EMERGENCY FISH PASSAGE AT A FRACTURED MAINSTEM COLUMBIA RIVER DAM

Todd N. Pearsons
Grant County Public Utility District, P.O. Box 878, Ephrata, WA 98823. E-mail: tpearso@gcpud.org

Thomas J. Dresser, Peter J. Graf, Michael S. Nicholls, Shannon Lowry, Michael C. Clement, and Curtis L. Dotson
Grant County Public Utility District, Ephrata, WA
On February 24, 2014, a hydro mechanic from Grant County Public Utility District (PUD) discovered an anomaly in the handrail and track on the deck of Wanapum Dam, a structure that spans the 2.6-km-wide Columbia River near Beverly, Washington (Figure 1). After alerting others and after further investigation, a 19.8-m-long, 5.1-cm-wide horizontal fracture causing an uplift and forward tilt of the dam was discovered. Grant County PUD immediately went into emergency mode and lowered the Wanapum Reservoir by 7.9 m to reduce the pressure against the massive concrete spillway, one of the largest spillway gate designs of its time (Photo 1).

News outlets reported stories with headlines such as “‘Serious Problem’: 65-Foot Crack Found in Columbia River Dam” (Welch 2014), “Potential Failure Situation Developing at Wanapum Dam” (Pratt 2015), and “Wanapum Dam Crack: With Spring Chinook on the Way Upstream Fish Passage High Priority” (Columbia Basin Bulletin 2014).

The lowered pool reduced the width of the crack to less than 2.5 cm, but it also left the adult fish passage structures dry at the top third portion of the fish ladders, which allows fish to ascend to water above the dam. Though fish were not yet migrating, the spring run of Chinook Salmon *Oncorhynchus tshawytscha*, which is listed as endangered in the upper Columbia River, would begin arriving on April 15. Record runs of Sockeye Salmon *O. nerka* and fall Chinook Salmon were predicted to begin arriving in early July.

Grant County PUD staff alerted resource agencies and tribes and developed a plan to pass fish around Wanapum Dam, and Chelan PUD worked with the agencies and tribes to pass fish at the upstream Rock Island Dam, where the lowered Wanapum pool could influence access to the fish ladder entrances. A professional facilitator organized weekly meetings for communication and decision making, but often the communication occurred more frequently as needs surfaced and decisions were required. A decision tree, developed and approved by the joint fishery parties, made up of U.S. Fish and Wildlife Service, National Marine Fisheries Service (NOAA Fisheries), Washington Department of Fish and Wildlife (WDFW), and the Colville and Yakama tribes, included two primary passage routes around the dam: (1) trap and transport and (2) a fish passage system structure at the top end of the two Wanapum Dam ladders.

The trap-and-transport route involved collecting salmon and steelhead *O. mykiss* at the Priest Rapids Dam Off-Ladder...
Adult Fish Trap (OLAFT), located about 29 km downstream of Wanapum Dam. The plan was to trap all adult fish migrating above Priest Rapids Dam by diverting them to the left bank ladder and trapping them at the OLAFT facility. Trapped fish would be shunted into large fish transport trucks and released upstream of Wanapum Dam. Such trapping was unprecedented at the OLAFT, so modifications to the facility were necessary. Sections were removed and spliced into other locations to move shunted fish into large pipes that would transport them to waiting tanker trucks. Fish would then be trucked around Wanapum Dam and released several kilometers upstream.

The fish passage system at Wanapum Dam was more daunting to envision and certainly less predictable as a tool to pass fish. Conceptually, 1.13 m$^3$/s of water would be pumped from the lowered pool above the ailing Wanapum Dam into the top end of the dry ladder. The water would enter the ladder through a 2.1-m-tall, 4.9-m-wide upwell box spanning the width of the ladder, essentially creating a false weir. The upwell box would deliver water to the top end of the ladder, stop water from spilling back into the Wanapum pool, provide flow to attract salmon to swim or jump over, and provide water to slide down a ramp that would direct fish to the Wanapum pool.

