DISTRIBUTION AND MOVEMENT OF STEELHEAD AND ANGLERS IN THE CLEARWATER RIVER, IDAHO

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AUTHORIZATION TO SUBMIT THESIS

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ABSTRACT

Steelhead *Oncorhynchus mykiss* is a species of high economic value and supports popular sport fisheries across the Pacific Northwest. The Clearwater River, Idaho, provides a trophy steelhead fishery and is home to wild- and hatchery-origin steelhead. Given the lack of information on the spatial and temporal overlap of wild and hatchery steelhead, as well as anglers, in the Clearwater River, radiotelemetry was used to describe the distribution of steelhead, and creel surveys were used to describe the distribution of anglers. In total, 289 wild (Potlatch River and Lochsa River) and hatchery (Dworshak and South Fork Clearwater River – local brood and general production) steelhead were radio tagged at Lower Granite Dam from September 2016 – June 2018. Steelhead were tracked in the Clearwater River using mobile tracking surveys (boat and vehicle) and 12 stationary antennas. The majority of wild and hatchery steelhead arrived in the Clearwater River in the fall with the exception of Lochsa River steelhead which arrived in the fall and following spring. Average daily movement of steelhead was minimal (mean = 0.3-4.7 km/d) and dependent on water temperature and flow. Steelhead were primarily detected in run habitats. Habitat use was partially related to season and length and age of steelhead. Wild and hatchery steelhead returned at high rates to their natal tributaries and release locations. Fates of wild and hatchery steelhead varied with fish either returning to spawning grounds, harvest by anglers (i.e., hatchery fish), or their fate was unknown. No straying was observed for wild or hatchery steelhead; however, steelhead overshooting their natal tributaries and release locations was documented. Spatial and temporal overlap of wild and hatchery steelhead was minimal. Anglers overlapped with hatchery steelhead in the fall, winter, and spring. Overlap of anglers and wild steelhead was minimal and largely occurred in the fall in the lower Clearwater River.

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DEDICATION

This thesis is dedicated to my parents, who have always been supportive of my education and career.

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INTRODUCTION

Steelhead *Oncorhynchus mykiss* is the anadromous form of Rainbow Trout and has a native distribution that includes portions of North America and Asia. In North America, steelhead were historically distributed throughout coastal drainages from Alaska to the Baja Peninsula of Mexico, and inland through the Columbia and Snake river basins (MacCrimmon 1971). The current distribution of steelhead extends from Port Heiden, Alaska, to southern California; steelhead remain in the Columbia and Snake river basins (Behnke 2002). Steelhead populations have experienced declines in distribution and abundance in many systems. Although a number of factors have contributed to the decline of steelhead, the primary factors associated with their poor status include changes to ocean conditions (Smith et al. 2000; Robards and Quinn 2002), water development (e.g., construction of hydroelectric dams), and land use activities (e.g., timber harvest, mining, urbanization; Chapman 1986; Nehlsen et al. 1991; Moyle 1994; Congleton et al. 2000). Steelhead populations are federally listed under the Endangered Species Act (ESA) as endangered and threatened in parts of California, and threatened in portions of Idaho, Oregon, and Washington.

Steelhead in the Clearwater River, Idaho, are valued economically, recreationally, and culturally (Gilbreath et al. 1976; Nehlsen et al. 1991). Recreational fisheries for steelhead have been increasing in popularity since the 1940s (Sheppard 1972). The Clearwater River provides what is considered a trophy steelhead fishery, attracting anglers from around the world (NPCC 2003). The steelhead season extends from July through May and covers hundreds of kilometers of rivers and streams, supporting both recreational and tribal fisheries (McCormick et al. 2015).

Steelhead in the Clearwater River are considered summer run (Sheppard 1972), and are separated into five wild populations (lower Clearwater River, South Fork Clearwater River, Lolo Creek, Selway River, and Lochsa River) and one hatchery stock (Dworshak National Fish Hatchery; Copeland et al. 2015). Since wild steelhead are listed as threatened under the ESA, they cannot be harvested by recreational anglers (U.S. Office of the Federal Register 1997). Therefore, the steelhead fishery in the Clearwater River is supported by the production of hatchery steelhead (identified by a clipped adipose fin) which provide angling and harvest opportunities for recreational and tribal fisheries (Waples et al. 1993; McCormick et al. 2012; McCormick et al. 2015).

The Idaho Department of Fish and Game (IDFG) has a long-term goal of conserving Idaho's steelhead runs to provide benefits for all users. Achieving this goal requires an in-depth understanding of how steelhead populations function relative to the fishery. Since the Clearwater River steelhead fishery is highly valued by anglers, it is essential that fishery managers sustain an economically important fishery while also conserving viable wild steelhead populations (Nelson et al. 2005). Previous studies in the Snake River basin have used run reconstruction models to provide the information on steelhead necessary for fisheries management (Copeland et al. 2015). Run reconstruction efforts have estimated the spatial distribution of steelhead using information on the abundance and probability of a given stock of steelhead moving among predetermined river reaches in the Columbia and Snake river basins. In Idaho, harvest and angling effort data have been collected through on-site angler surveys (i.e., creel surveys), as well as off-site angler surveys (i.e., mail, telephone, and internet surveys; Simpson and Bjornn 1965; Lindland et al. 1976; McCormick et al. 2015). Data collected through both run reconstruction efforts and various angler surveys have provided estimates of the total number of wild and hatchery steelhead returning to the Clearwater River and escapement. However, these estimates contain substantial uncertainty (Copeland et al. 2015). In particular, a major input to run reconstruction models is the spatial distribution of fishes, but the movement and distribution of wild and hatchery steelhead in the Clearwater River is poorly understood. Also, run reconstruction efforts do not include relevant data for wild steelhead and assumes that movement and distributions of wild steelhead are similar to hatchery fish. Additionally, little is known about rates of overshooting (i.e., fish pass natal stream before returning to natal stream; Keefer and Caudill 2013) and straying (i.e., do not return to natal stream; Quinn 1993), or broad-scale habitat use of steelhead in the system. Furthermore, fishery managers assume that wild and hatchery steelhead are equally vulnerable to the Clearwater River steelhead fishery. Gathering information on steelhead populations and angler use is crucial for effectively managing the fishery. Information on the spatial and temporal distribution of wild and hatchery steelhead, as well as anglers, may influence management decisions in directing angling effort towards hatchery fish and away from wild fish (Johnson and Kucera 1985; Nelson et al. 2005). Data may also provide insight on how release locations influence the distribution of hatchery steelhead and their final fate in the Clearwater River. Therefore, additional information is needed to better understand steelhead movement dynamics and angler use in the system.

The objectives of this research were to describe 1) the distribution and movement of wild- and hatchery-origin steelhead, 2) the distribution of anglers, 3) habitat use of steelhead, and 4) fate of steelhead in the Clearwater River. Radiotelemetry was used to evaluate movement of steelhead. Relocations of radio-tagged fish provided information on large-scale habitat use and spatial distributions to generate fishery-specific estimates of movement and residence time. Radio tracking also provided insight on stock-specific differences in migratory patterns among wild- and hatchery-origin steelhead. Angler counts identified locations of fishing effort. Results of this study identified the spatial distribution of steelhead and anglers that will aid in management and conservation efforts.

1: STUDY AREA

The Clearwater River watershed encompasses 25,000 km^2 in north-central Idaho (Munn and Brusven 2003; Figure 1). Major watersheds of the Clearwater River include the North Fork Clearwater River (NFCR), South Fork Clearwater River (SFCR), Lochsa River, and Selway River (Figure 1). The Clearwater River originates in the Bitterroot Mountains on the Idaho-Montana border at 2,164 m above sea level (msl; NPCC 2003). The Lochsa and Selway rivers converge to become the Middle Fork Clearwater River (MFCR) at Lowell, Idaho. The MFCR meets the SFCR at Kooskia, Idaho, forming the Clearwater River (Mallet 1974). Downstream, the NFCR meets the Clearwater River at Ahsahka, Idaho. The Clearwater River merges with the Snake River at 762 msl at Lewiston, Idaho, which merges with the upper Columbia River in Franklin County, Washington (Munn and Brusven 2003).

The Clearwater River steelhead fishery is open between July 1 and April 30 and is restricted to the area downstream of where Clear Creek meets the MFCR. From the mouth of the Clearwater River upstream to Memorial Bridge of U.S. Highway 12 at Lewiston, Idaho, the river is open July 1 to catch-and-release fishing and then open to harvest from August 1 through April 30. From Memorial Bridge upstream to Clear Creek, the river is open to catch-and-release angling from July 1 to October 14, and from October 15 to April 30, it is open to harvest. Regulations (e.g., length restrictions, bag limits) vary by year and are dependent on the number of steelhead returning to the Clearwater River.

2: METHODS

Data collection

The natal origins of steelhead in the Clearwater River were tracked using passive integrated transponder (PIT) tags. Wild juvenile steelhead were captured in the Clearwater River watershed from 2013–2016 using rotary screw traps in the Potlatch River, Lochsa River, Fish Creek (tributary of the Lochsa River), and SFCR. At each location, PIT tags were inserted into the body cavity of trapped juveniles migrating downstream (Marvin 2012). Smolts from DNFH and Clearwater Fish Hatchery were inserted with PIT tags before release into the Clearwater River or SFCR.

Adult steelhead that arrived at Lower Granite Dam between July 2016 and June 2017 (spawn year 2017; hereafter referred to as SY2017) and July 2017 and June 2018 (spawn year 2018; hereafter referred to as SY2018) were radio tagged using the separation-by-code system for preselected PIT-tag codes (Harmon 2003). Radio tags were allocated to steelhead across the run to ensure that fish arriving at various times at Lower Granite Dam were represented. Specifically, adult steelhead that migrated upstream were detected by PIT-tag arrays at hydroelectric facilities in the Columbia and Snake rivers. The PIT-tagged adults were monitored via the Columbia Basin PIT Tag Information System (Pacific States Marine Fisheries Commission 2016) and Columbia River Data Access in Real Time system (Townsend et al. 1997; Marvin 2012; Columbia Basin Research 2016). Adults were sorted at Lower Granite Dam by known spawning-ground destination using the PIT-tag information (McCutcheon et al. 1994). Targeted spawning destinations included Potlatch River, NFCR, SFCR, Lochsa River, and their tributaries.

The radio-tag groups consisted of wild Potlatch River steelhead (Potlatch steelhead) wild Lochsa River steelhead (Lochsa steelhead), hatchery Dworshak steelhead, and hatchery

SFCR steelhead. Potlatch and Lochsa steelhead are of high conservation interest and were selected to represent lower and upper wild Clearwater River steelhead. Dworshak and SFCR steelhead represent the two largest (i.e., highest number of smolt releases) hatchery groups in the Clearwater River basin. Steelhead from the SFCR were further divided into four sub-groups for radio tagging: conventional-general production, conventional-local brood, supplemental-general production, and supplemental-local brood. “Conventional” refers to steelhead that had their adipose fin removed; whereas, “supplemental” refers to hatchery steelhead with an intact adipose fin. Hatchery steelhead with an intact adipose fin were produced at DNFH and used to supplement the population of naturally spawning steelhead (Waples et al. 1993; Dittman et al. 2010; Berntson et al. 2011). “General production” fish were produced from adult hatchery steelhead returning to DNFH where they were spawned and their progeny were reared at DNFH and later released as smolts in the SFCR. “Local brood” were SFCR fish that were caught in the SFCR and transported to DNFH where they were spawned. Their progeny were reared at DNFH and the Clearwater River Hatchery (directly across the NFCR from DNFH), and then released as smolts in the SFCR.

Steelhead were radio tagged with Model MCFT2-3A radio tags (Lotek Wireless, Inc., Newmarket, Ontario, Canada). Tags were 16×46 mm, weighed 16 g, and did not exceed 1.7% of the fish’s body weight (Mellas and Haynes 1985). Transmitters were programmed (165.200 MHz and 164.260 MHz) with a continuous burst interval emitting a signal every 5 to 6 sec. The longevity of transmitters was approximately 320 days. Transmitters were gastrically implanted (Mellas and Haynes 1985) by dipping radio tags into glycerin for easy insertion down the esophagus into the stomach. A surgical rubber band was placed on each transmitter to increase transmitter retention (Keefer et al. 2004). Fish under 600 mm (fork length) were excluded from the study to reduce tag loss and fish mortality (Ramstad and Woody 2003).

