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Prepared in cooperation with Bonneville Power Administration and
the Public Utility District Number 1 of Lewis County, Washington

Behavior and Movement of Adult Winter Steelhead (*Oncorhynchus mykiss*) in the Upper Cowlitz River Basin, Washington, 2017–18

Open-File Report 2020–1054

U.S. Department of the Interior
U.S. Geological Survey

Cover: Looking downstream from U.S. Forest Service Road Number 25 bridge on the Cispus River, Washington. Photograph by Brian K. Ekstrom, U.S. Geological Survey, July 5, 2010.

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By Theresa L. Liedtke, Tobias J. Kock, Amy C. Hansen, Brian K. Ekstrom, and Ryan G. Tomka

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DAVID BERNHARDT, Secretary

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer (km)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as °F = (1.8 × °C) + 32.

Abbreviations

GPS	global positioning system
HOR	hatchery origin
NOR	natural origin
rkm	river kilometer(s)

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Executive Summary

A 2-year radiotelemetry study was completed to monitor the movements of adult winter steelhead (*Oncorhynchus mykiss)* in the upper Cowlitz River Basin. A reintroduction program was established to restore healthy and harvestable populations of steelhead because volitional access to the area was blocked in the 1960s after construction of dams in the lower river. A trap-and-haul program is used to move adult steelhead and salmon (*Oncorhynchus* spp.) upstream, around the dams and large reservoirs, and release them in the upper basin to spawn naturally. Fish are released into Lake Scanewa, the uppermost reservoir in the system, and into the Cowlitz and Cispus Rivers. The goal of this study was to describe the behavior, movement, and tributary use of adult steelhead in the upper Cowlitz River Basin to assist in evaluating the trap-and-haul program and reintroduction program. We were specifically interested in learning more about the locations where steelhead spawn. Individual fish were assigned one of four fates, based on their location during the spawning period: Cowlitz River, Cispus River, Lake Scanewa, or fallback below the dam that impounds the reservoir. A total of 215 steelhead were tagged for the 2017–18 study. Of these, 5 fish regurgitated their transmitters before or shortly after release, so 210 tagged fish were used for analyses, including 121 fish (57.6 percent) released into the Cispus River and 89 fish (42.4 percent) released into Lake Scanewa. The Cowlitz River release site was not evaluated. Hatchery-origin (HOR) and natural-origin (NOR) steelhead were included in the study. Within the first 10 days after release, most steelhead had moved at least 2 river kilometers away from their release site. Fish released into Lake Scanewa, however, moved from their release site significantly sooner than fish released into the Cispus River, regardless of origin or sex. Most radio-tagged steelhead (93–100 percent) made no more than one trip between the reservoir and one of the rivers prior to spawning.

Steelhead were predominantly assigned fates in the river closest to where they were released, but origin also played a role. Steelhead released into the Cispus River were assigned Cispus River fates more than 80 percent of the time, including both origins and both years. About 13 percent of NOR fish had fates in the Cowlitz River, but the proportion was lower for HOR fish (0–2 percent). Fallback was the least common fate for Cispus-released steelhead (three HOR fish in 2017), followed by the reservoir fate, ranging from 5 to 9 percent in 2017, and zero in 2018. The steelhead released into Lake Scanewa were almost exclusively NOR fish, which had primarily Cowlitz River fates (55–57 percent). We released only six HOR steelhead into Lake Scanewa, and they all had Cowlitz River fates. The reservoir fate was uncommon for both release sites, and it was consistently lower in 2018 compared to 2017. Flow conditions were higher in 2017, which may have affected steelhead movement patterns or timing. The three HOR

steelhead released in the Cispus River in 2017 were the only fish that fell back over Cowlitz Falls Dam, which represented 1.4 percent of the total study fish, 5.7 percent of the Cispus-released fish in 2017, and 9.4 percent of the Cispus-released HOR fish in 2017.

About 62 percent of the steelhead released in Lake Scanewa spawned in the Cowlitz River, with the remaining 38 percent in the Cispus River. Within the Cowlitz River, close to one-half (about 47 percent) of the fish spawned in the upper reach, and about 16 percent spawned in the lower reach. Steelhead released into Lake Scanewa that spawned in the Cispus River were minimal in reach 5 (4 percent) and distributed in approximately equal proportions in the middle (reach 6; 16 percent) and upper (reach 7; 18 percent) reaches. Steelhead released into the Cispus River spawned almost exclusively in the Cispus River (94 percent). The upper Cispus River reach (reach 7) was used by more fish (72 percent) than the middle Cispus reach (reach 6; 16 percent). Taken together, the upper Cowlitz River reach (reach 4) and upper Cispus River reach (reach 7) accounted for more than 71 percent of the spawning locations for radio-tagged steelhead. When the middle Cispus River reach (reach 6) is included with the upper reaches, they account for 87 percent of our described spawning sites. We described 12 tributaries in the Cowlitz River and 8 tributaries in the Cispus River where steelhead spawned. After spawning, about 53–63 percent of steelhead moved downstream as kelts, either being collected at Cowlitz Falls Dam or being detected downstream from the dam. More fish were collected from both release sites in 2018 compared to 2017. Across release sites and years, more NOR fish and females moved downstream as kelts. This study added to the understanding of the behavior and movement of adult steelhead in the upper Cowlitz River Basin, supporting the findings of previous studies in the basin and describing spawning sites in the system's two main rivers and their tributaries. Future research efforts in this system may use additional telemetry studies, genetic analyses, and spawning ground surveys to provide further insights into the progress of the reintroduction effort.

Introduction

Winter steelhead (*Oncorhynchus mykiss*) and other Pacific salmon (*Oncorhynchus* spp.) were excluded from the upper Cowlitz River Basin in the 1960s when Mayfield and Mossyrock Dams were constructed at river kilometer (rkm) 84 and rkm 105, respectively. However, the construction of Cowlitz Falls Dam (rkm 142) in the mid-1990s, which included a surface collection system to collect downstream migrants, provided an opportunity to reintroduce anadromous fish species to the upper Cowlitz River Basin (Serl and Morrill, 2011). The reintroduction effort included the development of a trap-and-haul program that moves juvenile and adult fish around Cowlitz River dams and large reservoirs. Adult salmon and steelhead that return to spawn in the Cowlitz River are collected downstream from Mayfield Dam at a collection facility, and fish destined for the upper Cowlitz River Basin are transported and released upstream from Cowlitz Falls Dam to spawn naturally. Juvenile salmon and steelhead that are progeny of transported adults eventually move downstream toward the ocean and encounter Cowlitz Falls Dam where they can be collected and transported downstream from Mayfield Dam. The reintroduction has successfully established populations of steelhead, Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and coastal cutthroat trout (*Oncorhynchus clarkii*) to areas upstream from Cowlitz Falls Dam (Serl and Morrill, 2011). These efforts are continuing with the goal of eventually establishing populations in the basin that are healthy and harvestable.

The trap-and-haul program uses three release sites upstream from Cowlitz Falls Dam where fish-hauling trucks can access the river to release adult salmon and steelhead. The primary release site is in Lake Scanewa (fig. 1), the reservoir created by Cowlitz Falls Dam. At this site, fish enter the reservoir near the confluence of the Cowlitz and Cispus Rivers. Spawning habitat is nearly absent in Lake Scanewa but released fish can choose to enter either the Cowlitz River or the Cispus River, which each contain abundant areas for spawning. The second site is on the Cowlitz River near Packwood, Washington, about 58 rkm upstream from the Lake Scanewa release site. The third site is on the Cispus River about 28 rkm upstream from the Lake Scanewa release site (fig. 1), next to the Tom Music Bridge (not shown) and uses the bridge's armoring to help protect the site from the high flows of winter and spring. The reservoir release site has advantages: it has the shortest transport time (from the adult collection facility downstream from Mayfield Dam) of all three release sites, and fish can select either the Cowlitz River or the Cispus River for entry; however, there are also concerns associated with releasing fish in the reservoir. The reservoir water temperatures can exceed 20 °C during summer months. The release site is a short distance upstream (3 rkm) from Cowlitz Falls Dam, so fish may be more susceptible to fallback downstream from the dam. Previous studies in the watershed have determined that fallback rates of reservoir-released hatchery-origin (HOR) steelhead are significantly higher than that of natural-origin (NOR) steelhead released in the reservoir (Kock and others, 2016). Current trap-and-haul strategies now incorporate releasing most NOR steelhead into Lake Scanewa and most HOR steelhead into the Cispus River.

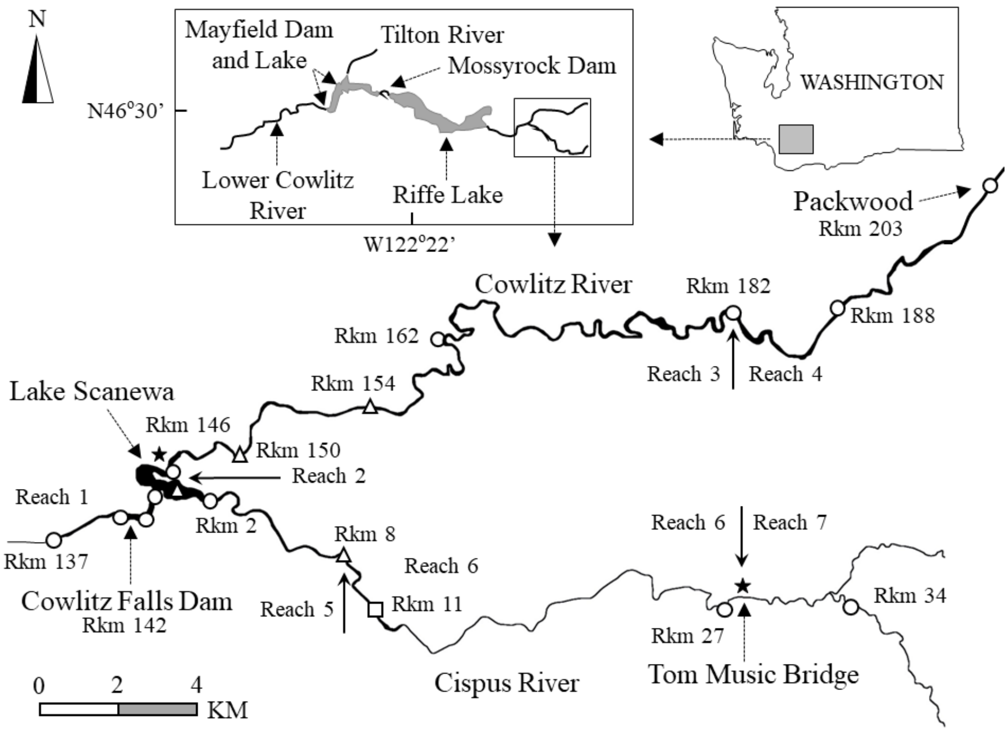

Figure 1. Map of the upper Cowlitz River Basin, Washington, showing fixed radiotelemetry sites used to monitor study fish in 2017 (open squares), 2018 (open triangles), and both years (open circles). Steelhead release sites are denoted by solid stars, and reaches are separated by arrows. KM, kilometers; Rkm, river kilometer.

Insufficient information about the fates of winter steelhead in the upper Cowlitz River Basin is available, specifically for areas where spawning may occur. Previous studies (Kock and others, 2016) monitored the movements and fates of steelhead but were not focused on spawning locations. In 2017, the U.S. Geological Survey began a 2-year radiotelemetry study to assess behavior, movement, and tributary use by adult steelhead in the upper Cowlitz River Basin for the Lewis County Public Utility District.

Methods

The Cowlitz River in southwestern Washington is a primary tributary to the lower Columbia River. The river drains 6,698 km^2 on the western slopes of the Cascade Range. Three dams are operated on the river including Mayfield Dam, Mossyrock Dam, and Cowlitz Falls Dam. The upper Cowlitz River Basin consists of two main rivers, the Cowlitz River and Cispus River (fig. 1). They share a confluence at rkm 144, near the center of Lake Scanewa, a small reservoir with a surface area of 264 ha The Cowlitz River upstream from Cowlitz Falls Dam drains 1,577 km^2 and the Cispus River drains 1,121 km^2.