The parties agreed to trap and transport until sufficient information was available to support meeting passage metrics at the modified fish passage system. Target metrics were developed using historical data regarding fish survival and travel time between Priest Rapids Dam and Rock Island Dam. If the low end of the measured survival and timing of fish that occurred during previous years using the fish ladders under normal operation could be exceeded, the fish passage system would be successful. Resource managers endorsed these metrics developed by Grant County PUD staff: travel time of less than 356 h, survival of at least 80% (uncorrected conversion), and less than 5% of the fish observed at the fish passage system died upon contact with the structure or Wanapum Pool. The first 200 hatchery-origin spring Chinook Salmon trapped at OLAFT would be passive integrative transponder (PIT) tagged, and another 50 hatchery-origin spring Chinook Salmon would be implanted with acoustic tags. The PIT tags would determine the success at meeting targets, and the acoustic tags used to evaluate any causes for failing to meet the targets. If the target metrics were met, trapping and hauling could cease and all fish would be allowed to pass via the fish passage system.

**CHALLENGES**

Design and construction of the OLAFT modifications were relatively simple, but the time constraints were not. Designs were drafted, reviewed internally and externally, and constructed in just over six weeks. It was completed on April 11, just in time for the spring Chinook migration. More challenging was assembling a fleet of fish transport trucks and certified drivers that could accommodate a 16-h shift, seven days a week. The WDFW provided the drivers, who agreed to add the shifts on top of their regular workload. Trucks were brought in from the WDFW and Grant County, Chelan County, and Douglas County PUD fleets. Furthermore, operational protocols for transport trucks were negotiated so that suitable numbers of fish could be transported without endangering their health. Trade-offs between low loading densities and the number of fish that could be transported in each load were debated and ultimately agreed on.

Design and construction of the fish passage system at Wanapum Dam was much more complicated. Grant County PUD engineers collaborated with Grant County PUD and NOAA Fisheries biologists on developing a design that could be constructed by April 15. It was determined that a series of pumps, an upwell box, and plywood ramp could be constructed by that date, but additional functionality (including an approach ramp, jump apron, human access ramp, and spiral slide), if needed, would have to wait.

Some of the key design challenges were the lack of important data, the short time frame for design and construction, the ability to add additional features at a later date, and approval from the resource agencies. It became clear early in the design that fish would have to drop 2.7 to 4.0 m from the bottom of the ramp to the reservoir. Staff worked to minimize this distance by steepening the gradient of the ramp and extending it as far as possible. There were also requests by the resource agencies to attach a spiral slide that would create a shorter drop.

Grant County PUD searched for information to determine how high adult salmon could fall without resulting in injury. No studies were found on adult spring Chinook Salmon, and a single study with small sample size was found for adult Atlantic Salmon *Salmo salar* released from a plywood flume 10.6 m and 18.0 m high. Due to scientific uncertainty, resource agencies advocated for a spiral slide to reduce the fall. Grant County PUD engineers determined that it was impossible for the spiral slide to be constructed by April 15. Ultimately, all parties agreed that design and construction of the spiral slide (Phase 2) would occur at a later date, but only if it was determined that the Phase 1 installation was insufficient.

It was clear that fish orientation when entering Wanapum pool was
as important to the resource agencies as the elevational drop. Concerns were raised over potential injury to gills if a fish landed tail first and the gill plate was open to the water. Other concerns were the potential damage to internal organs and released eggs if fish landed hard on their side. The desire for head-first orientation resulted in a request to include vanes on the plywood ramp to keep the fish in a head-first orientation as they entered the pool. Because fish jumped head first over the false weir, conceptually the vanes would allow fish to maintain that position as they continued down the slide.

