RECLAMATION
Managing Water in the West

Sockeye Smolt Outmigration at Cle Elum Dam

Results of Field Studies 2013-2014

Sockeye smolt in Cle Elum River (Photo: Tim Webster, WDFW)

U.S. Department of the Interior
Bureau of Reclamation

June 2015

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Fisheries and Wildlife Resources Group
86-68290

Prepared for:

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June 2015

SUMMARY:

The Yakima River Basin Water Enhancement Project (YRBWEP) legislation authorized the Bureau of Reclamation to build fish passage facilities at Cle Elum Reservoir. Interim downstream fish passage was constructed in 2005, and has operated since 2006. Since 2009, Yakama Nation Fisheries has been reintroducing adult sockeye salmon to the reservoir, allowing them to spawn in the Cle Elum River. Juvenile sockeye smolts were observed migrating out of Cle Elum Reservoir during interim fish passage operations which started as early as April 4 in 2011, and as late as May 13 in 2014.

Hydroacoustic monitoring of sockeye smolt migration was conducted in 2013 and 2014, and visual observations of fish were noted. These observations found sockeye migrated out of the reservoir using the interim flume with little or no delay at flows ranging from 100-300 cfs. Water velocities were measured at the flume entrance and velocity gradients were found to be within juvenile fish passage guidelines. Fish counts from the Chandler Juvenile Facility at Prosser Dam in the lower Yakima River showed that sockeye smolts arrived there within 4 days in 2013, and within 3 days in 2014, a distance of about 130 river-miles. The greatest abundance of migrants occurred from mid-April through mid-May; fish were most active at night.

Visual observations suggested a potentially significant but unknown proportion of sockeye smolts were injured while exiting the interim fish passage flume. Injuries most likely occurred when fish entered the Cle Elum River, as flume water velocities may reach 40 ft/sec. An evaluation of mortality at the interim fish passage flume could aid in a more complete understanding freshwater production and productivity of reintroduced sockeye salmon in Cle Elum Reservoir.

INTRODUCTION:

The U.S. Department of the Interior, Bureau of Reclamation, has been providing irrigation water in the Yakima River basin since the turn of the 20th century. The construction of the Tieton and Sunnyside divisions of the Yakima Project started in 1906 (Dick 1993). Construction on canals, dams, and reservoirs continued over the next several decades, with the completion of the last major dam at Cle Elum Reservoir in 1937. These and other facilities have helped in the development of over a half million acres of highly valued irrigated cropland as well as providing flood control, hydropower, and recreational benefits.

Reclamation facilities have also blocked fish migration, reduced instream flows, and altered aquatic habitat conditions, eliminating or reducing fishery resources in the Yakima basin, including runs of Chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), coho (*O. kisutch*), steelhead trout (*O. mykiss*) and bull trout (*Salvelinus confluentus*). Among these, sockeye are unique in being obligated to live in freshwater lakes for at least 1 year prior to migrating to the ocean. Yakima basin runs historically sustained significant Native American fisheries at Cle Elum, Kachess, Keechelus, and Bumping lakes in the Yakima basin, and these runs contributed to harvest in the Columbia River (Mullan 1986). Once dams were built to create storage reservoirs, the upstream and downstream migration of salmon was blocked, extirpating Yakima Basin sockeye runs.

Following a series of droughts which affected water supplies, the U.S. Congress passed Public Law 103-434, the Yakima River Basin Water Enhancement Project (YRBWEP), in 1994. The act had the goals of protecting and enhancing fish and wildlife resources through improved water management, while also improving the reliability of water supply for irrigation. Section 1206 of the act authorized Reclamation to make modifications to Cle Elum Dam to increase the amount of reservoir storage and to construct juvenile fish passage facilities.

Under this authorization, Reclamation has been working with partners, including Yakama Nation Fisheries, to explore whether fish passage features could be implemented at Cle Elum Dam to aid in the reintroduction of sockeye to the upper watersheds. Passage at Cle Elum Dam could benefit a myriad of other fish species and enhance ecosystem health of the Cle Elum watershed, the largest reservoir and river network in the Yakima Basin blocked to fish migration. The Yakima Basin Integrated Plan is also funding studies evaluating fish passage at Bumping, Kachess, Keechelus, and Rimrock reservoirs, along with permanent passage facilities at Cle Elum.

