Seven Mile Project Water Use Plan

Seven Mile Subadult Bull Trout Entrainment Monitoring

Reference: SEVMON#2

Seven Mile Water Use Plan Monitoring Program: Subadult Bull Trout Distribution and Habitat Utilization in the Salmo River and Seven Mile Reservoir (Interim Report 2).

Study Period: Oct 2007 to Jan 2009.

Canadian Columbia River Inter-tribal Fisheries Commission

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Executive Summary

The primary objective of this monitoring study is to reduce uncertainty related to the use of the Seven Mile Reservoir by Salmo River subadult bull trout and the potential for entrainment through the dam. To test hypotheses regarding reservoir use, Salmo River subadult bull trout (260 - 464 mm FL) were captured by angling and implanted with radio transmitters (nanotags). Fourteen fish were tagged in October 2007 and another nine in October 2008. This interim report summarizes data collected from October 2007 to January 2009.

During the first 14 months of observations, four radio tagged subadult bull trout were monitored in Seven Mile Reservoir. BT15 (405 mm FL) and BT32 (450 mm FL) were tagged in the Salmo River while BT184 (273 mm FL) and BT167 (500 mm FL) were tagged in the tailrace of Boundary Dam by Seattle City Light investigators. Genetic analysis confirmed that BT184 was of Salmo River origin and BT167 was of Trestle Creek origin. A fifth subadult bull trout captured in Seven Mile was too small to tag (250 mm FL) and also confirmed to be of Trestle Creek origin. Trestle Creek is a tributary to Lake Pend d'Oreille located 209 km and three dams upstream of the Salmo River confluence with the Seven Mile Reservoir/Pend d'Oreille River. The Trestle Creek bull trout (BT167) entered the Salmo River on January 18 2009. BT15 entered the reservoir on February 29 2008 and BT32 on November 01 2008.

The preliminary results of the monitoring program show that some subadult bull trout from the Salmo River do utilize the Seven Mile Reservoir (n=3, Hypothesis 1). All four radio tagged subadult bull trout were observed moving between the Salmo River and the tailrace of Boundary Dam. These fish remained in the reservoir during the summer, which is inconsistent with sub-hypothesis one that warm water temperatures limit use of the reservoir to fall, winter, and spring months. There were no detections of radio tagged bull trout in the tailrace of the Seven Mile Project (Hypothesis 2). Of the four radio-tagged bull trout in the reservoir, two had transmitters that expired while the fish were in the reservoir (BT184 and BT15) and the other two remain in the reservoir with transmitters active until April 2010 (BT167 and BT32).

Both subadult bull trout tagged in the Salmo River migrated to Seven Mile Reservoir during minimum temperatures and low flows (Hypothesis 3). In summer, these tagged bull trout moved towards confluences (Red Bird Creek and Salmo River) when reservoir temperatures approached 20.0^{o}C. The upper incipient lethal temperature for bull trout is reported at 20.9^{o}C. Temperature stratification in Seven Mile Reservoir may be influenced by discharge as cooler bottom reservoir temperatures were observed in a low flow year (17.9^{o}C mean daily maximum 2007) than in a higher than average discharge year (21.0^{o}C mean daily maximum 2008).

There has been substantial use of the Salmo River by various species tagged in the Pend d'Oreille River during the Boundary Dam telemetry studies. Six of the seven mountain whitefish (86%) confirmed alive after release into the Boundary tailrace entered the Salmo River, the majority during freshet of 2008. These fish were distributed as far as 22.5 km upstream and remained in the Salmo River until the fall. Three triploid rainbow trout, one naturalized rainbow trout, and two cutthroat trout also entered the Salmo River. Three of these rainbow trout and one cutthroat trout were entrained through Boundary Dam. Six of the total seven fish that were entrained through Boundary Dam passed in spring and summer during high flows, high power generation, and high spill.

Acknowledgements

The Seven Mile subadult bull trout entrainment monitoring is a Columbia River Water Use Plan (WUP) requirement implemented by BC Hydro, as specified in the Provincial Comptroller of Water Rights Columbia River WUP Order. Bob Westcott and Doug Johnson, BC Hydro project managers, are gratefully acknowledged for their assistance and support in the delivery of this program. Bob Westcott and Guy Martel of BC Hydro conducted field visits and editorial reviews to provide quality assurance in the data.

The Canadian Columbia River Inter-Tribal Fisheries Commission (CCRIFC) was the lead agency contracted by BC Hydro to conduct the subadult bull trout entrainment monitoring. Bill Green, Jamie Cristales and Jon Bisset are acknowledged for their contributions to the management and implementation of this program. Golder Associates (Paul Grutter) maintained the Seven Mile Dam tailrace monitoring station as a sub-contract to BC Hydro.

Westslope Fisheries Ltd. biologists Angela Prince and Scott Cope along with technicians Jim Clarricoates, Mark Thomas, and Kyle Shottanana (CCRIFC), conducted the field surveys.

Eagle Vision Geomatics & Archaeology Ltd. (Jose Galdamez), provided mapping and GIS services.

Al Solonsky (Seattle City Light), Jason Olsen (Kalispel Tribe), Bao Le (Longview and Associates), and Paul Grutter (Golder and Associates) assisted with data exchange across telemetry programs in the study area.

In addition we would like to thank all those private landowners that assisted in the guidance of the assessment and granted us access to the Salmo River.

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1. Introduction

This investigation is a requirement of the Water Use Plan for the BC Hydro Seven Mile Project and is part of a larger program designed to examine the risk of bull trout entrainment through the Seven Mile Dam. The larger project is intended to address the following management questions (BC Hydro 2007):

1) Whether Salmo River subadult bull trout (*Salvelinus confluentus*) are entrained through the dam.

2) Whether dam operations (primarily deep drawdowns during the winter) affect the rate of entrainment.

3) Whether entrainment has an effect on the bull trout population in the Salmo River watershed.

There is currently little information as to whether Salmo River subadult bull trout use the reservoir. The primary objective of this monitoring study is to reduce this uncertainty and to assess the potential for entrainment of subadult bull trout through the dam. A secondary objective is to obtain information on subadult bull trout life history and habitat use in the Salmo River system. This information will help to identify factors affecting population recovery and inform future operating decisions of the Seven Mile Dam.

This report summarizes the preliminary results (14 months) of a three year telemetry study designed to determine whether subadult bull trout from the Salmo River migrate to the Seven Mile Reservoir and are at risk of entrainment through the dam. Specific objectives of the 2008 telemetry study were:

- Capture and radio tag twenty subadult bull trout from the Salmo River;
- Monitor fish distribution and movement to identify and characterize critical habitats;
- Collect environmental data (temperature and discharge) from the Salmo River, Seven Mile Reservoir and the Seven Mile generating station tailrace.

1.1. Study Area

The Pend d'Oreille River is a tributary of the Columbia River. The river drains an area of 66 800 sq. km. mostly through the Clark Fork and its tributaries in western Montana, including a portion of the Flathead River in southeastern British Columbia. The full drainage basin of the river and its tributaries accounts for 43% of the entire Columbia River Basin. The Pend d'Oreille River begins at Lake Pend d'Oreille in Bonner County, Idaho, draining the lake from its western end near Sandpoint. The Clark Fork River enters the lake from its eastern end and Trestle Creek enters from the northeast. The Pend d'Oreille flows west, receiving the Priest River from the north, then flows west to Washington. Once in Washington, the river turns north, flowing along the eastern side of the Selkirk Mountains. It flows roughly parallel to the Idaho border for approximately 80 km, through the Colville National Forest, past Tiger and Metaline Falls. It crosses the international border into southeastern British Columbia, looping west for about 24

km and joining the Columbia from the east, approximately 3.2 km north of the international border and 8 km south of Montrose, B.C.

Located on the Pend d'Oreille River approximately 15 km southeast of the city of Trail B.C. (Figure 1.1), the Seven-Mile project consists of a 65 m high concrete gravity dam, with a crest length of 350 m, and a four-unit 805 MW powerplant. Due to the steep incised characteristics of the valley, the Seven Mile Project has the highest power yield per acre flooded of any operational hydroelectric plant in British Columbia. There are three hydroelectric facilities on the Pend d'Oreille River upstream of the facility: Boundary (Seattle City Light), Box Canyon (Pend d'Oreille County), and Albeni Falls (U.S. Army Corps of Engineers) with the closest being Seattle City Light's (SCL) Boundary Project located 16 kilometers upstream. Teck-Cominco's Waneta Project is located 9 km downstream. None of the five dams on the Pend d'Oreille provide for fish passage.

Seven Mile Reservoir is that portion of the Pend d'Oreille River (16 km) bound by the Seven Mile and Boundary facilities. Inflow is regulated by upstream projects, and is generally high from the spring runoff starting April/May and tapering off in August. The run-of-river reservoir fluctuates daily but the magnitude and rate of fluctuation is restricted to avoid bank erosion and in the summer further restricted for recreation. For stability of reservoir slopes, the maximum permissible rate of reservoir drawdown in the winter is 6.0 m per day and 1.2 m per hour. In the summer (01 June to 31 August) the number of days in which daily fluctuations in reservoir elevation exceeds 4.0 m per day and 0.6 m per hour is limited to ten days or less. The reservoir level is licensed to operate between 527.3 and 514.8 m; however, it usually operates at levels near 525 m. In the last five years of operations, the deeper drafts (to elevations less than 522 m) occurred three to six times per year primarily in the winter. A key management question was whether dam operations (primarily deep drawdowns during the winter) affect the rate of entrainment (BC Hydro 2007).

The Salmo River is a tributary of the Pend d'Oreille River located 12 km southeast of Nelson B.C. and flows in a southerly direction through the town of Salmo and confluences with the Pend d'Oreille River approximately 10 km upstream (south) of the Seven Mile Project and 6 km downstream of Boundary (Figure 1.1). The Salmo River drainage basin covers a total area of approximately 1,230 km^2. Mean annual discharge in the Salmo River is 31.84 cms (range 17.3 to 48.3 cms, 1949-2006 Water Survey of Canada Station No. 08NE074). The dominant biogeoclimatic zone at higher elevations is Englemann Spruce-Subalpine Fir and at lower elevations is Cedar-Hemlock (Braumandl and Curran 1992).

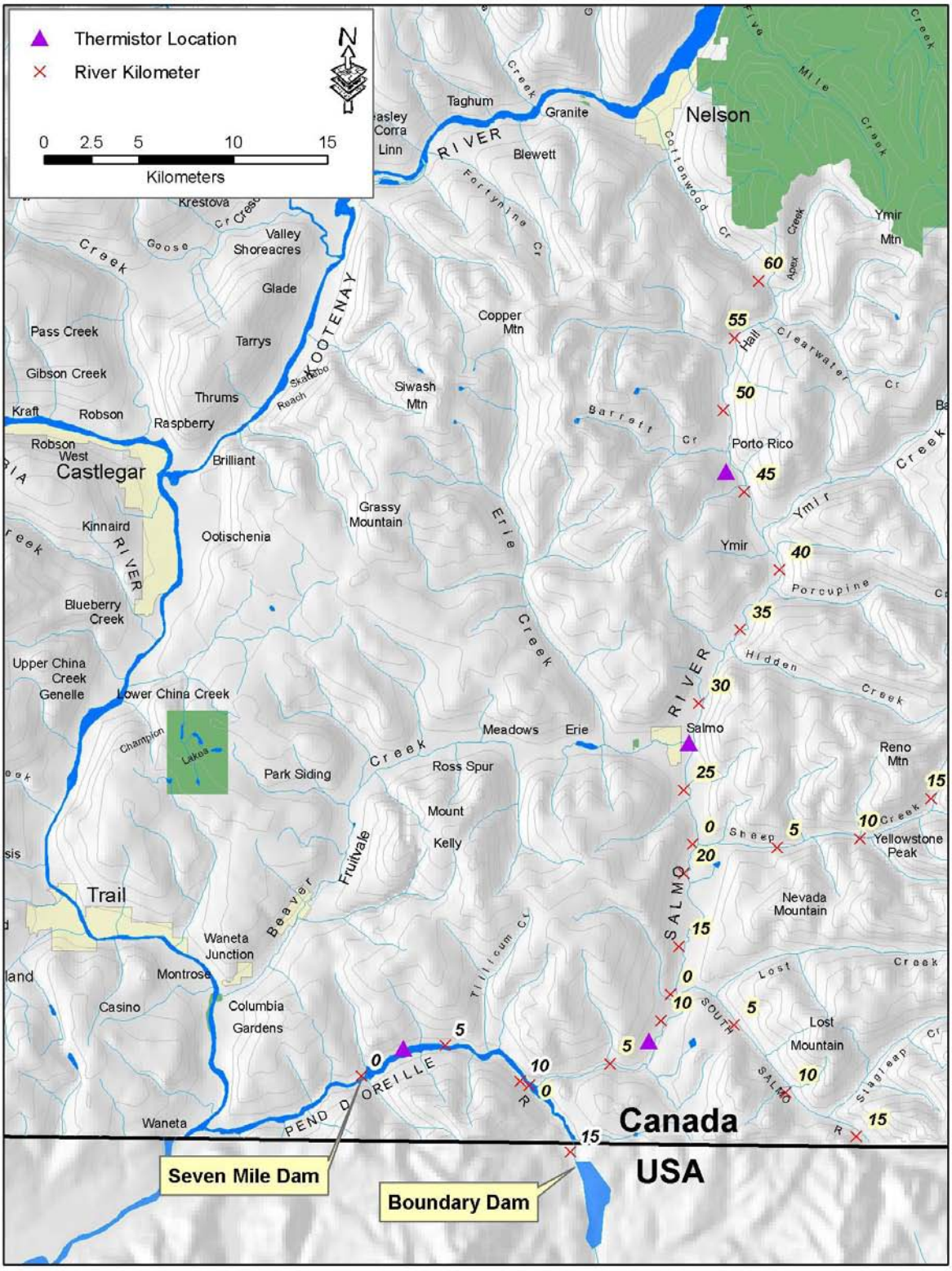

Figure 1.1 Subadult bull trout study area showing distance (river kilometers) from the Seven Mile Dam (white) and the Salmo/Pend'dOreille River confluence (yellow).

2. Methods

2.1. Capture and Tagging

Subadult bull trout were captured by angling with artificial flies and bait when water temperatures were < 15^{o}C. While alternate capture methods were explored (i.e., traps and night time dip netting; Bonneau et al. 1995), angling proved to be the only method successful in capturing the targeted age class (> 4 years of age, BC Hydro 2007).

Given the plasticity of age and size at maturity in bull trout populations, there was some uncertainty regarding life stage (i.e., adult vs. subadult). To address concerns, subadults were targeted in mid to lower mainstem river habitats during and immediately following the spawning period. Since repetitive spawning in the Salmo River bull trout population is reported at 85% (Baxter 2002), maturity for the majority of the population may be determined from external secondary sexual characteristics thereby reducing the need for invasive procedures and minimizing handling stress. In addition, a fall activation date ensured that all nano tags (lifespan = 6 to 12 months) were operational during the winter, when deep drawdowns in the reservoir primarily occur, to address key management questions (BC Hydro 2007).

An external exam was conducted on all bull trout. Characteristics assessed included length, fin condition (abrasion results from digging redds), ovipositor extension, coloring (mature fish often appear yellow or orange), and kype. Fish less than 450 mm FL were anaesthetized and examined internally with an otoscope to confirm reproductive status.

Captured fish were allowed to recover their oxygen deficit (created during capture) in an instream fish sleeve for 30 minutes prior to being anaesthetized and processed. Transmitters were surgically implanted on site according to the 2% rule (Winter 1983). Two sizes of coded transmitters were used: 10 large tags (NTC 6-2) for fish > 255 g and 10 small tags (NTC 6-1) for fish weighing between 140-250 g (150.760 MHz Lotek Engineering Inc. tags with a 5 sec burst rate). The smaller transmitters are estimated to last 6 months (80% of 232 days) and weigh 2.8 g while the large ones last one year (80% of 441 days) and weigh 4.5 g. Twenty NTC 6-2 tags with a 10 second burst rate were ordered in 2008 to extend the guaranteed lifespan to 542 days or 18 months.

Fish were anaesthetized in a 40 L bath of river water containing 2.0 ml clove oil yielding bath concentrations of 50 mg/l. Clove oil is a safe, inexpensive, and effective anaesthetic suitable for invasive procedures in the field (Prince and Powell 2000, Peake 1998, Anderson et al. 1997). The lowest effective dose of clove oil is recommended as time to recovery of equilibrium and fear response in salmonids has been shown to increase exponentially with exposure time (Keene et al. 1998). Because of its low solubility in water, the clove oil was first dissolved in 10-ml of ethanol (95%) before being added to the river water.

Times to anaesthesia, surgery, and recovery were recorded for quality assurance (Appendix A). The five stages of anaesthesia referred to in this investigation are: level one, partial loss of equilibrium with normal swimming motion; level two, total loss of equilibrium with normal swimming motion; level three, partial loss of swimming motion; level four, total loss of swimming motion and weak opercular motion; level five, no opercular motion (Yoshikawa et al. 1988). For surgical procedures, a minimum level four anaesthesia is required to ensure immobility.

Once anaesthetized to a stage four level, fish were weighed (g) and measured (FL mm) then placed on their dorsum in a V-shaped surgical table and partially submerged in a water bath to ensure the head and gills were in contact with oxygenated water. A small incision (2.0 cm) was made approximately 1.0 cm from the mid-ventral line and anterior to the pelvic fins. An equine intravenous catheter (1.7 X 133 mm) was inserted through the incision to a point 5-10 mm posterior and slightly caudal to the origin of the pelvic fins (Adams et al. 1998). The antenna wire was inserted through the catheter and the transmitter into the body cavity. The catheter was then pulled through the body wall and the transmitter gently pulled back to the pelvic girdle to prevent the transmitter from resting directly on the incision, which can increase the likelihood of tissue encapsulation and transmitter expulsion. High output PIT tags were also implanted interperitoneally to each fish. The incision was then closed using independent and permanent monofilament sutures (4/0 Ethicon). Once they regained equilibrium and swimming ability, fish were transferred to an instream sleeve and allowed 30 minutes to fully recover (i.e., attainment of fear response) before release.

2.2. Tracking

Monitoring began in October 2007 and was conducted bi-weekly for the months of October, November and from February to June to coincide with the best estimates of when fish movement would occur. Monthly tracking was conducted for the months of December, January, and July to September. At each fish location, river km (rkm), UTM, meso-habitat type (pool, glide, riffle, rapid) and habitat unit measurements of length, width, depth, dominant substrate and cover were recorded.

A remote telemetry station was installed near the confluence of the Salmo River (rkm=1.3)(11U 472483 5430706) on September 24 2007. The station was enclosed in weatherproof housing and used solar panels to recharge two 12-volt batteries that powered a Lotek SRX 400 receiver with W31CT software. The receiver was connected to two 4 element directional Yagi antennas (A1=downstream, A0=upstream) and one underwater antenna (A2=underwater) to detect and log coded transmitters on three frequencies 150.760 MHz (2007 frequency), 150.540 MHz (2008 frequency) and 151.400 MHz (Seattle City Light, Boundary Dam telemetry studies). In January 2009, a fourth frequency (151.890 MHz) was added to the remote station as the Kalispell Tribe began tagging bull trout in the Lake Pend d'Oreille region. The remote station was downloaded and maintained during tracking sessions.

In addition to the Salmo River confluence station, there were three other remote telemetry stations in the Seven Mile Reservoir study area operated by consultants for Seattle City Light (SCL) during 2007 and 2008. These stations were located at: Boundary Dam tailrace, US/Canada border, Redbird Creek, along with a fourth station in the Seven Mile tailrace operated as part of this study. As part of their ongoing entrainment studies, SCL consultant Golder and Associates conducted regular mobile tracking sessions from the Boundary Dam to the Salmo River confluence and searched for tagged bull trout from this program. As of December 2008, SCL concluded its investigations and dismantled all remote stations but one at Boundary Dam.

The Seven Mile tailrace station was installed by Golder and Associates on July 19, 2007 near the bypass tunnel bridge at the entrance of Seven Mile Dam, approximately 125 m downstream of the powerplant on the right bank. This site was selected primarily for its long unobstructed view downstream that would maximize the detection range of the station and increase the probability of tag detection. The station equipment consists of a Lotek radio receiver metal cabinet with two built-in deep-cycle marine batteries, two Kyocera KC50T 54 W solar panels, a

Lotek SRX_400 radio receiver, and 4 element Lindsay 8 dBi gain antenna. Both the receiver cabinet and solar panels are mounted on a 3 m long steel pole that was in turn mounted with bracket to a low metal perimeter railing. The cabinet is mounted on the pole approximately 1.0 m off the ground. The solar panels are mounted at the top of the pole with the panel facing southwest to ensure the panels received that maximum amount of sunlight available. The antenna is vertically mount on a 1.5 m length of PVC pipe that was in turn attached perpendicular to the steel pipe with the antenna pointing downstream. The radio receiver is installed and the receiver settings adjusted to optimize the gain setting in relation to the noise environment. At initial deployment, the receiver was programmed to scan both the BC Hydro radio tag frequency (150.760 MHz) and the Seattle City Light Boundary Relicensing Project frequency (151.400 MHz). In 2008 a second BC Hydro frequency was added (150.540 Mhz) as well as a frequency used by the Kalispell Tribe bull trout study based in Lake Pend Oreille (151.890 Mhz). The station is serviced at two month interval during which logged data is downloaded and station settings adjusted if required. From 2007 to the completion of the Boundary project field component in late 2008, a reference tag on Boundary frequency was used to verify antenna reception at the Seven Mile station. Limited boat-based range testing was also conducted in June 2008 to determine tag detection range of the station (Paul Grutter, Golder and Associates, personal communication 29 May 2009).

2.3. Environmental Data

2.3.1. Temperature and Discharge

Water temperature was recorded (15 minute intervals) at three locations in the Salmo River (rkms 3.0, 27.5, and 45.0) and two locations in the Pend d'Oreille River (Seven Mile reservoir and tailrace) (Figure 1.1). Two thermistors (Tidbit V2™ loggers) were installed at each location on June 14 2007 to provide replicates. On 26 March 2008, the lower river thermistors were relocated to rkm 8.5 (Water Survey of Canada Station), the lower distribution of tagged Salmo River subadult bull trout. Thermistors installed 2.0 km upstream of Seven Mile Dam had both surface and bottom loggers. The upper thermistor units were weighted to ensure they remained approximately one meter below the surface throughout water level fluctuations. The bottom thermistors were placed two meters from the anchor and attached to a trawl float 10 m above the loggers to prevent them from resting on the substrate. Total depth at the reservoir deployment site was 63.4 m at full pool.