Conceptual designs were drafted and then negotiated with resource agencies. The entire ramp had to be no more than 45.7 cm at the terminus in order to concentrate the water that would help cushion the fish’s entrance into the pool. Additionally, the design needed to allow attachment of the Phase 2 spiral slide. The final design included a maximum width between vanes of 45.7 cm and a minimum width of 22.9 cm at the terminus. Vanes would terminate as they angled down the ramp to a minimum width of 22.9 cm. The vane boards were 61.0 cm tall to reduce the potential for fish to jump over them. The resource agencies eventually approved the Phase 1 design and procurement of materials and construction began. The number of details that had to be considered to achieve an acceptable design was daunting but necessary to achieve the common agenda of safe fish passage.

CONSTRUCTION

Building the structure under rushed, cold, wet, and windy conditions was difficult. The final destination of the structure was in a 7.9-m-deep concrete hole. When weather permitted, contractors worked seven days a week to build and install pumps, the false weir, and the ramp. On many days, crane operations were called off due to wind speeds greater than 40.2 km/h. Cranes needed to move heavy equipment and were a safety requirement when workers were constructing within the concrete hole.

On April 15, Phase 1 of the left bank ladder fish passage system was completed (Photo 2). On April 26, a similar system was completed on the right bank ladder.

The project team worried that fish would stack up in the approach pool because they would not ascend the false weir or that they would be deprived of oxygen due to high densities. If the fish passage system did not work, Grant County PUD might forever be remembered as contributing to the demise of threatened and endangered species.

TESTING

The team wanted to fix any fatal flaws in the system before the Chinook Salmon arrived. Surplus hatchery steelhead were offered from the Wells Hatchery to test the ramp. The fish were delivered in a hatchery transportation truck on April 14. The plan was to place the hatchery steelhead on the ramp and observe their behavior. The team opted not to put the fish into the ladder because it was unknown whether they would swim or jump over the false weir. Additionally, staff needed to observe the fish as they navigated the ramp system. A crane lowered a Grant County PUD scientist in a basket down to the water surface of the concrete hole. A steelhead was placed into a sling, lowered to the scientist, and tossed onto the ramp to mimic various orientations. This process was repeated and documented 15 times.

To the amazement and cheers of those observing from the deck of the dam above the ladder exit, the steelhead slid down the ramp and entered the pool. Some fish turned around on the ramp and entered the pool tail first and some entered on their side, but all of the fish rapidly swam off. Fish also traveled with the falling water entering the Wanapum pool, which provided some cushioning from the drop. Though the team knew that the ramp could work and that the high elevation drop would not instantly kill adult fish, now they had to wait to see whether the endangered spring Chinook Salmon would swim over the false weir, survive the fall, and swim the long distance up to Rock Island Dam. The first group of fish would arrive soon.

Spring Chinook Salmon began arriving at Priest Rapids Dam on April 15. The first 250 hatchery-origin spring Chinook Salmon were injected with a single PIT tag, or both an acoustic and PIT tag, and released into the left bank ladder to continue their upstream migration. The team waited for antenna detections to indicate survival and travel time.

Concurrent with the tagging effort, observers recorded fish behavior in the holding pool below the false weir, ascending the false weir, going down the ramp, and entering Wanapum pool, which would indicate any obvious problems with the fish passage system. If fish reluctant to jump the weir stacked up, there was a problem. Fish stacking up on the ramp was also a problem. If fish died after dropping off the ramp and hitting the Wanapum pool, it was an even bigger problem.

EARLY TEST RESULTS

The first two weeks of operation were unsettling because the number of detections was slow and slow. But the team’s excitement grew days later when fish were finally detected at Rock Island Dam. Fish were also observed ascending the Wanapum Dam modified false weir, sliding down the ramp, and entering the reservoir without incident. Washington State Governor Jay Inslee made a special trip to Wanapum Dam soon after the new fish passage system was installed. “It’s a very ingenious contraption they figured out,” said Inslee (Folsom 2014).