In 2005, Reclamation constructed an interim fish passage facility at Cle Elum Dam. A narrow wooden flume was built to provide a surface passage route over the spillway. Flow into the flume is controlled by adjusting a series of weir boards. These boards allow the flume to operate from reservoir pool elevation of 2224.0 feet up to the full pool of 2240.0 feet (Figures 1 and 2). Flows in the flume during fish passage operations can range from around 90-400 cubic feet per second (Quentin Kreuter, Reclamation, personal communication), with 1-5 feet of head flowing over the center weir.

A series of studies were undertaken by Yakama Nation, Reclamation, and U.S. Fish and Wildlife Service personnel to explore fish use of this temporary passage facility. For these studies, groups of tagged hatchery-origin coho smolts were released into the reservoir either directly from a transport truck or held and released from a net pen. In 2006, 10,000 PIT-tagged coho were released from a net pen in the reservoir. Slightly over 600 of them were detected by a PIT-tag array built into the passage flume. The same was done in 2007, with the flume operating for a period of 98 days from early April through early July. During this time, almost 4,600 smolts were detected, with about 20 percent of those detections being fish released during 2006 (Reclamation 2006, 2008).

A.

B.

C.

Figure 1. A – Cle Elum Dam fish passage weir from upstream on spillway crest. The gantry and crane on top are used to drop 11-foot-wide x 1-foot-high weir boards into slots between the concrete pillars. Once weir boards are in place the spillway tainter gate is raised to allow fish a surface passage route over the dam boards and down a wooden flume.

B – Looking at the wooden spillway flume in a downstream direction as it is filling with water.

C – Spillway flume entry to Cle Elum River.