We divided the Cowlitz and Cispus Rivers into seven reaches to describe fish movement patterns (fig. 1). Reach 1 extended from the downstream side of Cowlitz Falls Dam at rkm 142 on the Cowlitz River to rkm 137 near the head of Riffe Lake. Reach 2 was bounded on the downstream end by Cowlitz Falls Dam and rkm 2 on the Cispus River and rkm 146 on the Cowlitz River and included part of Lake Scanewa. Reach 3, on the Cowlitz River, was about

33 rkm long and included the area from rkm 146 to 182. The upper reach of the Cowlitz River (reach 4) included the area upstream from rkm 182. We defined three reaches on the Cispus River. The downstream reach of the Cispus River (reach 5) was about 6 rkm long and included the area from rkm 2 to 8. The middle reach (reach 6) included rkm 8–28, and the upper reach of the Cispus River (reach 7) included the area upstream from rkm 28 (fig. 1).

Fish Tagging and Release

Adult steelhead were collected for tagging at the Cowlitz Salmon Hatchery (rkm 80), downstream from Mayfield Dam. The fish trap at the hatchery operates continuously during periods when adult salmon and steelhead are migrating. Fish are handled and sorted on weekdays by staff from Tacoma Power. An automatic crowder was inside the fish trap, and an exit chute near the top of the trap led to the area where anesthesia was administered. The crowder was used to force groups of fish (20–50 fish per group) into the exit chute for batch application of anesthesia. Fish were anesthetized using electrosedation (model EA–1000B, Smith-Root, Inc., Vancouver, Washington) to facilitate the sorting process. Groups of fish were crowded into a large holding basket and electrosedation was applied for about 30 seconds, after which fish were immobile and ready for sorting. Fish were sorted by species and origin and moved into one of eight concrete holding tanks where they could be transferred to the hatchery for spawning or loaded onto fish-hauling trucks and transported to upstream release sites. Tagging occurred after sorting and before fish were transferred to the holding tanks. Tagged fish were held overnight, in the same tanks as untagged fish, for release the day after tagging.

For each tagged fish, we noted origin, sex (visually assessed), and fork length (in centimeters). Once these data were collected, a radio transmitter was gastrically implanted using methods described by Keefer and others (2004). We used MCFT–3EM transmitters (Lotek© Wireless, Inc.; Newmarket, Ontario, Canada) that were 53×12 mm and weighed 10 g in air or TX–PSC–I–1200 transmitters (Sigma Eight, Inc.; Newmarket, Ontario, Canada) that were 45×16 mm and weighed 16 g in air. Transmitter type varied by year. A single band of silicon tubing (about 1 cm long) was placed around the lower part of each transmitter to decrease the likelihood that transmitters were regurgitated (Keefer and others, 2004).

On each release date, groups of fish were loaded onto fish-hauling trucks for transport to the upper Cowlitz River Basin, after the standard loading process for the trap-and-haul program. Loading was completed using water-to-water transfer from the holding tank to the fish-hauling truck. Transport trucks hauled about 130 adult steelhead in each load, and tagged fish were transported with untagged fish. For this study, tagged fish were only released at the Lake Scanewa and Cispus River release site (fig. 1). Transport time from the Cowlitz Salmon Hatchery to the Lake Scanewa release site was about 45 minutes. Transport from the Cowlitz Salmon Hatchery to the Cispus River release site was about 90 minutes. Releases normally occurred in the morning from 9:00 to 11:00 a.m. Fish were released directly from the transport truck into the river at the Lake Scanewa release site using a 1.0-m-long flume that minimized the drop from the truck to the river. At the Cispus River release site, the transport truck parked adjacent to a release pipe that conducted fish and water about 35 m to the river, under the Tom Music Bridge. Fish were released directly from the truck into the release pipe using a 1-m-long flume to span the gap between the truck and the pipe.

Fish Monitoring

A series of fixed-location radiotelemetry monitoring sites (hereinafter “fixed sites”) were deployed to detect tagged fish as they moved within the study area (fig. 1). Fixed sites monitored fish in the Cowlitz River, in the Cispus River, in Lake Scanewa, and when they passed downstream from Cowlitz Falls Dam. In March 2017, 15 fixed sites were deployed to monitor steelhead at the following locations:

- Downstream from Cowlitz Falls Dam near the head of Riffe Lake at rkm 137;
- In the tailrace of Cowlitz Falls Dam at rkm 141;
- Two receivers at the separator of the Cowlitz Falls Dam fish facility at rkm 142;
- In the forebay of Cowlitz Falls Dam at rkm 142;
- Upstream from Cowlitz Falls Dam in Lake Scanewa at rkm 144;
- Near the Day Use Park of Lake Scanewa at rkm 146;
- At the head of the reservoir on the Cowlitz Arm of Lake Scanewa at rkm 162;
- On the Cowlitz River at rkm 182;
- On the Cowlitz River at rkm 188;
- Near Packwood, Washington, on the Cowlitz River at rkm 203;
- In the Cispus Arm of Lake Scanewa at rkm 2;
- On the Cispus River at rkm 11;
- Near Yellowjacket Creek on the Cispus River at rkm 27; and
- On the Cispus River at rkm 34 (fig. 1).

In 2018, five additional fixed sites were deployed to monitor steelhead. One of the fixed sites deployed in 2017, on the Cispus River at rkm 11, was not used to monitor steelhead in 2018 (fig. 1), so there were 19 fixed sites monitoring in 2018. The five additional fixed sites deployed for the 2018 study were at the following locations:

- Near Cowlitz Falls Campground at Lake Scanewa at rkm 154;
- In the Cispus Arm of Lake Scanewa, downstream of rkm 1;
- Additional receiver in the forebay of Cowlitz Falls Dam at rkm 142;
- In the Cowlitz Arm of Lake Scanewa at rkm 150; and
- On the Cispus River at rkm 8 (fig. 1).

At most fixed sites, monitoring occurred from February or March each year through August, although some sites were monitored through the end of 2017 and into 2018 as part of other studies.

In both years, fixed sites contained a telemetry receiver (model SRX–400, SRX–600, or SRX–800 [Lotek© Wireless, Inc.; Newmarket, Ontario, Canada] or a model ORION [Sigma Eight, Inc.; Newmarket, Ontario, Canada]) connected to one or two Yagi antennas. Power was provided by a 12-volt battery that was recharged by a solar panel.

Fixed site detection data were supplemented with mobile tracking detections collected during March, April, May, and June. Mobile tracking was conducted by vehicle two times per week. Staff drove roads that bordered the rivers and reservoir in the study area while monitoring a telemetry receiver. Global positioning system (GPS) data were recorded for each detection location. Mobile tracking occurred in the Cowlitz River and the following tributaries: Lambert, Kiona, Miller, Silver, Killborn, Burton, Dry, Johnson, Smith, Skate, Lake, Muddy, Clear Fork, and Ohanapecosh Rivers and Creeks. A small amount of mobile tracking effort was also used in Davis, Hall, Butter, and Coal Creeks after initial efforts demonstrated that few fish were present. Additionally, mobile tracking occurred in the Cispus River and tributaries: Copper, Quartz, Crystal, Iron, Greenhorn, Yellowjacket, Camp, North Fork Cispus, and Prospect Rivers and Creeks. After initial observations determined that few fish were present, few mobile tracking efforts were used in East Canyon, Squaw, Adams, and Orr Creeks. At times during 2017, snow depth restricted mobile tracking efforts to tributaries in the lower 3 miles of the Cispus River: Yellowjacket Creek and the North Fork of the Cispus River.

River Flows

River flows in the upper Cowlitz River Basin are monitored by four streamgages operated by the U.S. Geological Survey (USGS). Two streamgages are on the Cowlitz River, upstream from Lake Scanewa near the towns of Packwood (USGS station 14226500) and Randle (USGS station 14231000). The third streamgage is on the Cispus River near the mouth of Yellowjacket Creek (USGS station 14231900). The fourth streamgage is downstream from Cowlitz Falls Dam and is known as the Kosmos streamgage (USGS station 14233500). Discharge data from the Randle, Cispus, and Kosmos streamgages are highly correlated for the following reasons: the Cowlitz and Cispus Rivers respond similarly to rainfall and snowmelt events given their proximity to each other, and discharge at the Kosmos streamgage is essentially the sum of discharge at the Randle and Cispus River streamgages. We present streamgage data from Randal for the Cowlitz River and from Yellowjacket Creek for the Cispus River. The USGS streamgage data described in this report are available in the USGS National Water Information System by querying the station identifier and time period of interest (U.S. Geological Survey, 2019).

Data Analysis

Detection records from fixed telemetry sites and from mobile tracking were merged with tagging and release data to create a combined detection dataset. Radio-tagged steelhead were monitored from their dates of release (March–May 2017 and February–May 2018) until at least July 25, 2018. Monitoring efforts for steelhead continued until late July or early August each year at most sites, but some 2017 sites were monitored through July 25, 2018. All GPS coordinates of fish locations were rounded to the nearest river mile in each river or creek and then converted to river kilometers. All data management, data processing, and data analysis were conducted in SAS® version 9.4 (Cary, North Carolina).

Residence time at the release site was calculated from the time of release until the first detection at least 2 rkm away, which was the smallest movement distance we could effectively measure. We used event-time analysis (Allison, 1995) to compare residence time at the release sites and movements by HOR and NOR fish after release. A Chi-square test of independence (Sokal and Rohlf, 1996) was used to test for differences in the proportions of fish that demonstrated different behavior patterns. Significance was determined using an alpha of 0.05.

We calculated the number of trips prior to spawning from release to the reservoir. A trip was defined as being detected in the reservoir (reach 2) and then detected in either reach 3 or 5 (fig. 1). Subsequent detections in the reservoir incremented the count.

Individual fish were assigned one of four fates, based on their location during the spawning period: Cowlitz River, Cispus River, Lake Scanewa, or fallback into Riffe Lake. Fish were assigned Cowlitz River or Cispus River fates if they were last detected in either river prior to the spawning period or if they were detected in either river or tributary during the spawning period. Fish were assigned a reservoir fate if they were last detected in Lake Scanewa prior to the onset of the spawning period or if they spent less than 4 days in one of the rivers before moving downstream and remaining in the reservoir after the onset of the spawning period. Fish were assigned a fallback fate if they were detected downstream from Cowlitz Falls Dam prior to the onset of the spawning period. We also assigned a second fate to estimate the percentage of fish that moved downstream as kelts. This second fate included four possible outcomes: (1) fish that did not move downstream after spawning, (2) fish that moved downstream after spawning but remained in Lake Scanewa, (3) fish that moved downstream after spawning and were collected at the Cowlitz Falls fish facility (at Cowlitz Falls Dam), and (4) fish that moved downstream after spawning and passed Cowlitz Falls Dam. We determined the percentage of kelts collected at the Cowlitz Falls Fish Facility by dividing the number of kelts collected by the total number of kelts available (that is, the sum of those that remained in Lake Scanewa, were collected, or passed the dam after spawning).

We used March 15 to demarcate the onset of spawning for steelhead. Steelhead detections after this date determined the presumed location of spawning. This date was established based on historical run timing and our knowledge of the system. Any fish collected at Cowlitz Falls Dam or passed downstream from the dam prior to March 15 was designated as a fallback.

Spawning location was determined as the most upstream known location in the Cowlitz or Cispus Rivers of a radio-tagged steelhead or the most upstream location within a tributary. If a fish was detected in more than one tributary, it was noted in both.

Results

River Environment

Discharge in the upper Cowlitz River Basin is largely affected by rainfall and snowmelt events. During February–August 2017, four peaks of mean daily flow near or greater than 10,000 ft^3/s occurred in the Cowlitz River. High flow events occurred in February and March, followed by another event in early May (fig. 2). Mean daily flow in 2017 from February 20 to July 25 (representing most of the monitoring period) was 4,523.9 ft^3/s (range 1,374.0–17,090.6 ft^3/s). Similar trends occurred in the Cispus River but on a much smaller scale. Mean daily flow was 1,796.8 ft^3/s (range 732.8–4,525.1 ft^3/s). In 2018, mean daily flow was lower than in 2017. The highest flow from February to August 2018 was in early February before the first release of tagged steelhead. Cowlitz River mean daily flows gradually increased until early April and remained around 5,000 ft^3/s through the end of May (fig. 2). During the 2018 study period, mean daily flow was 2,952.1 ft^3/s (range 934.1–7,377.1 ft^3/s) in the Cowlitz River and 1,128.4 ft^3/s (range 474.2–2,958.0 ft^3/s) in the Cispus River.

