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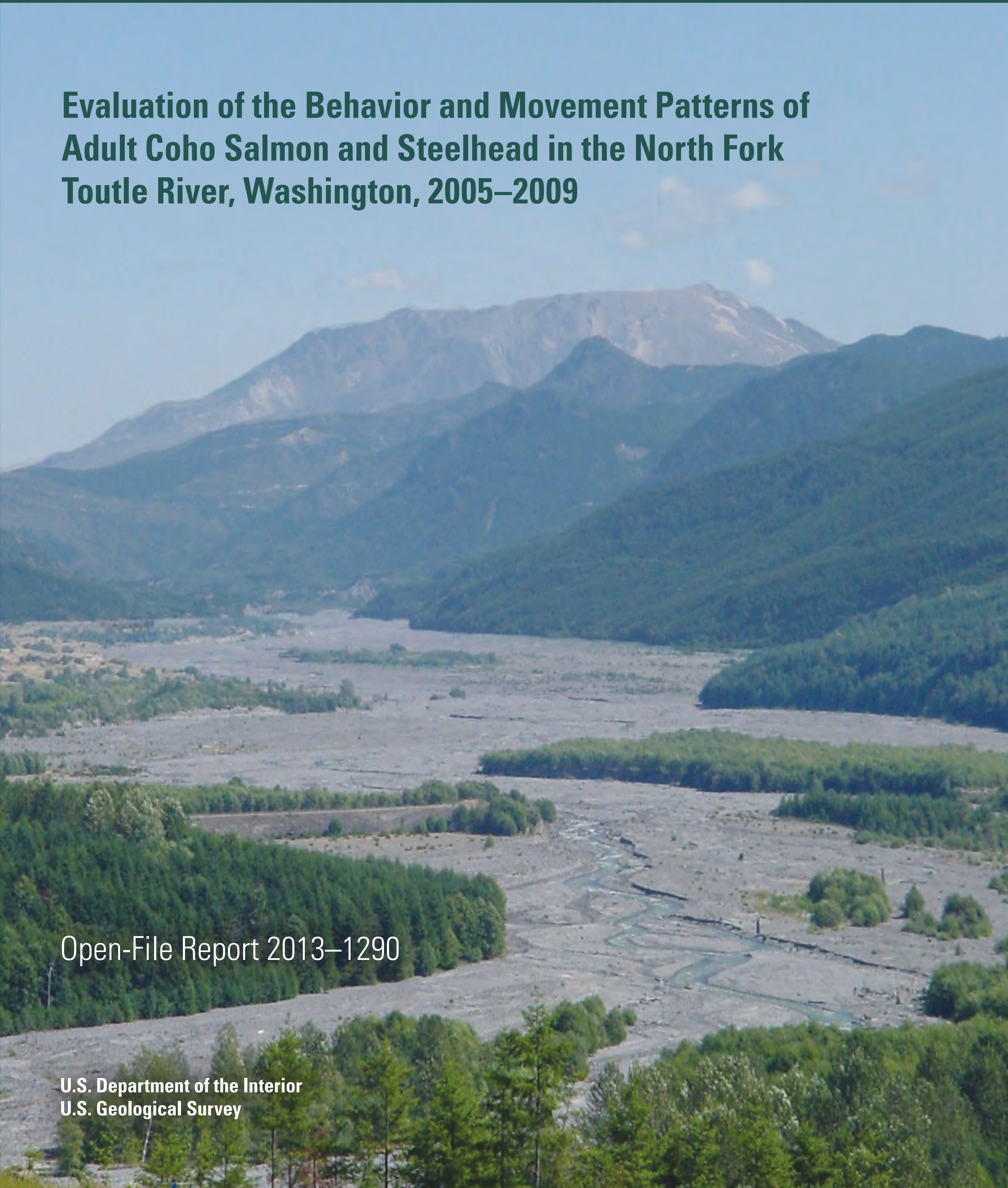
Evaluation of the Behavior and Movement Patterns of Adult Coho Salmon and Steelhead in the North Fork Toutle River, Washington, 2005–2009



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Cover: The North Fork Toutle River Valley looking toward the Mount St Helens National Volcanic Monument.

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By Theresa L. Liedtke, Tobias J. Kock, and Dennis W. Rondorf

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Conversion Factors

SI to Inch/Pound

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)
liter (L)	0.2642	gallon (gal)
gram (g)	0.03527	ounce, avoirdupois (oz)

Evaluation of the Behavior and Movement Patterns of Adult Coho Salmon and Steelhead in the North Fork Toutle River, Washington, 2005–2009

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Executive Summary

The 1980 eruption of Mount St. Helens severely affected the North Fork Toutle River (hereafter Toutle River), Washington, and threatened anadromous salmon (*Oncorhynchus* spp.) populations in the basin. The Toutle River was further affected in 1989 when a sediment retention structure (SRS) was constructed to trap sediments in the upper basin. The SRS completely blocked upstream volitional passage, so a fish collection facility (FCF) was constructed to trap adult coho salmon (*O. kisutch*) and steelhead (*O. mykiss*) so they could be transported upstream of the SRS. The Washington Department of Fish and Wildlife (WDFW) has operated a trap-and-haul program since 1989 to transport coho salmon and steelhead into tributaries of the Toutle River, upstream of the SRS. Although this program has allowed wild coho salmon and steelhead populations to persist in the Toutle River basin, the trap-and-haul program has faced many challenges that may be limiting the effectiveness of the program. We conducted a multi-year evaluation during 2005–2009 to monitor tagged fish in the upper Toutle River to provide information on the movements and behavior of adult coho salmon and steelhead, and to evaluate the efficacy of the FCF. Radio-tagged coho salmon and steelhead were released: (1) in Toutle River tributaries to evaluate the behavior and movements of fish released as part of the trap-and-haul program; (2) between the FCF and SRS to determine if volitional upstream passage through the SRS spillway was possible; (3) in the sediment plain upstream of the SRS to determine if volitional passage through the sediment plain was possible; and (4) downstream of the FCF to evaluate the efficacy of the structure. We also deployed an acoustic camera in the FCF to monitor fish movements near the entrance to the FCF, and in the fish holding vault where coho salmon and steelhead are trapped.

A total of 20 radio-tagged coho salmon and 10 radio-tagged steelhead were released into Alder and Hoffstadt Creeks, the locations where trap-and-haul fish were released during 2005–2006. None of the tagged fish left the tributaries where they were released, but four radio tags were detected near the release sites, and it was not possible to determine if this was because the transmitters were regurgitated, or if some of the tagged fish had died. The results from this portion of the study indicated that trap-and-haul fish remain in the tributaries where they can spawn, but the trap-and-haul process is labor-intensive, and handling stress and mortality could occur.

Tagged-fish releases upstream of the FCF showed that the SRS spillway was a complete migration barrier for all coho salmon and most steelhead. We released a total of 20 radio-tagged coho salmon and 23 radio-tagged steelhead during 2005–2007. No tagged coho salmon passed upstream through the SRS spillway, whereas 13 percent of the radio-tagged steelhead did migrate upstream through the structure. Radio-tagged coho salmon and steelhead that did not pass upstream remained in the FCF–SRS reach for an average of 7.5 and 16.1 d, respectively, before moving downstream. These data show that trap-and-haul releases of fish immediately upstream of the FCF would not be beneficial to coho salmon and steelhead populations in the system.

Releasing tagged fish into the sediment plain was only moderately successful for coho salmon, but a large percentage of tagged steelhead moved upstream through the sediment plain to areas where spawning could presumably occur. During 2005–2009, we released 47 tagged coho salmon and 65 tagged steelhead into the sediment plain. Only 28 percent of the coho salmon were later detected upstream of the sediment plain, and the highest percentage of the release group (62 percent) never left the sediment plain. However, 69 percent of the steelhead moved upstream through the sediment plain and entered Toutle River tributaries or remained in the mainstem Toutle River where spawning could presumably occur. Adult steelhead can survive freshwater spawning, outmigrate to the ocean, and then return to spawn in successive years; 12 percent of the tagged steelhead successfully moved downstream of the FCF after the spawning period, and 5 percent of the tagged steelhead returned to the FCF a year after they were originally tagged.

Evaluations at the FCF showed that the structure was not efficient at collecting adult salmon. During 2008–2009, 9 radio-tagged coho salmon and 11 radio-tagged steelhead were released to observe behavior near the facility and to estimate the recapture rate in the FCF. None of the tagged coho salmon were recaptured and only 27 percent of the tagged steelhead were recaptured. Additionally, we observed fish behavior at the FCF with an acoustic camera and found that relatively large numbers (>100 fish/sampling period) of adult salmon entered the FCF but similar numbers of fish exited during these periods as well. This suggested that the efficacy of the FCF was low.