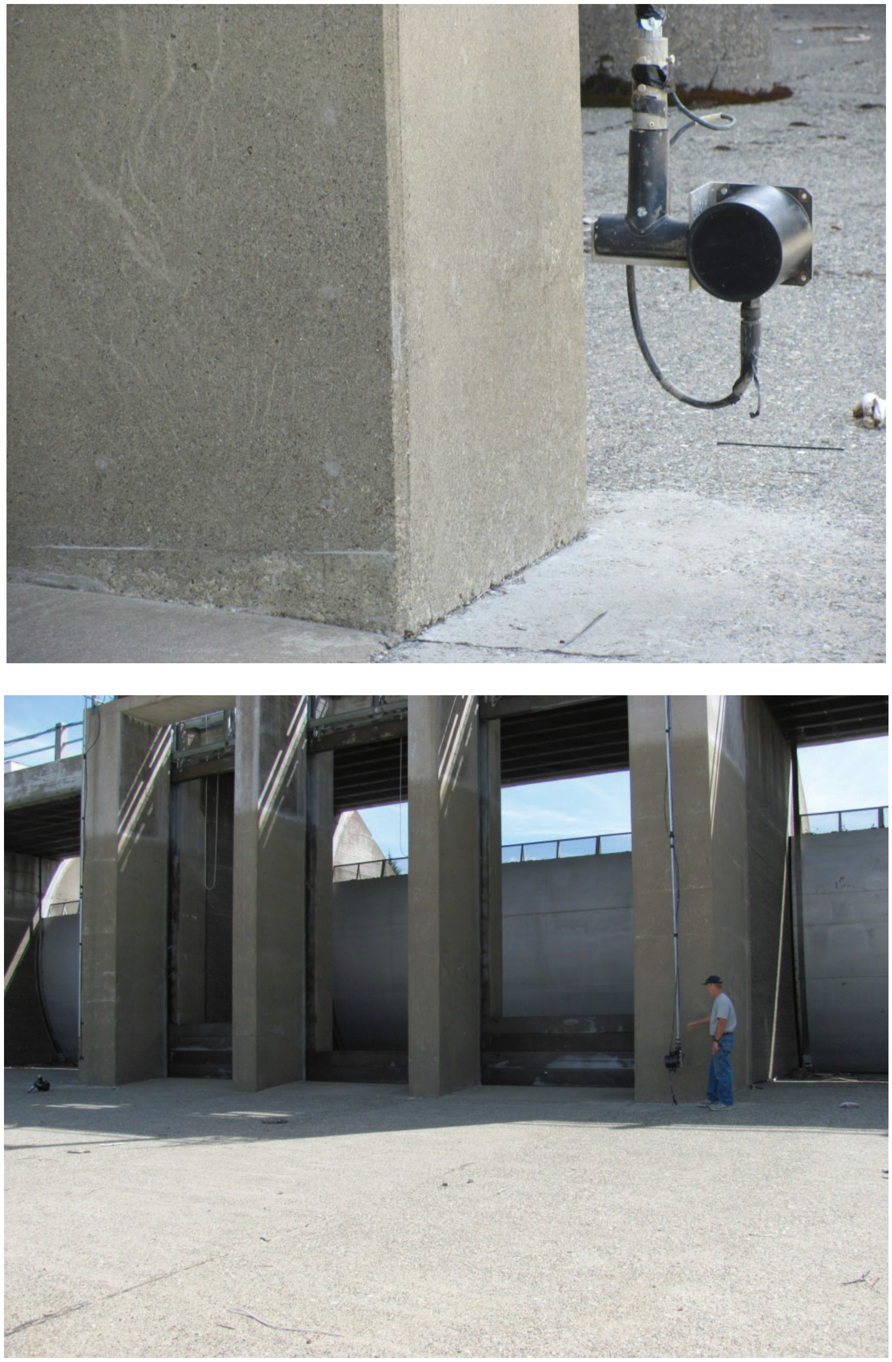

Figure 2. Picture of DTX split-beam transducer prior to reservoir levels rising to spillway elevations. The ROS rotator can be seen to the left of the sonar head, which was attached via a custom fabricated aluminum plate. In the lower picture, both units can be seen hanging from the safety rail at the top of the gate structure, one on either side of the gates, used for spilling during the study period.

In 2008, two groups of smolts were released into the reservoir in late April, one group from a net pen, and another group released directly to the upstream portion of the reservoir. Fish passage from the flume was initiated on June 6, 2008, and within a couple of days, large pulses of tagged coho that had been released directly into the upper reservoir were observed passing down the flume. Following this initial pulse, low numbers of fish were observed to continue passing down the flume through the end of the study. Near the end of June, a secondary pulse of movement was observed, and composed primarily of fish that had been released from net pens. It was hypothesized that the difference in timing of fish movement between the two groups was related to the fact that the group of fish released directly into the upper reservoir had more time to traverse the reservoir and stage, whereas the net pen fish were held long-term in the pens, and only released a few days prior to flume operations commencing (Lind et al. 2009).

In 2009, 1,000 adult sockeye salmon, consisting of stocks from the Wenatchee and Okanogan river basins, were transported from Priest Rapids Dam on the Columbia River and placed directly into Cle Elum Reservoir, allowing them to move up into the river and tributaries for spawning. The progeny of these spawners reared in Cle Elum Reservoir for 1+ years. Once these fish became smolts, they migrated through Cle Elum Reservoir and used the temporary passage facility to exit the reservoir over the spillway. Outmigrating sockeye smolts were observed at both Roza and Prosser dams, indicating successful passage out of Cle Elum. Since the original release, numbers of adult fish released into Cle Elum each year have varied based on availability of adults, but in 2010, 2,500 fish were transported into the reservoir; 4,100 in 2011; 10,000 in 2012; 4,000 in 2013; and 10,179 in 2014.

Little information, however, existed concerning how and when sockeye smolts exit the reservoir and their behavior approaching the fish passage facility. Obtaining naturally spawned sockeye smolts in sufficient numbers for continued PIT-tagging for monitoring of outmigration would be extremely difficult. Additionally, since a new fish bypass structure is being proposed, it was important to understand the behavior of fish as they approach the dam and bypass.

The objectives of this study were to use a hydroacoustic array mounted on the dam to describe the outmigration timing and abundance of fish, and to describe local behavior and movement patterns of smolts as they approach the interim passage facility. These data were supplemented with visual observations of smolts in the Cle Elum River and smolt counts from the Chandler Juvenile Facility from 2011-2014.

