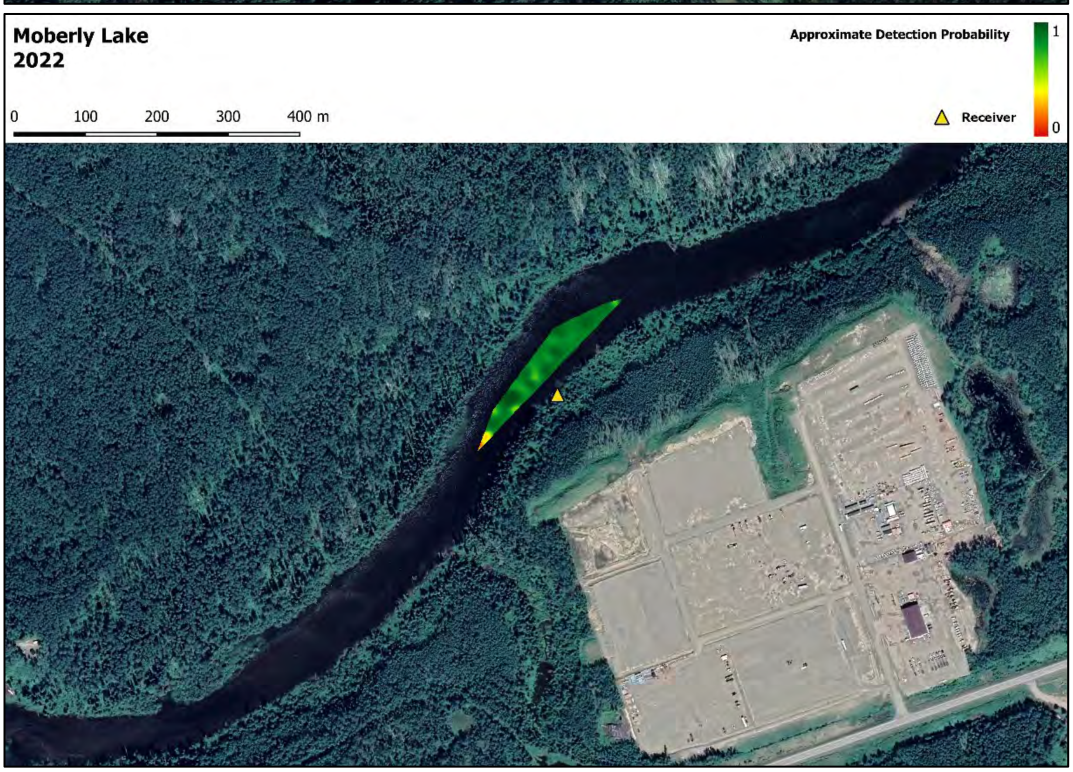
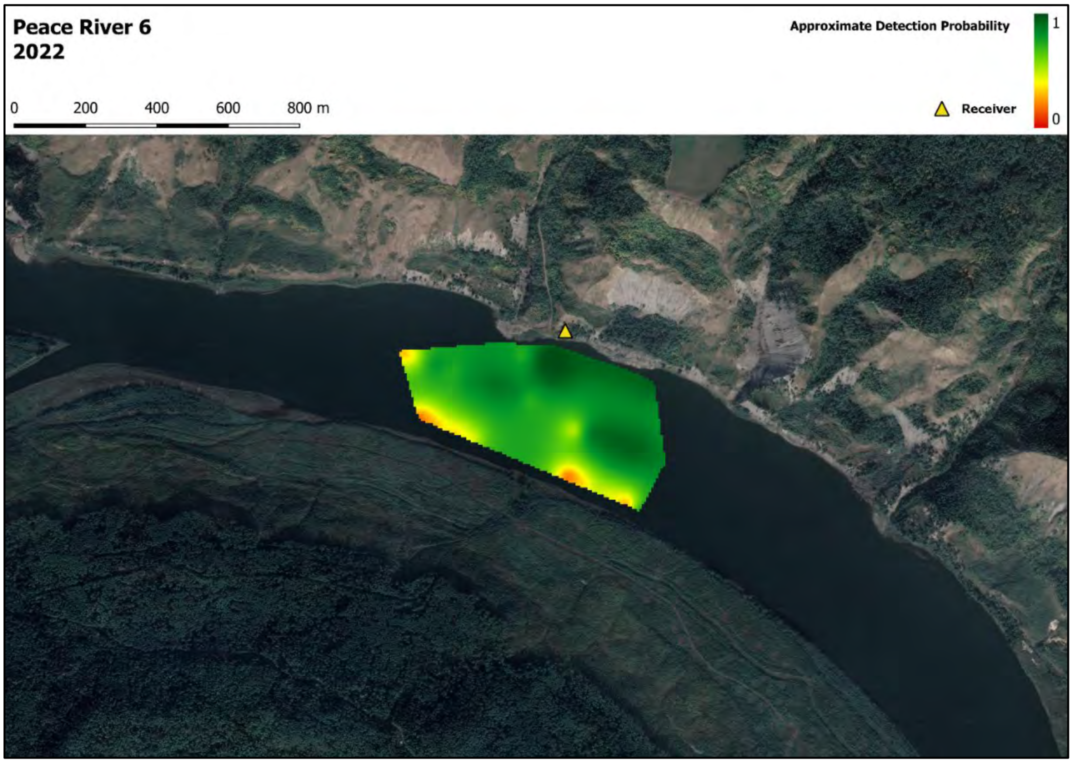


Figure 8 continued (Part 8 of 16).



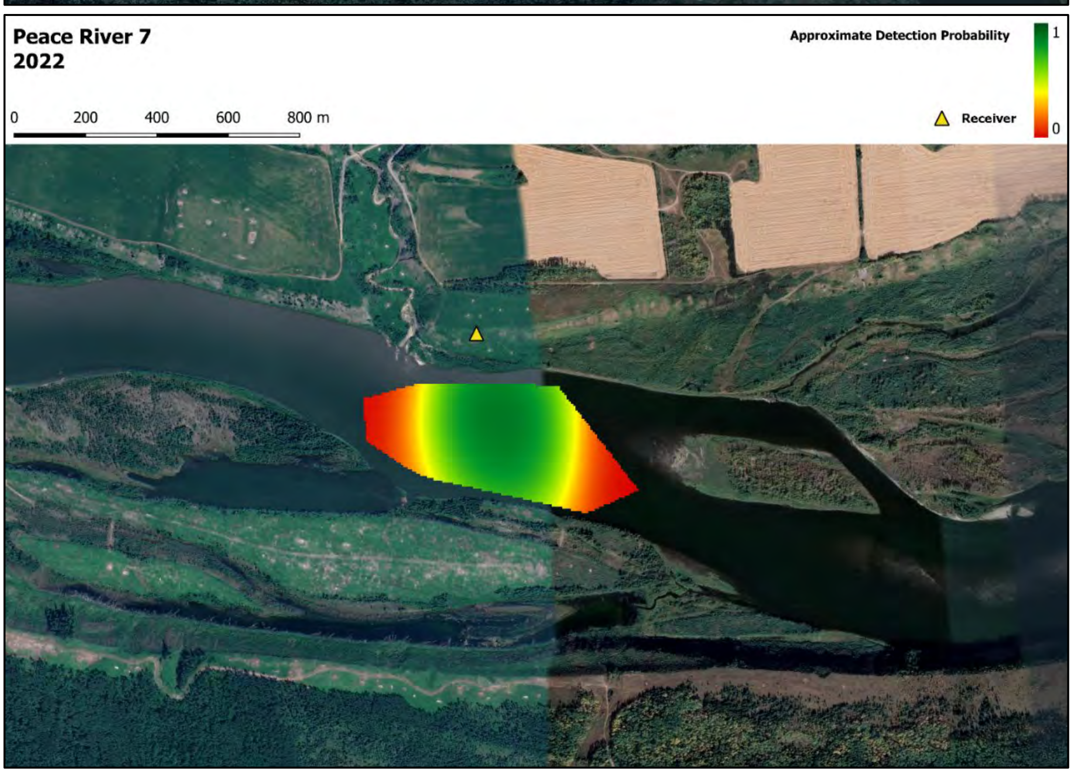


Figure 8 continued (Part 9 of 16).

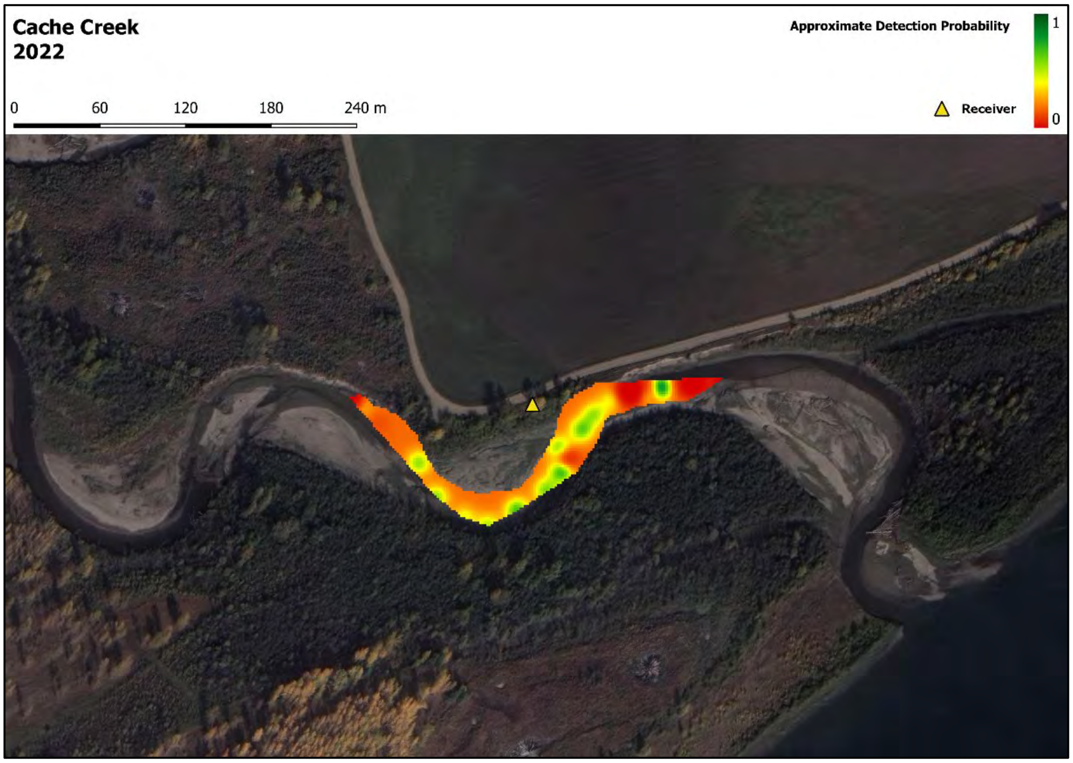


Figure 8 continued (Part 10 of 16).

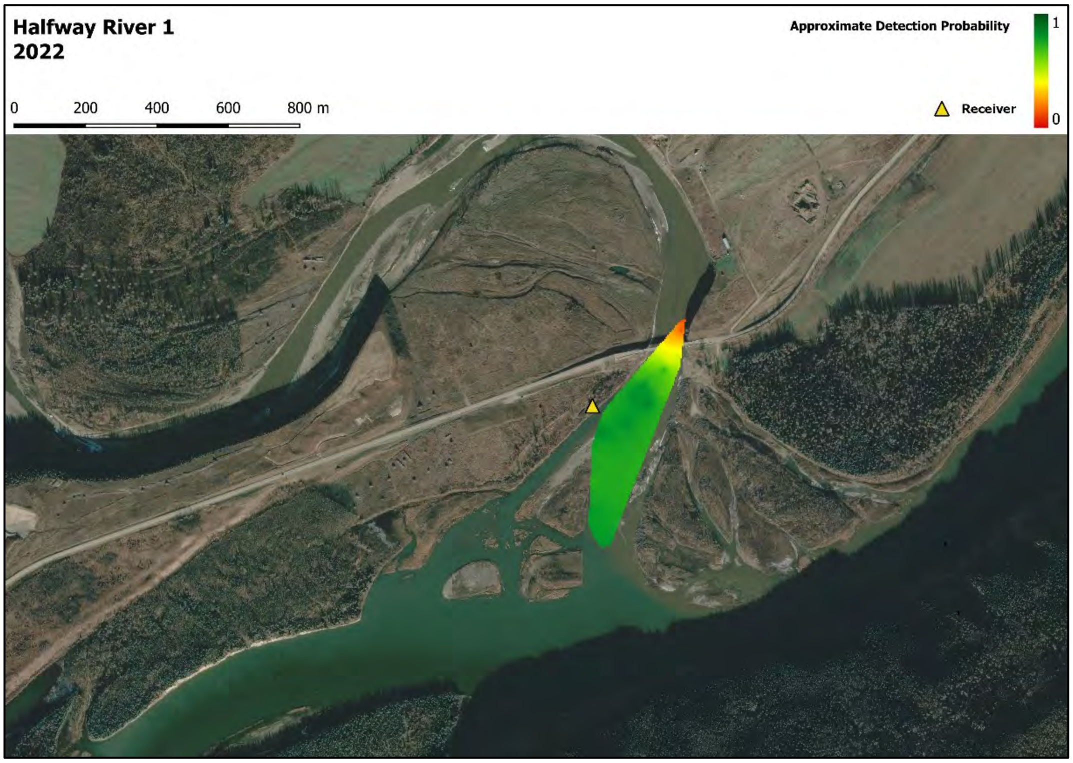


Figure 8 continued (Part 11 of 16).

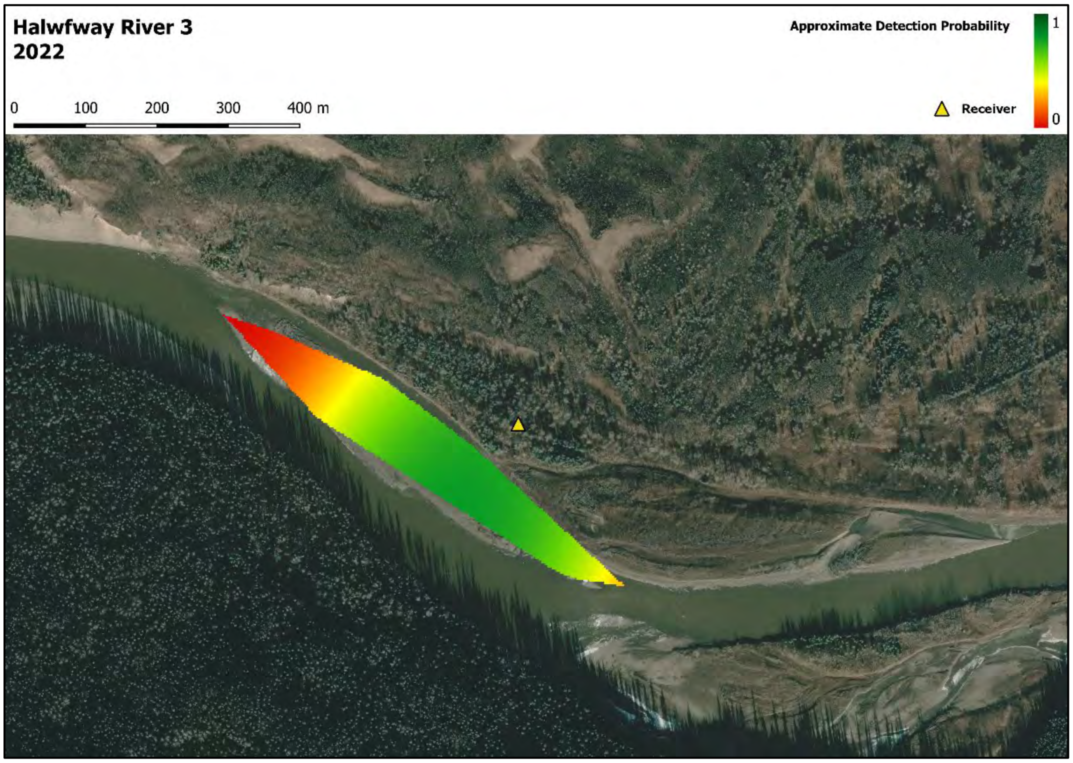
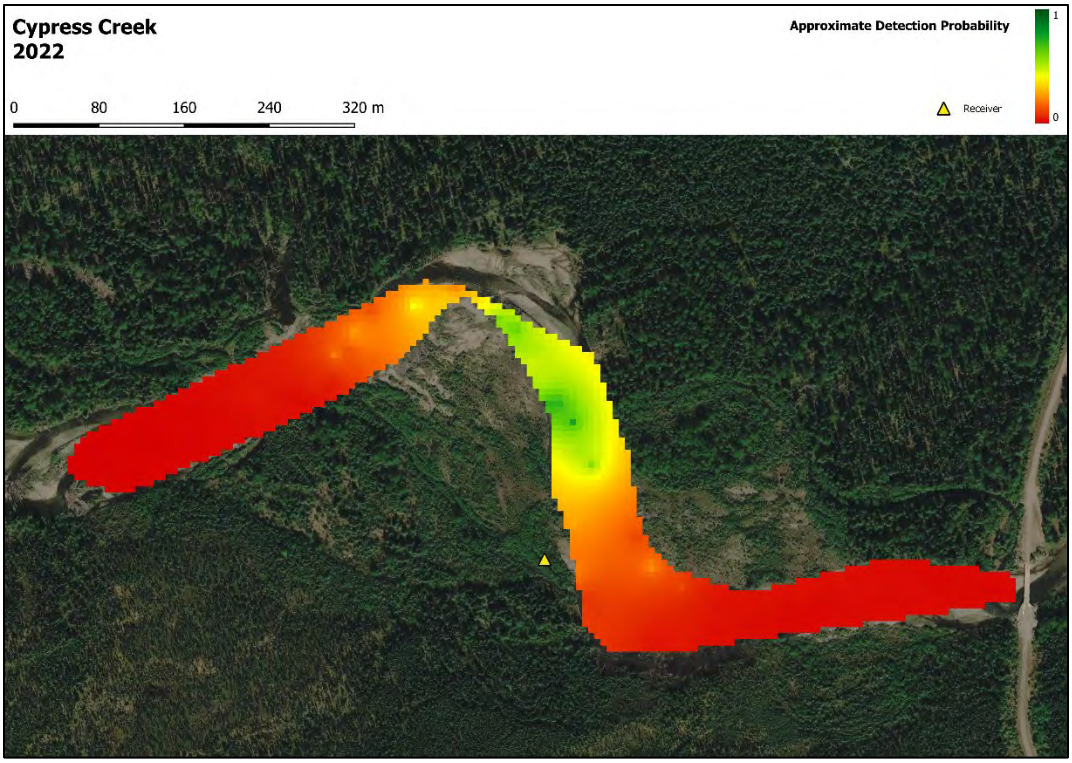


Figure 8 continued (Part 12 of 16).



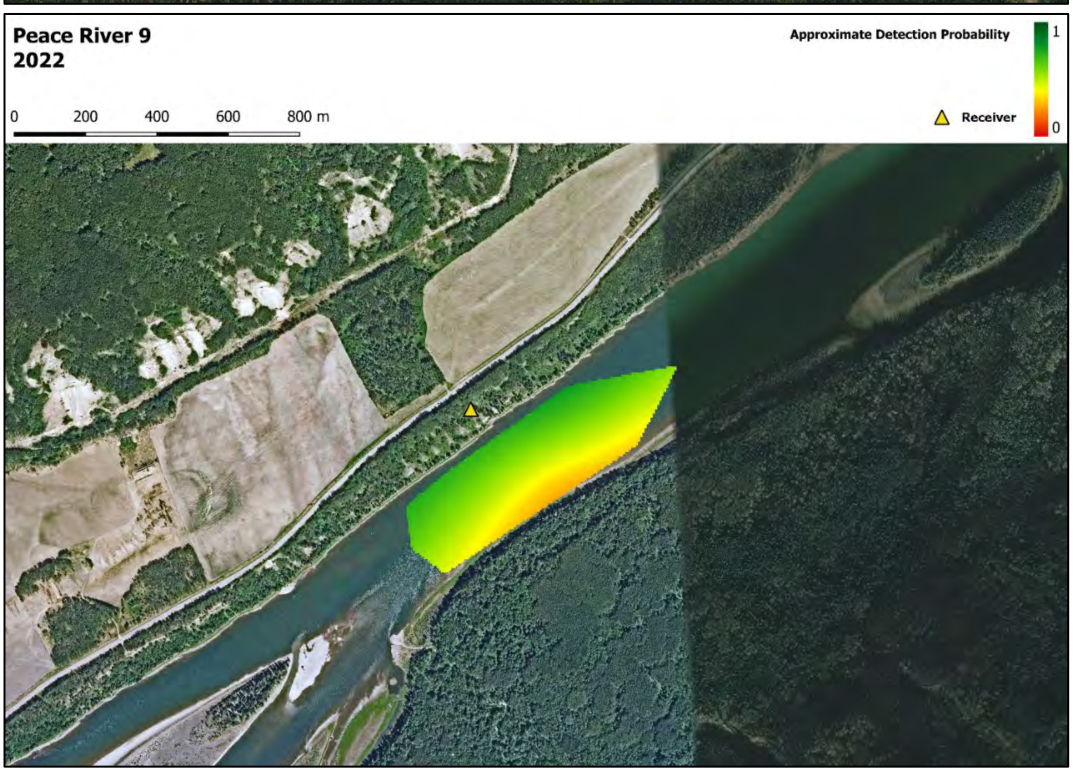
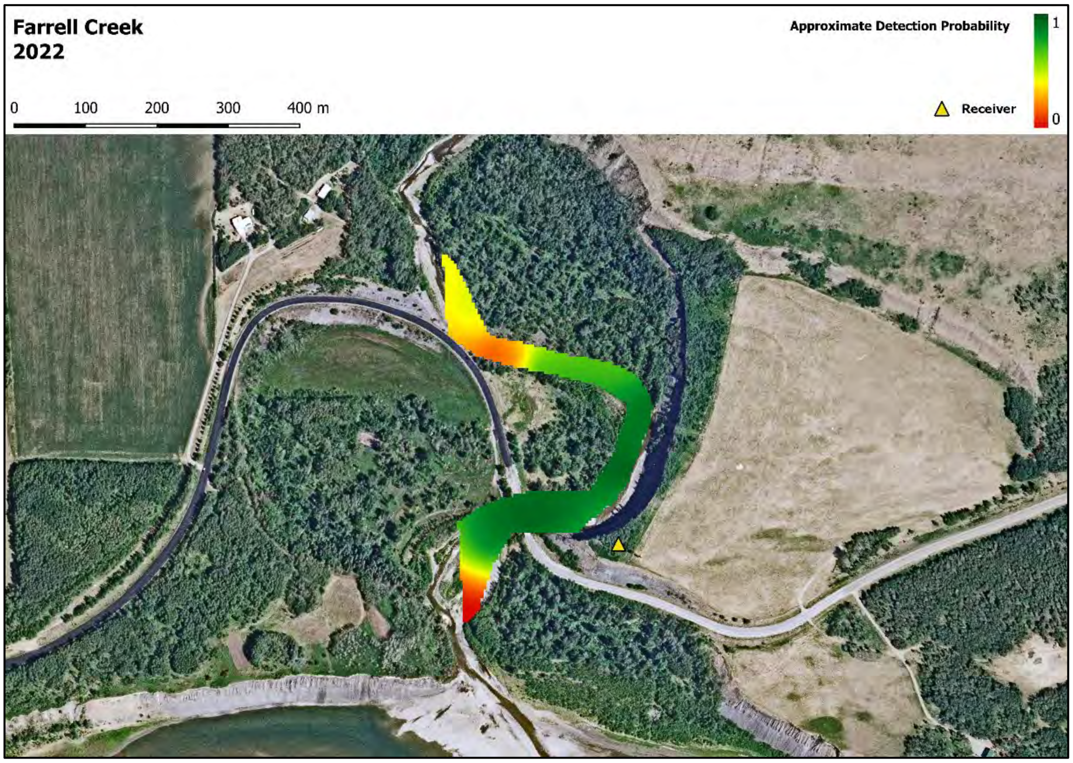


Figure 8 continued (Part 13 of 16).



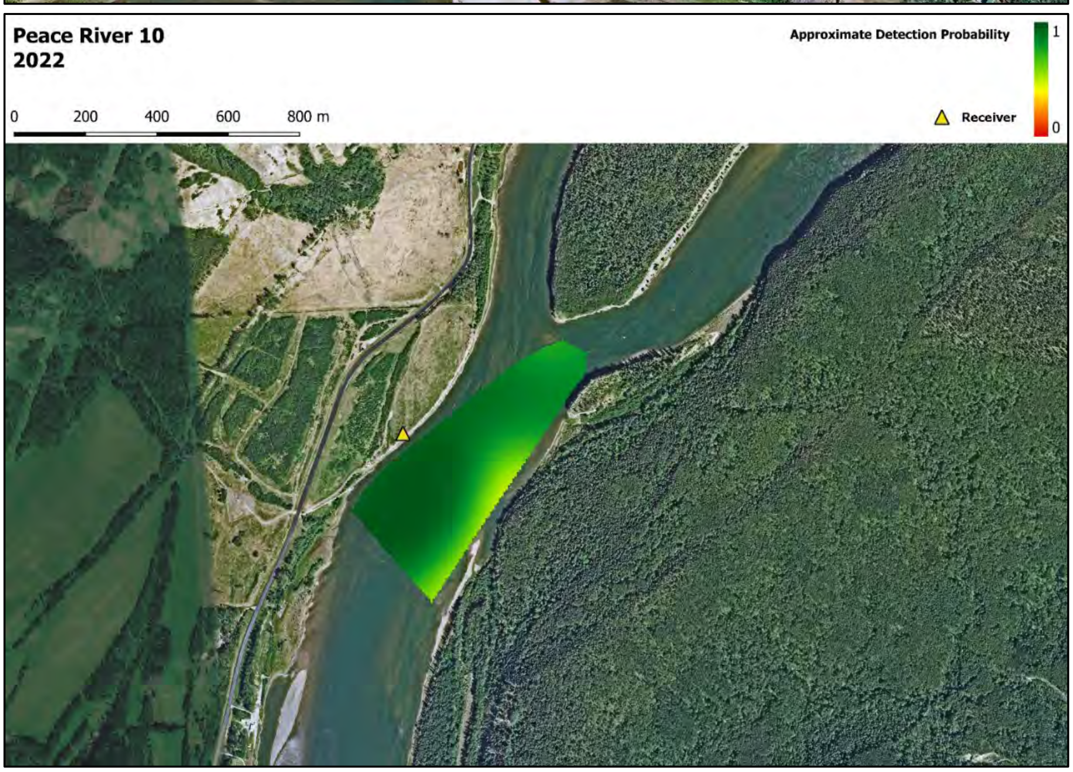


Figure 8 continued (Part 14 of 16).

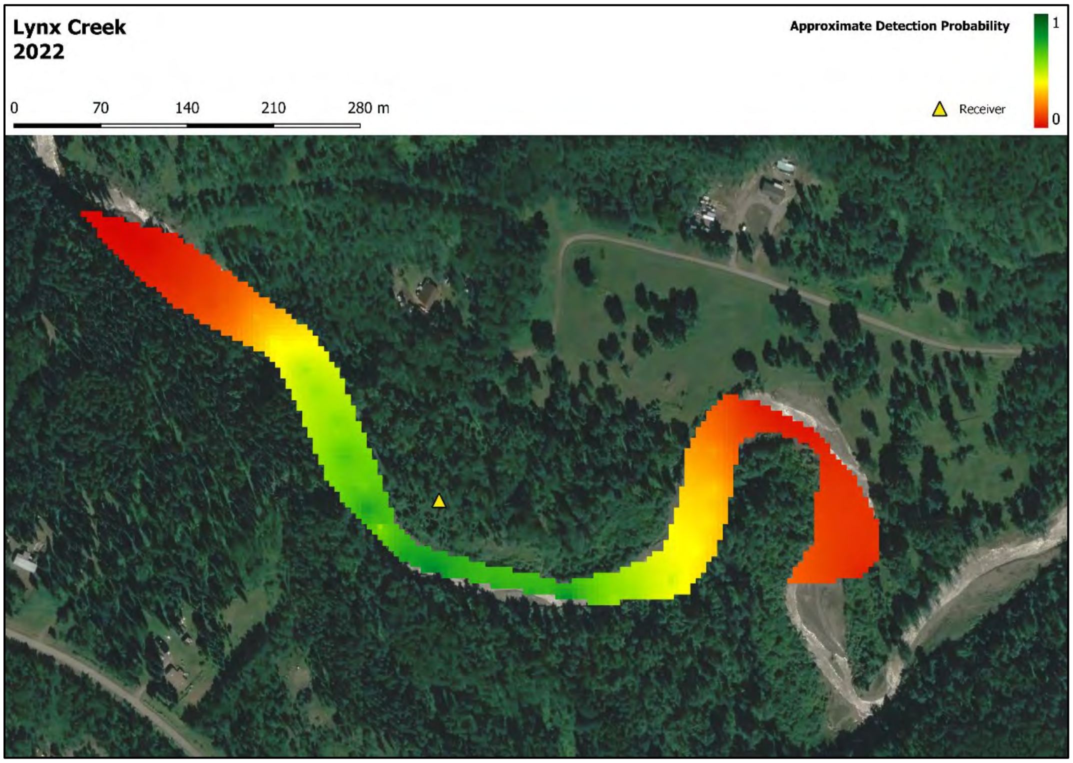
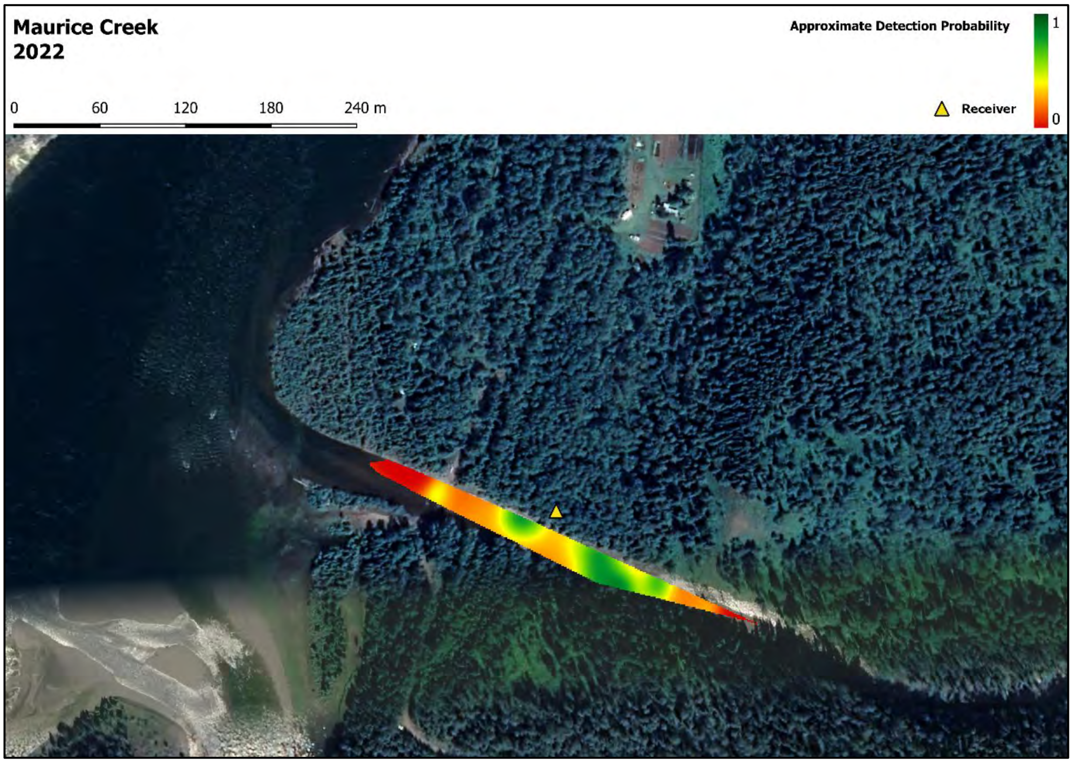


Figure 8 continued (Part 15 of 16).



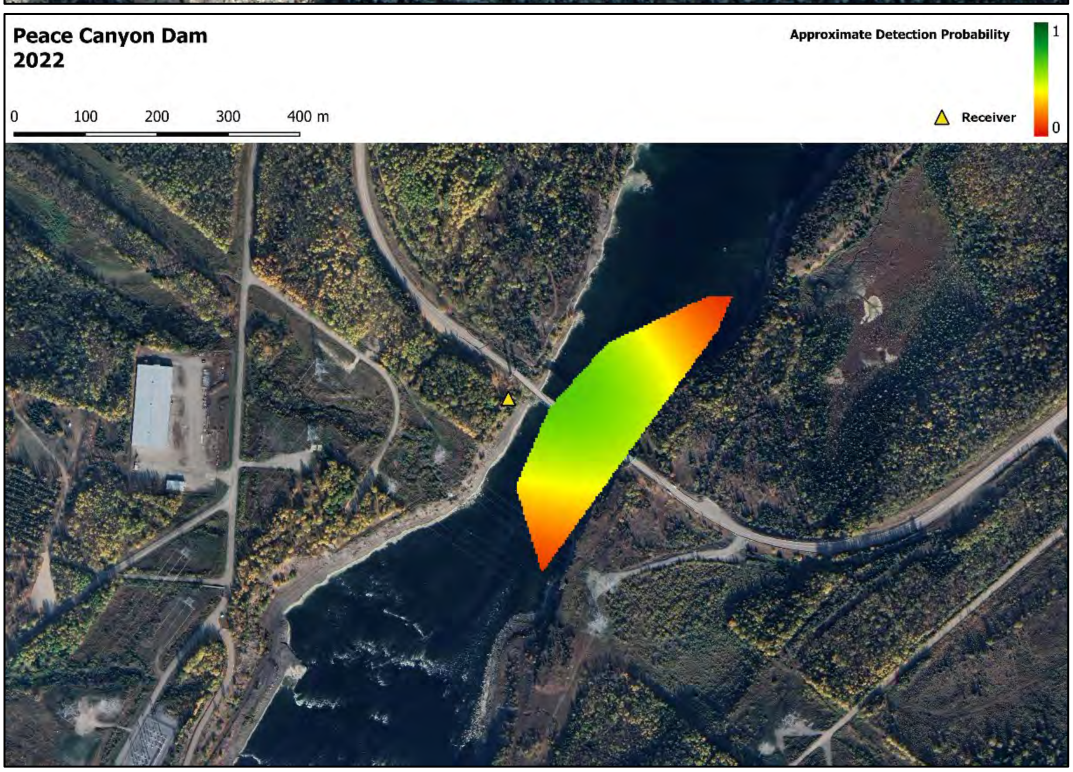


Figure 8 continued (Part 16 of 16).

Lastly, Site C Dam was range tested over a large detection space made of four fixed-station receivers (see part 6 of Figure 8). As displayed, the area immediately downstream of Site C Dam has relatively reduced detection ranges, which is a function of the ambient noise created by the construction activity. Near constant construction activity including, but not limited to, heavy machinery use, electrical powerlines, and radio communication creates interference that is picked up on the receiver as code 999. To maximize function in areas such as this, the sensitivity of the receiver must be reduced, which minimizes the interference, but also impacts the effective range.

Table 9. Inflection point (distance at which 50% of transmissions are detected), in metres (with standard errors in brackets) for model 6-2 Lotek nano tags, for range tests of specific antennas performed in 2022. See Appendix F. Inflection point estimates that were not statistically significant ("ns") have been excluded.

Station Name	Antenna One (DS)	Antenna Two (US)	Antenna Three (Trib)
Peace River #1A	501 (120)	420 (26)	
Peace River #1B	130 (26)	265 (11)	
Peace River #2	553 (32)	362 (14)	
Pouce Coupe River	193 (16)		242 (16)
Peace River #3	ns	ns	
Kiskatinaw River	ns		178 (6)
Beatton River	ns	-	ns
Peace River #4	750 (83)		
Peace River #5	416 (9)	394 (15)	
West Side Channel	108 (3)	64 (4)	
East Side Channel	169 (14)	109 (4)	
South Side Channel	369 (39)	291 (25)	
Site C Dam	89 (2)	55 (1)	
Moberly River #1	505 (18)	443 (83)	
Moberly River #2	258 (25)	ns	
Moberly River #3	157 (19)	208 (22)	
Moberly Lake	ns	-	
Peace River #6	483 (17)	402 (18)	
Peace River #7	482 (20)	291 (40)	
Cache Creek	ns	82 (11)	
Peace River #8	480 (31)	328 (33)	
Halfway River #1	ns	197 (24)	
Halfway River #2	480 (55)	406 (18)	
Halfway River #3	231 (15)	197 (9)	
Chowade River	298 (10)	462 (35)	
Cypress Creek	ns	ns	
Peace River #9	500 (112)	412 (62)	
Farrell Creek	221 (10)	349 (47)	-
Peace River #10	750 (130)	449 (32)	
Lynx Creek	187 (23)	149 (18)	
Peace River #11	750 (155)	ns	
Maurice Creek	35 (5)	93 (8)	
Peace Canyon Dam	ns	106 (21)	

Similar to previous years, a logistic curve was fit to the detection proportion data from test tag drags, and the parameter values used to estimate the 'inflection point', i.e., the distance at which 50% of the signals were detected. The median inflection point for all tested stations was 291 m (range: 35-750 m; Table 9). Range testing logistic curve figures are displayed in Appendix F.

Fixed-Station Detection Efficiency

Detection efficiency[40] was calculated *post-hoc* to compliment detection probability[41] in evaluating and validating the fixed-station array (Adams et al. 2012, Kessel et al. 2014). Detection efficiencies were between 43.8 and 100% (median = 84.6%) for fixed-stations or combinations of fixed-stations in 2022 (Table 10, Figures 9 and 10). The detection efficiency calculation is only possible at fixed-stations with adequate detection coverage both upstream and downstream of the fixed-station to validate movements. Therefore, detection efficiency was not calculated at Peace Canyon Dam or Peace River #1A/1B on the Peace River as well as multiple tributary stations including Maurice Creek, Lynx Creek, Farrell Creek, Chowade River, Cypress Creek, Cache Creek, Pouce Coupe River, or the West/East/South Side Channels.

At many of the stations, the detection efficiencies in 2022 were similar to those in 2021 (Figures 9 and 10). Among the 17 fixed-stations analyzed in 2022, two exhibited combined (upstream/downstream) detection efficiencies that were below 70% (i.e., Peace River 5 and Halfway River 3, Table 10).

Table 10. Fixed-station detection efficiencies in 2022 for upstream and downstream movement orientations.