Once radio-tagged steelhead arrived in the Clearwater River, radiotelemetry surveys were conducted. Radio-tagged steelhead were relocated using a combination of 12 fixed telemetry stations (hereafter referred to as fixed stations; Figure 1). Locations of fixed stations were selected based on accessibility, areas of low noise, and current or future fishery management areas. Model SRX-400A, Model SRX-600, and Model SRX-800D receivers (Lotek Wireless, Inc., Newmarket, Ontario, Canada) were used at fixed stations. Directional Yagi antennas (Lotek Wireless, Inc., Newmarket, Ontario, Canada) were positioned with a direct line of sight towards the river and away from objects that might hinder signal reception (e.g., radio towers; McCleave et al. 1978; Lee et al. 1985). Fixed stations were powered by a 12-volt battery. Receivers switched from 164.260 MHz to 165.200 MHz at 7 sec intervals. Fixed stations continuously tracked from August through June during SY2017 and SY2018. Data downloads and battery changes occurred on a weekly basis.

Mobile radio tracking of steelhead was conducted by vehicle and drift boat. The main-stem Clearwater River and MFCR were divided into eight sampling reaches (Table 1). In SY2017 and SY2018, mobile tracking by vehicle was conducted once per week in reaches 1-8. Additionally, the NFCR was tracked during vehicle surveys. Mobile tracking was also conducted from a drift boat to obtain a more accurate location of steelhead. During boat tracking, a directional Yagi antenna and a SRX800-M/MD-Series receiver (Lotek Wireless, Inc., Newmarket, Ontario, Canada) were used. Receivers switched from 164.260 MHz to 165.200 MHz at 7 sec intervals. Sampling reaches 1-7 were surveyed by drift boat once per month during SY2017 and SY2018. Sampling reach 8 was not surveyed by drift boat due to the lack of boat access. Mobile tracking methods entailed homing in on fish by monitoring the signal strength and adjusting the gain on the receiver (McCleave et al. 1978; Eiler 2012).When a transmitter was detected during mobile tracking, the macrohabitat type used by the fish was recorded. Macrohabitat type was defined as riffle, glide, run, or pool (Bisson et al. 1988; Hawkins et al. 1993; Beechie et al. 2005). The availability (total length [km]) of each habitat was estimated during the summer of 2017 by floating from the mouth of the Lochsa River to the mouth of the Clearwater River (157 km) and using a global positioning system to map the locations of each habitat type.

The ability to detect radio-tagged steelhead at various depths and distances in the Clearwater River was estimated. Transmitters at a depth of 14 m could be detected at distances up to 20 m. The majority of the Clearwater River is shallower than 14 m with a few exceptions (e.g., Big Eddy ~26 m). Trials similar to those of Simpkins and Hubert (1998) were conducted to evaluate the location error when relocating radio tags. Location error was 1.6 m (SE ± 0.1) at a distance of 250 m from antenna to the radio tag and decreased to 1.1 m (SE ± 0.1) at 50 m. Beacon tags were deployed in the water directly across the river from each fixed station. Beacon tags had burst intervals programmed for every 8 hrs to confirm that the fixed stations were operating.

Anglers on the Clearwater River and MFCR were surveyed by IDFG using a roving-roving survey. Roving creel surveys were conducted every Saturday and Sunday and on two randomly selected weekdays. Creel clerks surveyed and geo-referenced boat and shore anglers from sampling reaches 1–5 on weekdays; all sampling reaches (1–8) were surveyed on weekends (Table 1). Angler count surveys were selected using a systematic random design. The initial count time was randomly selected and subsequent count times were established at 3 hour intervals for a total of three counts per day. One of the three angler count times was randomly selected for collecting geo-reference locations of anglers. The starting location and terminus of angler geo-reference surveys were randomly selected. During each survey, the creel clerk would either start at the mouth of the Clearwater River and travel upriver and end at Orofino Bridge (NFCR was included in survey) or travel downstream from Orofino Bridge to the mouth of the Clearwater River (including NFCR). During weekend surveys, creel clerks would either travel from Orofino Bridge upriver towards Clear Creek or downriver from Clear Creek to Orofino Bridge.

Data analysis

The detection probability of each fixed station was estimated across both years of the study and an average was taken for each fixed station. In SY2017 and SY2018, the number of unique radio-tagged steelhead detected at each fixed station varied (mean ± SD; SY2017, 86 ± 59; SY2018, 53 ± 40). Detection probability for each station was estimated by the number of unique radio-tagged steelhead that were detected at an individual fixed station, divided by the number of unique radio-tagged fish detected at upstream fixed stations. Detection probability was generally high but varied from 0.46 to 1.00 (mean ± SD; 0.81 ± 0.05) in SY2017 and from 0.59 to 1.00 (0.87 ± 0.06) in SY2018.

Arrival of radio-tagged steelhead in the Clearwater River was determined by the first fixed station in Lewiston, Idaho, or from mobile tracking downstream of the first fixed station to the mouth of the Clearwater River (Figure 1, Table 1). Steelhead relocations collected via mobile tracking efforts were mapped with ArcGIS (Esri, Redlands, California) for each individual fish. The distance between each relocation, in order by date, was calculated and direction of the movement (i.e., upstream or downstream) was noted. The distance between two consecutive relocations was divided by the number of days between those relocations to estimate the average minimum kilometers per day that a fish moved (excluding fish detected in the NFCR) by month.

The river kilometer of each relocation for individual steelhead was defined using ArcGIS. When assigning river kilometers to steelhead relocations, steelhead in the NFCR were placed at the mouth of the NFCR since steelhead tend to move in and out of the NFCR. River kilometers were also assigned to boat and shore anglers and their locations were collected from angler geo-references. The proportional use of the main-stem Clearwater River by wild and hatchery steelhead and anglers was estimated using a kernel density estimator (Vokoun 2003). The density estimate was described by detections of radio-tagged fish along the main-stem Clearwater River. Peaks in the utilization distribution were locations used most frequently by steelhead. The univariate kernel density estimator was defined as:

$$\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right)$$

where $K(x)$ was the Gaussian kernel function, h was the bandwidth, and X_i was a random sample of sample size n (Vokoun 2003; Vokoun and Rabeni 2005). A Sheather-Jones plug-in model was used to select the bandwidth (Jones et al. 1996). The kernel density function was estimated for wild steelhead (i.e., Potlatch and Lochsa), hatchery steelhead (i.e., Dworshak and SFCR), and anglers (i.e., boat and shore combined) in the fall (September - November), winter (December - February), and spring (March - May) using R statistical software (R Development Core Team, 2017).

The mean weekly abundance of wild and hatchery steelhead and anglers in a given sampling reach was evaluated from September through April for SY2017 and SY2018.

Relocations of individual steelhead were used to evaluate which sampling reach each steelhead occupied on a weekly basis during its time in the Clearwater River. For instance, if an individual steelhead was detected in sampling reach 1 during the first week of September and was not relocated again until the last week of October in sampling reach 3, then the fish was placed in sampling reach 1 for every week leading up to the last week of October. Locations were grouped as wild (Lochsa and Potlatch) or hatchery (Dworshak and SFCR) steelhead. For each sampling reach, a mean weekly abundance of wild and hatchery steelhead and anglers was summarized by month. Additionally, both spawn years were combined and Pearson correlation coefficient (r) was used evaluate the correlation between angler abundance and wild and hatchery steelhead abundances using R statistical software (Higgins 2004; R Development Core Team 2017).

Habitat use of radio-tagged steelhead in the Clearwater River was evaluated during the fall and winter. In the spring, the majority of steelhead had already left the main-stem Clearwater River for spawning in tributaries. The proportion of steelhead habitat used relative to availability was estimated. Since not all tagging groups used the entire river, availability of habitat differed by radio-tag group. The amount of available habitat was determined by the furthest upstream relocation of an individual fish from each group. The furthest upstream sampling reach was reach 5 for Potlatch steelhead, reach 7 for Dworshak and SFCR steelhead, and reach 8 for Lochsa steelhead.

Habitat use was analyzed using a mixed-effect multinomial logistic regression model using the mlogit package in R statistical software (R Development Core Team, 2017). The random effect was habitat type (i.e., pool, riffle, run, and glide) and the fixed effect was the unique individual radio-tagged steelhead (SY2017 and SY2018 combined). Covariates included total age of the fish, fork length (mm), season (fall and winter), and origin (wild and hatchery). Akaike's information criterion corrected for small sample size (AIC_c) and was used to rank 15 candidate models (Burnham and Anderson 2002). Top models had an AIC_c value that was within 2.0 of the best model (i.e., $\Delta AIC_c \leq 2$). Top models were further evaluated using Akaike weight (w_i).

Return rates of steelhead to their natal tributaries or release locations were estimated from fixed stations located at the mouth of tributaries and PIT-tag arrays in tributaries. Additionally, timing of steelhead entering natal tributaries and release locations was compared to tributary discharge and water temperature. Water temperature data for the SFCR were obtained from temperature loggers deployed at Stites, Idaho, by the Nez Perce Tribe Department of Fisheries Resources Management. Additional water temperature data, as well as river discharge, were gathered from the U.S. Geological Survey National Water Information System (station numbers: 13337000, 13340000, 13341050, 13341570, 13342500, and 13338500).

In addition to estimating steelhead return rates to natal tributaries or release locations, the fate of steelhead was also assessed. Fate was defined as the final destination of radio-tagged steelhead in the Clearwater River. Fate of steelhead was estimated from mobile tracking surveys and fixed stations. Additional surveys included flights in 2017 (flight surveys were not conducted in 2018 due to weather conditions) and mobile tracking (i.e., vehicle tracking) of various tributaries throughout the Clearwater River basin. The fate of an individual steelhead was classified as a return to natal tributary or release site (i.e., Potlatch River, NFCR, SFCR, or Lochsa River), return to non-natal tributary or non-release site, angler harvest, possible harvest, DNFH trap, dead or shed, and unknown. A fish was classified as harvested when an angler reported the harvest of a radio-tagged fish. A steelhead was classified as a "possible harvest" when radiotelemetry data suggested that the radio tag was no longer in a fish. For example, a radio tag that was detected multiple times per day moving up or down the river at the rate of a vehicle or boat was considered a possible harvest. Steelhead classified as "DNFH trap" were fish that were collected for broodstock at DNFH and "dead or shed" were radio tags that remained in one location for an extended period of time until the end of the study. Steelhead classified as "unknown" were fish that were last detected in the main-stem Clearwater River and never relocated.

Fixed stations and mobile tracking efforts provided insight to the proportion of radio-tagged steelhead that demonstrated kelting behavior. A kelt was defined as a post-spawn steelhead that was observed migrating downstream (Wertheimer and Evans 2005). Therefore, any sustained downstream movement of radio-tagged steelhead in the spring that was observed migrating out of the Clearwater River and into the Snake River was considered a kelt. The proportion of radio-tagged Potlatch, Lochsa, Dworshak, and SFCR steelhead that displayed kelting behavior was estimated.

3: RESULTS

One-hundred and seventy-eight wild (n = 38) and hatchery (n = 140) steelhead were captured at Lower Granite Dam and implanted with radiotransmitters from August 25, 2016 – June 5, 2017 (Table 2). During SY2018, one-hundred and eleven steelhead (wild, n = 18; hatchery, n = 93) were radio-tagged from September 10, 2017 – April 19, 2018. Radio-tagged steelhead included wild Potlatch and Lochsa steelhead, and hatchery Dworshak and SFCR fish. Total length of radio-tagged fish during SY2017 varied from 650 to 880 mm (mean ± SD; 788.4 ± 49.7 mm) and from 590 to 920 mm in SY2018 (732.9 ± 78.5 mm; Table 2).