Additional temperature measurements were obtained in the reservoir during the period of stratification recorded in 2007 (i.e., August 06 and 07 2008). Measurements of water temperature at 2 m depth intervals were collected at five sites from the forebay area (rkm 2.5) upstream to the Salmo River (rkm 10.5) using a YSI 600-QS multimeter and a 61 m cable. Three additional sites (at rkm 3.3, 7.8, and 9.5) measured surface and bottom temperatures only.

BC Hydro provided data on Seven Mile reservoir level (average hourly and daily elevation m as measured in the forebay). Water Survey of Canada (WSC) provided hydrometric data on the Salmo River (Station No. 08NE074) (rkm=8.4, Figure 1.1). Historical data (1949 to 2006) were summarized to provide comparisons of mean annual and monthly discharge.

3. Results and Discussion

3.1. Capture and Tagging

Angling for bull trout occurred from 06 October to 02 November 2008. Sampling locations ranged from river km 6.0 to 42.0 (Figure 1.1). A total of 63 bull trout (150 to 720 mm FL) and 36 rainbow trout were captured. In 2007, 16 bull trout (260 to 550 mm FL), two brook trout, one rainbow cutthroat trout hybrid, and 40 rainbow trout were captured (Prince 2008). The smallest adult captured measured 470 mm and was a male that readily expressed milt. All bull trout < 450 mm FL were immature. Our observations were consistent with data from a three year study on the adult population of Salmo River bull trout where radio tagged fish < 500 mm did not spawn (Baxter 2002). Since annual growth rates for bull trout populations range from 28 mm to 46 mm (Stelfox 1997, Hvenegaard and Fairless 1998, Downs et al. 2006), fish tagged at 450 mm or less were considered immature for the duration of the observation period (transmitter lifespan = 6 to12 months).

From the 63 bull trout captured in 2008, nine subadults (350 to 450 mm FL) from river km 7.5 to 20.8 were selected for transmitter implant. Due to transmitter size restrictions, the minimum size of fish suitable for tagging was 260 mm or 140 g. Of the nine subadults, three were females, one was male, and five were undetermined (Appendix A).

3.1.1. Biological Characteristics

Bull trout occur in naturally low densities and exhibit multiple life history forms (fluvial, adfluvial, and anadromous) that can coexist within a single population (Reiman and McIntyre 1993, Homel and Budy 2008, Dunham et al. 2008). Bull trout reach maturity at approximately seven years of age, with ages ranging between five to nine, and have maximum lifespans that may exceed 15 years (Fraley and Shepard 1989, Mushens et al. 2003, Dunham et al. 2008). From otolith microchemistry, emigration of bull trout from their natal streams usually occurs at age 3 to 5 and fish > 300 mm are more likely to undertake long distance migrations (Downs et al. 2006, Brenkman et al. 2007, Monnet et al. 2008).

There is considerable variability in bull trout length at age for fish larger than 250 mm and lengths in age-5 fluvial bull trout can range from 292 mm to 452 mm (Al-Chokhachy and Budy 2008). Subadult bull trout captured and implanted with radio tags (n = 23) range from 260 mm to 464 mm (Appendix A). Median fork length and weight of the study population were 405 mm and 590 g. Two size classes of subadults were captured corresponding to two cohorts (Figure 3.1). Since fish were not aged, cohort identification is approximate. Three and four year old fish measured < 270 mm and weighed < 180g, while the five and six year old subadults measured 350-450 mm and weighed > 200g.

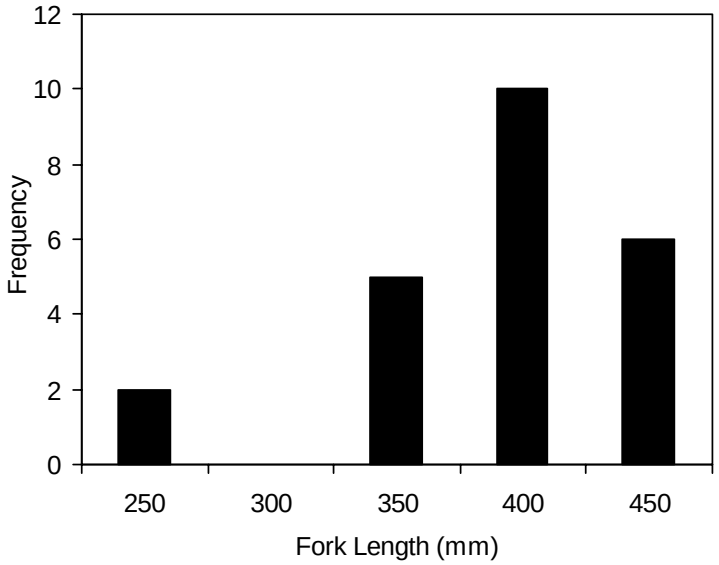

Figure 3.1 Length-Frequency histogram of radio tagged subadult bull trout (n = 23) in the Salmo River (2007 and 2008).

3.2. Migration and Movement

Fourteen fish (frequency 150.760) were tagged in October 2007 and nine (frequency 150.540) were tagged in October 2008. Four of the 2007 group, BT21-24, were implanted with the smallest nano tags which expired in April 2008 (pre-freshet, Table 3.1). Ten of the 2007 group, BT11-20, were implanted with the larger nano tags that expired in October 2008. All fish tagged in 2008 were implanted with large nano tags that had an increased burst rate to extend lifespan to 18 months. These tags will expire in April 2010. Thus, within this report, there are three months of observations reported for BT31-39 (Oct 08 to Jan 09), eight months for BT21 and BT24 (Oct 07 to Apr 08), and twelve months for BT11-20 (Oct 07 to Oct 08).

Table 3.1 Transmitter lifespan of nano tags implanted in subadult bull trout of the Salmo River. Interim data is reported to January 2009.

Transmitter Implant Date	Frequency	Codes	N	Transmitter Expiry Date
October 2007	150.760	21-24	4	April 2008
		11-20	10	October 2008
October 2008	150.540	31-39	9	April 2010

Two of the fish from the 2007 group (BT23 and BT22) were either suspected or confirmed dead shortly after tagging. BT23 moved downstream in a punctuated manner for a total distance of 1.2 km over two months after which it did not show any further movement (Appendix B). This

fish was confirmed dead as the transmitter was recovered in a carnivore den along the river bank (suspect mink den). BT22 did not show any movement after release and was assumed to have either succumbed to the tagging procedure, expelled its transmitter, or been predated upon shortly after release. Radio tagged subadult salmonids have been shown to have an increased risk of predation from other fish that is believed to result from the antenna making it easier for predators to detect, target, and capture tagged fish (Adams et al. 1998). BT22 measured 267 mm FL and weighed 180 g and BT23 measured 360 mm FL and 370 g (Appendix A).

The movement patterns for all tagged fish (n=23) are graphed in relation to Salmo River temperature and discharge and presented in Appendix B. Movements of bull trout that entered the reservoir are also presented in relation to reservoir temperature and elevation data. Only bull trout that assumed to be alive based on movements are discussed (n=21).

3.2.1. Reservoir Use

In fourteen months of observations (October 2007 to January 2009), four radio tagged subadult bull trout were monitored in Seven Mile Reservoir: two from this program and two from the SCL investigation. BT15 was 405 mm FL and tagged on September 18 2007 at Salmo River km 30.25. BT32 was 450 mm FL and tagged on October 06 2008 at rkm 16.0. BT184 (FL = 273 mm and 180 g) was tagged by SCL in the tailrace of Boundary Dam on June 22 2007 and confirmed through genetic testing to be of Salmo River origin (SCL 2009a). BT167 (500 mm estimated length) was also tagged in the tailrace of Boundary Dam in November 2008 (Al Solonsky, Seattle City Light, *pers. comm.* 2009). A third bull trout was captured in the tailrace of Boundary Dam but was too small to tag (250 mm estimated length). Both of the November 2008 bull trout captures at Boundary were determined to be of Trestle Creek origin (Bao Le, Longview Associates, *pers. comm*. 2009), which is a tributary to Lake Pend d'Oreille (Figure 1.1).

BT15 was 405 mm FL and tagged on September 18 2007 at Salmo River km 30.25. It remained at its capture location (Salmo River km 30.25) until December then began a downstream migration to the Salmo/Pend d'Oreille confluence (Figure 3.2). It arrived at the confluence on February 28 2008, remained within range of the remote station for 24 hours after which time it moved out into the Pend d'Oreille beyond the range of detection of the remote station but within the influence of the Salmo River. BT15 was detected 100 m downstream of the confluence during manual tracking sessions on March 10 2008 and again on March 28 2008 at 9:00 PST. Two hours later, on March 28 2008, BT15 was detected 700 m upstream of the confluence in the Pend d'Oreille at Seattle City Light's Redbird Creek station (10:47 to 11:02 PST, Paul Grutter Golder Associates Ltd., *pers. comm.* 2008)(Figure 3.3). The fish then returned to the Salmo River and was logged at the remote station from 11:48 to 12:30 PST March 28 2008. BT15 returned to the reservoir where it remained at large for three months though several attempts were made to locate it through mobile tracking sessions on the reservoir. On July 06 2008 BT15 was detected at the confluence of the Salmo River from 14:29 to 15:11 PST then returned to the reservoir for the remainder of its transmitter lifespan (expiry date October 2008).

BT32 was 450 mm FL and tagged on October 06 2008 at rkm 16.0. It migrated to the confluence in 11 days (first remote station detection was October 17 2008, Figure 3.4). The fish remained near the confluence until November 01, and then entered the reservoir. BT32 was briefly detected at the Salmo remote station on the November 25 from 7:19 to 7:49 PST and again on December 03 from 3:27 to 3:36 PST. Later on December 03, BT32 was detected at Redbird Creek (8:34 to 9:18 PST), then in the tailrace of Boundary Dam (16:30 PST) where it was routinely detected until December 10 at 10:23 PST (Paul Grutter, Golder Associates Ltd.,

pers. comm. 2009)(Figure 3.5). Later, on December 10, BT32 moved downstream and was detected at Red Bird Creek until December 11 at 1:58 PST. This was the last detection of BT32 at the time of reporting. The transmitter of BT32 will be operational until April 2010.

BT184 was captured on June 22 2007, in the tailrace of Boundary Dam and genetically determined to be of Salmo River origin. It was consistently detected in the tailrace until July 05, after which time it moved rapidly downstream and was last recorded at the Red Bird Creek station (SCL 2009a). There were no further detections of this fish and the transmitter expired in December 2007 (SCL 2009a).

BT167 was captured in November 2008 in the tailrace of Boundary Dam and genetically determined to be of Trestle Creek origin. It entered the Salmo River at 17:04 on 18 January 2009.

While there was no apparent association between river discharge or reservoir elevation and subadult bull trout movement (Figure 3.2 to 3.7), the movements of three of the four fish appeared to be influenced by water temperatures. BT15 migrated downstream when minimum water temperatures were reached in December (Figure 3.2). Once at the confluence with the Pend d'Oreille (February 28 2008), BT15 remained within the influence of the Salmo River where mean daily water temperatures were warmer than in Seven Mile reservoir (3.6 ^{o}C vs. 2.3 ^{o}C respectively). By March 20 2008, the relative temperatures of the two rivers had reversed with reservoir temperatures warmer than the Salmo River and BT15 entered the reservoir at a temperature of 4.9^{o}C (March 28 2008, Figure 3.3).

BT32 also migrated to the reservoir during a period of rapid temperature declines (Figure 3.4). Mean daily water temperatures in the mid Salmo River were 8.4 ^{o}C at capture (October 06 2008) and reached 4.1^{o}C six days later on October 12 2008. Like BT15, BT32 entered the reservoir when mean daily water temperatures reached 4.1^{o}C (01 November 2008, Figure 3.5). In a recent study on subadult bull trout, minimum water temperature was closely associated with seasonal migration timing (Homel and Budy 2008).

After three months in the reservoir, BT15 returned to the Salmo River confluence area, on July 06 2008, possibly to occupy cold-water refugia during the period of summer maximums (Figure 3.2). On July 06, mean daily water temperatures in the reservoir were 19.7^{o}C and in the Salmo River 12.9 ^{o}C. Similarly, BT184 moved rapidly downstream from Boundary Dam when water temperatures approached 20 ^{o}C on July 05 2007 (SCL 2009a). This rapid movement did not coincide with any obvious operational change at Boundary Dam (SCL 2009a). The upper incipient lethal temperature for bull trout is reported at 20.9^{o}C with peak growth occurring at 10.9-15.4^{o}C (Selong et al. 2001). Mortality is inversely related to temperature with 79% survival at 20^{o}C over 60 days (mortality first observed at 31 days). The time to 100% mortality is 15 days at 23^{o}C and 42 days at 22^{o}C (Selong et al. 2001). In a recent synthesis of bull trout ecology, both food availability and temperature were identified as the major factors that influence movement and migratory behavior of bull trout (Dunham et al. 2008).

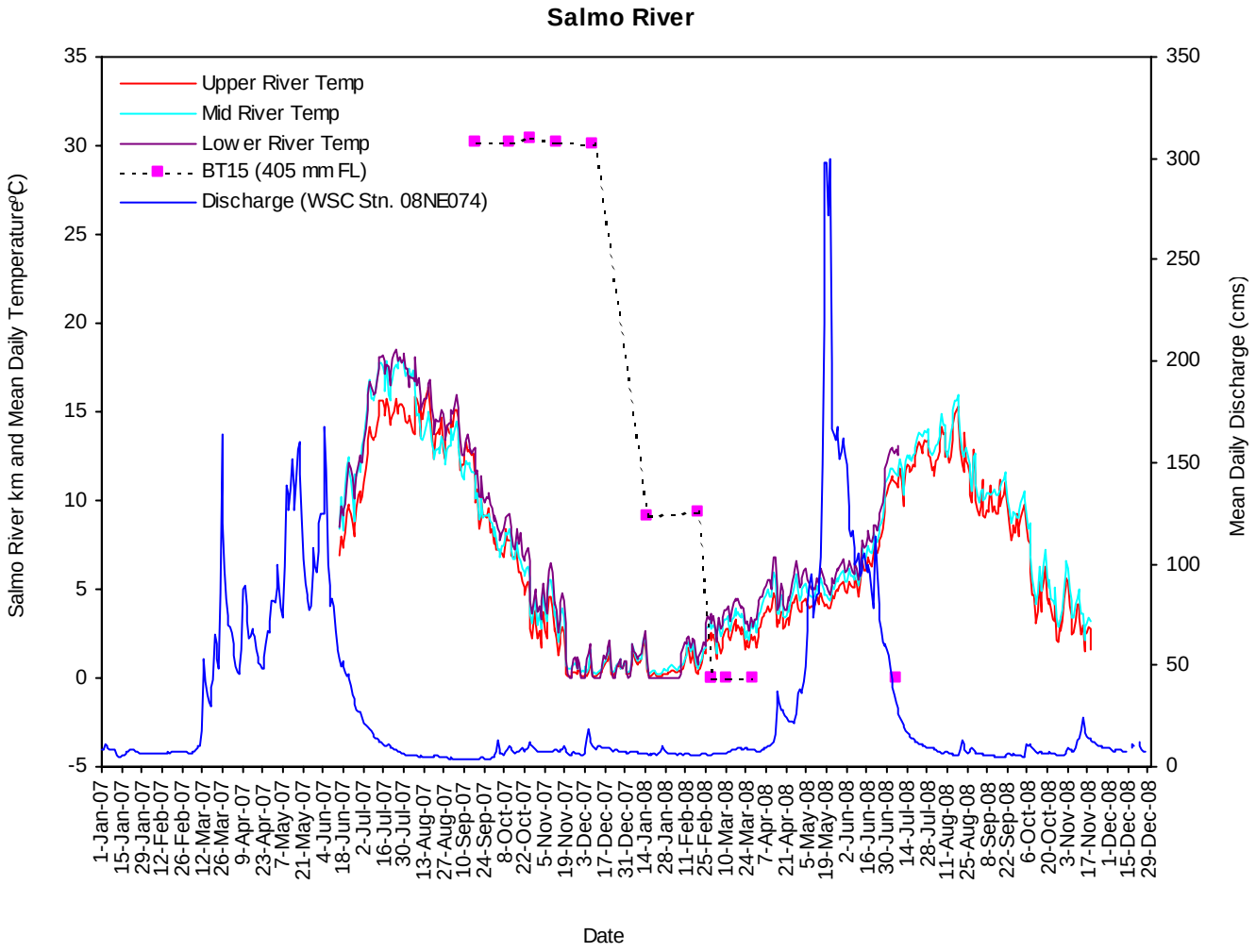

Figure 3.2 Movement data of a radio tagged subadult bull trout (BT15) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection. BT15 left the Salmo River on February 29 2008 and was subsequently detected at the Salmo/Pend d'Oreille confluence on March 10, March 28, and July 06 2008 but did not return to the Salmo River for the duration of the transmitter lifespan (tag expiration date October 2008).

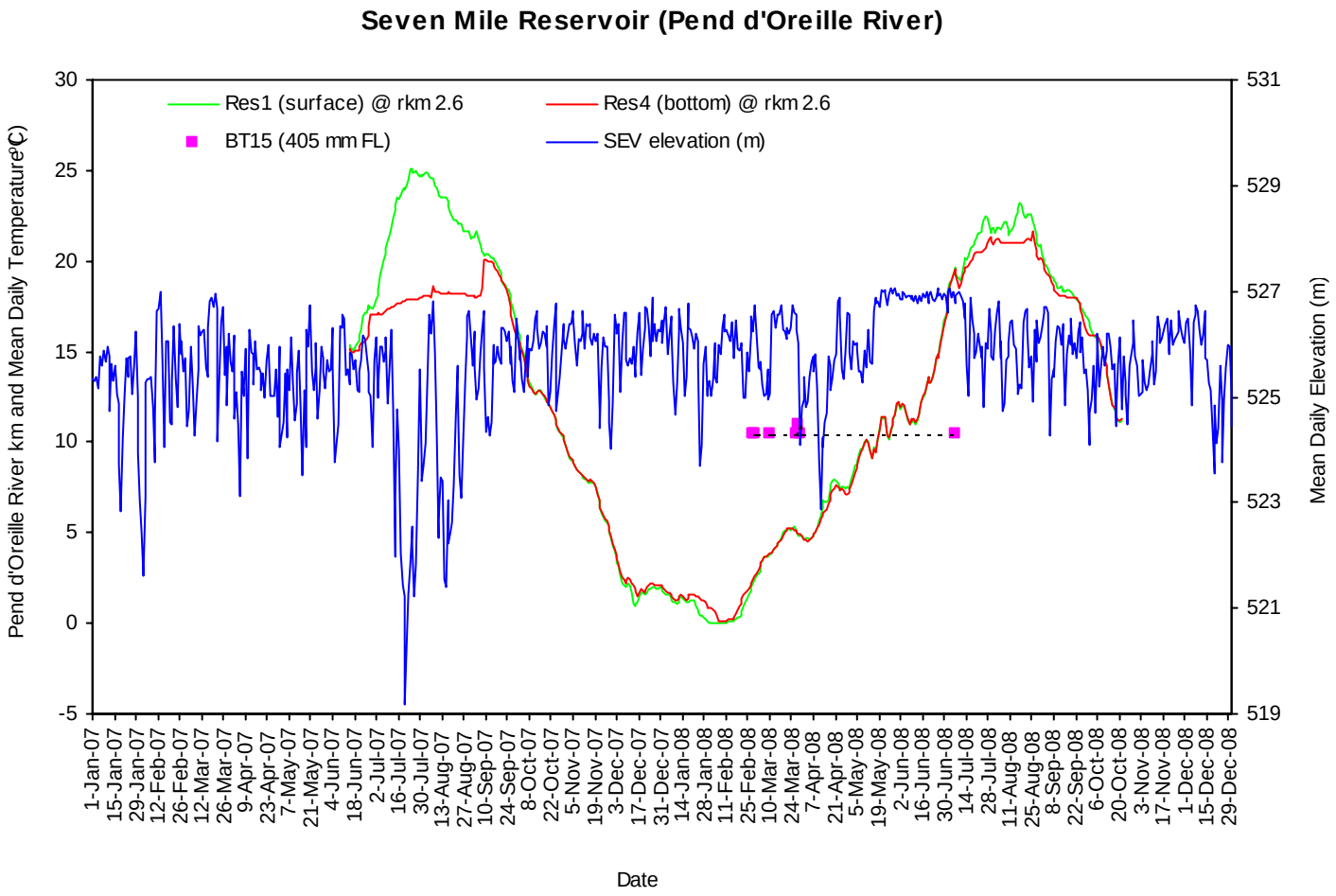

Figure 3.3 Movement data of a radio tagged subadult bull trout (BT15) in relation to mean daily water temperature and reservoir elevation (m). Each point represents a tracked location or remote station detection. BT15 left the Salmo River (Pend d'Oreille rkm 10.5) on February 29 2008 and was subsequently detected at the Red Bird Creek confluence March 28 2008. BT15 was last detected in Seven Mile Reservoir on July 06 2008 and did not return to the Salmo River for the duration of transmitter lifespan (expiry October 2008).