		Upstream		Downstream		Both	
Station Name	**River Type**	**Det. Eff.**	**N**	**Det. Eff.**	**N**	**Det. Eff.**	**N**
Peace River 2	Peace River	87.5%	24	65.7%	35	74.6%	59
Peace River 3	Peace River	100.0%	30	80.5%	41	88.7%	71
Peace River 4	Peace River	97.0%	6	92.5%	53	95.0%	119
Peace River 5	Peace River	63.2%	76	72.0%	93	68.0%	169
Site C	Peace River	91.7%	12	91.7%	48	91.7%	60
Peace River 6	Peace River	53.8%	26	91.3%	46	77.8%	72
Peace River 7	Tributary	64.3%	28	95.6%	45	83.6%	73
Peace River 8	Peace River	65.5%	29	82.6%	46	76.0%	75
Peace River 9	Peace River	94.7%	19	86.4%	22	90.2%	41
Peace River 10	Peace River	91.7%	24	95.7%	23	93.6%	47
Peace River 11	Peace River	92.9%	14	75.0%	12	84.6%	26
Moberly River 1	Tributary	83.3%	36	86.2%	29	84.6%	65
Moberly River 2	Tributary	100.0%	4	100.0%	3	100.0%	7
Halfway River 1	Tributary	97.4%	38	90.0%	30	94.1%	68
Halfway River 2	Tributary	100.0%	53	100.0%	33	100.0%	86
Halfway River 3	Peace River	67.7%	31	0.0%	17	43.8%	48
Beatton River	Tributary	83.3%	36	86.2%	29	84.6%	65

[40] Defined as the proportion of study fish known to have passed a particular fixed-station.

[41] Defined as the probability to detect a test tag's transmission at various distances from a receiver antenna.

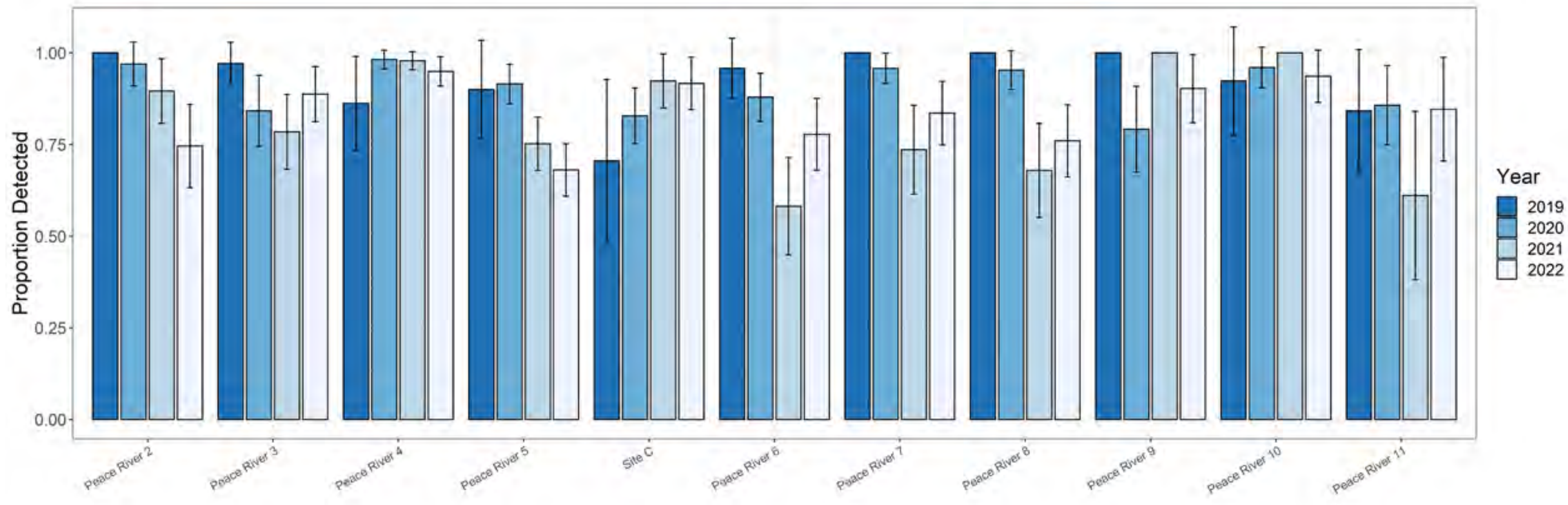


Figure 9. **Detection efficiency by fixed-station and year for applicable Peace River fixed-stations. Error bars show the 95% confidence intervals.**

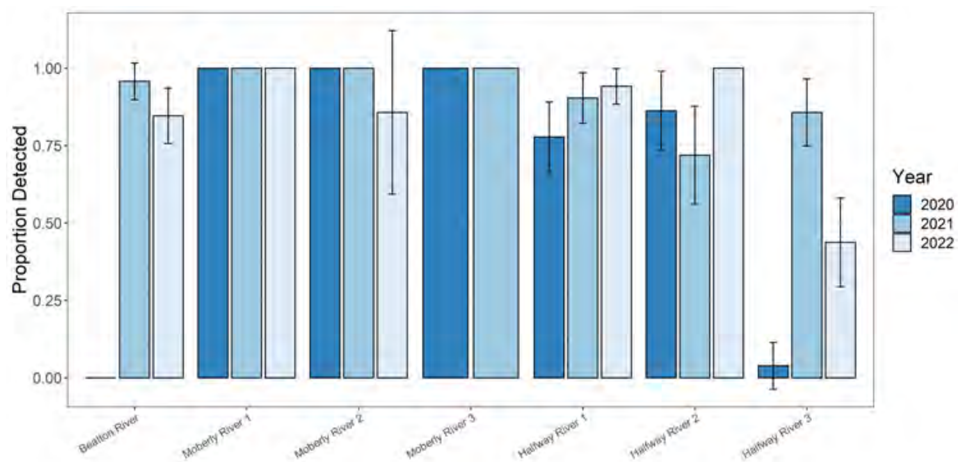


Figure 10. **Detection efficiency by fixed-station year for applicable tributary fixed-stations. Error bars show the 95% confidence intervals.**

Table 11. Locations of radio-tagged Bull Trout detections during two Halfway River mobile tracking surveys (each survey taking 2 days of flying to complete) in 2022. Tributary detections shaded yellow. Among-survey movements indicated in center column, if known. Entrance and exit date (movements past the Halfway #1 fixed-station) are shown for each fish. If the detection is missed at Halfway River #1, then approximate dates are inferred. "H3", "H2", and "H1" are the three Halfway fixed-station receivers. Four tags (shown with blue shading) entered the Halfway River, and were last detected moving upstream past H2 or H3 (late May-early July). Tags assumed to have been shed (that had not moved since last year) are not included.

Tag	Enter	8 & 9 Sept Survey	Movement	18 & 19 September Survey	Exit
768	18 Jul 2022	Graham River, rkm 91	None	Graham River, rkm 91	Did Not
769	15 May 2022	missed	-	Chowade River, rkm 52	Did Not
809	3 Aug 2022	Halfway R. above Fiddes, rkm 253	Down/Upstream	Fiddes Creek, rkm 2	Did Not
813	15 Jul 2022	Cypress Creek, rkm 43	Downstream	Cypress Creek, rkm 20	24 Sep 2022
836	24 May 2022	missed	-	missed	24 Sep 2022
940	18 Aug 2022	Chowade River, rkm 35	-	missed	30 Sep 2022
941	2 Jul 2022	missed	-	Outside	17 Sep 2022
957	13 May 2022	missed	-	missed	Did Not
974	6 Jul 2022	Cypress Creek, rkm 2	None	Cypress Creek, rkm 2	Did Not
977	14 Jul 2022	missed	-	missed	Did Not
994	21 May 2022	missed	-	missed	Did Not
1002	14 Jul 2022	Cypress Creek, rkm 44	Downstream	Cypress Creek, rkm 38	Did Not
1004	23 Jun 2022	Halfway R. between Cameron & Graham, rkm 76	Downstream	Halfway R. between Cameron & Graham, rkm 69	25 Sep 2022
1043	21 Jun 2022	Halfway R. above Fiddes, rkm 242	Downstream	Halfway R. between Cypress & Fiddes, rkm 194	22 Sep 2022
1045	22 Jul 2022	Chowade River, rkm 6	Downstream	Halfway River @H1, rkm 1	18 Sep 2022
1051	22 May 2022	Graham River, rkm 48	Downstream	Outside	15 Sep 2022
1054	4 May 2022	Cypress Creek, rkm 35	None	Cypress Creek, rkm 35	Did Not
1061	15 May 2022	missed	-	missed	Did Not
1077	1 May 2022	Cypress Creek, rkm 25	None	Cypress Creek, rkm 23	Did Not
1081	20 Jul 2022	Cypress Creek, rkm 36	None	Cypress Creek, rkm 36	Did Not
1099	24 May 2022	missed	-	Halfway R. between Cameron & Graham, rkm 89	23 Sep 2022
1107	12 May 2022	Cypress Creek, rkm 47	Downstream	Halfway River @H2, rkm 5	19 Sep 2022
1119	18 May 2022	Chowade River, rkm 44	None	Chowade River, rkm 44	24 Sep 2022
1124	28 Jun 2022	missed	-	missed	Did Not
1139	6 Jul 2022	Graham River, rkm 19	Downstream	Outside	15 Sep 2022
1165	31 Jul 2022	missed	-	Chowade River, rkm 48	30 Sep 2022
1166	27 Jun 2022	missed	-	missed	23 Sep 2022
1169	9 Jun 2022	Chowade River, rkm 40	Upstream	Chowade River, rkm 47	10 Oct 2022
1185	24 May 2022	missed	-	Chowade River, rkm 43	21 Sep 2022
1190	18 May 2022	Graham River, rkm 94	-	missed	21 Sep 2022
1193	7 Sep 2022	Halfway River @H2, rkm 8	-	missed	23 Sep 2022
1196	28 Aug 2022	Needham Creek, rkm 4	-	missed	Did Not
1208	24 May 2022	Cypress Creek, rkm 35	Downstream	Outside	16 Sep 2022
1213	18 May 2022	Halfway R. between Cameron & Graham, rkm 54	None	Halfway R. between Cameron & Graham, rkm 54	Did Not
1216	12 May 2022	Cypress Creek, rkm 61	None	Cypress Creek, rkm 60	Did Not
1218	25 May 2022	missed	-	Chowade River, rkm 38	Did Not
1235	19 May 2022	Chowade River, rkm 1	-	missed	Did Not
1518	9 Aug 2022	Halfway R. between H3 & Cameron, rkm 13	Downstream	Outside	9 Sep 2022

Every expected downstream movement was missed by Halfway River 3 in 2022 and upstream movements were below average as well (Table 10). It is likely that a portion of the river, opposite to the receiver, is shadowed by the island that separates it (Figure 8 part 12). For the 2023 field season, the Halfway River 3 antennas will be re-installed higher to eliminate the shadowing and thoroughly range tested to confirm the fix.

At the Peace River 5 fixed-station, a side channel opposite to the receiver could have impacted the 2022 detection efficiency (Figure 8 part 4). There were 93 analyzable passage movements at Peace River 5 in 2022, the highest number of all the analyzed fixed-stations. Many of these movements, both missed and detected, were repeated by the same individual. As an example, Tag ID 1101 was detected passing Peace River 5 five times in 2022 and was missed another nine times. This individual Bull Trout first passed Peace River 5 heading in an upstream direction towards Site C in May 2022 before proceeding to repeatedly move back and forth between Site C and Peace River 4 until the end of the 2022 field season in October.

Mobile Tracking Detection Efficiency

The Halfway River overflights (Figures E1 and E2) yielded a detection efficiency of 67% (Table 11), having detected 46 of a possible 69 Bull Trout detection events across the two mobile tracking surveys (Appendix D, Figure D1). Six of the 37 radio-tagged Bull Trout that travelled up the Halfway River beyond the Halfway #1 fixed-station in September 2022 were missed by both mobile surveys, including four that were not detected leaving the system (i.e., were last detected moving upstream past H2 or H3 (21 May, 25 May, 28 June, and 1 July).

Movement Analysis

Magnitude, Seasonality, and Direction

Region-wide seasonal movement patterns were interpreted from monthly movement distance. Tributary entrance and exit plots (Figures 11 through 16) were created using all applicable telemetry data collected from 2019 through 2022. The tributaries analyzed varied among the study species, and were based on their known/expected migratory behaviours, detection coverage, or the presence of notable movements in the dataset.

Arctic Grayling

As expected, Arctic Grayling used the Moberly River in April, May, and June to spawn (Figure 11A[42]). More specifically, Arctic Grayling largely entered the Moberly River in April/May and exited in May/June (Figure 11B). Although a few Arctic Grayling entrance and exit behaviours were recorded at other tributary stations (e.g., Beatton River, Pine River) these behaviours were markedly less frequent, and the majority of associated residence times were less than 48 hours and appeared unrelated to spawning behaviour.

In the Peace River in 2022, Arctic Grayling displayed upstream tendencies in April and May followed by increased activity with both upstream and downstream movements in June through August, and potentially showed a downstream tendency in September. Many of the movements were accompanied with high standard errors due mainly to small 'per month' sample sizes available for analysis (e.g., Peace River upstream in August 2022 was n = 2).

---

[42] The Moberly River was not mobile tracked in 2022, therefore the effort between study years is not equivalently displayed in the figure.

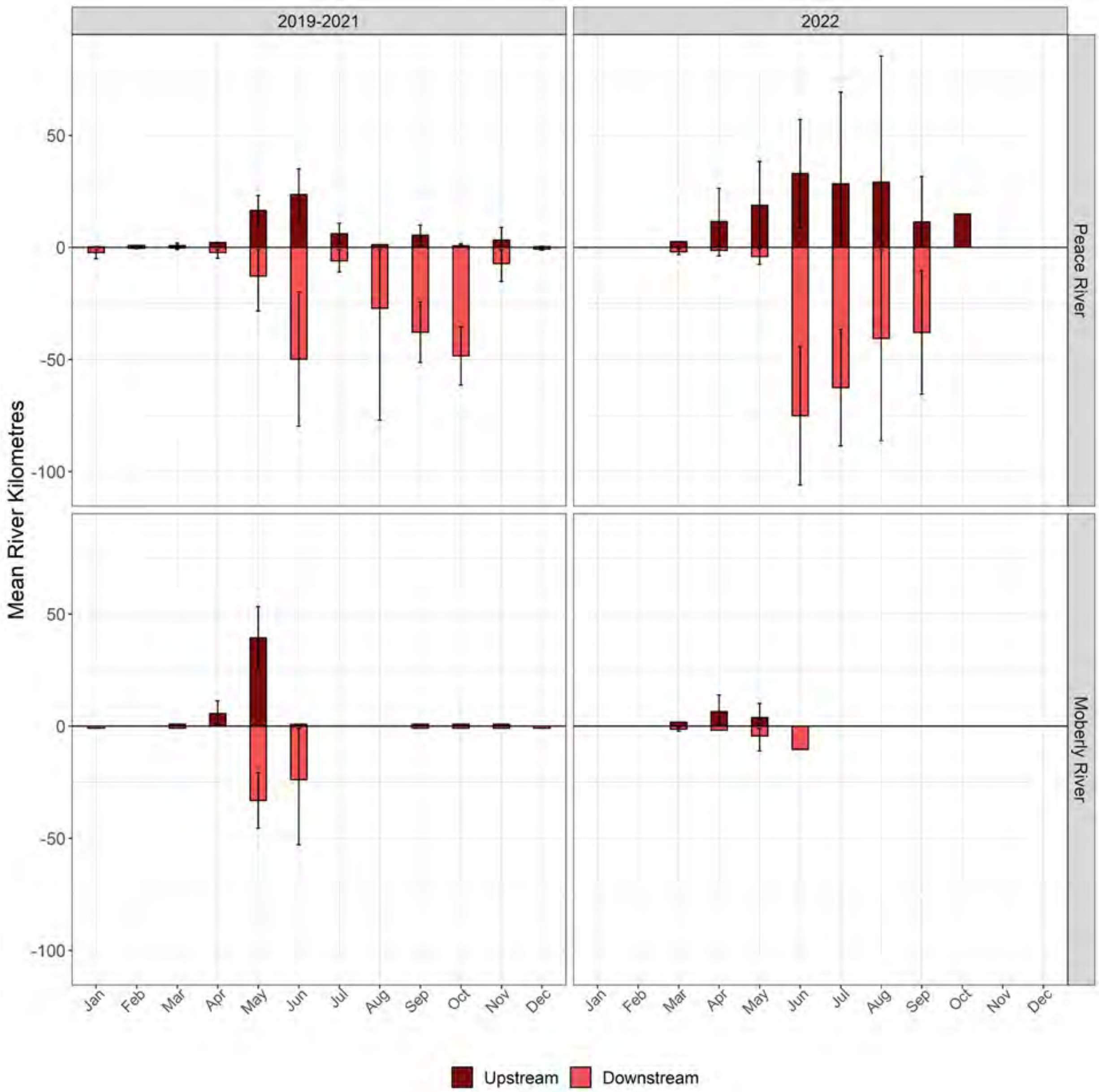


Figure 11A. Mean movements (in RKM), by month, for Arctic Grayling in the Peace River, calculated from all data collected 2019 through 2022. Positive values refer to upstream movement, and negative values refer to downstream movement. Error bars show the 95% confidence limits.

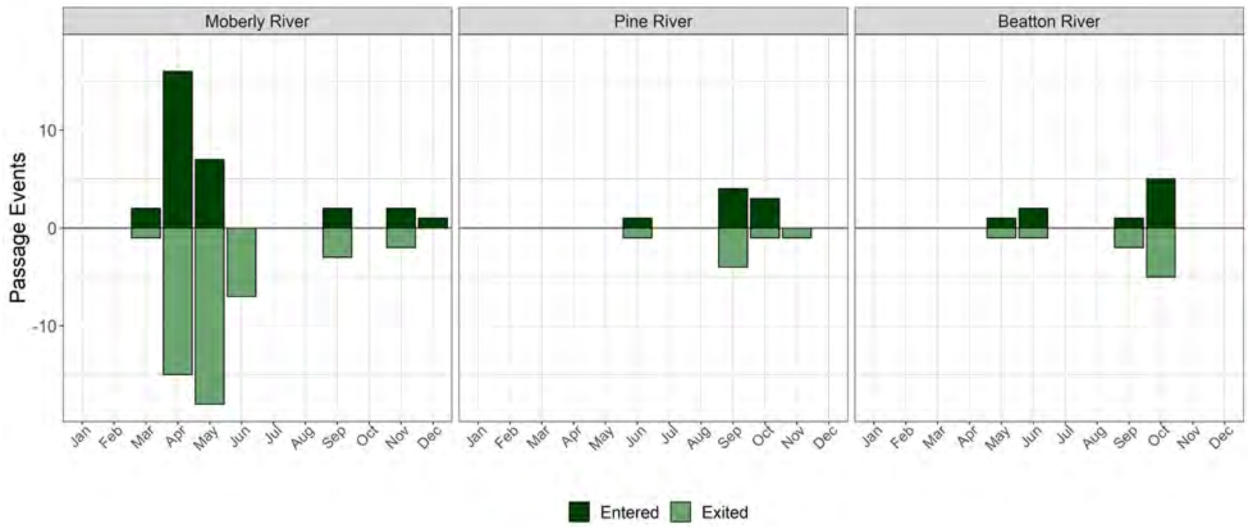


Figure 11B. Tributary entrance and exit movements for Arctic Grayling, tallied per individual study fish by month.

Bull Trout

Similar to 2019-2021, Bull Trout in 2022 exhibited generally balanced upstream and downstream movements throughout the Peace River in April through October, with decreased movements recorded through the winter months (Figure 12A). A decrease in activity appears ubiquitous throughout winter months, although much of the array is offline during this period, which decreases the certainty of that generalization.

Primary tributary movements by Bull Trout were recorded in the Halfway River, with entrance behaviours occurring between April and September (with a small spike occurring in May), and exit behaviours largely occurring in September and October (Figure 12B)[43]. Following entrance into the Halfway River, Bull Trout proceeded upstream in July, August, and September, with downstream movements largely occurring in September and October following spawning.

At the Pine River (Figure 12B), a secondary spawning river system to the Halfway River (Mainstem Aquatics 2012, Geraldes and Taylor 2022), entry and exit behaviours were primarily in and around the month of September. These movements may be indicative of spawning behaviour, but without additional upstream fixed-stations and/or mobile tracking efforts in the Pine River, the purpose of these Bull Trout movements remain speculative.

Similar to Arctic Grayling and not displayed in Figure 12B, Bull Trout exhibited entrance and exit behaviours in lower quantities at numerous other tributaries (e.g., Maurice Creek, Farrell Creek, Moberly River, Beatton River, and Kiskatinaw River) throughout the study period, and for shorter residences.

[43] Note that any study fish transported and released into the Halfway River (i.e., the Halfway River Boat Launch) were removed from this analysis to avoid bias.

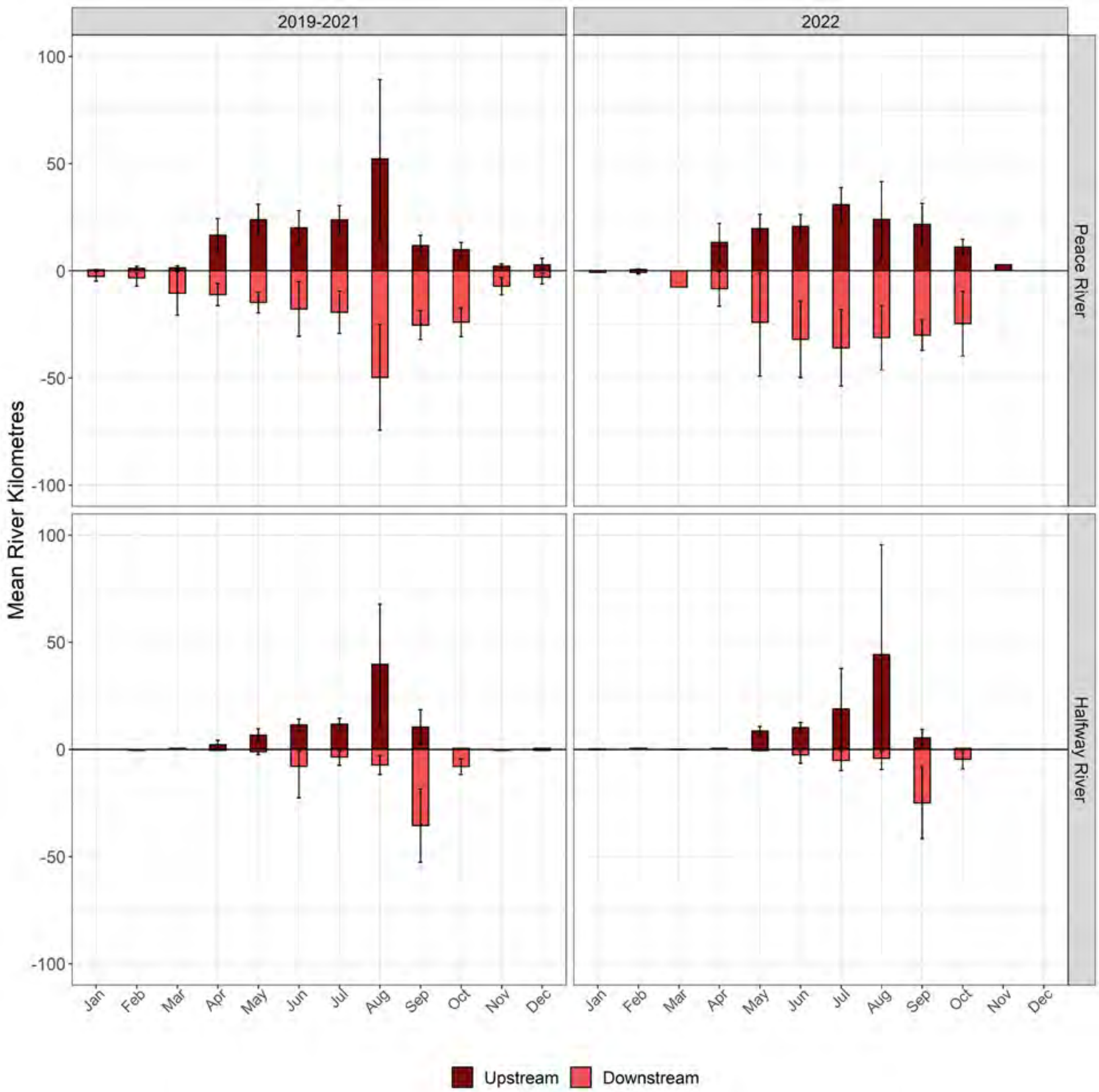


Figure 12A. Bull Trout mean monthly movements. Details as in Figure 11A.

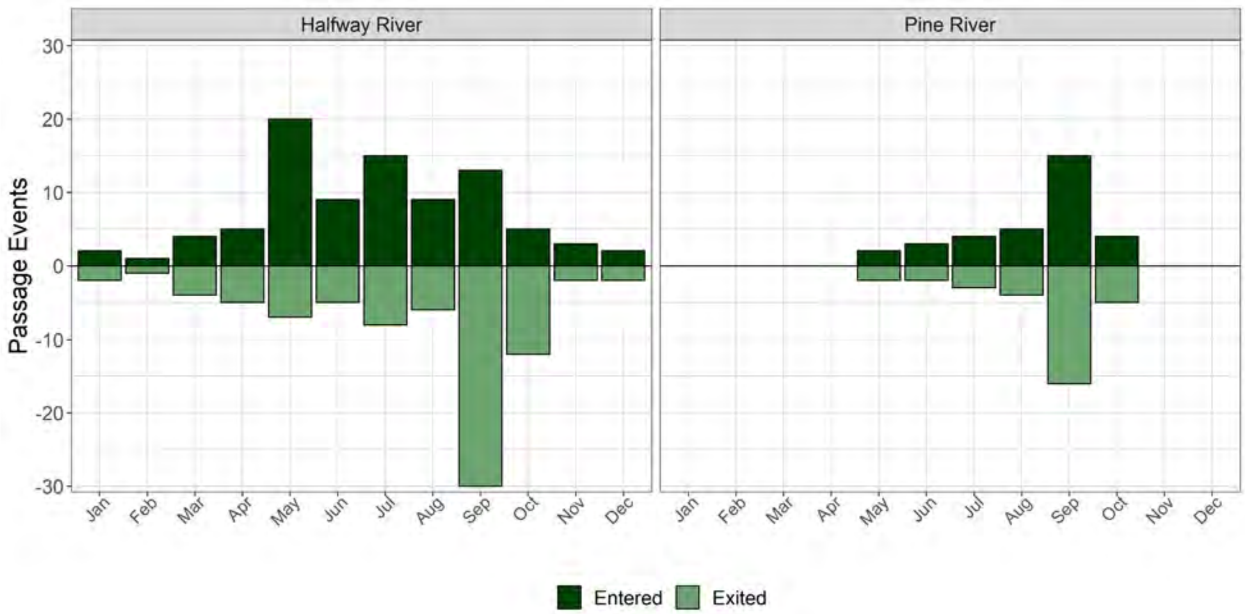


Figure 12B. Monthly tributary entrance/exit movements for Bull Trout. Details as in Figure 11B.

Burbot

Burbot tracks were hampered by relatively few detections that failed to provide a reliable picture of seasonal movement behaviours (Figure 13). Fewer detections by Burbot could be the result of a sedentary lifestyle (i.e., study fish did not move past fixed-stations often), and/or a preference for deeper water (radio signals attenuate over depth[44]). All of which being further exacerbated by the relatively low sample size (n=27). The 2022 telemetry data included only 38 detections from four unique individuals, and few detections were associated with any notable movements (Figure 13A).

Mountain Whitefish

Mountain Whitefish telemetry in 2022 failed to yield any notable movement trends, which could be interpreted as resident throughout most of the field season (Figure 14A). There were some movements recorded in May and June 2022 followed by a potential increase in activity in September and October 2022. As displayed in Figure 14A, large upstream movements made in May 2019-2021 and July 2022 were each made by a single individual and are outlier events. Furthermore, the majority of tracked Mountain Whitefish were tagged in September and October 2021 which immediately preceded the downstream behaviour displayed in 2019-2021 (Figure 14A). Mountain Whitefish tributary entrance and exit behaviours were recorded at the Pine River and Halfway River fixed-stations in September and October (Figure 14B).

[44] Although the Peace River is consistently shallow throughout (<4 in most locations) relatively small changes in depth (~2m) can significantly downgrade the ability to detect and code radio signals.

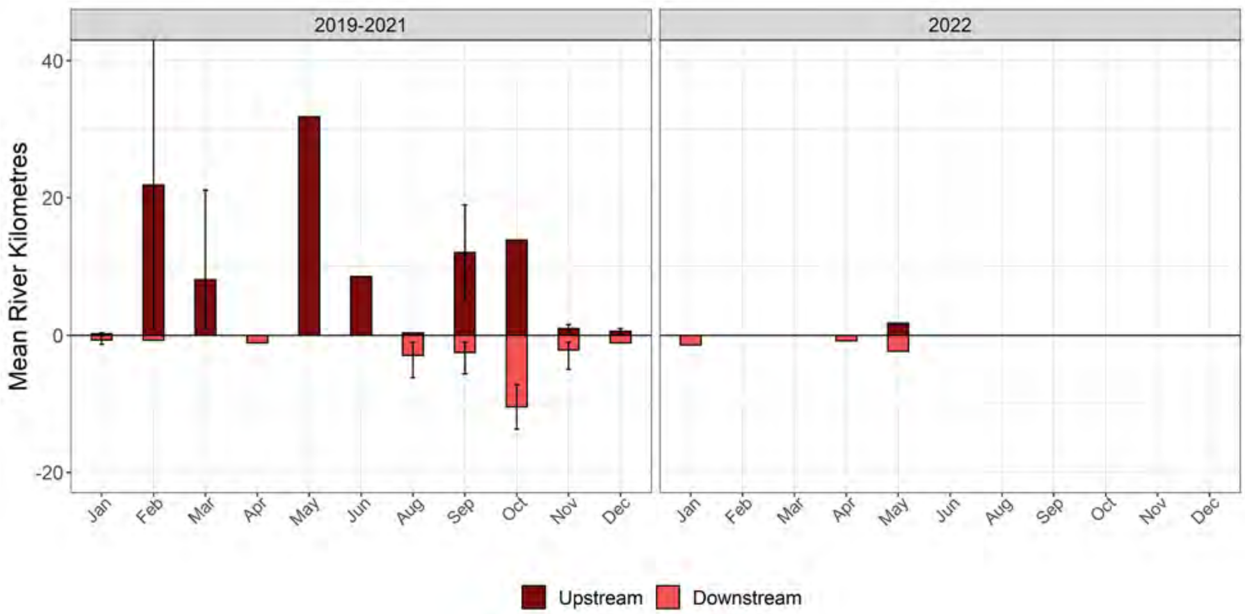


Figure 13A. Burbot mean monthly movements. Note the non-standard Y-axis scale. Details as in Figure 11A.

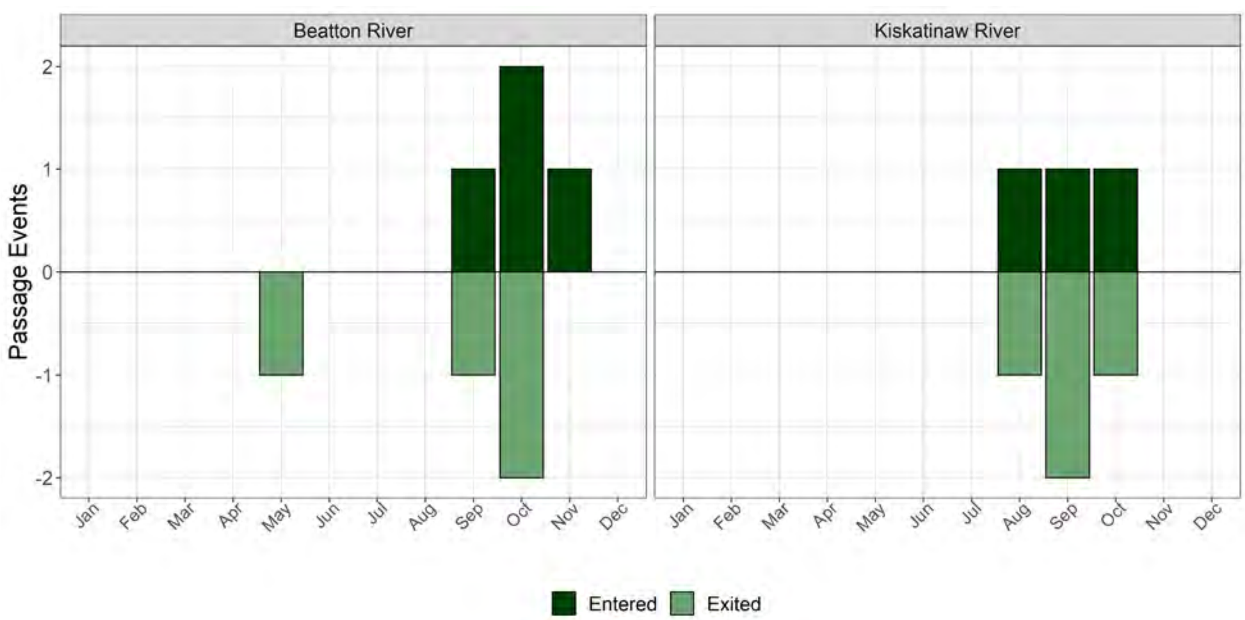


Figure 13B. Monthly tributary entrance/exit movements for Burbot. Details as in Figure 11B.

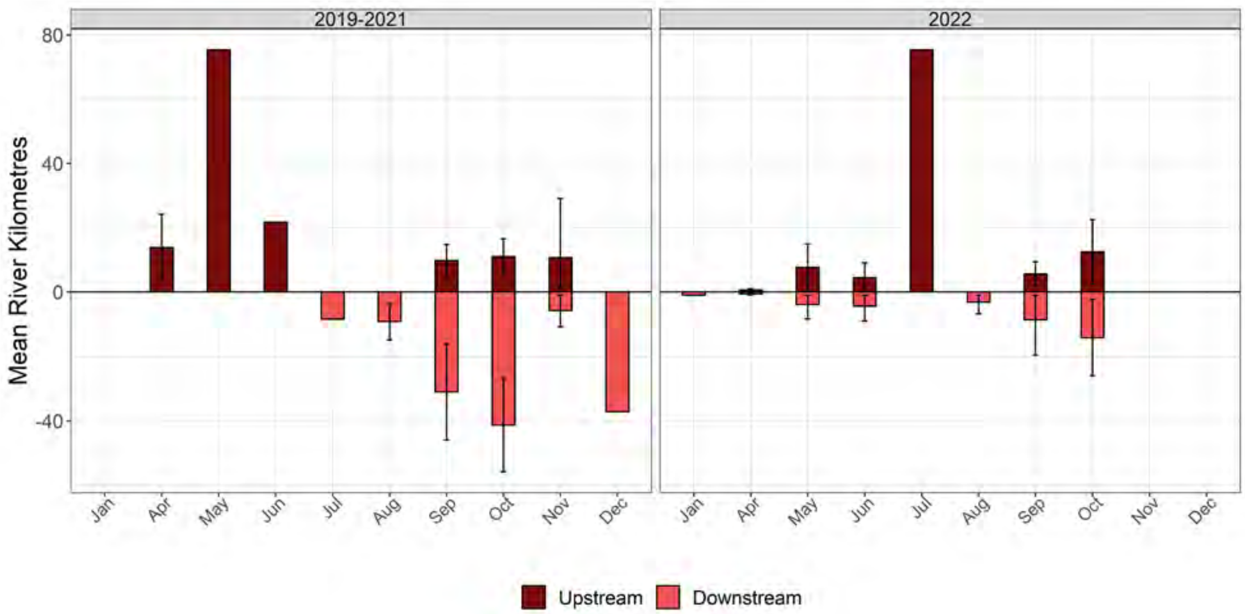


Figure 14A. Mountain Whitefish mean monthly movements. Additional details as in Figure 11A.

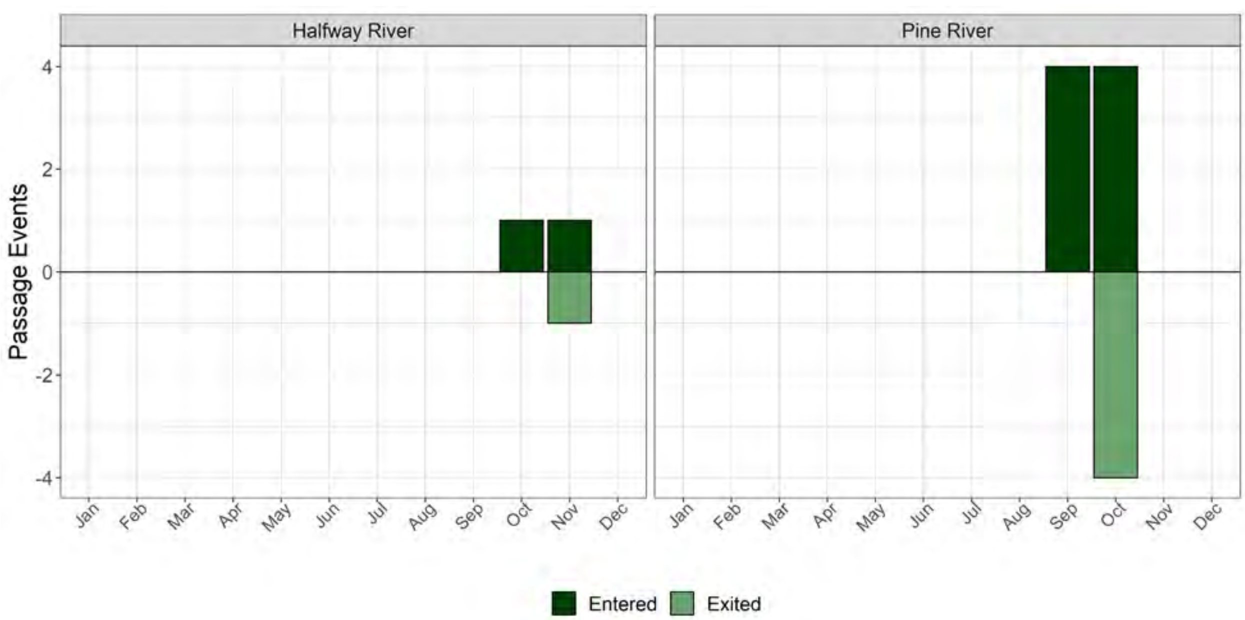


Figure 14B. Monthly tributary entrance/exit movements for Mountain Whitefish. Details as in Figure 11B.