Our study was limited by the number of fish that could be handled each year and the number of transmitters that could be purchased annually, but our evaluations provided the first empirical data on adult salmon behavior and movement patterns in the Toutle River since the 1980 eruption of Mount St. Helens. Since the completion of this work, the U.S. Army Corps of Engineers has altered the SRS spillway and sediment plain; however, our results do provide information to assist fishery managers tasked with the complex management of wild salmon populations in the Toutle River. Future evaluations of juvenile and adult salmon behavior and movement likely will be required to effectively manage these populations in this complex system.

Introduction

Anadromous salmonids (*Oncorhynchus* spp.) in the North Fork Toutle River (hereafter Toutle River), Washington, have faced many challenges since the 1980 eruption of Mount St. Helens. The aquatic and riparian environment of the Toutle River was severely affected by the eruption. The upper 25 km of the drainage basin were buried in a layer of mud, ash, and debris that was estimated to be 45 m deep (Voight and others, 1981; Glicken, 1998). This blocked access to some tributary streams, increased suspended sediments to levels that were shown to be lethal for fish, and completely eliminated riparian cover in most areas affected by the eruption (Stober and others, 1981; Bisson and others, 2005). However, anadromous salmonid (hereafter salmon) populations persisted due to returns of ocean-rearing individuals that were not affected by the eruption, straying from nearby populations, and reintroduction efforts by the Washington Department of Fish and Wildlife (WDFW; Martin and others, 1984; Lucas, 1985; Leider, 1989; Bisson and others, 2005).

Given the massive sediment load in the upper Toutle River, it became clear that long-term sediment transport would be problematic to downstream areas, so the U.S. Army Corps of Engineers (USACE) constructed a sediment retention structure (SRS) in 1989 that completely blocked upstream fish passage (fig. 1). The SRS has been very effective at trapping sediments and has created a broad sediment plain that extends approximately 6 km upstream of the structure. Water flow across the sediment plain consists of shallow sheet flows (typically <0.3 m) that are interspersed with temporary channels during most months of the year. As a result of the sediments that accumulated immediately upstream of the structure, all river flow was diverted around the northern edge of the SRS in 1998 through a 671m long, rough-bed channel (hereafter SRS spillway). The SRS spillway is currently the only passage option for downstream migrating fish. Because the SRS blocked upstream fish passage, the USACE also constructed a fish collection facility (FCF; fig. 1), 3 rkm downstream of the SRS. The FCF provided the ability to trap adult salmon returning to the Toutle River, and WDFW has been using the FCF to conduct a trap-and-haul operation since 1989. Captured fish are transported upstream of the SRS and released into a limited number of tributaries that have adequate access. This trap-and-haul program has allowed salmon to persist in the Toutle River, upstream of the SRS, but these efforts have faced various challenges.

The effectiveness of the Toutle River trap-and-haul program has not been optimal because of operational challenges of the FCF and limited availability of staffing. Although the FCF was designed and constructed as a state-of-the-art fish handling facility, many of the original fish handling features became inoperable through time because of the high sediment load of the Toutle River (AMEC Earth & Environmental Inc., 2010). As a result, collecting and moving salmon at the FCF is labor-intensive. Automated fish handling devices no longer work, so fish must be manually netted and loaded into trucks. Once fish have been removed from the FCF and transported upstream, a substantial amount of accumulated sediments have to be removed from the trap so that it will operate effectively during the next collection period. Additionally, staffing at the FCF is limited, so the program is conducted primarily by volunteers and a single WDFW technician. As a result of these challenges, the Toutle River trap-and-haul program was operating at a minimum level by the mid-2000s. The FCF was allowed to collect fish from Wednesday to Friday each week during September–November (targeting coho salmon), and March–May (targeting winter steelhead), and fish were removed from the trap and transported upstream each week on Fridays. This schedule was successful in collecting and transporting adult salmon, and an average of 282 adult steelhead and 284 adult coho salmon were trapped and transported each year during 2000–2005. However, given the partial operating schedule and limited operating capabilities of the FCF, it is likely that only a portion of the returning adult salmon were collected and transported each year.

In 2005, the U.S. Geological Survey partnered with the Cowlitz Indian Tribe and Steward and Associates (a consulting firm) to conduct a series of research evaluations in the Toutle River to determine movement patterns of adult salmon, evaluate the effectiveness of the trap-and-haul program, and collect data that could be used to determine if other options existed for increasing adult salmon returns to the upper Toutle River. During 2000–2005, the trap-and-haul program was releasing adult salmon into Alder and Hoffstadt Creeks (fig. 1), so we were interested in determining the fate of these fish and understanding their movement patterns following release. By releasing fish directly into these streams, the trap-and-haul program was reducing the exposure of adult salmon to the mainstem Toutle River, which was still recovering from the 1980 eruption of Mount St. Helens. However, adult salmon were not necessarily returned to their natal stream, so it was possible that fish were leaving a specific stream following release in search of their natal stream for spawning. We also were interested in evaluating whether adult salmon could move upstream through the SRS spillway and through the sediment plain. If this was possible, adult salmon could be released upstream of the FCF or SRS, which would reduce much of the transportation effort of the trap-and-haul program. These release strategies also would allow adult salmon to self-select a spawning stream. Finally, we were interested in evaluating fish behavior near the FCF to determine the efficacy of the FCF, and to better understand the relative success of the trap-and-haul program. Various evaluations were conducted during 2005–2009 to address the following objectives: (1) determine the fate of adult salmon transported from the FCF and released into Alder and Hoffstadt Creeks; (2) determine if adult salmon could ascend the SRS spillway; (3) determine if adult salmon could move upstream through the sediment plain; and (4) determine the efficacy of the FCF.

Methods

We used radiotelemetry and acoustic camera techniques to assess fish movements in the Toutle River. We used radiotelemetry to determine fish movements in the Toutle River, in tributary streams, through the SRS spillway, and in the FCF. We used the acoustic camera in and around the FCF to determine the efficacy of the structure. All fish that were radio-tagged were obtained from the FCF trap during days when the trap-and-haul crew were processing fish. Given the relatively small annual run sizes encountered at the FCF, we were only able to tag a small number of fish each season to minimize impacts to the population. Fish tagging and monitoring occurred during seven field seasons from September 2005 to May 2009, with radiotelemetry and acoustic camera activities addressing the four study objectives (table 1). Coho salmon were tagged and monitored during the autumn periods and steelhead were tagged and monitored during the spring periods.

Tagging

All study fish were subjected to normal handling procedures by trap-and-haul staff and were then gastrically fitted with a radio transmitter. We selected gastric tagging to minimize handling and stress to the fish immediately prior to a migration and spawning period (Liedtke and Wargo-Rub, 2012). During each tagging day, an anesthetic bath was prepared by bubbling carbon dioxide gas (30 L/min) into 378 L of river water for 4 min. Fish were hand netted from the trap and placed into the anesthetic bath. Fish were then monitored until equilibrium was lost, and removed from the bath. Gender was visually determined, length measurements and scale samples were collected, and each fish was fitted with a Floy® tag (Floy Tag, Inc., Seattle, Washington) on the dorsal portion of the fish. We used 7-V radio transmitters from Lotek Wireless, Inc. (Newmarket, Ontario) that measured 8.25 cm in length, 1.27 cm in diameter, weighed 13 g in air, and had a rated operating life of 296 d. Transmitters emitted a signal every 5 s and operated on 1 of 4 radio frequencies with unique codes, allowing individual fish identification. A single band of silicon surgical tubing (about 5 mm wide; 3 mm thick; 12 mm inside-diameter) was placed around the transmitter (near the top) to increase roughness and reduce the likelihood of transmitter regurgitation. Transmitters were implanted according to the methods of Keefer and others (2004). The antenna was bent where it exited from the mouth so that it trailed alongside the fish externally. After tagging, fish were placed in either a 111 L (FCF and SRS release groups) or 1,514 L (tributary release group) oxygenated transport tank, where they were held until release (within 2 h).