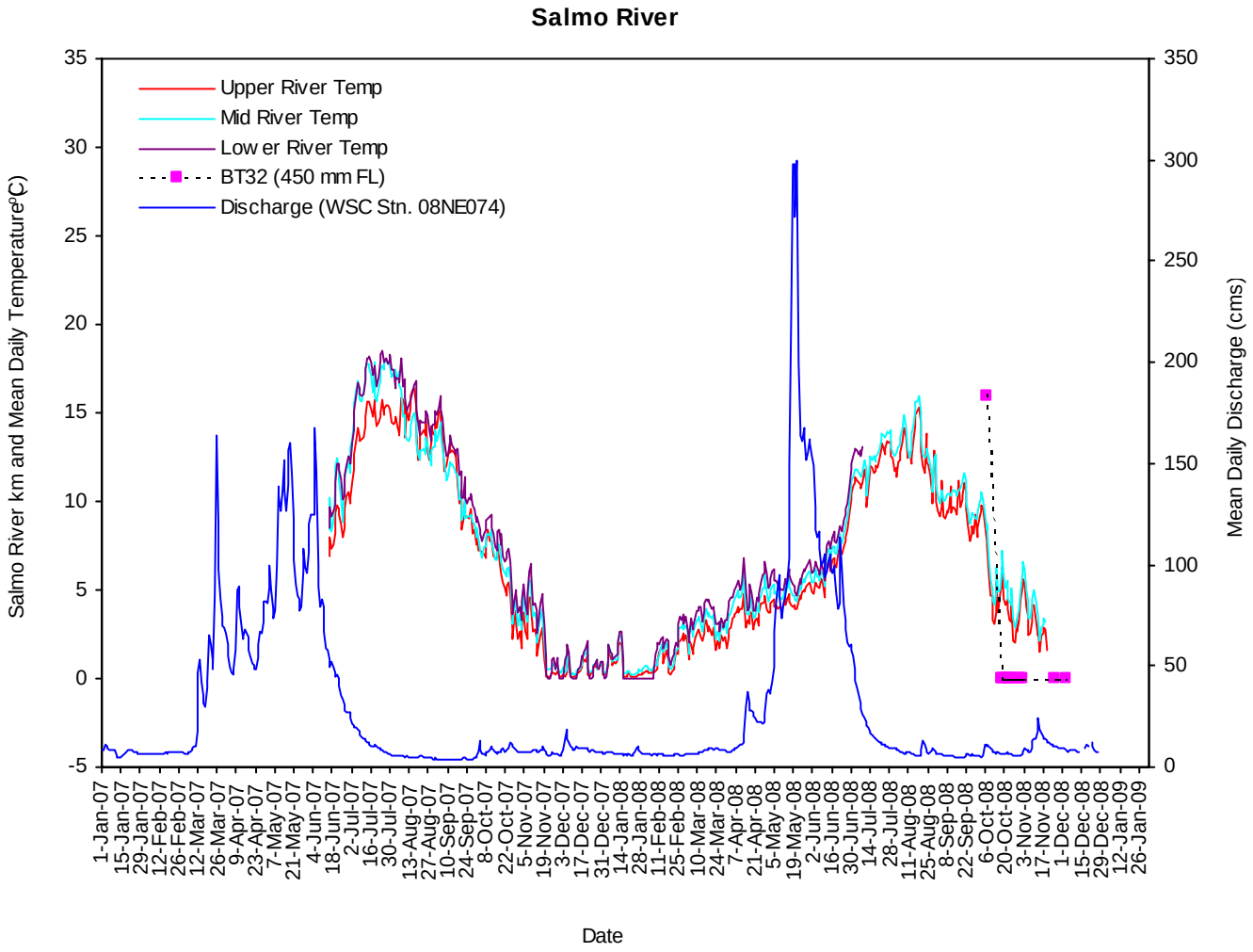

Figure 3.4 Movement data of a radio tagged subadult bull trout (BT32) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection. BT32 left the Salmo River on November 01 2008 and was subsequently detected at the Salmo/Pend d'Oreille confluence on November 25 and December 03 2008 (tag expiration date April 2010).

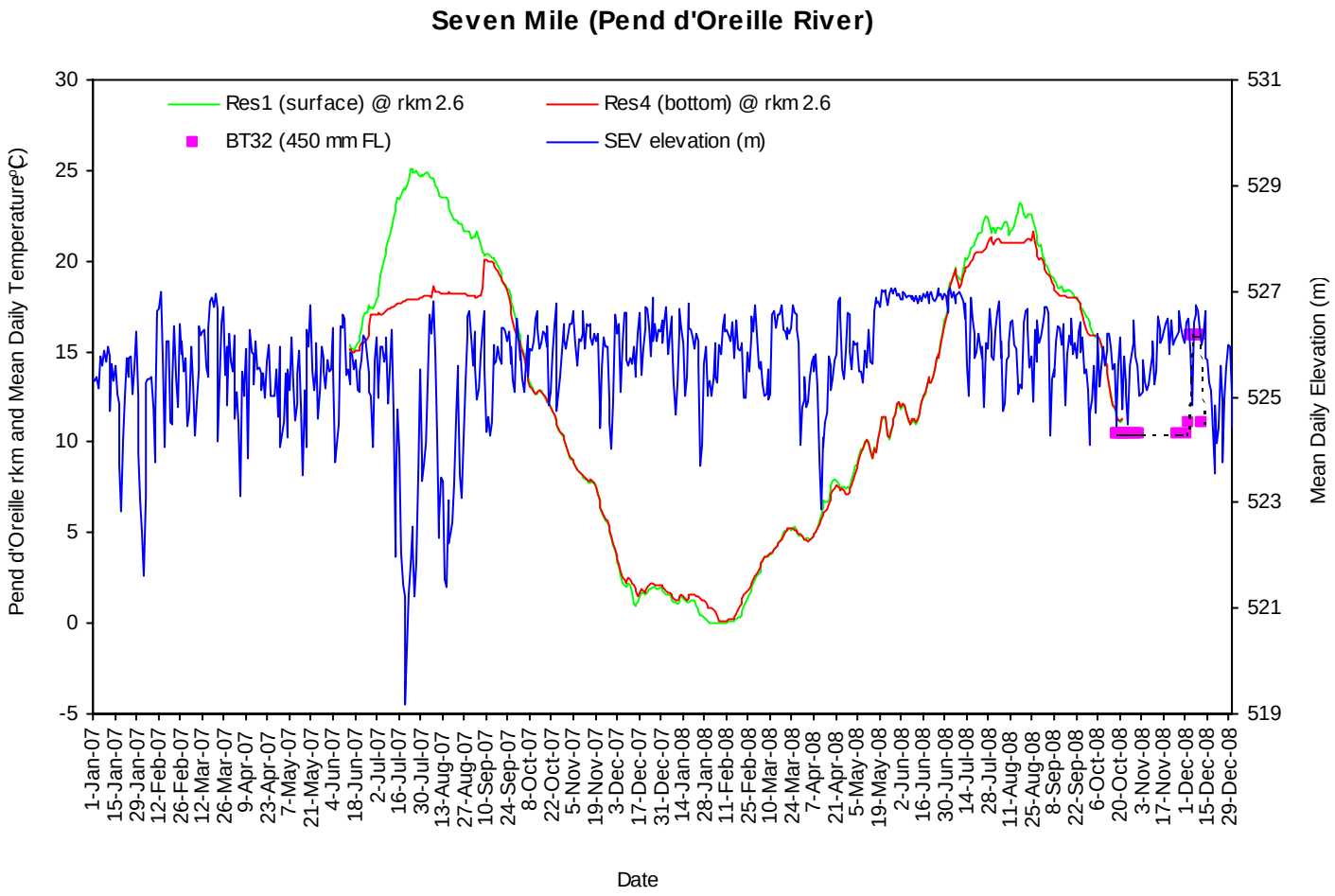

Figure 3.5 Movement data of a radio tagged subadult bull trout (BT32) in relation to mean daily water temperature and reservoir elevation (m). Each point represents a tracked location or remote station detection. BT32 left the Salmo River (Pend d'Oreille rkm 10.5) on November 01 2008 and was subsequently detected at the Red Bird Creek confluence December 03, 10 and 11 2008 and at continuously at the Boundary Dam tailrace from December 03 to 10 2008. BT32 remains at large in Seven Mile Reservoir (transmitter expiration date April 2010).

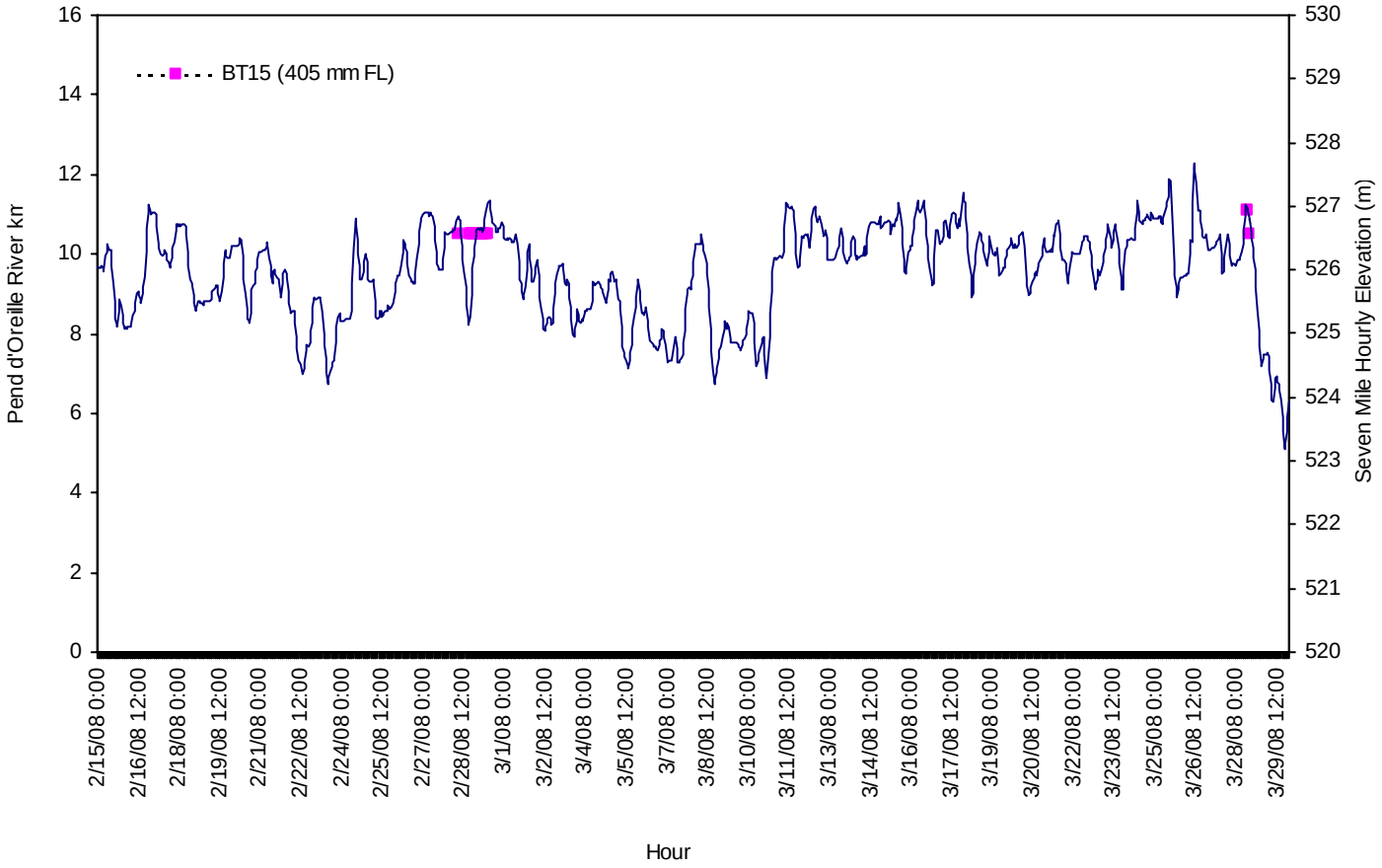

Figure 3.6 Movement data of a radio tagged subadult bull trout (BT15) in relation to hourly reservoir elevation (m). Each point represents a tracked location or remote station detection in the reservoir. BT15 left the Salmo River (Pend d'Oreille rkm 10.5) on February 29 2008 and was subsequently detected at the Red Bird Creek and Salmo River confluences on March 28 2008.

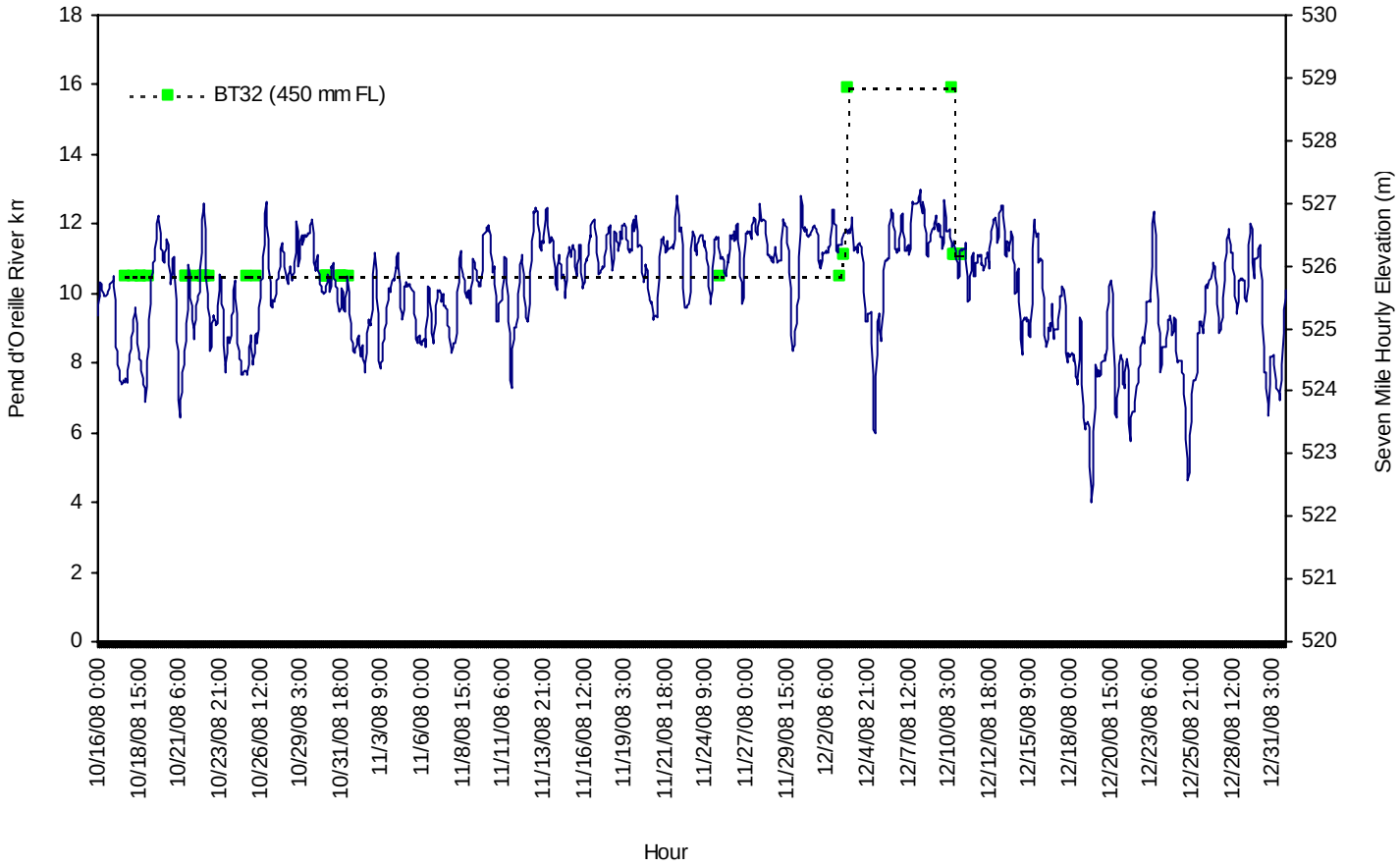

Figure 3.7 Movement data of a radio tagged subadult bull trout (BT32) in relation to hourly reservoir elevation (m). Each point represents a tracked location or remote station detection. BT32 left the Salmo River (Pend d'Oreille rkm 10.5) on November 01 2008 and was subsequently detected at the Red Bird Creek confluence December 03, 10 and 11 2008 and at continuously at the Boundary Dam tailrace from December 03 to 10 2008. BT32 remains at large in Seven Mile Reservoir (transmitter expiration date April 2010).

3.2.2. Mainstem and Tributary Use

During 14 months of observations, subadult bull trout showed both resident and migratory behaviors (Appendix B). Three of the 12 fish tagged in 2007 showed a resident strategy (i.e., movement within a one km stream segment) and nine showed migratory tactics (movement > 10km, Homel 2007, Al-Chokhachy and Budy 2008). Two of the three resident fish had the small transmitters with a lifespan of six months; the remainder had 12 months of observational data.

Within the migratory group, five fish (BT11, BT13, BT14, BT15, BT19) accessed another creek/river (open symbols designate detection in alternate waterbody, Appendix B). BT15 entered the Pend d'Oreille, BT11 entered Clearwater Creek (headwater tributary), BT13 and BT19 entered Sheep Creek, and BT14 entered the South Salmo River. All bull trout that moved out of the Salmo River were detected within one km of an upstream migration barrier.

3.3. Other Species Use of the Salmo River

There has been substantial use of the Salmo River by other salmonid species tagged in the Pend d'Oreille River during the Boundary Dam biotelemetry studies (Appendix C).

Six of the seven (86%) mountain whitefish confirmed alive after release into the Boundary tailrace entered the Salmo River, the majority during the freshet of 2008 (Appendix C; codes 108, 112, 114, 116, 117, and 118). These fish were distributed as far as 22.5 km upstream (SCL 2009a) and remained in the Salmo until the fall.

One naturalized rainbow (Code 188) and three rainbow triploid carryovers (Codes 31, 47, and 171) also entered the Salmo River from the Pend d'Oreille. Codes 47, 171, and 188 were entrained through Boundary Dam and Code 31 was released in Boundary tailrace (SCL 2009a). Five of ten tagged native rainbows (50%) and 15 of 74 tagged triploid rainbows (20%) were entrained through Boundary Dam (SCL 2009b).

Two cutthroat trout entered the Salmo River during the spring and summer (Appendix C). Code 113 was released in the tailrace of Boundary Dam November 16 2007 and Code 198 released April 18 2008 in the tailrace of Box Canyon Dam and entrained through Boundary Dam on May 07 2008 (SCL 2009a). Two of ten tagged cutthroat (20%) were entrained through Boundary Dam (SCL 2009a).

Six of the seven trout were entrained in spring and summer during high flows, high power generation, and high spill (SCL 2009a). Of the 15 entrained triploid releases, eight were from the upper reservoir or Box Canyon tailrace and entrained during high flows in 2008 (SCL 2009b). One cutthroat trout was entrained in February during an atypical drawdown (i.e., 2.5 m greater than typical reservoir reduction in February, SCL 2009a).

3.4. Environmental Data

In addition to testing hypotheses on subadult bull trout entrainment risk, this monitoring program provides important information on seasonal migrations in relation to water temperature, river discharge, and reservoir elevation. The relationship between these variables will help to identify periods when entrainment may be of greater concern.

3.4.1. Temperature

Bull trout have demonstrated the highest thermal sensitivity of native BC fish species tested and as such, provincial water quality guidelines recommend a mean weekly maximum temperature of 15.0 ^{o}C (Oliver and Fidler 2001). In 2007, Salmo River water temperatures exceeded a daily mean value of 15 ^{o}C for 37 days from July 04 to 09 August and peaked at 18.5 ^{o}C on July 24 (Figure 3.2). In contrast, mean daily temperatures during 2008 exceeded 15 ^{o}C for only two days, on August 17 and 18 and peaked at a maximum value of 15.9 ^{o}C on August 18 2008 (Figure 3.2). Mean daily reservoir temperatures near the surface followed a similar pattern as the Salmo River with higher temperatures in 2007 than in 2008 (peak at 25.2 ^{o}C on July 24 2007 compared with 23.2 ^{o}C on August 17 2008, Figure 3.8). Temperatures at the bottom of Seven Mile reservoir showed the opposite trend, with cooler temperatures in 2007 compared with 2008 (Figure 3.8).

Thermal stratification within the reservoir was observed in 2007 and to a lesser degree in 2008 (Figure 3.8). The Oregon State Department of Environmental Quality defines cold-water refugia as an area with at least 2 ^{o}C cooler water than the surrounding water when temperatures are warm (SCL 2009a). The maximum difference between mean daily surface and bottom temperatures was 7.3 degrees on July 24 2007 and 2.2 degrees on August 17 2008. Temperature differences between surface and bottom measurements were observed in the lower reservoir and at the confluence of the Salmo River (Figure 3.9). In general, water temperatures decreased with proximity to the Salmo River (Figure 3.9).

Thus, it appears that Seven Mile Reservoir could offer cold-water refugia to benthic oriented fish during periods of high temperatures. Thermal stratification in Seven Mile Reservoir was unexpected given the overall reservoir flushing rate. Flushing rate refers to the time required to fully replace the reservoir volume based on inflows. The total volume of Seven Mile reservoir is 41.75 thousand cubic feet per second per day (kcfsd). The average July inflow is 23.8 kcfs and in August is 12.2 kcfs; therefore, the average flushing rate in July is 1.75 days and in August 3.4 days.

The higher than average discharge in 2008 may have influenced stratification. There was no spill in 2007 at the Seven Mile Project and deep drawdowns to 519 m occurred during the summer stratification period. At the same time, average discharge from Boundary Dam was approximately half of the normal average inflow at 10 kcfs for July and August 2007 (SCL 2009a). The maximum mean daily temperature at the bottom of Seven Mile Reservoir was 17.9 ^{o}C on July 24 2007. In contrast, there was a spill at the Seven Mile Project from 16 May to 11 July 2008 (period of stable elevation, Figure 3.7), no deep drawdowns in the summer, and average discharge from Boundary Dam was more than twice that of 2007 (approximately 23 kcfs = average July inflow, SCL 2009a). The maximum mean daily temperature at the bottom of Seven Mile in 2008 was 21.0 ^{o}C on August 17.

3.4.2. Discharge

In 57 years of records by Water Survey of Canada (WSC), mean annual discharge in the Salmo River averaged 31.84 cms and ranged from 17.3 cms to 48.3 cms (1949-2006). Annual discharge in 2007 and 2008 measured 28.84 and 29.75 cms respectively. The lowest mean annual discharge on record 17.3 cms occurred in 2001. In 2007, the spring-melt dominated freshet happened earlier than normal in the Salmo River (Figures 3.10) contributing to early peak summer water temperatures (15 ^{o}C by July 04 2007). Though annual yields were similar, peak discharge in 2007 was 50% that of 2008 (Figure 3.10). The spring melt in 2007 was early and protracted compared with 2008.