Arrival timing of wild and hatchery steelhead into the Clearwater River varied by radio-tag group but generally remained consistent across years (Figure 2). In total, 266 of the radio-tagged steelhead were detected in the Clearwater River (Table 2). During SY2017, 93% of Potlatch steelhead, 97% Dworshak steelhead, and 92% SFCR steelhead entered the Clearwater River in the fall. During SY2018, 100% of Potlatch fish, 98% Dworshak steelhead, and 91% SFCR steelhead were in the Clearwater River by the end of the fall. Interestingly, in SY2017 roughly 32% of the Lochsa steelhead entered in the fall, 10% in the winter, 47% in the following spring, and 11% were not detected until they reached the Lochsa River (detected in the Lochsa River at PIT tag antennae, the radio tag likely malfunctioned or was shed by the fish). The majority of the Lochsa fish that entered in the spring overwintered downriver of Lower Granite Dam. In SY2018, approximately 56% of the Lochsa steelhead entered in the fall, 33% in the spring, and 11% were not detected until they were in the Lochsa River. No differences in the entrance timing of local brood and general production steelhead (i.e., SFCR steelhead) into the Clearwater River was observed.

Movement of all groups of radio-tagged steelhead in the Clearwater River were combined to gain a general understanding of movements rates which were variable across seasons and spawn years (Figure 3). In SY2017, mean movement was 3.6 km/d (SE = 0.5 km/d) in the fall, 0.8 km/d (SE = 0.3) in the winter, and 4.7 km/d (SE = 1.9) in the spring. Similar movement patterns were observed in SY2018 with the highest movement rates in the fall (3.2 ± 0.4 km/d), followed by winter (1.1 ± 0.4 km/d) and spring (0.3 ± 0.1 km/d).

Wild steelhead were primarily distributed in the lower Clearwater River (downstream of the NFCR confluence) across seasons (Figure 4). However, in the spring Lochsa steelhead were distributed throughout the entire Clearwater River. In the fall, extent of use of Potlatch steelhead in both spawn years was from the mouth of the Clearwater River upstream to DNFH and the NFCR confluence at rkm 64. By winter, Potlatch steelhead moved out of the area near the mouth of the Clearwater River and were distributed between rkm 20 and 64. As spring approached, Potlatch steelhead migrated down river and resided between rkm 0 and 24. Lochsa steelhead displayed similar patterns of use in the Clearwater River. In the fall and winter, Lochsa fish were mostly found in the lower Clearwater River but their distribution was from rkm 0 to 110 in SY2017 and rkm 10 to 64 in SY2018. By spring, additional Lochsa steelhead entered the Clearwater River (demonstrated by the peak in the kernel density estimate between rkm 0 and 24) and Lochsa steelhead moved upriver to the Lochsa River (Figure 4).

The distribution of hatchery steelhead in the Clearwater River varied by season but patterns were consistent across spawn years (Figure 4). In the fall and winter, Dworshak steelhead distribution varied from rkm 0 to 115 during SY2017 and from rkm 0 to 110 during SY2018. However, the highest proportion of Dworshak steelhead were concentrated near

DNFH at rkm 64. During the spring of SY2017 and SY2018, all Dworshak fish congregated near DNFH with the exception of two fish in SY2018 that were relocated downstream near rkm 28. The SFCR steelhead occupied a large area of the Clearwater River during the fall and winter of both spawn years with a distribution from the mouth of the Clearwater River up to rkm 140 (Figure 4). In the winter of both spawn years, the majority of SFCR steelhead moved upstream and out of locations near the Clearwater River confluence. As spring approached, SFCR steelhead in both spawn years were between rkm 10 and 120 with a high concentration of fish near DNFH. The spatial and temporal distribution of local brood and general production steelhead in the Clearwater River were similar.

Boat and shore anglers were mostly concentrated near DNFH across all seasons and spawn years (Figure 4). Anglers fished between rkm 0 to 130 during the fall and the majority of effort was placed in the lower Clearwater River with an emphasis near DNFH. We observed some overlap between wild steelhead and anglers, but angler distributions were more closely aligned with hatchery steelhead distributions in the fall. By winter and into spring, angler distributions overlapped with hatchery steelhead distributions near DNFH and there was little to no overlap among anglers and wild steelhead.

The mean weekly abundance of wild and hatchery steelhead and anglers varied spatially and temporally (Figure 5). The number of anglers and wild steelhead were highly correlated in September ($r = 0.88$), but poorly correlated thereafter ($r \leq 0.14$). In contrast, the number of anglers and hatchery steelhead were highly related throughout the year ($r \geq 0.64$).

The proportion of large-scale habitat (i.e., glide, pool, riffle, and run) in the Clearwater River varied by sampling reach. Sampling reaches 2-7 were dominated by runs (49 – 73%)

and sampling reach 1 consisted mostly of pools (91%) and reach 8 was dominated by riffles (40%). Runs were the majority of the habitat in the Clearwater River (54%) followed by riffles (30%), glides (9%), and pools (7%).

Habitat use of wild and hatchery steelhead in the Clearwater River varied among radio-tag groups, seasons, and spawn years but steelhead primarily selected run habitat (Figure 6). In the fall of SY2017, Potlatch, Dworshak, and SFCR steelhead used pools in a higher proportion than was available. Lochsa and SFCR steelhead were detected in runs in a higher proportion than available. In the fall of SY2018, Lochsa, Dworshak, and SFCR steelhead used pools in a higher proportion than was available and Potlatch, Dworshak, and SFCR fish used runs in a greater proportion that was available. During the winter of SY2017 and SY2018, Potlatch, Lochsa, Dworshak, and SFCR steelhead used runs in a higher proportion than was available. In general, steelhead during the fall and winter of SY2017 and SY2018 used riffles in proportion to their availability. In SY2017, Potlatch, Dworshak, and SFCR steelhead occupied glides in proportion to availability with the exception of Lochsa steelhead which used glides at a higher proportion than was available. In SY2018, Potlatch steelhead were the only radio-tag group of fish that was detected in glides. The top mixed-effect multinomial logistic regression model predicting the presence of steelhead in a specific habitat type included fork length, age, and the fall season (Table 3). Therefore, in the fall, as length and age of a steelhead increased, steelhead were more likely to select a run over other habitat types than in the winter.

Return rates and timing of wild steelhead to their natal tributaries and fate of steelhead varied by group (Table 4). Seventy-nine percent of radio-tagged Potlatch steelhead in the Clearwater River during SY2017 returned to the Potlatch River. The remaining Potlatch steelhead were categorized as unknowns. Forty-three percent of SY2018 Potlatch fish returned to the Potlatch River and the remaining fish had fates of dead or shed (14%) and unknown (43%; Table 4). Eighty-four percent of SY2017 Lochsa steelhead returned to the Lochsa River and the remaining 16% had unknown fates. In SY2018, 89% of Lochsa fish made it to the Lochsa River and 11% were categorized as unknown.

Similar to wild fish, return rates and timing of hatchery steelhead to their release locations and fates of fish varied by radio-tag group. Seventy-two percent of Dworshak steelhead returned to the NFCR during SY2017 and 93% returned to the same location in SY2018. A large proportion of Dworshak steelhead returned to the NFCR, but their release location (near the mouth of NFCR) was not their final fate. Dworshak fish that returned to the NFCR cannot migrate upstream since the river is blocked by Dworshak Dam. Therefore, steelhead tended to linger at the confluence of the NFCR and Clearwater River where they are vulnerable to the DNFH broodstock trap and harvest. A higher proportion of Dworshak steelhead returned to their release location in SY2017 than in SY2018 because in SY2018, DNFH increased their trapping rates (Table 4). The remaining Dworshak steelhead were harvested, possibly harvested, died or shed their tag, or their fate was unknown. Fates of SFCR steelhead in the Clearwater River varied between general production and local brood. In SY2017, 58% of general production steelhead returned to the SFCR and 74% of local brood returned to the SFCR. In SY2018, general production and local brood steelhead displayed similar return rates (68%) to the SFCR (Table 4). In both spawn years, a small proportion of general production and local brood steelhead returned to a non-release location (i.e., NFCR). Interestingly, one general production steelhead in SY2017 entered the DNFH trap. Kelting behavior of wild and hatchery steelhead was documented. During SY2017, roughly 64% of Potlatch, 42% of Lochsa, 18% of Dworshak, and 27% of SFCR steelhead kelted. Similarly, 50% of Potlatch, 44% of Lochsa, 14% of Dworshak, and 27% of SFCR steelhead were observed kelting in SY2018.

Although straying was not observed for wild or hatchery steelhead in the Clearwater River basin, some wild and hatchery steelhead overshot their natal tributary or release location. Data collected from fixed stations and mobile tracking surveys documented Potlatch, Dworshak, and SFCR steelhead overshooting in both spawn years. Lochsa steelhead overshooting the Lochsa River was not observed since our study site only went as far upriver as the mouth of the Lochsa River. In both spawn years, radio-tagged Potlatch steelhead (36-43%) overshot the Potlatch River up to 41 rkm (mean ± SD; SY2017, 15.0 ± 11.7; SY2018, 18.5 ± 11.1). Dworshak steelhead (19-31%) overshot their release location near the mouth of the NFCR up to 49 rkm (SY2017, 14.9 ± 12.9; SY2018, 23.3 ± 19.9). As for SFCR steelhead, 11% of SY2017 and 7% of SY2018 fish overshot the SFCR with fish relocated as far as 4 rkm (3.5 ± 0.1) upriver.

4: DISCUSSION

Timing of wild and hatchery steelhead into rivers plays an important role in fisheries management (Mackey et al. 2001) and is highly variable among systems and among different groups within populations (Beacham et al. 2012; Copeland et al. 2017). Migration timing of steelhead into freshwater systems is dependent on water temperature, discharge, and photoperiod (Robards and Quinn 2002; Keefer et al. 2008), and the differences among populations are largely genetic (Hess et al. 2016). Previous research conducted by Keefer et al. (2008) suggested that hatchery steelhead from the Clearwater River migrated through the Columbia and Snake rivers later than wild steelhead from the Clearwater River. The authors also estimated that approximately 53% of Clearwater River steelhead overwintered in Lower Granite Reservoir and an additional 25% overwintered in the lower Columbia River. Unlike Keefer et al. (2008), we found that the majority of wild and hatchery steelhead arrived in the Clearwater River around the same general time period in the fall. The exception was that about half of the Lochsa steelhead arrived in the Clearwater River in the fall and the other half arrived the following spring.

Once steelhead entered the Clearwater River, their movement varied by season. Steelhead movement averaged from 0.3 – 4.7 km/d depending on the season and spawn year, and was much less than what has been reported in other systems. For instance, steelhead in the Dean and Fisher channels of British Columbia were observed moving upstream and downstream with an average travel time of 17.2 km/d in the late spring and early summer (Ruggerone et al. 1990). Haynes et al. (1986) observed high movement rates (12.0 km/d) of steelhead in the Great Lakes during the spring, as did English et al. (2006) for steelhead in the mid-Columbia River (20.0 km/d) and Skeena River, British Columbia (12.0-16.0 km/d).

However, it is important to note that differences in movement rates of steelhead across systems could be attributed to the size of the river and the distance needed to travel to reach spawning grounds. During our study, rates of steelhead movements were lowest in the winter of SY2017 and in the spring of SY2018. Dissimilar patterns were likely the result of differences in water temperature and discharge. Previous research conducted in the Columbia River showed that steelhead movements were low in the winter and increased in the spring with the onset of warming water temperatures (Keefer et al. 2008). Similar results have been reported for other anadromous salmonids (e.g., Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *O. kisutch*; Dittman and Quinn 1996; Caudill et al. 2007; Quinn et al. 2016). Discharge and water temperature in the Clearwater River during the winter of SY2017 was lower (mean ± SD; 303 ± 127 m^3/s; 3.4 ± 0.6 °C) than flows and temperature in the winter of SY2018 (490 ± 168 m^3/s; 4.3 ± 0.4 °C). As such, steelhead in SY2018 started to display increased movements earlier in the year than in SY2017.