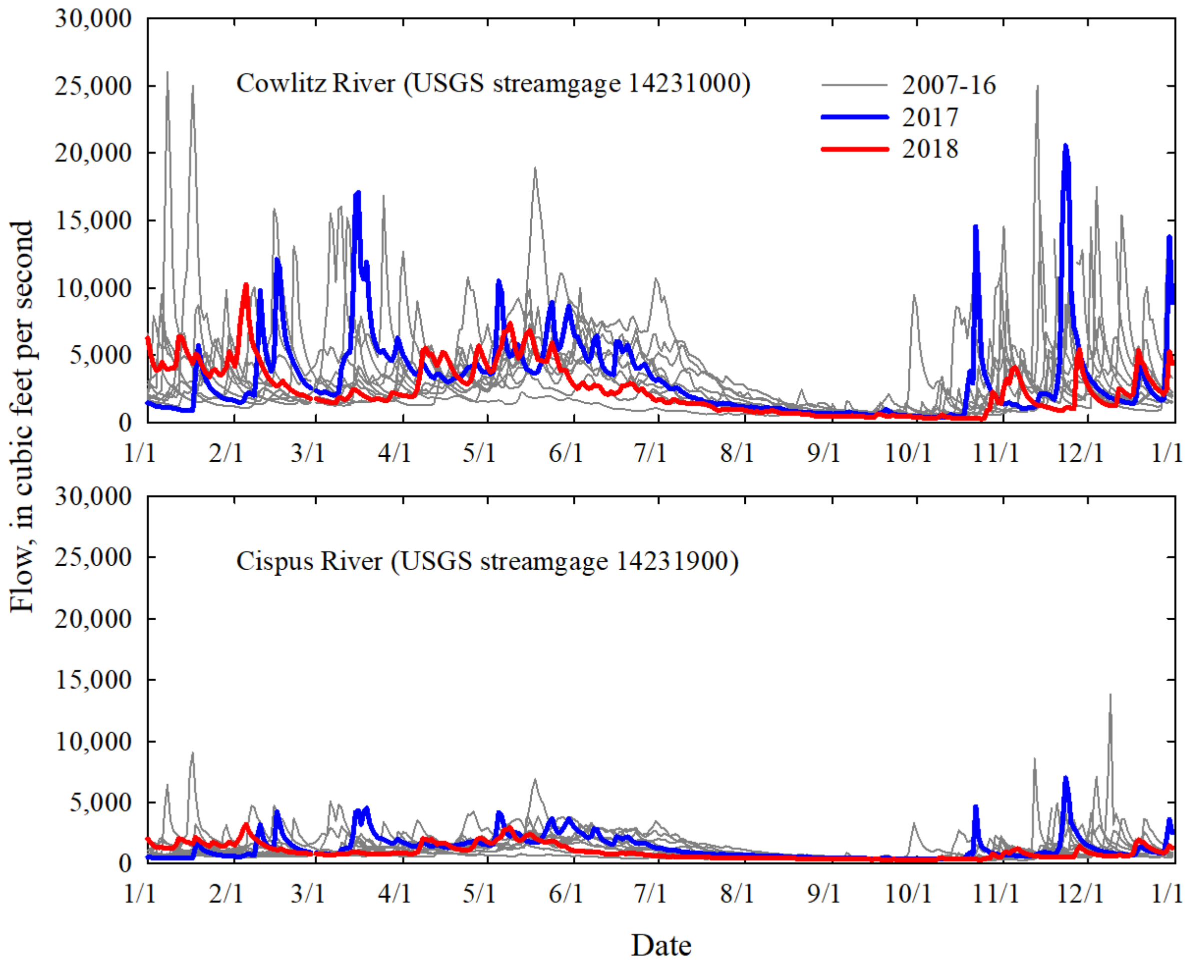

Figure 2. Graphs showing mean daily flow, in cubic feet per second, at two U.S. Geological Survey (USGS) streamgages in the upper Cowlitz River Basin, Washington, during the two study periods (2017 and 2018) and the previous 10 years (2007–16). Top graph, USGS station 14231000 on Cowlitz River at Randle, Washington. Bottom graph, USGS station 14231900 on Cispus River.

Fish Tagging and Release

A total of 215 adult winter steelhead were radio-tagged during the 2 years of study. Five steelhead regurgitated their transmitter prior to or shortly after release, so 210 steelhead were used in the final analysis (tables 1 and 2). The final tagged population included 121 fish (57.6 percent) released into the Cispus River and 89 fish (42.4 percent) released into Lake Scanewa. By origin and sex, the overall study group included 43 HOR males, 40 HOR females, 59 NOR males, and 68 NOR females. The overall mean fork length of tagged fish was 71.1 cm (standard deviation, 8.1 cm), and mean size was similar between HOR (71.2 cm) and NOR (71.0 cm) tagged steelhead.

Table 1. Number of hatchery-origin and natural-origin male and female adult steelhead radio-tagged; released into the Cispus River, Washington; and used for analysis in 2017 and 2018.

[**Abbreviations:** HOR, hatchery origin; NOR, natural origin]

Release date	Number of males		Number of females	
	HOR	NOR	HOR	NOR
2017				
March 21.	3	0	1	0
March 28.	0	0	1	0
April 4.	5	0	2	0
April 11	2	6	4	1
April 17	1	2	2	0
April 24	1	2	0	0
April 26	1	0	2	1
May 1	1	0	1	1
May 4	0	4	2	4
May 8	0	0	3	0
2017 subtotal	14	14	18	7
2018				
February 20	2	0	0	0
March 13	2	0	0	0
March 15	3	0	0	0
March 20	1	0	1	0
March 22	1	0	0	0
April 13	0	7	0	8
April 16	3	1	5	4
April 18	9	0	5	0
April 23	2	0	2	0
April 30	2	0	2	0
May 8	1	0	0	0
May 10	1	0	2	0
May 15	1	0	0	0
May 22	0	0	0	3
2018 subtotal	28	8	17	15
Total				
2017–18	42	22	35	22

Table 2. Number of hatchery-origin and natural-origin male and female adult steelhead radio-tagged; released into Lake Scanewa, Washington; and used for analysis in 2017 and 2018.

[**Abbreviations:** HOR, hatchery origin; NOR, natural origin]

Release date	Number of males		Number of females	
	HOR	NOR	HOR	NOR
2017				
April 25	0	1	0	3
April 27	0	1	0	3
May 2	0	0	2	1
May 9	0	0	2	1
May 11	0	1	0	0
May 16	0	0	0	1
May 18	0	0	0	2
May 22	0	0	1	0
2017 subtotal	0	3	5	11
2018				
March 6	0	1	0	1
March 9	0	0	0	1
March 13	0	2	0	2
March 15	0	2	0	2
March 20	0	1	0	1
March 27	0	5	0	1
March 29	1	0	0	1
April 2	0	1	0	2
April 4	0	4	0	3
April 6	0	3	0	8
April 9	0	4	0	4
April 11	0	11	0	9
2018 subtotal	1	34	0	35
Total				
2017–18	1	37	5	46

Behavior

Most of the radio-tagged steelhead moved at least 2 rkm away from the release site within the first 10 days after release; however, fish released at Lake Scanewa moved faster than fish released at the Cispus River site. In 2017, all tagged fish were detected at least 2 rkm away from the Lake Scanewa release site by 9.6 days after release, and the median was 0.6 day (fig. 3). Median residence time at the Cispus River release site in 2017 was 2.2 days, and 90 percent of fish were detected at least 2 rkm away by 8.3 days. By origin, median HOR residence time was 1.8 days and median NOR residence time was 4.4 days after release at the Cispus River release site. Too few HOR fish were released at the Lake Scanewa site in either year for comparisons. Similar trends occurred with fish tagged and released in 2018 (fig. 3). After release at the Lake

Scanewa site, 99 percent of fish were detected at least 2 rkm away within 3.7 days. Median time to move at least 2 rkm from the Cispus River release site in 2018 was 3.1 days, and 90 percent of fish moved by 14.0 days. Median HOR steelhead residence time was 3.3 days and median NOR steelhead residence time was 2.5 days after release at the Cispus River release site. Travel away from the Lake Scanewa release site was faster than the Cispus River release site in both years (Wilcoxon test, 2017: Z score [Z]=32.2, probability [P]<0.0001; 2018: Z=38.8, P<0.0001). There were no significant differences in travel time away from release sites by origin or sex in either year; however, median residence time was about one-half day shorter for males than females after release at the Cispus River site. Median residence time by month of release varied by month and origin, and residence times were shorter for NOR fish than HOR fish (fig. 4).

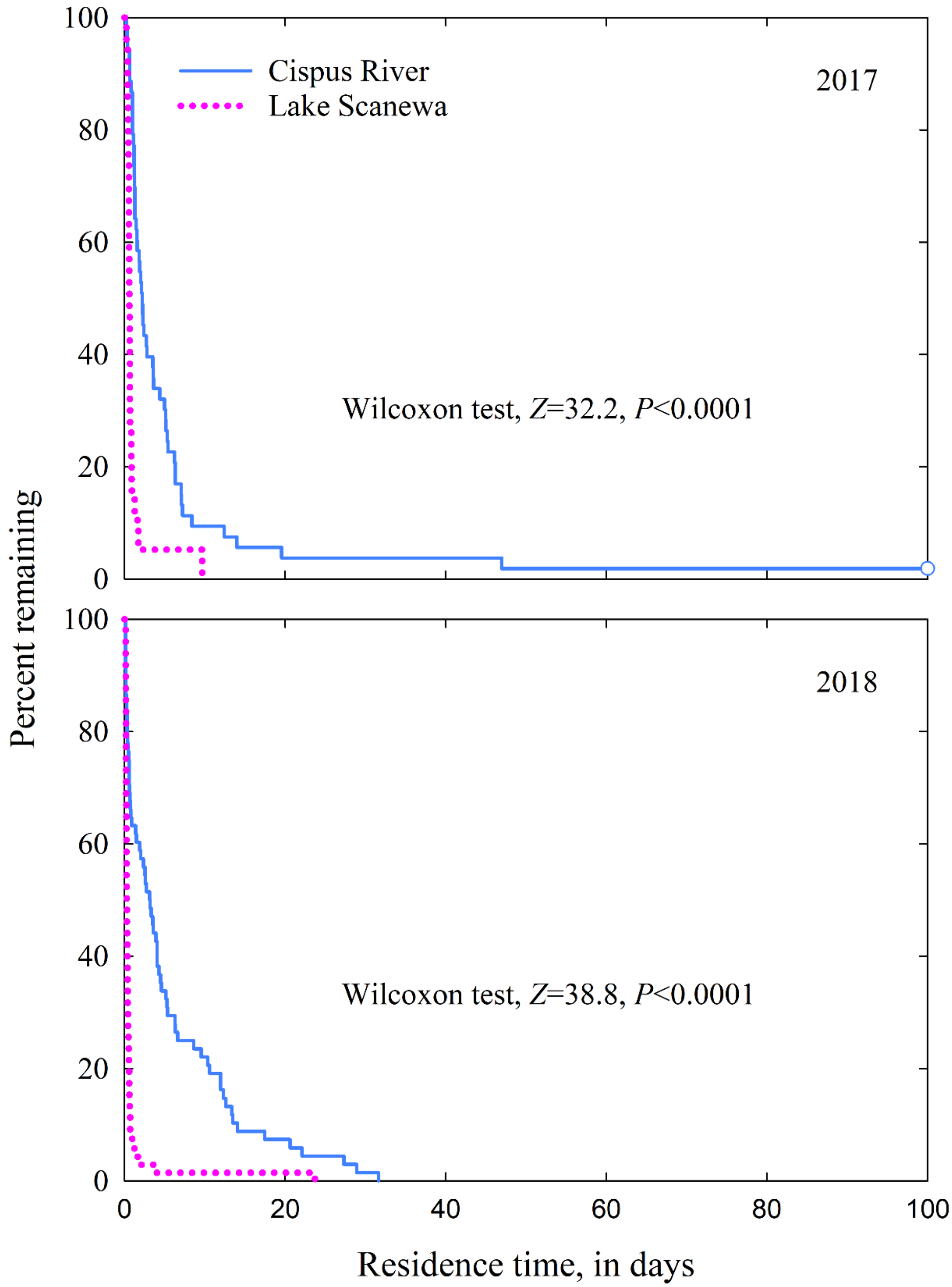

Figure 3. Graphs showing radio-tagged adult steelhead residence time (in days) after release into one of two locations in the upper Cowlitz River Basin, Washington, until movement at least 2 river kilometers away, 2017 (top graph) through 2018 (bottom graph). Fish not detected moving within the follow-up period of 100 days were censored (open circle). *Z* score, *Z*; *P*, probability; <, less than.

