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Adult Sockeye Salmon (*Oncorhynchus nerka*) Behavior and Movement from Roza Dam to Cle Elum Dam, Washington, 2018

Open-File Report 2019–1053

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

Cover: Tailrace of Cle Elum Dam, Washington. Photograph by Scott D. Evans, U.S. Geological Survey, September 12, 2017.

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Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	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.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Volume	
liter (L)	33.81402	ounce, fluid (fl. oz)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Abbreviations

Ecology	Washington State Department of Ecology
Integrated Plan	Yakima Basin Integrated Plan
RAMF	Roza Adult Monitoring Facility
Reclamation	Bureau of Reclamation
rkm	river kilometer

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Abstract

An evaluation was conducted to describe adult sockeye salmon (*Oncorhynchus nerka*) upstream movement patterns from Roza Dam to Cle Elum Dam in the Yakima Basin, Washington. Sockeye salmon adults that arrive at Roza Dam are currently trapped and transported upstream of Cle Elum Dam because upstream fish-passage facilities are not currently in place at the dam. However, these facilities are being designed, so resource managers wanted to confirm that sockeye salmon could successfully move upstream through the Roza Dam-to-Cle Elum Dam reach. A total of 20 adult sockeye salmon were collected, tagged with a radio transmitter, and released at Roza Dam during July 2018. These fish were monitored using a series of fixed monitoring sites and mobile tracking for 2 months. All tagged sockeye salmon successfully moved upstream and were detected in the tailrace of Cle Elum Dam. Median elapsed time from release at Roza Dam to first detection at Cle Elum Dam was 17 days (d) and ranged from 7 to 30 d. We examined migration delay at the Town Ditch diversion dam by comparing elapsed time of detection at that site to elapsed time of detection at other sites in the study area. We found that median elapsed time at the Town Ditch site (19.7 hours) was substantially higher than median elapsed time at other sites (1.7 hours or less). This suggests that tagged sockeye salmon were delayed at the diversion dam. However, most tagged fish (75 percent) arrived at Cle Elum Dam within 20 d of release, and all fish arrived within 30 d, which suggests that delay at the diversion dam may be of little consequence. Our results suggest that adult sockeye salmon can readily migrate upstream from Roza Dam to Cle Elum Dam.

Introduction

Sockeye salmon (*Oncorhynchus nerka*) historically were present in the Yakima Basin, Washington, but the population was eliminated in the early 1900s when several impassable dams were constructed (Bureau of Reclamation, 2007). These dams blocked access to four lakes in the Yakima Basin (Bumping, Keechelus, Kachess, and Cle Elum lakes) which provided important spawning and rearing habitat for anadromous fish. As a result, sockeye salmon had been absent from the basin for nearly a century. In 2002, as part of a settlement agreement with the Yakama Nation, the Bureau of Reclamation (Reclamation) agreed to evaluate the feasibility of constructing fish-passage structures at six reservoir dams in the Yakima Basin, eventually determining that it was feasible (Bureau of Reclamation, 2005, 2008). After the feasibility determination, Cle Elum Dam was selected to be the first site where passage facilities would be constructed. The Yakama Nation and Washington Department of Fish and Wildlife then began

planning efforts to reintroduce sockeye salmon into the Yakima Basin and in 2009, the Yakama Nation began releasing adult sockeye salmon into Cle Elum Reservoir. The initial reintroduction effort consisted of outplanting 1,000 adult sockeye salmon in Cle Elum Reservoir, where they could spawn along shorelines or move upstream into the Cle Elum River (fig. 1). Outplanted fish were collected for translocation at Priest Rapids Dam on the main-stem Columbia River and originally were destined for either the Wenatchee or Okanogan Rivers (Galbreath and others, 2016; Matala and others, 2016). Monitoring efforts indicated that outplanted adults could successfully spawn upstream of Cle Elum Dam and produce progeny that eventually migrated to the ocean (Brian Saluskin, Yakama Nation, oral commun., 2017). Based on this success, annual outplanting efforts have continued since 2009, and in some years as many as 10,000 adult sockeye salmon collected at Priest Rapids Dam have been released into the reservoir. Releases now include fish from three origins: (1) Wenatchee River and (2) Okanogan River sockeye salmon (both collected at Priest Rapids Dam; and (3) Yakima River sockeye salmon (collected at Roza Dam; fig. 1). The latter fish (3) are the progeny of sockeye salmon (1 and 2) that spawned naturally, after outplanting, in the Cle Elum River system.