Tributary Releases

Radio-tagged coho salmon and steelhead were released into Alder and Hoffstadt Creeks during autumn 2005 and spring 2006, respectively, to determine the movement patterns and fate of fish in the trap-and-haul program. Tagged fish were transported by truck along with non-tagged fish as part of the normal trap-and-haul process during the two monitoring periods. A total of 20 radio-tagged coho salmon and 10 radio-tagged steelhead were released into Alder and Hoffstadt Creeks during the study period, and release numbers were evenly split between the two streams for both species (table 2). Following tagging and loading onto the truck at the FCF, fish were transported to the release site, which took approximately 1 h. The transportation tank received a continuous supply of oxygen during the transportation period. Upon arriving at the release site, trap-and-haul staff manually netted individual fish from the transportation tank and placed them into a release pipe (fig. 2), through which each fish passed prior to entering the stream. At each release site, the stream is located downstream of the road and the banks are steep, so the release pipe provided the ability to safely release fish without climbing up and down the steep banks. Each release pipe was comprised of multiple sections of plastic pipe (3.0-m long, 0.3-m diameter) that were linked together to form a conduit that spanned the distance between the road and the stream (fig. 2). At Alder Creek, the release pipe was approximately 15.2-m long, and at Hoffstadt Creek the release pipe was approximately 12.2-m long. Fish were individually released through the release pipe until all fish had been released. Daily tributary release numbers of both tagged and untagged fish typically were low (5–10 fish/d).

Sediment Retention Structure Spillway Releases

Tagged coho salmon and steelhead were released upstream of the FCF during autumn 2005, spring 2006, autumn 2006, and spring 2007, to determine if adult salmon could pass upstream through the SRS spillway (table 3). On each release date, tagged coho salmon or steelhead were transported (one or two fish at a time) in an insulated 111 L container to a site located approximately 200 m upstream of the FCF where they were released. A total of 20 coho salmon and 23 steelhead were tagged and released upstream of the FCF during the study period (table 3).

Sediment Plain Releases

Radio-tagged coho salmon and steelhead were released upstream of the SRS to determine if adult salmon could move upstream through the sediment plain (tables 4 and 5). On each release date, tagged coho salmon or steelhead were transported (one or two fish at a time) in an insulated 111 L container to a site located approximately 150 m upstream of the SRS, where they were released. A total of 47 coho salmon and 64 steelhead were tagged and released into the sediment plain during the study period (tables 4 and 5).

FCF Releases

Radio-tagged steelhead and coho salmon were released downstream of the FCF to determine the efficacy of the structure and to better understand fish behavior around the trap. Tagged coho salmon were transported (one or two fish at a time) in an insulated 111 L container to a site located approximately 6 rkm downstream of the FCF where they were released. Transportation methods were similar for steelhead, except that fish were released immediately downstream of the FCF because of concerns that fish released farther downstream would be more likely to leave the system, and thus not be re-collected for transportation upstream. A total of 9 coho salmon and 11 steelhead were tagged and released downstream of the FCF during the study (table 6).

Steelhead Outmigration and Respawning

Adult steelhead can survive freshwater spawning and outmigrate to the ocean, then return to spawn in subsequent years (hereafter repeat spawn), so we analyzed the data to determine the number of fish that were detected leaving the Toutle River after the spawning period. We examined detection records from tagged steelhead that were released in the sediment plain or that passed upstream through the SRS spillway, because these fish had the opportunity to locate potential spawning areas and still be detected moving downstream following the spawning period. Fish that were only detected downstream of the SRS spillway were not included in the analysis for several reasons: (1) it is unlikely that these fish spawned within the study area because of the lack of suitable spawning habitat between the SRS spillway and the Lower Toutle site; (2) it would be difficult to determine if downstream movements by these fish were made while returning to the ocean, or while searching for areas to spawn. However, fish that were in the sediment plain could be observed moving upstream to areas where spawning habitat was located, spending a period of time when spawning could occur (>7 d for our analysis), and then moving downstream toward the ocean. To qualify as an outmigration movement, tagged steelhead detections (moving downstream in our study area) had to be preceded by a series of valid detections including: (1) detection at one of the tributary or mainstem Toutle River monitoring sites located upstream of the sediment plain (fig. 1); and (2) at least 7-d residence time in an area located upstream of the sediment plain during April and May (spawning period).

Monitoring Array and Mobile Tracking

We used a combination of fixed radiotelemetry monitoring sites and mobile tracking to monitor radio-tagged fish during the study. A total of nine fixed sites were deployed within the study area to monitor for tagged fish throughout the entire study period. The mainstem Toutle River was monitored by six fixed sites, and the tributaries to the Toutle River were monitored by three fixed sites (fig. 1). Mainstem fixed sites were located 4.8 rkm downstream of the FCF (Lower Toutle site), at the FCF (FCF site), 400 m downstream of the SRS spillway (Lower SRS site), 400 m upstream of the SRS spillway (Upper SRS site), 4.5 rkm upstream of the SRS (Middle Toutle site), and 11 rkm upstream of the SRS (Upper Toutle site). Additionally, we deployed three fixed sites that monitored Alder, Hoffstadt, and Bear Creeks, respectively (fig. 1). During 2008–2009, we added two additional fixed sites to this array to collect data to describe fish behavior near the FCF. The first fixed site was just downstream of the FCF, at the confluence of the Green and Toutle Rivers (fig. 1). The second fixed site was in the FCF fish ladder. Five underwater antennas were used at this site to monitor fine-scale movements of tagged fish within the FCF and helped to describe the timing of FCF entry and exit events along with residence time within the structure (fig. 3).

Mobile tracking was conducted to supplement detection data collected by fixed sites. Project personnel typically were on-site one time per week during the tagging and monitoring periods, and they conducted mobile tracking when possible. When tagged fish were detected by mobile trackers, they recorded the transmitter identification number, the date of detection, and the detection location. These data were merged with data from the fixed sites for analysis.

Acoustic Camera Sampling

An acoustic camera (Sound Metrics Corp., Lake Forest Park, Washington) was used at the FCF during 2008–2009 to describe the behavior of adult salmon in and around the FCF. The acoustic camera is an underwater imaging device that uses acoustic beams to create near-video-quality images. The camera does not require light for imaging, so it has become a popular and effective tool for observing and quantifying fish during all hours of the day (Tiffan and others, 2004, 2005). The acoustic camera was deployed at six locations (fig. 4; table 7). At each location, the acoustic camera was deployed and the image was observed for a short time (<1 h) to determine if the image quality was reasonable, based on the turbulence and turbidity at each site. The acoustic camera provided acceptable imaging at three of the locations—the FCF entrance (location C; fig. 4) and two locations that monitored the entrance to the fish holding vault (locations E and F; fig. 4). These locations allowed us to observe fish entering and exiting the FCF, and the fish holding vault. Based on these findings, the acoustic camera was deployed at these locations for 21 d for periods ranging from 6 to 24 h. Video records from these locations were then reviewed and the number of fish that entered and exited the FCF and the fish holding vault were enumerated. The remaining locations (locations A, B, and D; fig. 4) did not provide conditions that resulted in acceptable imaging with the acoustic camera and were not included in the analyses.

Results

Tributary Releases

Radio-tagged coho salmon and steelhead released into Alder and Hoffstadt Creeks had limited dispersal and were never detected outside of the tributaries where they were released. Of the 10 radio-tagged coho released into Alder Creek, five fish (50 percent) were detected by mobile tracking, and five fish (50 percent) were never detected. During December 2005, four radio transmitters were recovered near the Alder Creek release site (three from fish previously detected by mobile tracking and one from an undetected fish), but it was not possible to determine if the transmitters had been regurgitated or if the fish had been killed or died. The majority of coho released into Hoffstadt Creek were detected near the release site by mobile tracking (9 fish, 90 percent), and one fish was never detected. During the steelhead monitoring period, one (20 percent) of the Alder Creek-released fish was detected by mobile tracking near the release site, and four fish (80 percent) were never detected. Of the fish released into Hoffstadt Creek, mobile tracking detected three (60 percent) fish near the release site, one fish (20 percent) was detected at the Hoffstadt Creek fixed site, and one fish (20 percent) was never detected.

All radio-tagged coho salmon and steelhead released into Alder or Hoffstadt Creeks remained within the tributary where they were released. None of the radio-tagged coho salmon or steelhead released into tributaries were detected on fixed sites monitoring areas outside of the tributaries. Releases of tagged fish into Alder or Hoffstadt Creeks were not conducted after 2006 because (1) the 2005 and 2006 tributary releases did not provide insights into fish movements in the system because the fish remained in tributaries; (2) the number of fish annually available for tagging in the Toutle River was limited; and (3) the number of radio transmitters available for tagging was limited.

Sediment Retention System Spillway Releases

Most of the coho salmon released upstream of the FCF moved upstream to the base of the SRS spillway, but none of these fish entered or passed through the spillway. We released 20 radio-tagged coho salmon upstream of the FCF during autumn 2005 and autumn 2006 (table 3). Eighteen (90 percent) of these fish initially moved upstream approximately 3 km and were detected at the Lower SRS site and two fish (10 percent) remained near the FCF or moved downstream (fig. 5*A*). The median elapsed time from release to first detection at the Lower SRS site was 7.5 d (range=5.4 h to 18.1 d), and the median residence time of tagged fish at this location was 5.5 d. Mobile tracking efforts were conducted inside the SRS spillway but we did not detect tagged coho salmon upstream of the falls at the lower margin of the spillway. Eventually, 17 (85 percent) of the fish released upstream of the FCF moved downstream and passed the FCF, and three fish (15 percent) remained in the reach between the FCF and the SRS (fig. 5*B*).