Knowledge of wild and hatchery steelhead distributions is important since overlap could permit ecological interactions and lead to changes in fisheries management (Mackey et al. 2001). Compared to other studies, spatial and temporal overlap of wild and hatchery steelhead populations in the Clearwater River was minimal. Wild Potlatch and Lochsa steelhead primarily used the lower Clearwater River in the fall and winter. Hatchery steelhead were also found in the lower Clearwater River in the fall, but the majority moved upriver towards the NFCR and SFCR by late fall and early winter. Unfortunately, few studies have published information on the overlap of wild and hatchery steelhead. Mackey et al. (2001) conducted a study in Forks Creek, Washington, using radiotelemetry to investigate the spatial distribution of wild- and hatchery-origin steelhead and reported substantial overlap among populations. Nelson et al. (2005) used radiotelemetry to describe the distribution of prespawning wild and hatchery steelhead in the Vedder-Chilliwack River, British Columbia. They found considerable overlap in the spatial distribution of wild and hatchery steelhead. Differences among studies are likely attributed to variations in distances between wild steelhead spawning grounds and release locations of hatchery fish, which ultimately influences spatial distributions. In our study, hatchery stocking locations and wild steelhead spawning grounds were not in close spatial proximity (minimum distance 37-96 rkm). Nonetheless, overlap between wild and hatchery steelhead in the Clearwater was minimal and occurred for a short period of time in the early fall.

Knowledge of the spatial and temporal overlap between wild and hatchery steelhead is important, but understanding the angler distribution in relation to wild and hatchery steelhead distributions is also critical for fisheries management. We are unaware of any studies that have evaluated the relationship between angler and steelhead distributions. Consequently, our understanding of angler dynamics in steelhead fisheries is limited. In the Clearwater River, steelhead and angler distributions overlapped during both years, but the extent and location of overlap varied by season. An important finding from this study was that little overlap was observed between wild steelhead and anglers. Minimal overlap of anglers and wild (i.e., Potlatch and Lochsa) steelhead occurred during the late summer and early fall in the lower Clearwater River, but by mid-October, anglers concentrated most of their effort in and around the NFCR and SFCR. A change in the distribution of anglers was undoubtedly a response to the distribution of hatchery steelhead given that angler distributions mirrored those of hatchery fish throughout the fall, winter, and spring of both spawn years. Moreover, the majority of angling effort was focused near the mouth of the NFCR and DNFH where hatchery fish congregate. Not only are densities of steelhead high near the NFCR, but anglers recognize that steelhead returning to the NFCR and DNFH are hatchery fish available for harvest. Although information on angler distributions is lacking for other steelhead fisheries, studies conducted in other fisheries have suggested that anglers focus effort in areas with high fish abundance (Post et al. 2008; Melstrom et al. 2017). For instance, Hunt (2005) identified general attributes that influenced an angler's selection of a fishing site which included locations of fishing quality (e.g., large quantities of fish). Post and Parkinson (2012) conducted a study in British Columbia, Canada, to evaluate temporal and spatial patterns of angling effort and suggested that anglers allocate efforts in locations with high fish densities.

One of the many reasons why the Clearwater River is a popular steelhead fishery is because the river contains a variety of suitable steelhead habitats, which, in return, offers an abundance of fishing locations throughout the system. Large-scale habitat in the Clearwater River is dominated by runs followed by riffles, glides, and pools. Our modeling efforts suggested that length, age, and season were somewhat related to habitat use of steelhead. However, the most important observation was that both wild and hatchery steelhead in the Clearwater River were most often observed in runs throughout the year and occupied runs in a greater proportion than was available. Similar results have been reported for adult steelhead in the Vedder-Chilliwack River, British Columbia (Nelson et al. 2005), and Steamboat Creek, Oregon (Baigun 2003), where fish used run and pool habitats. Steelhead tend to use deep, low-velocity habitats characteristic of runs and pools to reduce energetic expenditures (Keefer et al. 2008). Therefore, steelhead were commonly relocated in runs given that most are relatively deep in the Clearwater River (~2-3 m). The proportion of steelhead occupying pools in the Clearwater River was likely underestimated because radiotelemetry is limited in deep waters (Koehn 2012).

Steelhead overwinter in freshwater, such as the Clearwater River, before moving to tributaries to spawn (Busby et al. 1996; Robards and Quinn 2002). The timing of escapement of steelhead to natal tributaries and release locations is useful for estimating the proportion of fish that remain in a fishery. Previous research conducted in the Clearwater River has suggested that hatchery steelhead (i.e., Dworshak) did not start to return to DNFH and the NFCR until early March (Pettit 1977). Byrne et al. (1992) reported that hatchery steelhead returned to their release location six weeks earlier than wild steelhead in the Clearwater River. In our study, timing of escapement was relatively consistent across spawn years but varied among steelhead groups. Slight differences in timing of steelhead escapement across years were most likely related to differences in water temperature and discharge (Bjornn and Reiser 1991; Robards and Quinn 2002). Wild and hatchery steelhead were observed returning to their natal tributaries and release locations at high rates, but the timing varied among groups. For instance, Dworshak steelhead returned to the NFCR and DNFH from fall through winter and were vulnerable to the Clearwater River steelhead fishery until it closed. The majority of SFCR steelhead were observed moving into the SFCR in late winter and early spring, but a small group of fish escaped the Clearwater River fishery in the fall. Furthermore, wild steelhead were less likely to spend as much time in the Clearwater River steelhead fishery as hatchery steelhead. The majority of Potlatch steelhead moved out of the Clearwater River before spring when the fishery came to a close. Lochsa steelhead were observed migrating through the Clearwater River and into the Lochsa River starting in April and continuing through June when the steelhead fishery was closed.

In the Clearwater River, the final fate of steelhead varied widely among tagging groups and the fate of wild and hatchery steelhead provided insight on the distribution of fishes and hatchery effectiveness. Previous research has assessed the fate of radio-tagged fish to better understand in-river survival and distribution of fishes (Keefer et al. 2004; English et al. 2005; Nelson et al. 2005; Keefer et al. 2017). Keefer et al. (2005) evaluated the fate of radio-tagged steelhead in the Columbia and Snake rivers and found that the majority of steelhead escaped to spawning grounds. The remaining fish were either reported as harvested by anglers or classified as unknown. Most of the wild steelhead in our study returned to their natal tributary and the remaining fish were classified as unknowns, with the exception of a few fish that were categorized as dead or shed. Most of the hatchery steelhead returned to their release location and few fish fell into the other six fate categories. Steelhead that were classified with an unknown fate could have been harvested (recreational and tribal) and not reported, had transmitters that malfunctioned, or strayed and were never relocated. In the Clearwater River, unknown fish were likely harvested but not reported since there is an abundance of both recreational and tribal anglers (tribal fisheries can harvest hatchery and wild steelhead) that fish in areas where most steelhead were last relocated.

The fate of local brood and general production steelhead is of particular interest with regard to hatchery effectiveness. Hatchery steelhead (i.e., local brood and general production steelhead) in the Clearwater River were more successful at homing to release sites than to their rearing location. Slaney et al. (1993) studied hatchery steelhead in the Chilliwack River, British Columbia, and found that homing was most influenced by rearing location. Nelson et al. (2005) evaluated the behavior and survival of wild- and hatchery-origin steelhead in Vedder-Chilliwack River, British Columbia, and observed a considerable amount of hatchery steelhead returning to the hatchery rather than release locations. Hatchery steelhead returning to release or rearing locations is likely influenced by spatial proximity of the two locations, such that, if the two locations are relatively close to one another then steelhead are likely to return to rearing locations (Slaney et al. 1993; Dittman and Quinn 1996; Nelson et al. 2005). Also, the amount of time hatchery-reared smolts spend in the river prior to emigrating to the ocean influences their ability to home to their release site (Keefer and Caudill 2013). Furthermore, local brood and general production steelhead were highly successful in homing to the SFCR which is ideal for maintaining a steelhead fishery and for hatchery steelhead supplementation in the SFCR.

Natal homing and non-natal straying of salmonids has been well studied and most studies have shown that behaviors are highly variable among populations and hatchery groups (Scheer 1939; Hasler et al. 1978; Quinn 1993; Dittman and Quinn 1996; Dittman et al. 2010; Schroeder et al. 2011; Keefer and Caudill 2013; Westley et al. 2013). Schroeder et al. (2011) studied steelhead in 16 rivers along the Oregon coast and found that steelhead exhibit moderate straying. Similar results were found among salmonids in southeast Vancouver Island, British Columbia (Labelle 1992), and in the Clackamas River, Oregon (Kostow et al. 2003). In the Clearwater River, straying of radio-tagged wild and hatchery steelhead was not observed despite extensive mobile tracking of tributaries, flight surveys, and via PIT-tag antenna arrays. Overshooting natal tributaries or release locations is quite common in steelhead populations. Richins and Skalski (in press) evaluated eight populations of steelhead in the Columbia and Snake river basins and found that some fish overshot their natal tributaries up to 120 rkm. Boggs et al. (2004) observed that ~ 30% of steelhead passing over Columbia and Snake river dams eventually fell back and returned to downriver tributaries or hatcheries (i.e., overshoot fallbacks). Wild and hatchery steelhead in the Clearwater River were estimated to overshoot their natal tributaries or release locations anywhere from 4 to 49 rkm.

5: MANAGEMENT IMPLICATIONS

Results from this study have important implications for the conservation and management of wild and hatchery steelhead. The primary limitation to our study was the inability to relocate all radio-tagged steelhead and provide a final fate. Unfortunately, given the size of the Clearwater River basin, relocating all steelhead during every tracking event is unlikely without additional telemetry equipment and personnel. Nevertheless, we were able to evaluate the return rates of steelhead to natal tributaries and release locations, which ultimately provided information on hatchery effectiveness. During SY2017, very few radio-tagged Dworshak steelhead were collected at the DNFH trap and used for broodstock, even though a large proportion of Dworshak steelhead returned to the NFCR and DNFH. Our observations prompted hatchery managers in SY2018 to increase trapping rates (i.e., amount of time the trap was open to allow steelhead to move into the hatchery). Consequently, there were more radio-tagged Dworshak steelhead collected at DNFH trap in SY2018 than in SY2017. Future management may consider reducing the number of hatchery steelhead that are left in the river to naturally spawn (Byrne et al. 1992) by adjusting DNFH trapping rates. Additionally, local brood and general production steelhead returned at high rates to the SFCR. Hatchery steelhead returning to the SFCR is ideal for providing harvest opportunities of conventional steelhead throughout the mainstem Clearwater River and SFCR as well as establishing a supplemental steelhead population in the SFCR. Future management may acknowledge using either local brood or general production steelhead for hatchery stocking in the SFCR.

Due to the diversity of life history strategies of wild and hatchery steelhead in the Clearwater River, management of steelhead is complex. No single strategy describes the timing of steelhead into the Clearwater River or the spatial and temporal distribution of wild and hatchery fish. In fact, differences in the timing, distribution, and movement among wild populations and hatchery groups were common. The spatial and temporal distribution of steelhead in the Clearwater River suggests very little overlap between wild and hatchery steelhead. This observation will increase the ability of fishery managers to further direct angling effort away from wild fish and place angling effort on hatchery steelhead. Findings from our study indicate that as hatchery steelhead enter the Clearwater River, anglers tend to follow the fish as they move upriver towards release locations. As such, anglers focus their efforts on hatchery steelhead that concentrate in large numbers near the NFCR and DNFH. This suggests that the Clearwater River has a highly compartmentalized fishery. Further observations have revealed that wild steelhead, once in the Clearwater River, return at very high rates to their natal tributaries and straying of wild and hatchery steelhead is minimal. Furthermore, information collected during this study suggests that current fishing regulations in the Clearwater River are providing for a diversity of angling opportunities while conserving wild steelhead and offering harvest of hatchery fish. Future management and conservation efforts of steelhead may consider population-specific behaviors and distributions of both wild and hatchery steelhead when implementing fishing regulations.

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Table 1. Sampling reaches in the Clearwater River and Middle Fork Clearwater River. The boundaries of the sampling reaches were defined by fixed telemetry stations.