In 2012, the Yakima Basin Integrated Plan (Integrated Plan) was completed by the Yakima River Basin Water Enhancement Project Workgroup (composed of representatives of the Yakama Nation; Federal, State, county, and city governments; environmental organizations; and irrigation districts). The Integrated Plan identifies a comprehensive approach to Yakima Basin water resource and ecosystem restoration improvements to be implemented over 30 years (Bureau of Reclamation and Washington State Department of Ecology, 2012). The Integrated Plan includes seven elements:

1. Reservoir fish passage (upstream and downstream),
2. Structural and operational changes to existing facilities at dams,
3. Surface water storage,
4. Groundwater storage,
5. Habitat/watershed protection and enhancement,
6. Enhanced water conservation, and
7. Market reallocation.

In 2015, Reclamation and the Washington State Department of Ecology (Ecology) began working on fish passage at Cle Elum Dam, as the first Integrated Plan fish-passage project. Construction is currently underway on a facility to provide downstream fish passage, and planning efforts are being conducted for a second facility that will collect upstream migrants for transport around the dam. Once these facilities are completed, juvenile and adult sockeye salmon will be able to volitionally pass Cle Elum Dam. Adult sockeye salmon of Yakima River origin are currently collected at Roza Dam and transported upstream for release in Cle Elum Reservoir.

The combined efforts to reintroduce sockeye salmon and develop fish passage in the Cle Elum River system are aimed at addressing the long-term vision to establish self-sustaining populations of anadromous fish upstream of Cle Elum Dam. In 2017, results from four radio-tagged sockeye salmon suggested the potential for issues related to upstream fish movement from Roza Dam to Cle Elum Dam. Four sockeye salmon that returned to Roza Dam in July 2017 were radio-tagged and released into the forebay of the dam as part of a larger telemetry study being conducted at Cle Elum Dam (Kock and others, 2018). One of these tagged fish moved upstream and arrived at Cle Elum Dam 16 days (d) after release. The remaining three fish moved upstream initially, but stopped moving 2.2 river kilometers (rkm), 22.2 rkm, and 28.7 rkm upstream of Roza Dam. These fish never resumed migration beyond these locations, and their

fate remained unclear. Based on those limited results, the potential for successful migration from Roza Dam to Cle Elum Dam appeared to be unclear. A follow-on study was developed for 2018 to further assess movement and behavior patterns in the Roza Dam-to-Cle Elum Dam reach. This report describes that study and summarizes observations and results from the evaluation.

Methods

Fish Tagging and Release

Twenty sockeye salmon were collected, tagged, and released at the Roza Adult Monitoring Facility (RAMF), adjacent to Roza Dam on the Yakima River. All tagging occurred on July 6, July 9, and July 10, 2018. After fish ascended the adult fish ladder and entered the holding vault, they were crowded into a tank where they were anesthetized. The anesthetic bath was created by mixing 416 L of fresh river water with buffered tricaine methanesulfonate (MS-222) at a concentration of 30–40 parts per million. Individual fish were removed from the anesthetic bath and the following data were collected in the following manner:

1. Sex was determined via ultrasound,
2. A fork length measurement was taken (in centimeters),
3. Fish were scanned for the presence of a passive integrated transponder or coded-wire tag, and
4. A DNA sample was taken (small clip from the caudal fin).