A portion of the tagged steelhead ascended the SRS spillway and moved upstream of the sediment plain. A total of 23 radio-tagged steelhead were released upstream of the FCF during spring 2006 and 2007 (table 3). Nineteen (83 percent) of these fish initially moved upstream and were detected at the Lower SRS site, and four of these fish (17 percent) remained near the FCF or moved downstream of the FCF (fig. 6*A*). The median residence time of tagged steelhead at the Lower SRS site was 16.1 d. Eventually, 3 (13 percent) of the radio-tagged steelhead moved upstream through the SRS spillway and sediment plain, 5 steelhead (22 percent) stayed in the reach between the FCF and the SRS, and 15 steelhead (65 percent) moved downstream past the FCF (fig. 6*B*). Tagged steelhead that did not ascend the SRS spillway had a median residence time of 25.7 d in the FCF reach before moving downstream. Of the three fish that ascended the SRS spillway, one fish entered Hoffstadt Creek and the other two were last detected in the mainstem Toutle River at the Middle Toutle site.

Sediment Plain Releases

Radio-tagged coho salmon released into the sediment plain were only marginally successful at moving upstream to locate potential spawning areas. A total of 47 radio-tagged coho salmon were released into the sediment plain during three field seasons from 2005 to 2008. Most of these fish (29 fish, 62 percent) remained within the sediment plain, but some fish (13 fish, 27 percent) were detected upstream of the sediment plain, and some (5 fish, 11 percent) moved downstream past the SRS, and were last detected between the SRS and the FCF (fig. 7*A*). Tagged coho salmon that moved upstream of the sediment plain were last detected in Alder Creek (4 fish), Hoffstadt Creek (4 fish), in the mainstem Toutle River (2 fish at the Middle Toutle site; 2 fish at the Upper Toutle site), and in Bear Creek (1 fish; fig. 7*B*). The proportion of tagged fish that moved upstream of the sediment plain was similar during 2005 (38 percent) and 2006 (35 percent), whereas none of the coho salmon that were released during 2008 were ever detected in upstream areas.

Tagged steelhead were more successful than coho salmon at moving upstream through the sediment plain. We tagged and released 65 steelhead into the sediment plain during three field seasons from 2006 to 2009. In addition to these fish, three tagged steelhead released downstream of the SRS moved upstream and into the sediment plain, so a total of 68 tagged steelhead were available to assess sediment plain behavior and movement patterns. A large number of the tagged fish (47 fish; 69 percent) moved upstream of the sediment plain, 11 steelhead (16 percent) remained within the sediment plain, and 10 fish (15 percent) moved downstream, past the SRS and were last detected between the FCF and the SRS (fig. 8*A*). Of the fish that moved upstream of the sediment plain, most were last detected in the mainstem Toutle River (18 fish at the Middle Toutle site; 4 fish at the Upper Toutle site), Alder Creek (16 fish), Hoffstadt Creek (5 fish), and Bear Creek (4 fish; fig. 8*B*).

Steelhead Outmigration and Respawning

Some tagged fish moved downstream after the spawning period, but relatively few fish were detected downstream of the SRS spillway. A total of 68 tagged steelhead were present upstream of the SRS spillway during the study period, and 10 moved downstream prior to spawning so 58 tagged steelhead had the possibility of spawning in the upper Toutle River basin and then outmigrating to the ocean. Fourteen (24 percent) of these fish were detected outmigrating during our study. However, only seven (12 percent) of the tagged fish were detected downstream of the SRS spillway, which suggests that outmigration success was low. However, three tagged fish from the spring 2006 study period were recaptured at the FCF during 2007. All these fish that were recaptured at the FCF had retained their Floy® tag but lost their radio transmitter. Fish that did not move downstream of the SRS spillway were last detected at the Middle Toutle site (4 fish) or in the sediment plain (3 fish).

Fish Collection Facility Releases

Radio-tagged coho salmon that were released downstream of the FCF did not return to the FCF. A total of nine radio-tagged coho salmon were released downstream of the FCF and six fish (67 percent) moved upstream to the Green River/Toutle River confluence, which is just downstream of the FCF. The median residence time for tagged fish at the confluence of the Toutle and Green Rivers was 4.4 d. Mobile tracking detected one other tagged fish just downstream of the confluence.

A substantial proportion of the radio-tagged steelhead that were released downstream of the FCF returned and re-entered the FCF, but the proportion of tagged fish that were recaptured was relatively low. A total of 11 radio-tagged steelhead were released downstream of the FCF, and 7 (64 percent) eventually re-entered the FCF. Tagged fish that were released early in the season had a higher likelihood of re-entering the FCF and being re-collected. Four of the five tagged fish (80 percent) that were released in March re-entered the FCF, and three tagged fish (60 percent) were re-collected. Six tagged fish were released in April and three (50 percent) re-entered the facility, but these fish were not re-collected. Overall, three of the tagged fish (27 percent) were re-collected during the study period. The median residence time for tagged steelhead near the FCF and Green River/Toutle River confluence was 9.1 d.

Detections of tagged fish inside the FCF suggest that some fish leave the FCF on days when trap-and-haul staff remove fish from the trap. For example, on May 1, 2009, three fish were detected inside the fish holding vault at 0800 h (fig. 9). Trap-and-haul staff arrived shortly thereafter and began manipulating the facility so that fish could be netted from the fish holding vault and transported. Detection records show that the three tagged fish left the fish holding vault between 0900 and 0930 h, and moved down the fish ladder (fig. 9). By 1313 h on that same day (residence time within the FCP of just more than 5 hours), all three tagged fish had exited the FCF (fig. 9). These fish were never re-collected at the FCF.

Acoustic Camera Monitoring

The imaging capabilities of the acoustic camera were poor at several locations, but we were able to observe fish behavior near the FCF entrance and in the fish holding vault. The combined effects of turbidity and turbulence at locations A, B, and D (fig. 4) eliminated the imaging capabilities of the acoustic camera. However, at locations near the FCF entrance and fish holding vault (locations C, E, and F; fig. 4) the acoustic camera provided acceptable imaging capabilities, and we were able to collect information on fish behavior from these deployments. The number of fish observed at these locations varied substantially (table 8). During some sampling periods, we did not observe any fish, and on other sampling periods we observed rather large numbers of fish (>100 fish/period) that were entering and exiting the observation area. On days when fish were observed, there were not strong trends in the direction of fish movement. For example, on April 11, 2008, we observed 115 fish entering the FCF, but also observed 114 fish exiting the FCF (table 8). We could not discern individual fish with the acoustic camera, so it is not clear if this was many fish making low numbers of movements in and out of the FCF, or low numbers of fish making numerous movements in and out of the structure. Generally, it appeared that when fish were moving, they were able to readily enter and exit the FCF and fish holding vault.

Discussion

The Toutle River has been substantially affected by the 1980 eruption of Mount St. Helens and the subsequent construction of the SRS and FCF. This study provided the first empirical data on adult salmon behavior and movement patterns in the basin since the eruption occurred. Using radiotelemetry and an acoustic camera, we were able to describe movement patterns within the basin, evaluate the potential for providing volitional passage in the system, and determine the efficacy of the FCF as part of the trap-and-haul program. Although in some cases, the numbers of tagged fish used to evaluate release sites was low or inconsistent through the years, these evaluations were the first to provide information to managers on the movements of salmon in this system since the eruption.

All radio-tagged fish that were released into tributaries of the Toutle River remained within the original tributary where they were released, but relatively few fish were monitored, and handling effects on the tagged fish may have biased our results. A total of 30 tagged coho salmon and steelhead were released into Toutle River tributaries during 2005–2006, and none of these fish were detected outside of their original release tributary. This would seem to indicate that the trap-and-haul program is yielding the desired results of moving fish from the FCF to areas with suitable spawning habitat and that successful results are occurring. However, a substantial amount of fish handling is required for the program, beginning with hand netting at the FCF and ending with releases into release pipes that transport fish into the stream. This process could be stressful for the fish, and it is possible that injuries and mortality are occurring. We believe that some of our tagged fish died or regurgitated transmitters shortly after release during 2005–2006 based on the number of detections that occurred near the release sites and recoveries of transmitters that were no longer inside fish. However, annual stream surveys conducted by the Weyerhaeuser Corporation in Hoffstadt Creek show that juvenile coho salmon and steelhead are present in these streams (Brian Fransen, Weyerhaeuser Corporation, oral commun.) so it is apparent that successful reproduction is occurring as a result of trap-and-haul efforts. Future evaluations focusing on the survival and spawning behavior of tributary-released fish would be beneficial for understanding the overall effects of the program on salmon recovery efforts in the basin.