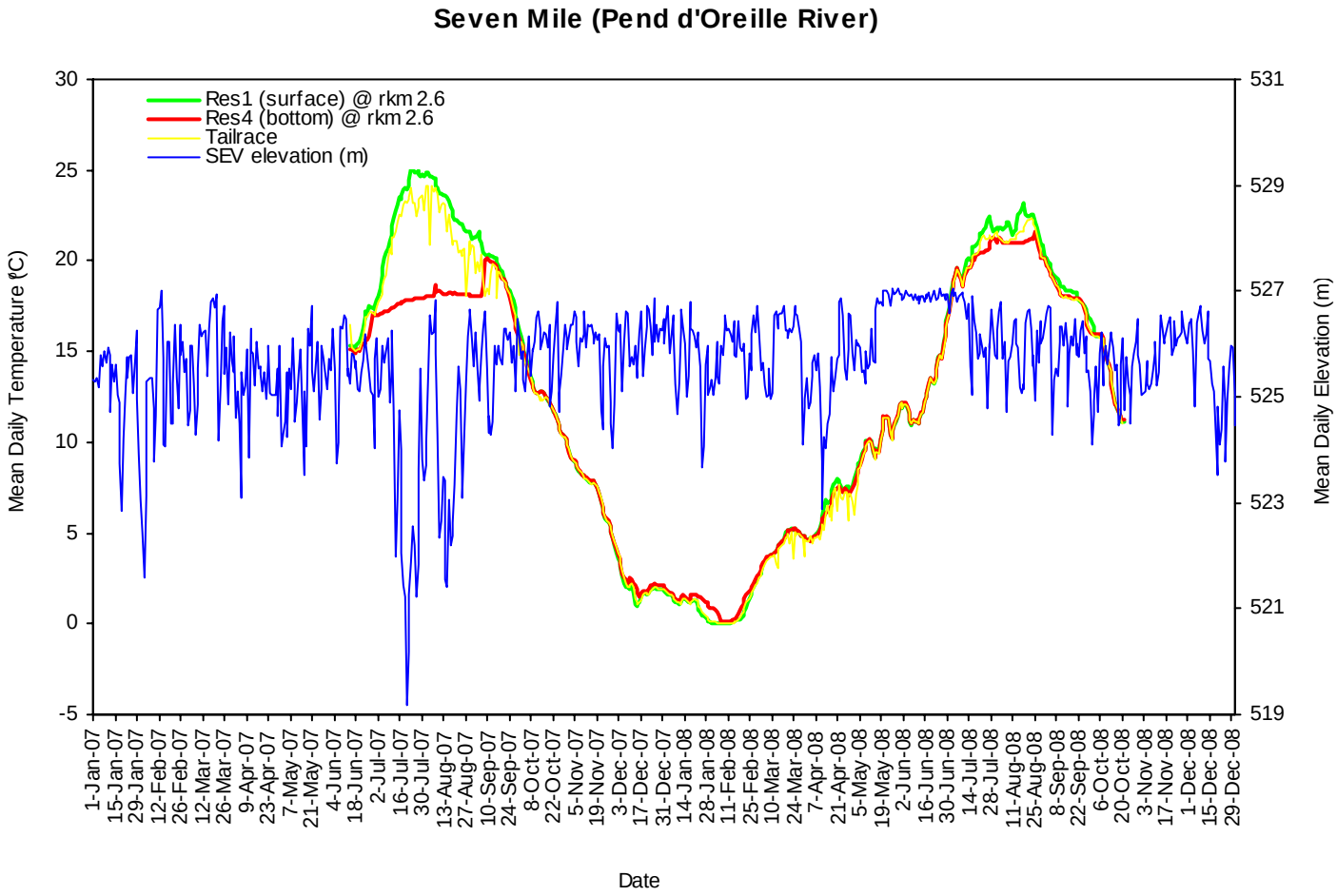

Figure 3.8 Mean daily temperature at the surface and the bottom of Seven Mile Reservoir in relation to average daily elevation (m). The deep drawdowns in July and August 2007 are atypical. The period of relatively stable elevation in May and June 2008 represents spill at the Seven Mile Dam. The thermal stratification of 7.33 degrees in 2007 and 2.23 degrees in 2008 signifies a benthic cold-water refugia within the reservoir.

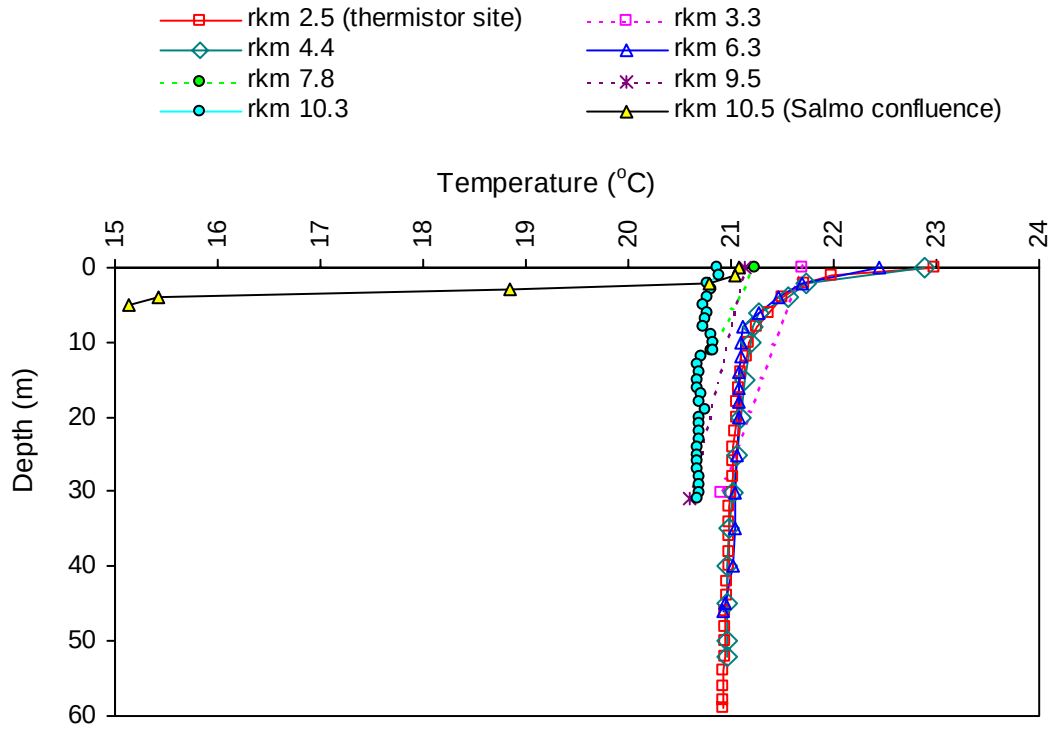

Figure 3.9 Temperature profiles (two meter depth intervals) for five sites in the Pend d'Oreille River between the Seven Mile Project (rkm 0.0) and the Salmo River (rkm 10.5) on August 06 and 07 2008. Sites with dashed lines have only surface and bottom measurements.

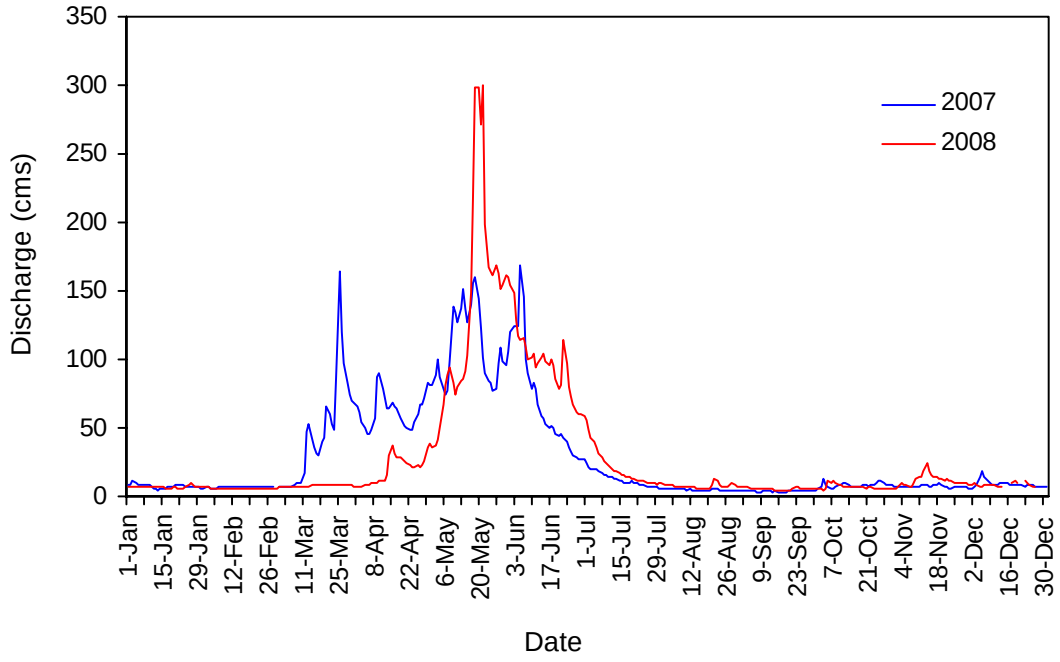

Figure 3.10 Mean daily discharge for the Salmo River 2007 & 2008 (2008 data are unofficial, WSC Station No. 08NE074).

4. Summary and Conclusions

Hypothesis 1: Use of Reservoir by Subadult Bull Trout.

H1: Subadult bull trout from the Salmo River do not migrate to or utilize the Seven Mile Reservoir.

The preliminary results indicate that some subadult bull trout (n=3) from the Salmo River do utilize Seven Mile Reservoir. The downstream movements of BT15 and BT32 in February and November 2008, suggest that Salmo River subadult bull trout that enter the reservoir are not residents that have strayed or been flushed (BC Hydro 2003) but are migratory individuals. Subadult bull trout migration is defined as the annual downstream movement between distinct habitat types (Homel and Budy 2008).

The movements of BT15 and BT184 are inconsistent with sub-hypothesis 1, that warm water temperatures limit use of the reservoir to fall, winter, and spring months (BC Hydro 2007) as both subadult bull trout remained in the reservoir year round. Year round rearing in the reservoir was considered less likely than seasonal migrations (BC Hydro 2007), although subadult bull trout have previously been captured year round in Seven Mile Reservoir (R.L.&L. 1995) and in many habitats considered thermally unsuitable for rearing (Monnet et al. 2008). Once in the reservoir, subadult bull trout will usually spend an additional three to five years rearing before they sexually mature (Stelfox 1997, Mushens et al. 2003, Downs et al. 2006).

All four radio tagged subadult bull trout in the reservoir moved between the Salmo River and the tailrace of Boundary Dam. Currently, there are no reservoir remote stations downstream of the Salmo River; thus reservoir use in these areas is uncertain; however, the majority of bull trout previously captured in Seven Mile Reservoir fish investigations were captured in the lower and middle sections of the reservoir (R.L.&L. 1995). Subadult bull trout are a benthic oriented, nocturnal species (Jakober 1995, Ratliff et al. 1996, Muhlfeld et al. 2003, Downs et al. 2006, Homel and Budy 2008) and therefore are expected to enter shallow depths during periods of darkness (i.e., depths sufficient for radio signal detection). The majority of detections in the reservoir in this study were at night.

During the first 14 months of observations, five bull trout ranging in size from 250 mm to 500 mm FL were documented in the Seven Mile Reservoir (BT15, BT32, BT184, BT167, and one too small to tag). Based on a size estimate of 500 mm, BT167 may be considered an adult. Of the bull trout captured in Seven Mile Reservoir in 1994/95 (n=12), 33-44% were adults (FL = 574 mm, 590 mm, 604 mm, and 715 mm, lengths reported for 9 of 12 fish) (Table 3.7 in R.L.&L. 1995). In a three year study on adult Salmo River bull trout (n=20), Baxter (2002) noted that seven of the 10 fish tagged in the fall of 2000 disappeared in the fall of 2001 and may have entered the reservoir. Adult bull trout may remain in their natal stream after spawning and emigrate the subsequent year (Homel and Budy 2008), and switch annually from a resident tactic to a migratory one (Hilderbrand and Kershner 2000, McDowall 2001).

Hypothesis 2: Bull Trout Entrainment

H2: Sub-adult bull trout are not entrained through the Seven Mile Project

Bull trout that migrate to the reservoir may become entrained through Seven Mile dam either during directed downstream migrations, or during chance movements past the penstock or

spillway intake areas within the dam forebay during reservoir rearing (BC Hydro 2007). Of the four radio-tagged bull trout in the reservoir, two had transmitters that expired while the fish were in the reservoir (BT184 and BT15) and the other two remain in the reservoir with transmitters active until April 2010 (BT167 and BT32). There were no detections of radio tagged bull trout in the tailrace of the Seven Mile Project. There were two bull trout of Trestle Creek origin in Seven Mile Reservoir (captured in the tailrace of Boundary Dam), which were presumably entrained. The rate of entrainment through Boundary Dam was greatest in spring and summer during high flows, high power generation, and high spill (SCL 2009a).

Hypothesis 3: Entrainment and Dam Operations

H3: Rate of entrainment of bull trout is independent of operational changes that could be implemented at the Seven Mile Facility

In addition to testing hypotheses on subadult bull trout entrainment risk, this monitoring program provides important information on the life history, and habitat use of subadult bull trout in the Pend d'Oreille and Salmo Rivers. The relationship between seasonal migrations, water temperature and discharge will help to identify years or seasons when entrainment may be of greater concern. This information will help to inform future operating decisions and includes:

1. Estimating the abundance of subadult bull trout in the Salmo River watershed through a mark-recapture estimate. This was decided against due to subadult habitat use and the inability to snorkel or get good mark-recapture estimates (Bill Green (CCRIFC) and James Baxter (Fish and Wildlife Compensation Program), personal communication 2008).

2. Identifying high use and preferred habitats in the watershed (Appendix B). Radio tagged subadult bull trout over wintered in the lower reaches of the Salmo River and Seven Mile Reservoir (Appendix B). In the Salmo River, 17 of 21 subadult bull trout (81.0%) over wintered downstream of the South Salmo River from rkm 7.5 to 11.5 in rapids with boulders (57%, Prince 2008). During the summer months seven of 12 tagged subadult bull trout were located in the upper reaches of the Salmo mainstem and its tributaries Clearwater, Sheep, and South Salmo (Appendix B). Salmo River subadult bull trout that entered Seven Mile Reservoir (n=3) remained year round to rear and were observed near confluences (Red Bird Creek, Salmo River) and the tailrace of Boundary Dam.

3. Describing seasonal migrations in relation to water temperature, river discharge, and reservoir elevation (Appendix B, Figures 3.2 to 3.8). Both subadult bull trout migrated to Seven Mile Reservoir during minimum temperatures and low flows (November and February). In summer, tagged bull trout moved towards confluences (Red Bird Creek and Salmo River) when reservoir temperatures were high. In each case, reservoir water temperatures approached 20.0^{o}C while the Salmo River measured 12.9^{o}C (Figure 3.8). The upper incipient lethal temperature for bull trout is reported at 20.9^{o}C (Selong et al. 2001). Temperature stratification in Seven Mile may be influenced by discharge as cooler bottom reservoir temperatures were observed in a low flow year (17.9^{o}C mean daily maximum 2007) than in a higher than average discharge year (21.0^{o}C mean daily maximum 2008).

5. Recommendations

Effort in Year 3 of the program will focus on increasing the sample size (n) and the size distribution of the monitored population. As well, effort will be directed at improving the information on subadult bull trout reservoir use. The following recommendations are made to improve the program:

1. Increase number of capture days from 10 to 15 and distribute effort across seasons. Studies on subadult bull trout have shown two seasonal migration periods one spring and one fall, thus, we recommend a session in early March (pre-freshet) in addition to the fall sampling period.
2. Given the benthic, nocturnal behavior of subadult bull trout, we recommend that remote stations be installed downstream of the Salmo River: one in the middle section (i.e. Limpid Creek) and another near the forebay to monitor the movements of subadult bull trout in the reservoir (SCL maintains one station at Boundary tailrace). These stations would provide information on reservoir use and potential entrainment risk by tagged subadult bull trout currently in Seven Mile (BT32, BT36 entered March 09, BT39 March 10 2009, and BT167) as well as for any future migrants from fish tagged in Oct/Nov 2008 and those yet to be tagged in 2009. With the thermal refugia identified in the lower reservoir, and the higher catch rates reported for bull trout in the middle and lower sections of the reservoir (R.L.&L. 1995), a station near the forebay would address hypotheses regarding the risk of bull trout entrainment (BC Hydro 2007).
3. Having observed several Pend d'Oreille River fish including radio tagged bull trout of Trestle Creek origin in the Salmo River; tissue samples should be collected to determine genetic origins of bull trout captured and tagged in the Salmo River.

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Appendix A. Capture and tagging information for subadult bull trout equipped with radio transmitters in the Salmo River, B.C. (October 2007 & 2008)

Radio Tag Code (150.760)	Date	Time (PDT)	Location			Habitat			Water Temp (°C)	Air Temp (°C)	PIT	Weight (g)	Fork Ln (mm)	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery Time	
			(rkm) [1]	UTM (11U) easting	UTM (11U) northing	Habitat Type	Dominant Substrate	Dominant Cover								equilibrium (min:sec)	release (min:sec)
22	11-Sep-07	18:35	36.5	483547	5455587	Pool	Cobble	LWD	13.5	16.2	985121001739459	180.0	267.0	1:46	4:50	9:00	60:00
12	12-Sep-07	13:45	20.7	480218	5442348	Pool	Bedrock	Depth	11.0	25	985121001503704	500.0	381.0	1:48	8:28	10:28	60:00
20	14-Sep-07	11:00	20.7	480212	5442343	Pool	Bedrock	Depth	11.5	20.5	985121001474030	700.0	350.0	1:48	9:01	12:06	28:00
11	14-Sep-07	12:30	21.4	480540	5443006	Pool	Bedrock	Depth	12.0	21.5	985121001708849	750.0	422.0	3:58	10:54	12:36	28:12
18	17-Sep-07	12:45	34.4	482761	5454308	Pool	Small Cobble	LWD	11.0	20	985121001617792	575.0	392.0	2:34	7:44	10:08	32:27
17	17-Sep-07	13:48	34.4	482761	5454308	Pool	Small Cobble	LWD	11.0	20	985121001577517	700.0	420.0	3:18	8:50	11:09	29:21
15	18-Sep-07	14:38	30.25	481121	5450950	Glide	Cobble	cutbank/swd	11.5	22	985121001501678	520.0	405.0	2:34	8:19	13:40	25:00
13	21-Sep-07	10:00	17.9	480542	5439921	Pool	Cobble	cutbank/lwd	11.0	18	985121001708804	220.0	360.0	2:24	8:40	12:20	53:20
19	02-Oct-07	8:50	17.9	480512	5439921	Pool	Cobble	LWD	9.0	7	U	540.0	433.0	3:22	8:16	12:22	25:39
14	02-Oct-07	17:30	14.25	480100	5437049	Pool	Cobble	LWD	9.0	8	U	900.0	464.0	3:20	9:22	14:18	35:23
21	03-Oct-07	8:30	17.6	480822	5439875	Glide	Cobble	Boulder	9.0	12	U	140.0	260.0	4:30	12:15	14:53	40:10
23	03-Oct-07	10:00	17.6	480822	5439875	Glide	Cobble	Boulder	9.0	13	U	370.0	360.0	2:20	10:32	15:32	23:16
16	03-Oct-07	14:41	17.9	480542	5439921	Pool	Cobble	cutbank/lwd	9.0	13	U	540.0	370.0	2:36	9:36	11:30	31:35
24	04-Oct-07	8:00	17.9	480542	5439921	Pool	Cobble	cutbank/lwd	9.0	13	U	620.0	384.0	3:19	7:59	12:22	31:47
32	06-Oct-08	17:30	16	480491	5438508	Pool	Gravel	LWD	9.7	11.5	985121001498035	900.0	450.0	3:00	5:00	8:00	15:00
31	07-Oct-08	10:45	10.73	479585	5434211	Riffle	Cobble	Flow Margin	9.5	14	985121001739484	760.0	410.0	2:30	5:00	7:00	24:00
36	07-Oct-08	12:07	10.2	479193	5434039	Pool	Cobble	LWD	9.7	19.5	985121001577004	930.0	450.0	2:20	8:00	5:00	14:00
33	07-Oct-08	13:17	10.2	479193	5434039	Pool	Cobble	LWD	9.7	19.5	985121001729905	780.0	420.0	2:30	8:00	13:00	17:00
34	07-Oct-08	16:30	8.64	478450	5432994	Glide	Boulder	Boulder	10.3	15	U	790.0	430.0	2:15	6:00	5:00	12:00
37	09-Oct-08	11:56	20.75	480203	5442355	Riffle	Cobble	Surface disruption	6.5	7.2	U	500.0	38.5	3:00	7:00	4:00	9:00
38	16-Oct-08	13:23	9.15	478883	5433181	Riffle	Cobble	Boulder	6.5	11.9	U	635.0	430.0	2:30	8:00	1:30	9:00
35	16-Oct-08	15:55	8.55	478478	5432906	Riffle	Cobble	Boulder	6.5	11.7	U	590.0	405.0	2:35	5:00	4:00	11:00
39	02-Nov-08	15:30	7.15	478145	5431615	Rapid	Boulder	Boulder	8.3	14.1	985121001708842	350.0	350.0	2:30	7:00	10:00	15:00

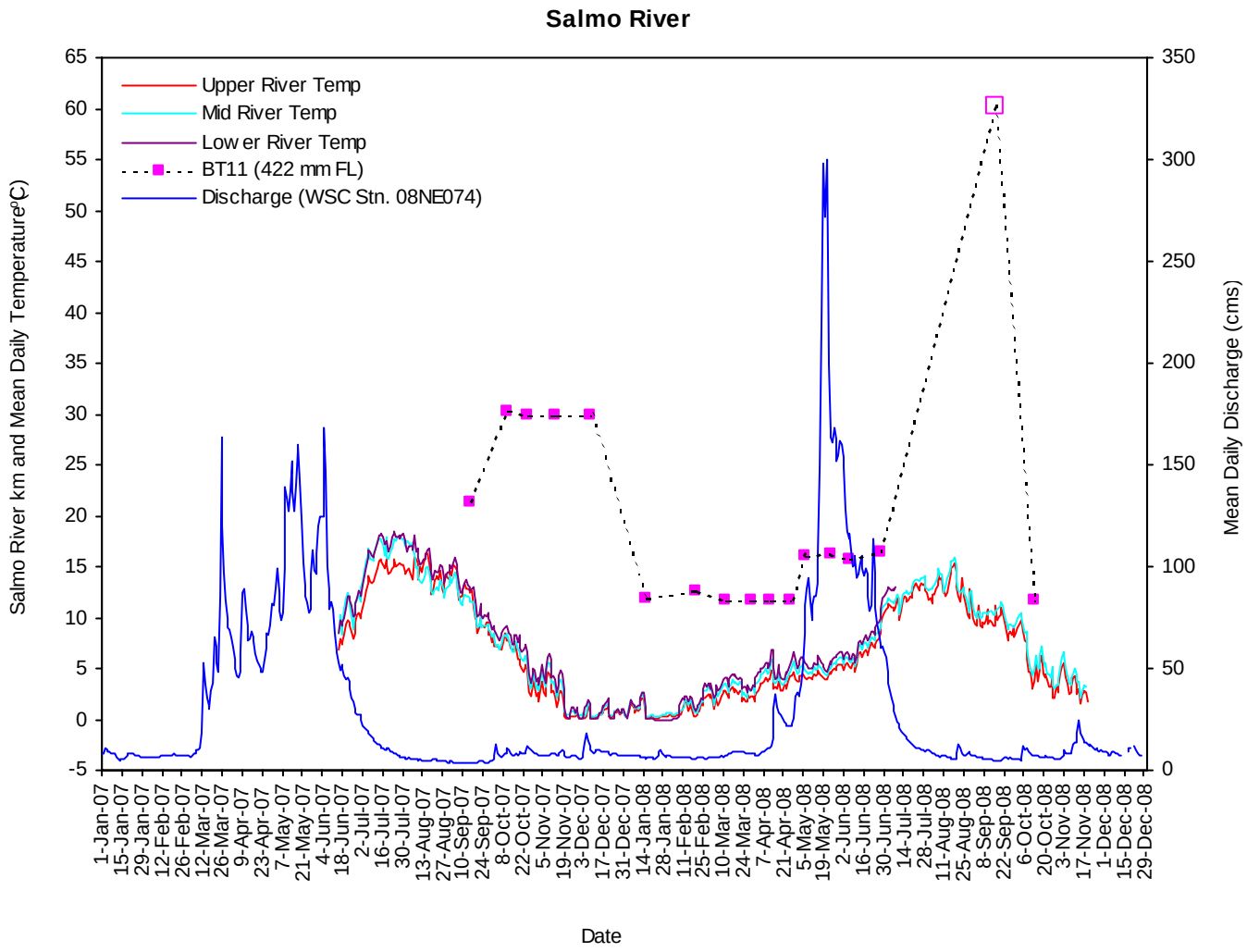

Figure B1 Movement data of a radio tagged subadult bull trout (BT11) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date October 2008). Open symbols indicate locations in Clearwater Creek, a tributary to the Salmo River.