			Coordinates			
Sampling reach	**Telemetry section**	**rkm**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
1	Mouth of Clearwater River - Clearwater Paper Mill	0 - 7	46.42616	-117.03178	46.43227	-116.96540
2	Clearwater Paper Mill - Spalding Railroad Bridge	7 - 22	46.43227	-116.96540	46.45675	-116.79112
3	Spalding Railroad Bridge - Nez Perce Tribal Hatchery	22 - 36	46.45675	-116.79112	46.51468	-116.65758
4	Nez Perce Tribal Hatchery - Peck, Idaho	36 - 56	46.51468	-116.65758	46.49888	-116.43965
5	Peck, Idaho -Orofino Bridge	56 - 72	46.49888	-116.43965	46.47400	-116.25185
6	Orofino Bridge - Kamiah Park	72 - 108	46.47400	-116.25185	46.23018	-116.01933
7	Kamiah Park - Clear Creek	108 - 124	46.23018	-116.01933	46.13350	-115.95000
8	Clear Creek - mouth of Lochsa River	124 - 157	46.13350	-115.95000	46.14365	-115.59749

Table 2. The number of steelhead by radio-tag group that were radio tagged at Lower Granite Dam and the number of steelhead that were detected in the Clearwater River during spawn year 2017 (July 2016 – June 2017) and spawn year 2018 (July 2017 – June 2018). The minimum, maximum, and mean (± SD) fork length for each radio-tag group are included.

			Fork length (mm)			
Radio-tag group	**Lower Granite Dam**	**Clearwater River**	**Minimum**	**Maximum**	**Mean**	**SD**
			Spawn year 2017			
Wild						
Potlatch	15	14	650	760	702	46
Lochsa	23	19	690	830	759	39
Hatchery						
Dworshak National Fish Hatchery	60	58	710	880	808	40
South Fork						
General production	40	36	720	850	782	35
Local brood	40	38	660	870	805	45
Total	178	165				
			Spawn year 2018			
Wild						
Potlatch	8	7	600	810	660	87
Lochsa	10	9	600	710	658	46
Hatchery						
Dworshak National Fish Hatchery	43	42	620	920	728	76
South Fork						
General production	14	13	670	850	800	57
Local brood	36	30	640	860	746	69
Total	111	101				

Table 3. Comparisons of mixed-effect multinomial logistic regression models predicting habitat use (run verses pool, riffle, and glide) of steelhead sampled from the Clearwater River, Idaho, during spawn year 2017 (September 2016 – June 2017) and spawn year 2018 (September 2017 – June 2018). Akaike's information criterion corrected for small sample size (AIC_c), change in AIC_c (ΔAIC_c), and Akaike's weight (w_i) were used to evaluate and select the top model from a set of candidate models. The AIC_c values were calculated from the number of model parameters (k) and sample size. Variables include season (fall and winter), origin of steelhead (wild and hatchery), and fork length, and age (ocean and freshwater) of steelhead.

Variable(s)	**k**	**AIC_c**	**ΔAIC_c**	**w_i**
Fork length + age + fall	21	644.78	0.00	0.83
Wild + fall + age + fork length	24	648.71	3.93	0.12
Age + fall	18	650.69	5.91	0.04
Fork length + age	18	654.05	9.27	0.01
Wild + fall + age	21	655.74	10.96	0.00
Wild + age + fork length	21	658.28	13.50	0.00
Age	15	660.02	15.24	0.00
Wild + age	18	665.59	20.81	0.00
Fall + fork length	18	697.63	52.85	0.00
Fall	15	701.28	56.50	0.00
Wild + fall + fork length	21	704.32	59.54	0.00
Wild + fall	18	710.35	65.57	0.00
Fork length	15	710.94	66.16	0.00
Wild + fork length	18	715.25	70.47	0.00
Wild	15	720.90	76.12	0.00

Table 4. Proportion of steelhead by radio-tag group that were classified into different fates for spawn year 2017 (July 2016 – June 2017) and spawn year 2018 (July 2017 – June 2018). Fates include natal tributary or release location, non-natal tributary, angler harvest, possible harvest, Dworshak National Fish Hatchery (DNFH), dead or shed, or unknown.

Radio-tag group	Natal tributary or release location	Non-natal tributary or non-release location	Angler harvest	Possible harvest	DNFH trap	Dead or shed	Unknown
			Spawn year 2017				
Wild							
Potlatch	0.79	0.00	0.00	0.00	0.00	0.00	0.21
Lochsa	0.84	0.00	0.00	0.00	0.00	0.00	0.16
Hatchery							
DNFH	0.45	0.00	0.12	0.19	0.07	0.05	0.12
South Fork							
General production	0.58	0.14	0.08	0.03	0.03	0.00	0.14
Local brood	0.74	0.05	0.05	0.05	0.00	0.05	0.06
			Spawn year 2018				
Wild							
Potlatch	0.43	0.00	0.00	0.00	0.00	0.14	0.43
Lochsa	0.89	0.00	0.00	0.00	0.00	0.00	0.11
Hatchery							
DNFH	0.24	0.00	0.19	0.19	0.26	0.05	0.07
South Fork							
General production	0.69	0.08	0.00	0.00	0.00	0.00	0.23
Local brood	0.67	0.07	0.07	0.03	0.00	0.03	0.13

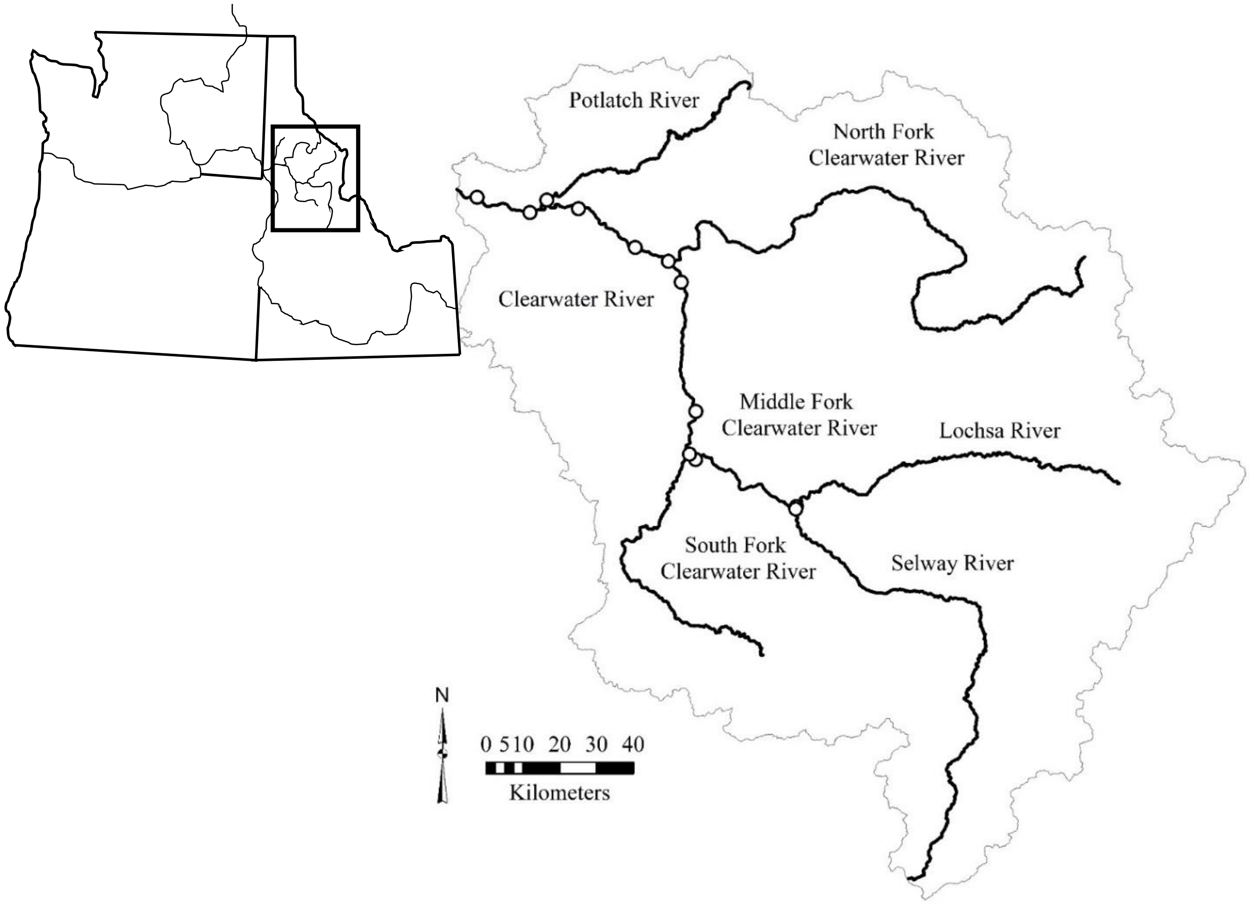


Figure 1. Location of fixed telemetry stations in the main-stem Clearwater River, Middle Fork Clearwater River, and at the mouth of primary tributaries (open circles). The fixed stations ran continuously and were in operation from September 2016 - June 2017 and September 2017 - June 2018.

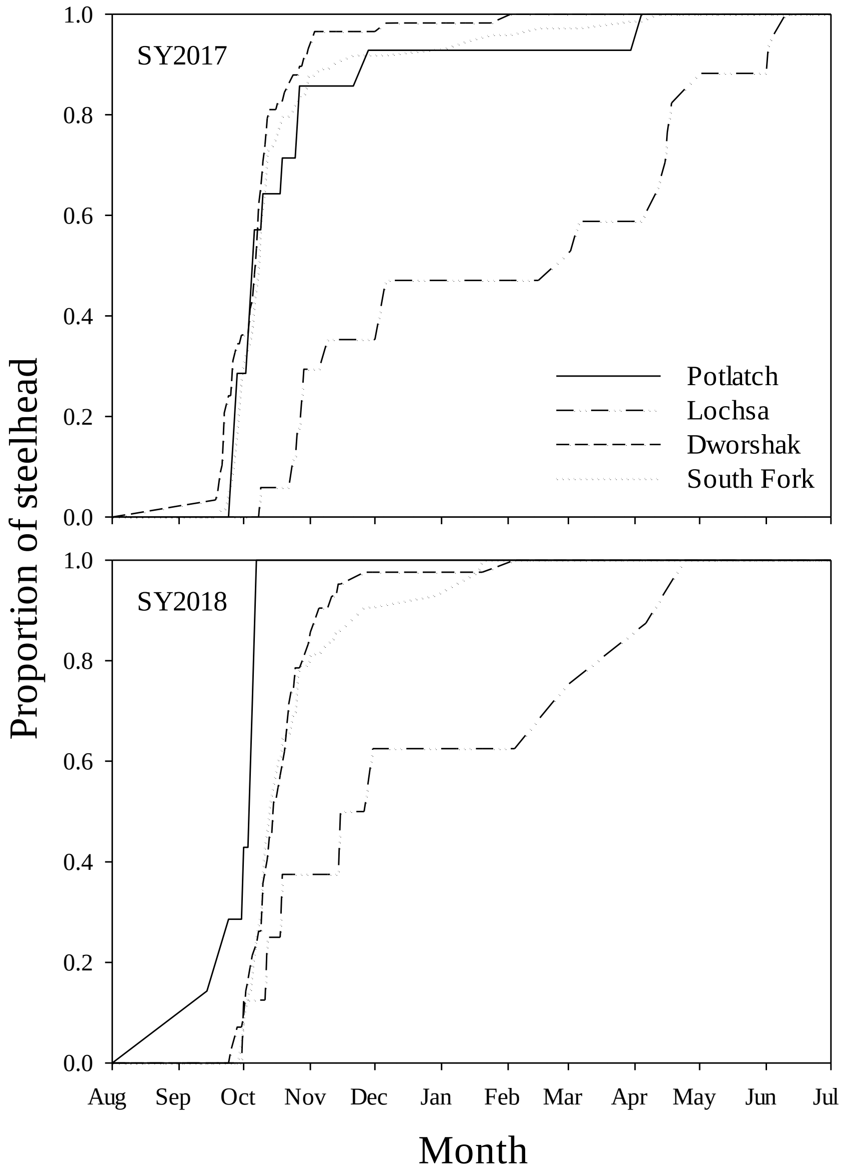


Figure 2. The cumulative distribution of steelhead by radio-tagged group (i.e., Potlatch River, Lochsa River, Dworshak, and South Fork Clearwater River) that entered the Clearwater River from August 2016 through June 2017 of spawn year 2017 (SY2017; July 2016 – June 2017) and August 2017 through June 2018 spawn year 2018 (SY2018; July 2017 – June 2018).