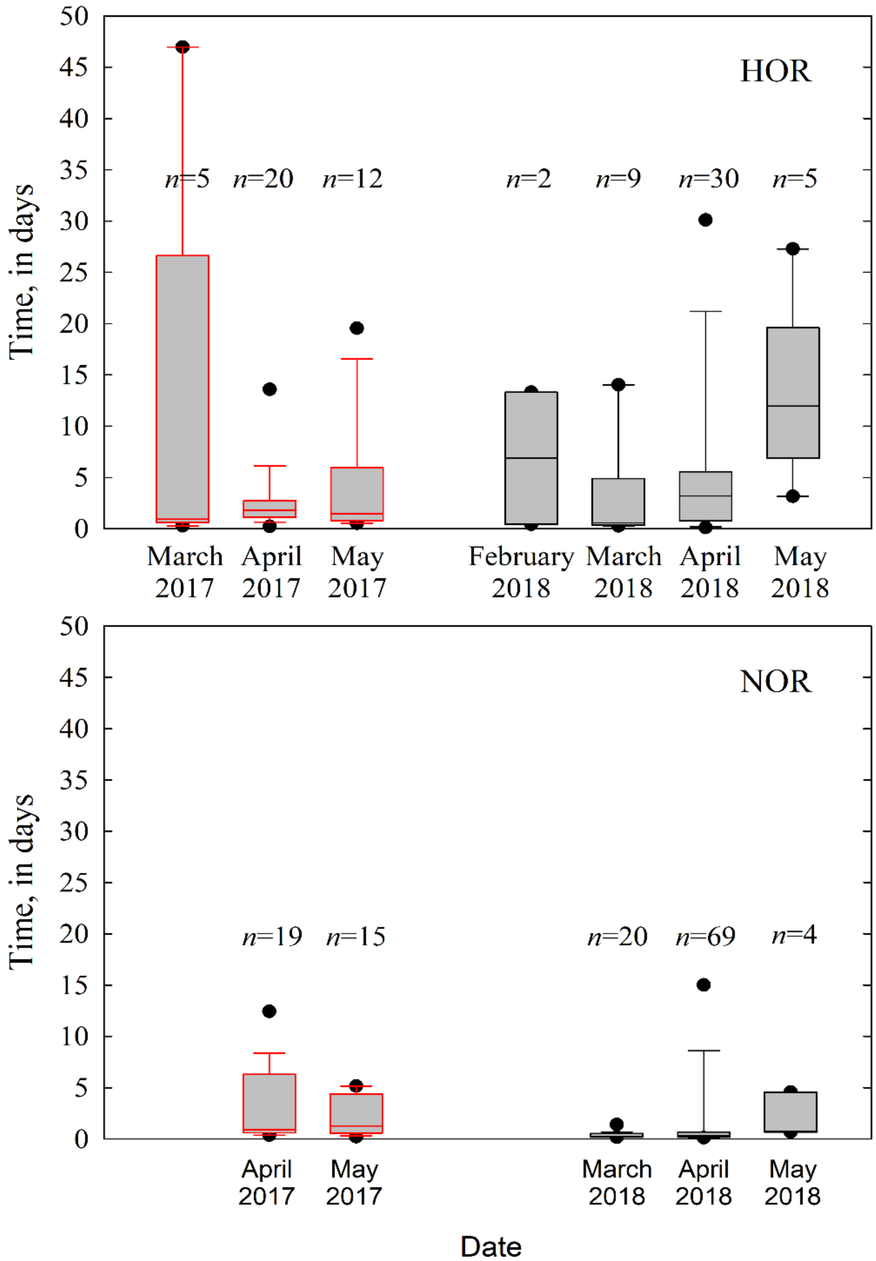

Figure 4. Graphs showing radio-tagged adult steelhead residence time (in days) by origin (HOR, hatchery origin; NOR, natural origin), and date of release, after release into one of two locations in the upper Cowlitz River Basin, Washington, until movement at least 2 river kilometers away, 2017 (boxes outlined in red) and 2018 (boxes outlined in black). Box hinges are 25th and 75th percentiles, horizontal bars inside the boxes are the median, whiskers are 10th and 90th percentiles, and dots are 5th and 95th percentiles. Sample sizes (*n*) of each group are shown. No NOR fish were released in March 2017 or February 2018.

Dispersal though the upper Cowlitz River Basin was similar between release sites and years, with some differences observed by origin. Of the fish released at the Cispus River site, 67.9–73.5 percent were detected moving into Lake Scanewa by year (table 3). A total of 14.3 percent of 2017 NOR fish and 17.4 percent of 2018 NOR fish were detected in the Cowlitz River after release at the Cispus River site. Few to none of the HOR fish released at the Cispus River site were detected in the Cowlitz River. Of the Cispus-released fish, 11.8–24.5 percent were detected in the tailrace, with similar numbers between origin in 2017 and twice as many NOR fish as HOR fish in 2018. Of the fish released in Lake Scanewa, 68.4–88.6 percent of fish were detected upstream from the release site in the Cowlitz River and 73.7–84.3 percent of fish were detected downstream from the release site in Lake Scanewa (table 3). Few HOR fish were released at the Lake Scanewa site for comparison by origin. About one-third of fish released at the Lake Scanewa site were detected in the Cispus River by year (31.6–42.9 percent). About one-half as many fish released in Lake Scanewa were detected in the tailrace compared to those released in the Cispus River.

Table 3. Percentage of adult radio-tagged steelhead detected in the Cispus River, Cowlitz River, Lake Scanewa, or the tailrace below Cowlitz Falls Dam after release into one of two locations in the upper Cowlitz River Basin, Washington, 2017–18.

[Individual fish can be represented in multiple categories. **Origin:** HOR, hatchery origin; NOR, natural origin]

Release site	Origin	Number of fish released	Percentage detected			
			Cispus River	Cowlitz River	Lake Scanewa	Tailrace
2017						
Cispus	HOR	32	100.0	0.0	68.8	25.0
	NOR	21	100.0	14.3	66.7	23.8
	Combined	53	100.0	5.7	67.9	24.5
Lake Scanewa	HOR	5	0.0	100.0	40.0	0.0
	NOR	14	42.9	57.1	85.7	14.3
	Combined	19	31.6	68.4	73.7	10.5
2018						
Cispus	HOR	45	100.0	6.7	71.1	8.9
	NOR	23	100.0	17.4	78.3	17.4
	Combined	68	100.0	10.3	73.5	11.8
Lake Scanewa	HOR	1	0.0	100.0	100.0	0.0
	NOR	69	43.5	88.4	84.1	7.2
	Combined	70	42.9	88.6	84.3	7.1

Movement into the Cowlitz and Cispus Rivers was related to release location and origin. More than three-quarters of fish released in the Cispus River were detected in reach 6 or 7 of the Cispus River (73.6–94.3 percent), although fewer HOR fish than NOR fish were detected in the upper Cispus River (fig. 1, table 4). Less than 8 percent of fish were detected in reach 5, although this reach only consisted of mobile detections. About 10 percent of fish released in the Cispus River moved to the Cowlitz River and were detected primarily in reach 3 (13 fish), with fewer in reach 4 (6 fish). By origin, fewer HOR fish than NOR fish were detected in reach 3 and no HOR fish were detected in reach 4. Similar to the Cispus River-released fish, about one-half of the fish released in Lake Scanewa and detected in reach 3 were detected in reach 4 (table 4), although the Lake Scanewa-released fish were detected about tenfold more than Cispus River-released fish by year. The percentages of radio-tagged steelhead released into Lake Scanewa that were detected in the Cispus River included 10.5–12.9 percent in reach 5, 26.3–41.4 percent in reach 6, and 15.8–18.6 percent in reach 7 by year (table 4).

Table 4. Percentage of adult radio-tagged steelhead detected in the Cowlitz River or Cispus River after release into one of two locations in the upper Cowlitz River Basin, Washington, 2017–18.

[Individual fish can be represented in multiple categories**. Origin:** HOR, hatchery origin; NOR, natural origin]

Release site	Origin	Released	Percentage detected by reach				
			Cowlitz River		Cispus River		
			3	4	5	6	7
2017							
Cispus	HOR	32	9.4	0.0	6.3	93.8	65.6
	NOR	21	14.3	14.3	4.8	95.2	85.7
	Combined	53	11.3	5.7	5.7	94.3	73.6
Lake Scanewa	HOR	5	100.0	20.0	0.0	0.0	0.0
	NOR	14	92.9	57.1	14.3	35.7	21.4
	Combined	19	94.7	47.4	10.5	26.3	15.8
2018							
Cispus	HOR	45	6.7	0.0	8.9	84.4	71.1
	NOR	23	17.4	13.0	4.3	95.7	82.6
	Combined	68	10.3	4.4	7.4	88.2	75.0
Lake Scanewa	HOR	1	100.0	100.0	0.0	0.0	0.0
	NOR	69	88.4	46.4	13.0	42.0	18.8
	Combined	70	88.6	47.1	12.9	41.4	18.6

Most radio-tagged steelhead made fewer than two trips between the reservoir and one of the rivers prior to spawning (table 5). Most fish (59.4–100.0 percent), regardless of origin or release site, did not enter the reservoir prior to spawning. For fish released at the Cispus River site, trends were similar between years. A total of 8.9–21.9 percent of HOR and NOR fish (combined) made one trip to the reservoir, 4.8 percent (one fish) of NOR fish made two trips, 3.1 percent (one fish) of HOR fish made three trips, and 3.1 percent (one fish) of HOR fish made a total of seven trips to the reservoir prior to spawning (table 5). Few HOR fish were released at Lake Scanewa in either year, and none of those six fish were detected in the reservoir prior to spawning. NOR fish released in Lake Scanewa followed the same trends as the Cispus River fish, making 0–2 trips each year.

Table 5. Percentage of radio-tagged adult steelhead making trips between Lake Scanewa and the Cowlitz River or Cispus River in the upper Cowlitz River Basin, Washington, prior to spawning, 2017–18.

[**Abbreviations:** HOR, hatchery origin; NOR, natural origin]

Number of trips	Cispus River released		Lake Scanewa released	
	HOR	NOR	HOR	NOR
2017				
0	71.9	81.0	100.0	71.4
1	21.9	14.3	0.0	21.4
2	0.0	4.8	0.0	7.1
3	3.1	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	3.1	0.0	0.0	0.0
2018				
0	91.1	87.0	100.0	59.4
1	8.9	13.0	0.0	36.2
2	0.0	0.0	0.0	4.3

Fates

Most of the fish released in the Cispus River were assigned fates in the Cispus River regardless of year or origin, whereas most fish released in Lake Scanewa were assigned fates outside the reservoir, in the rivers. More than 80 percent of radio-tagged steelhead released in the Cispus River had Cispus River fates, and the next largest group was about 14 percent of NOR fish with Cowlitz River fates (table 6). In 2017, 18.8 percent of HOR fish and 4.8 percent of NOR fish released at the Cispus River site had reservoir or fallback fates compared to zero fish in 2018. All the HOR fish released in Lake Scanewa were assigned a Cowlitz River fate. Of the NOR fish released in Lake Scanewa, about 56 percent were assigned a Cowlitz River fate followed by about 40 percent with Cispus River fates. In 2017, 7.1 percent had a Lake Scanewa fate compared to 1.4 percent in 2018. There were no fallbacks from either release site in 2018. In total, 3 of 210 fish released in 2017 and 2018 (1.4 percent) fell back prior to spawning, and these were all HOR fish released at the Cispus River site in 2017. All three fish were first detected moving downstream from Cowlitz Falls Dam during May 4–6, 2017. During this 3-day period, both turbines were operating, spillway 4 was open, and mean hourly total project discharge was 13,752 ft^3/s (fig. 2).