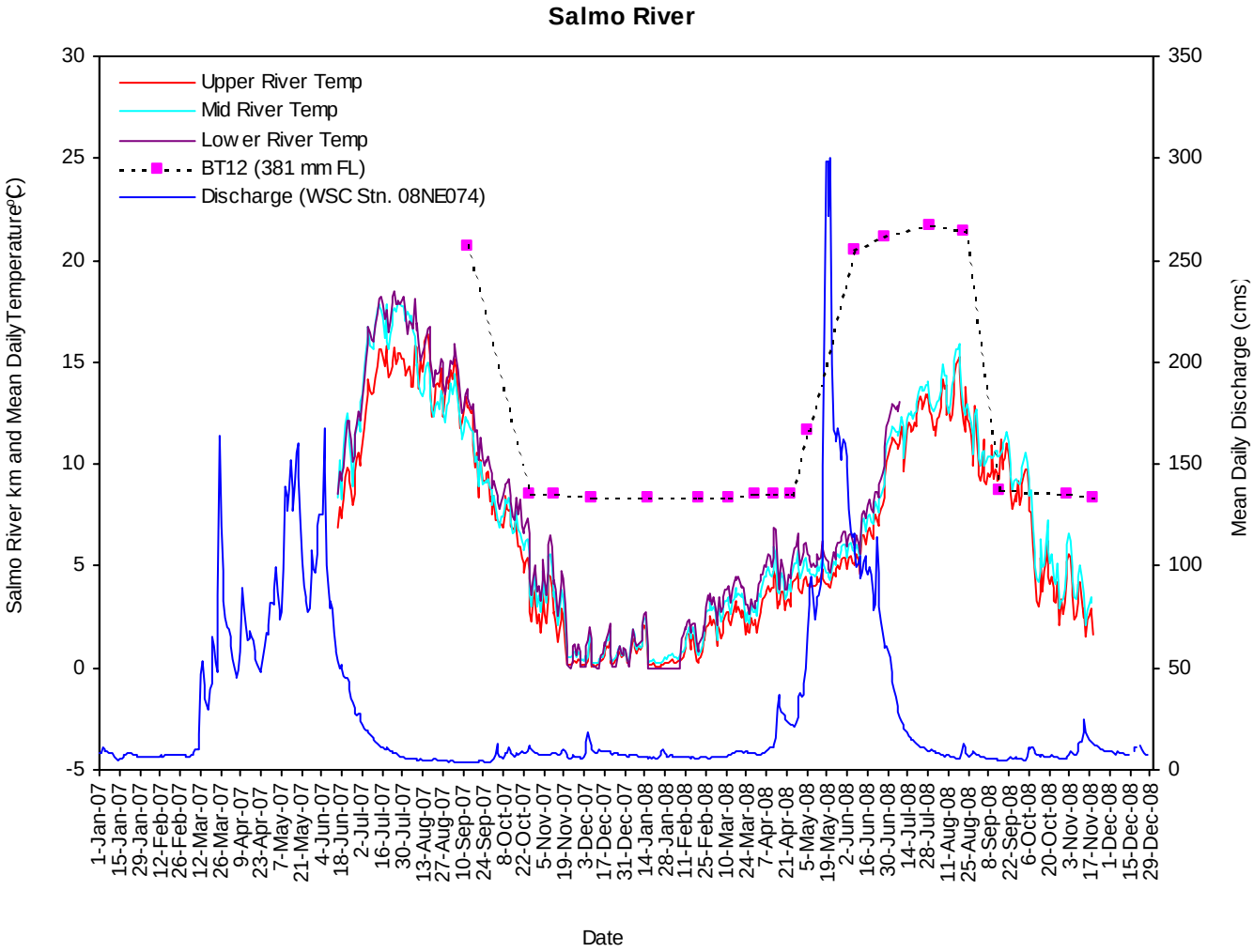

Figure B2 Movement data of a radio tagged subadult bull trout (BT12) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date October 2008).

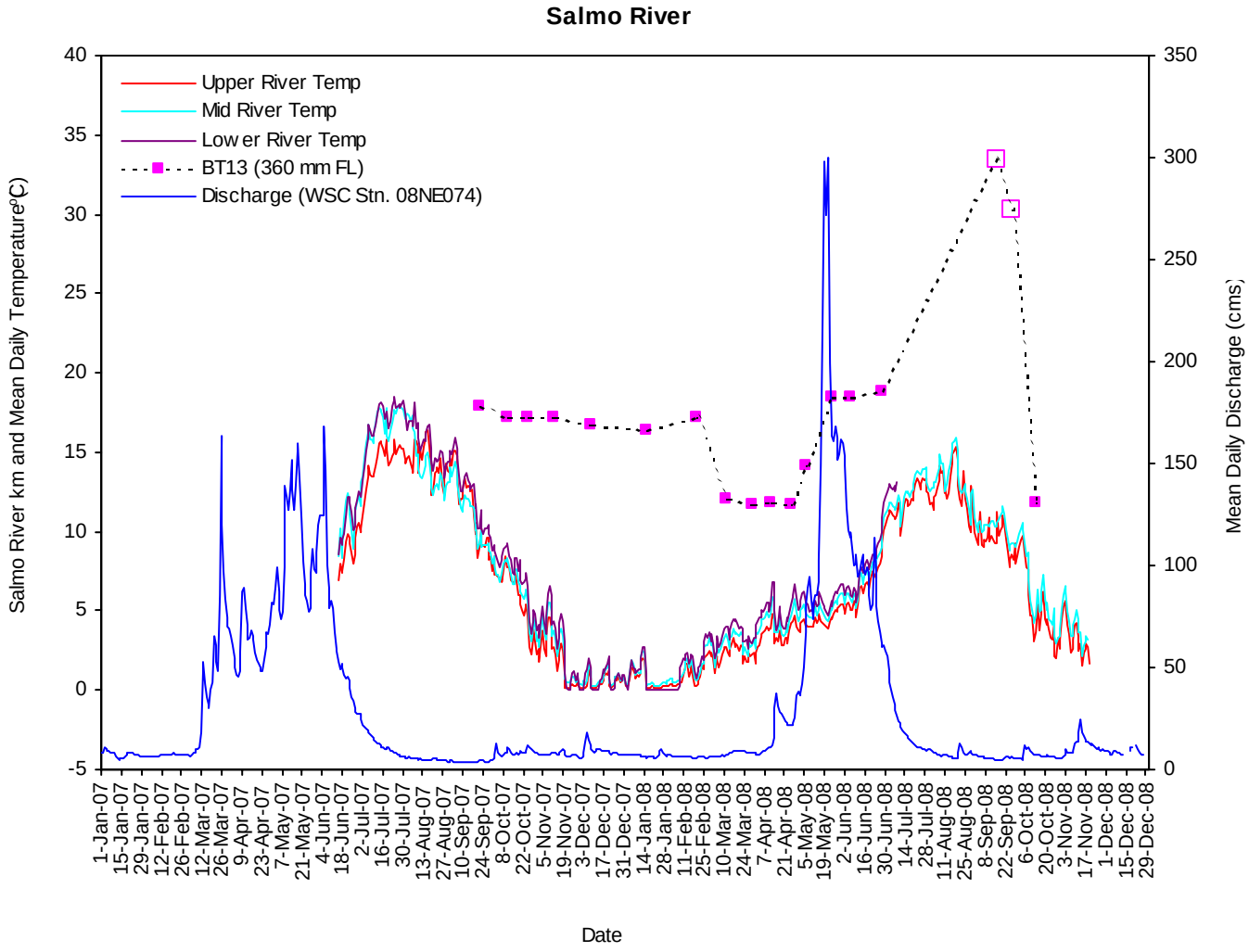

Figure B3 Movement data of a radio tagged subadult bull trout (BT13) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date October 2008). Open symbols indicate locations in Sheep Creek, a tributary to the Salmo River.

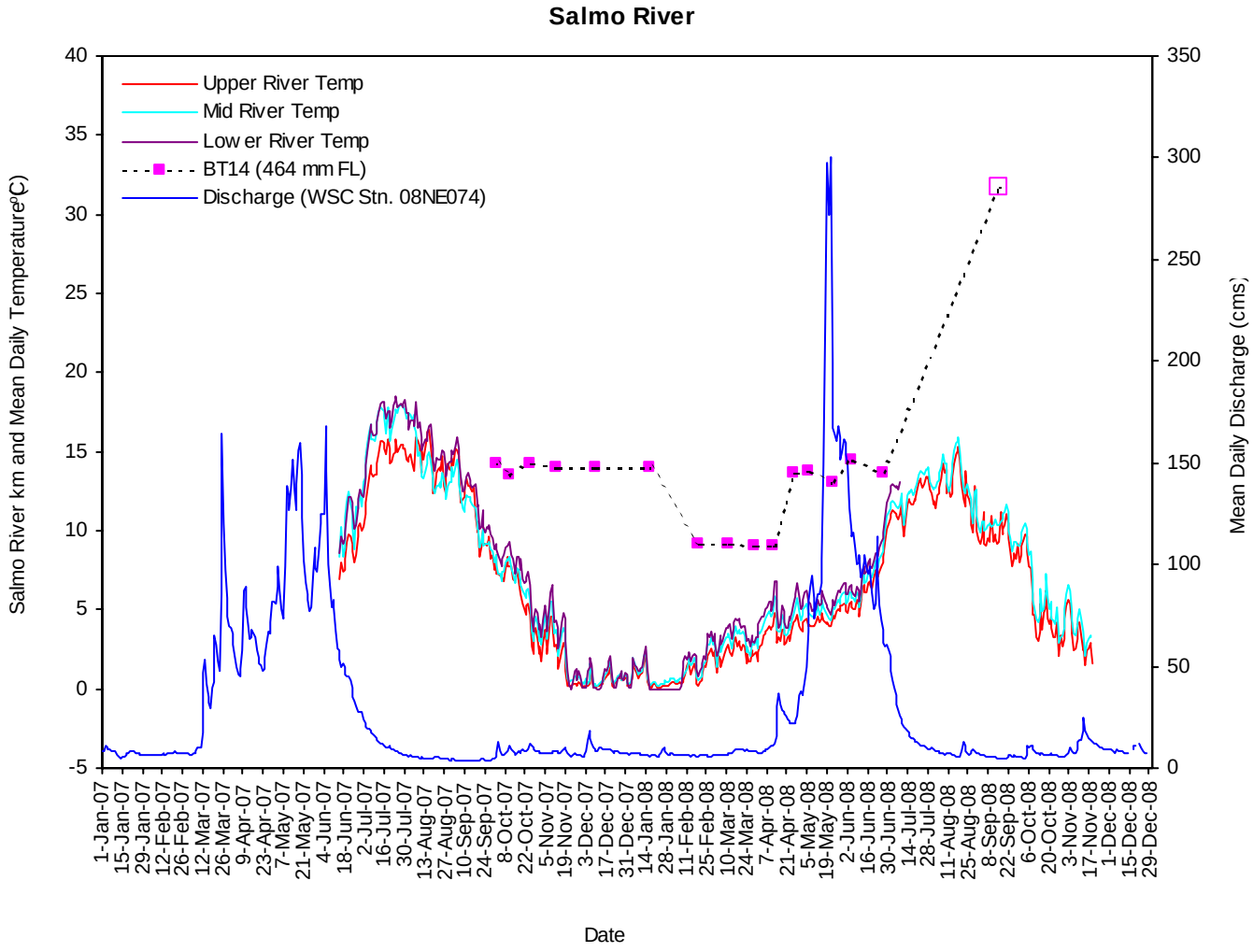

Figure B4 Movement data of a radio tagged subadult bull trout (BT14) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date October 2008). Open symbols indicate locations in the South Salmo River, a tributary to the Salmo River.

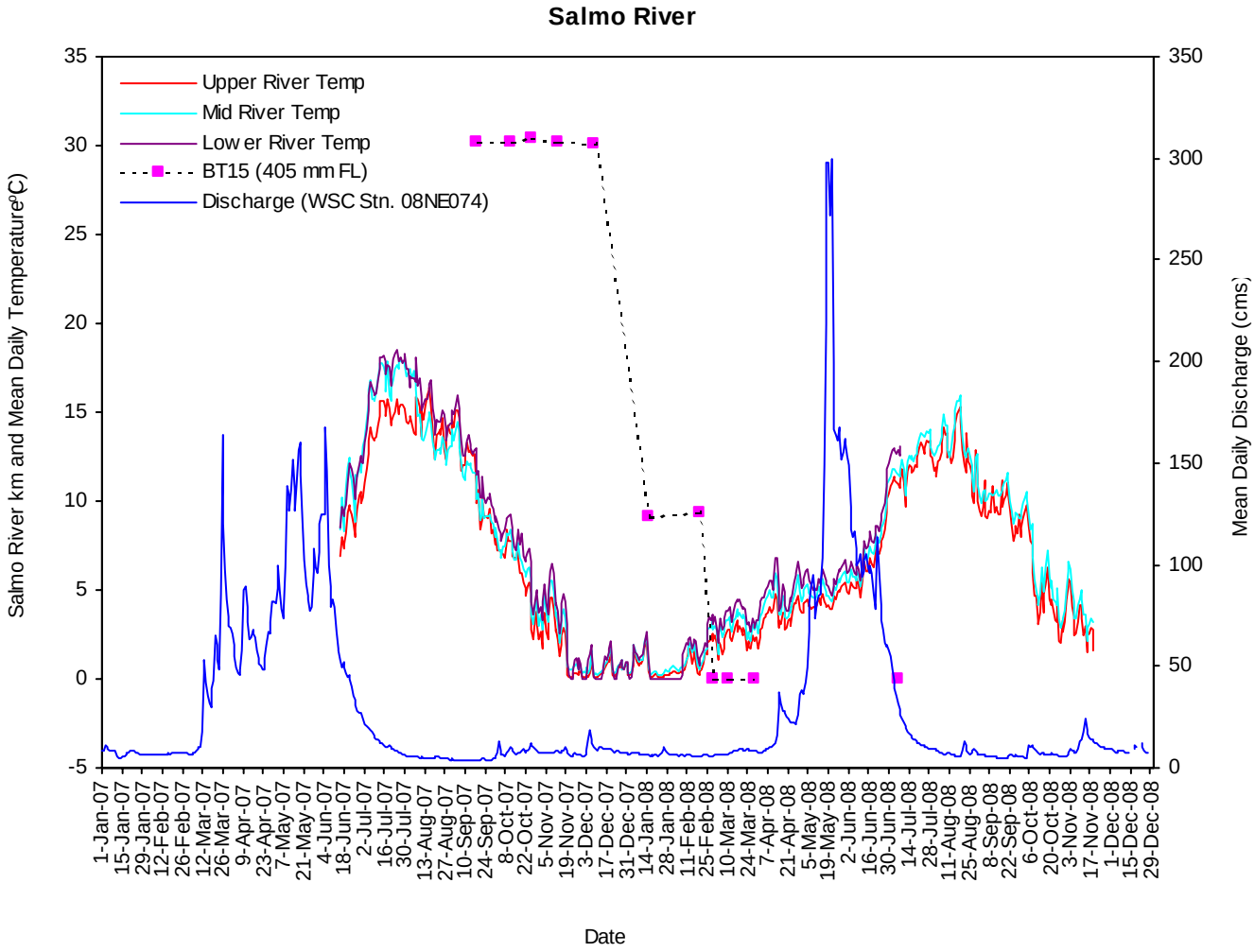

Figure B5 Movement data of a radio tagged subadult bull trout (BT15) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection. BT15 left the Salmo River on February 29 2008 and was subsequently detected at the Salmo/Pend d'Oreille confluence on March 10, 28 and July 06 2008 but did not return to the Salmo River for the duration of the transmitter lifespan (tag expiration date October 2008).

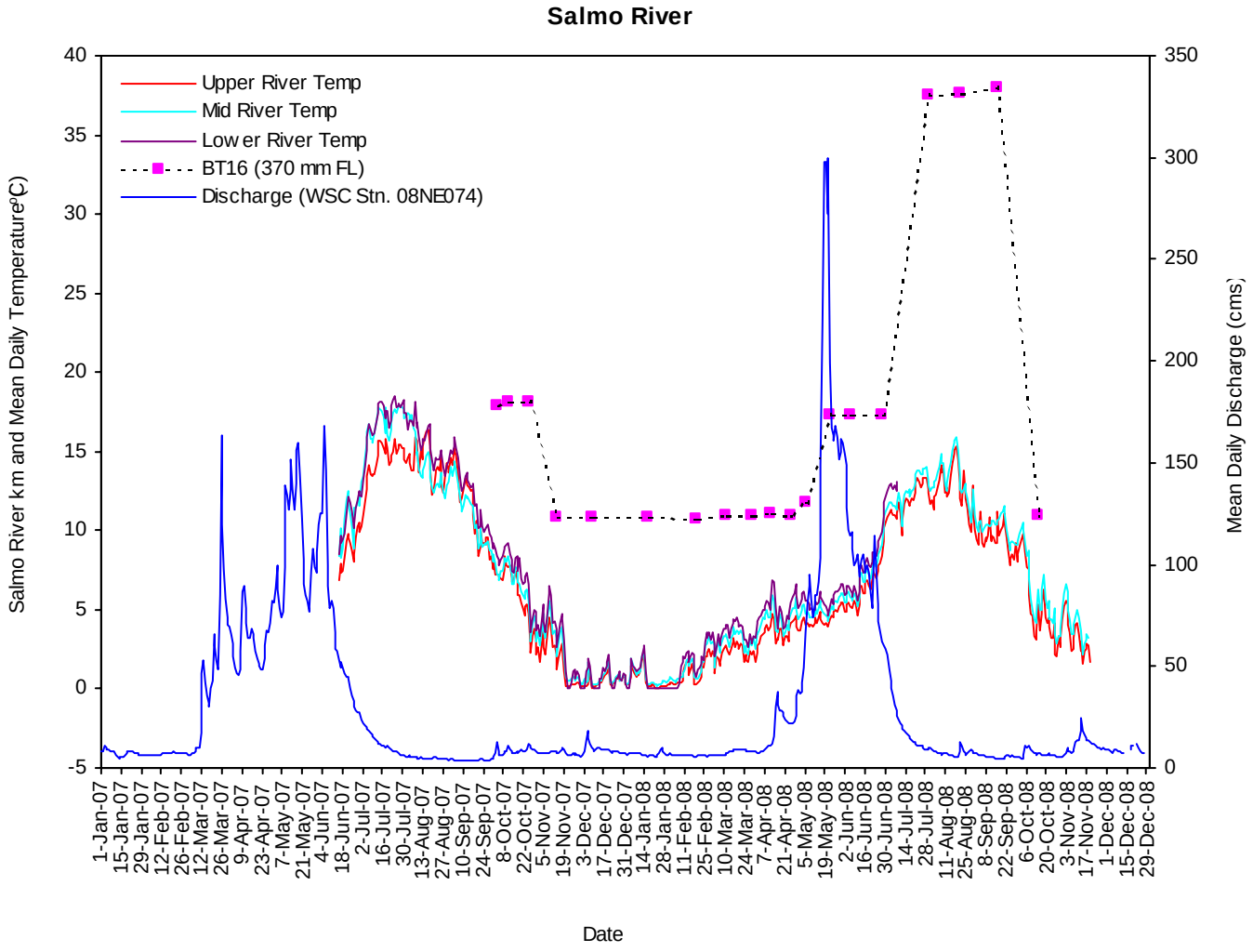

Figure B6 Movement data of a radio tagged subadult bull trout (BT16) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date October 2008).