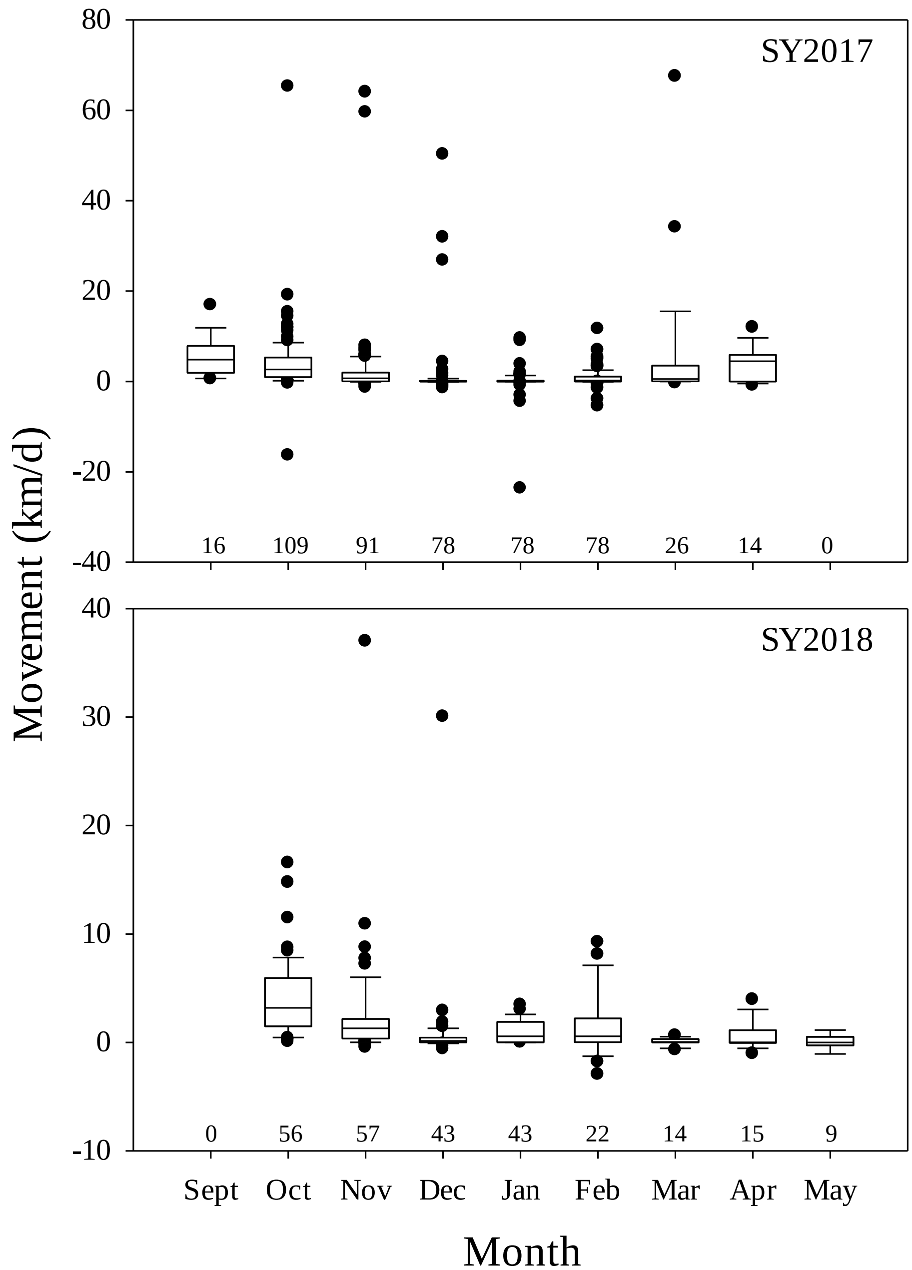
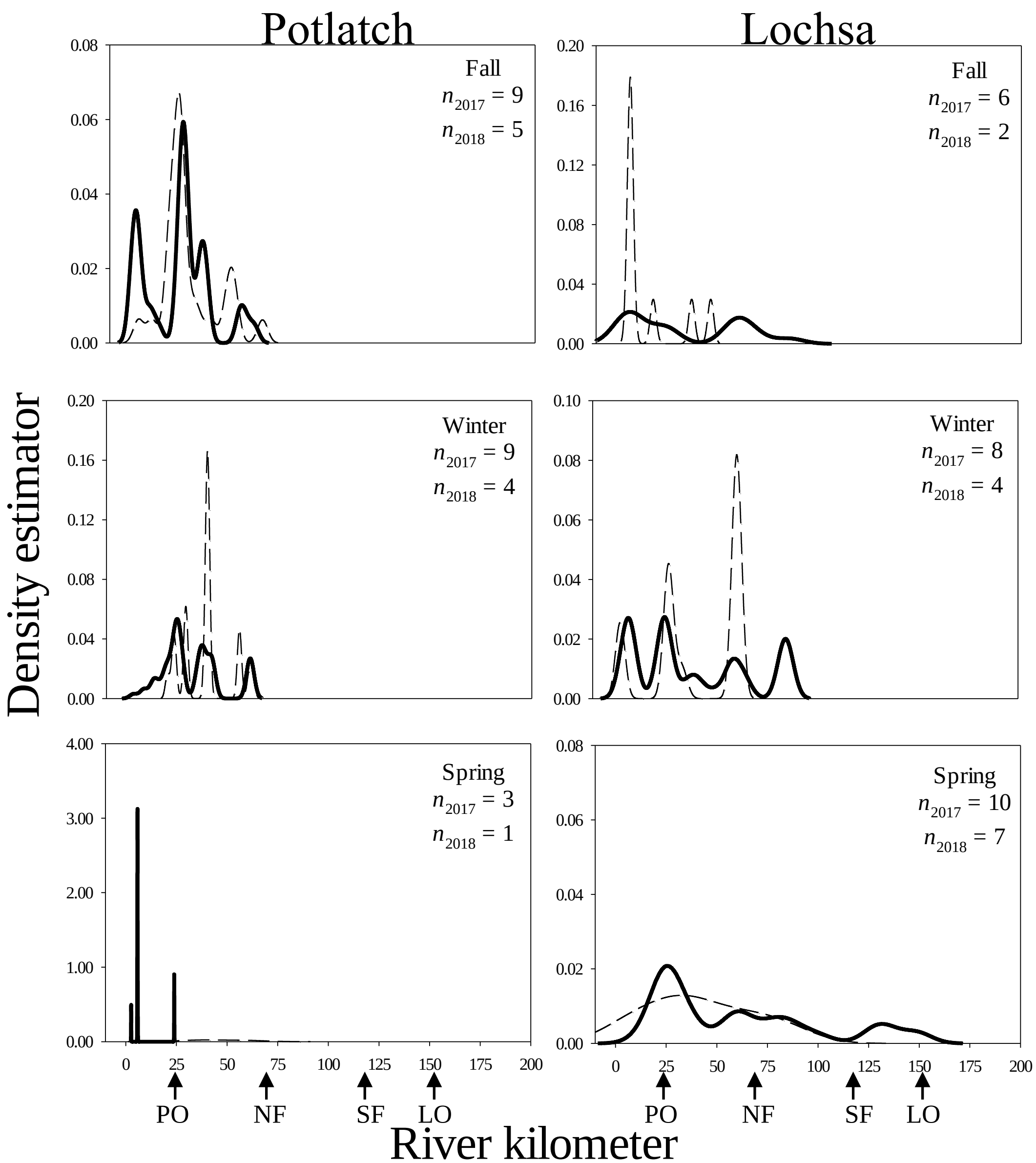
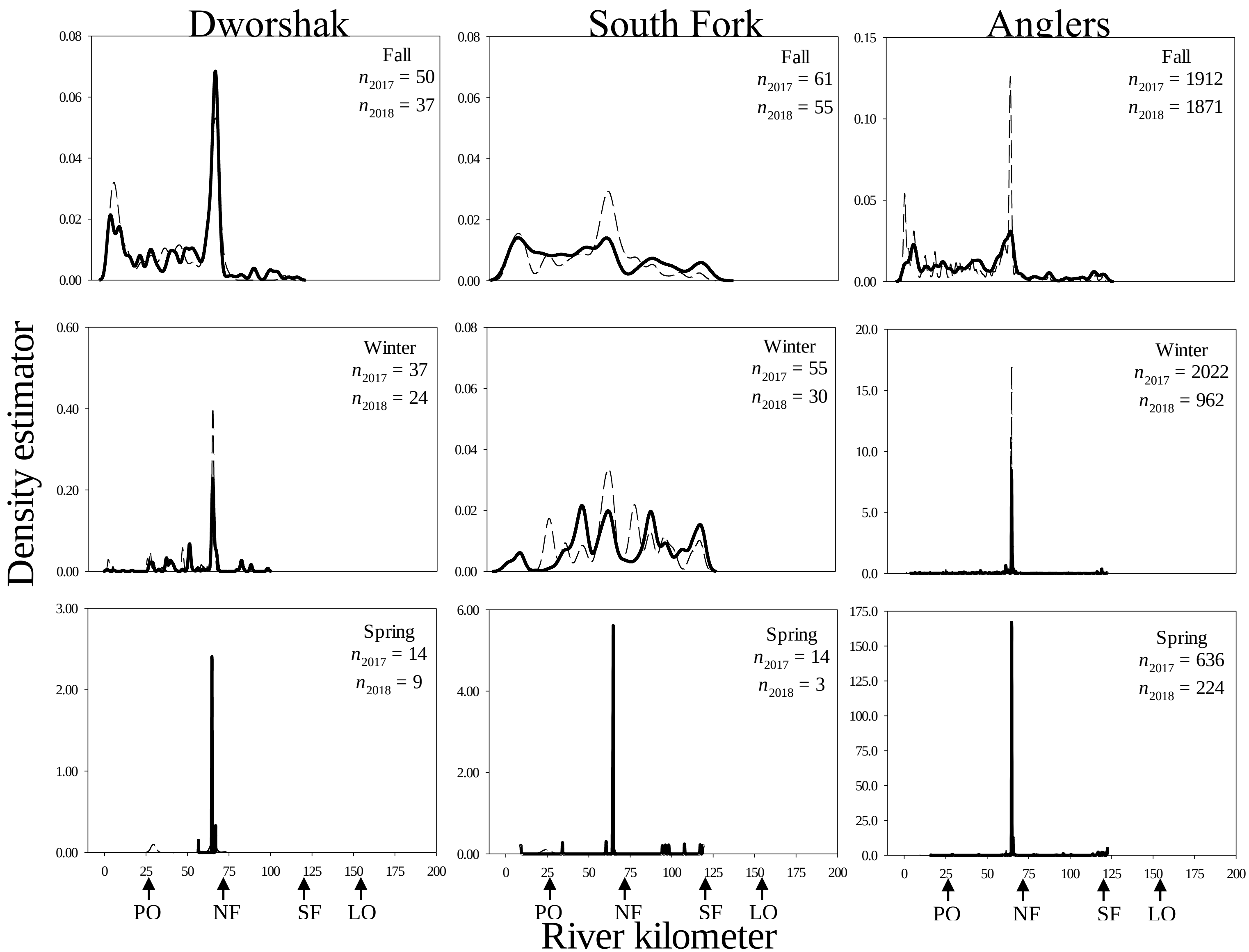