Table 6. Percentage of adult radio-tagged steelhead assigned to Cispus River, Cowlitz River, Lake Scanewa, or fallback below Cowlitz Falls Dam, Washington, with fates by release site and origin, 2017–18.

[**Origin:** HOR, hatchery origin; NOR, natural origin]

Release site	Origin	Total	Cispus River	Cowlitz River	Lake Scanewa	Fallback
2017						
Cispus	HOR	32	81.3	0.0	9.4	9.4
	NOR	21	81.0	14.3	4.8	0.0
Lake Scanewa	HOR	5	0.0	100.0	0.0	0.0
	NOR	14	35.7	57.1	7.1	0.0
2018						
Cispus	HOR	45	97.8	2.2	0.0	0.0
	NOR	23	87.0	13.0	0.0	0.0
Lake Scanewa	HOR	1	0.0	100.0	0.0	0.0
	NOR	69	43.5	55.1	1.4	0.0

Kelts

Distribution of radio-tagged steelhead after spawning varied by release site, origin, and sex. A total of 5.7 percent (3 of 53) of fish released in the Cispus River in 2017 were fallbacks prior to spawning. No other fallbacks prior to spawning were documented (table 7). After spawning, the highest proportions of fish were not detected moving downstream (that is, they remained upstream) or were collected at Cowlitz Falls Dam (table 7). From 29.4 to 39.6 percent of fish were not detected moving downstream after spawning, regardless of release site or year, although they were predominantly male. About 50 percent of 2018 steelhead and from 26.4 to 42.1 percent of 2017 steelhead were collected at the dam, with similar proportions between sexes. By year and release site, about 10 percent of fish were last detected in Lake Scanewa. The remaining fish (11.9 percent) passed downstream from Cowlitz Falls Dam (fallback after spawning) and a higher percentage of female fish moved downstream than male fish (7 males and 28 females). The percentage of kelts collected at the Cowlitz Falls Fish Facility was 53.7 percent in 2017 and 71.1 percent in 2018. The breakdown by sex and origin of collected kelts included the following: 72.7 percent of male HOR steelhead, 66.7 percent of female HOR steelhead, 70.3 percent of male NOR steelhead, and 59.6 percent of female NOR steelhead.

Table 7. Percentage of adult radio-tagged steelhead that fell back below Cowlitz Falls Dam prior to or after spawning, remained upstream, or were collected at the dam, by sex, origin, and release site in the upper Cowlitz River Basin, Washington, 2017–18.

[**Origin:** HOR, hatchery origin; NOR, natural origin. **Sex:** M, male; F, female]

Release site	Origin	Sex	Fallback prior to spawning	Not detected moving downstream	Last detected in Lake Scanewa	Collected at Cowlitz Falls Dam	Fallback after spawning	Total
2017								
Cispus	HOR	M	7.1	71.4	7.1	14.3	0.0	14
	HOR	F	11.1	16.7	11.1	33.3	27.8	18
	NOR	M	0.0	50.0	14.3	28.6	7.1	14
	NOR	F	0.0	14.3	0.0	28.6	57.1	7
Total			5.7	39.6	9.4	26.4	18.9	53
Lake Scanewa	HOR	M	0.0	0.0	0.0	0.0	0.0	0
	HOR	F	0.0	60.0	0.0	40.0	0.0	5
	NOR	M	0.0	33.3	0.0	66.7	0.0	3
	NOR	F	0.0	27.3	18.2	36.4	18.2	11
Total			0.0	36.8	10.5	42.1	10.5	19
2018								
Cispus	HOR	M	0.0	35.7	3.6	46.4	14.3	28
	HOR	F	0.0	27.8	11.1	55.6	0.0	18
	NOR	M	0.0	37.5	12.5	50.0	0.0	8
	NOR	F	0.0	13.3	6.7	53.3	26.7	15
Total			0.0	29.4	7.4	51.5	11.8	68
Lake Scanewa	HOR	M	0.0	0.0	0.0	0.0	0.0	1
	HOR	F	0.0	0.0	0.0	0.0	0.0	0
	NOR	M	0.0	32.4	14.7	47.1	5.9	34
	NOR	F	0.0	28.6	14.3	48.6	8.6	35
Total			0.0	30.0	14.3	48.6	7.1	70

Spawning Locations

Spawning locations of radio-tagged steelhead were related to release location but varied within the basin. Fish released into Lake Scanewa predominantly were detected in the Cowlitz River. In both years, more fish from this release site were found to spawn in the upper Cowlitz River (reach 4; fig. 1) than in the lower Cowlitz River (reach 3; table 8; figs. 5 and 6; appendix tables 1.1 and 1.2). In 2017, the farthest upstream location was at Smith Creek (rkm 197.5) compared to the Ohanapecosh River (rkm 215.7) in 2018. Five fish released in Lake Scanewa in 2017 spawned in the Cispus River: in Yellowjacket (rkm 27.0) and Camp (rkm 28.3) Creeks and the Cispus River (rkm 30.5 and 37.0). Of the fish released into Lake Scanewa in 2018, 41.0 percent were located in the Cispus River or tributaries, with 4 fish in the lower (reach 5), 12 fish in the middle (reach 6), and 13 fish in the upper Cispus River (reach 7). Few fish released in the Cispus River were thought to have spawned in the Cowlitz River or tributaries in either year (table 8, figs. 5 and 6; appendix tables 1.1 and 1.2). These locations include Lambert Creek (rkm 147.7), Cowlitz River (rkm 185.1, 203.6, 203.6), Johnson Creek (rkm 197.5), and Skate Creek (rkm 202.3). Most steelhead released in the Cispus River moved into the upper Cispus River (reach 7), followed by the middle Cispus River (reach 6), and the fewest into the lower Cispus River (reach 5). Tributary use in the Cispus River included Quartz, Crystal, Iron, Greenhorn, Yellowjacket, Camp, and Prospect Creeks as well as the North Fork Cispus River. The maximum upstream location of steelhead in the North Fork Cispus River was rkm 12.9, and a total of 22 fish were located there between years and release sites. Maps of spawning locations by origin and unique tag code are presented in appendix 1. No tagged fish were detected in the following Cowlitz River tributaries during mobile tracking efforts: Davis, Hall, Butter, and Coal Creeks. Tagged fish were not detected in the following Cispus River tributaries during mobile tracking efforts: East Canyon, Squaw, Adams, and Orr Creeks.

Table 8. Number of radio-tagged steelhead at spawning locations in the upper Cowlitz River Basin, Washington, by release site and release year.

[Fish that entered more than one tributary are represented in both rivers. River kilometers 146.0–215.7 are locations in the Cowlitz River or at the confluence of a tributary. River kilometers 2.0–48.3 are locations in the Cispus River or at the confluence of a tributary. **Rkm:** River kilometer]

River	Reach	Rkm	Cispus River		Lake Scanewa	
			2017	2018	2017	2018
Cowlitz	3	146.0–182.0	0	0	4	4
Lambert	3	147.7	0	1	0	0
Kiona	3	161.4	0	0	0	1
Miller	3	165.4	0	0	0	1
Silver	3	169.8	0	0	1	3
Cowlitz	4	182.0–215.7	1	2	4	18
Killborn	4	185.1	0	0	1	0
Burton	4	188.5	0	0	1	0
Dry	4	196.3	0	0	1	0
Smith	4	196.7	0	0	2	4
Johnson	4	197.5	1	0	0	5
Skate	4	202.3	1	1	0	4
Lake	4	208.1	0	0	0	1
Ohanapecosh	4	215.7	0	0	0	1
Cispus	5	2.0–8.0	0	1	0	0
Quartz	5	6.6	1	2	0	2
Crystal	5	6.9	1	2	0	2
Cispus	6	8.0–28.2	4	8	0	9
Iron	6	13.8	0	0	0	1
Greenhorn	6	19.8	0	1	0	1
Yellowjacket	6	27.0	3	3	2	1
Cispus	7	28.2–48.3	28	33	2	9
Camp	7	28.3	1	1	1	0
NF Cispus	7	32.3	6	13	0	3
Prospect	7	46.5	0	2	0	1

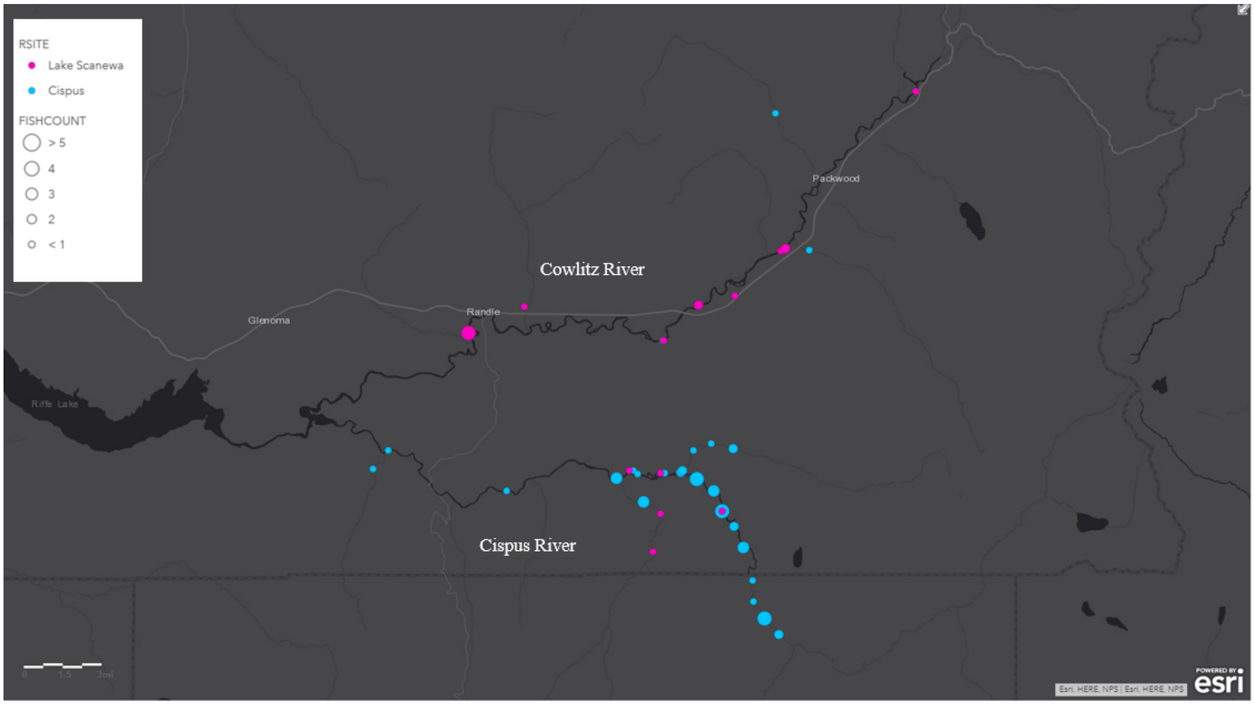

Figure 5. Image showing locations of adult radio-tagged steelhead spawning in the upper Cowlitz River Basin, Washington, by release site, 2017. Map image is the intellectual property of Esri and is used herein under license. Copyright © 2020 Esri and its licensors. All rights reserved. Rsite, release site; >, greater than; <, less than. Cispus release site is the Cispus River release site.