Rainbow Trout

Rainbow Trout tracked in 2022, as in 2019-2021, had relatively indiscriminate seasonal movements in the Peace River without an easily discernable pattern (Figure 15A). Tributary use that may correspond with spawning activity (tributary entrance in April-May and exit behaviour in June-July, Mainstem 2012) was observed primarily in the Halfway River, as well as the Pine River and Maurice Creek (Figure 15B). Additionally, the two fixed-stations upstream in the Halfway River (Figure 5) detected Rainbow trout movements in May through July (Figure 15A).

Outside those displayed in Figure 15B, tributary entrance and exit behaviours by Rainbow Trout were exhibited across numerous tributaries throughout the operational field season, many of which were for short duration residence times (<24 hours).

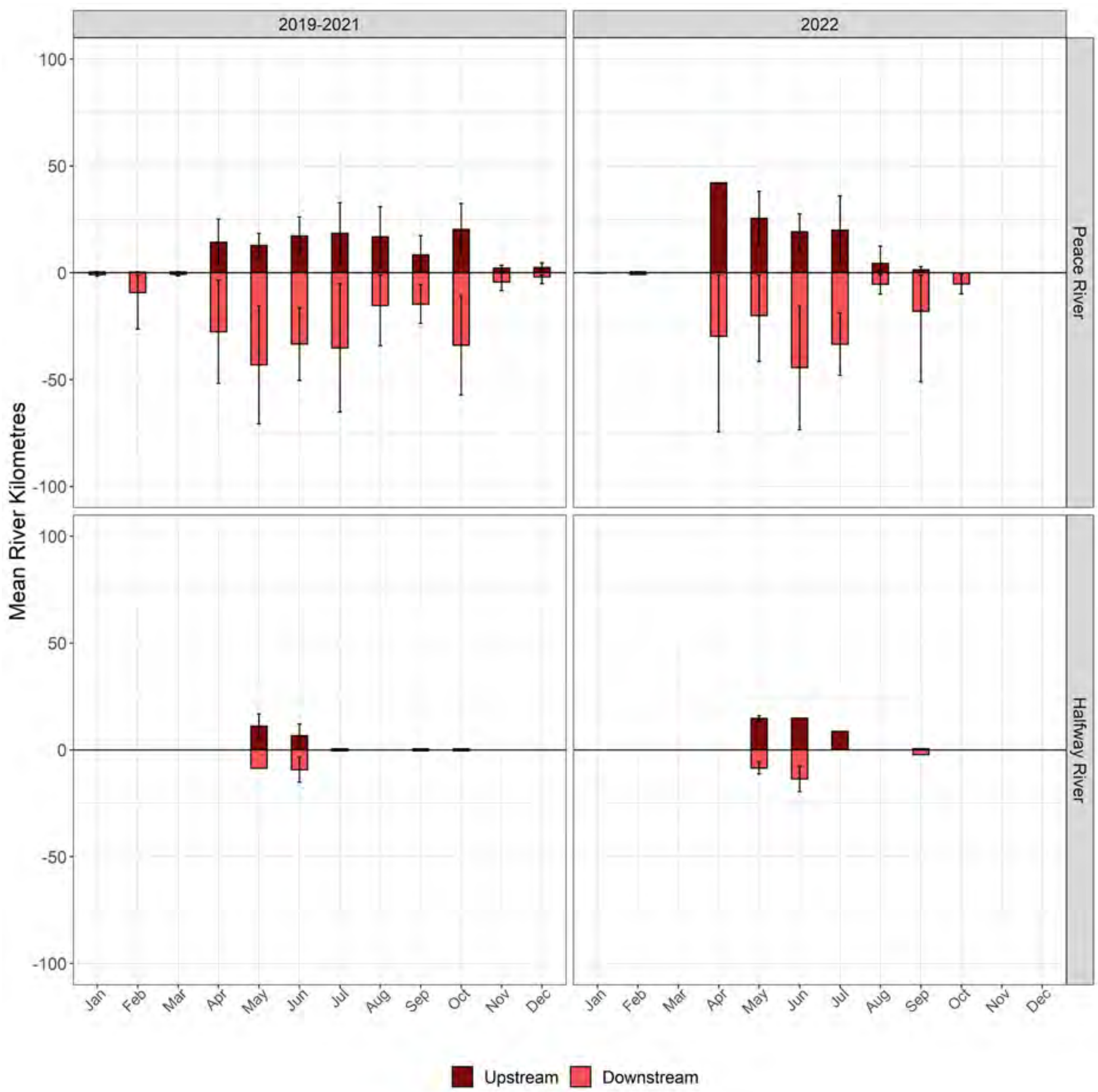


Figure 15A. Rainbow Trout mean monthly movements. Details as in Figure 11A.

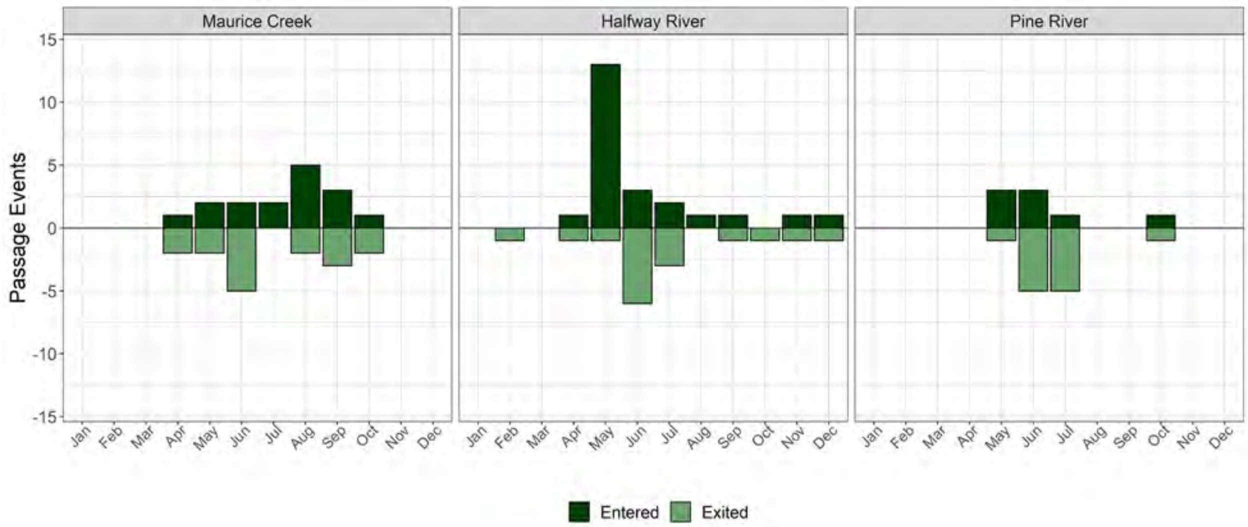


Figure 15B. Monthly tributary entrance/exit movements for Rainbow Trout. Details as in Figure 11B.

Walleye

Peace River Walleye movements in 2022 were largely upstream in June and July, followed by both downstream and upstream movements from August to October (Figure 16A). In the Beatton River, Walleye were recorded moving upstream in May and downstream in June, which is indicative of springtime spawning behaviours (Mainstream 2012, Robichaud et al. 2023). It is noteworthy, however, that upstream telemetry in the Beatton River was limited to April/May mobile surveys (Appendix Table D2), which means additional granularity throughout the year was not possible. The majority of tributary use by Walleye was focused around the Beatton River, with some summertime activity around the Pine River, Kiskatinaw River, and Pouce Coupe River (Figure 16B).

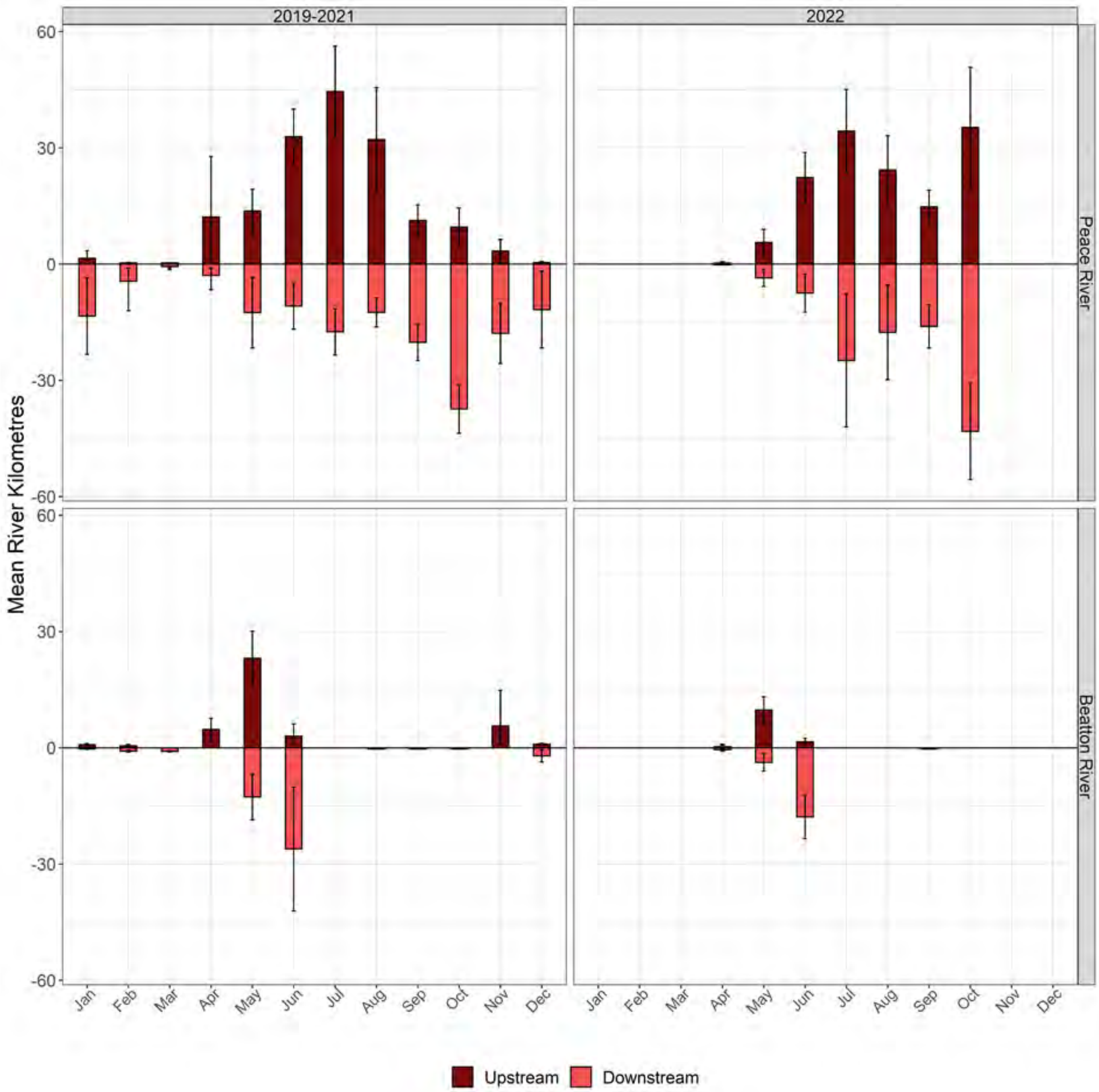


Figure 16A. Walleye mean monthly movements. Details as in Figure 11A.

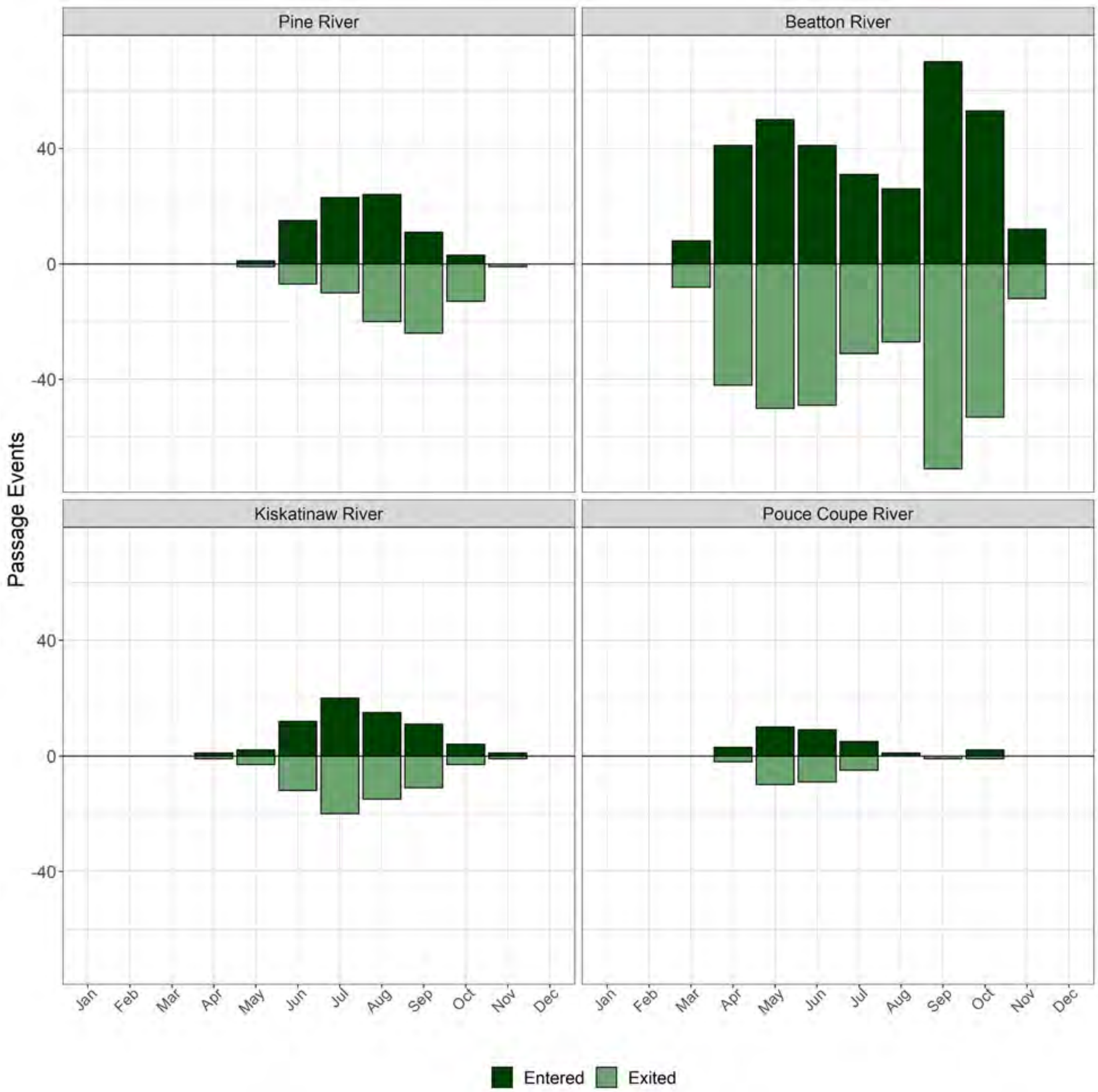


Figure 16B. Monthly tributary entrance/exit movements for Walleye. Details as in Figure 11B.

Spawn Timing and Distribution

Arctic Grayling

Moberly River mobile tracking did not occur in 2022, which means Moberly River Arctic Grayling peak spawn timing and probable spawner locations were not determined. That said, by using the Moberly River fixed-station array, probable spawners were identified, and entrance and exit behaviours were evaluated.

Two radio-tagged Arctic Grayling exhibited spawning behaviour in the Moberly River in 2022. This represented 25.0% of the 8 Arctic Grayling that were still being actively tracked[45]. Though the sample size is low, the 2022 percentage of spawning Arctic Grayling from active individuals was similar to the 2021 calculation of 23.1% (n= 26) and was a reduction from the 2020 estimate of 58.3% (n= 24).

One of the spawning Arctic Grayling entered on 23 March 2023, passed Moberly River 3 on 25 April 2023, presumably spawned, and then migrated back downstream and exited on 24 May 2023. The second, entered on 29 April 2023, passed Moberly River 3 on 4 May 2023, and then migrated downstream to eventually exit on 10 June 2023.

Bull Trout

In 2022, a total of 38 adult Bull Trout exhibited spawning behaviours in the Halfway River and its tributaries (Figures 17, E1, and E2). Of these spawning Bull Trout, 17 were released directly into the Halfway River (i.e., the Halfway River Boat Launch) between 4 May and 9 August 2022, which may have affected normal entrance behaviours[46]. Therefore, these fish were culled when calculating Bull Trout entrance timing into the Halfway River.

The median date on which Bull Trout entered the Halfway River was 2 July 2022 (range = 1 May to 7 September 2022) and for those that exited, the median date was 23 September 2022 (range = 9 September to 10 October 2022; Table 11). A similarly wide range in Bull Trout entrance dates was also reported in 2020 and 2021 with Bull Trout entering between 26 April and 17 July 2020 (Hatch et al. 2021) and between 21 April and 18 September 2021 (Hatch et al. 2022). Furthermore, exit timing dates in 2022 were similar to those recorded in 2020 (6 September to 7 October) and 2021 (20 September to 4 November).

After entering the Halfway River in 2022, eighteen Bull Trout have not yet been recorded exiting the system and are either continuing to reside in the Halfway River, are a mortality, or shed their radio tags during spawning or migration. Five of the Halfway River spawning Bull Trout from 2022 were also recorded spawning in 2021.

According to the movement patterns of these 38 Bull Trout, peak spawning in the Halfway River presumably occurred sometime around 13 September 2022. Ten Bull Trout were identified to have spawned in the Chowade River, nine in Cypress Creek, five in the upper Halfway River (upstream of the Cameron River), three in the Graham River, one in Fiddes Creek, and one in Needham Creek. The

---

[45] Actively tracked refers to a radio-tagged study fish released before and with detections during or after the analysis period.

[46] Among these 17 Butt Trout, 10 were captured downstream of Site C, radio-tagged and released into the Halfway River between 4 May and 9 August 2022, while the remaining 7 were captured downstream of Site C by contingent electrofishing and re-released into the Halfway River between 12 May 2022 and 14 July 2022.

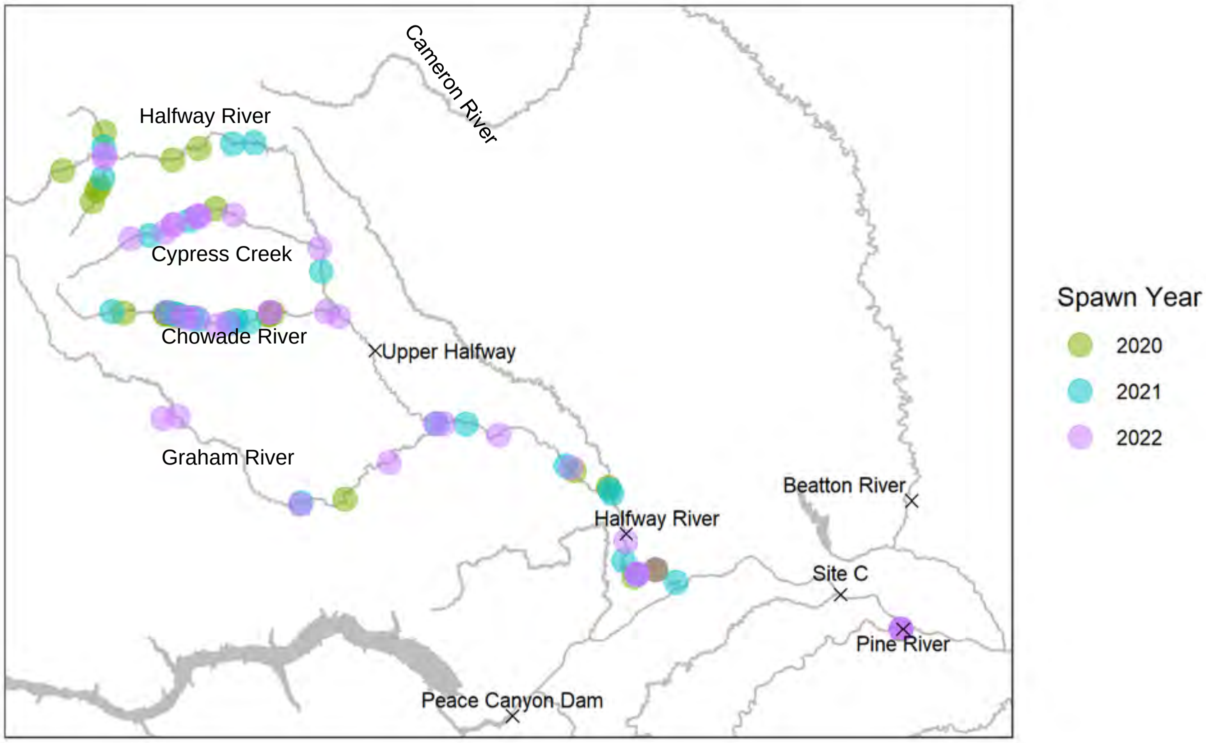


Figure 17. Probable Bull Trout spawning locations in the Halfway River and its tributaries are shown with colours indicating spawn year. Note that Pine River include fish detected in both 2020 (n=1) and 2022 (n=4).

remaining nine were last detected in the lower Halfway River between Halfway River 3 and the Cameron River[47] (Figure 17). Two Bull Trout were detected in about the same location in 2022 as in 2021, including one fish (Tag ID 809) that was detected near or in Fiddes Creek, and another (Tag ID 768) that was detected at or near the mouth of Graham River.

Most of the Bull Trout that spawned in the Halfway River migrated from upstream of Site C (n=21), the remaining Bull Trout (n=17) came from downstream of Site C and were therefore captured and transported to the Halfway River Boat Launch.

In 2022, four radio-tagged Bull Trout entered and exited the Pine River within the 2022 spawning window, which might be indicative of spawning given the Pine River is another tributary where Peace River Bull Trout are known to spawn (Mainstream Aquatics 2012, Geraldes and Taylor 2022). However, the Pine River is only monitored at the Peace River confluence and whether these movements are related to spawning cannot be determined without additional upstream resolution.

[47] These study fish may not have been tracked effectively into the upper reaches, are mortalities or shed their tags.

Discussion

Study Objectives

The objective of the 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 from key indicator species in the Peace River and its tributaries. To accomplish this, a fixed radio telemetry array was operated along the Peace River and many of its tributaries in 2022.

The fixed radio telemetry array is intended to operate during the construction[48] and operation[49] of the Project, and will compliment the baseline studies conducted from 1996-1999[50] and 2005-2009[51]. The contribution of telemetry data from the 2022 study year adds to the ever-growing resource of telemetry data that can be leveraged by BC Hydro to address management questions across various monitoring programs and tasks as the Project transitions from construction to operations.

The telemetry array in 2022 consisted of 34 fixed-stations that collected over 17 million valid detections while operating over 98.9% of the intended study period. Range testing in 2022 yielded a median 50% detection range of 291 m (range: 35-750 m)[52] and the median detection efficiency of analyzable fixed-stations was 85% (range: 44-100%). All of these results were within the operational expectations that define a successful collection period. The magnitude, direction, and seasonal variability of movements from key indicator species were displayed to generalize seasonal movement trends and highlight the capacity of the fixed-station array for more specific analyses.

The objective of Peace River Arctic Grayling and Bull Trout Movement Assessment (Mon-1b, Task 2a) is to determine the magnitude, direction, and seasonality of Arctic Grayling and Bull Trout movements within the Peace River, Site C Reservoir, and tributaries, to help evaluate the effects the Project may have on these metrics, and to inform various monitoring programs. In 2022, Moberly River mobile surveys were not conducted, and the operation of the fixed radio telemetry array (Mon-1b, Task 2d) was the primary contributor to evaluating the timing, direction, and magnitude of Arctic Grayling movements into, within, and out of the Moberly River in May and June. The Bull Trout movements in the Halfway River in August and September 2022 were monitored using the fixed radio telemetry array (Mon-1b, Task 2d) in conjunction with two multi day mobile tracking surveys in September. The telemetry data produced useful information about the timing, direction, and magnitude of Bull Trout movements into, within, and out of the Halfway River watershed in 2022. Both datasets and all analyses added to the growing depth of knowledge for pre-operational Site C Bull Trout and Arctic Grayling behaviours that will be a useful comparison to these behaviours after reservoir filling.

Management Questions

Since July 2019, there have been 1076 radio-tagged Arctic Grayling (n= 78), Bull Trout (n=410), Burbot (n= 27), Mountain Whitefish (n= 75), Rainbow Trout (n= 236), and Walleye (n= 250) released into the Peace River and its tributaries. From these 1076 radio-tagged study fish, the fixed radio telemetry array and mobile tracking efforts have collected over 55 million valid detections across hundreds of kilometres of

---

48 Construction Years 5 to 10 (2019-2024).

49 Operation Years 1-4 (2024-2028), 10-11 (2034-2035), 15-16 (2039-2040), 20-21 (2044-2045), 25-26 (2049-2050) and 29-30 (2053-2054).

50 BC Ministry of Environment from 1996-1999 (Burrows et al. 2001, AMEC & LGL 2010b)

51 AMEC and LGL from 2005-2009 (AMEC & LGL 2008a, b, 2009, 2010a)

52 Calculated as the 50% logistic inflection point during the range test analysis.

the Peace River and its tributaries. These data build on the telemetry data collected from 1996 to 1999 and 2005 to 2009 and are intended to answer and provide guidance across a myriad of management questions outlined in the FAHMFP[53].

Data collection, however, is ongoing, and some management questions will be better answered at a later date. The questions detailed below were carefully curated as subjects that can be addressed or at least partially addressed with the data available at the time of writing this report. Further, information on these questions could assist immediate management decisions and guide ongoing monitoring under the FAHMFP.

Arctic Grayling

Three questions were addressed about Arctic Grayling and are a continuation to the answers originally provided in Hatch et al. (2022) with the addition of data collected in 2022: 1) How many fish moved in/out of the Moberly River, and where in that tributary might spawning be occurring? 2) What proportion of Arctic Grayling in the Moberly River spawn upstream versus downstream of the inundation zone approximated at 12 RKM upstream from the current river mouth? 3) Will Arctic Grayling from the Moberly River move into the Site C Reservoir, or into areas downstream of Site C?

To answer these questions, there were 8 adult Arctic Grayling available for the analysis (n= 1 from 2019, n= 1 from 2020, n= 6 from 2021). The nine Arctic Grayling radio-tagged in 2022 were released during or later than the Arctic Grayling spawning period and were therefore removed from this analysis. No juvenile Arctic Grayling were used for this analysis.

In 2022, two Arctic Grayling were detected moving into the Moberly River from the Peace River before peak spawning in May 2022. This represented 25.0% of the Arctic Grayling adults that were released before May 2022 and confirmed active on or after May 2022 (n= 8). This is similar to 2021 at 23.1% (n= 6) and reduction from 2020 at 58.3% (n= 24).

Both of the Arctic Grayling that spawned in 2022 passed the Moberly River 3 fixed-station and thereby were presumed to have spawned above the 12 RKM inundation zone. This matches previous study years as 90% of Moberly River Arctic Grayling spawned above the inundation line in 2020 and 2021 combined.

Arctic Grayling probable spawning locations were not estimated in 2022. In 2021, the average Arctic Grayling spawned at RKM 32.3 (range = 6.2 to 68.8) and at 54.8 in 2020 (range = 1.5 to 108.9).

Across all study years, 22 Moberly River spawning behaviours were recorded by 20 individual Arctic Grayling (i.e., two Arctic Grayling spawned in the Moberly River over multiple years). Outside of spawning, nine of these Arctic Grayling (45.0%) inhabited areas of the Peace River upstream of Site C (RKM 106), while four (20.0%) primarily inhabited Peace River reaches downstream of Site C. The remaining seven (35.0%) Arctic Grayling used areas both upstream and downstream of Site C during non-spawning portions of the year (range = 75 to 215 RKM).

Bull Trout

No Bull Trout management questions were addressed with the inclusion of the 2022 telemetry data.

---

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

Burbot

The Burbot management question is to describe movements from November through February (i.e., winter) movements. However, no new data were collected that could expand from that presented in Hatch et al. (2022).

Mountain Whitefish

Two interrelated questions were asked about Mountain Whitefish and are an extension from what was provided in Hatch et al. (2022): 1) In the fall, are Mountain Whitefish milling or migrating? 2) Where might they be spawning?

There were 47 Mountain Whitefish tagged in 2021, and 28 tagged in 2020. The 28 Mountain Whitefish tagged in August 2020 were all tagged with a Lotek Nano 3-2 radio-tag, which has a short 185-day battery life, therefore all 2020 Mountain Whitefish tags were expired during the 2022 operational period. The 47 Mountain Whitefish tagged in 2021 were tagged with the bigger and longer lasting Nano NTF-6-2 tag to extend the tracking period. Immediately following release in 2021, 42.6% (n= 20) of those Mountain Whitefish were tracked moving appreciably downstream, which might be indicative of tagging and handling effects, given Mountain Whitefish are known to be sensitive to the surgical implantation of transmitters (Taylor et al. 2011).

In 2022, 29 Mountain Whitefish were detected by the fixed-station array with 18 individuals detected in the fall of 2022 (September, October, November). The prominent behaviour recorded (n= 13) was resident (non-migratory) within a defined range. Seven individuals were milling between the 108R Side Channel and downstream of Site C, five between Peace River 3 and Peace River 5, and one upstream of Site C near Peace River 8. One Mountain Whitefish migrated from Peace River 3 on 23 July 2023 towards Peace River 1, presumably exiting the LAA on 13 September 2023 after migrating 75 RKM downstream.

The remaining four Mountain Whitefish detected in the fall of 2022 were detected at the Pine River fixed-station. Two of which were milling nearby the Pine River before entering, while one migrated from above Site C (detected at Peace River 7 on 30 September 2022) and another migrated from downstream (detected at Peace River 3 on 2 May 2023). These individuals appeared to enter the Pine River between 29 September and 16 October and exited between 19 October and 23 October. One individual has not been detected since entry in October 2022.

Observations of Mountain Whitefish in the Pine River in the fall were also made in 2020 (October, n= 1) and 2021 (September[54] , n= 3), as well as in 2006 and 2007 (n= 5). These movement patterns corroborate with baseline genetic information that show some Peace River Mountain Whitefish originate from the Pine River (Taylor et al. 2014).

No Mountain Whitefish were recorded entering the Halfway River in 2022, a behaviour that was recorded in October 2021 (n= 1) and in 2006/2007 (n= 12).

Rainbow Trout

No Rainbow Trout management questions were addressed with the inclusion of the 2022 telemetry data.

Walleye

No Walleye management questions were addressed with the inclusion of the 2022 telemetry data.

[54] The Pine River fixed-station did not operate through October in 2021 (i.e., demobilized on 3 October 2021).

References

Adams, S.A., J.W. Beeman, and J.H. Eiler. 2012. Telemetry Techniques: A User Guide for Fisheries Research. American Fisheries Society, Bethesda, MD.

AMEC Earth & Environmental and LGL Ltd. 2008a. Peace River fisheries investigation. Peace River tributary spring spawning migration, tributary summer juvenile rearing, and radio telemetry studies 2006. Report for BC Hydro Environmental Resources, Vancouver, BC.

AMEC Earth & Environmental and LGL Ltd. 2008b. Peace River fisheries investigation. Peace River and Pine River radio telemetry study 2007. Report for BC Hydro Environmental Resources, Vancouver, BC.

AMEC Earth & Environmental and LGL Ltd. 2009. Peace River fisheries investigation. Peace River and Pine River radio telemetry study 2008. Report for BC Hydro Environmental Resources, Vancouver, BC.

AMEC Earth & Environmental and LGL Ltd. 2010a. Peace River fisheries investigation Peace River and Pine River radio telemetry study 2009. Report for BC Hydro Environmental Resources, Vancouver, BC.

AMEC Earth & Environmental and LGL Ltd. 2010b. Analysis and assessment of the Ministry of Environment's Peace River Bull Trout and Arctic Grayling radio telemetry database 1996 to 1999. Report for BC Hydro Environmental Resources, Vancouver, BC.

Beeman, J., and R. Perry. 2012. Bias from false-positive detections and strategies for their removal in studies using telemetry. Pages 505-518 *in* N.S. Adams, J.W. Beeman, and J. H. Eiler, eds. Telemetry techniques: a user guide for fisheries research. American Fisheries Society, Bethesda, MD.

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.

English, K.K., D. Robichaud, and P. Wainwright. 2012. Database management and "real-time" data analysis systems for fish telemetry studies. Pages 491-504 *in* N.S. Adams, J.W. Beeman, and J. H. Eiler, eds. Telemetry techniques: a user guide for fisheries research. American Fisheries Society, Bethesda, MD.

Geraldes A., and E.B. Taylor. 2022. Site C Clean Energy Project - Fish Genetics Study – 2021 Status Report for Bull Trout, Arctic Grayling and Rainbow Trout. Report for BC Hydro, Vancouver BC.

Hatch, K., D. Robichaud, and C. Fitzgerald. 2020. 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). Report for BC Hydro, Vancouver BC.

Hatch, K., D. Robichaud, and C. Fitzgerald. 2021. Site C Clean Energy Project – Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b) Task 2a – Peace River Arctic Grayling and Bull Trout Movement Assessment; and Task 2d – Site C Fish Movement Assessment – Construction Year 6 (2020). Report for BC Hydro, Vancouver BC.

Hatch, K., D. Robichaud, B. Cox, and S. Crawford. 2022. Site C Clean Energy Project – Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program (Mon-1b) Task 2a – Peace River Arctic Grayling and Bull Trout Movement Assessment; and Task 2d – Site C Fish Movement Assessment – Construction Year 7 (2021). Report for BC Hydro, Vancouver BC.

Hiemstra P.H., E.J. Pebesma, C.J.W. Twenhöfel, and G.B.M. Heuvelink. 2009. Real-time automatic interpolation of ambient gamma dose rates from the Dutch Radioactivity Monitoring Network. Computers & Geosciences 35: 1711-1721.

Jepsen, N., C. Schreck, S. Clements, and E. Thorstad. 2005. A brief discussion on the 2% tag/bodymass rule of thumb. *In* Aquatic Telemetry: Advances and Applications – Proceedings of the Fifth Conference on Fish Telemetry: 9-13 June 2005; Ustica, Italy. Ed. Spedicato M.T., G. Lembo, and G. Marmulla. Rome: FAO; 2005:255-259.

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.

Liedtke, T.L., and A.M. Wargo-Rub. 2012. Techniques for telemetry transmitter attachment and evaluation of transmitter effects on fish performance. Pages 45-87 *in* N.S. Adams, J.W. Beeman, and J. H. Eiler, eds. Telemetry techniques: a user guide for fisheries research. American Fisheries Society, Bethesda, MD.

Mainstream Aquatics Ltd. 2012. Site C Clean Energy Project EIS Volume 2 Appendix O. Fish and Fish Habitat Technical Data Report. Report for BC Hydro, Vancouver BC. Report No. 12002F.

Nelson, J.S., and M.J. Paetz. 1992. The fishes of Alberta 2nd Edition. University of Alberta Press, University of Alberta, Edmonton, AB.

Putt, A., D. Ramos-Espinoza, LJ Wilson, C. Middleton, J. Buchanan, M. Chung, and C. Martin. 2020. Site C Reservoir Tributaries Fish Community and Spawning Monitoring Program – 2019 Peace River Bull Trout Spawning Assessment (Mon-1b, Task 2b). Report for BC Hydro, Vancouver BC.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Robichaud, D., K. Hatch, and S. Crawford. 2023. Walleye Spawning and Rearing Use Survey (Mon-2, Task 2e) 2022. Report for BC Hydro, Vancouver, BC.

Smircich, M.G., and J.T Kelly. 2014. Extending the 2% rule: the effects of heavy internal tags on stress physiology, swimming performance, and growth in Brook Trout. Animal Biotelemetry 2: 16.

Taylor, M.K., K.V. Cook, B. Lewis, D. Schmidt, and S.J. Cooke. 2011. Effects of intracoelomic radio transmitter implantation on Mountain Whitefish (*Prosopium williamsoni*). Northwest Science 85: 542-548.

Taylor, E.B., M.M. Yau, and A.B. Mattock. 2014. Population Structure in three species of co-distributed salmonid fishes in the Peace River and tributaries near a major proposed hydroelectric development in Northeastern British Columbia. River Research Applications: Volume 30, Issue 9, Pages 1120-1133.

TrichAnalytics. 2020. Site C Clean Energy Project – Fish Otolith and Fin Ray Microchemistry Study – Construction Years 1 to 4 (2015 to 2019). Report for BC Hydro, Vancouver BC.

Whelan, C., J. Krick, C. Walters, T. Sherstone, K. Healey, D. West and F.J.A. Lewis. 2023. Site C Clean Energy Project. Offset Effectiveness Monitoring of Side Channel Site 108R – Year 3 Program Summary. Draft V1. Consultant's report prepared for BC Hydro by Ecofish Research Ltd., May 31, 2023.

WSP (WSP Canada Inc.). 2023a. Summary of Site C Contingent Boat Electroshocking Activities – 2022. Technical Memorandum Prepared for BC Hydro, Vancouver, British Columbia. Golder Report No. 20136470-030-TM-RevA-3000.

WSP (WSP Canada Inc.). 2023b. Peace River Large Fish Indexing Survey (Mon-1b, Task 2a) – 2022 investigations. Report for BC Hydro, Vancouver BC. [in preparation]

Zar, J. H. 1984. Biostatistical Analysis. Prentice-Hall Inc., Englewood Clifffs, NJ.