Volitional upstream passage through the SRS spillway was not possible for coho salmon, and only possible for a limited number of steelhead. Thirteen percent of the tagged steelhead were able to move upstream through the SRS spillway, which showed that volitional passage was possible for some steelhead. However, because all coho salmon and most steelhead were not able to pass upstream through the SRS spillway, releasing fish upstream of the FCF, rather than directly into tributaries, is not a viable alternative for the trap-and-haul program. It also is important to note that the height of the SRS spillway (at the upstream end) was increased by the USACE during the summer of 2012 so findings from our study may not be applicable to current (2013) conditions. The use of telemetry to monitor tagged fish attempting to move upstream through the SRS spillway was effective and would be a viable approach if this issue is of interest in the future.

The sediment plain appears to be a partial migration barrier as well. Coho salmon and steelhead were able to pass upstream through the sediment plain and locate known spawning tributaries, but some fish remained in the sediment plain where suitable spawning habitat probably does not exist because of the extremely high sediment load and regularly changing channel structure. Twenty-eight percent of the coho salmon and 70 percent of the steelhead that were in the sediment plain eventually moved upstream and entered a tributary, or remained in the mainstem Toutle River. These observations indicate that sediment plain fish releases are fairly successful for steelhead and only marginally successful for coho salmon. It is unlikely that fish that remained in the sediment plain were able to reproduce successfully because the substrate consists of fine sands and sediments and the risk of predation is high due to shallow water and a complete lack of riparian vegetation. The sediment plain also continues to undergo extensive changes. Large flow events can alter the course of the mainstem Toutle River across the sediment plain and the SRS is still effectively trapping sediments upstream of the structure. For example, when the study began in 2005, we placed two antennas approximately 3 m above ground at the mouth of Alder Creek, which is located 2.4 rkm upstream of the SRS. Sediment accumulations at this site were substantial enough that the antennas were touching the ground by 2010. Anthropogenic changes to the sediment plain have occurred during this period as well. The USACE installed grade-building structures in the sediment plain as part of a pilot study in 2010 that were designed to help stabilize the sediments and create a more riverine-like environment (Fenton Khan, U.S. Army Corps of Engineers, oral commun., July 2013). These structures should create small islands and a semi-permanent river channel through the upper end of the sediment plain, which would stabilize the river's course through this reach. Additional research likely will be required to evaluate the ability of salmon to move through the sediment plain because of the dynamic changes that occur, and the fact that our data collection occurred prior to the installation of the river-training structures by the USACE.

The number of post-spawn steelhead outmigrants that successfully moved downstream of the FCF was low during our study. Only 12 percent (6 fish) of the tagged steelhead that were detected in reaches upstream of the sediment plain successfully moved downstream of the FCF after the spawning period. This proportion seems low when compared to recollection rates of adult post-spawn wild steelhead at Cowlitz Falls Dam, located on the upper Cowlitz River, Washington. During 2006–2007, recollection rates of post-spawn steelhead were 34 and 33 percent, respectively (John Serl, Washington Department of Fish and Wildlife, oral commun., July 2013). Fleming (1998) estimated that respawner proportions for steelhead populations throughout their range were approximately 10 percent, and in lower Columbia River tributaries the percentages have been as high as 17 percent (Leider and others, 1986). By comparison, respawner rates were 5 percent during our study and this was only for fish that were tagged during 2006. Maximizing respawner rates in the Toutle River is an important goal given the limited number of adult steelhead that are collected and transported each year.

Data collected during our study suggest that the FCF is inefficient at trapping adult salmon for the trap-and-haul program, and operations of the FCF during 2008–2009 may have contributed to these inefficiencies. During the 2008–2009 telemetry studies, none of the tagged coho salmon and only three (27 percent) of the tagged steelhead were recaptured at the FCF. The acoustic camera sampling showed that adult salmon were readily entering the FCF and the fish holding vault, but those fish were apparently not retained within the FCF, because the number of exit events typically matched the number of entrance events on each sampling day. At least three steelhead that were in the fish holding vault on the morning of a trap-and-haul date were not captured because those fish moved downstream and out of the FCF at about the same time the trap-and-haul staff began working to prepare the FCF for netting fish. Finally, tagged coho salmon and steelhead remained near the FCF or Green River/Toutle River confluence for a short time after release (4.4 d for coho salmon; 9.1 d for steelhead). During 2008–2009, the trap-and-haul program was collecting and transporting fish once each week, which likely increased the inefficiencies of fish collection at the FCF because most fish would only have the opportunity to be collected within a single trap-and-haul cycle (1-week period). Given these findings, WDFW has since increased the frequency of trap-and-haul events to three times per week during the peak migration period of each species and have observed increases in the total number of adult salmon transported each year (Chris Gleizes, Washington Department of Fish and Wildlife, oral commun., July 2013).

Management of wild salmon populations in the Toutle River is a complex issue because of the competing need to minimize sediment-related impacts to downstream areas. Our multi-year evaluation provided information to assist fishery managers in the basin, but some of that information is outdated as a result of the dynamic changes that have occurred in the system since the research was completed. Additionally, we focused on adult salmon in the basin, and there is a similar need for studies to evaluate juvenile salmon survival and outmigration timing in the Toutle River. Given the complexities in the system, long-term efforts to conduct research likely will be required to inform fishery managers tasked with protecting wild salmon in the Toutle River basin.

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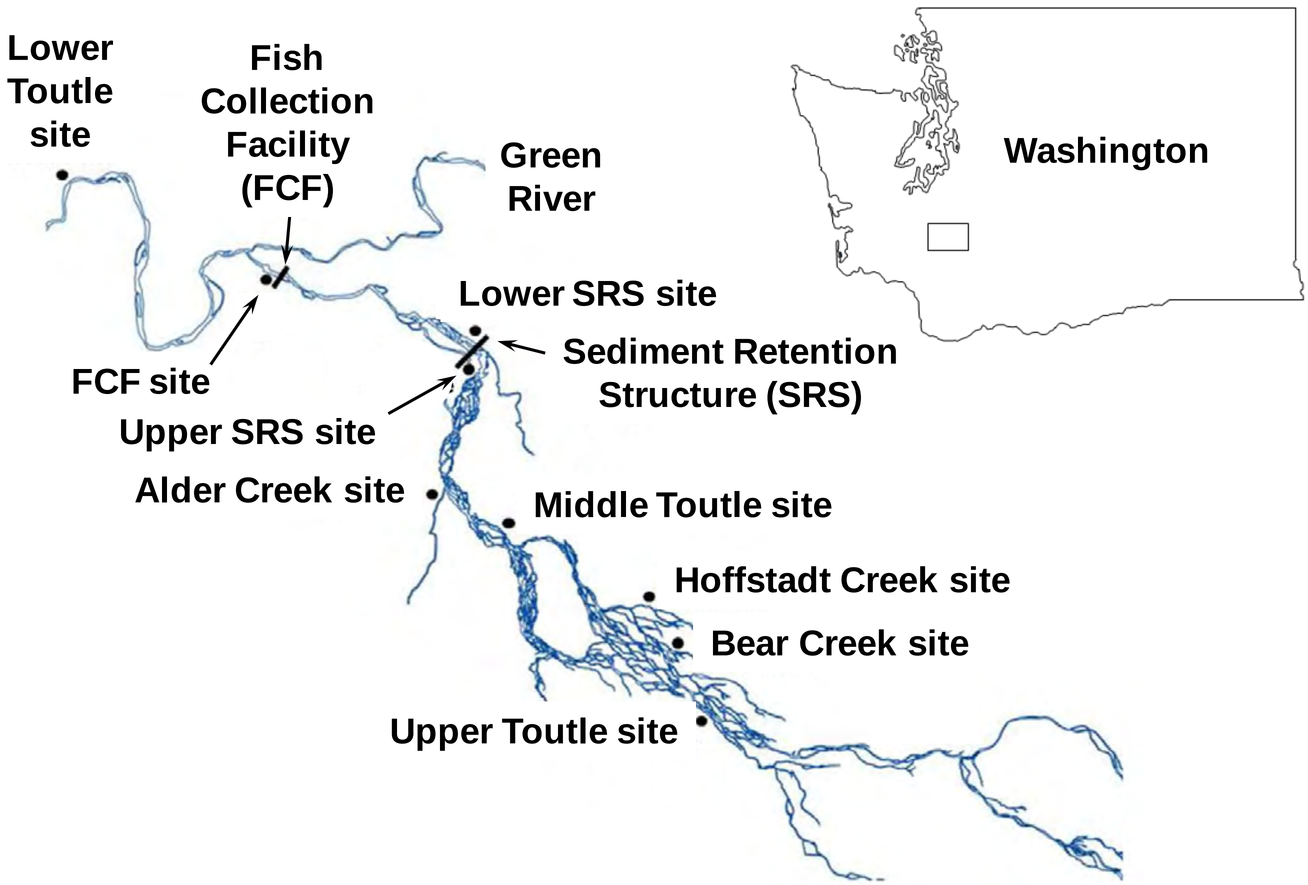

Figure 1. Schematic map of the North Fork Toutle River, Washington, showing the locations of the fish collection facility (FCF), sediment retention structure (SRS), major tributaries, and fixed radiotelemetry monitoring sites.