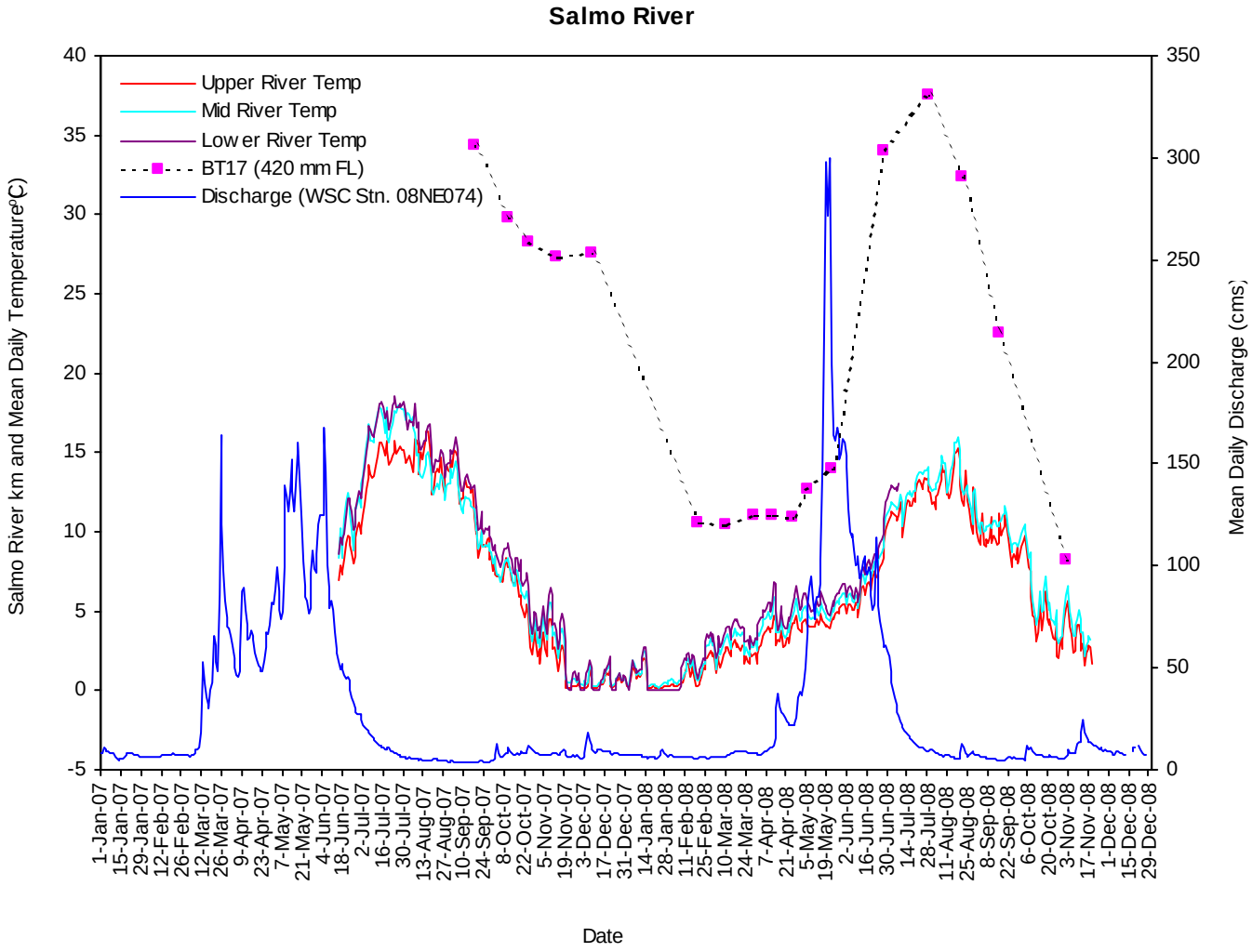

Figure B7 Movement data of a radio tagged subadult bull trout (BT17) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date October 2008).

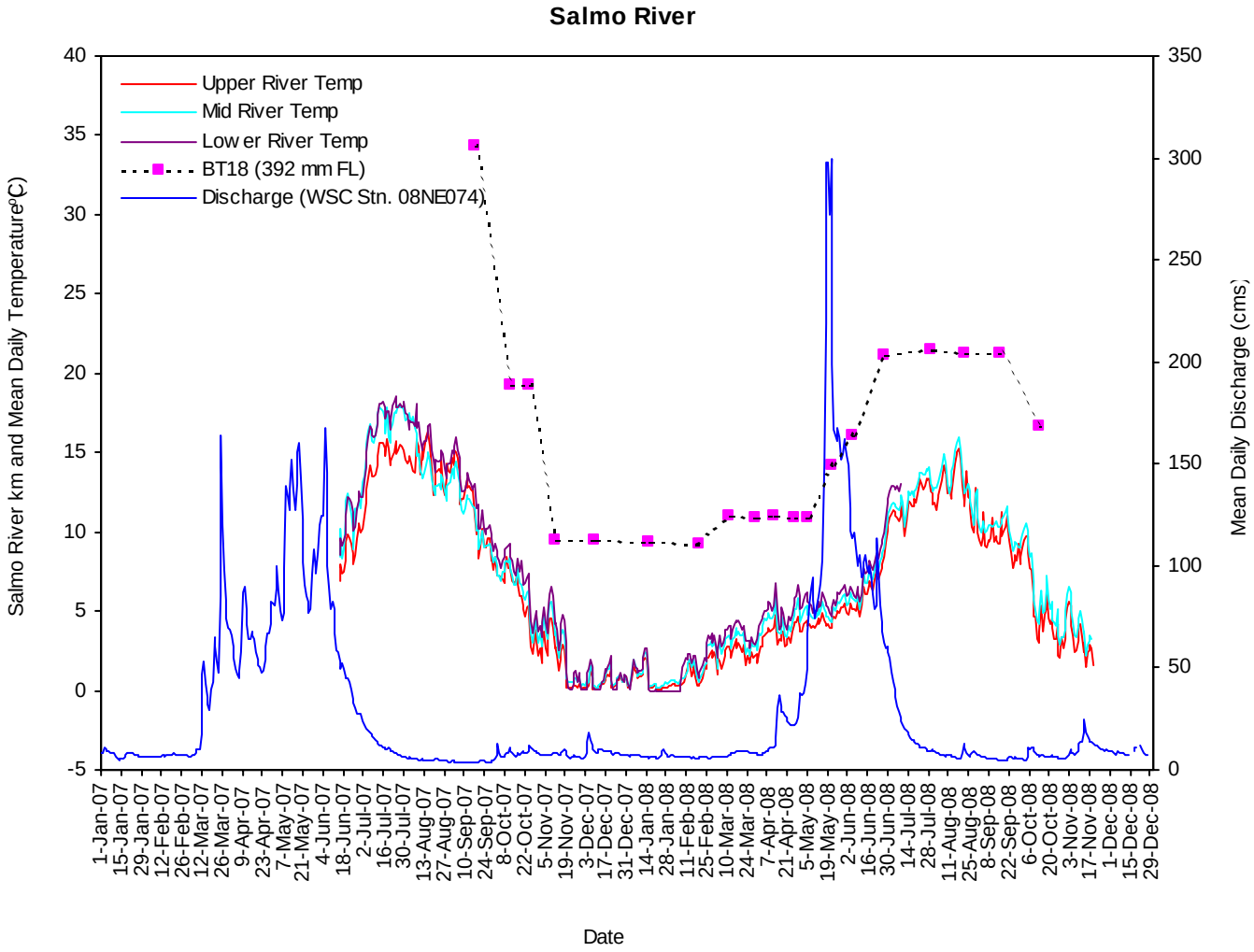

Figure B8 Movement data of a radio tagged subadult bull trout (BT18) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date October 2008).

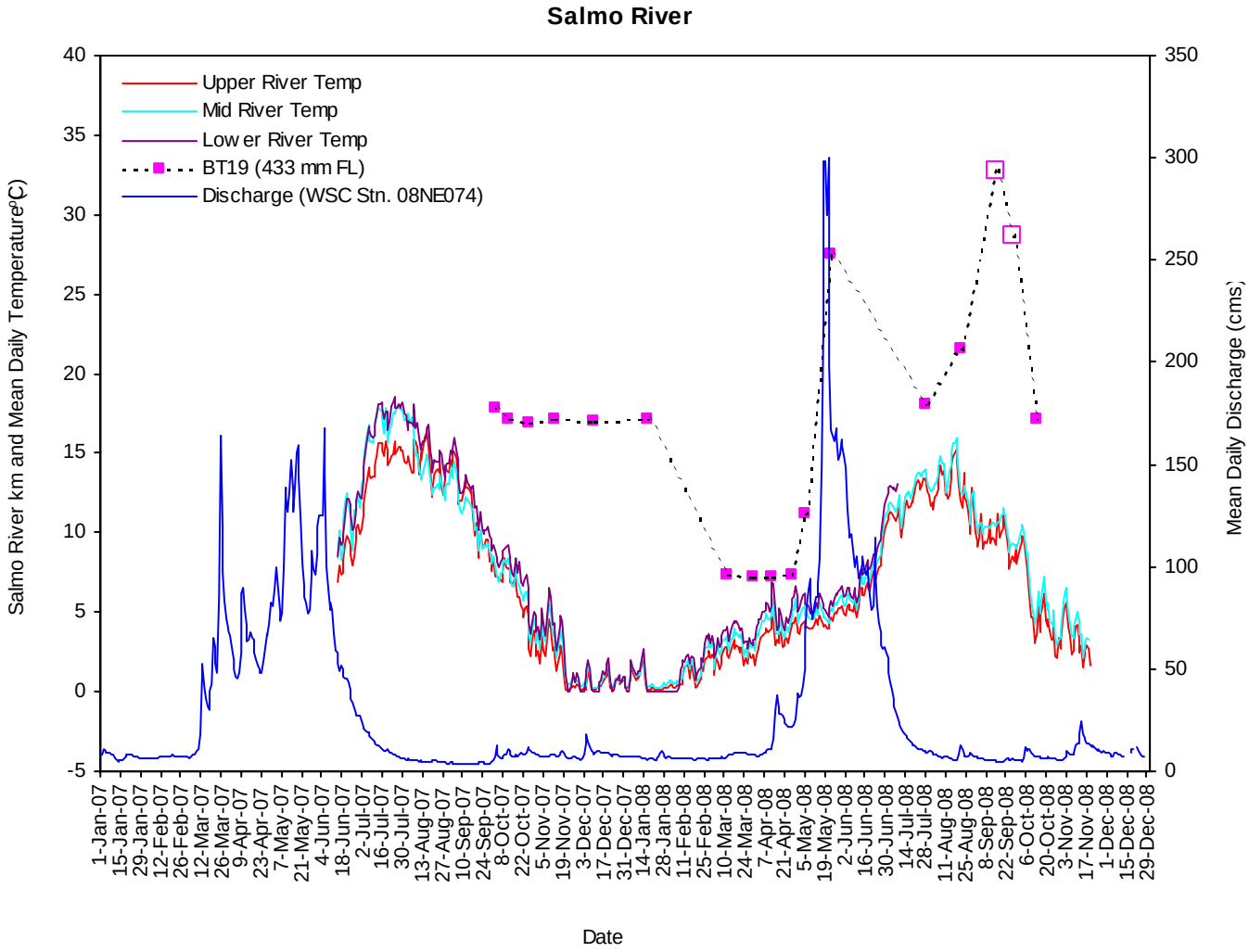

Figure B9 Movement data of a radio tagged subadult bull trout (BT19) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date October 2008). Open symbols indicate locations in Sheep Creek, a tributary to the Salmo River.

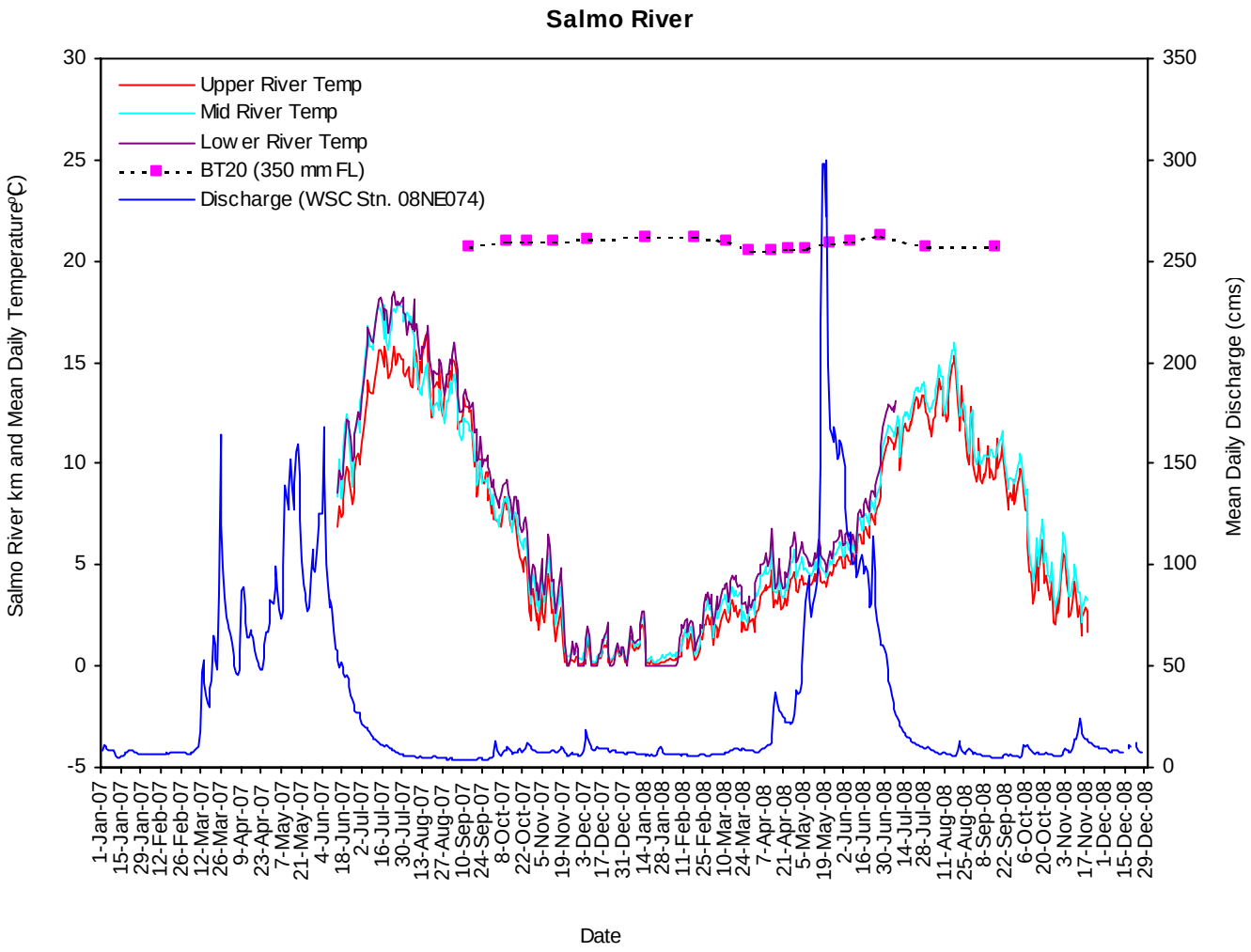

Figure B10 Movement data of a radio tagged subadult bull trout (BT20) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date October 2008).

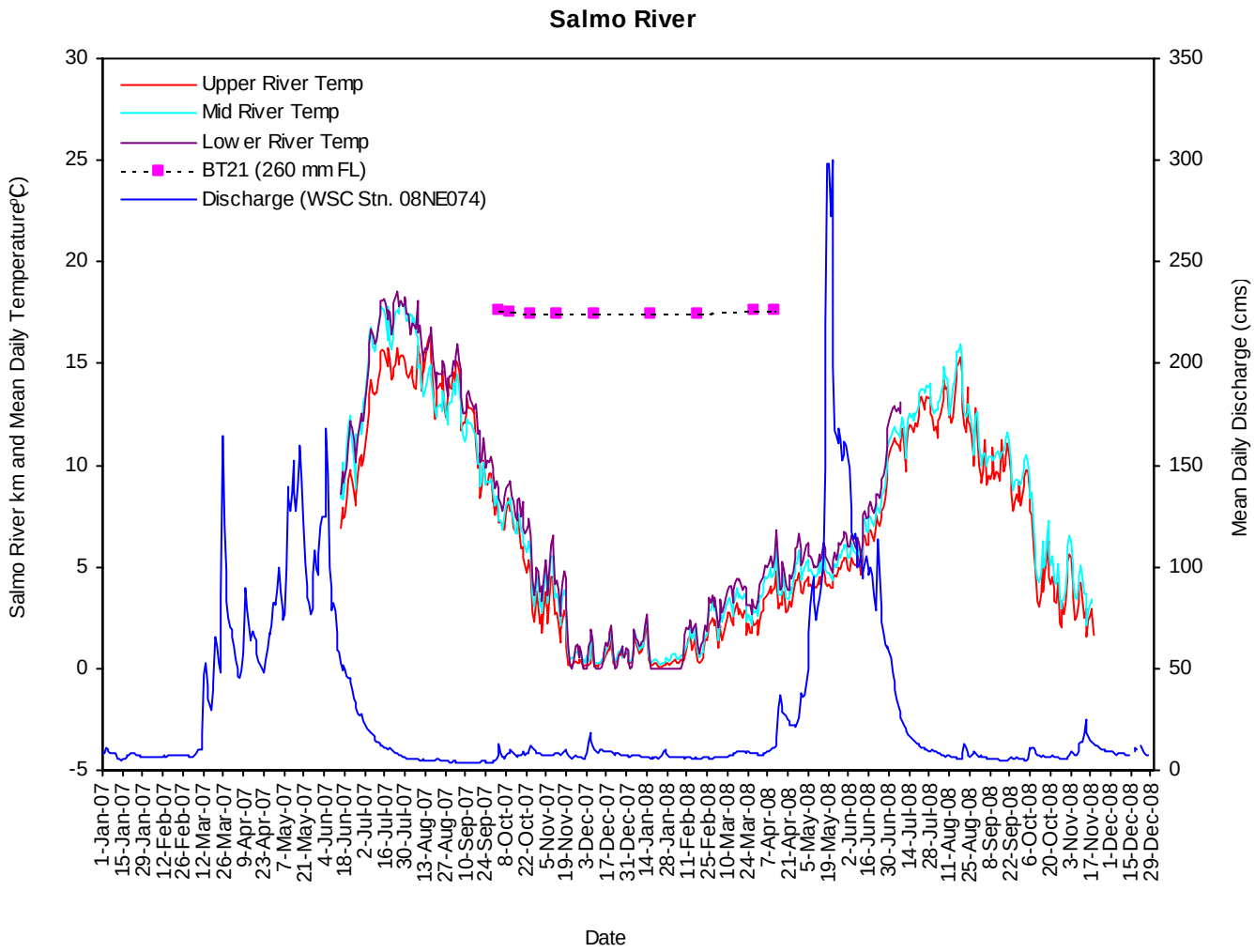

Figure B11 Movement data of a radio tagged subadult bull trout (BT21) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2008).

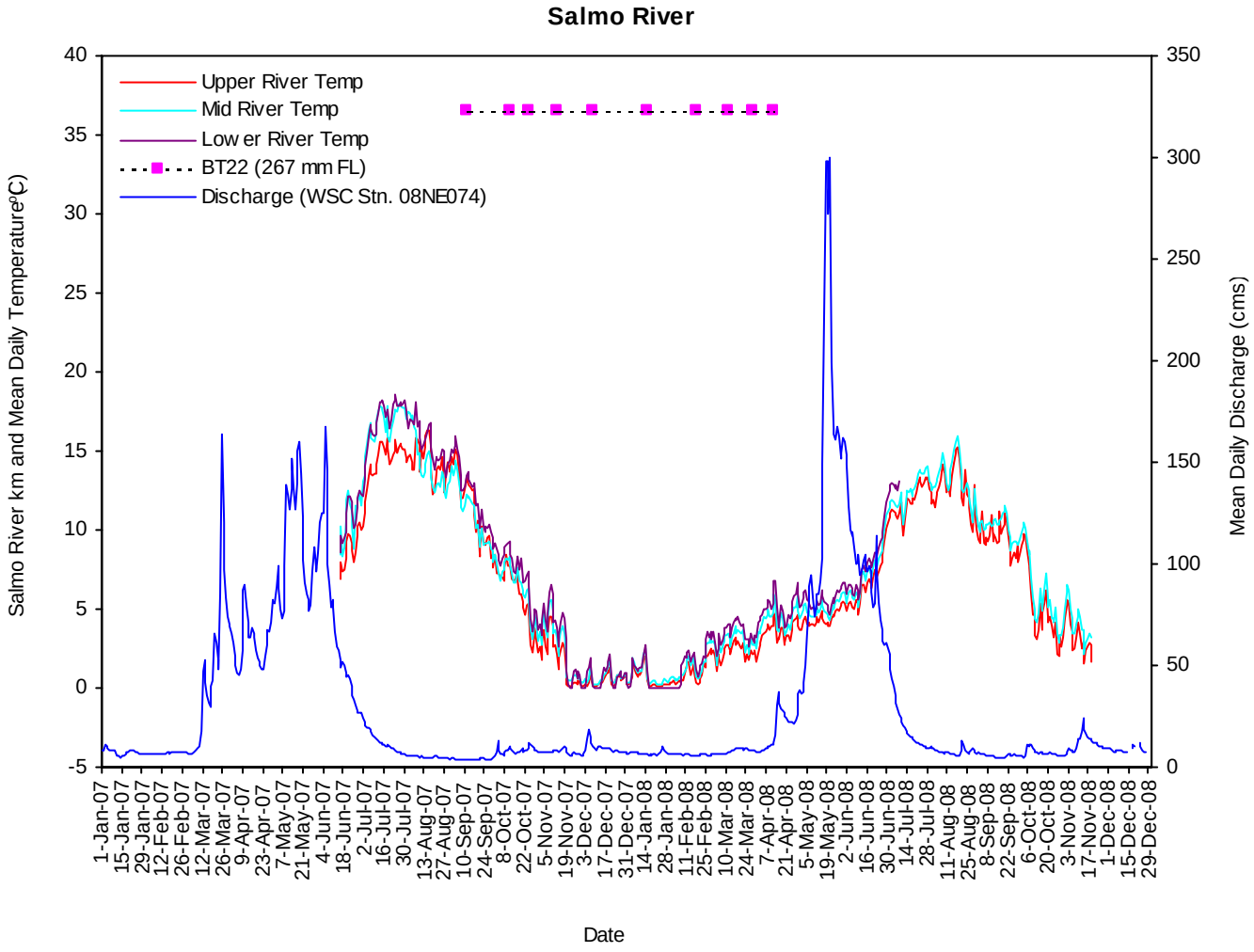

Figure B12 Movement data of a radio tagged subadult bull trout (BT22) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2008). Considered a mortality based on lack of movement.