Some fish were then tagged with a passive integrated transponder (9 of 20 fish) and all fish were tagged with a radio transmitter (model Pisces; Sigma Eight, Inc., Newmarket, Ontario). The radio transmitter was implanted gastrically using procedures described in Keefer and others (2004). Tagged fish were then transferred to a recovery container filled with fresh river water until they regained equilibrium. Once this occurred, tagged fish were released into the forebay of Roza Dam through a pipe that passed from the RAMF to the forebay.

Fish Monitoring Array

A total of six fixed monitoring sites were established to detect tagged fish moving within the study area. All monitoring sites contained radiotelemetry equipment and were downstream of Cle Elum Dam (fig. 1). Two sites were located on Roza Dam—one site monitored the tailrace of the dam (Yakima rkm 205.7; Roza Tailrace site) and the other site monitored the forebay (Yakima rkm 205.8; Roza Forebay site). The remaining sites were located at Yakima rkm 221.8 (Red's Fly Shop site), at Yakima rkm 259.6 near Thorp, Washington (Town Ditch site), at the Cle Elum Salmon Hatchery (Yakima rkm 297.2; Salmon Hatchery site), and in the tailrace of Cle Elum Dam (Cle Elum rkm 12.7; Cle Elum site). These sites were operated continuously from July 3 to August 20, 2018.

Mobile tracking occurred weekly to collect additional information on the locations of tagged fish in the study area. An automobile was used to slowly drive along the river between Roza and Cle Elum dams while monitoring for the presence of tagged fish. When a tagged fish was encountered the date, time, and GPS location of the detection was recorded. This was conducted one time per week during the period that tagged fish were monitored in the study area.