Figure 2. Photograph showing release pipe used by trap-and-haul staff to release adult coho salmon (*O. kisutch*) and steelhead (*O. mykiss*) in Hoffstadt Creek, Washington.

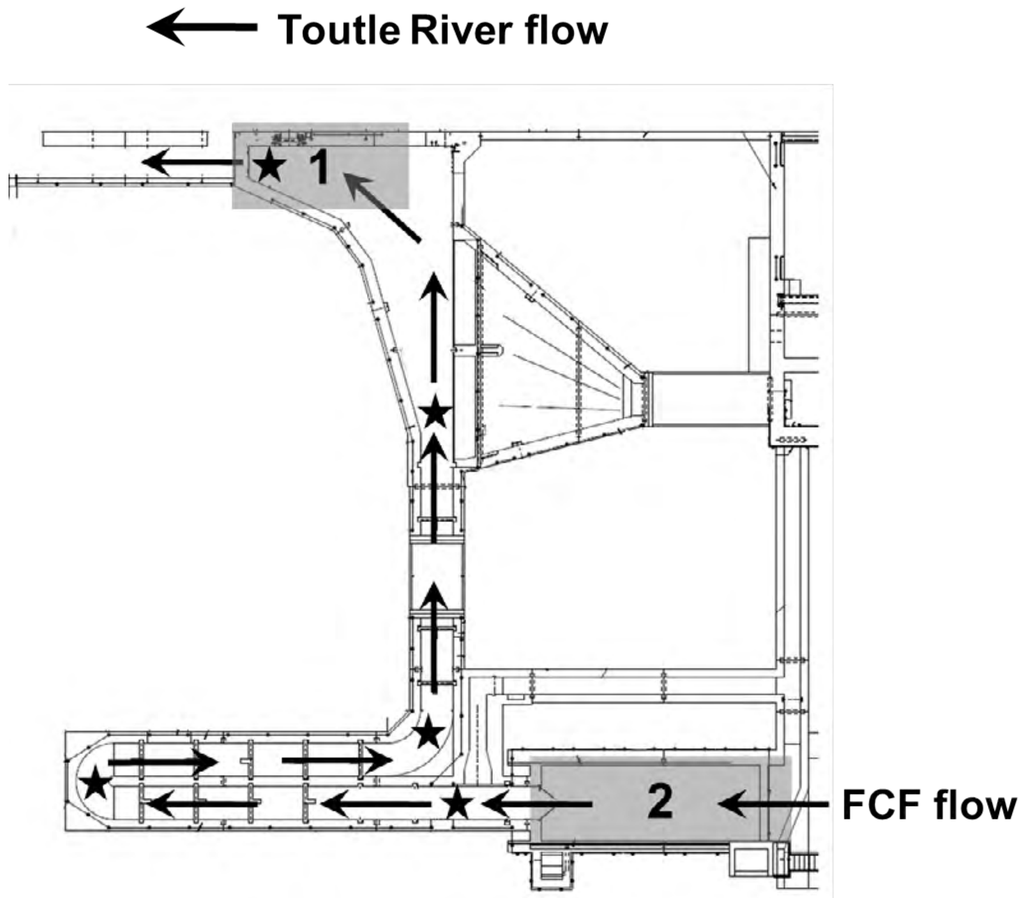

Figure 3. Schematic of the Toutle River fish collection facility (FCF) and the location of underwater antennas (stars) that were used to monitor fine-scale movements of radio-tagged coho salmon and steelhead during 2008–2009. The FCF entrance (shaded area 1) and the fish holding vault (shaded area 2) also are shown.

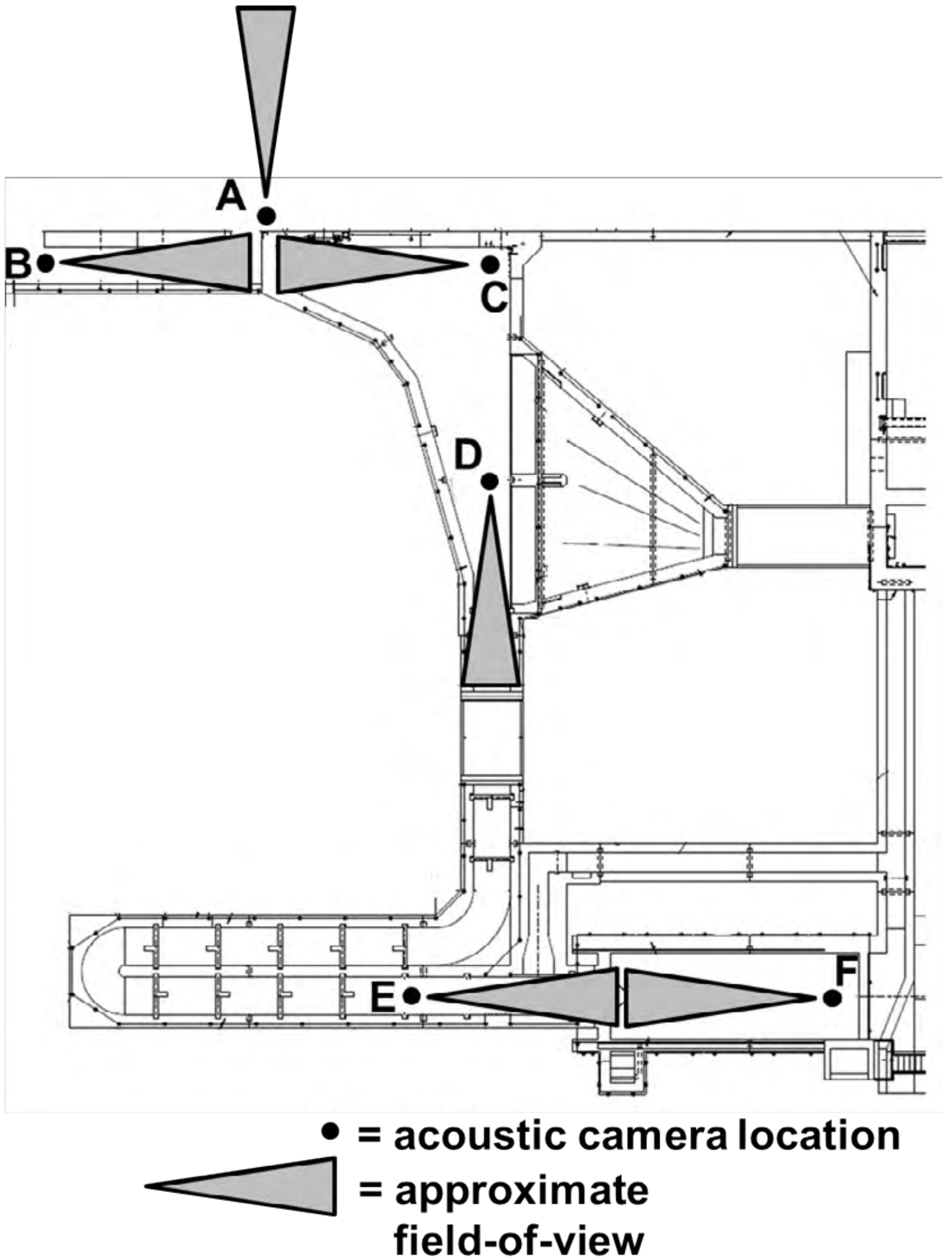

Figure 4. Schematic of the Toutle River fish collection facility showing the approximate location and field-of-view of an acoustic camera during 2008–2009.