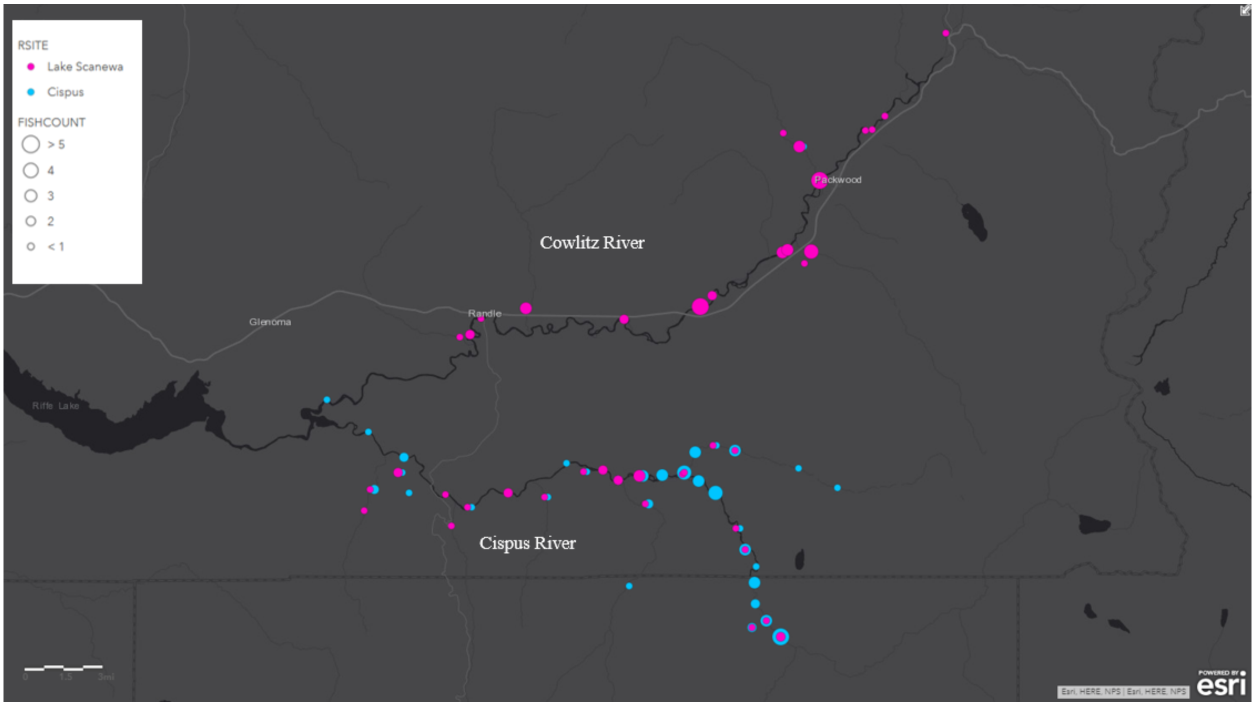

Figure 6. Image showing locations of adult radio-tagged steelhead spawning in the upper Cowlitz River Basin, Washington, by release site, 2018. Map image is the intellectual property of Esri and is used herein under license. Copyright © 2020 Esri and its licensors. All rights reserved. Rsite, release site; >, greater than; <, less than. Cispus release site is the Cispus River release site.

Some of the tagged steelhead entered multiple tributaries. Only males demonstrated this behavior. In 2017, one steelhead was located in both Dry Creek and Smith Creek in the upper Cowlitz River (reach 4, tag code 2291, NOR). In 2018, four steelhead were found in multiple tributaries: Crystal and Quartz Creeks (tag code 2457, HOR) in the lower Cispus River (reach 5), Camp and Yellowjacket Creeks (tag code 1133, HOR) in the upper Cispus River (reach 7), and Johnson and Smith Creeks (tag code 1261, NOR) and Johnson and Skate Creeks (tag code 1323, HOR) in the upper Cowlitz River (reach 4).

One female HOR steelhead (80-cm fork length) released on April 17, 2017, in the Cispus River and collected at the Cowlitz Falls Fish Facility was determined to have fallen back prior to spawning. This fish was returned to Lake Scanewa on April 21, 2017. This fish entered the Cispus River on April 22, 2019, and then Crystal Creek (rkm 6.6, reach 5) on April 25, 2017, where we captured a video recording of it being courted by a wild rainbow trout (https://www.usgs.gov/media/videos/anadromous-steelhead-and-resident-rainbow-trout-interactions). The following week, the radio tag was recovered without the fish present in Crystal Creek.

Discussion

This study used radiotelemetry to monitor adult steelhead movements in the upper Cowlitz River Basin to describe fates and spawning locations and to assist in the evaluation of reintroduction efforts. Our previous studies of adult steelhead were conducted from 2005 to 2012 (Kock and others, 2016) and provided the first insights into how steelhead moved in the system after release into Lake Scanewa or at release sites in the rivers. Kock and others (2016), however, provided only coarse information on final locations in the upper reaches of the rivers because their study objectives were broader, focused on estimating the proportion of fish that fell back over Cowlitz Falls Dam prior to spawning and describing the proportion of fish present in the rivers during the spawning period. The current study was designed as a continuation of Kock and others (2016), with the goal of refining the descriptions of steelhead spawning locations in the Cowlitz and Cispus Rivers and their tributaries.

Steelhead were predominantly assigned fates in the river closest to where they were released, but origin also played a role. Steelhead released into the Cispus River were assigned Cispus River fates more than 80 percent of the time, including both origins and both years. Fish origin affected the number of fish that left the Cispus River and were assigned Cowlitz River fates. About 13 percent of NOR fish had fates in the Cowlitz River, but the proportion was lower for HOR fish (0–2 percent). Fallback was the least common fate for Cispus River-released steelhead (three HOR fish in 2017), followed by the reservoir fate, ranging from 5 to 9 percent in 2017, and zero in 2018. Kock and others (2016) reported similar patterns in fate for steelhead released in the Cispus River: Cispus River was the most common fate for both origins, and more NOR fish moved to the Cowlitz River than HOR fish. The steelhead released into Lake Scanewa were almost exclusively NOR fish, which had primarily Cowlitz River fates (55–57 percent). We released only six HOR steelhead into Lake Scanewa, and they all had Cowlitz River fates. The next most common fate for reservoir-released NOR steelhead was the Cispus River (36–44 percent), with few fish having reservoir fates (1–7 percent), and none documented to fall back over the dam. These findings confirm the importance of the Cowlitz River for NOR fish released into the reservoir, as reported by Kock and others (2016). These authors reported that the Cowlitz River was the most common fate for NOR fish released into the reservoir (53 percent), followed by 29 percent assigned a Cispus River fate. The reservoir fate was uncommon for both release sites, and it was consistently lower in 2018 compared to 2017. Flow conditions were higher in 2017, which may have affected steelhead movement patterns or timing.

We documented few fallback events. Three HOR steelhead released in the Cispus River in 2017 were the only fish that fell back over Cowlitz Falls Dam. These fish represented 1.4 percent of the total study fish, 5.7 percent of the Cispus River-released fish in 2017, and 9.4 percent of the Cispus River-released HOR fish in 2017. All three fish were detected in the dam tailrace in early May 2017 during high flow conditions and spill operations. These findings compare well with Kock and others (2016) who reported that 1.9 percent of HOR steelhead released in the Cispus River fell back, with more fallback events occurring during high flow conditions.

Steelhead dispersal patterns were similar between release sites and years. Within the first 10 days after release, most steelhead had moved at least 2 rkm away from their release site. Fish released into Lake Scanewa, however, moved from their release site significantly sooner than fish released into the Cispus River, regardless of origin or sex. Most radio-tagged steelhead (93–100 percent) made no more than one trip between the reservoir and one of the rivers prior to spawning, a finding similar to a previous study (Kock and others, 2016).

After spawning, about 53–63 percent of steelhead moved downstream as kelts, either being collected at Cowlitz Falls Dam or being detected downstream from the dam. More fish were collected from both release sites in 2018 compared to 2017. Across release sites and years, NOR fish and females moved downstream as kelts. Females are more common as kelts than males (Evans and others, 2004), likely because the cost of breeding competition is higher for females (Evans and others, 2008) and they presumably leave spawning areas after spawning is complete to maximize their chances of survival and potential return to spawn again. Kock and others (2016) reported that 29 percent of tagged steelhead moved downstream from the dam, as evidenced by either being collected or detected in the tailrace. Their proportion may have been lower than our proportion because they had more fallbacks during their study years. Our results are similar to Kock and others (2016) in that we found similar proportions of HOR and NOR fish moving downstream but a higher proportion of females compared to males.

One of the main objectives of this study was to document spawning sites for steelhead in the upper Cowlitz River Basin. We used a monitoring approach that was more spatially extensive than that of Kock and others (2016) so steelhead movements within each of the main rivers could be described by river reach, and we used intensive mobile tracking to monitor the use of tributaries by tagged fish. We found that most (about 62 percent) steelhead released in Lake Scanewa spawned in the Cowlitz River, with the remaining 38 percent in the Cispus River. Within the Cowlitz River, close to one-half (about 47 percent) of the fish were presumed to have spawned in the upper reach, and about 16 percent spawned in the lower reach. Steelhead released into Lake Scanewa that spawned in the Cispus River were minimal in the lower reach (4 percent) and distributed in approximately equal proportions in the middle (16 percent) and upper (18 percent) reaches. Steelhead released into the Cispus River were presumed to spawn almost exclusively in the Cispus River (94 percent). The upper Cispus River reach was used by more fish (72 percent) than the middle Cispus River reach (16 percent). Taken together, the upper Cowlitz reach and upper Cispus River reach accounted for more than 71 percent of the spawning locations for radio-tagged steelhead. When the middle Cispus River reach is included with the upper reaches, they account for 87 percent of our described spawning sites. The lower Cispus and Cowlitz River reaches, combined, accounted for 13 percent of spawning sites. We described 12 tributaries in the Cowlitz River and 8 tributaries in the Cispus River where steelhead spawned, and further detail is provided in figures and tables in the appendix. Our summaries of spawning locations should be useful for resource managers in the Cowlitz River Basin because they may help refine their trap-and-haul procedures to best serve their reintroduction goals.

The fate summaries we present are useful to improve our understanding of dispersal patterns in the upper Cowlitz River Basin, but they should be interpreted cautiously because our study design did not directly address important factors such as prespawn mortality, harvest, or confirmed spawning success. Based on our study approach, estimates of Cowlitz River, Cispus River, and reservoir fates may be biased. Some steelhead detected in the Cowlitz and Cispus Rivers likely died prior to spawning because of natural factors such as disease or predation or were harvested by anglers. Additionally, steelhead that survived to the onset of spawning did not all likely spawn successfully. We have greater confidence in our estimates of fallback, however, because we were able to detect fish within minutes of their fallback event.

This study added to the understanding of the behavior and movement of adult steelhead in the upper Cowlitz River Basin, supporting the findings of Kock and others (2016) under different environmental conditions and describing spawning sites in the system's two main rivers and their tributaries. Future research efforts in this system may use additional telemetry studies, genetic analyses, and spawning ground surveys to provide further insights into the progress of the reintroduction effort.

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Appendix 1. Detailed Summary of Spawning Locations of Radio-Tagged Steelhead in the Upper Cowlitz River Basin

This appendix presents a detailed summary of the spawning locations of radio-tagged winter steelhead in the upper Cowlitz River Basin. Table 1.1 is a summary of steelhead released in 2017, and table 1.2 is a summary of steelhead released in 2018. The tables individually identify each tagged steelhead and report its origin, sex, fork length, release site, fate and spawning location. Spawning locations are visually depicted by origin for 2017 (fig. 1.1) and 2018 (fig. 1.2) to assist managers in evaluating the potential for interactions between hatchery origin and natural origin steelhead in this system.

Table 1.1. Spawning locations of radio-tagged steelhead released at two sites in the upper Cowlitz River Basin, Washington, in 2017.