Appendices

Appendix A. Spatial Distributions of Fish Releases

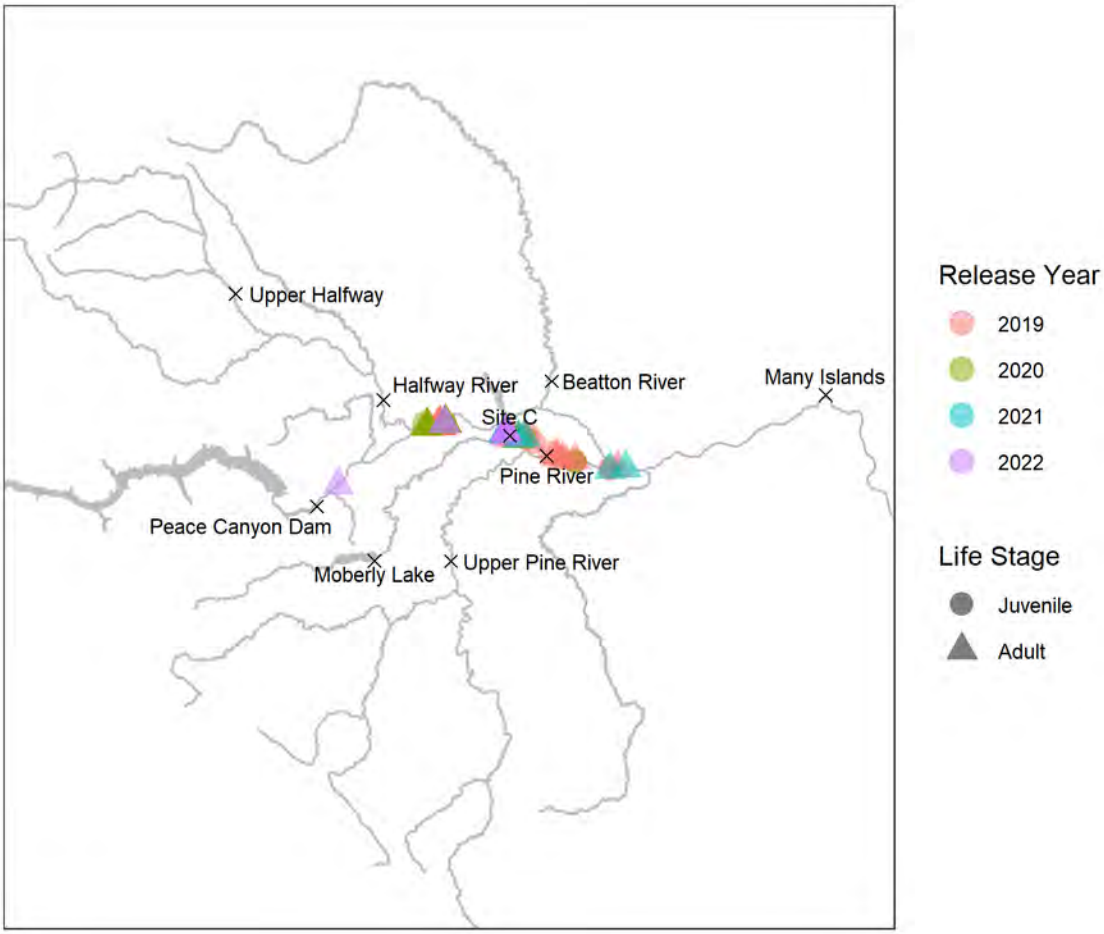


Figure A1. Arctic Grayling release locations and points of reference (×) from the present dataset (2019 to 2022). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.

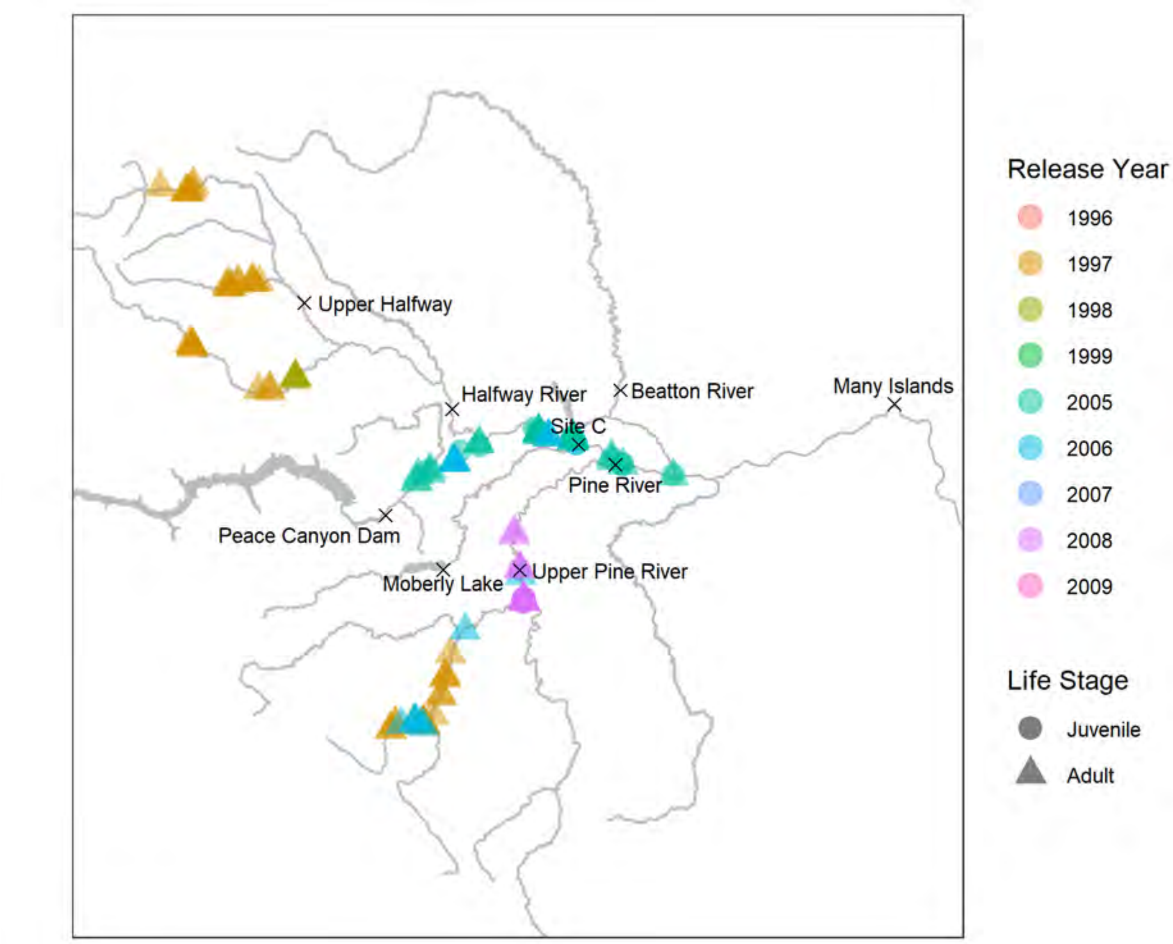


Figure A2. Arctic Grayling release locations and points of reference (×) from the historical dataset (1996 to 1998 and 2005 to 2008). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.

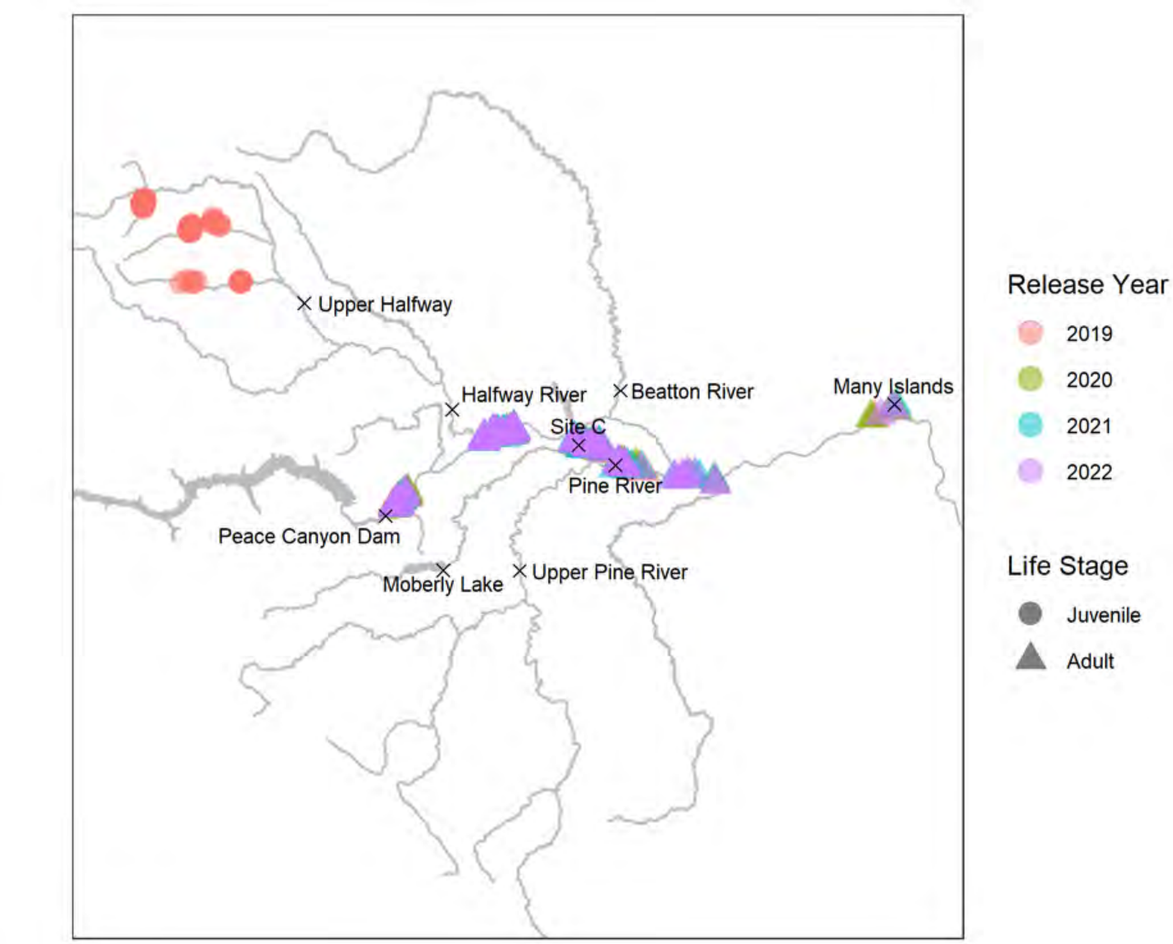


Figure A3. **Bull Trout release locations and points of reference (×) from the present dataset (2019 to 2022). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.**

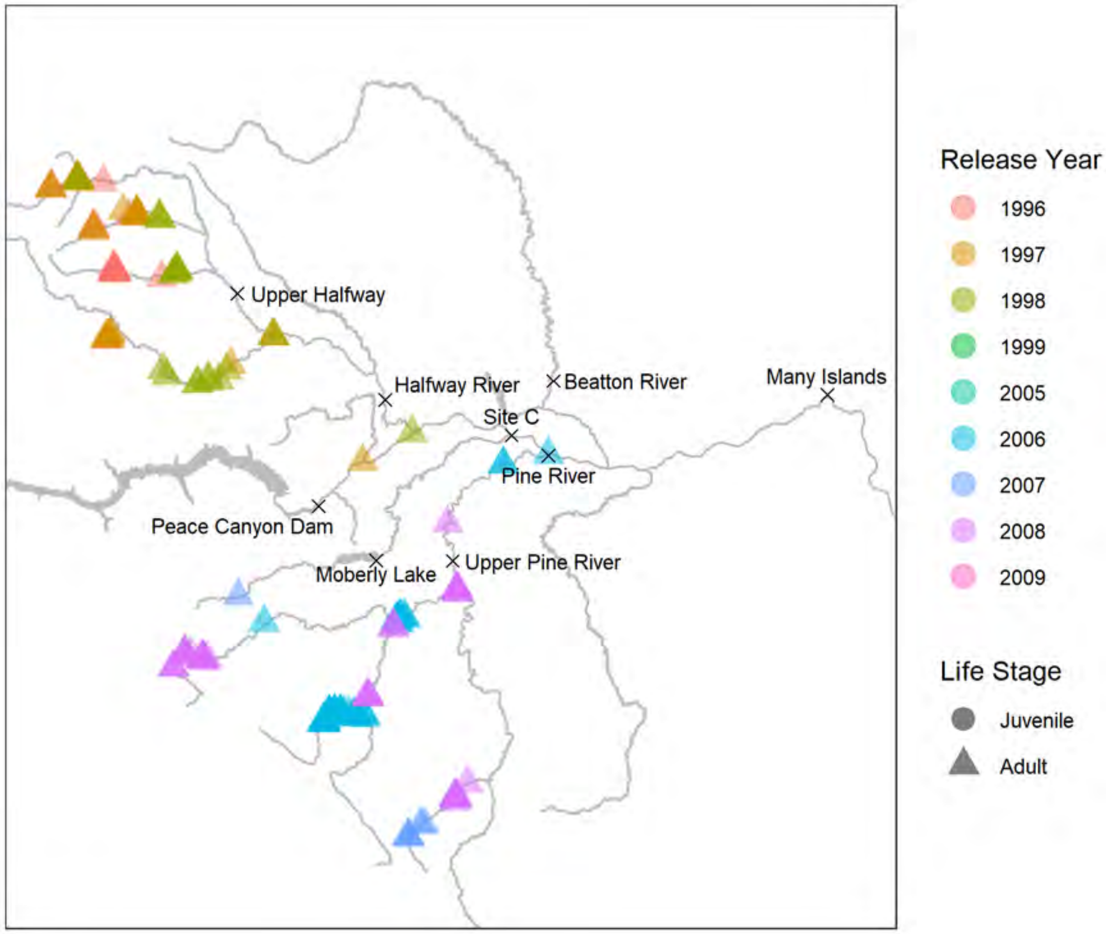


Figure A4. **Bull Trout release locations and points of reference (×) from the historical dataset (1996 to 1998 and 2005 to 2008). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.**

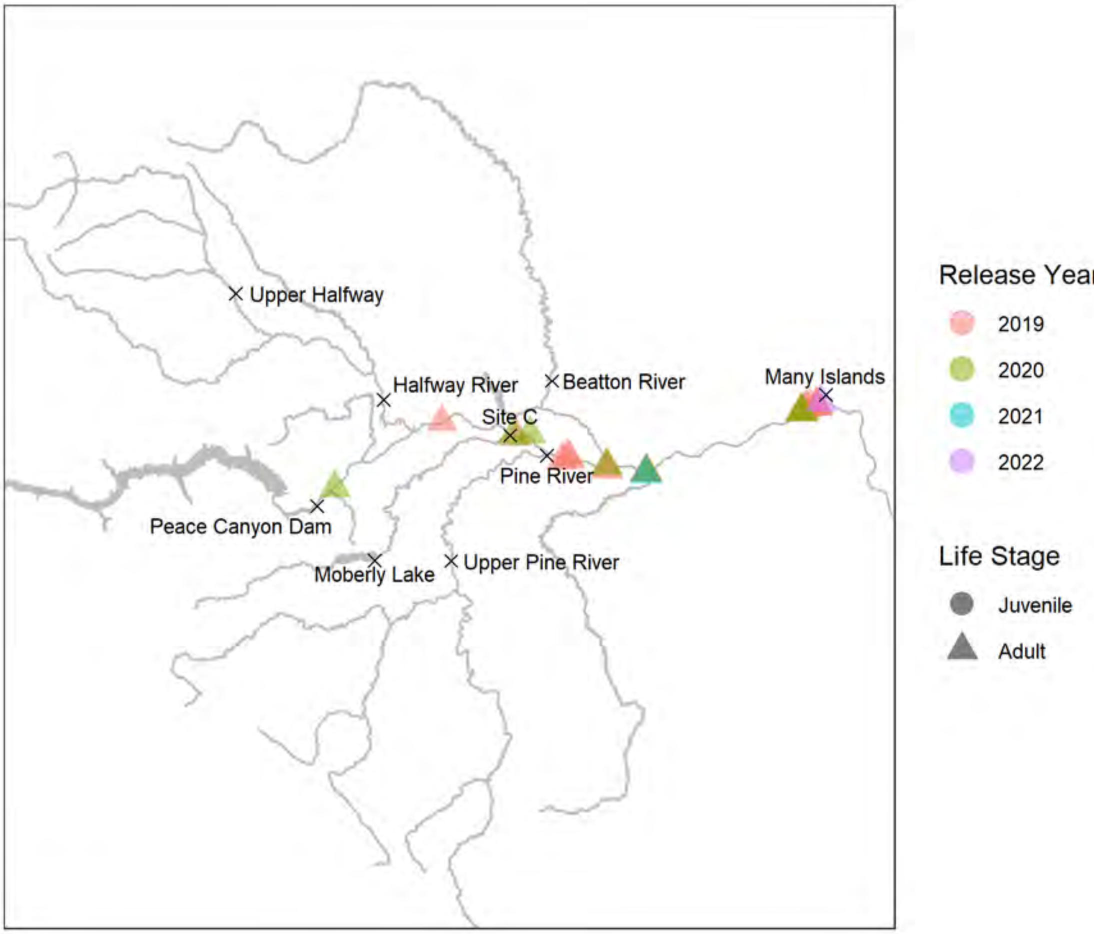


Figure A5. **Burbot release locations and points of reference (×) from the present dataset (2019 to 2022). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.**

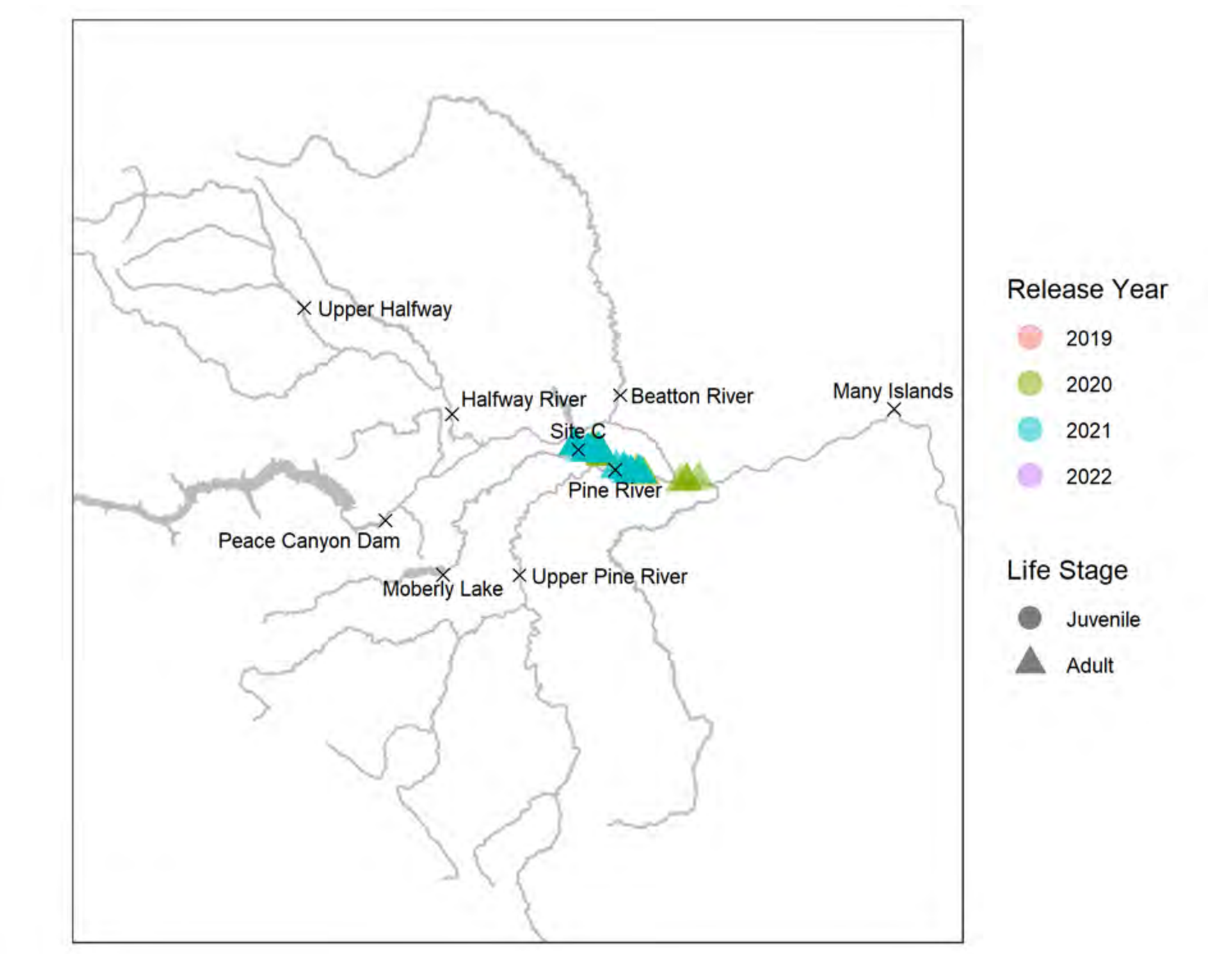


Figure A6. **Mountain Whitefish release locations and points of reference (×) from the present dataset (2019 to 2022). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.**

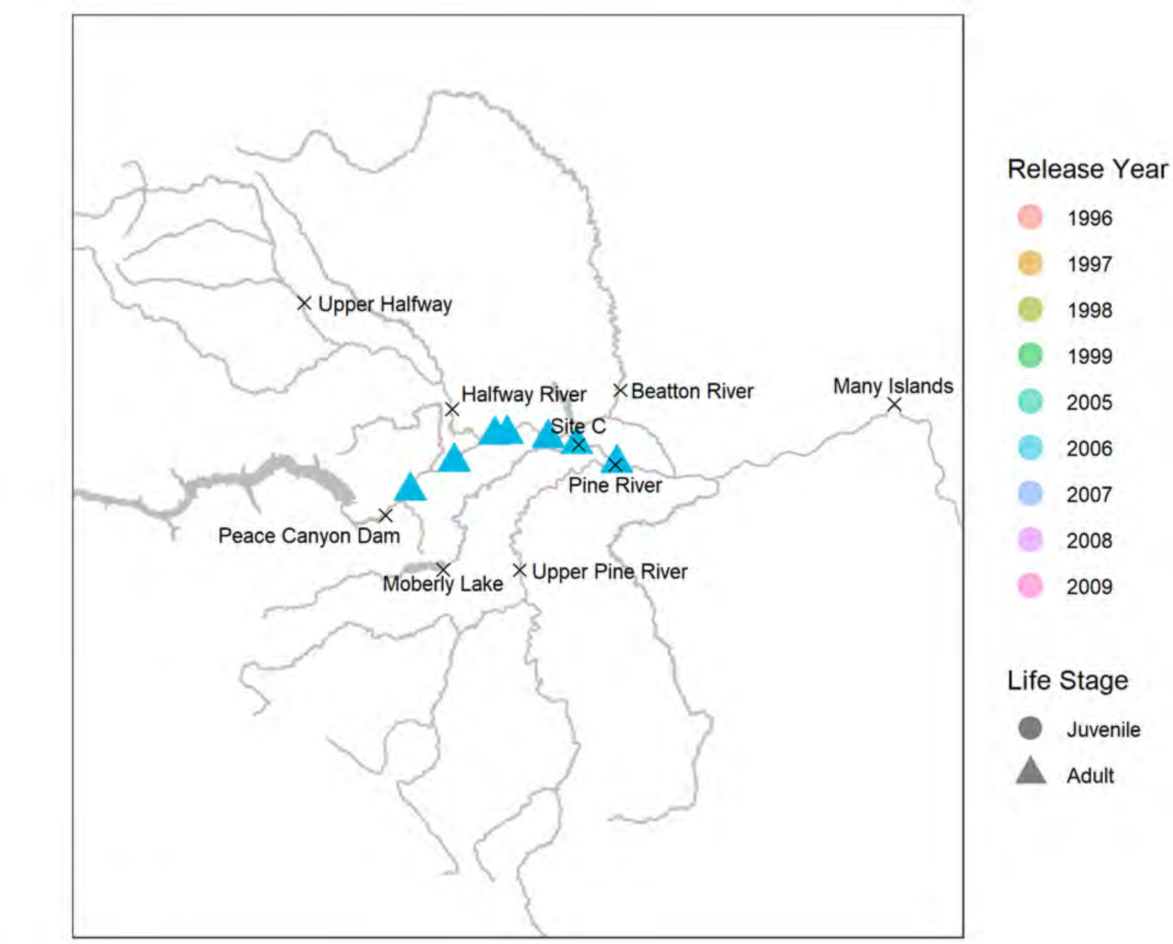


Figure A7. Mountain Whitefish release locations and points of reference (×) from the historical dataset (1996 to 1998 and 2005 to 2008). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.

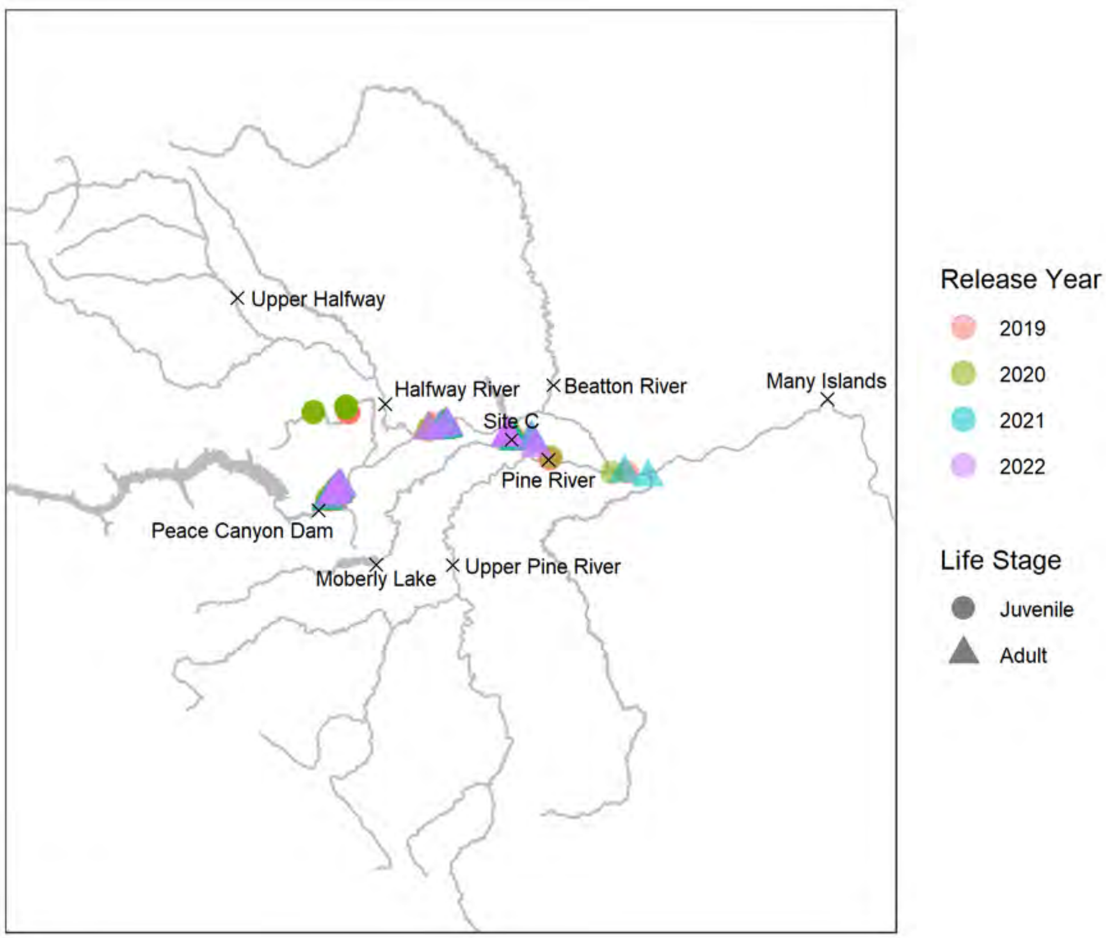


Figure A8. **Rainbow Trout release locations and points of reference (×) from the present dataset (2019 to 2022). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.**

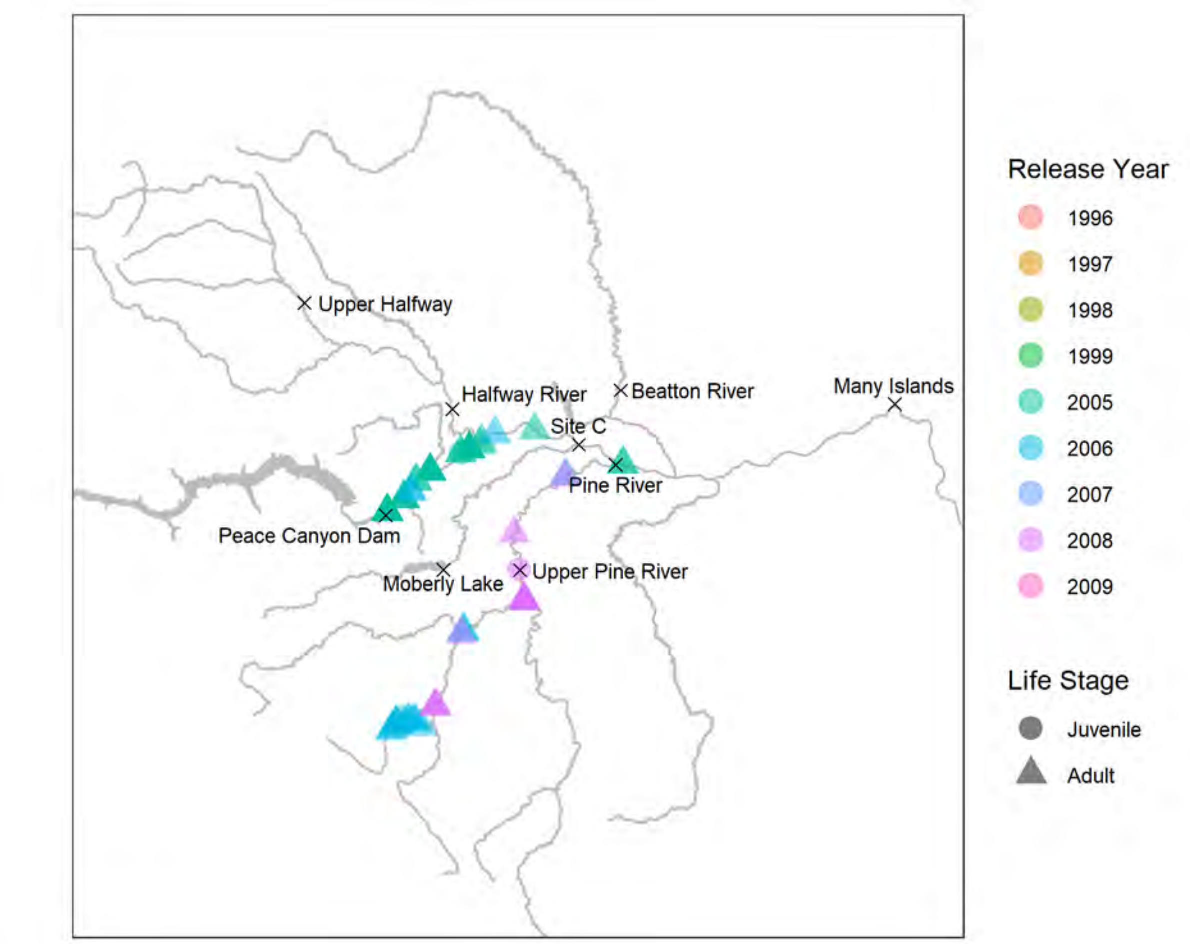


Figure A9. **Rainbow Trout release locations and points of reference (×) from the historical dataset (1996 to 1998 and 2005 to 2008). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.**

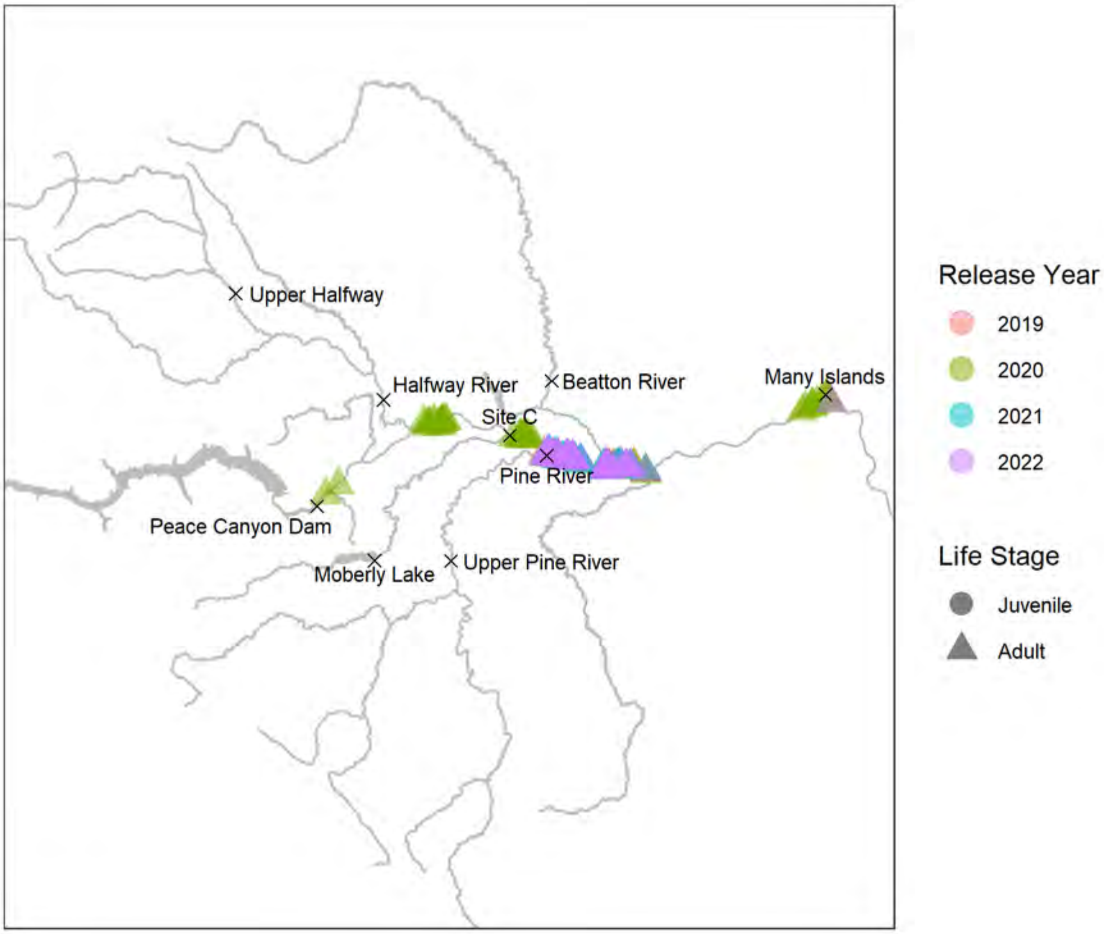


Figure A10. Walleye release locations and points of reference (×) from the present dataset (2019 to 2022). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.

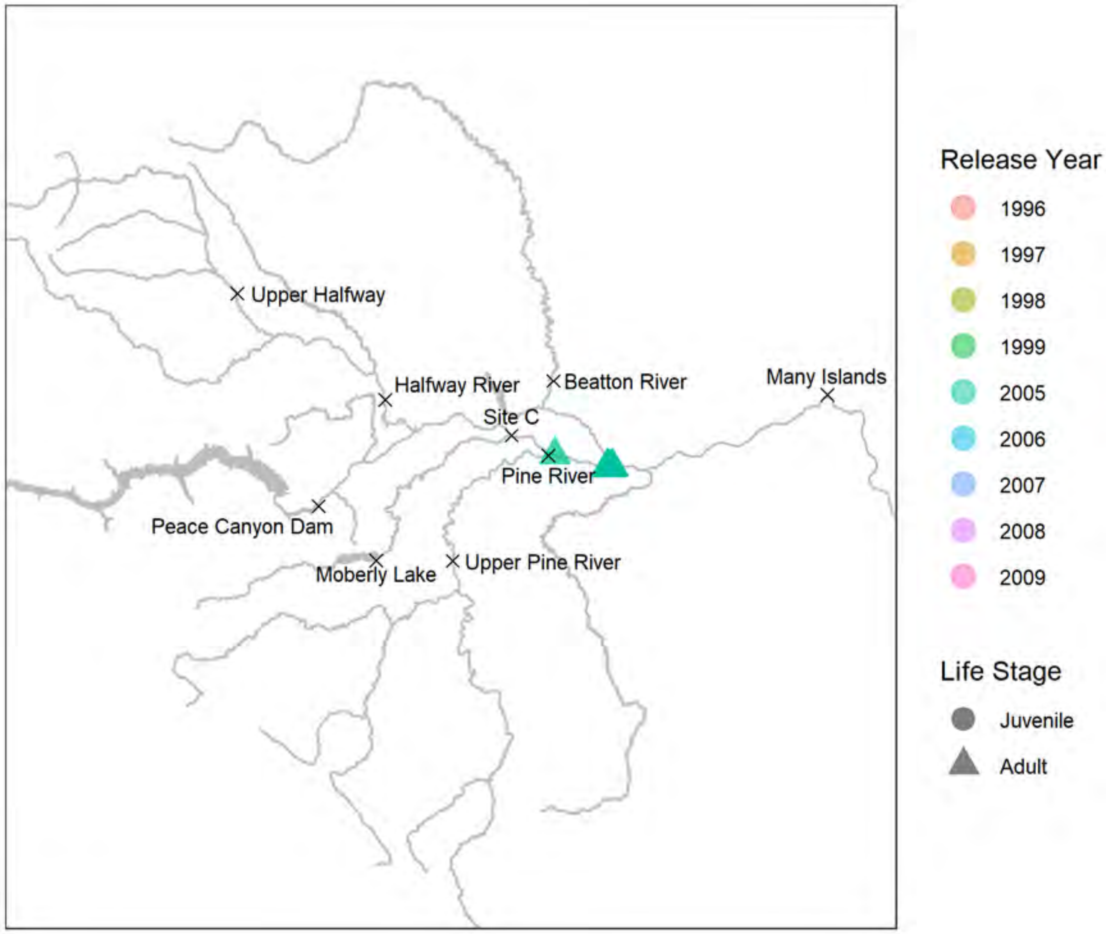


Figure A11. Walleye release locations and points of reference (×) from the historical dataset (1996 to 1998 and 2005 to 2008). Juvenile fish are depicted as circles, adults depicted as triangles. Point colours indicate year of release.