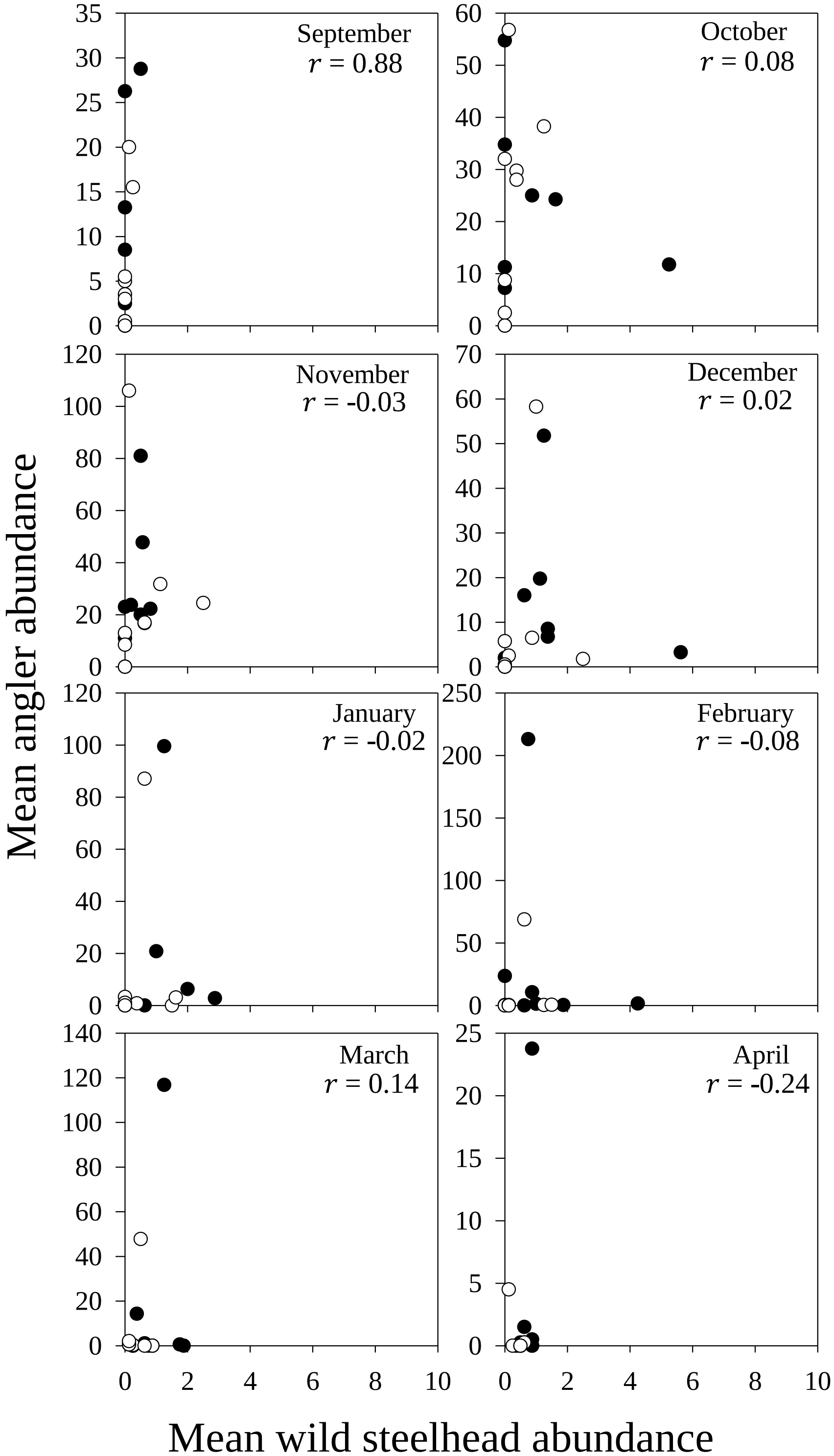
Figure 3. Movement rates of radio-tagged steelhead (wild and hatchery) by month in the main-stem Clearwater River and Middle Fork Clearwater River in spawn year 2017 (SY2017; July 2016 – June 2017) and in spawn year 2018 (SY2018; July 2017 – June 2018). Positive values indicated upstream movements, whereas negative values indicated downstream movements. The boxplots are shown with medians, first and third quartiles, and outliers (black points). Numbers above months represent the number of individual radio-tagged steelhead relocated during each month.


Potlatch
Lochsa
Fall
n_{2017} = 9
n_{2018} = 5
Fall
n_{2017} = 6
n_{2018} = 2
Winter
n_{2017} = 9
n_{2018} = 4
Winter
n_{2017} = 8
n_{2018} = 4
Spring
n_{2017} = 3
n_{2018} = 1
Spring
n_{2017} = 10
n_{2018} = 7
Density estimator
River kilometer
PO
NF
SF
LO



Dworshak
South Fork
Anglers
Fall
n_{2017} = 50
n_{2018} = 37
Fall
n_{2017} = 61
n_{2018} = 55
Fall
n_{2017} = 1912
n_{2018} = 1871
Winter
n_{2017} = 37
n_{2018} = 24
Winter
n_{2017} = 55
n_{2018} = 30
Winter
n_{2017} = 2022
n_{2018} = 962
Spring
n_{2017} = 14
n_{2018} = 9
Spring
n_{2017} = 14
n_{2018} = 3
Spring
n_{2017} = 636
n_{2018} = 224
Density estimator
River kilometer
PO
NF
SF
LO

Figure 4. Kernel density estimates for detections of radio-tagged wild steelhead (Potlatch River and Lochsa River), hatchery steelhead (Dworshak and South Fork Clearwater River), and anglers (boat and shore) in the main-stem Clearwater River, Idaho, in spawn year 2017 (July 2016 – June 2017; solid) and spawn year 2018 (July 2017 – June 2018; dashed). Seasons include fall (September – November), winter (December – February), and spring (March – May). The number of fish detected by year and season for spawn year 2017 and spawn year 2018 are included. Arrows along the x-axis represent where the Potlatch River (POT), North Fork Clearwater River (NF), South Fork Clearwater River (SF), and Lochsa River (LOC) meet the main-stem Clearwater River.


September
r = 0.88
October
r = 0.08
November
r = -0.03
December
r = 0.02
January
r = -0.02
February
r = -0.08
March
r = 0.14
April
r = -0.24
Mean angler abundance
Mean wild steelhead abundance

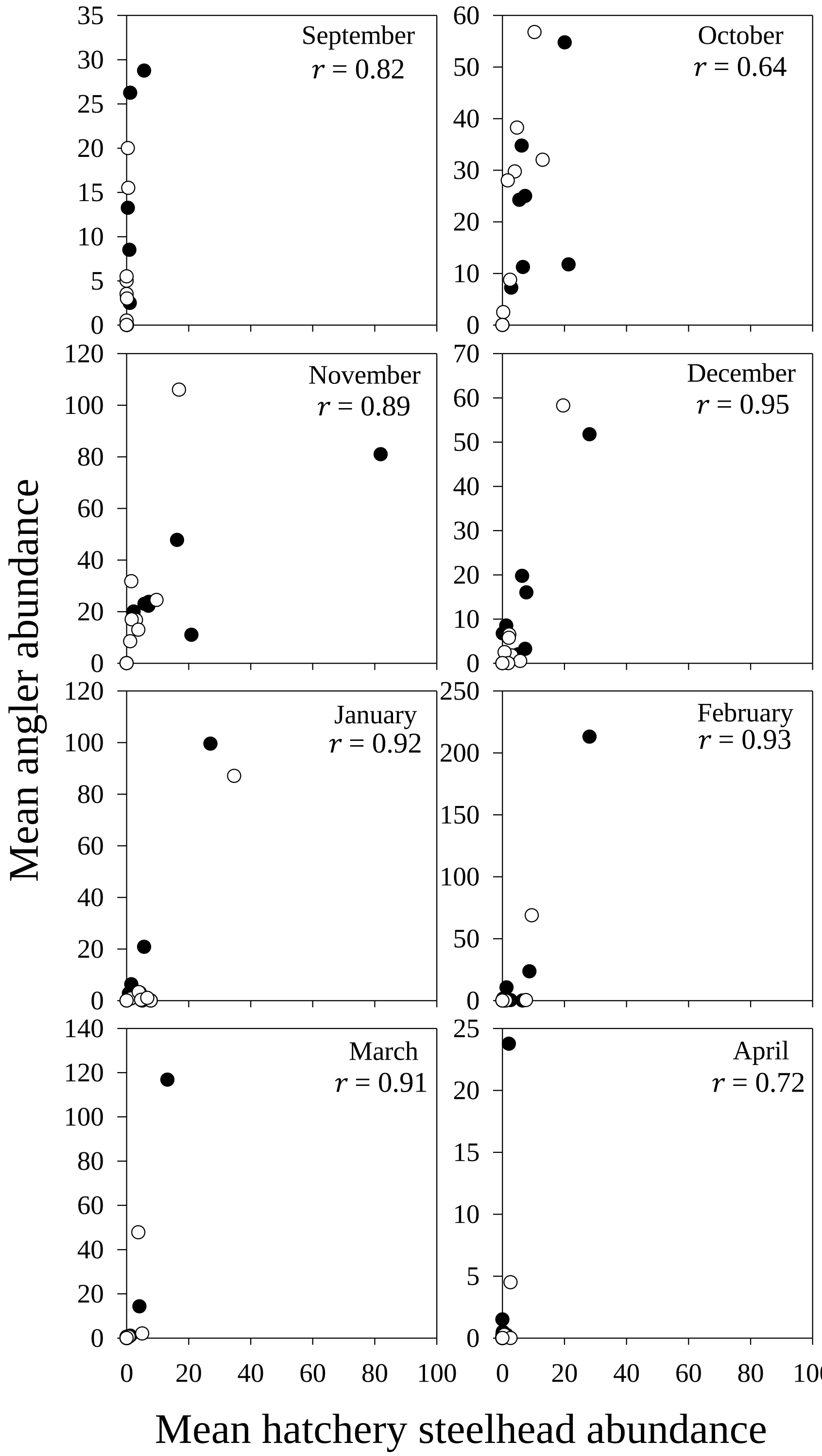


Figure 5. The weekly mean abundance per month of wild and hatchery steelhead and anglers across eight sampling reaches in the Clearwater River during spawn year 2017 (SY2017; July 2016 – June 2017, closed circle) and spawn year 2018 (SY2018; July 2017 – June 2018, open circle). Pearson correlation coefficients (r) are included.