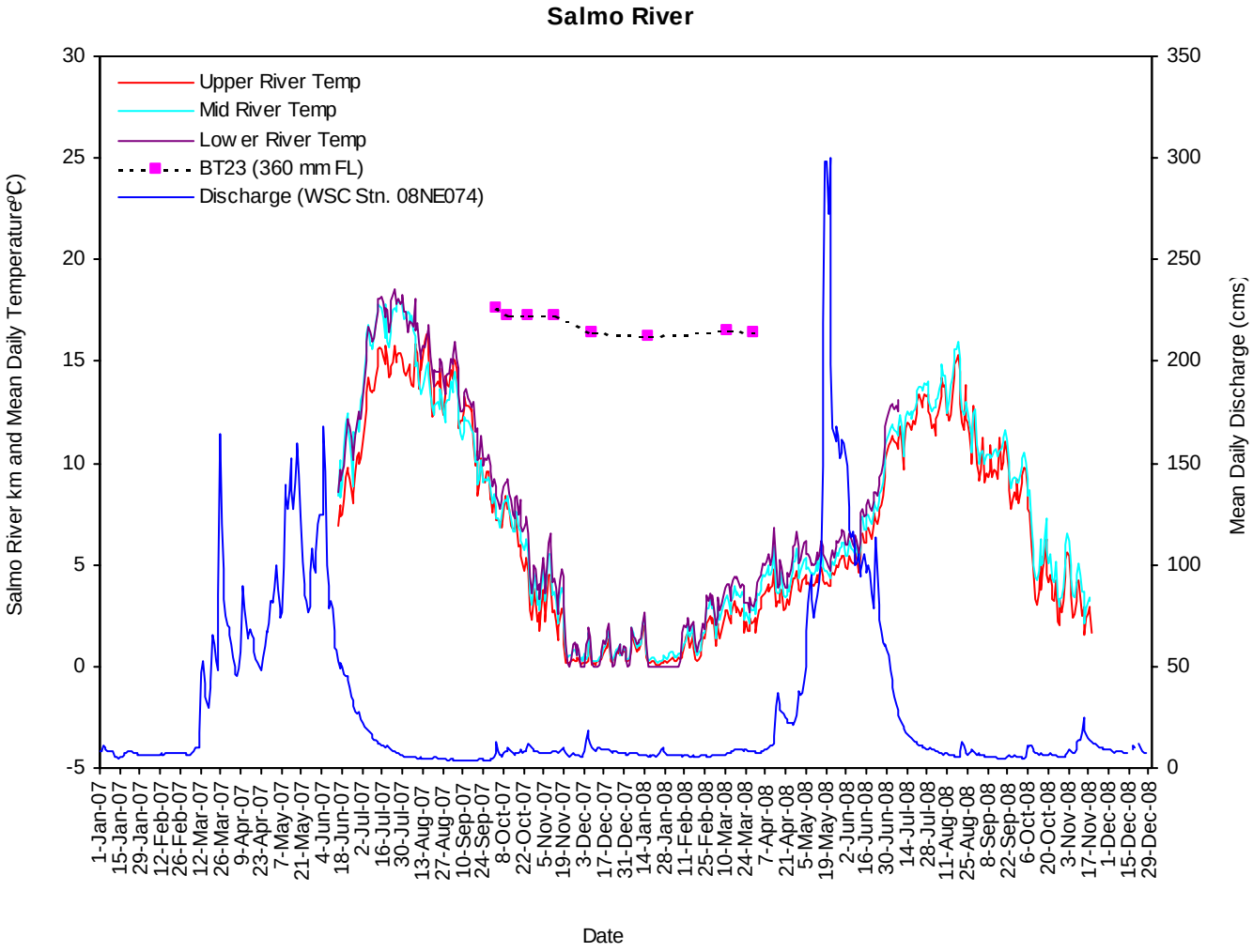

Figure B13 Movement data of a radio tagged subadult bull trout (BT23) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2008). Considered a mortality by January 2008. Transmitter recovered from carnivore den when snow melted in March 2008.

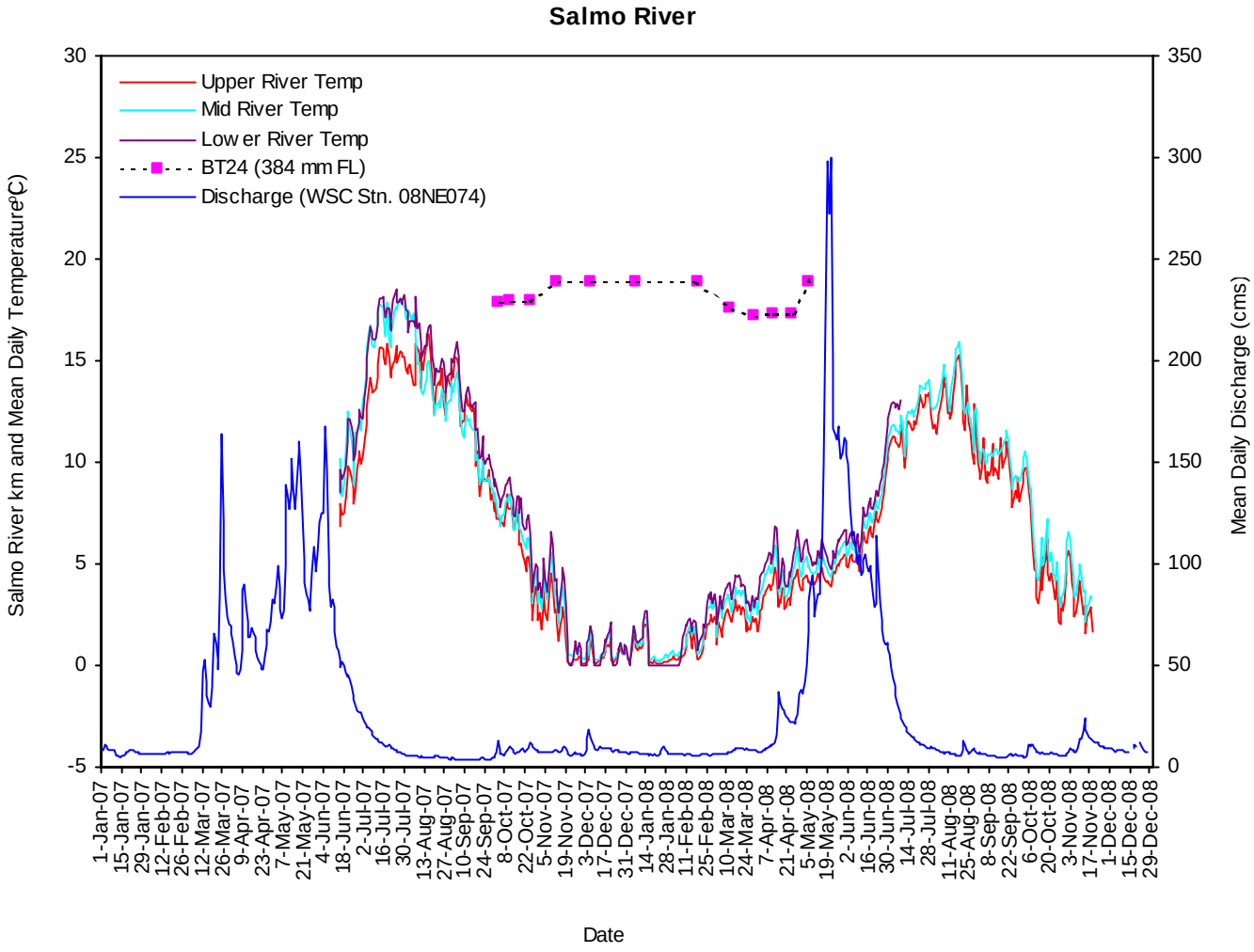

Figure B14 Movement data of a radio tagged subadult bull trout (BT24) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2008).

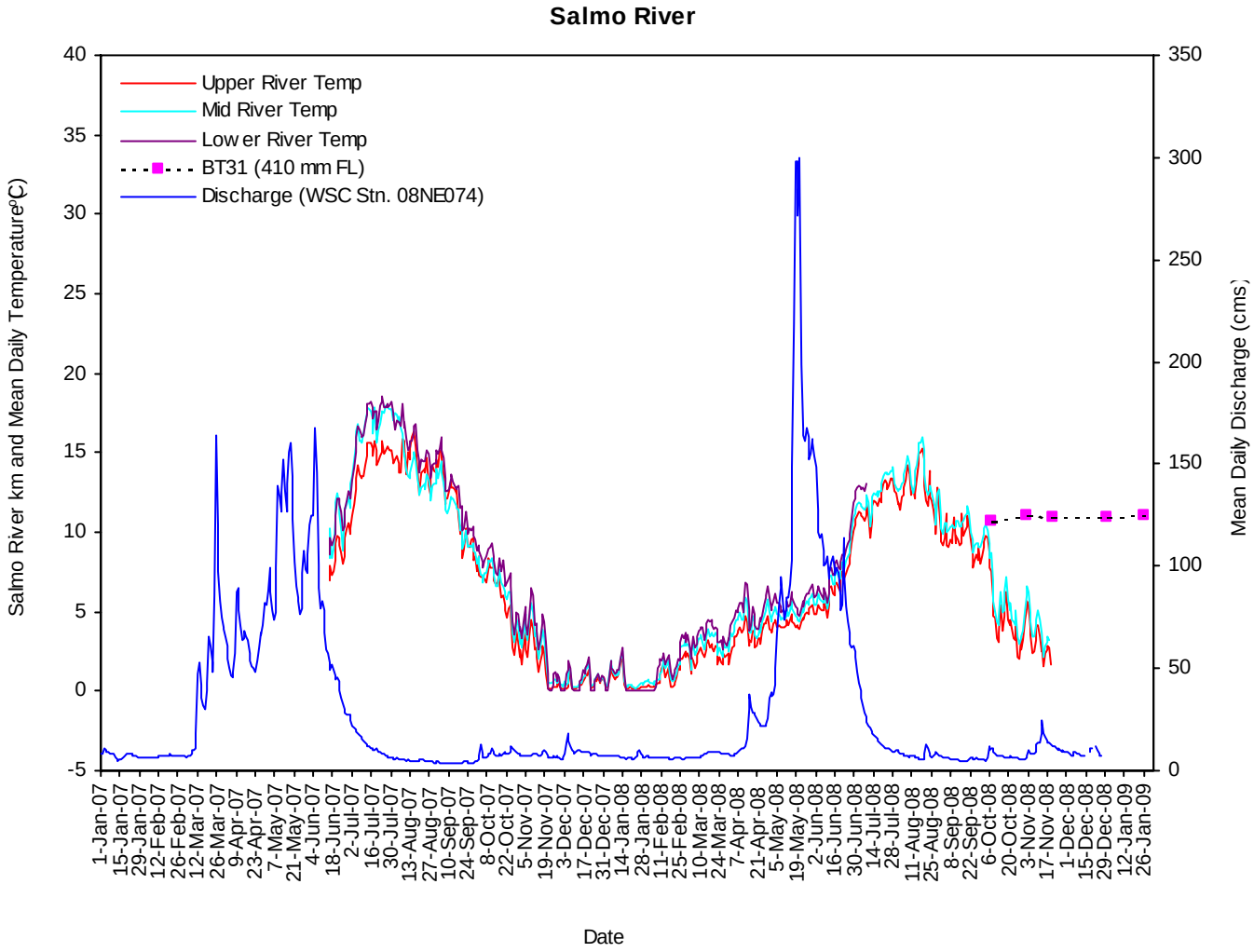

Figure B15 Movement data of a radio tagged subadult bull trout (BT31) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2010).

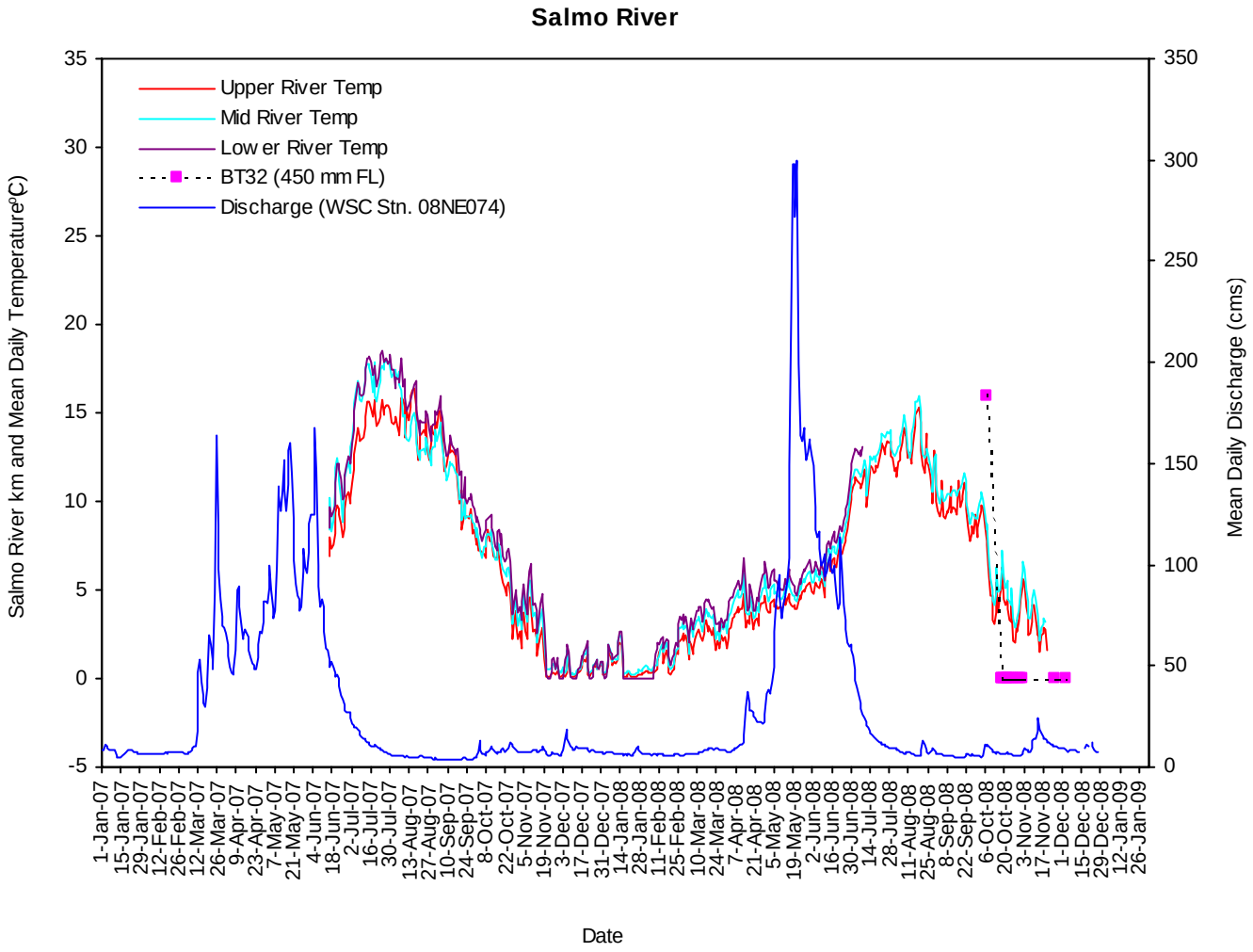

Figure B16 Movement data of a radio tagged subadult bull trout (BT32) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection. BT32 left the Salmo River on November 01 2008 and was subsequently detected at the Salmo/Pend d'Oreille confluence on November 25 and December 03 2008, Red Bird Creek on December 03, 10 and 11 and at Boundary Dam continuously from December 03-10 2008 (tag expiration date April 2010).

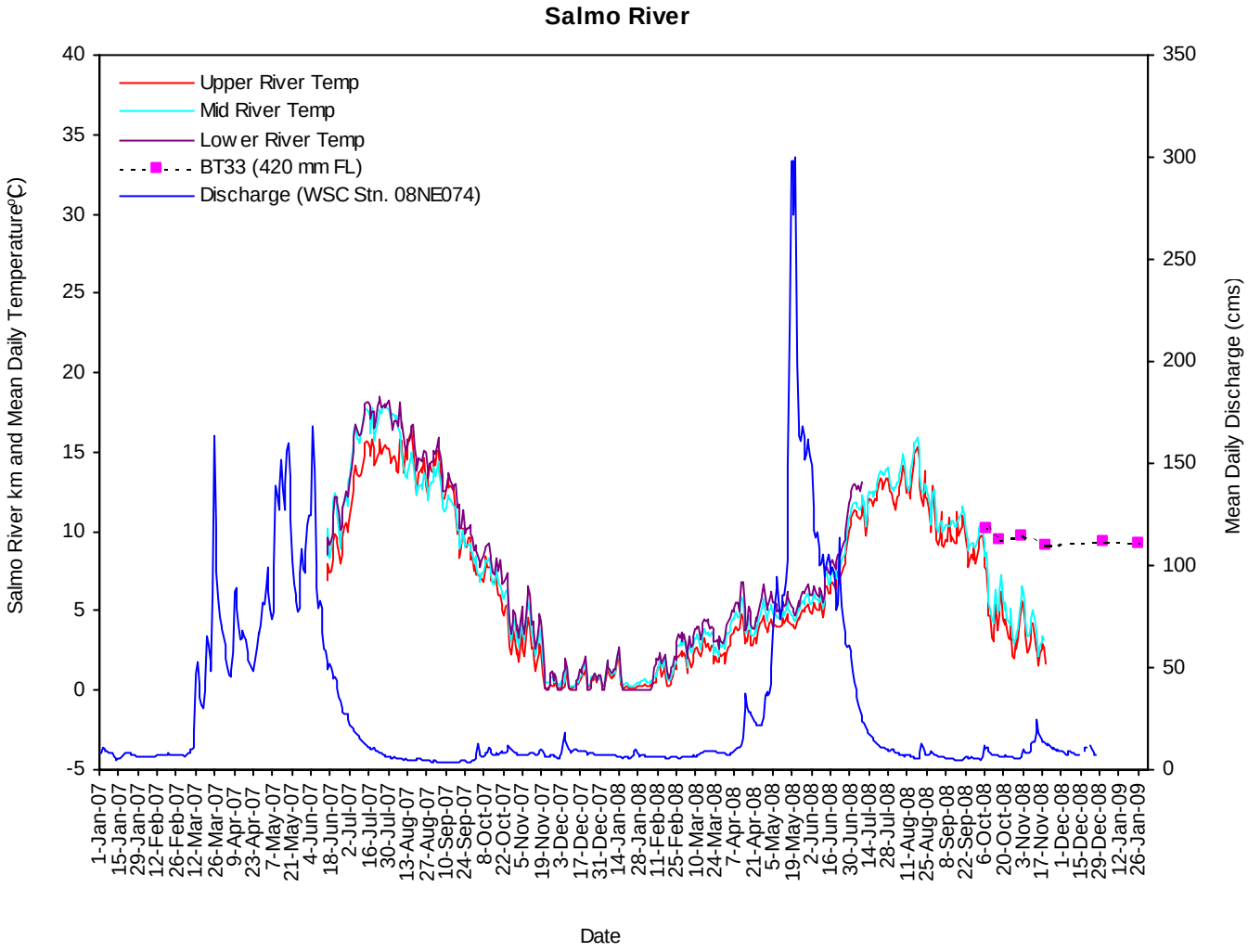

Figure B17 Movement data of a radio tagged subadult bull trout (BT33) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2010).