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

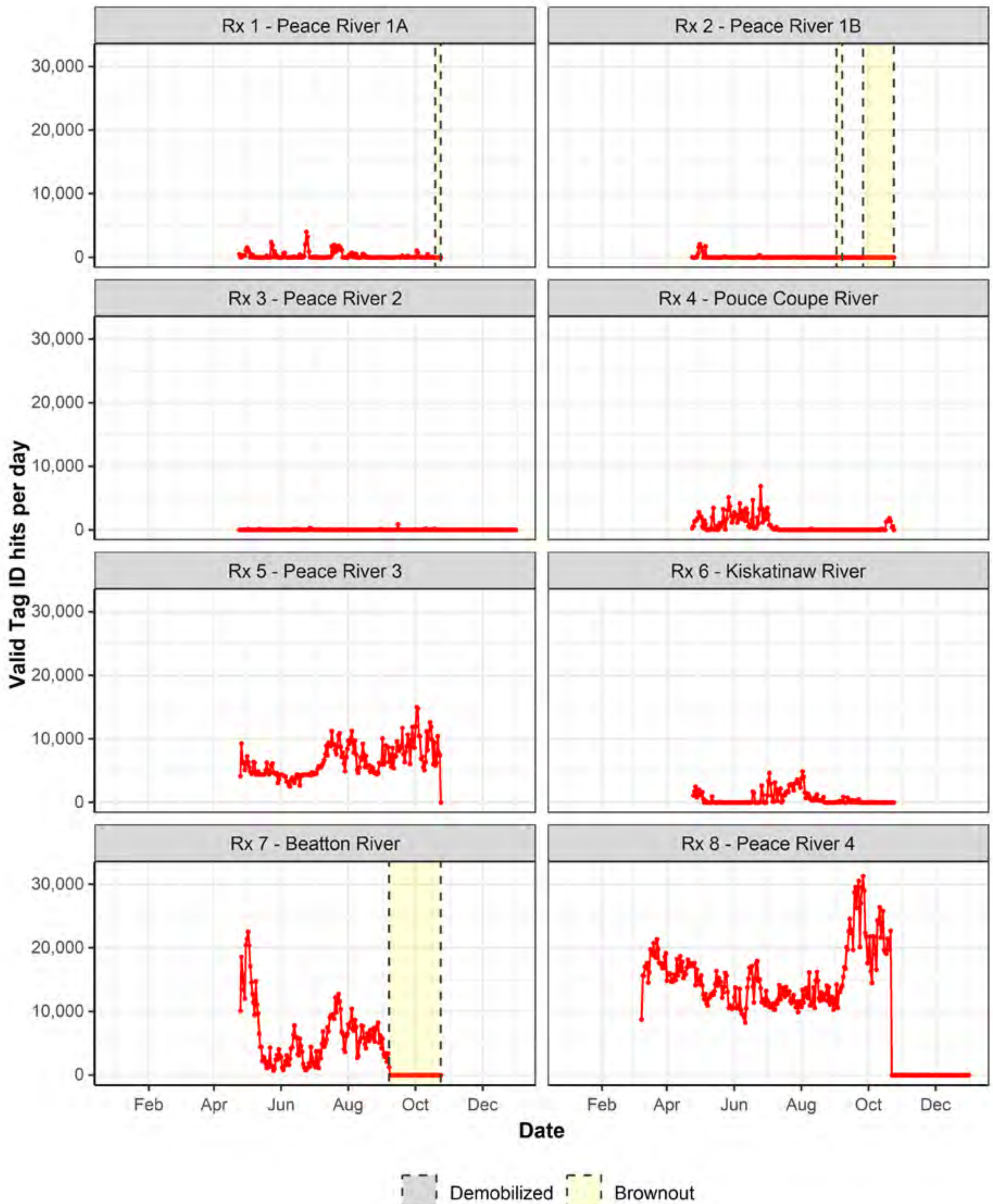


Figure B1. **Validated detection signals by station organized into hits per day in 2022. The spaces highlighted with a yellow or gray rectangle signify periods in which receiver outages had occurred and data collection did not proceed. The figure continues on the six next pages.**

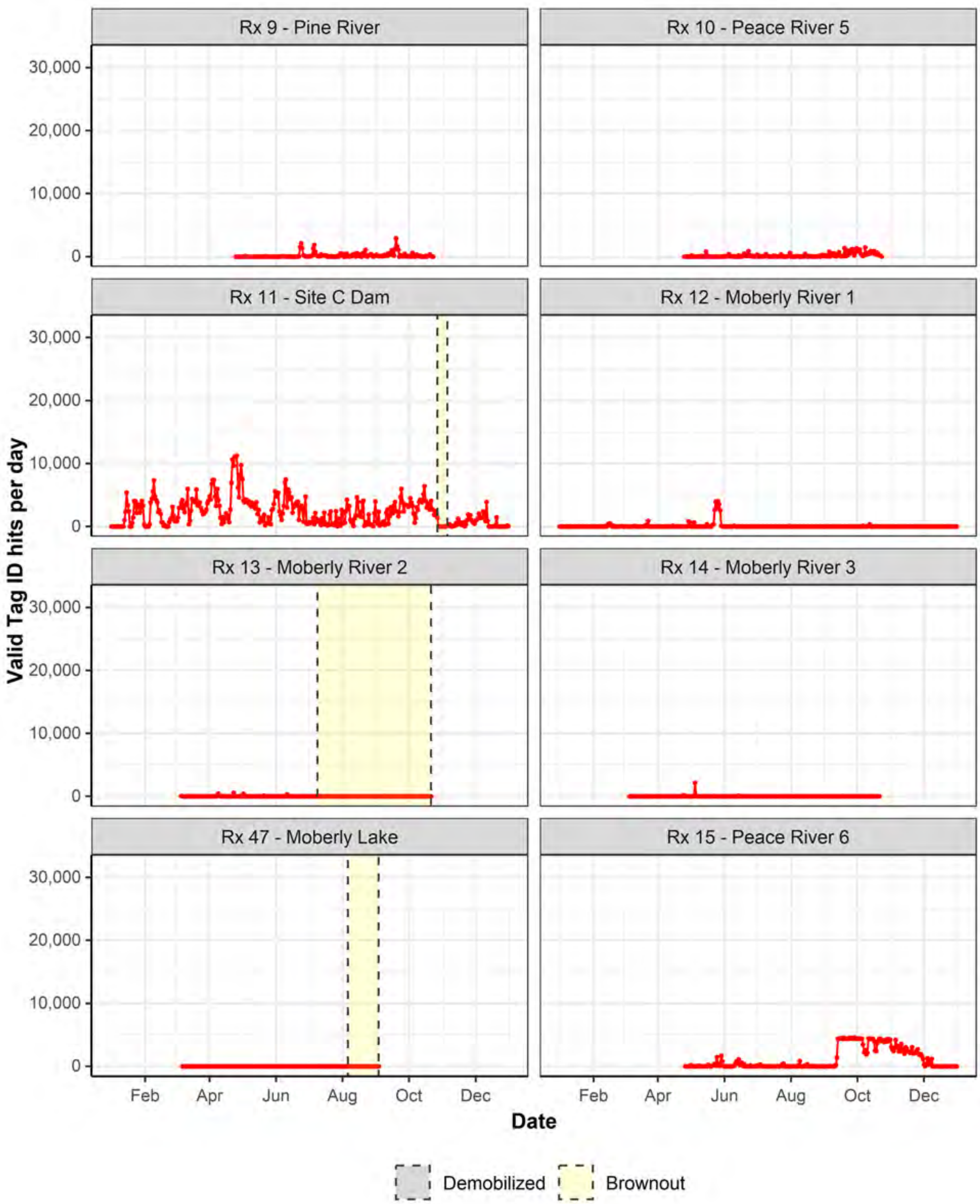


Figure B1 continued (part 2 of 7).

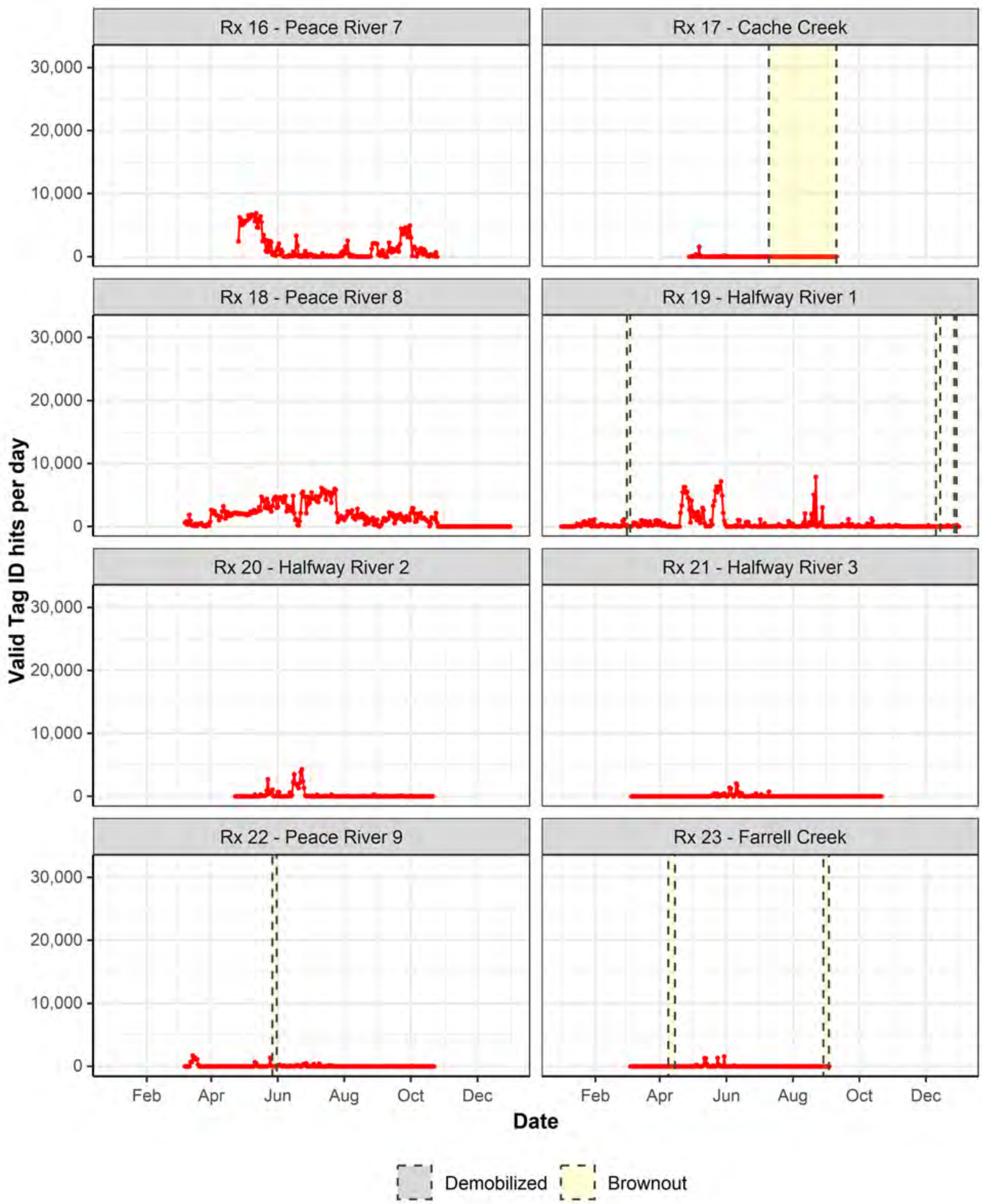


Figure B1 continued (part 3 of 7).

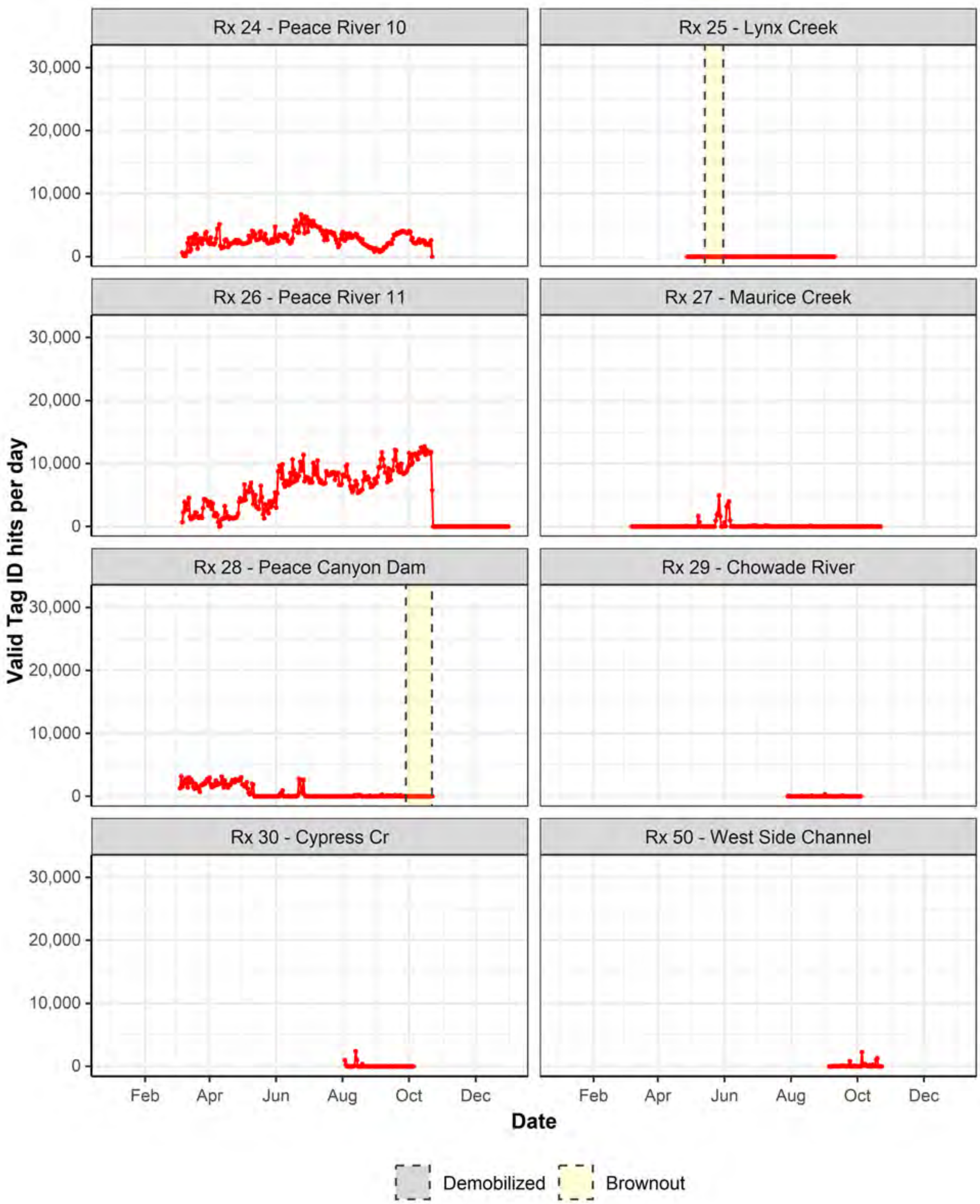


Figure B1 continued (part 4 of 7).

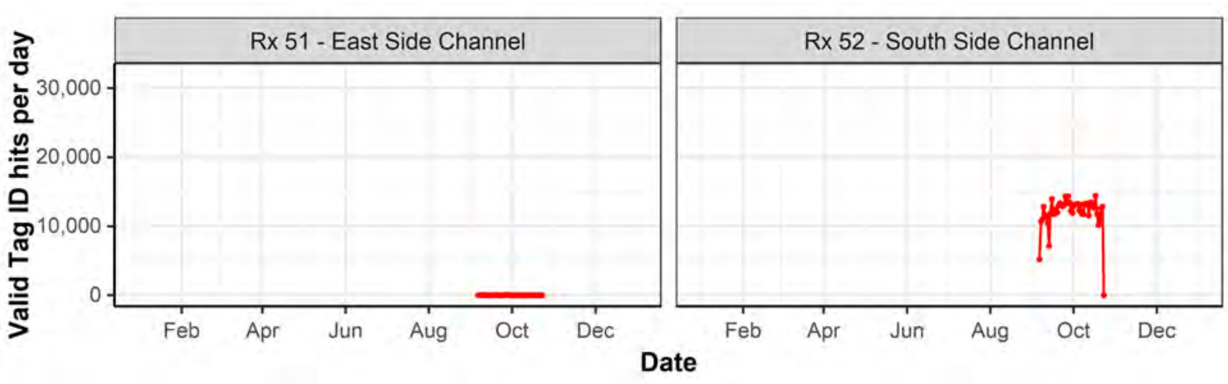


Figure B1 continued (part 5 of 7).

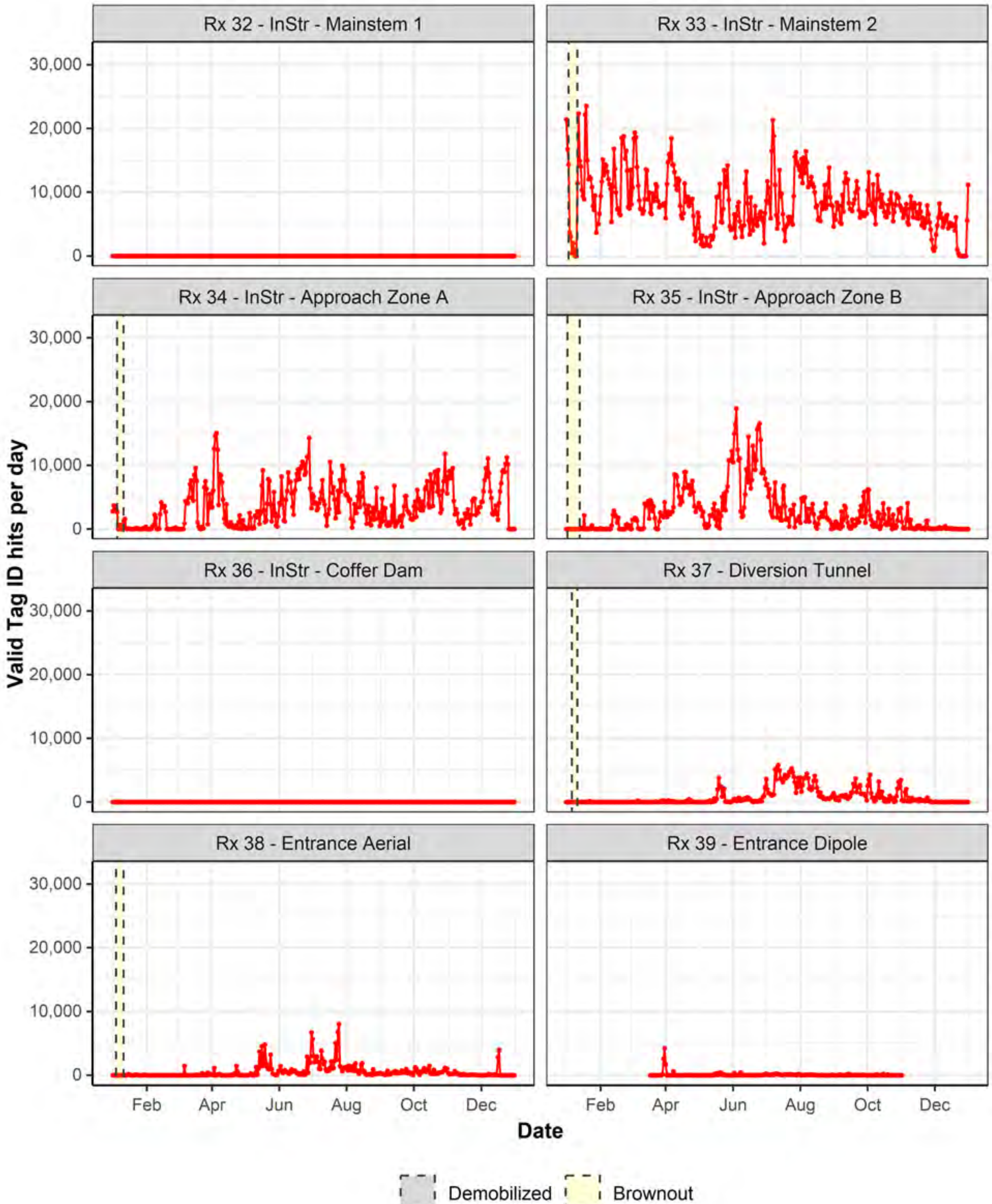


Figure B1 continued (part 6 of 7).

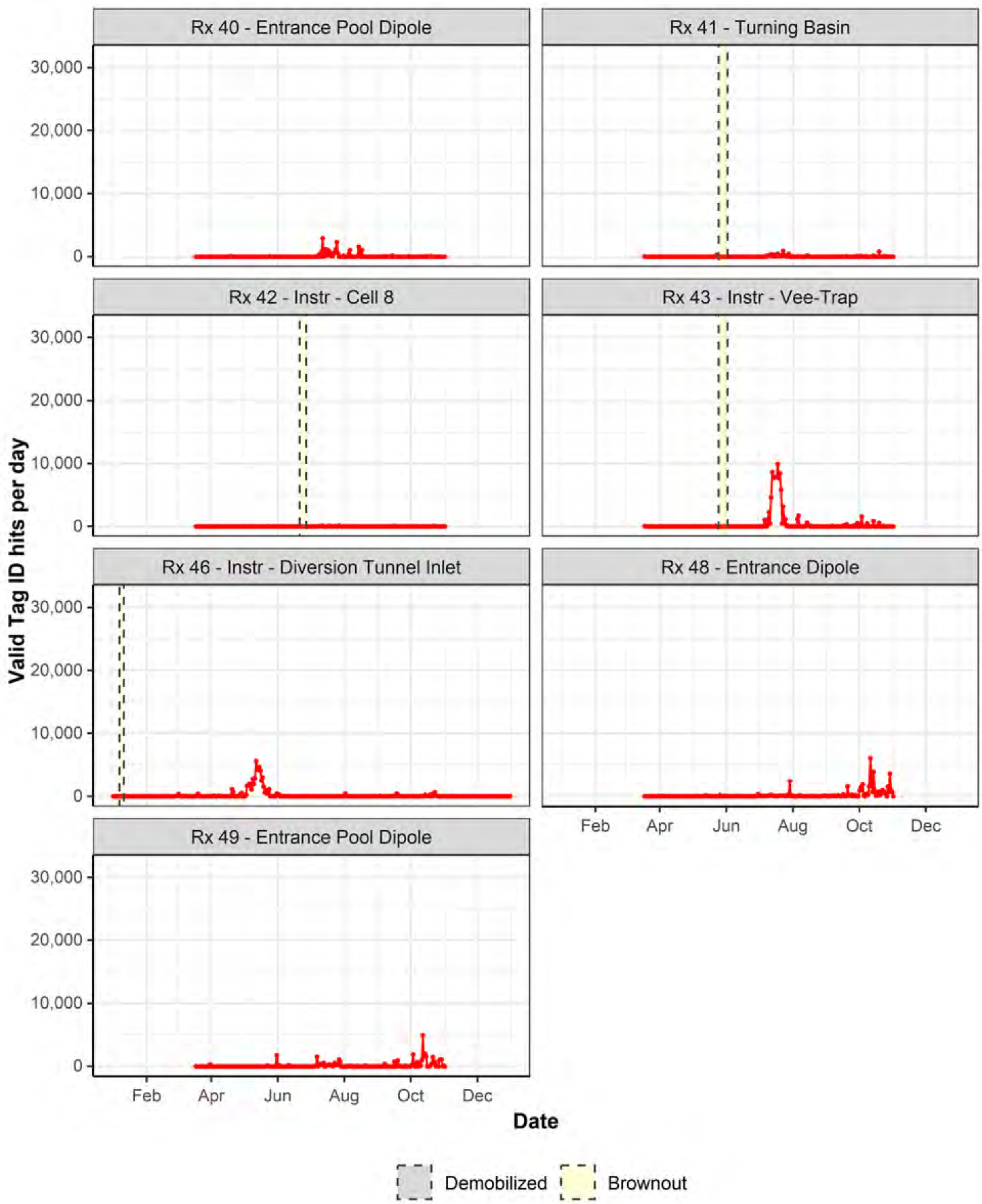


Figure B1 continued (part 7 of 7).

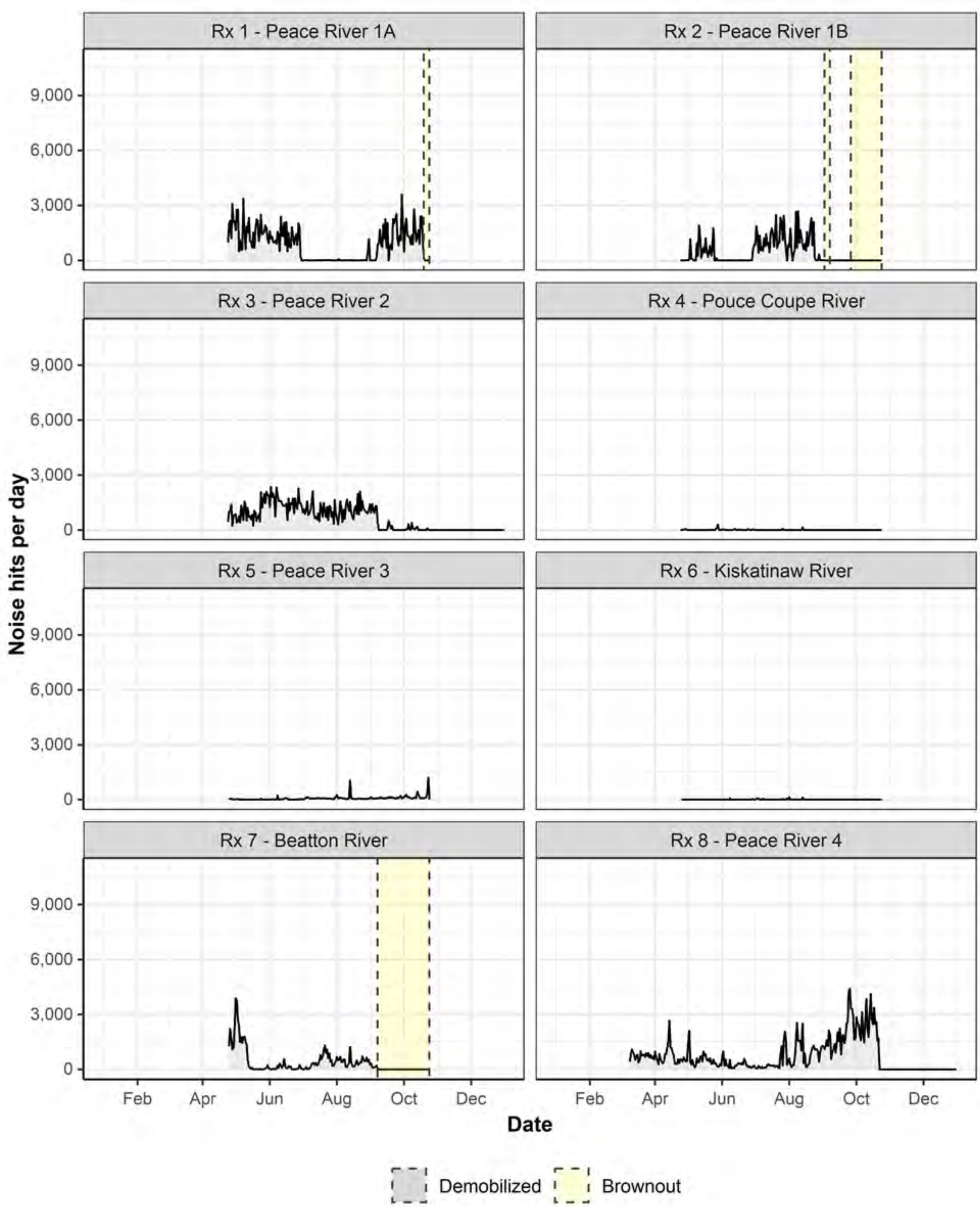


Figure B2. **Noise (Code 999) signals by station organized into hits per day in 2022. The spaces highlighted with a yellow or gray rectangle signify periods in which receiver outages had occurred and data collection did not proceed. The figure continues on the six next pages.**

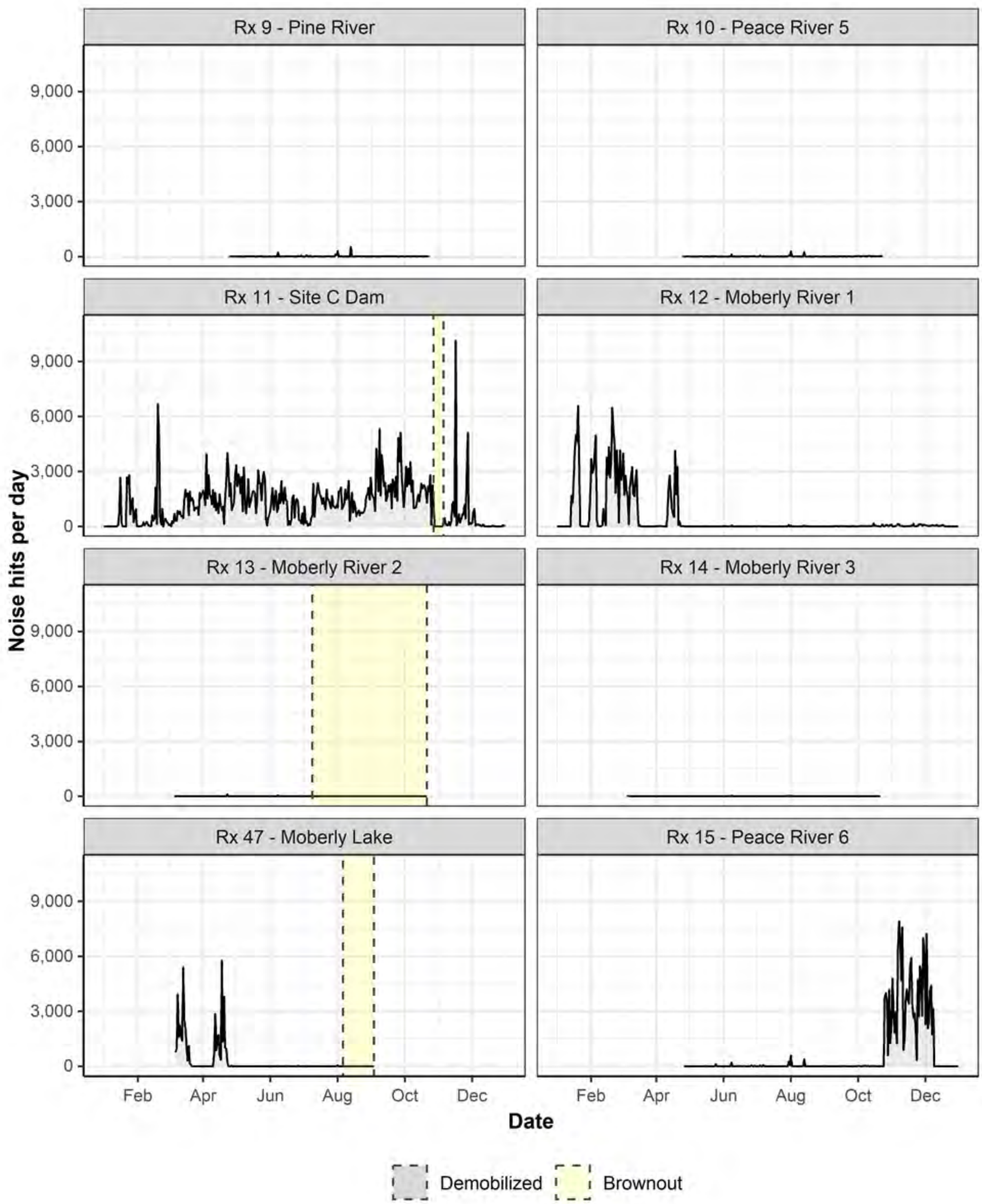


Figure B2 continued (part 2 of 7).

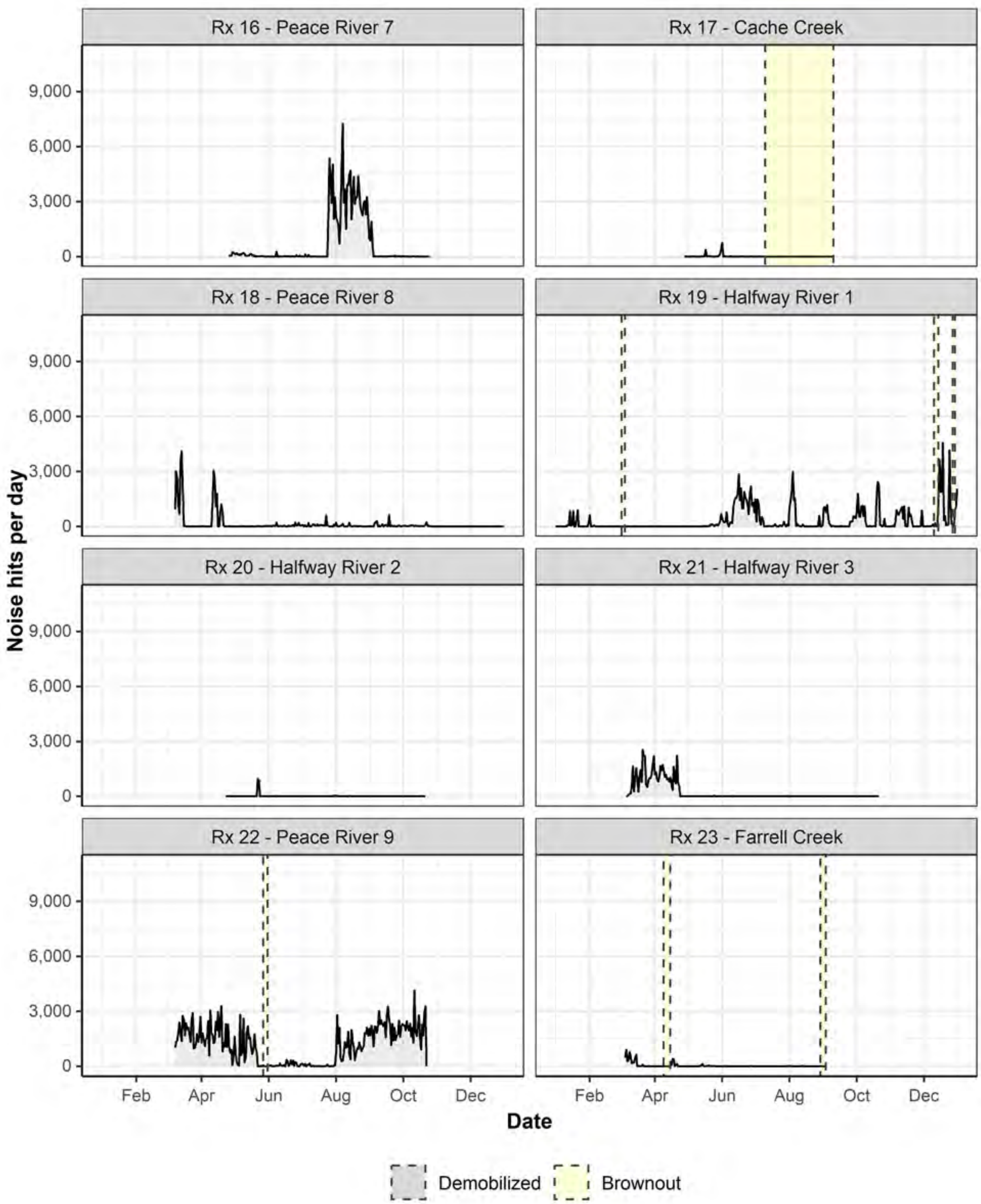


Figure B2 continued (part 3 of 7).

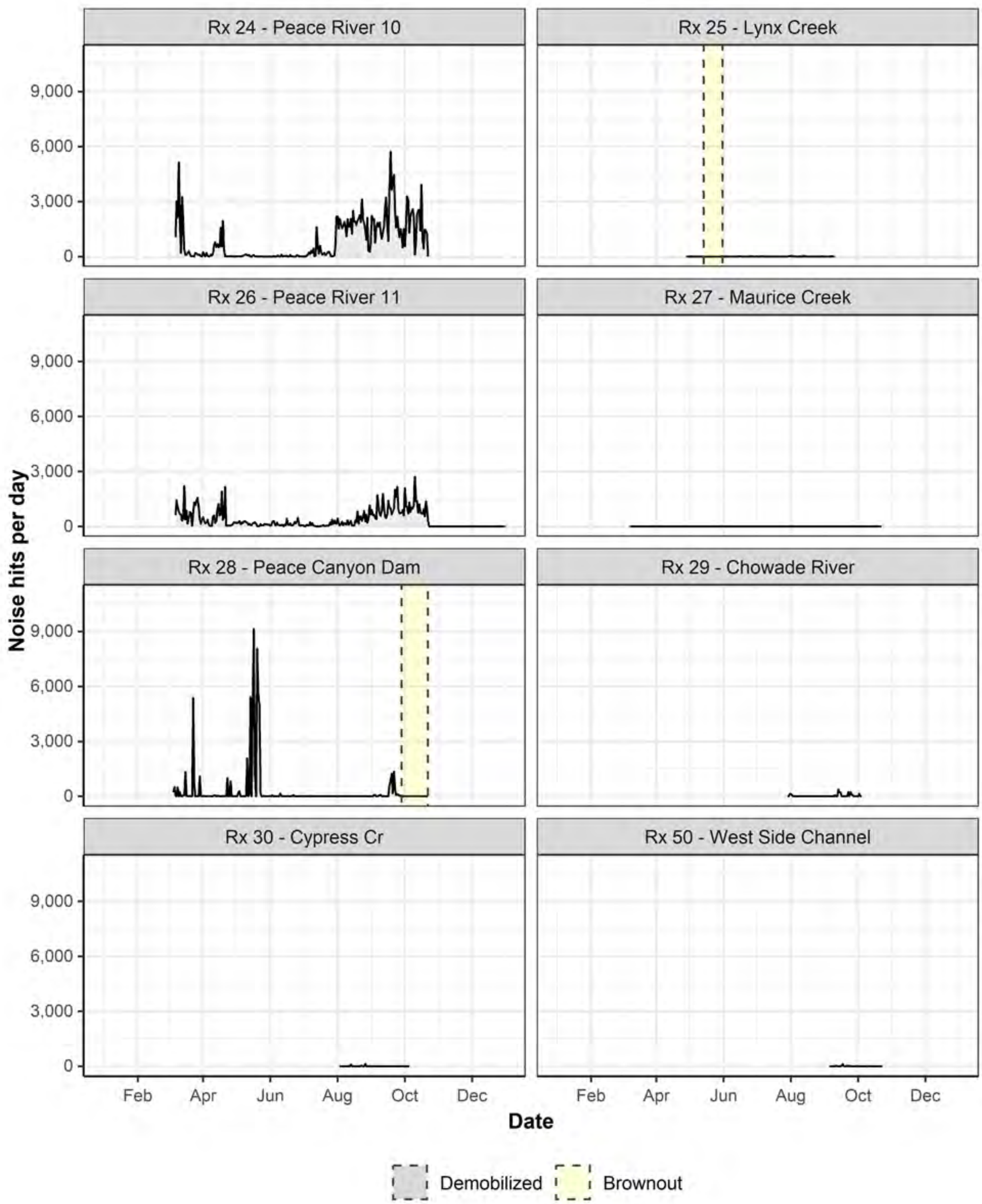


Figure B2 continued (part 4 of 7).