Though the team’s confidence in meeting the target metrics grew with each new tag detection, a discrepancy emerged in the number of Chinook Salmon counted at the visual counting station near the ladder entrance and the number entering the OLAFT midway up the Priest Rapids Dam fish ladder. Chinook Salmon were observed stacking up downstream of the trapping facility. Unexpectedly, the major impediment to migrating fish in the Columbia River was not at Wanapum Dam but rather at the Priest Rapids Dam fish trap. All fish ascending the Columbia River were forced to ascend a 45.7-cm-wide denil at the facility. Grant County PUD biologists recommended that trapping be ceased due to passage delays. Additionally, the resource agencies agreed that passage was on target at Wanapum Dam, and trapping and transporting adults at Priest Rapids Dam was ceased on May 9.

Over a three-week period, a total of 605 adult spring Chinook Salmon and 42 steelhead were collected at the OLAFT, placed into fish trucks, and transported to and released at Rocky Coulee, approximately 4.8 km upstream of Wanapum Dam. All other nontarget species were sorted through a swing gate and diverted back to the left bank ladder. As long as the fish passage system was working well, trapping and hauling did not have to be reimplemented. If ladder passage was not working well, Grant County PUD could remobilize the effort, but a record number of steelhead, Sockeye Salmon, and summer and fall Chinook Salmon predicted to return to Priest Rapids Dam beginning in June made this a far less desirable option. Early
estimates exceeded an unprecedented 1 million fish. In reality, only a small fraction of that number of fish could be safely trapped at the OLAFT.

But the crisis was averted when survival targets for spring Chinook Salmon reaching Rock Island Dam were met by May 10. Though it was apparent that the fish passage system had worked as well as a fully functioning ladder, there was little time to celebrate if Grant County PUD was going to be ready for the more than 50,000 fish set to arrive and ascend Wanapum Dam each day starting in early July.

PHASE 2: MESSING WITH SUCCESS?

Despite the dramatic success of the modified fish passage system, the resource agencies determined that Phase 2 construction should be implemented. Grant County PUD contracted with a pool slide company in Oregon to make an enclosed circular water slide that would attach to the end of the slide and be anchored to the dam. There was only a small window of time for construction. The spring Chinook Salmon run would end around June 1 followed closely by the arrival of summer Chinook Salmon. The Sockeye Salmon run was likely to peak between July 8 and 18, and steelhead would begin showing up in the last week of July. The plan was to install Phase 2 elements on the left bank ladder first, followed by the right bank.

Spring is generally windy in Grant County, making it difficult to find days when cranes can be safely used. As a safety precaution, cranes cannot operate when wind speeds exceed 40.2 km/h. Additionally, pumps had to be shut off during construction, which prevented fish from ascending the ladder. Construction had to occur primarily during the night when fish were less active.

Phase 2 also included installation of an approach ramp, a human-access ramp, and a jump apron. The approach ramp was a 45° angle metal grate intended to reduce the amount of jumping behavior and height. The ramp extended from the ladder floor to about 45.7 cm below the top of the false weir. A human-access ramp extending over the top of the ramp was installed to provide emergency access if fish stacked up. The jump apron was a heavy-duty coated canvas tarp that enclosed the upper third of the ramp to prevent fish from jumping out of the ramp and landing on the dry bottom of the concrete fish ladder exit. These three Phase 2 improvements were planned to accommodate the jumping behavior of Sockeye Salmon and steelhead, as well as the expected record Sockeye Salmon return. Biologists wrestled with an appropriate height for the jump apron. Based on the jumping height and distance of steelhead, Chinook Salmon, and Sockeye Salmon, the jump apron was designed at 2.4 m above the ramp at the top end and 1.8 m above the ramp 2.4 m down the ramp.

On June 13, crews attached the spiral slide to the left bank ramp. The right bank was modified on June 19 (Photo 3). Fish now slid down the ramp and exited with only a 61 cm drop. As the number of Sockeye Salmon picked up, more people arrived to observe passage over the dam. At the peak of migration, more than 30 fish could be observed on the ramp at any given time.