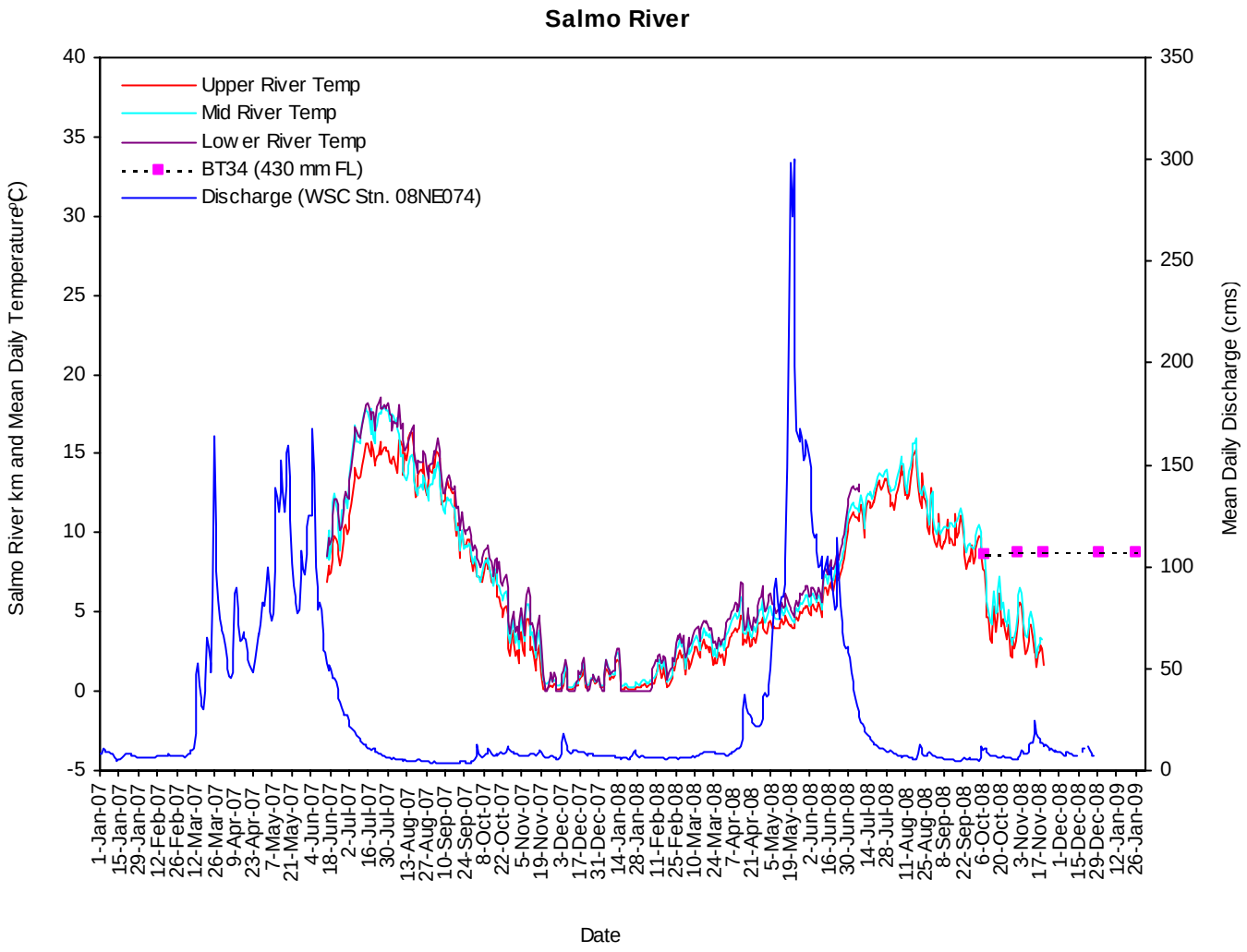

Figure B18 Movement data of a radio tagged subadult bull trout (BT34) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2010).

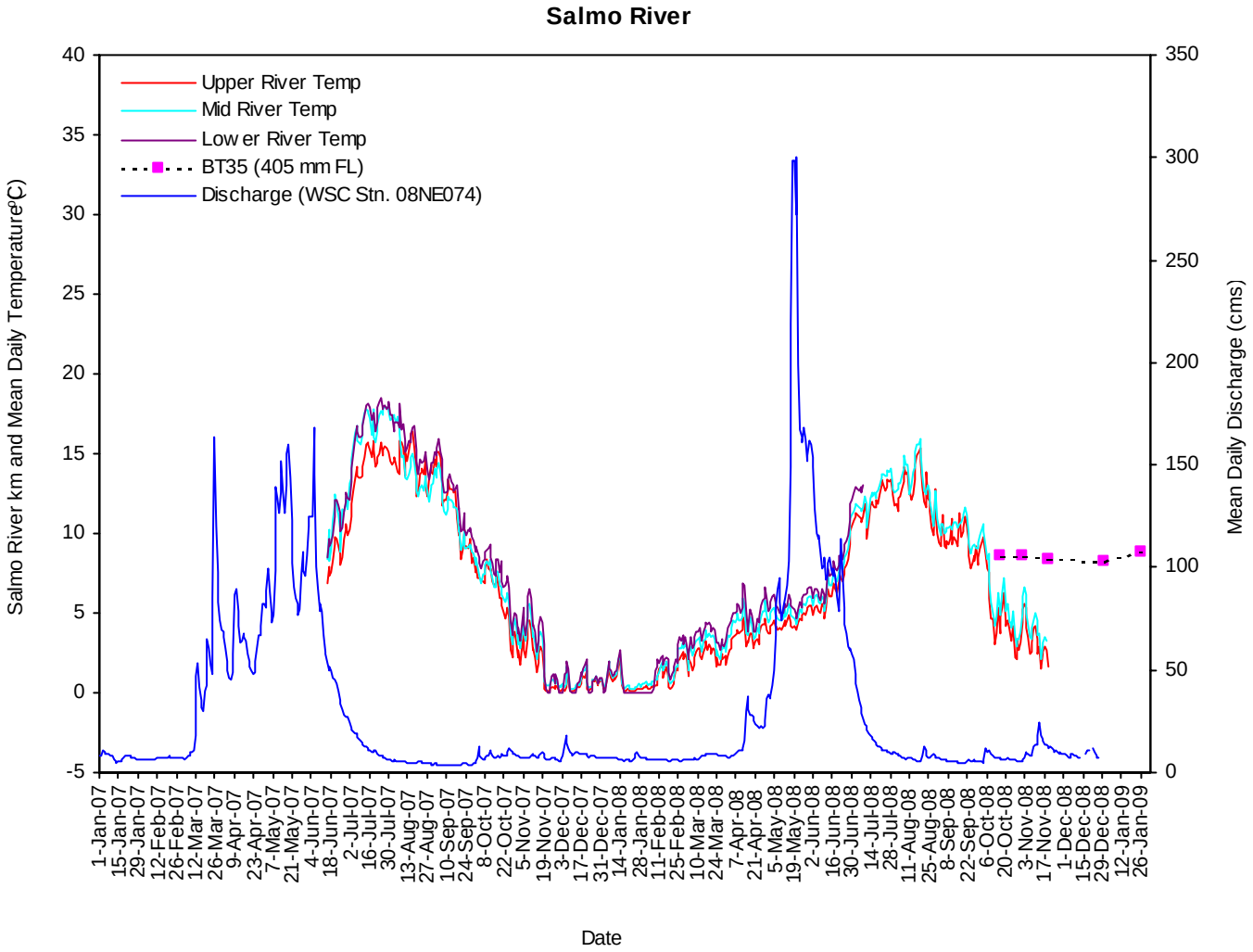

Figure B19 Movement data of a radio tagged subadult bull trout (BT35) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2010).

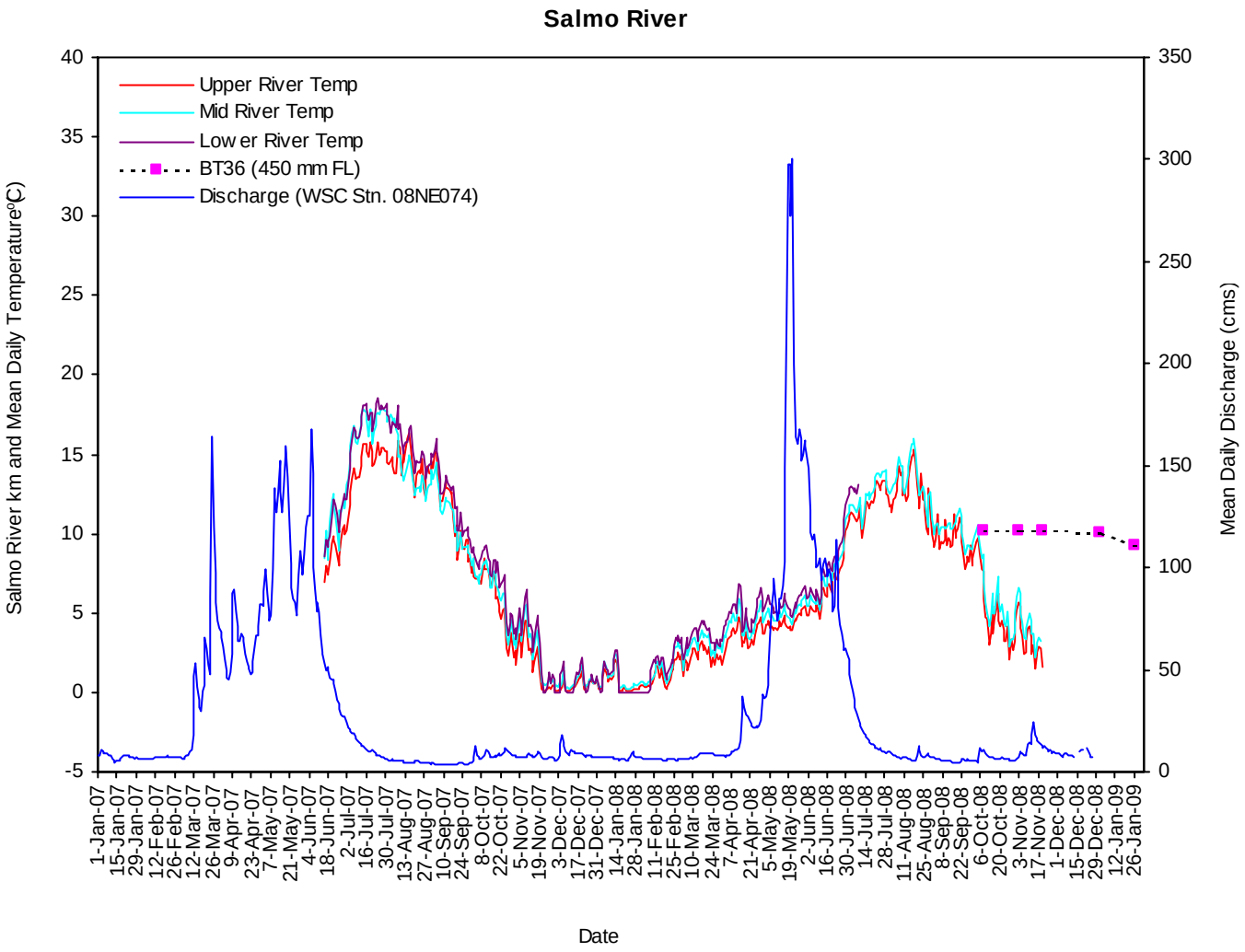

Figure B20 Movement data of a radio tagged subadult bull trout (BT36) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2010).

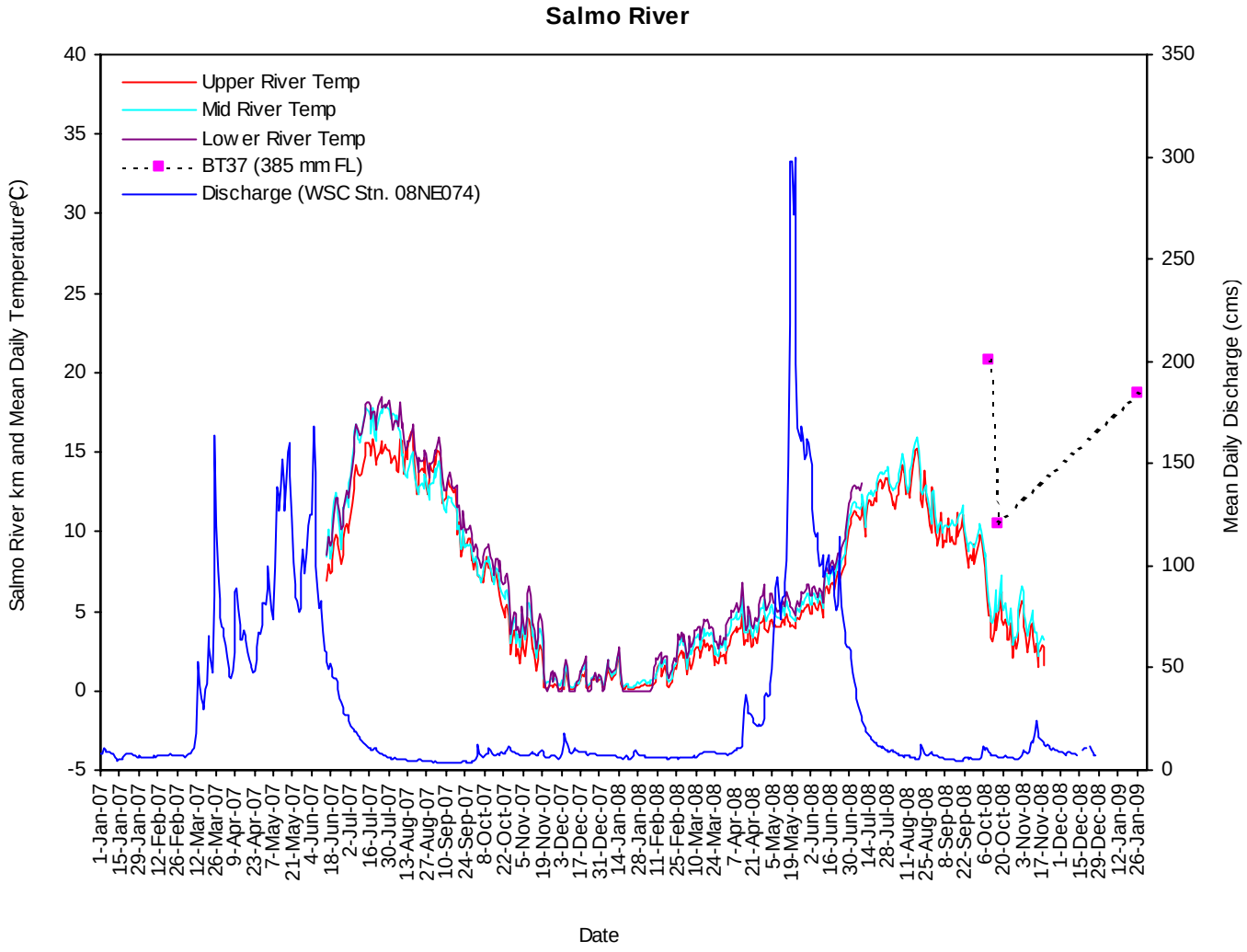

Figure B21 Movement data of a radio tagged subadult bull trout (BT37) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2010).

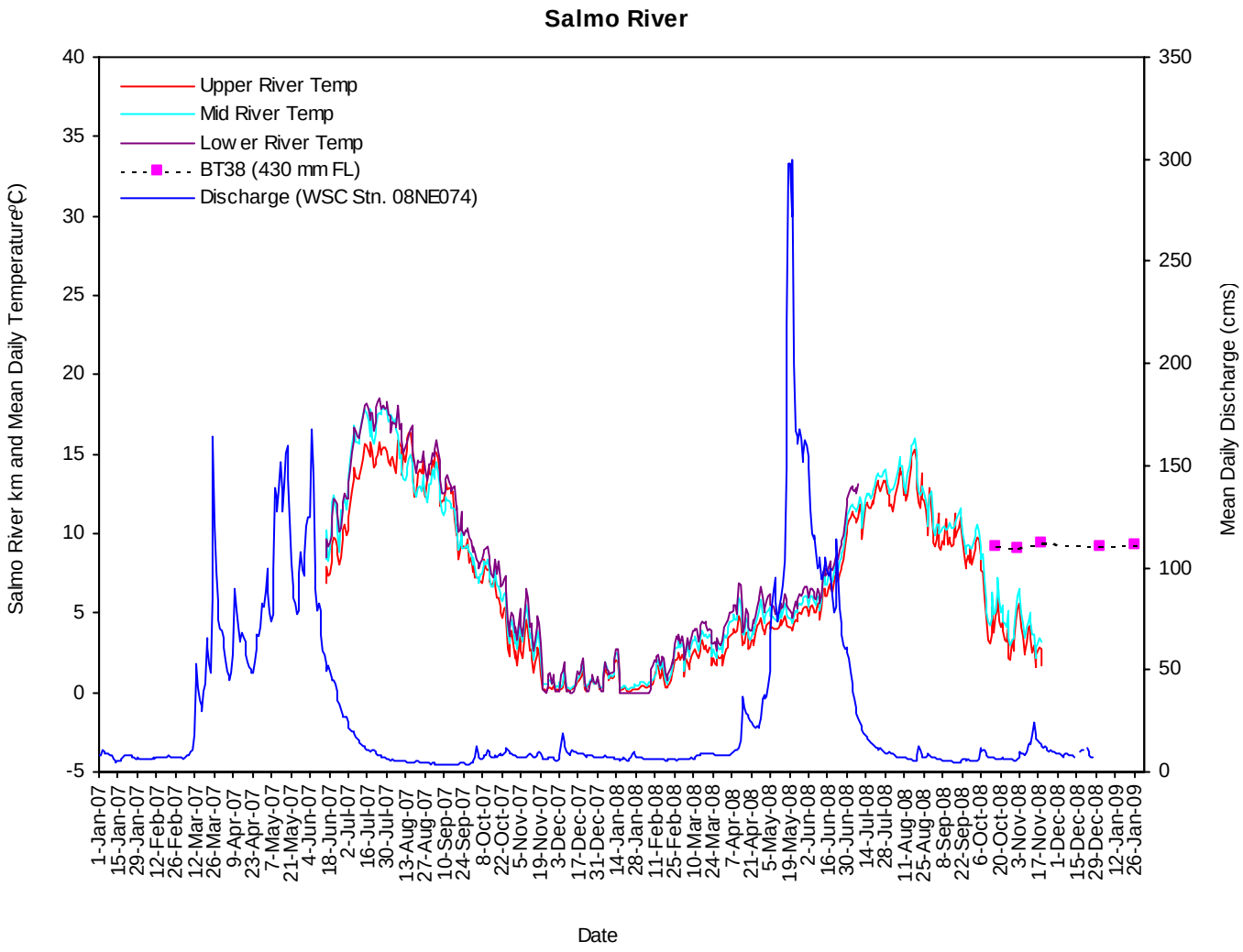

Figure B22 Movement data of a radio tagged subadult bull trout (BT38) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2010).

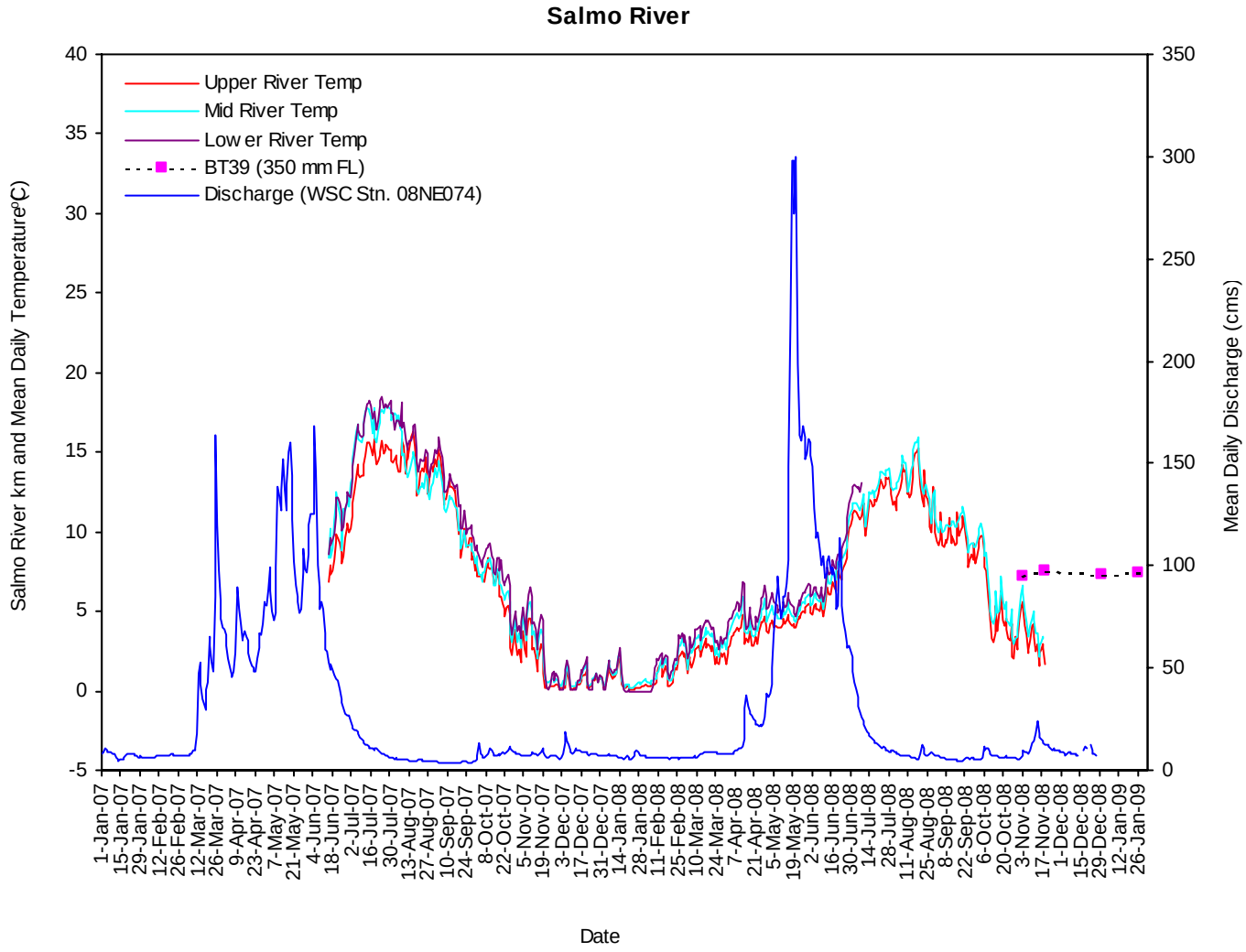

Figure B23 Movement data of a radio tagged subadult bull trout (BT39) in relation to mean daily water temperature and discharge. Each point represents a tracked location or remote station detection (tag expiration date April 2010).

Appendix C Fish detection record (dates) at the Salmo River remote station (rkm 1.2). Dates separated by dashes indicate period of daily detections (inclusive). Other than BT15 and BT32, all detections were of fish tagged in the Pend d'Oreille River. Fish codes 47, 171, 188, and 198 were entrained through Boundary Dam (SCL 2009a and 2009b).

Species	Code	2007			2008											2009
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Bull Trout	15					28,29	28				6						
	32													17-19, 21-23, 25-26, 30-31	1, 25	3	
	167																18
Rainbow	31	26		5,6,19			29	10,11,21,25	18,19					26		5,6,19	
	47									19-30	1-11, 23 31	1, 5-27				25-28, 31	6-7
	171																8,9
	188											20-30	4				
Cutthroat	113								4-9	12, 19-29	25, 31						
	198										4 -14, 23-27, 29-31						
Mountain whitefish	108							7			23-31	1-26					
	112			16-18													
	114							5-7, 10-11	15-18	9-25	25-31	1-16,19, 22-27, 29-31	1-5				
	116				21-24							3-18, 22-27	1-2				
	117								6,15,17-19		14						
	118					18	14-18	12,29	4-8, 15-19	11-20		7-18, 22-28	1-4, 17-30				