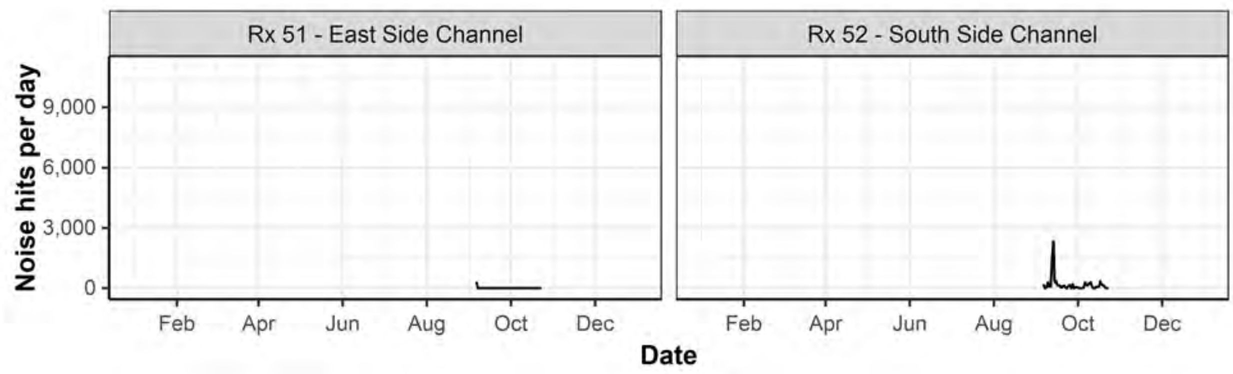


Figure B2 continued (part 5 of 7).

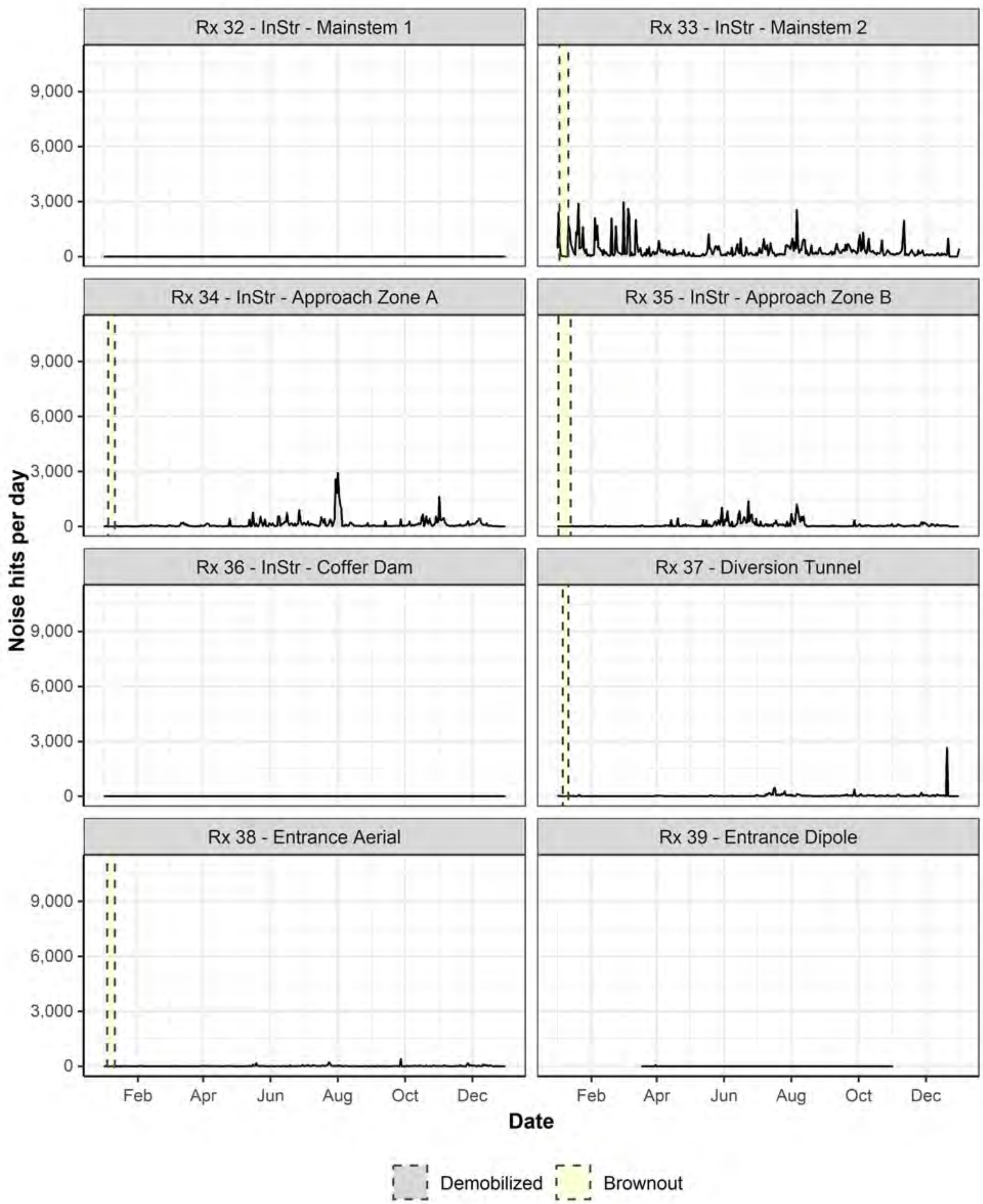


Figure B2 continued (part 6 of 7).

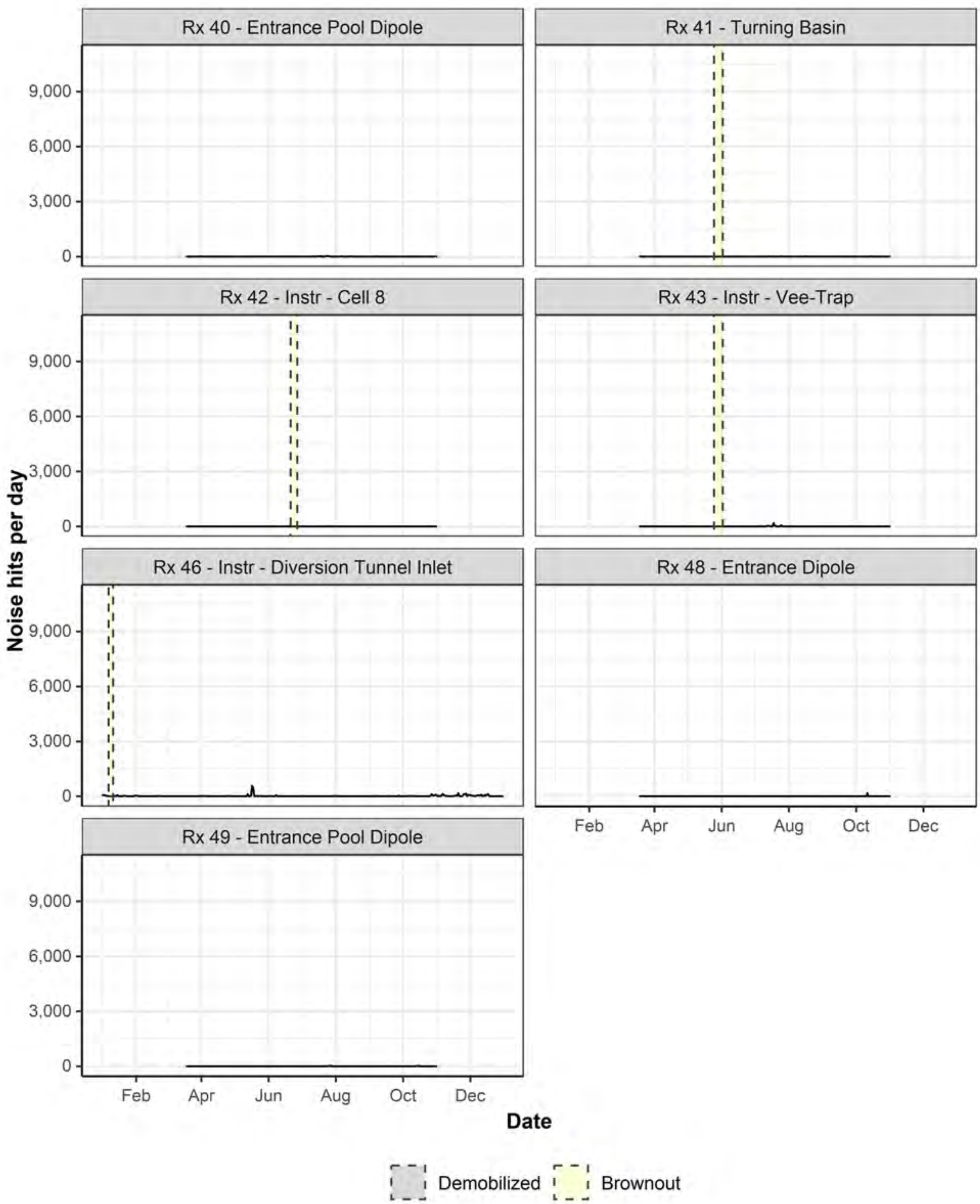


Figure B2 continued (part 7 of 7).

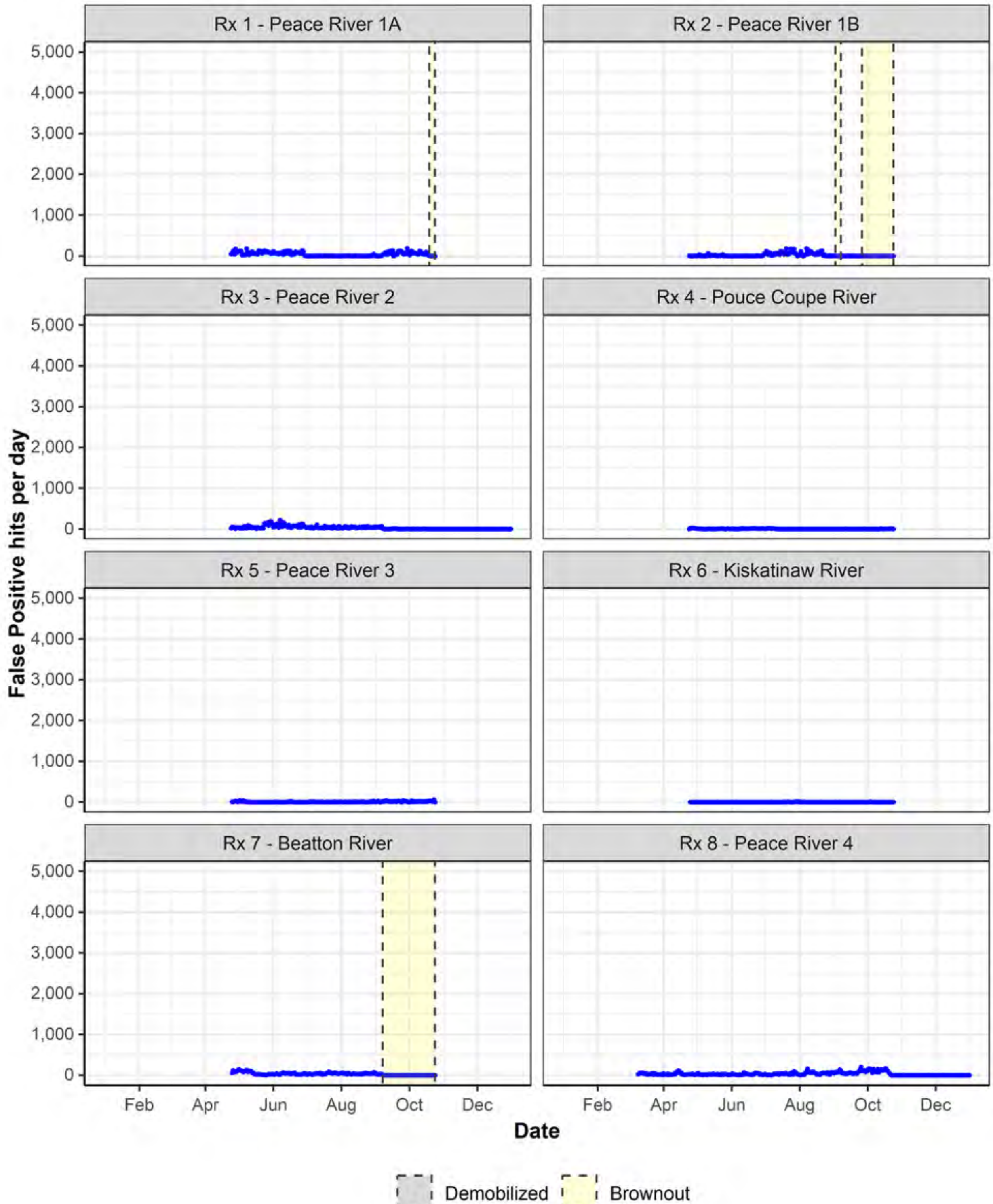


Figure B3. **False positive signals by station organized into hits per day in 2022. The spaces highlighted with a yellow or gray rectangle signify periods in which receiver outages had occurred and data collection did not proceed. The figure continues on the six next pages.**

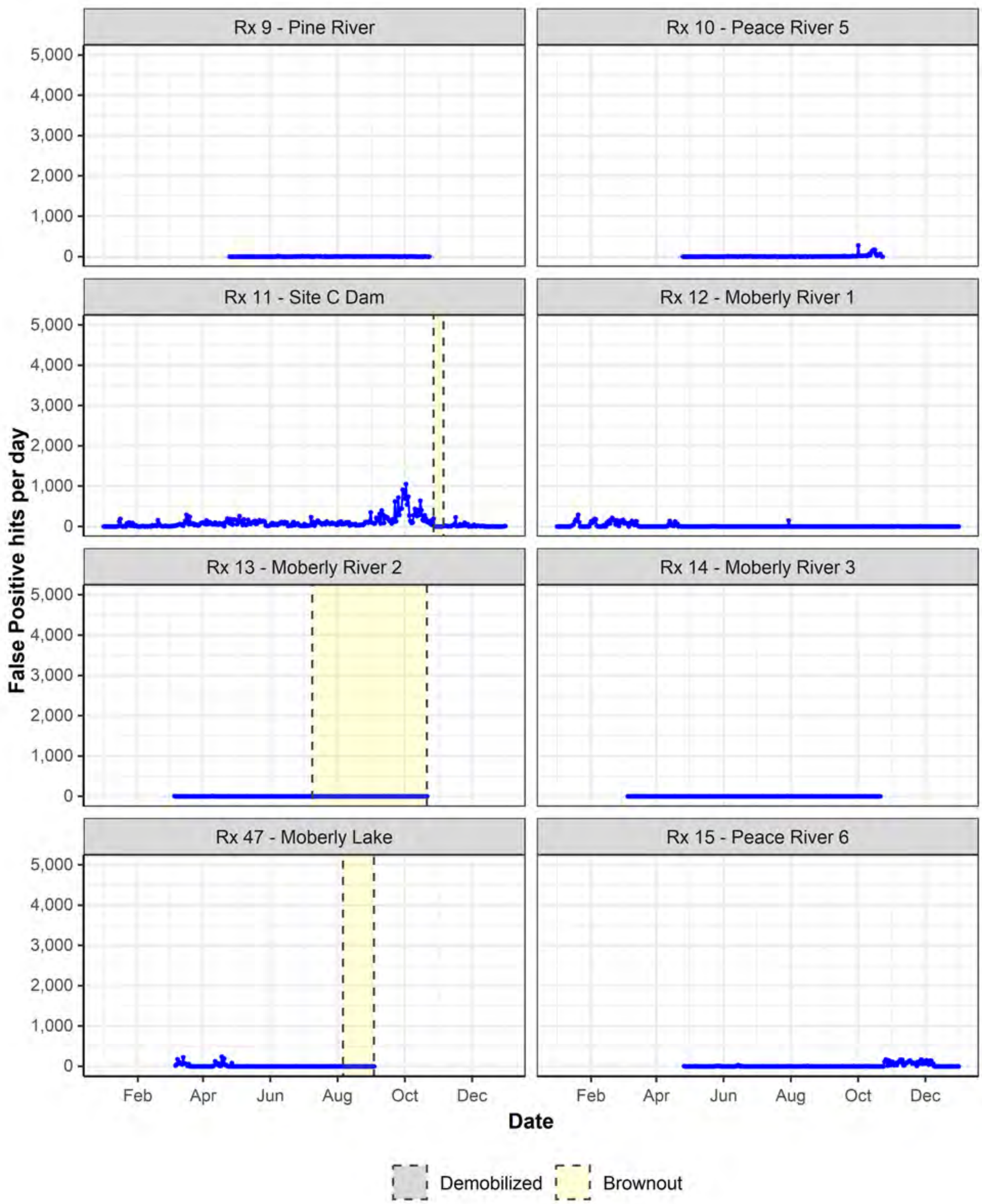


Figure B3 continued (part 2 of 7).

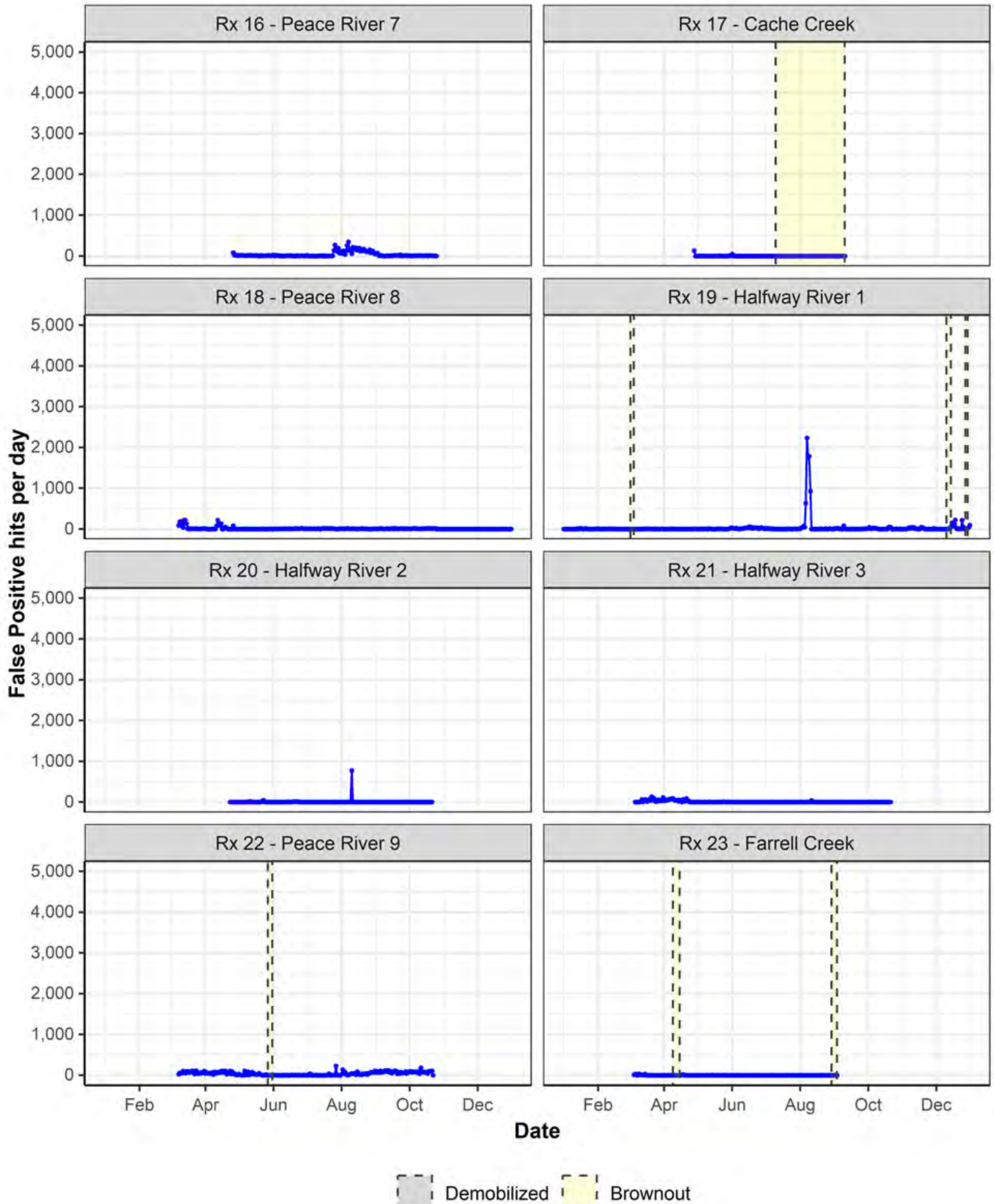


Figure B3 continued (part 3 of 7).

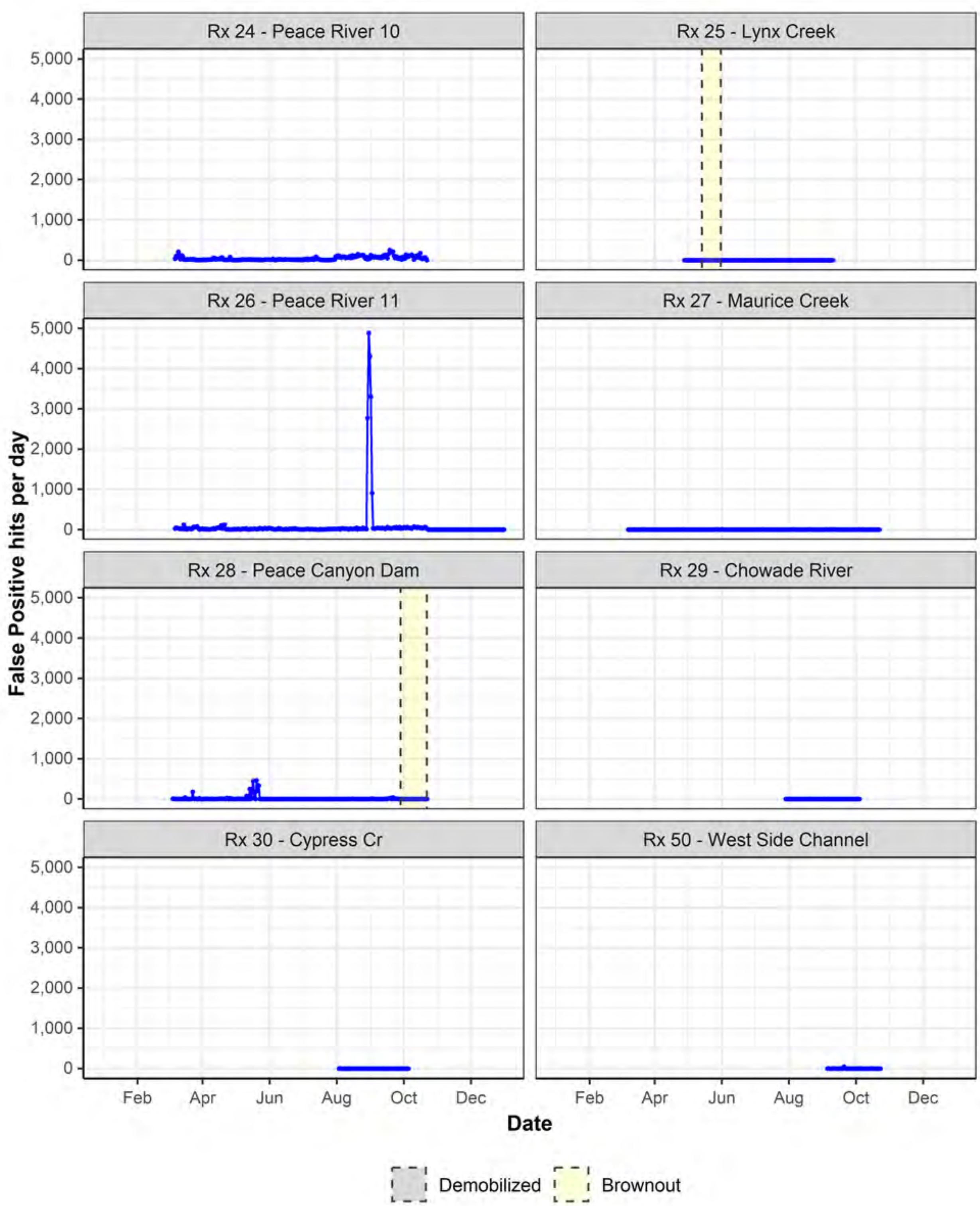


Figure B3 continued (part 4 of 7).

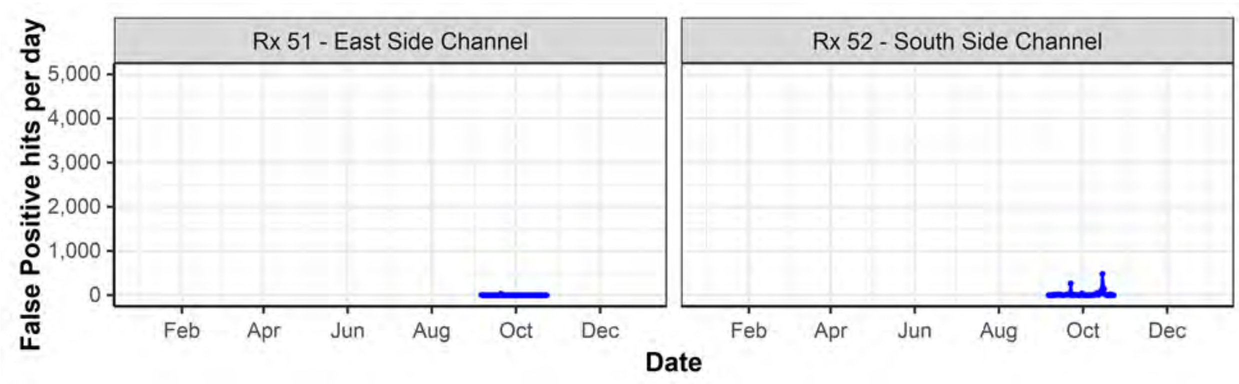


Figure B3 continued (part 5 of 7).

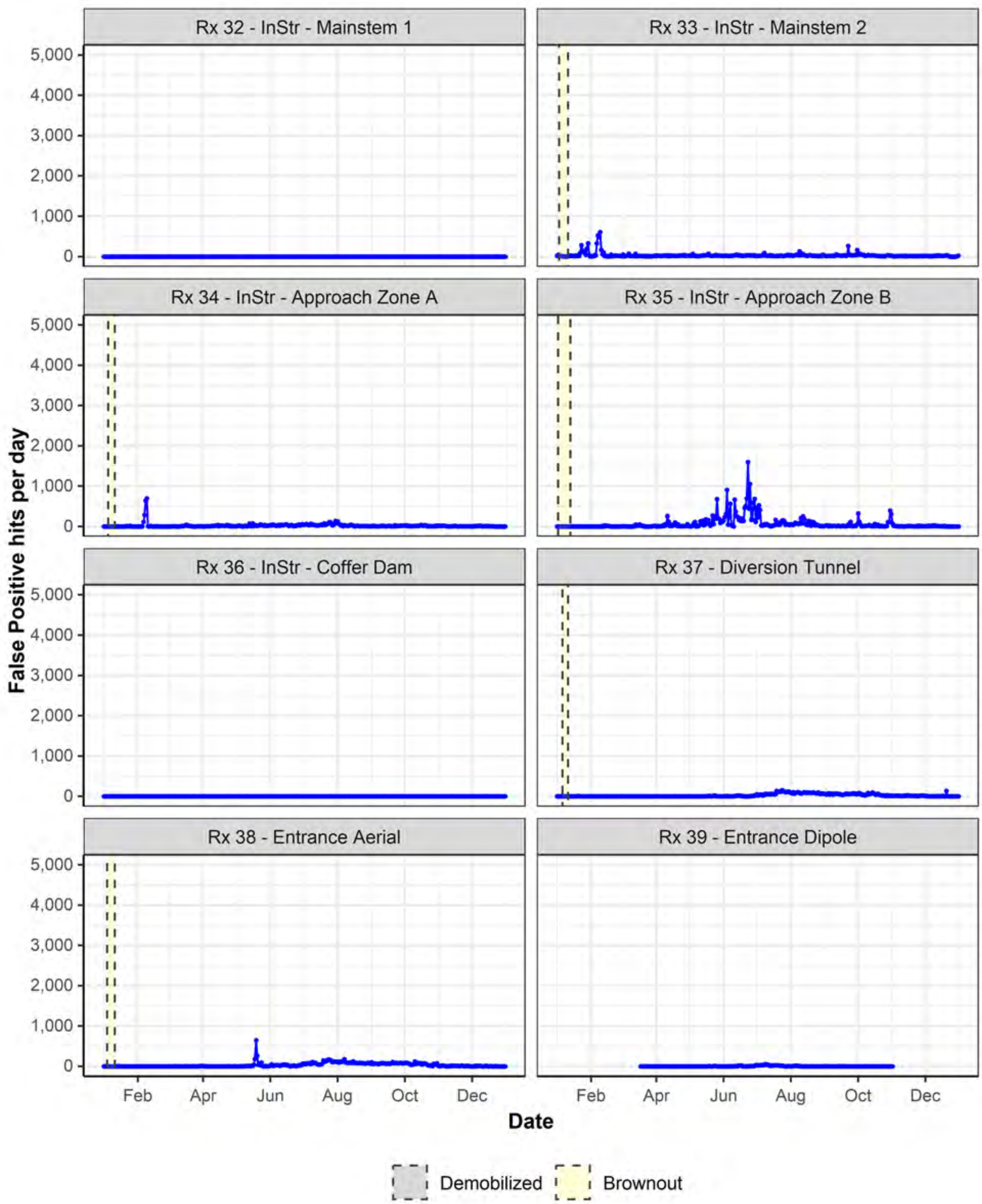


Figure B3 continued (part 6 of 7).

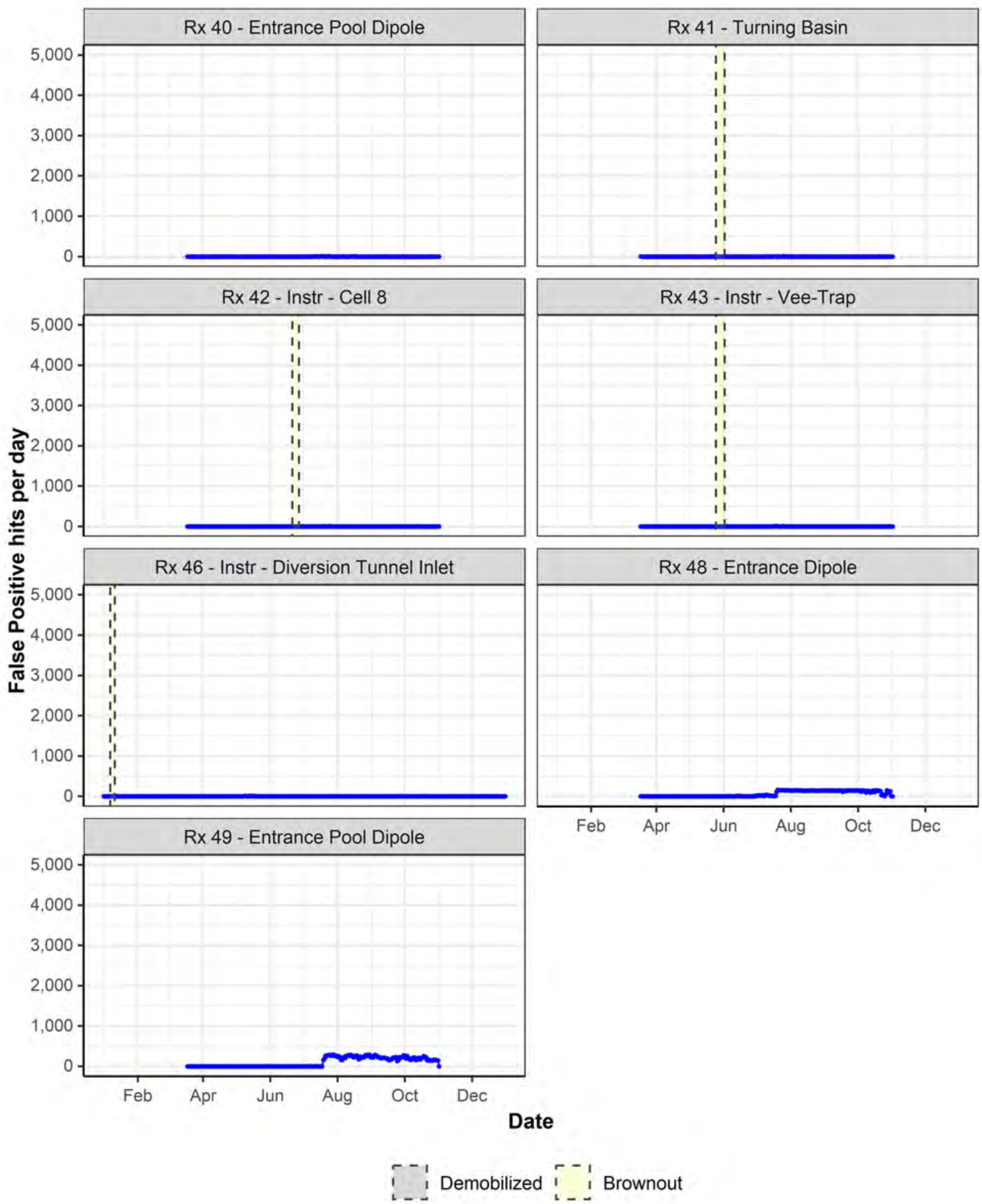


Figure B3 continued (part 7 of 7).

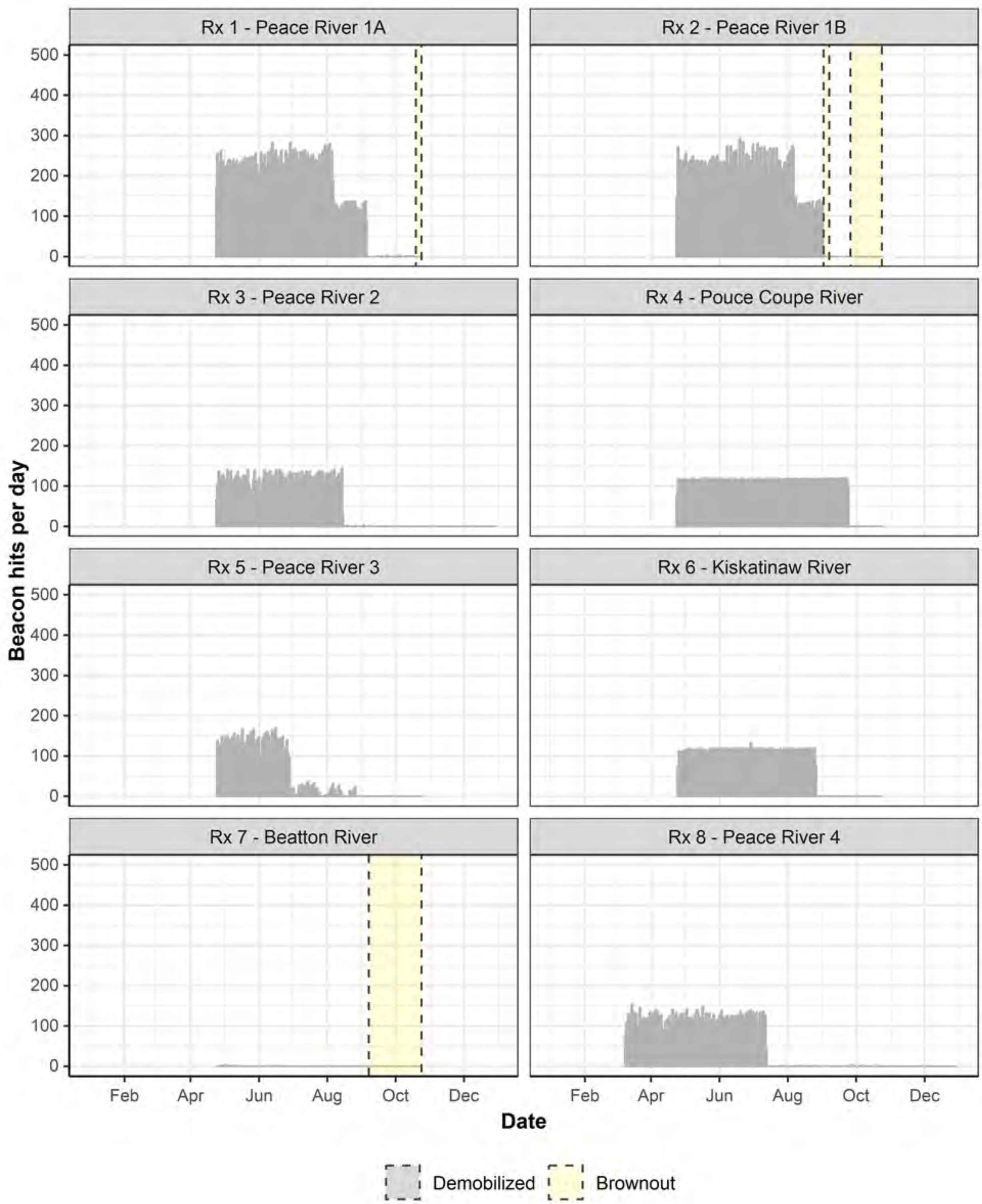


Figure B4. **Beacon tag signals by station organized into hits per day in 2022. The spaces highlighted with a yellow or gray rectangle signify periods in which receiver outages had occurred and data collection did not proceed. The figure continues on the six next pages.**

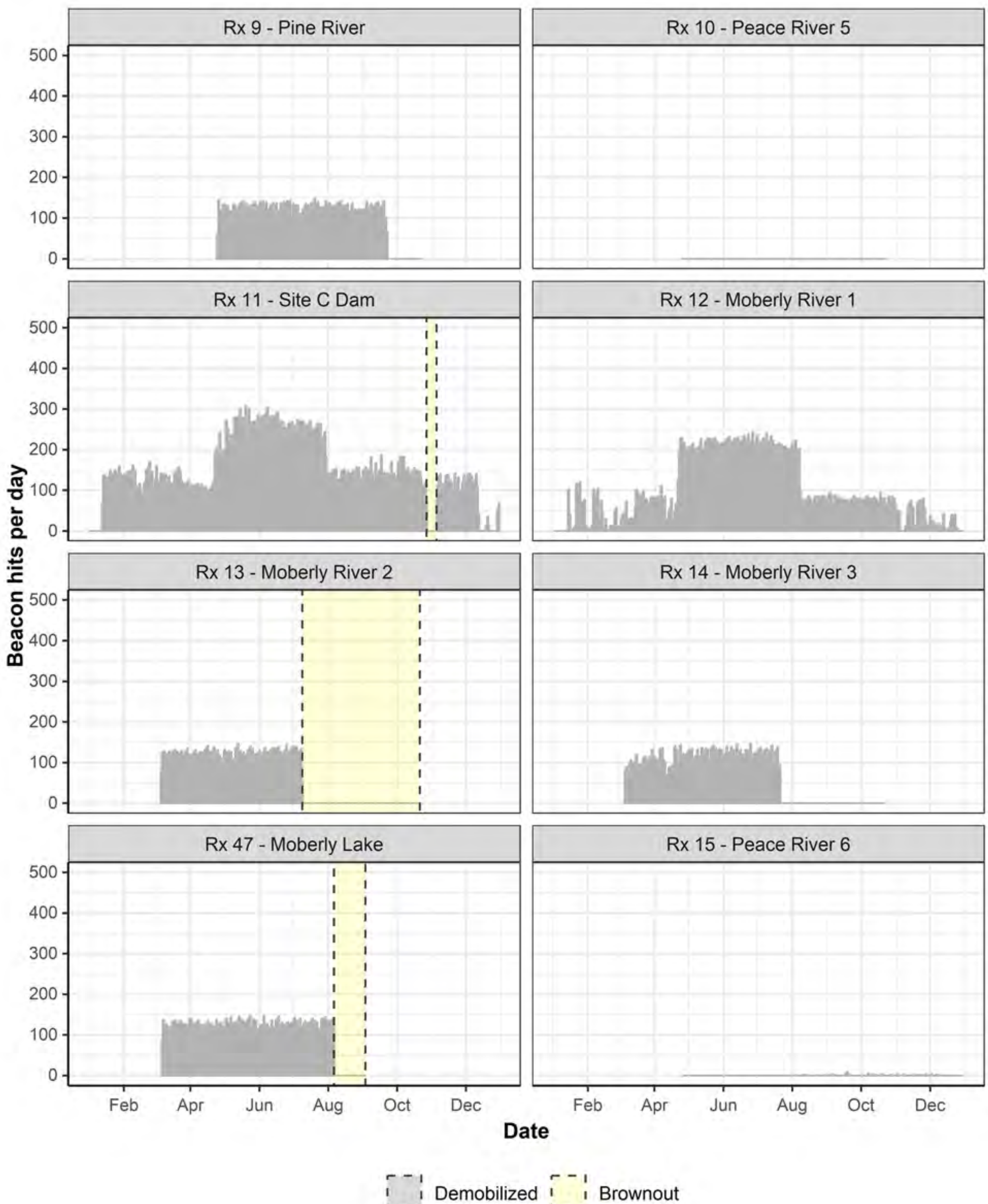


Figure B4 continued (part 2 of 7).