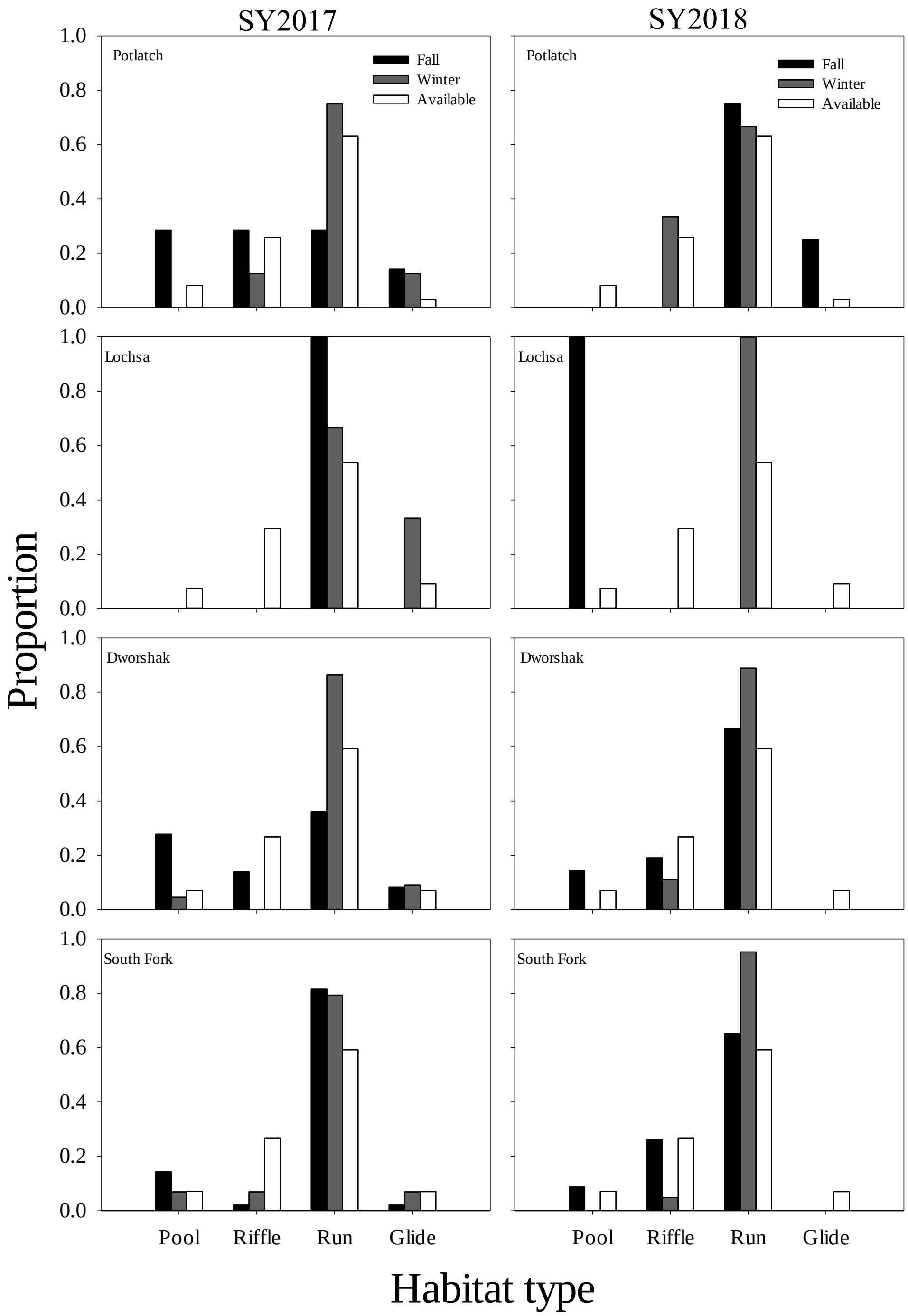


Figure 6. The proportion of radio-tagged wild Potlatch River and Lochsa River steelhead and hatchery Dworshak and South Fork Clearwater River steelhead observed in pools, riffles, runs, and glides in the Clearwater River during the fall (September – November) and winter (December – February) of spawn year 2017 (SY2017; July 2016 – June 2017) and spawn year 2018 (SY2018; July 2017 – June 2018).

Appendix A. Estimated detection probability for each fixed telemetry station (fixed station) for spawn year 2017 (SY2017; July 2016 – June 2017) and spawn year 2018 (SY2018; July 2017 – June 2018) with standard error for the detection probability of SY2017 and SY2018.

Fixed Station	**SY2017**	**SY2018**	**SE**
Clearwater Paper	0.89	1.00	0.06
Spalding	0.74	0.89	0.08
Cherrylane	0.46	0.59	0.06
Peck	0.83	0.59	0.12
Orofino	0.88	1.00	0.06
Kamiah	0.77	0.78	0.00
Clear Creek	1.00	1.00	0.00
Lochsa	0.73	1.00	0.13
South Fork	0.94	1.00	0.03
North Fork	NA	NA	NA
Potlatch	NA	NA	NA

Appendix B. The probability that boat and shore anglers and steelhead from Potlatch River, Lochsa River, Dworshak Nation Fish Hatchery, and South Fork Clearwater River (SFCR) would be in reaches 1 – 8 in the Clearwater River during the fall (September – November) winter (December – February) and spring (March – May) of spawn year 2017 (July 2016 – June 2017) and spawn year 2018 (July 2017 – June 2018). The probability of use was estimated from a kernel density estimator.

		Probability of use		
Radio-tag group	**Sampling reach**	**Fall**	**Winter**	**Spring**
		Spawn year 2017		
Potlatch	1	0.22	0.02	0.83
Potlatch	2	0.10	0.20	0.00
Potlatch	3	0.49	0.39	0.17
Potlatch	4	0.14	0.26	0.00
Potlatch	5	0.05	0.13	0.00
Potlatch	6	0.00	0.00	0.00
Potlatch	7	0.00	0.00	0.00
Potlatch	8	0.00	0.00	0.00
Lochsa	1	0.21	0.10	0.01
Lochsa	2	0.25	0.20	0.14
Lochsa	3	0.12	0.24	0.26
Lochsa	4	0.10	0.13	0.13
Lochsa	5	0.23	0.14	0.13
Lochsa	6	0.09	0.19	0.18
Lochsa	7	0.00	0.00	0.02
Lochsa	8	0.00	0.00	0.13
Dworshak	1	0.14	0.14	0.00
Dworshak	2	0.13	0.13	0.00
Dworshak	3	0.08	0.08	0.00
Dworshak	4	0.18	0.18	0.00
Dworshak	5	0.40	0.40	1.00
Dworshak	6	0.06	0.06	0.00
Dworshak	7	0.01	0.01	0.00
Dworshak	8	0.00	0.00	0.00
SFCR	1	0.10	0.02	0.00
SFCR	2	0.16	0.04	0.08
SFCR	3	0.13	0.03	0.09
SFCR	4	0.20	0.24	0.00
SFCR	5	0.15	0.21	0.32
SFCR	6	0.18	0.29	0.26
SFCR	7	0.07	0.17	0.25

SFCR	8	0.01	0.00	0.00
Angler	1	0.10	0.01	0.00
Angler	2	0.15	0.04	0.02
Angler	3	0.12	0.03	0.03
Angler	4	0.20	0.12	0.06
Angler	5	0.28	0.72	0.77
Angler	6	0.09	0.02	0.03
Angler	7	0.06	0.06	0.09
Angler	8	0.00	0.00	0.00
		Spawn year 2018		
Potlatch	1	0.04	0.00	0.00
Potlatch	2	0.23	0.04	0.05
Potlatch	3	0.49	0.29	0.23
Potlatch	4	0.20	0.55	0.45
Potlatch	5	0.04	0.12	0.23
Potlatch	6	0.00	0.00	0.04
Potlatch	7	0.00	0.00	0.00
Potlatch	8	0.00	0.00	0.00
Lochsa	1	0.27	0.14	0.12
Lochsa	2	0.51	0.19	0.15
Lochsa	3	0.02	0.33	0.18
Lochsa	4	0.20	0.03	0.23
Lochsa	5	0.00	0.49	0.14
Lochsa	6	0.00	0.00	0.17
Lochsa	7	0.00	0.00	0.01
Lochsa	8	0.00	0.00	0.00
Dworshak	1	0.20	0.06	0.00
Dworshak	2	0.13	0.00	0.00
Dworshak	3	0.11	0.16	0.38
Dworshak	4	0.16	0.09	0.01
Dworshak	5	0.39	0.69	0.59
Dworshak	6	0.01	0.00	0.02
Dworshak	7	0.00	0.00	0.00
Dworshak	8	0.00	0.00	0.00
SFCR	1	0.09	0.00	0.00
SFCR	2	0.12	0.00	0.09
SFCR	3	0.09	0.13	0.62
SFCR	4	0.19	0.12	0.00
SFCR	5	0.33	0.31	0.29
SFCR	6	0.15	0.35	0.00
SFCR	7	0.03	0.09	0.00
SFCR	8	0.00	0.00	0.00
Angler	1	0.17	0.01	0.00

Angler	2	0.15	0.01	0.00
Angler	3	0.11	0.04	0.00
Angler	4	0.14	0.04	0.00
Angler	5	0.35	0.94	0.96
Angler	6	0.06	0.00	0.01
Angler	7	0.02	0.01	0.03
Angler	8	0.00	0.00	0.00

Appendix C. Wild steelhead radio tagged by anglers in the Clearwater River.

Due to low returns of PIT-tagged steelhead of known origin to the Clearwater River, additional steelhead were required for tagging. Between October and December 2018, sampling crews conducted hook-and-line surveys between river kilometers 0 and 35 to radio tag additional wild steelhead. Crews consisted of two to four people who either angled from a drift boat or a jet boat. Hook-and-line sampling occurred over 11 days with one to three boats per day. Once a steelhead was landed, the fish was identified as either a wild steelhead or a hatchery steelhead (clipped adipose fin). All hatchery steelhead were released and wild steelhead were scanned for coded wire tags (CWT) and passive integrated transponder (PIT) tags. If a steelhead with an intact adipose fin had either a CWT or PIT tag, then the fish was presumed to be a hatchery supplemental steelhead and was released. Wild steelhead were placed into an Aqui-S bath which consisted of 56.8 ml of river water and 3 ml of Aqui-S. Time in solution varied from 300 to 900 s and water temperature varied from 8 to 14 °C. Once steelhead were anesthetized, fork length (mm) was recorded, a scale and genetic sample were taken, a PIT tag was inserted, and the fish was radio tagged gastrically. Steelhead were placed in a recovery tube in the river and monitored for a minimum of 300 seconds before being released. Scale samples were sent to IDFG's Nampa Research Lab and genetic samples were sent to IDFG's Eagle Fish Genetics Lab to determine age, sex, and origin. From hook-and-line sampling, 19 wild steelhead were radio tagged, of which 10 were from the Clearwater River basin.

Table C.1. Wild steelhead radio-tagged by anglers in the Clearwater River during the fall of 2018. The radio-tag number (Tag ID), origin (genetic stock identification, GSI), and observations and the last detection of each individual radio-tagged steelhead are included. Based on the GSI results, steelhead were from the lower Clearwater River (LOCLWR) and upper Clearwater River (UPCLWR) or from the Snake River and its tributaries; lower Snake River (LSNAKE), Grande Ronde River (GRROND), and Imnaha River (IMNAHA). There were two steelhead origins that could not be identified (NA).

Tag ID	Date radio tagged	Origin (GSI)	Type	Observation and last detection
368	10/2/2017	LOCLWR	wild	Cottonwood creek near Coyote Creek (4/5/18)
371	10/3/2017	NA	wild	Between Johns Creek and MP 28 (4/4/18)
348	10/10/2017	LOCLWR	wild	South Fork Clearwater River (4/30/18)
359	10/10/2017	LSNAKE	wild	Detected every week near Gibbs boat ramp (regurgitated tag or dead fish)
350	10/12/2017	GRROND	wild	Spalding Railroad Bridge (10/26/17)
366	10/12/2017	IMNAHA	wild	Detected at Spalding Railroad Bridge 11/20/17 then was last detected downriver (12/12/17)
367	10/12/2017	GRROND	wild	Clearwater Paper Mill (11/22/17)
381	10/12/2017	LSNAKE	wild	Nez Perce Tribal Hatchery on 3/2/18 then migrated out of the Clearwater River (3/13/18)
349	10/16/2017	UPCLWR	wild	Detected at the North Fork Clearwater River on 12/11/18 then left the Clearwater River (2/1/18)
354	10/16/2017	UPCLWR	wild	Detected tag every week in the mouth of the Clearwater River (regurgitated tag or dead fish)
372	10/18/2017	UPCLWR	wild	North Fork Clearwater River (2/28/18)
357	10/19/2017	LOCLWR	wild	Last detection near mouth of Potlatch River (1/5/18)
379	10/19/2017	UPCLWR	wild	Detected tag every week in the mouth of the Clearwater River (regurgitated tag or dead fish)
351	10/30/2017	LSNAKE	wild	Mission Creek (1/25/18)

374	10/30/2017	LSNAKE	wild	Lapwai Creek (4/16/18)
355	12/1/2017	NA	wild	NFCR (3/1/18)
364	12/1/2017	LOCLWR	wild	Detected tag every week near Clearwater Paper Mill (regurgitated tag or dead fish)
378	12/1/2017	LOCLWR	wild	Potlatch River (2/6/18)
377	12/19/2017	UPCLWR	wild	Orofino Creek (4/5/18), the fish kelted and left the Clearwater River (5/7/18)