[**Fate:** CIS, Cispus River Basin; COW, Cowlitz River Basin; RES, Reservoir; **Origin:** HOR, hatchery origin; NOR, natural origin. **Sex:** F, female; M, male. **Length:** Fork length in centimeters. **River:** NF, North Fork. **Rkm main:** River kilometer main, which designates river kilometer in either Cowlitz or Cispus River. **Rkm tributary**: River kilometer tributary, which designates river kilometer within the tributary (or not applicable [NA], if no tributary) where spawning occurred]

Tag code	Release site	Fate	Origin	Sex	Length	Spawning location		
						River	Rkm main	Rkm tributary
1123	Cispus	CIS	NOR	M	46	Quartz	6.6	1.6
2135	Cispus	CIS	HOR	F	80	Crystal	6.9	0.0
2011	Cispus	CIS	HOR	M	90	Cispus	17.7	NA
1203	Cispus	RES	HOR	F	74	Yellowjacket	27.0	3.2
1207	Cispus	CIS	NOR	M	56	Yellowjacket	27.0	3.2
2041	Cispus	CIS	HOR	F	77	Yellowjacket	27.0	3.2
2097	Lake Scanewa	CIS	NOR	F	71	Yellowjacket	27.0	4.8
2193	Lake Scanewa	CIS	NOR	F	55	Yellowjacket	27.0	8.0
1183	Cispus	CIS	HOR	F	78	Cispus	27.2	NA
1077	Cispus	CIS	HOR	F	79	Cispus	27.4	NA
1151	Cispus	CIS	HOR	M	86	Cispus	28.0	NA
2211	Lake Scanewa	CIS	NOR	M	49	Camp	28.3	0.0
2263	Cispus	CIS	HOR	F	61	Camp	28.3	0.0
1067	Cispus	CIS	NOR	M	83	Cispus	29.0	NA
1055	Cispus	CIS	NOR	M	80	Cispus	30.6	NA
1289	Lake Scanewa	CIS	NOR	F	63	Cispus	30.6	NA
1259	Cispus	CIS	NOR	F	73	Cispus	32.2	NA
2253	Cispus	CIS	HOR	F	65	Cispus	32.2	NA
1165	Cispus	CIS	HOR	M	86	NF Cispus	32.3	0.0
1169	Cispus	CIS	HOR	F	79	NF Cispus	32.3	0.0

Tag code	Release site	Fate	Origin	Sex	Length	Spawning location		
						River	Rkm main	Rkm tributary
1297	Cispus	CIS	HOR	F	80	NF Cispus	32.3	1.6
1117	Cispus	CIS	HOR	F	78	NF Cispus	32.3	3.2
2051	Cispus	CIS	NOR	M	68	NF Cispus	32.3	4.8
2087	Cispus	CIS	NOR	M	69	NF Cispus	32.3	4.8
2033	Cispus	CIS	HOR	M	78	Cispus	34.3	NA
2043	Cispus	CIS	HOR	F	76	Cispus	34.3	NA
2265	Cispus	CIS	HOR	F	77	Cispus	34.3	NA
2277	Cispus	CIS	NOR	F	57	Cispus	34.3	NA
1177	Cispus	CIS	HOR	M	64	Cispus	35.4	NA
1225	Cispus	CIS	HOR	M	60	Cispus	35.4	NA
2035	Cispus	CIS	HOR	F	75	Cispus	35.4	NA
1175	Cispus	CIS	NOR	M	56	Cispus	37.0	NA
2017	Cispus	CIS	NOR	F	67	Cispus	37.0	NA
2021	Cispus	CIS	HOR	M	84	Cispus	37.0	NA
2037	Cispus	CIS	HOR	F	80	Cispus	37.0	NA
2237	Lake Scanewa	CIS	NOR	F	69	Cispus	37.0	NA
1287	Cispus	CIS	HOR	F	75	Cispus	38.6	NA
2063	Cispus	CIS	HOR	M	87	Cispus	38.6	NA
1061	Cispus	CIS	NOR	M	66	Cispus	40.2	NA
2039	Cispus	CIS	NOR	F	64	Cispus	40.2	NA
2101	Cispus	CIS	NOR	M	75	Cispus	40.2	NA
1075	Cispus	CIS	NOR	M	75	Cispus	43.5	NA
1113	Cispus	CIS	HOR	M	82	Cispus	45.1	NA
1059	Cispus	CIS	NOR	F	73	Cispus	46.7	NA
1149	Cispus	CIS	NOR	F	71	Cispus	46.7	NA
1229	Cispus	CIS	HOR	M	46	Cispus	46.7	NA
2029	Cispus	CIS	HOR	M	83	Cispus	46.7	NA
1187	Cispus	CIS	HOR	F	79	Cispus	48.3	NA
2129	Cispus	CIS	NOR	M	75	Cispus	48.3	NA
1271	Lake Scanewa	COW	HOR	F	81	Cowlitz	162.2	NA
1279	Lake Scanewa	COW	HOR	F	73	Cowlitz	162.2	NA
2049	Lake Scanewa	COW	HOR	F	73	Cowlitz	162.2	NA
2079	Lake Scanewa	COW	HOR	F	80	Cowlitz	162.2	NA
1139	Lake Scanewa	COW	NOR	M	65	Silver	169.8	1.6
1107	Cispus	COW	NOR	M	74	Cowlitz	185.1	NA
1147	Lake Scanewa	COW	HOR	F	70	Killborn	185.1	0.0
2167	Lake Scanewa	COW	NOR	F	83	Cowlitz	188.3	NA
2209	Lake Scanewa	COW	NOR	F	72	Cowlitz	188.3	NA
2083	Lake Scanewa	COW	NOR	F	64	Burton	188.5	3.2
2231	Lake Scanewa	COW	NOR	F	63	Cowlitz	196.3	NA
2291	Lake Scanewa	COW	NOR	M	54	Dry	196.3	0.0

Tag code	Release site	Fate	Origin	Sex	Length	Spawning location		
						River	Rkm main	Rkm tributary
2291	Lake Scanewa	COW	NOR	M	54	Smith	196.7	0.0
2181	Lake Scanewa	COW	NOR	F	66	Smith	196.7	0.0
1161	Cispus	COW	NOR	M	71	Johnson	197.5	1.6
2045	Cispus	COW	NOR	F	62	Skate	202.3	6.4
2071	Lake Scanewa	COW	NOR	F	68	Cowlitz	212.4	NA

Table 1.2. Spawning locations of radio-tagged steelhead released at two sites in the upper Cowlitz River Basin, Washington, in 2018.

[**Fate:** CIS, Cispus River Basin; COW, Cowlitz River Basin. **Origin:** HOR, hatchery origin; NOR, natural origin. **Sex:** F, female; M, male; **Length:** Fork length in centimeters. **River:** NF, North Fork. **Rkm main**: River kilometer main, which designates river kilometer in either Cowlitz or Cispus River **Rkm tributary**: River kilometer tributary, which designates river kilometer within the tributary (or not applicable [NA], if no tributary) where spawning occurred]

Tag code	Release site	Fate	Origin	Sex	Length	Spawning location		
						River	Rkm main	Rkm tributary
2446	Cispus	CIS	HOR	M	63	Cispus	4.8	NA
1255	Lake Scanewa	CIS	NOR	M	68	Quartz	6.6	3.2
2443	Cispus	CIS	HOR	M	65	Quartz	6.6	3.2
1424	Lake Scanewa	CIS	NOR	F	64	Quartz	6.6	4.8
2457	Cispus	CIS	HOR	M	72	Quartz	6.6	4.8
1411	Lake Scanewa	CIS	NOR	F	73	Crystal	6.9	1.6
2215	Lake Scanewa	CIS	NOR	F	82	Crystal	6.9	1.6
2463	Cispus	CIS	HOR	F	67	Crystal	6.9	1.6
2457	Cispus	CIS	HOR	M	72	Crystal	6.9	3.2
2189	Cispus	CIS	NOR	F	68	Cispus	8.7	NA
2197	Cispus	CIS	HOR	F	64	Cispus	8.7	NA
2444	Lake Scanewa	CIS	NOR	F	82	Cispus	12.9	NA
2091	Lake Scanewa	CIS	NOR	F	78	Iron	13.8	1.6
2013	Lake Scanewa	CIS	NOR	F	69	Cispus	14.5	NA
2299	Cispus	CIS	HOR	F	70	Cispus	14.5	NA
1301	Lake Scanewa	CIS	NOR	F	67	Cispus	17.7	NA
2459	Lake Scanewa	CIS	NOR	F	81	Cispus	17.7	NA
1140	Cispus	CIS	HOR	F	67	Greenhorn	19.8	1.6
2461	Lake Scanewa	CIS	NOR	M	75	Greenhorn	19.8	1.6
2205	Cispus	CIS	HOR	M	73	Cispus	22.5	NA
1410	Lake Scanewa	CIS	NOR	F	74	Cispus	24.1	NA
2219	Cispus	CIS	HOR	F	62	Cispus	24.1	NA
2223	Lake Scanewa	CIS	NOR	M	76	Cispus	25.7	NA
2450	Lake Scanewa	CIS	NOR	M	70	Cispus	25.7	NA
1420	Lake Scanewa	CIS	NOR	M	76	Yellowjacket	27.0	3.2
2447	Cispus	CIS	HOR	M	63	Yellowjacket	27.0	3.2
1132	Cispus	CIS	HOR	M	66	Yellowjacket	27.0	11.3
1133	Cispus	CIS	HOR	M	67	Yellowjacket	27.0	11.3
1195	Lake Scanewa	CIS	NOR	M	73	Cispus	27.2	NA
2440	Cispus	CIS	HOR	F	65	Cispus	27.2	NA
2019	Cispus	CIS	HOR	F	65	Cispus	27.4	NA
2099	Cispus	CIS	HOR	M	84	Cispus	27.4	NA
2435	Lake Scanewa	CIS	NOR	F	72	Cispus	27.4	NA

Tag code	Release site	Fate	Origin	Sex	Length	Spawning location		
						River	Rkm main	Rkm tributary
1133	Cispus	CIS	HOR	M	67	Camp	28.3	6.4
1138	Cispus	CIS	HOR	M	71	Cispus	29.0	NA
1173	Lake Scanewa	CIS	NOR	M	73	Cispus	29.0	NA
1421	Cispus	CIS	NOR	M	60	Cispus	29.0	NA
2015	Cispus	CIS	HOR	F	66	Cispus	29.0	NA
2125	Lake Scanewa	CIS	NOR	F	83	Cispus	29.0	NA
2445	Lake Scanewa	CIS	NOR	F	79	Cispus	29.0	NA
1121	Cispus	CIS	HOR	M	63	Cispus	30.6	NA
2109	Cispus	CIS	HOR	M	64	Cispus	30.6	NA
2235	Cispus	CIS	HOR	F	81	Cispus	30.6	NA
1427	Cispus	CIS	HOR	F	62	Cispus	32.2	NA
2217	Lake Scanewa	CIS	NOR	M	86	Cispus	32.3	NA
1127	Cispus	CIS	HOR	F	61	NF Cispus	32.3	0.0
1403	Cispus	CIS	HOR	F	67	NF Cispus	32.3	0.0
1415	Cispus	CIS	HOR	M	61	NF Cispus	32.3	0.0
1426	Cispus	CIS	HOR	M	66	NF Cispus	32.3	0.0
2093	Lake Scanewa	CIS	NOR	F	78	NF Cispus	32.3	0.0
1407	Cispus	CIS	HOR	M	69	NF Cispus	32.3	1.6
2137	Cispus	CIS	NOR	F	63	NF Cispus	32.3	1.6
2191	Cispus	CIS	HOR	M	67	NF Cispus	32.3	1.6
1227	Cispus	CIS	HOR	F	64	NF Cispus	32.3	3.2
1311	Lake Scanewa	CIS	NOR	M	68	NF Cispus	32.3	3.2
1413	Cispus	CIS	HOR	M	64	NF Cispus	32.3	4.8
2085	Cispus	CIS	HOR	M	67	NF Cispus	32.3	4.8
2433	Lake Scanewa	CIS	NOR	F	69	NF Cispus	32.3	4.8
2434	Cispus	CIS	HOR	M	70	NF Cispus	32.3	4.8
1269	Cispus	CIS	HOR	M	65	NF Cispus	32.3	9.7
1319	Cispus	CIS	HOR	M	66	NF Cispus	32.3	12.9
1245	Cispus	CIS	HOR	F	66	Cispus	34.3	NA
1422	Cispus	CIS	NOR	M	49	Cispus	34.3	NA
2025	Cispus	CIS	HOR	M	67	Cispus	34.3	NA
1136	Cispus	CIS	NOR	F	67	Cispus	35.4	NA
2436	Cispus	CIS	NOR	F	68	Cispus	35.4	NA
2437	Cispus	CIS	NOR	F	66	Cispus	35.4	NA
2452	Cispus	CIS	HOR	M	56	Cispus	35.4	NA
2458	Lake Scanewa	CIS	NOR	F	73	Cispus	38.6	NA
2462	Cispus	CIS	HOR	M	65	Cispus	38.6	NA
1185	Cispus	CIS	NOR	F	85	Cispus	40.2	NA
1273	Cispus	CIS	NOR	M	75	Cispus	40.2	NA
1295	Lake Scanewa	CIS	NOR	M	66	Cispus	40.2	NA
2065	Cispus	CIS	NOR	M	75	Cispus	40.2	NA