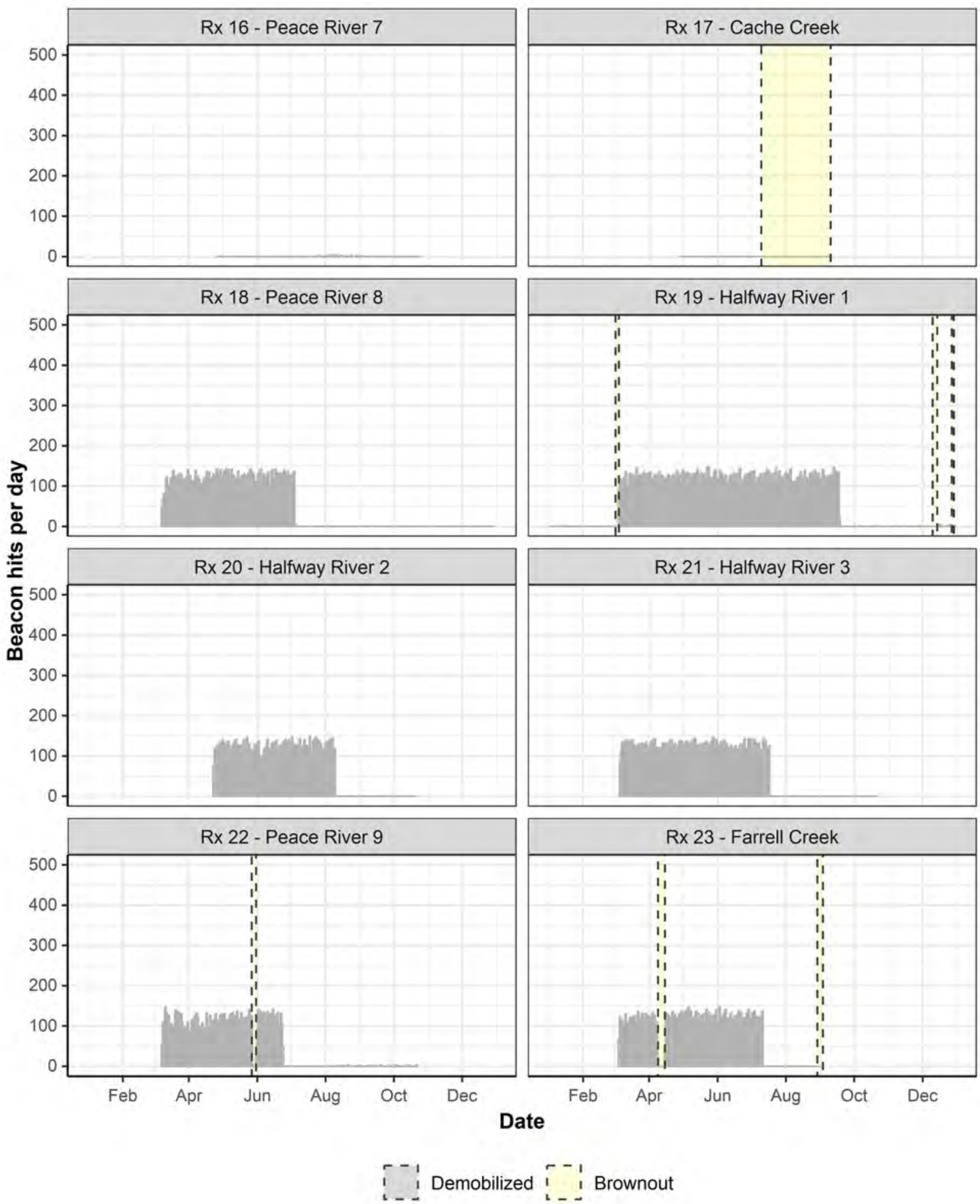


Figure B4 continued (part 3 of 7).

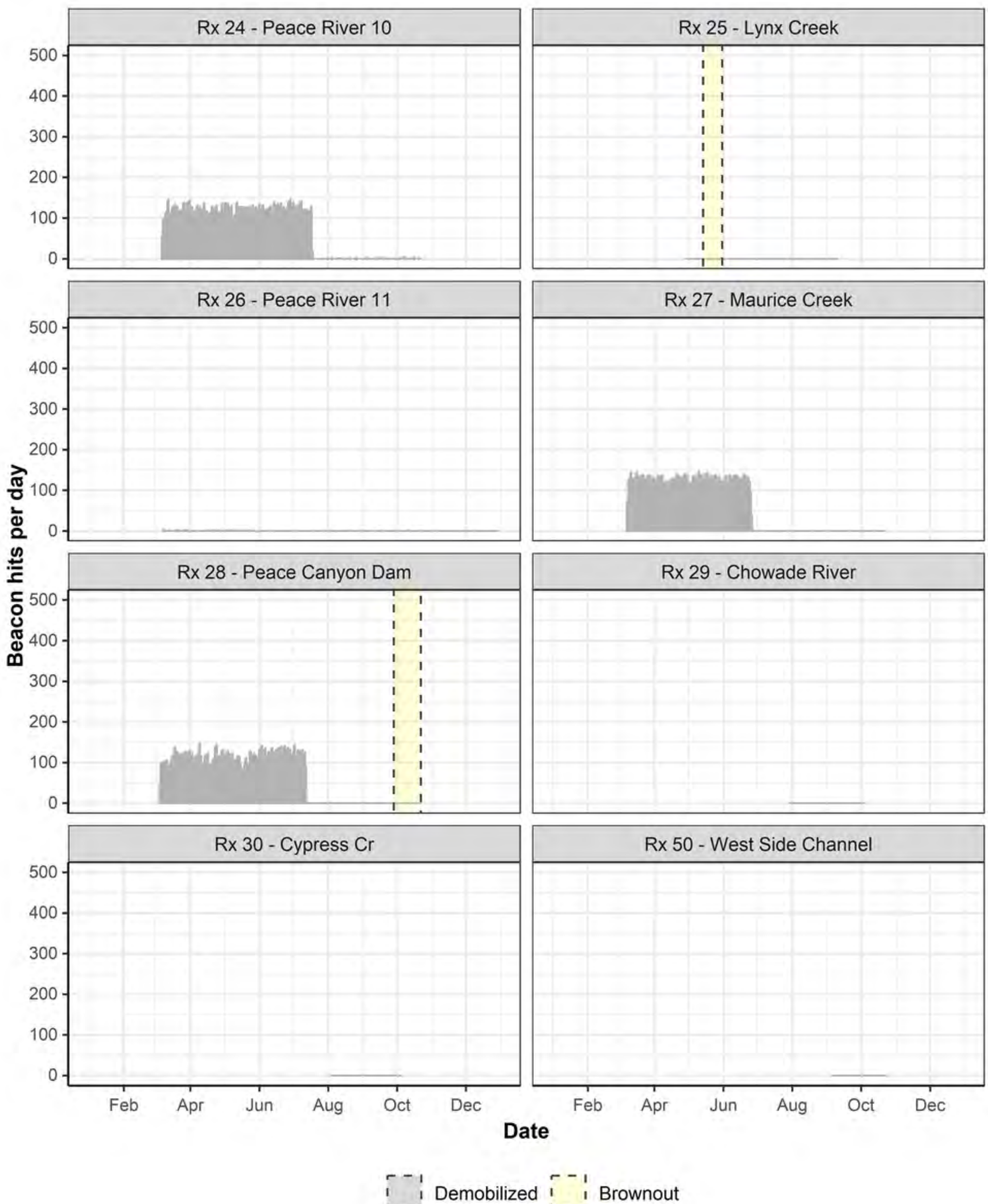


Figure B4 continued (part 4 of 7).

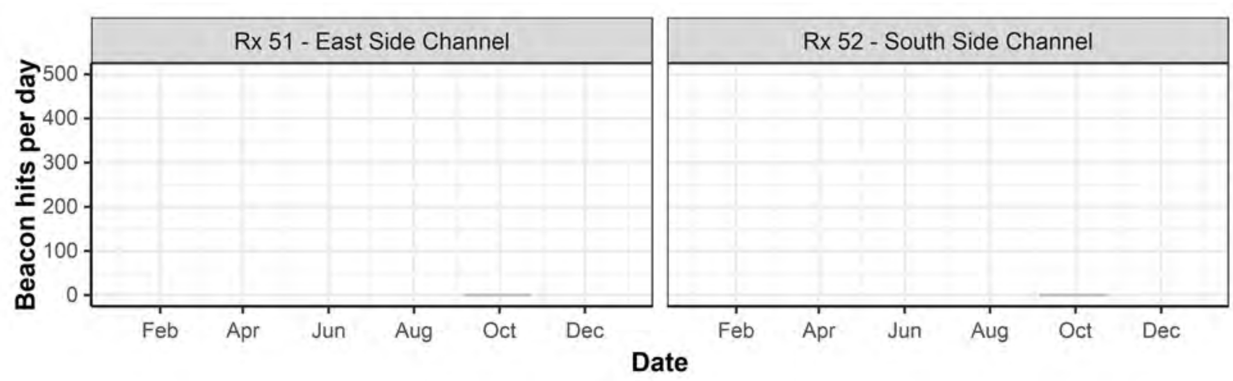


Figure B4 continued (part 5 of 7).

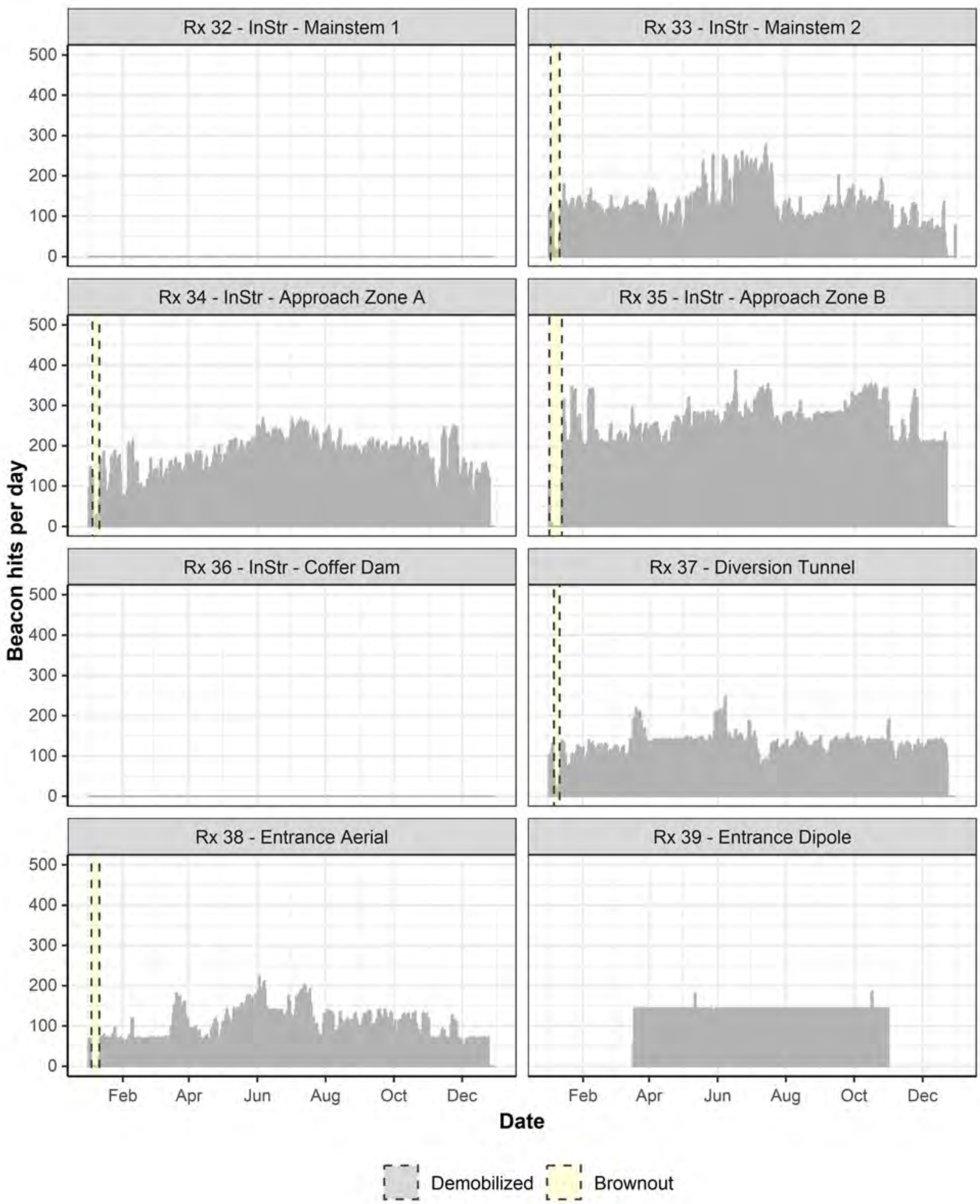


Figure B4 continued (part 6 of 7).

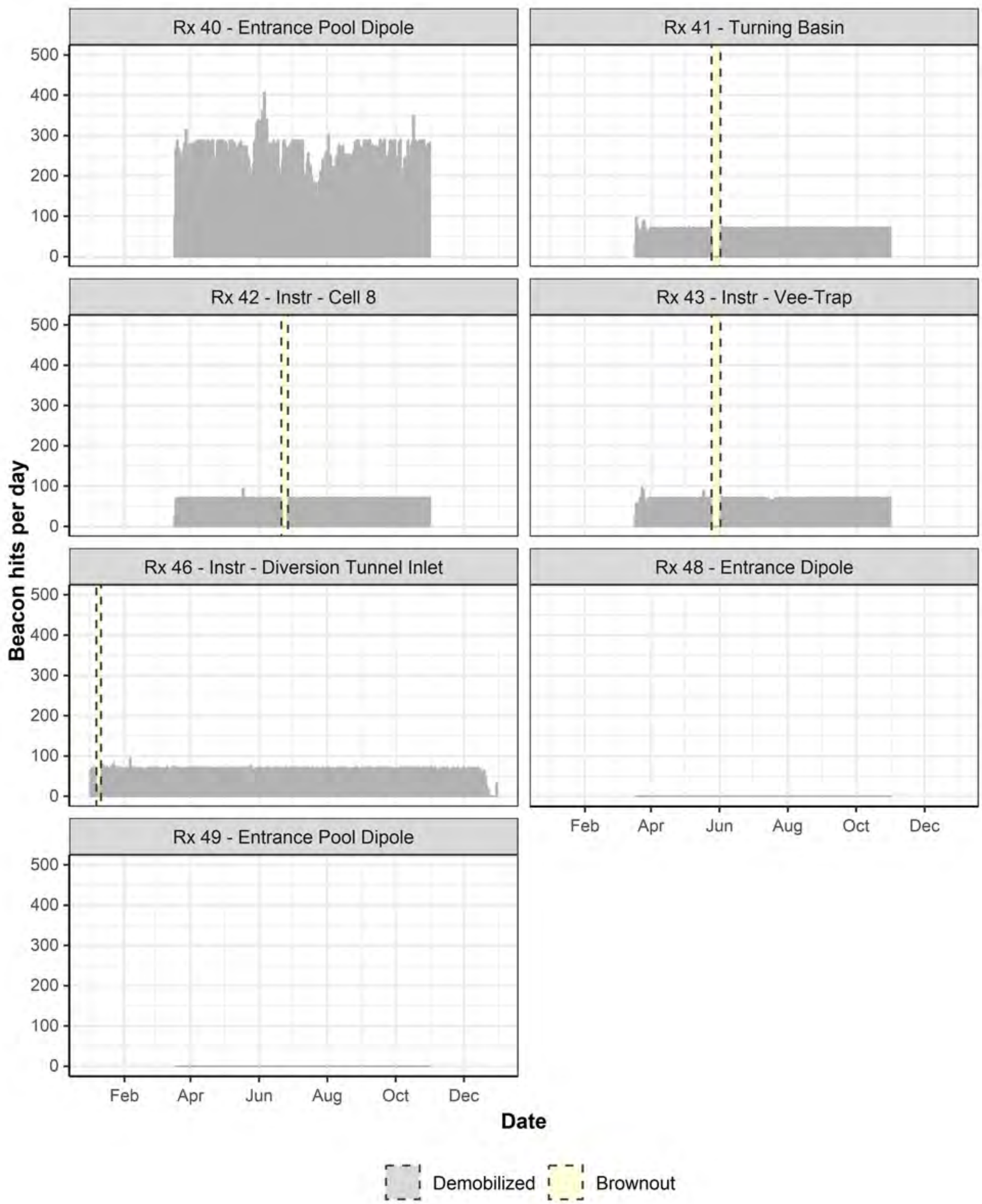


Figure B4 continued (part 7 of 7).

Appendix C. Site C Telemetry Database

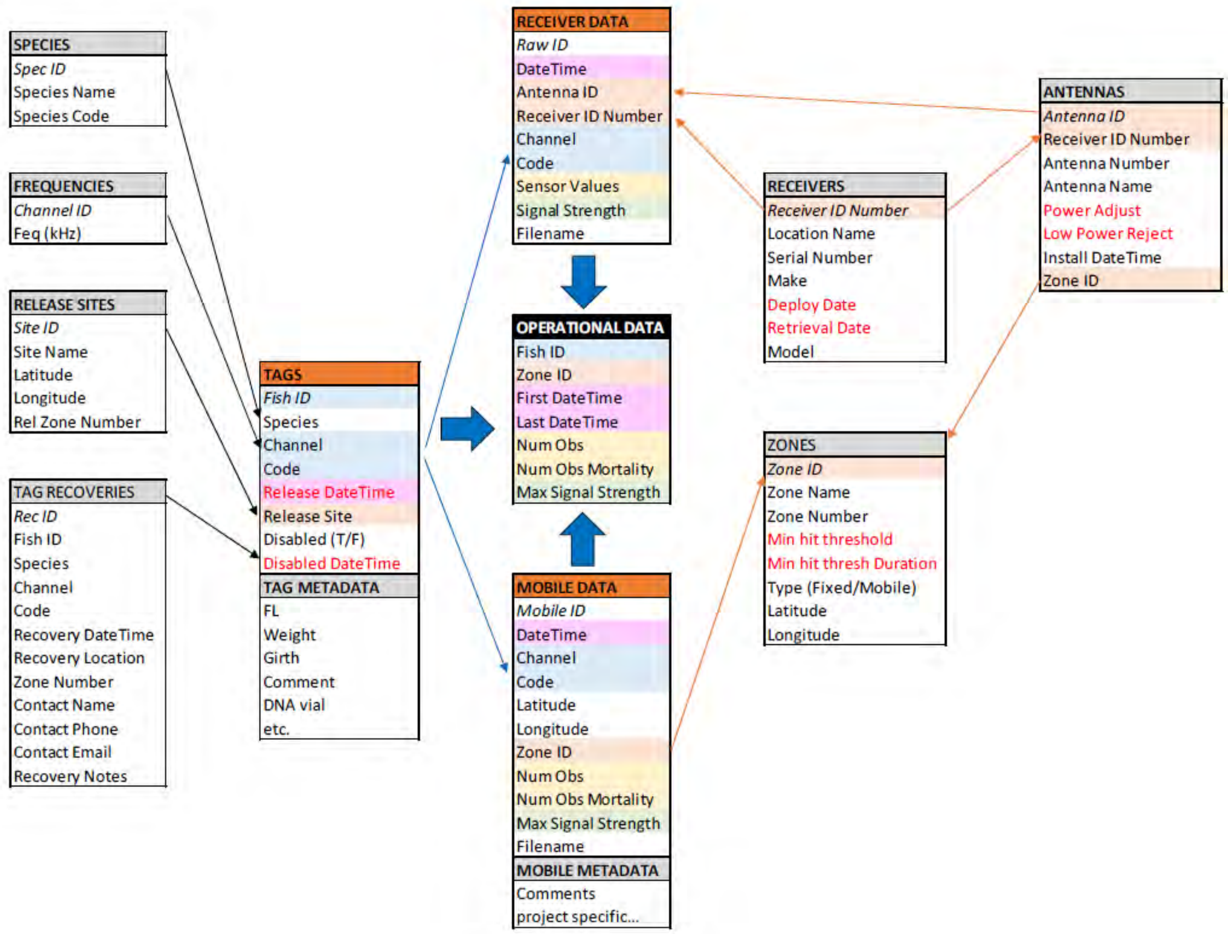


Figure C1. Visual representation of the database, displaying how each of the tables relate to each other.

Table C1. 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 C1
DetRadio_FilesImported	Record of SRX800 detection files imported	not displayed in Figure C1
EquipmentFunctionality	List of equipment inventory and status	not displayed in Figure C1
DownTime	Station outages with date ranges and notes	not displayed in Figure C1
StationDeployments	Station deployment locations and notes	not displayed in Figure C1
StationEquipment	Equipment inventory per station	not displayed in Figure C1

Table C2. Details for data requests from the Site C Fish Movement Database; including request and fulfillment dates along with information about the requester, fulfiller and data delivered.

Date Requested	Date Fufilled	Request Organization	Request Name	Request Contact (Email)	Fufiller Name	Fufiller Contact	Data Description
3-Aug-22	3-Aug-22	Instream Fisheries	Pete Moniz	pete@instream.net	David Robichaud	drobichaud@lgl.com	Number of tags that were active in 2021
3-Aug-22	3-Aug-22	Instream Fisheries	Pete Moniz	pete@instream.net	David Robichaud	drobichaud@lgl.com	list tags that would have been active in 2021
14-Sep-22	15-Sep-22	BC Hydro	Nich Burnett	nich.burnett@bchydro.com	Kyle Hatch	khatch@lgl.com	full, completely filtered (cleaned) dataset from summer 2019 to present in R format
14-Sep-22	22-Sep-22	BC Hydro	Nich Burnett	nich.burnett@bchydro.com	David Robichaud	drobichaud@lgl.com	full, completely filtered (cleaned) dataset from summer 2019 to present in R format
26-Oct-22	26-Oct-22	Golder	Dustin Ford	Dustin_Ford@golder.com	David Robichaud	drobichaud@lgl.com	Detections of Rainbow Trout in Farrell and Maurice creeks.
17-Nov-22	23-Nov-22	Instream Fisheries	Pete Moniz	pete@instream.net	David Robichaud	drobichaud@lgl.com	transmitter and fish metadata for tags released in 2022
19-Feb-23	21-Feb-23	Instream Fisheries	Katrina Cook	Katrina@instream.net	David Robichaud	drobichaud@lgl.com	Detections of some PIT tagged study fish that appeared to have borne multiple acoustic tags over the years
1-Aug-22	9-Aug-22	BC Hydro	Nich Burnett	nich.burnett@bchydro.com	Ben Cox	bcox@lgl.com	Video animation of Billy the Bull Trout (Tag 898) movements captured from Shiny app
14-Sep-22	6-Oct-22	BC Hydro	Nich Burnett	nich.burnett@bchydro.com	Ben Cox	bcox@lgl.com	Request Shiny app be ready for a 19 Oct meeting with a First Nation group.

Appendix D. Mobile Tracking Routes

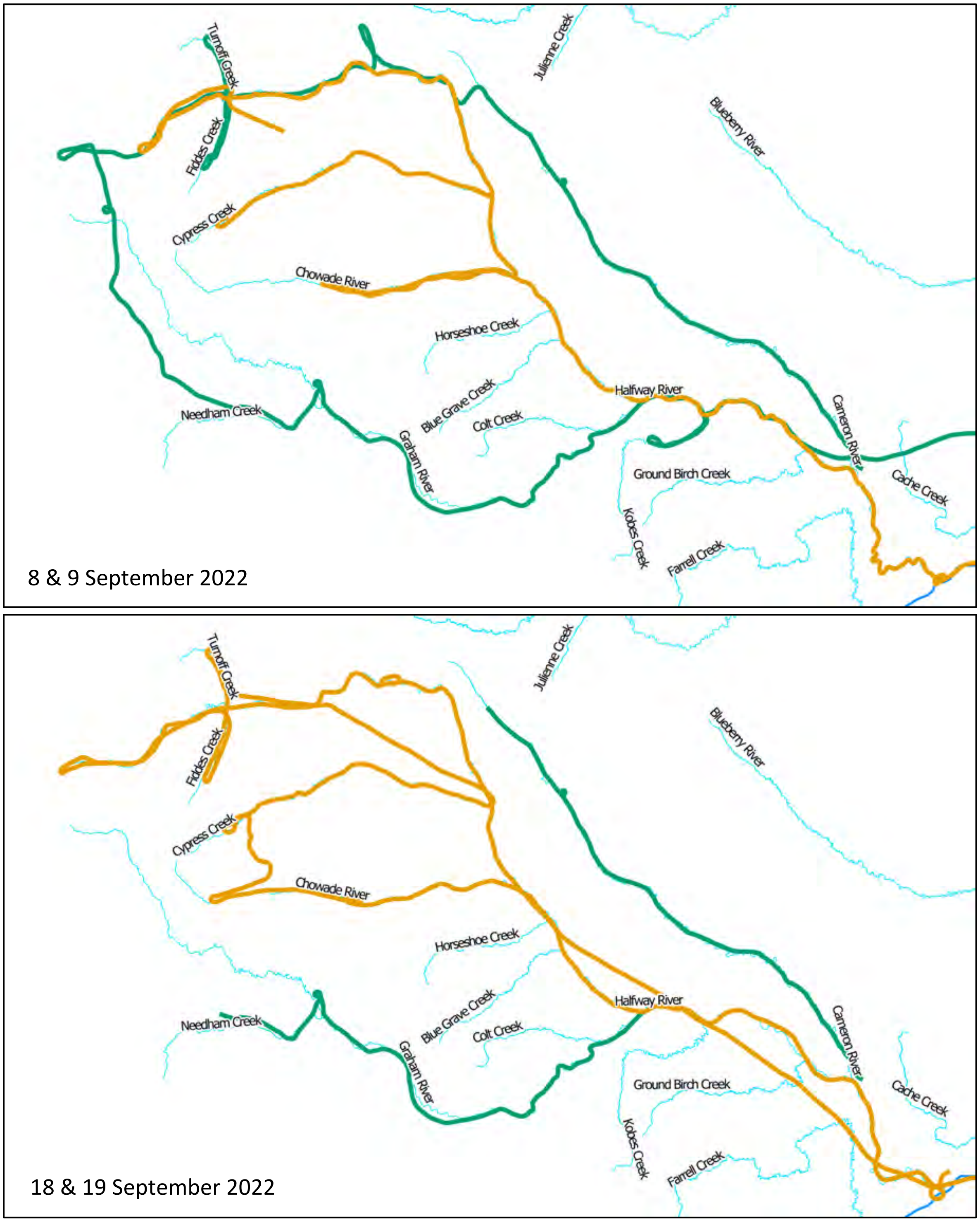


Figure D1. **Tracking routes (surveys took two flights – shown in orange and green – to complete) for two mobile-telemetry tracking surveys of the Halfway River watershed, September 2022 (see Table 5). Some overland flight segments have been removed for figure clarity.**

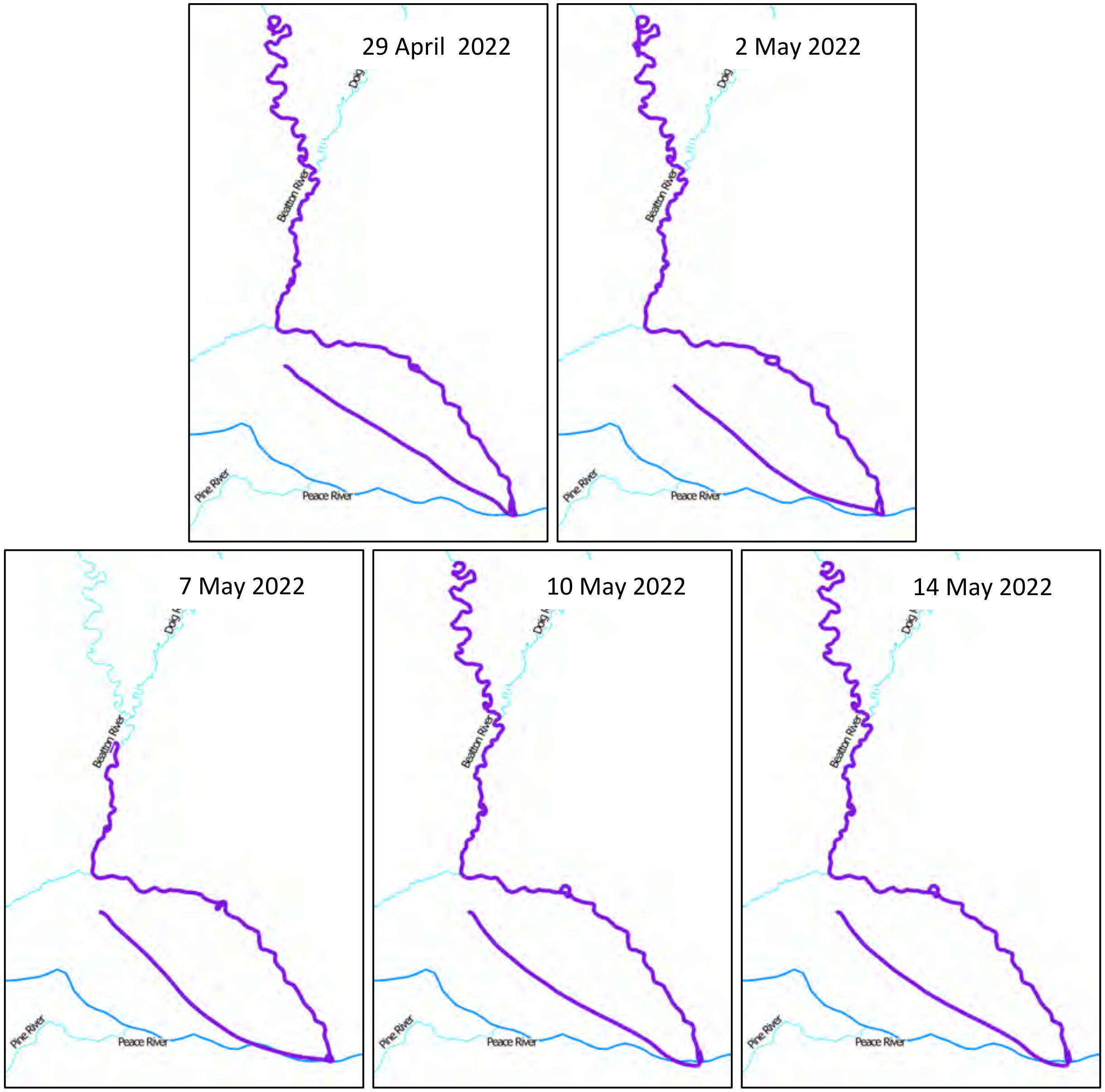


Figure D2. **Tracking route for ten mobile-telemetry tracking flights of the Beatton Rivers, April-June 2022. Continued overleaf. Details are in a separate report (Robichaud et al. 2023) that addresses the objectives of the Walleye Spawning and Rearing Use Survey (Mon-2 Task 2e).**

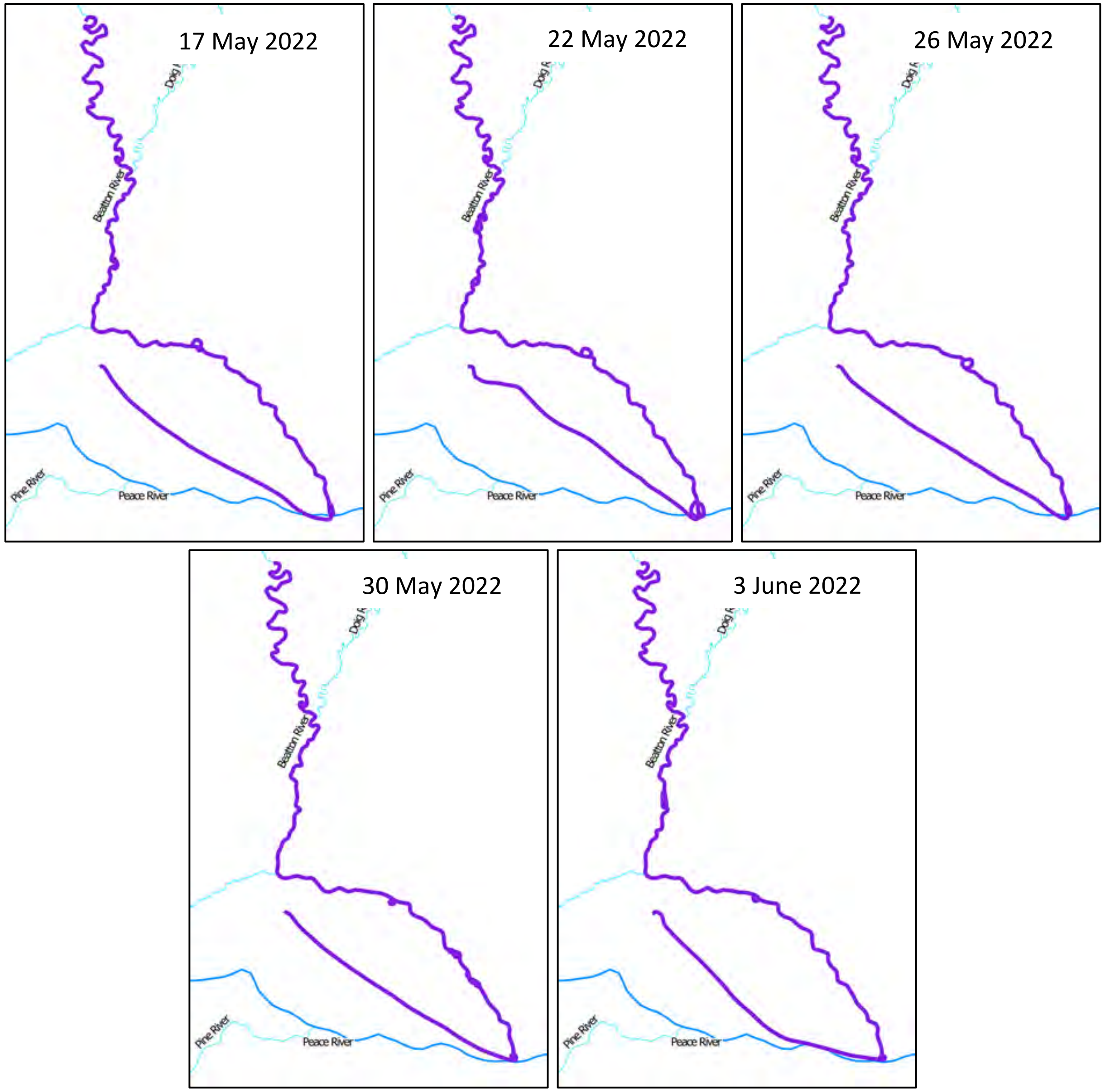


Figure D2 continued (page 2 of 2).