PACIFIC LAMPREY

Though much of the team’s focus was on safe passage for salmon and steelhead, Pacific Lamprey *Entosphenus tridentatus* were on their way as well, presenting a new set of challenges. Salmon and steelhead, which have firm bodies and large caudal fins to allow them to generate great speed, are built to swim fast...
and jump high. In contrast, lampreys are shaped like snakes with round sucker-like mouths and small fins, a morphology that does not promote fast swimming or high jumping. Lampreys use their mouths to clamp onto flat surfaces and take short bursts to the next attachment spot, sometimes only centimeters from the previous location. Because most fish ladders are designed to pass salmon and steelhead, they are not conducive to passing lampreys. Retrofits to existing ladders have included ramps and holding pools that allow lampreys to suck to ramps, burst swim, repeat, and rest. Retrofits to Priest Rapids and Wanapum dams were constructed in 2010. These design elements needed to be included at the modified ladders at Wanapum Dam as well.

Thirty-and-a-half-centimeter-wide, 2.9-m-long lamprey ramps were installed on both sides of the terminal pool leading to the false weir. The ramps, made of smooth steel, were angled at 45° to the floor and hugged the walls of the ladder pool, allowing lampreys to easily find the ramps and prevent them from falling off. The top end of the ramp went over the false weir and directly onto the plywood ramp on the downstream side that descends to the Wanapum pool. The plan was to provide suckable surfaces all the way up and over the lamprey ramp.

The resource agencies were not convinced the lamprey modifications would work, even with the success of the ladder designs for spring Chinook Salmon passage. The agencies required that lampreys be trapped in the ladders at both Priest Rapids and Wanapum dams and transported above Rock Island Dam to reduce the risk of complete failure. However, it was clear to everyone that many, if not most, of the lampreys would pass the lamprey traps and encounter the modified passage structures at the top of the Wanapum Dam fish ladders.

Most of the 36 lamprey traps were similar to the design of minnow or slat traps but were longer and narrower to accommodate the long and slender lamprey. Approximately 40 traps were installed in various locations throughout four fish ladders and fished 7 days a week, 24 h per day. The goal was to capture the highest proportion of the run possible and transport them above Rock Island Dam. The rest of the lampreys would have to suck and swim up and over the new passage system.

A test was conducted to see whether any lampreys would make it over the new system. Fish were trapped at John Day and Priest Rapids dams, trucked upstream to Wanapum Dam, tagged, and placed in the fish ladder. Because lampreys migrate primarily at night, infrared video cameras were set up to record their activities. Review of the video tapes and behavioral observations revealed that though lampreys successfully ascended the ramps, once the flow of the water changed direction on the opposing angled ramp, the lampreys would suck on and not slide down to the Wanapum pool. In fact, most would swim back up the ramp and back into the holding pool below the false weir. Grant County PUD staff proposed installing perforated metal plating on the ramp to make it difficult for lampreys to get suction and stick to the ramp. The fix had to be approved by the resource agencies. Though lamprey advocates wanted the whole top end of the ramp to be lined with perforated plating, salmon advocates were concerned that the additional plating would increase abrasion to salmon and ultimately expose them to greater risk of disease. The compromise was to line the top 1.2 m of the two outermost lanes of the ramp immediately upstream of the lamprey ramps. Once installed, biologists viewed the videos to determine whether their solution worked. Unfortunately, the lampreys found a 2.5-cm strip of unplated wall to suck onto and reascend the ramp. The team was disappointed that the solution did not work as planned. However, further observations revealed that some of the lampreys did release suction and descend into Wanapum pool, and some of the lampreys were dislodged by other fish moving through the system. An attempt to dislodge the lampreys by blasting them with water from a high-pressure hose was unsuccessful, but there was one other technique that had promise.