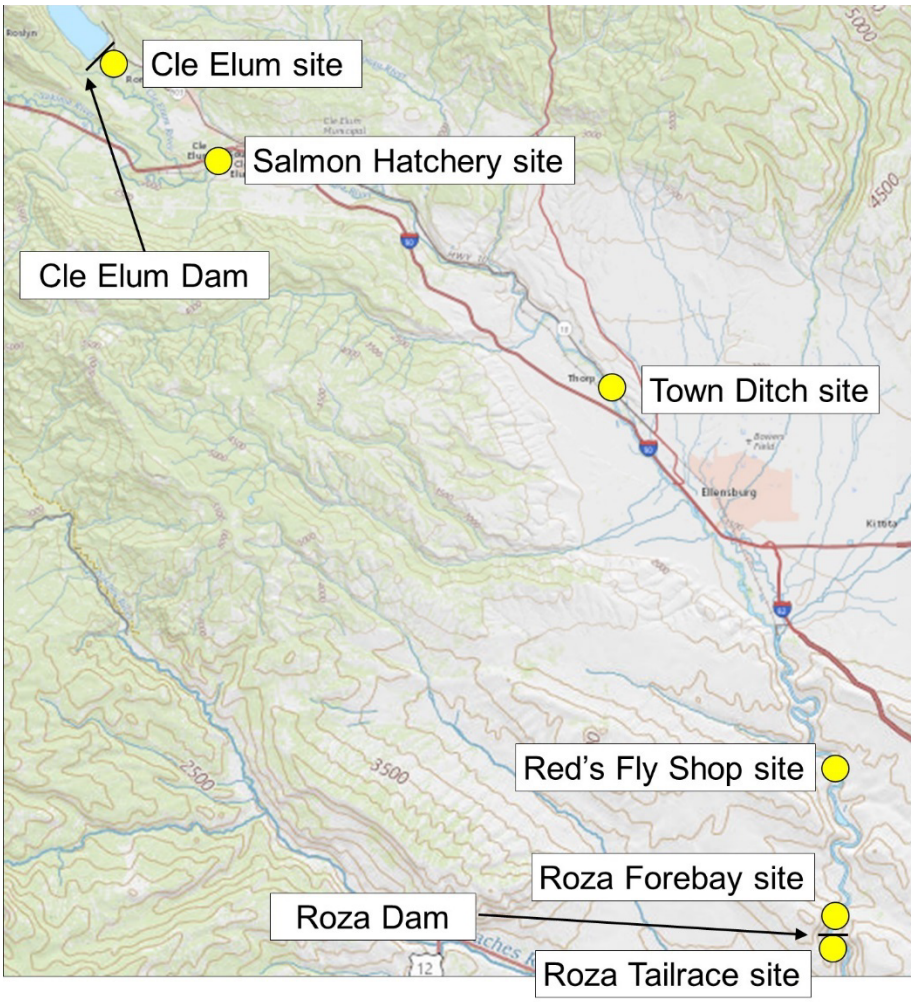

Figure 1. Schematic showing the locations of fixed radio telemetry monitoring sites (yellow circles) used to detect tagged fish in the reach between Roza Dam and Cle Elum Dam, Washington.

Data Analysis

Detection records from fixed monitoring sites were merged with tagging and release records to create a preliminary dataset. The preliminary dataset was then integrated with all mobile tracking records to create a draft dataset that was proofed using an automated program to remove non-valid detection records. Records were determined to be non-valid if:

1. They occurred prior to release,
2. The signal strength was less than the 90th percentile of the signal strength of detections of tag identification codes that were not released during the study (noise),
3. There were less than three consecutive detections at a given monitoring station (consecutive detections had to be 60 s or less apart), and
4. It was impossible for the detection to occur geographically (for example, detections at separate locations with timestamps that would have exceeded the swimming capability of the fish).

These criteria were used in the automated program to remove non-valid detection records from the dataset containing actual detections of study fish. The auto-proofed dataset was then manually reviewed to confirm that the autoproofing process was successful and to verify that the dataset could be considered final for analysis. This final dataset was used for all data queries and analyses presented in this report.

Fish Behavior

We examined the final dataset to describe the behavior of tagged fish that were released into the Roza Dam forebay. The percent of tagged fish that moved upstream and arrived at Cle Elum Dam was calculated by dividing the number of fish detected in the tailrace of Cle Elum Dam by the number of tagged fish released at Roza Dam. Reach-specific travel times were calculated by subtracting the first detection at an upstream monitoring site from the last detection at a downstream monitoring site. Travel rates were calculated by dividing the travel time in a reach by the length of the reach.

We queried detection records to determine if there was evidence that the Town Ditch diversion dam delayed upstream movement of tagged sockeye salmon. To do this, we first calculated residence times of tagged fish at the Roza Forebay, Red's Fly Shop, Town Ditch and Salmon Hatchery sites. Residence times were determined by subtracting the time of last detection at each site from the time of first detection at that same site. Next, we compared travel times and travel rates within each reach and compared those to travel times and travel rates in the reach between Red's Fly Shop and the Salmon Hatchery site (the Town Ditch diversion dam is located within this reach). If delays occurred at the diversion dam, we would expect to see extended residence times at the monitoring site located there, along with slower travel rates in the reach between Red's Fly Shop and the Salmon Hatchery site.

Results

Fish Tagging and Release

Twenty adult sockeye salmon were tagged and released during the study. Two fish were tagged and released on July 6, and nine fish were tagged and released each day on July 9 and July 10 (table 1). Most tagged fish (14) were female. Mean fork length of the tagged population was 49.9 cm.

Table 1. Tagging date, number of fish tagged, sex and mean fork length of adult sockeye salmon that were collected, tagged, and released at Roza Dam, Washington, 2018.
[Fork length range is presented in parentheses. cm, centimeter]

Tagging date	Number of fish	Sex	Mean fork length (cm)
July 6	2	F	50.5 (50–51)
July 9	4	F	49.3 (48–50)
July 9	5	M	49.2 (47–54)
July 10	8	F	50.6 (48–52)
July 10	1	M	49.0
Total July 6–10	14	F	50.2 (48–52)
	6	M	49.2 (47–54)

Fish Behavior

All tagged sockeye salmon moved upstream from Roza Dam and arrived in the tailrace of Cle Elum Dam. Median travel time from Roza Dam to Cle Elum Dam was 17 d, ranging from 7 to 30 d (fig. 2). Reach-specific travel times and travel rates are presented in table 2. Median residence times at Roza Forebay, Red's Fly Shop, and Salmon Hatchery sites were 1.7 hours or less, substantially lower than at the Town Ditch site (19.7 hours; fig. 3). Travel rates from Red's Fly Shop site to the Cle Elum Salmon Hatchery site were the slowest of all reaches in the study area (table 2).