Tag code	Release site	Fate	Origin	Sex	Length	Spawning location		
						River	Rkm main	Rkm tributary
2451	Cispus	CIS	NOR	F	79	Cispus	41.8	NA
1221	Cispus	CIS	HOR	M	66	Cispus	43.5	NA
1239	Cispus	CIS	NOR	M	74	Cispus	43.5	NA
1417	Cispus	CIS	NOR	F	63	Cispus	43.5	NA
1430	Cispus	CIS	HOR	M	63	Cispus	45.1	NA
2163	Cispus	CIS	NOR	F	72	Cispus	45.1	NA
1412	Cispus	CIS	HOR	F	61	Prospect	46.5	0.0
2249	Lake Scanewa	CIS	NOR	F	72	Prospect	46.5	0.0
2442	Cispus	CIS	HOR	M	64	Prospect	46.5	0.0
1171	Lake Scanewa	CIS	NOR	M	69	Cispus	46.7	NA
1401	Cispus	CIS	NOR	F	67	Cispus	46.7	NA
2438	Cispus	CIS	NOR	F	71	Cispus	46.7	NA
2455	Cispus	CIS	NOR	M	73	Cispus	46.7	NA
1257	Cispus	CIS	HOR	F	62	Cispus	48.3	NA
1281	Lake Scanewa	CIS	NOR	M	73	Cispus	48.3	NA
1425	Cispus	CIS	NOR	M	80	Cispus	48.3	NA
2031	Cispus	CIS	HOR	M	66	Cispus	48.3	NA
2081	Cispus	CIS	NOR	F	69	Cispus	48.3	NA
2233	Cispus	CIS	NOR	M	81	Cispus	48.3	NA
2439	Lake Scanewa	CIS	NOR	M	71	Cispus	48.3	NA
2453	Cispus	CIS	HOR	M	66	Cispus	48.3	NA
1293	Cispus	COW	HOR	F	72	Lambert	147.7	0.0
1404	Lake Scanewa	COW	NOR	M	66	Kiona	161.4	1.6
1423	Lake Scanewa	CIS	NOR	F	71	Cowlitz	162.2	NA
1428	Lake Scanewa	COW	NOR	M	71	Cowlitz	162.2	NA
2069	Lake Scanewa	COW	NOR	F	82	Miller	165.4	0.0
1406	Lake Scanewa	COW	NOR	M	58	Silver	169.8	1.6
1408	Lake Scanewa	COW	NOR	M	68	Silver	169.8	1.6
1419	Lake Scanewa	COW	NOR	M	73	Silver	169.8	1.6
1267	Lake Scanewa	COW	NOR	F	70	Cowlitz	181.2	NA
1309	Lake Scanewa	COW	NOR	M	63	Cowlitz	181.2	NA
1325	Lake Scanewa	COW	NOR	F	78	Cowlitz	188.3	NA
1402	Lake Scanewa	COW	NOR	F	81	Cowlitz	188.3	NA
1429	Lake Scanewa	COW	NOR	M	72	Cowlitz	188.3	NA
2283	Lake Scanewa	COW	NOR	F	81	Cowlitz	188.3	NA
2303	Lake Scanewa	COW	NOR	M	73	Cowlitz	188.3	NA
2454	Lake Scanewa	COW	NOR	F	71	Cowlitz	188.3	NA
1405	Lake Scanewa	COW	NOR	M	77	Cowlitz	189.9	NA
2023	Lake Scanewa	COW	NOR	F	61	Cowlitz	189.9	NA
1414	Lake Scanewa	COW	NOR	F	83	Cowlitz	196.3	NA
2199	Lake Scanewa	COW	NOR	F	71	Cowlitz	196.3	NA

Tag code	Release site	Fate	Origin	Sex	Length	Spawning location		
						River	Rkm main	Rkm tributary
2251	Lake Scanewa	COW	NOR	F	74	Cowlitz	196.3	NA
1416	Lake Scanewa	COW	NOR	F	85	Smith	196.7	0.0
2460	Lake Scanewa	COW	NOR	F	66	Smith	196.7	0.0
1285	Lake Scanewa	COW	NOR	M	77	Smith	196.7	1.6
1261	Lake Scanewa	COW	NOR	M	69	Smith	196.7	1.6
1261	Lake Scanewa	COW	NOR	M	69	Johnson	197.5	1.6
1418	Lake Scanewa	COW	NOR	F	79	Johnson	197.5	1.6
1432	Lake Scanewa	COW	NOR	F	74	Johnson	197.5	1.6
2089	Lake Scanewa	COW	NOR	F	80	Johnson	197.5	1.6
1323	Lake Scanewa	COW	HOR	M	87	Johnson	197.5	3.2
1323	Lake Scanewa	COW	HOR	M	87	Skate	202.3	3.2
1201	Lake Scanewa	COW	NOR	M	90	Skate	202.3	3.2
1247	Cispus	COW	NOR	F	77	Skate	202.3	3.2
2119	Lake Scanewa	COW	NOR	F	78	Skate	202.3	3.2
2073	Lake Scanewa	COW	NOR	M	77	Skate	202.3	4.8
1131	Lake Scanewa	COW	NOR	M	70	Cowlitz	203.6	NA
1141	Lake Scanewa	COW	NOR	F	61	Cowlitz	203.6	NA
1157	Lake Scanewa	COW	NOR	M	71	Cowlitz	203.6	NA
1409	Cispus	COW	NOR	F	73	Cowlitz	203.6	NA
1431	Cispus	COW	NOR	F	70	Cowlitz	203.6	NA
2057	Lake Scanewa	COW	NOR	M	81	Cowlitz	203.6	NA
2103	Lake Scanewa	COW	NOR	M	62	Cowlitz	203.6	NA
2456	Lake Scanewa	COW	NOR	M	64	Cowlitz	207.6	NA
2448	Lake Scanewa	COW	NOR	M	69	Lake	208.1	0.0
1134	Lake Scanewa	COW	NOR	M	76	Cowlitz	209.2	NA
2145	Lake Scanewa	COW	NOR	F	74	Ohanapecosh	215.7	1.6

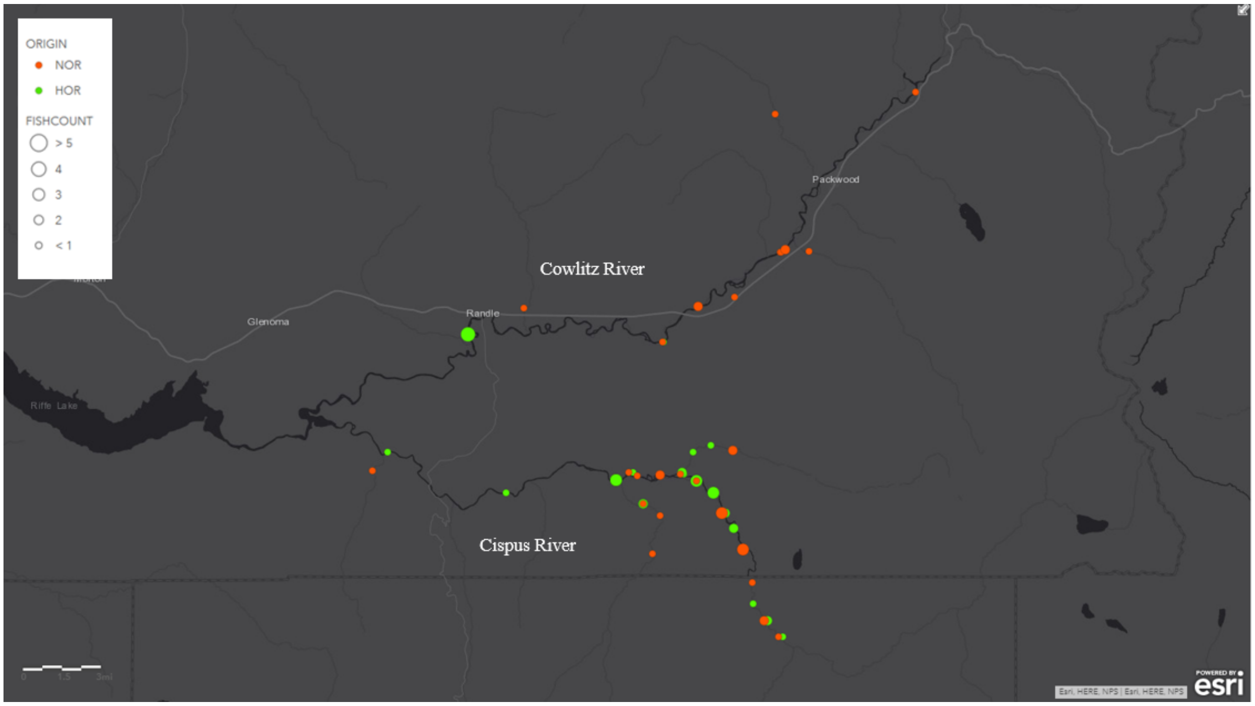

Figure 1.1. Image showing locations of adult radio-tagged steelhead spawning in the upper Cowlitz River Basin, Washington, by origin (NOR, natural origin; HOR, hatchery origin) in 2017. Map image is the intellectual property of Esri and is used herein under license. Copyright © 2020 Esri and its licensors. All rights reserved. >, greater than; <, less than.

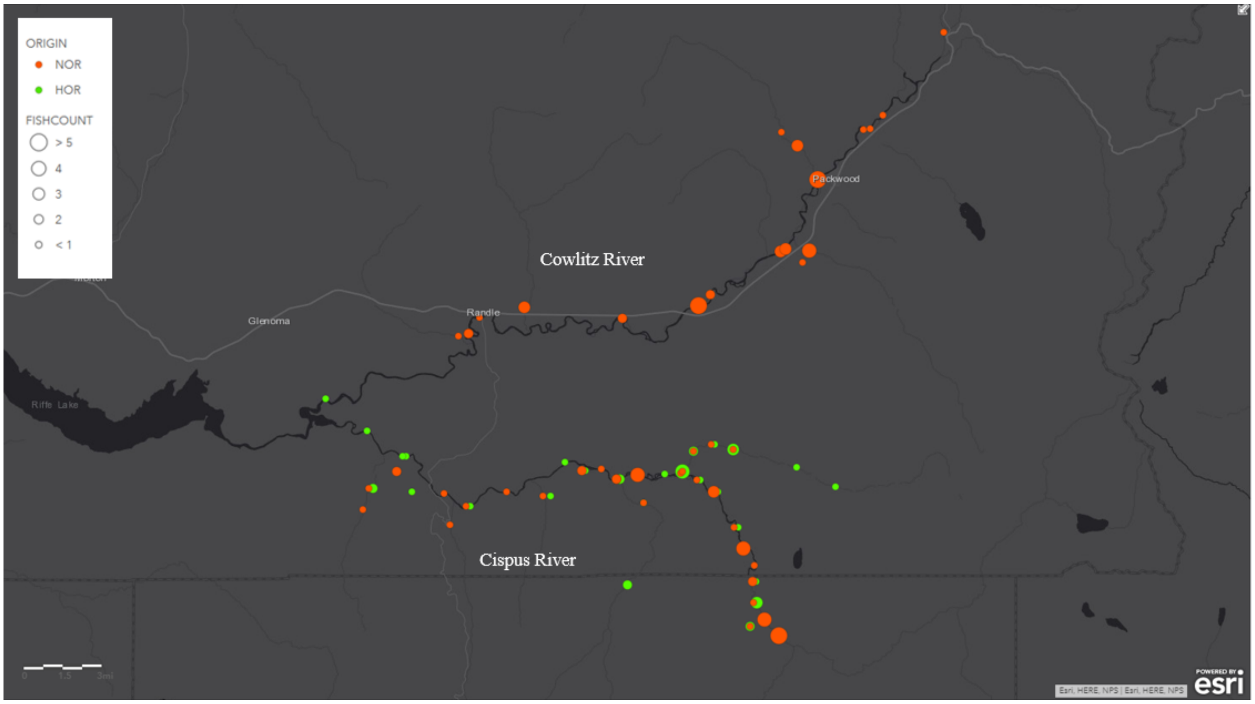

Figure 1.2. Image showing locations of adult radio-tagged steelhead spawning in the upper Cowlitz River Basin, Washington, by origin (NOR, natural origin; HOR, hatchery origin) in 2018. Map image is the intellectual property of Esri and is used herein under license. Copyright © 2020 Esri and its licensors. All rights reserved. >, greater than; <, less than.

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For more information concerning the research in this report, contact the
Director, Western Fisheries Research Center
U.S. Geological Survey
6505 NE 65th Street
Seattle, Washington 98115-5016
https://www.usgs.gov/centers/wfrc

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