Biologists knew that lampreys had a keen sense of smell and would detach in other river locations when they smelled the odors of humans. The team gargled clean water, spit it into a squirt gun, and fired from the observation deck, 7.9 m above the highly suctioned lampreys. To the team’s amazement, it worked. Lampreys would dislodge after smelling the human saliva and ultimately descend to the Wanapum pool where they continued their upstream migration.

From July 17 to September 30, a portion of the lampreys ascending ladders at Priest Rapids and Wanapum dams were trapped and hauled above Rock Island Dam at Kirby Billingsley Hydro Park, approximately 3.2 km south of East Wenatchee, Washington.
**MAINTENANCE OF WATER DELIVERY PUMPS**

For the fish passage system to work, a sufficient amount of water had to be delivered through the false weir and to the top end of the fish ladder. Low amounts of water resulted in low elevations in the holding pool, making it difficult for fish to swim or jump up to the ramp. Divers cleaned the pump intakes, located 3.0 to 4.6 m below the water surface, whenever the water levels in the holding pools decreased by 15.2 cm below the optimal depth. During April and May, pump cleaning occurred every 1 to 3 weeks on the left bank system but was rarely needed on the right bank. After the intakes were cleaned, the holding pool elevation was restored to the optimal elevation. This system worked until July 29 when water elevations could not be restored after repeated cleaning. After much head-scratching and testing, the team determined that there was a problem with one of the pumps. When it was discovered that the backup pump had been loaned out by a contractor, another pump was pulled out of storage. Crews quickly rewired the pump and the system was back up and running. Another disaster averted.

Some months later, when huge amounts of plants and debris began floating toward Wanapum pool, divers had to clean the pumps every 2 to 3 days to keep the passage system operational.

**JUVENILE SURVIVAL**

Though the team's primary focus was on upstream adult fish passage, juveniles migrating downstream to the ocean also had to make their way through a lowered Wanapum pool. Resource agencies were concerned about survival impacts and wanted to know how the lowered pool might influence survival. To study the effect, yearling Chinook Salmon and steelhead were collected at Wanapum Dam, surgically implanted with acoustic tags, placed in water-tight aluminum boxes, and flown were collected at Wanapum Dam, surgically implanted with acoustic tags, placed in water-tight aluminum boxes, and flown.

To the downstream, the fish had to pass through a lowered Wanapum pool. The other 52% passed over the modified passage and OLAFT modifications; Grant PUD hydro operators managing pump cleaning; John Monahan for assistance with OLAFT trap and haul; Steve Gwynn for designing the OLAFT modifications; Blue Leaf Inc. for collecting behavioral information; Battelle Russell Langshaw for design review and tag study development; Skyler Street for design work on the fish passage system; Chelan County PUD for their experience; Dennis Rohr for providing facilitation support; NOAA Fisheries engineer Bryan Nordlund for guidance on the fish passage system design; Chelan County PUD for their work and success at passing fish at Rock Island Dam; Dave Duvall and Eric Lauver for administering the OLAFT trap and haul; Steve Gwynn for designing the OLAFT modifications; Skyler Street for design work on the fish passage system; Russell Langshaw for design review and tag study development; Blue Leaf Inc. for collecting behavioral information; Battelle for conducting the acoustic tag work; Mark Woodward for managing pump cleaning; John Monahan for assistance with Pacific Lamprey passage; Bob Rose, Tom Skiles, and Brian McLraith for lamprey tube trap design and providing test fish from John Day Dam; Kuney-Goebel JV for constructing the fish passage and OLAFT modifications; Grant PUD hydro operators for crane work and monitoring pumps; and WDFW, Chelan PUD, and Douglas PUD for providing trap-and-haul staffing and fish trucks. Thanks are also extended to Lisa Anderson for creating the map.