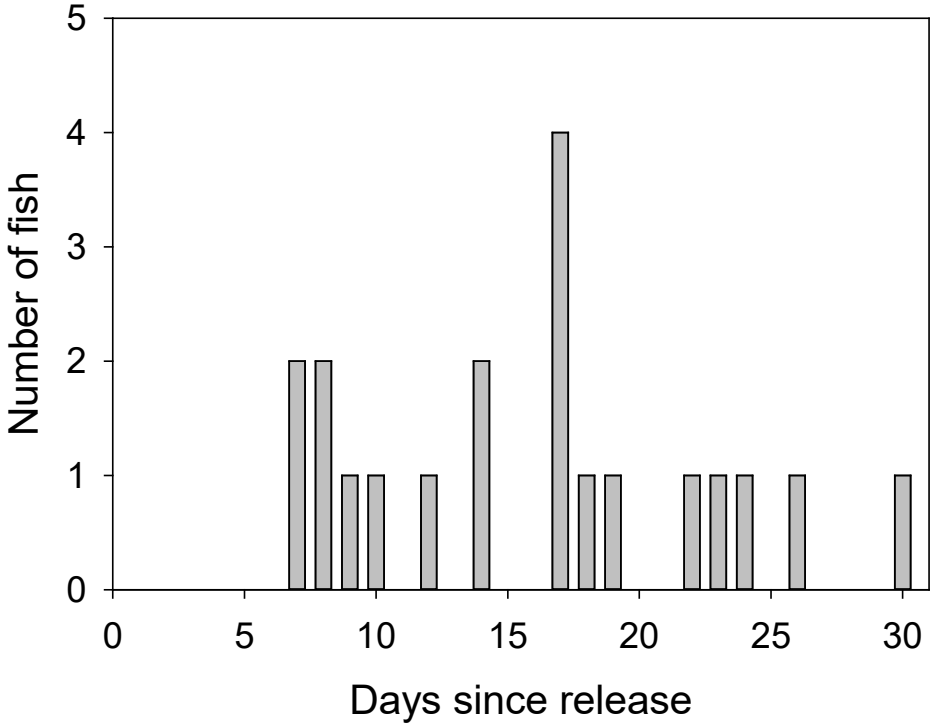

Figure 2. Graph showing frequency of travel times (in days) for tagged sockeye salmon from release at Roza Dam to arrival at Cle Elum, Washington, 2018.

Table 2. Median travel time and travel rate of tagged sockeye salmon in five reaches between Roza Dam and Cle Elum Dam, Washington, 2018.

[Ranges of travel times and travel rates are presented in parentheses. d, day; km/d, kilometer per day]

Reach	Travel time (d)	Travel rate (km/d)
Roza Dam forebay to Red's Fly Shop	1.1 (0.5–2.6)	14.4 (6.1–32.9)
Red's Fly Shop to Town Ditch diversion dam	3.9 (2.1–5.9)	9.6 (6.4–18.3)
Town Ditch diversion dam to Cle Elum Salmon Hatchery	5.4 (2.7–11.1)	7.0 (3.4–14.0)
Cle Elum Salmon Hatchery to Cle Elum Dam tailrace	2.2 (1.3–7.0)	6.6 (2.0–10.6)
Red's Fly Shop to Cle Elum Salmon Hatchery	12.6 (5.1–25.1)	6.0 (3.0–14.8)