Appendix E. Additional Tracking Maps

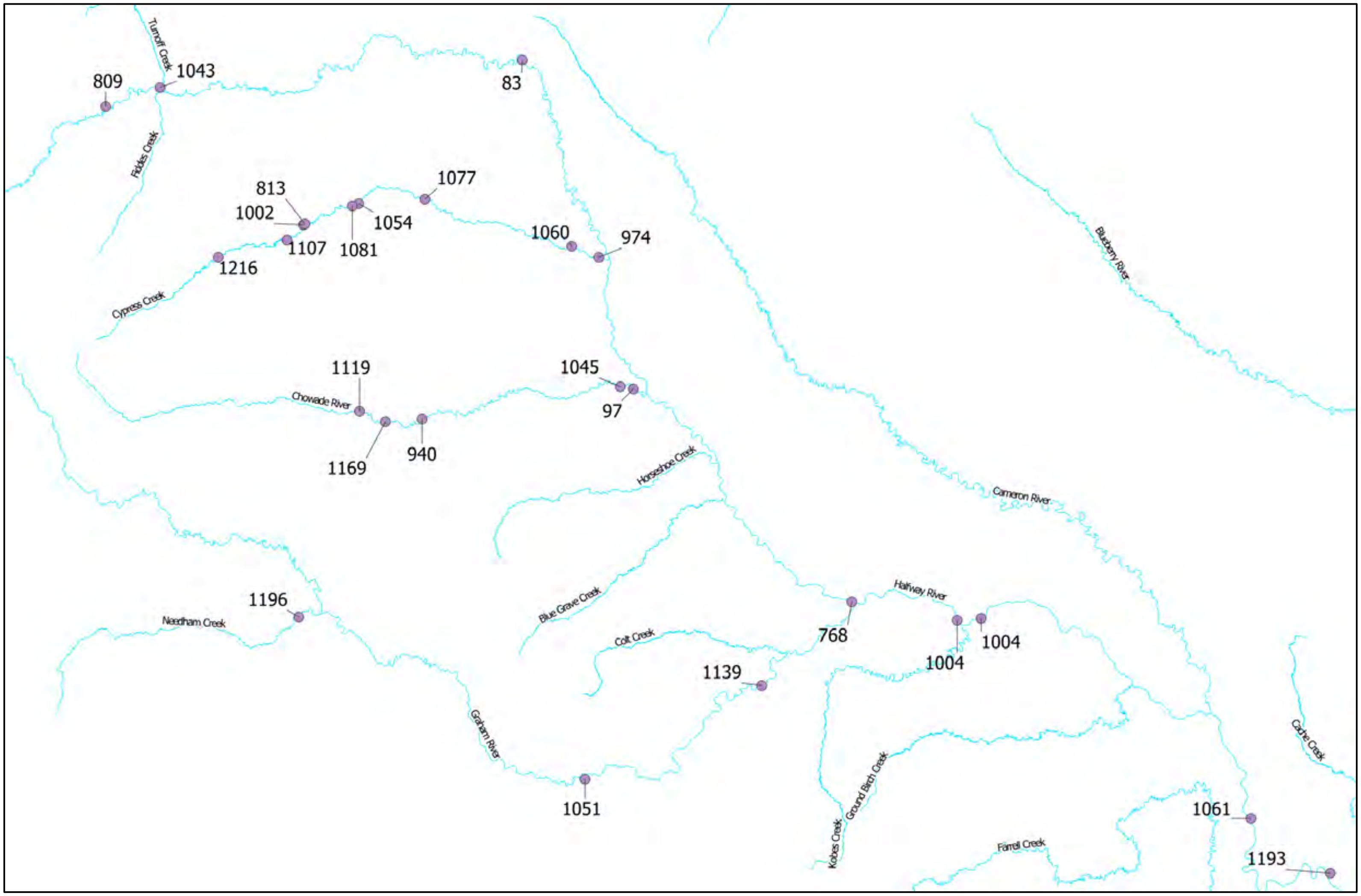


Figure E1. **Bull Trout detection locations, labeled with a unique Tag ID number, during the first of Halfway River mobile tracking surveys, 8 & 9 September 2022. Duplicates refer to study fish detected on multiple flight dates. Presumed shed tags (that had not moved since last year) are not shown.**

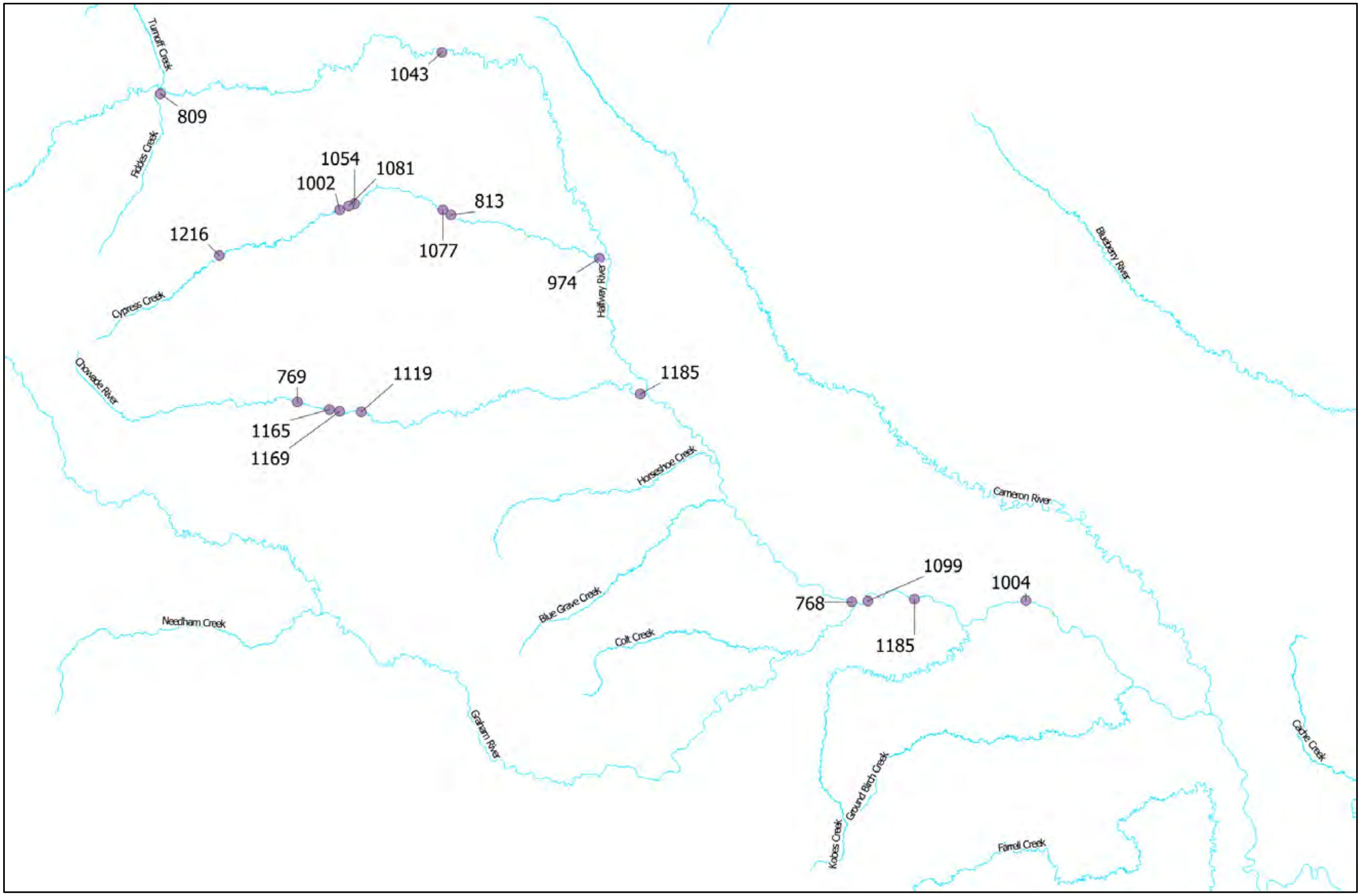


Figure E2. **Bull Trout detection locations, labeled with a unique Tag ID number, during the second of two Halfway River mobile tracking surveys, 18 & 19 September 2022. Presumed shed tags (that had not moved since last year) are not shown.**

Appendix F. Range Test Logistic Figures

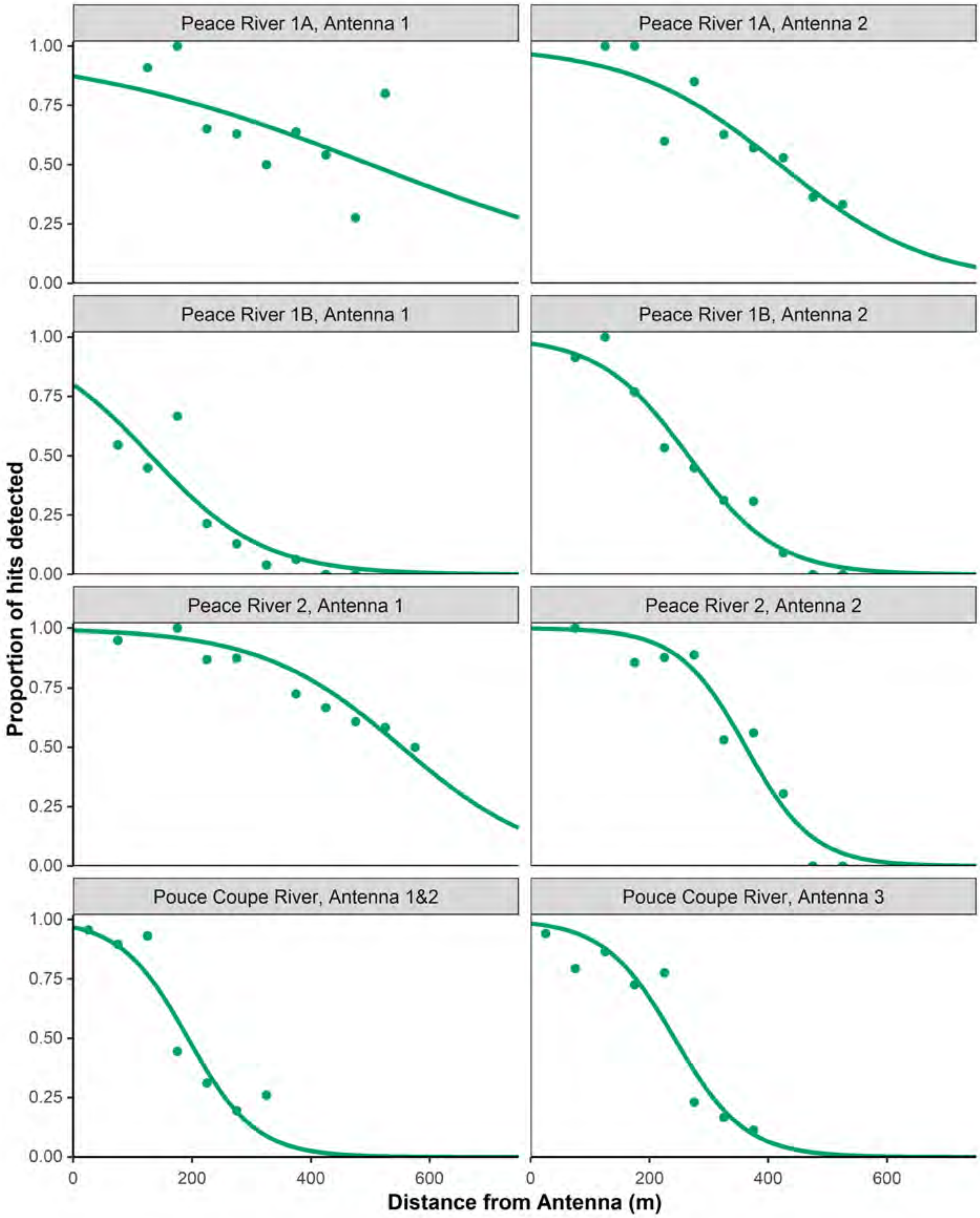


Figure F1. **Range test results for specific antennas at fixed stations tested in 2022. Figure continues on following eight pages.**

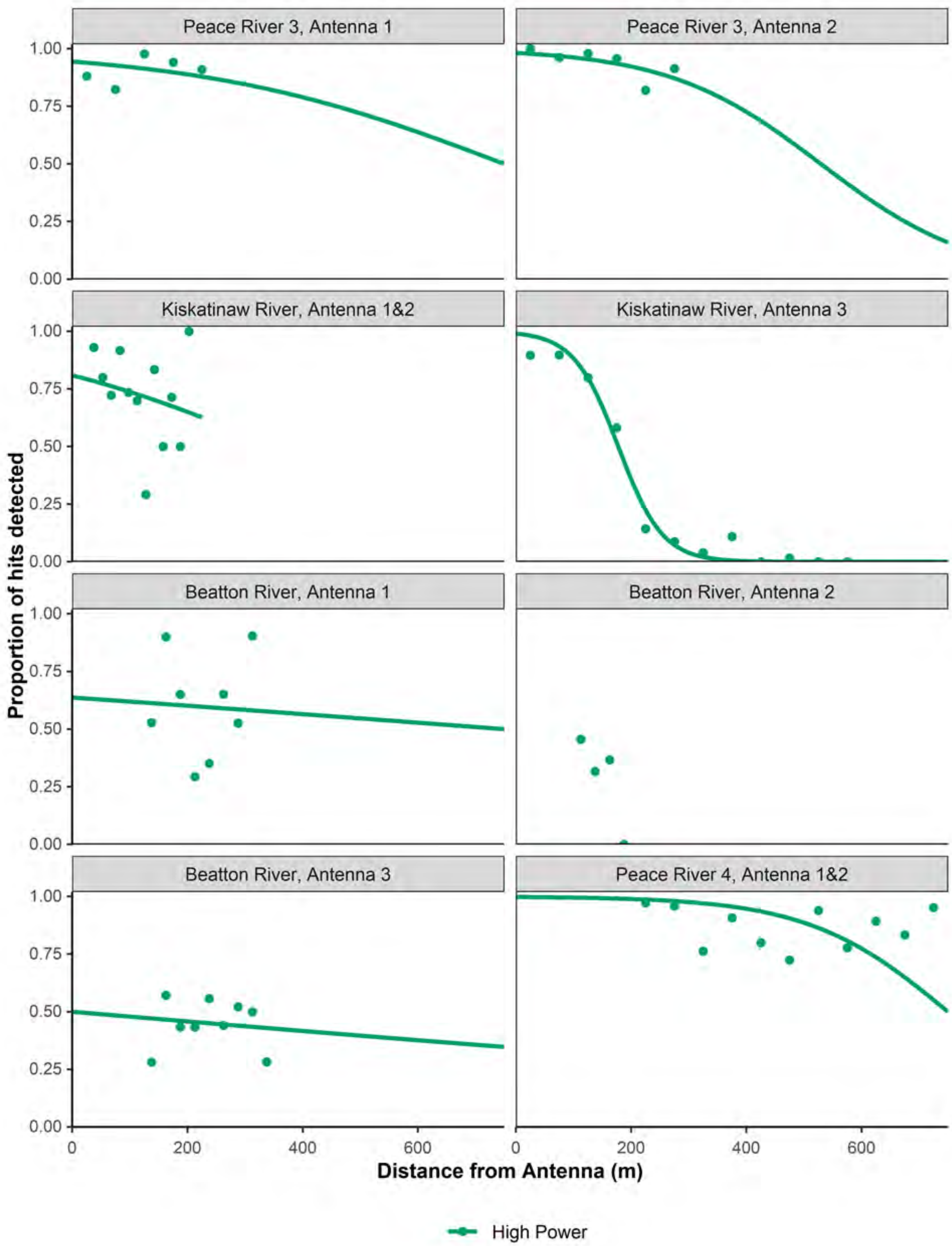


Figure F1 continued (part 2 of 9).

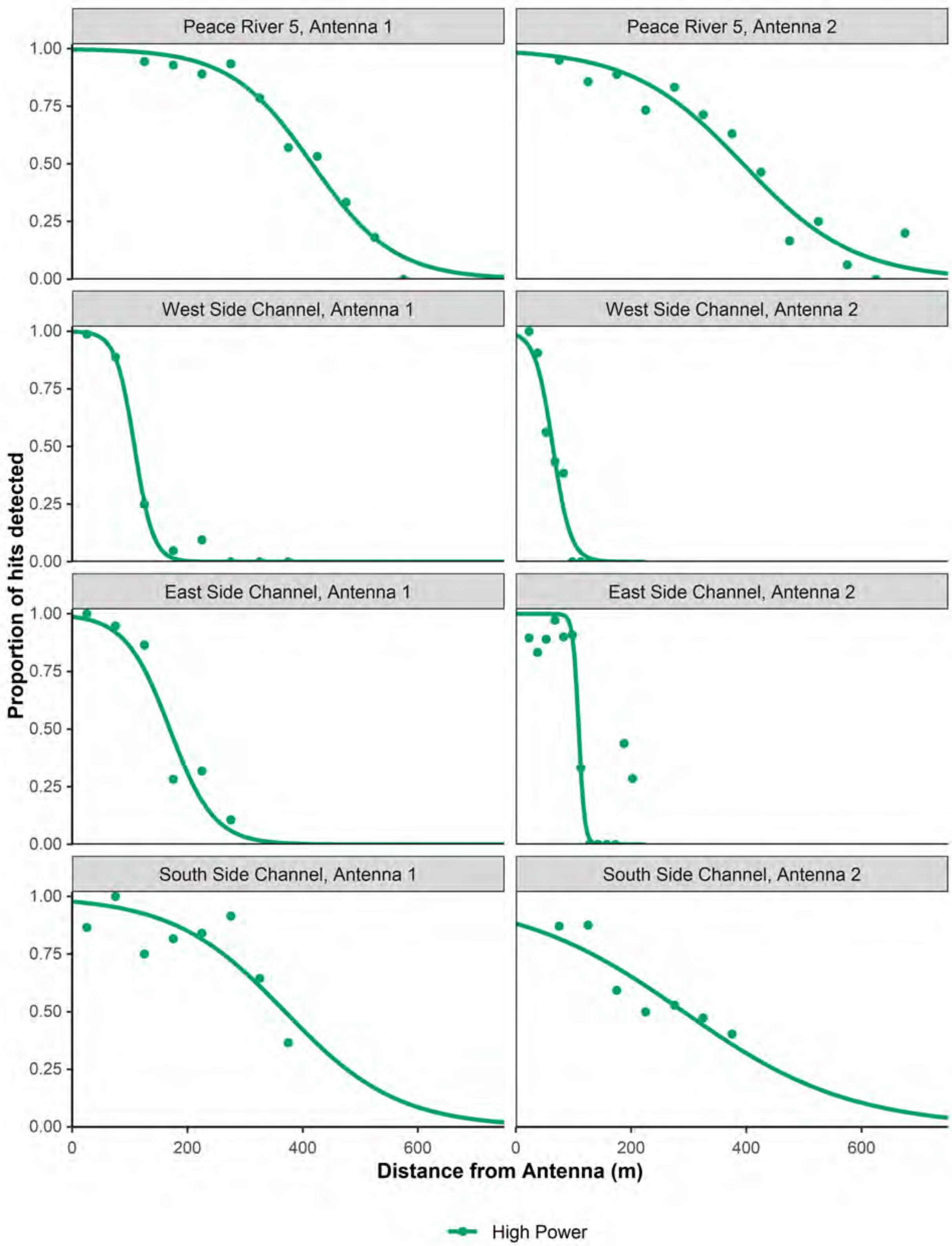


Figure F1 continued (part 3 of 9).

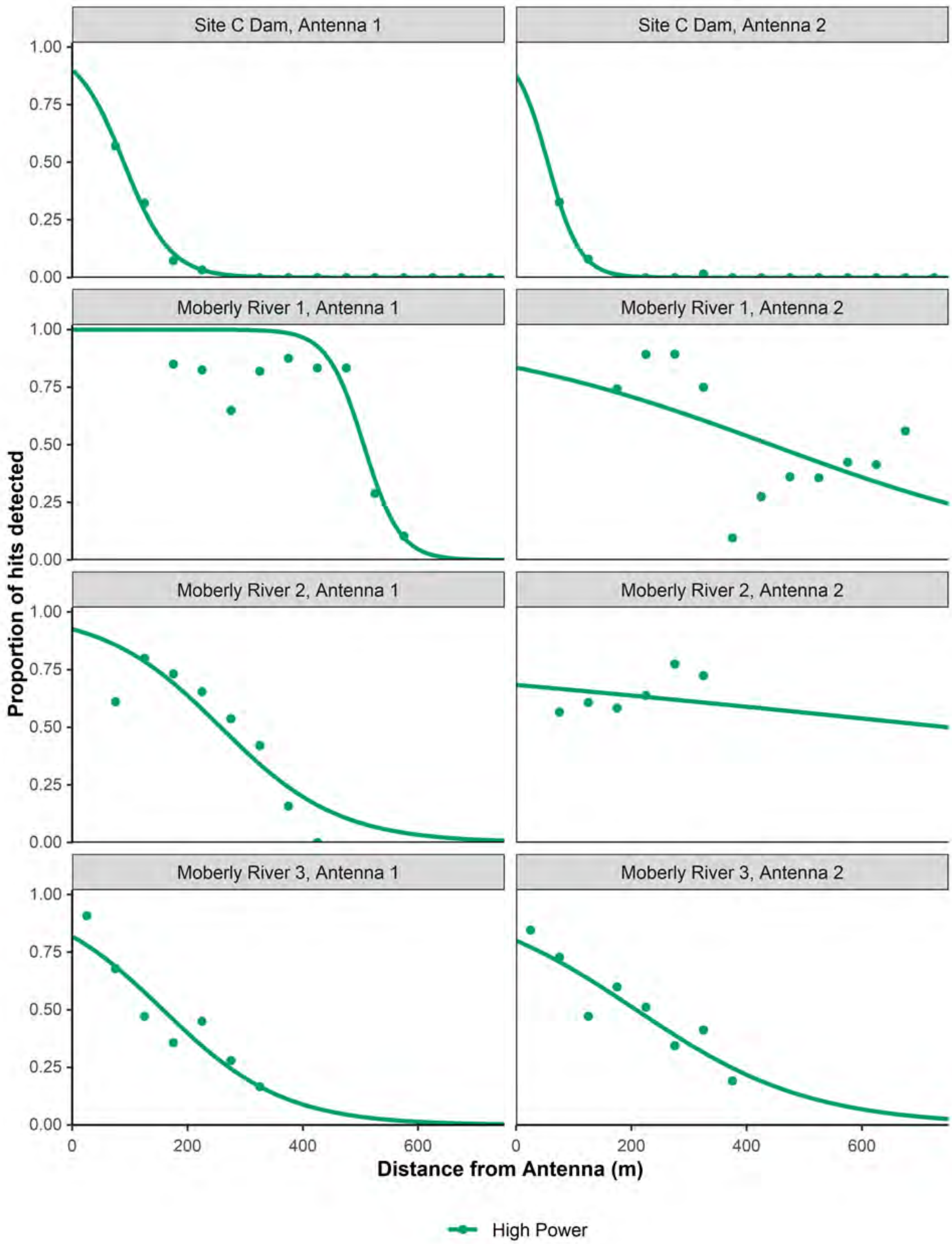


Figure F1 continued (part 4 of 9).

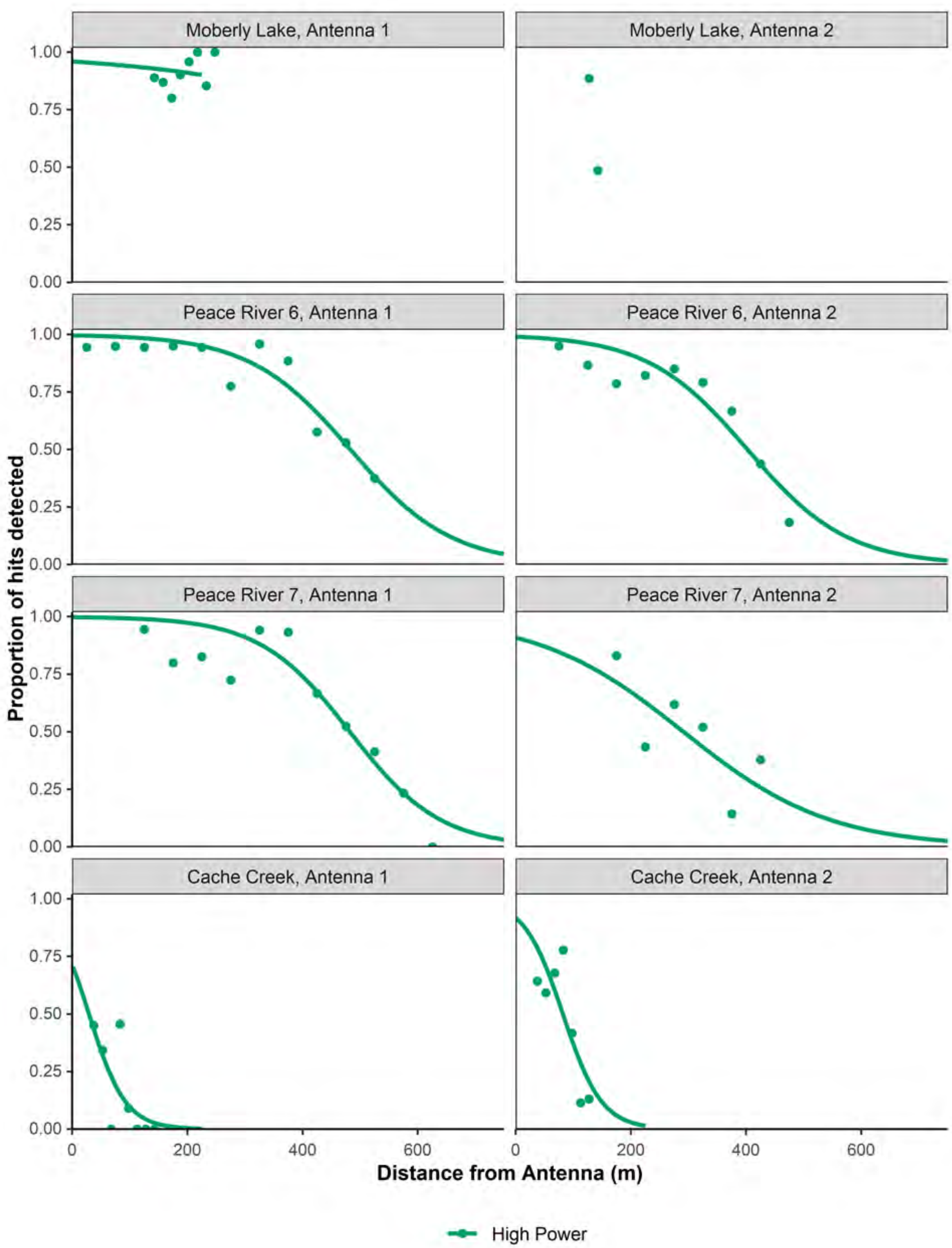


Figure F1 continued (part 5 of 9).

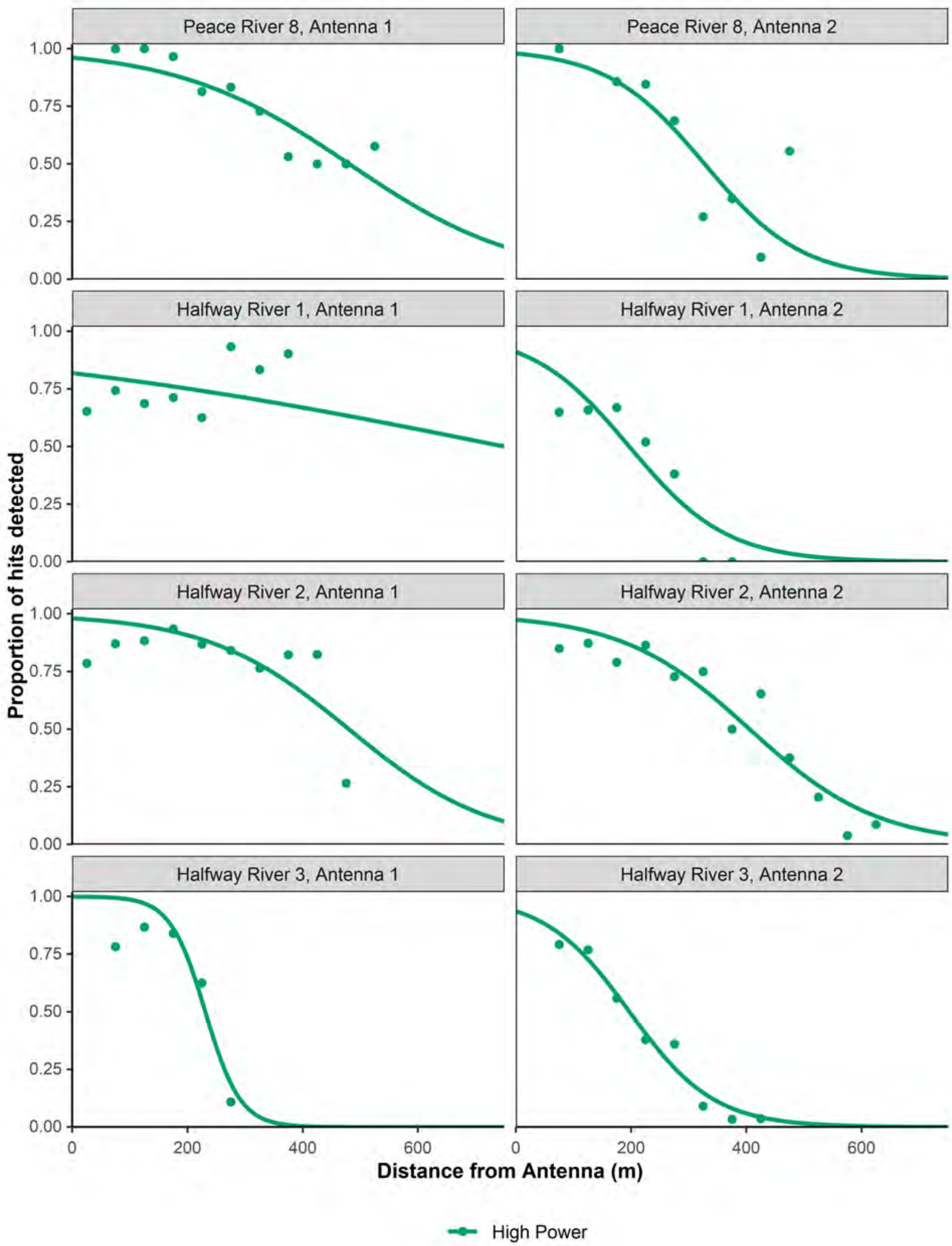


Figure F1 continued (part 6 of 9).

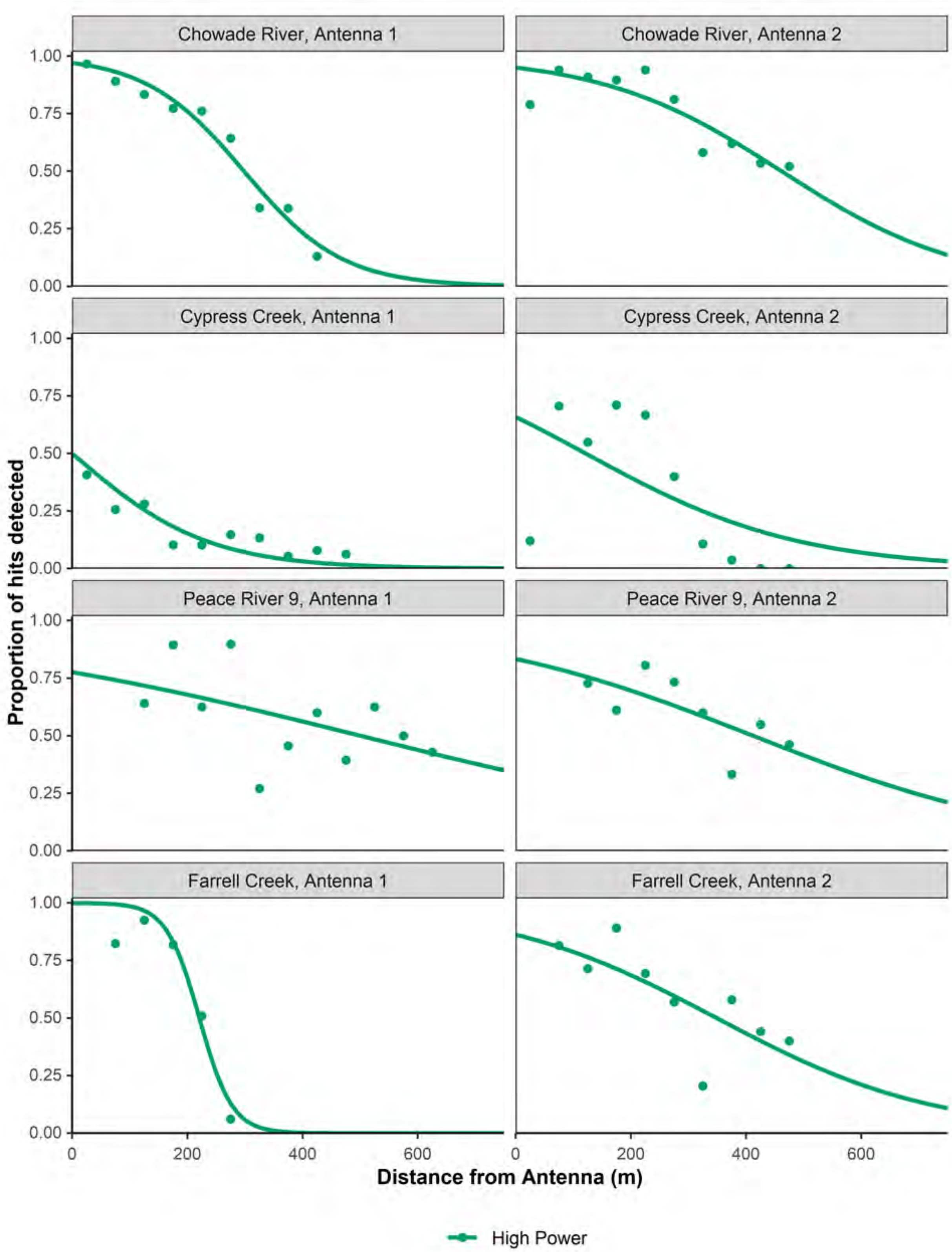


Figure F1 continued (part 7 of 9).

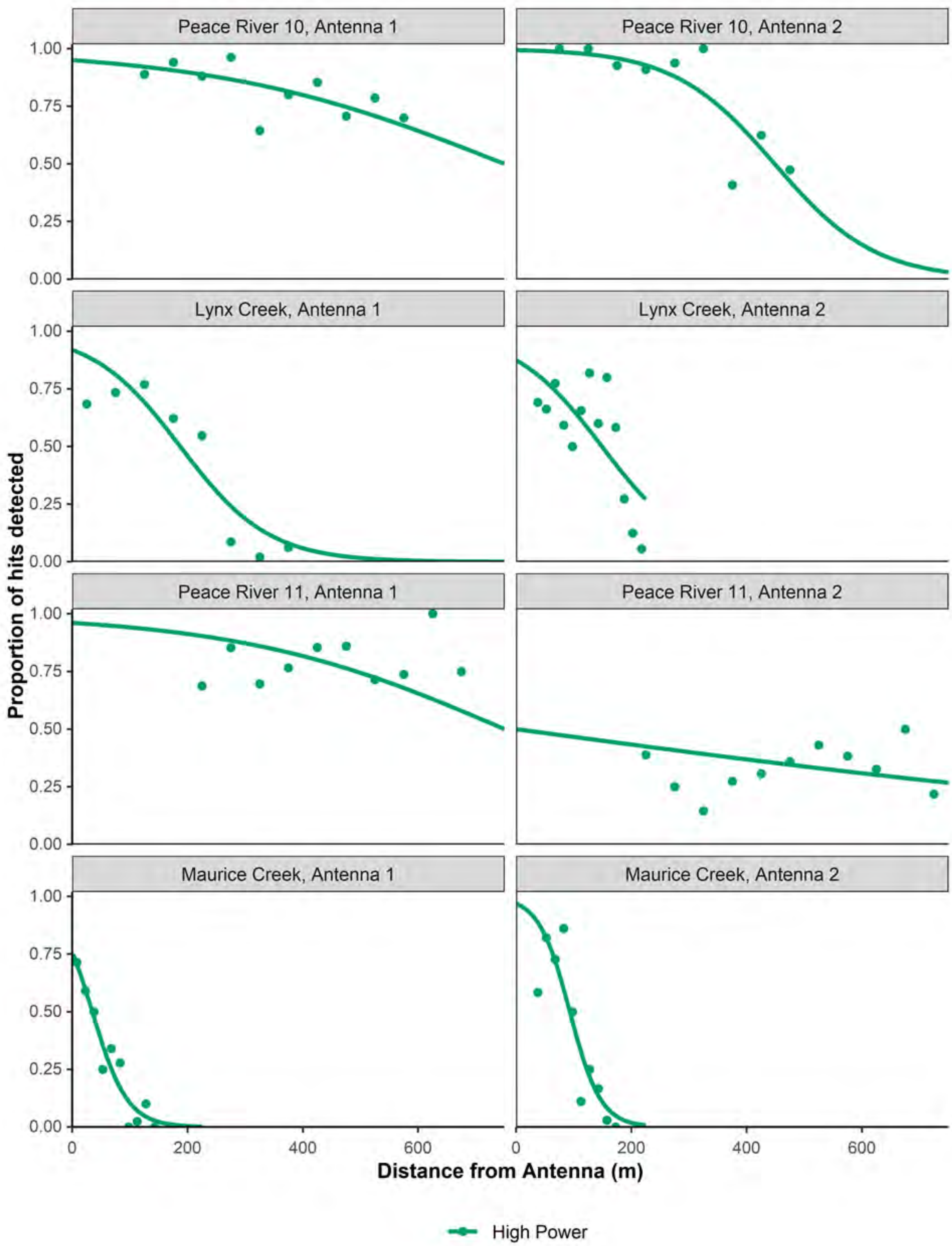


Figure F1 continued (part 8 of 9).

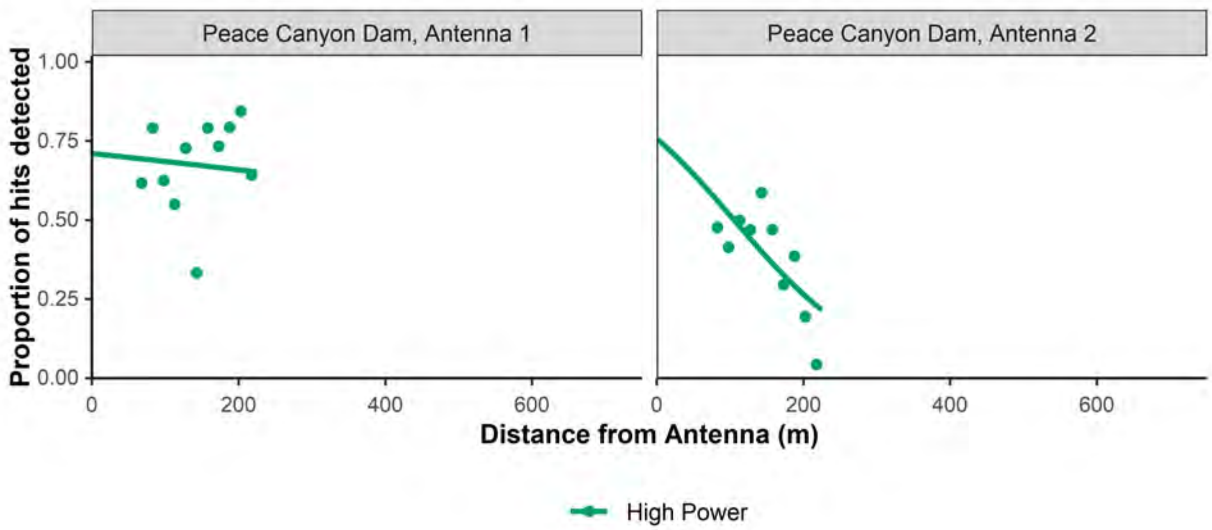


Figure F1 continued (part 9 of 9).