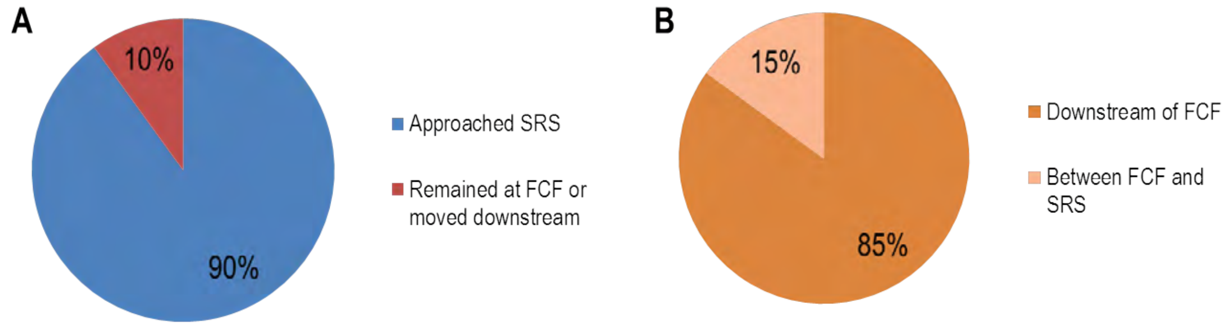

Figure 5. Initial (*A*) and final (*B*) locations where radio-tagged coho salmon were detected following release upstream of the Toutle River fish collection facility (FCF)during 2005–2006. SRS is the sediment retention structure.

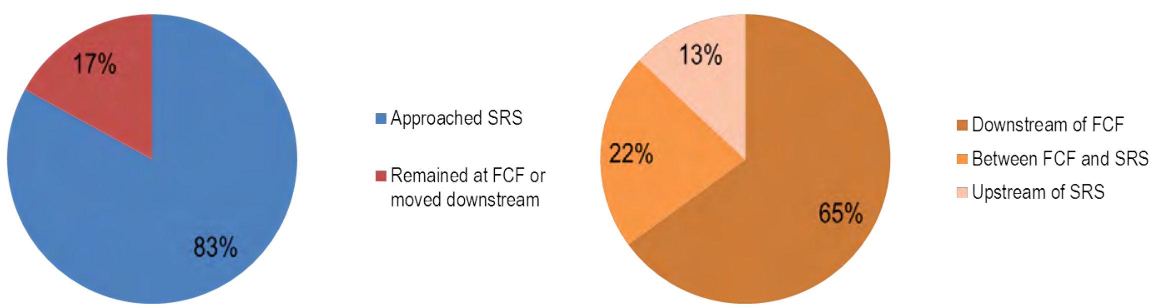

Figure 6. Initial (*A*) and final (*B*) locations where radio-tagged steelhead were detected following release upstream of the Toutle River fish collection facility (FCF)during 2005–2006. SRS is the sediment retention structure.

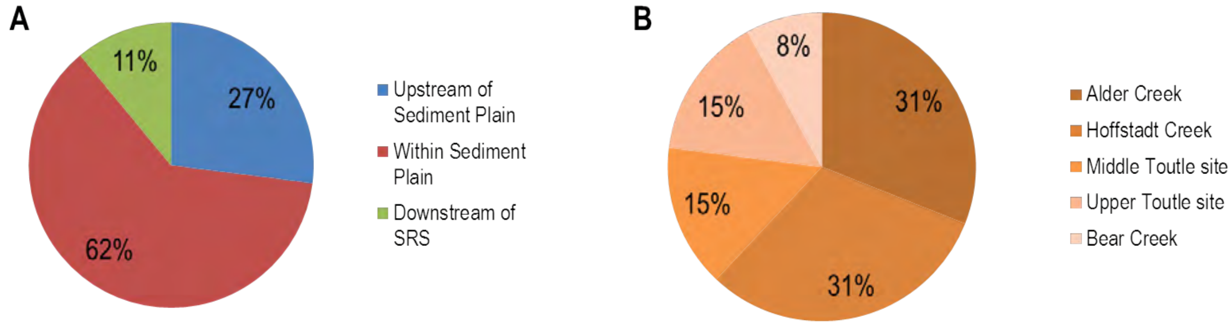

Figure 7. Initial (*A*) and final (*B*) locations where radio-tagged coho salmon were detected following release into the sediment plain upstream of the sediment retention structure (SRS)during 2005–2006 and 2008.

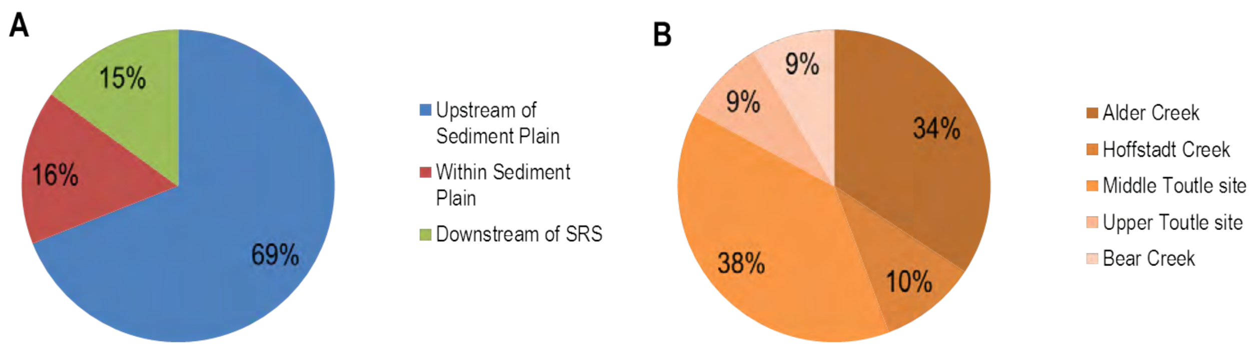

Figure 8. Initial (*A*) and final (*B*) locations where radio-tagged steelhead were detected following release into the sediment plain upstream of the sediment retention structure (SRS)during 2006–2007 and 2009.

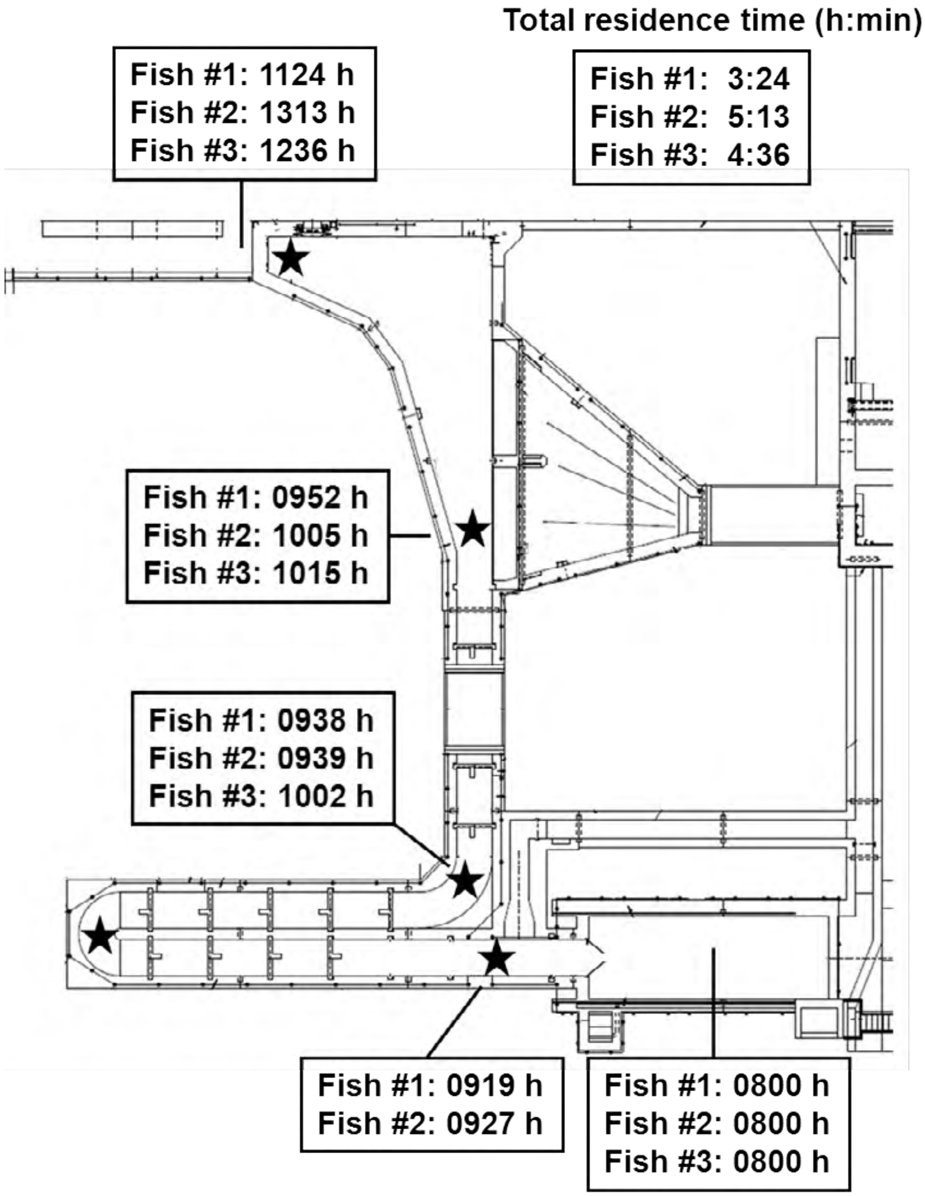

Figure 9. Schematic of the Toutle River fish collection facility (FCF) showing a series of detection events, and the overall residence time within the FCF for three radio-tagged steelhead detected on May 1, 2009.