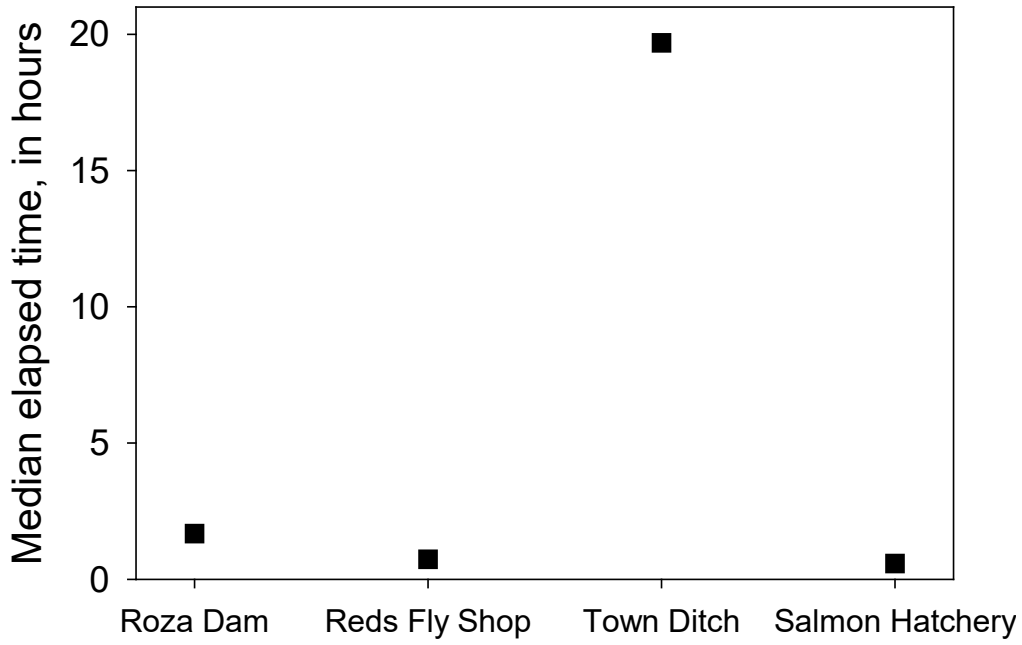

Figure 3. Graph showing median elapsed time (in hours) for individual tagged sockeye salmon at fixed monitoring sites between Roza Dam and Cle Elum Dam, Washington, 2018.

Discussion

All radio-tagged sockeye salmon in the study successfully moved upstream from the forebay of Roza Dam to the tailrace of Cle Elum Dam. Tagged fish moved through this reach in 30 d or less. These results show that Yakima River sockeye salmon have a high probability of successfully moving from Roza Dam to Cle Elum Dam, if necessary, in the future. We found that travel rates were highest in the downstream-most reach where fish were released and decreased successively as tagged fish moved upstream through the remaining reaches.

The Town Ditch diversion dam appeared to affect upstream fish movement as tagged fish spent substantially more time at this site than at other sites in the study area. The diversion dam spans the entire Yakima River, so fish must locate the ladder entrance, located on the right bank, to pass the dam. This had the potential to delay fish, which is why we were interested in examining movement rates at the site. We found that travel rates from Red's Fly Shop to the Cle Elum Salmon Hatchery were lowest of any reach in the study, which is important because the Town Ditch site was located within this reach. However, 15 of 20 tagged fish arrived at Cle Elum Dam within 20 d of release at Roza Dam, and all fish arrived at Cle Elum Dam within 30 d of release. Thus, delay at the Town Ditch diversion dam may be of little consequence.

Monitoring of tagged sockeye salmon was terminated shortly after all tagged fish arrived in the Cle Elum Dam tailrace, so we don't know where these fish were located during the spawning period. In 2017, we found that 20 percent of the tagged sockeye salmon that were released upstream of Cle Elum Dam eventually moved downstream and passed the dam prior to the start of spawning (Kock and others, 2018). Information on the spatial distribution of sockeye salmon downstream of Cle Elum Dam may be useful in the future to determine which regions of the watershed are important for sockeye salmon that do not remain upstream of Cle Elum Dam.

Acknowledgments

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