**THE NUMBERS**

More fish passed Wanapum Dam in 2014 than in any other year since dam construction was completed in 1963. Of the nearly 800,000 adult fish that passed safely upstream of Wanapum Dam (Figure 2), more than 99% traveled through the modified fish passage system. Only 1% were trapped and transported around the dam. None of the hundreds of thousands of fish observed ascending the fish passage system died upon entering the Wanapum pool, despite a variety of impact orientations (e.g., head, tail, body first upon entry) and impact velocities that exceeded 7.6 m/s. There were no mortalities observed from the trapping and hauling of salmon, and less than 1% of the lampreys that were trapped and hauled died during the process. Travel time of PIT-tagged adult spring Chinook Salmon between Priest Rapids Dam and Rock Island Dam (93.3 km) was surprisingly good, and survival approached 100%.

A total of 2,263 Pacific Lamprey were trapped at Priest Rapids and Wanapum dams and transported above Rock Island Dam. This represented 48% of the lampreys that passed Rock Island Dam. The other 52% passed over the modified passage system.

Juvenile salmon and steelhead survival migrating downstream through Wanapum pool contributed toward exceeding the survival standard (86.5% survival) for the Priest Rapids Project, which included the 93.3-km stretch between the base of Rock Island Dam and the tailrace of Priest Rapids Dam (Figure 1). Survival exceeded 89% for both Chinook Salmon (90.8%) and steelhead (89.3%) in the Priest Rapids Project area. Survival in the Wanapum Dam and pool was 92.9% for steelhead and 94.5% for yearling Chinook Salmon.

**DECONSTRUCTION OF FISH PASSAGE SYSTEM**

On November 15, 2014, Grant County PUD received notification from its federal regulators that the Wanapum pool level could be increased by 5.2 m and operate within a range of 170.1 to 171.3 m above sea level. This would allow the permanent fish ladders to operate within their design specifications. Before the pool could be raised, both the left- and right-bank slides, plywood ramps, weir, and pumps were removed. Grant County PUD resumed normal operations of the reservoir on March 21, 2015.

**SUCCESS**

The monumental effort described in this article demonstrates that unprecedented problems can be solved quickly when agencies, tribes, and utilities work together to achieve a common goal. Keys to this success were the early development of quantitative goals, implementation of robust and shared monitoring, agreement on clear decision points, and prioritization of frequent communication. Furthermore, it was fortuitous that working relationships had been established well before the emergency and that experienced technical experts and facilitation support were a part of the response team. Newspapers, TV stations, and other media outlets recognized the fish passage success and reported on the level of work and cooperation. Clearly, the response to the fracture in Wanapum Dam resulted in an unprecedented fish passage success.

**ACKNOWLEDGMENTS**

A monumental effort such as the one described in this article can only be accomplished by a team of hard-working, creative, and credible people. We thank some of the key individuals by name here but acknowledge the many others who were key to accomplishing the emergency fish passage at Wanapum Dam. We thank the members of the Priest Rapids Coordinating Committee for participating in such a grand collaborative experience; Dennis Rohr for providing facilitation support; NOAA Fisheries engineer Bryan Nordlund for guidance on the fish passage system design; Chelan County PUD for their work and success at passing fish at Rock Island Dam; Dave Duvall and Eric Lauver for administering the OLAFT trap and haul; Steve Gwynn for designing the OLAFT modifications; Skyler Street for design work on the fish passage system; Russell Langshaw for design review and tag study development; Blue Leaf Inc. for collecting behavioral information; Battelle for conducting the acoustic tag work; Mark Woodward for managing pump cleaning; John Monahan for assistance with Pacific Lamprey passage; Bob Rose, Tom Skiles, and Brian McLraith for lamprey tube trap design and providing test fish from John Day Dam; Kuney-Goebel JV for constructing the fish passage and OLAFT modifications; Grant PUD hydro operators for crane work and monitoring pumps; and WDFW, Chelan PUD, and Douglas PUD for providing trap-and-haul staffing and fish trucks. Thanks are also extended to Lisa Anderson for creating the map.
Figure 2. The abundance of species counted at Rock Island Dam from 2000 to 2014. The data were collected by Chelan Public Utility District and accessed through DART (Data Access in Real Time).

REFERENCES