Table 1. Study periods, species monitored, and activities by study objective.

[SRS, sediment retention structure; FCF, fish collection facilities]

Period	Season	Species	Objective 1	Objective 2	Objective 3	Objective 4
Sept.–Dec. 2005	Autumn 2005	Coho	Tributary releases	SRS releases	Sediment plain releases	
March–June 2006	Spring 2006	Steelhead	Tributary releases	SRS releases	Sediment plain releases	
Sept.–Dec. 2006	Autumn 2006	Coho		SRS releases	Sediment plain releases	
March–June 2007	Spring 2007	Steelhead		SRS releases	Sediment plain releases	
March–April 2008	Spring 2008	Steelhead				Acoustic camera
Oct.–Dec. 2008	Autumn 2008	Coho			Sediment plain releases	FCF releases and acoustic camera
March–May 2009	Spring 2009	Steelhead			Sediment plain releases	FCF releases and acoustic camera

Table 2. Number of adult coho salmon and steelhead that were radio-tagged and released into Alder Creek and Hoffstadt Creek,Washington,2005–2006.

Release date	Alder Creek	Hoffstadt Creek
Coho salmon		
Oct. 7, 2005	5	0
Oct. 14, 2005	0	5
Oct. 21, 2005	1	0
Oct. 28, 2005	4	5
Total	**10**	**10**
Steelhead		
Mar. 3, 2006	1	2
Mar. 17, 2006	2	0
Mar. 31, 2006	0	3
Apr. 7, 2006	2	0
Total	**5**	**5**

Table 3. Number of adult coho salmon and steelhead that were radio-tagged and released upstream of the fish collection facility to determine if adult salmon could pass upstream through the spillway during 2005–2007.

Release date	Number of fish released
Coho salmon	
Oct. 7, 2005	5
Oct. 21, 2005	5
Total released in autumn 2005	**10**
Sept. 29, 2006	1
Oct. 6, 2006	2
Oct. 20, 2006	2
Oct. 25, 2006	2
Oct. 27, 2006	3
Total released in autumn 2006	**10**
Total coho salmon released during study	**20**
Steelhead	
Mar. 3, 2006	2
Mar. 10, 2006	2
Mar. 17, 2006	2
Mar. 24 2006	2
Apr. 7, 2006	1
Apr. 14, 2006	1
Apr. 21, 2006	1
Total released in spring 2006	**11**
Mar. 16, 2007	2
Mar. 23, 2007	2
Mar. 30, 2007	2
Apr. 6, 2007	2
Apr. 20, 2007	2
Apr. 27, 2007	2
Total released in spring 2007	**12**
Total steelhead released during study	**23**

Table 4. Number of adult coho salmon that were radio-tagged and released upstream of the sediment retention structure to determine if adult salmon could move upstream through the sediment plain during 2005–2008.

Release date	Number of fish released
Sept. 30, 2005	3
Oct. 14, 2005	3
Oct. 28, 2005	2
Total released in autumn 2005	**8**
Sept. 29, 2006	2
Oct. 6, 2006	1
Oct. 13, 2006	1
Oct. 20, 2006	8
Oct. 25, 2006	14
Oct. 27, 2006	3
Total released in autumn 2006	**29**
Nov. 7, 2008	6
Nov. 14, 2008	4
Total released in autumn 2008	**10**
Total coho salmon released during study	**47**

Table 5. Number of adult steelhead that were radio-tagged and released upstream of the sediment retention structure to determine if adult salmon could move upstream through the sediment plain during 2006–2009.

Release date	Number of fish released
Mar. 10, 2006	4
Mar. 17, 2006	2
Mar. 24, 2006	4
Mar. 31, 2006	4
Apr. 7, 2006	3
Apr. 14, 2006	2
Apr. 21, 2006	2
Total released in spring 2006	**21**
Mar. 16, 2007	5
Mar. 23, 2007	6
Mar. 30, 2007	5
Apr. 6, 2007	6
Apr. 20, 2007	6
Apr. 27, 2007	8
Total released in spring 2007	**36**
Mar. 20, 2009	1
Apr. 3, 2009	1
Apr. 10, 2009	2
Apr. 27, 2009	1
Apr. 24, 2009	1
May 1, 2009	1
Total released in spring 2009	**7**
Total steelhead released during study	**64**

Table 6. Number of adult coho salmon and steelhead that were radio-tagged and released downstream of the fish collection facility to determine the efficacy of the structure during 2008–2009.

Release date	Number of fish released
Coho salmon	
Oct. 10, 2008	1
Oct. 24, 2008	8
Total coho salmon released during the study	**9**
Steelhead	
Mar. 13, 2009	2
Mar. 20, 2009	2
Mar. 27, 2009	1
Apr. 3, 2009	1
Apr. 10, 2009	2
Apr. 17, 2009	2
Apr. 24, 2009	1
Total steelhead released during study	**11**

Table 7. Summary of acoustic camera sampling conducted near the fish collection facility on the Toutle River during 2008–2009.

[Sampling locations are identified in figure 4 of this report. Sampling dates with no sampling hours or duration were due to poor imaging conditions as a result of site-specific turbidity and turbulence levels. –, no data available]

Sampling period	Sampling date	Sampling location	Sampling hours	Sampling duration (h)
Spring 2008	Mar. 19	F	1300 to 239	11
	Mar. 20	F	0000 to 2359	24
	Mar. 21	F	0000 to 0900	9
	Mar. 27	C	1200 to 2359	12
	Mar. 28	C	0000 to 2359	24
	Mar. 29	C	0000 to 0700	7
	Apr. 2	E	1100 to 2359	13
	Apr. 3	E	0000 to 2359	24
	Apr. 4	E	0000 to 1200	12
	Apr. 10	C	0900 to 2359	15
	Apr. 11	C	0000 to 2359	24
	Apr. 12	C	0000 to 0600	6
	Apr. 16	E	0900 to 2359	15
	Apr. 17	E	0000 to 2359	24
	Apr. 18	E	0000 to 0900	9
	Apr. 23	C	0800 to 2359	16
	Apr. 24	C	0000 to 2359	24
	Apr. 25	C	0000 to 0700	7
Autumn 2008	Oct. 6	A, B	–	–
	Oct. 7	A, B	–	–
	Nov. 24	B, D	–	–
	Nov. 25	B, D	–	–
	Nov. 26	B, D	–	–
	Nov. 27	B, D	–	–
	Nov. 28	B, D	–	–
	Dec. 12	C	0900 to 1500	6
Spring 2009	Mar. 20	A	–	–
	Apr. 9	C	1000 to 2359	15
	Apr. 10	C	0000 to 0700	7
	Apr. 15	A, D	–	–
	Apr. 16	A, D	–	–
			Total	**304**

Table 8. Summary of fish movements observed with an acoustic camera in the Toutle River fish collection facility (FCF) during 2008–2009.

Sampling date	FCF location	Number of fish entering location	Number of fish exiting location
Mar. 19, 2008	Fish holding vault	5	3
Mar. 20, 2008	Fish holding vault	4	3
Mar. 21, 2008	Fish holding vault	0	0
Mar. 27, 2008	FCF entrance	141	141
Mar. 28, 2008	FCF entrance	0	0
Mar, 29, 2008	FCF entrance	1	0
Apr. 2, 2008	Fish holding vault	24	52
Apr. 3, 2008	Fish holding vault	30	133
Apr. 4, 2008	Fish holding vault	9	21
Apr. 10, 2008	FCF entrance	160	124
Apr. 11, 2008	FCF entrance	115	114
Apr. 12, 2008	FCF entrance	13	8
Apr. 16, 2008	Fish holding vault	6	3
Apr. 17, 2008	Fish holding vault	12	17
Apr. 18, 2008	Fish holding vault	0	1
Apr. 23, 2008	FCF entrance	85	78
Apr. 24, 2008	FCF entrance	52	25
Apr. 25, 2008	FCF entrance	1	0
Dec. 12, 2008	FCF entrance	0	0
Apr. 9, 2009	FCF entrance	0	0
Apr. 10, 2009	FCF entrance	4	30

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