METHODS:

Fish passage monitoring was accomplished using a Biosonics DTX hydroacoustic system utilizing two 6.5^0 splitbeam transducers, one operating at 200 khz and the other at 420 khz. The transducers were put in place prior to reservoir levels reaching the elevation of the spillway, thus allowing for easier mounting. Transducers were mounted on either side of the spillway structure, and oriented to face each other across the inlets to the spillway gates (Figure 2). Each transducer was mounted to an ROS(Remote Ocean Systems) pan and tilt rotator which, in turn, was attached via a base plate to a 10-foot-long, 2-inch diameter conduit pipe. Several lengths of conduit were screwed together to achieve the desired length (distance to water surface). The conduit was held in place via mounting brackets attached to the safety railing around the top of the spillway gates. The rotators were used to fine tune the aiming of the sonar heads, and the mount along the railing allowed the units to be manually raised and lowered to track changes in water depth associated with increasing reservoir levels. The bypass structure was operated such that weir boards were added on a periodic basis as the reservoir rose to maintain flow over the structure to no more than 1 to 2 feet in depth. Transducer depth was adjusted accordingly to ensure the zone of entrainment was always being monitored.

Data was collected via the Bisonics Visual Acquisitions program installed on a laptop computer, and saved to the computer's internal hard drive. Units were allowed to run continuously for the study duration. Data collection parameters were set at 5 pings per second, 0.4ms pulse width and a collection threshold of -75db, which was well below any expected target size. Files were named according to time and date, and were 30 minutes in length in an effort to minimize data loss during any system outages. During site visits, all data was backed up to external hard-drives to further minimize the chance of data loss.

The DTX surface unit, associated laptop computer, and rotator control unit were maintained in a set of job boxes next to the dam in 2013, and, in 2014, in a small weatherproof enclosed trailer. All power was routed through a UPS to minimize the effects of short-term power fluctuations. Further, a Verizon MIFI hotspot was used to provide a wireless connection, and allowed for remote control of data collection and to check system integrity.

All acoustic data was analyzed using Echoview version 6.x, and data output to Excel-compatible spreadsheets. Once imported to Echoview, raw DTX data was thresholded when needed to remove the effects of wind-generated acoustic noise in the water column. The dataset was then echo integrated and exported as NASC (Nautical Area Scattering Coefficient). This value was exported as an average 30-minute value for each dataset, and served as a relative index of fish numbers which could be compared across time periods within each year. While not providing true numbers of fish, it does provide an index that is directly comparable from one period to the next.

Meteorological data was obtained from several local sites that had archived wind readings available. Most days, a strong down canyon wind began to develop on Cle Elum in mid- to late afternoon. Due to the location of the dam at the lower end of the valley, strong wave action impacted the ability to identify fish at certain times of the day. Incorporating wind data allowed us to differentiate periods of noise from periods of high fish movement.

In 2013, a series sustained equipment failures prevented us from capturing the first couple of days of smolt passage. Flume operations started April 22, but the acoustic systems were not operational until April 25. Reservoir levels were not up to the elevation of the transducers during installation; thus, we were not able to complete a full preoperational test. The units were powered up and the transducer connections checked, but circuit board failures prevented the transmittal of data. In both cases, it appeared the damage had occurred when the units were shipped to the study site. The manufacturer is nearby in Seattle, which allowed the unit to be repaired quickly and placed back online, but full hydroacoustic operations were not achieved until April 28. Hydroacoustic data collection was uninterrupted during fish passage operations in 2014.

RESULTS AND DISCUSSION:

During the hydroacoustic study, the operational start date of the fish passage flume was April 22 in 2013, and May 13 in 2014, due to differences in annual reservoir volumes. In 2014, fish passage was shut down May 21-22 and 28-29 for repairs (Figure 11). Since there was no information regarding the numbers, age distribution, spatial distribution, or general disposition of sockeye smolts in Cle Elum Reservoir, we can only make inferences about differences in the pattern of fish movement through the structure each year. During both years of our study, the start date of flume operations was significantly earlier in the season than it was for the tagged coho smolt releases of 2006-2008, when flume operation began in early June. In the two other years of sockeye passage (Figure 10), operations started April 4, 2011, and April 24, 2012. The date of flume operation is potentially significant when evaluating flume operation effects on fish migration as more fish become ready to migrate as the season progresses.

Several data analyses techniques were tried in an effort to obtain the highest resolution possible out of our datasets. Ideally, single-target tracking would have provided the greatest amount of data, as it would have allowed individual trajectories to be developed for fish. Unfortunately, it was quickly determined that generating traces for individual fish was not possible. Smolts moving around in the forebay tended to form small or large schools (Figure 3), and only rarely were present in low enough numbers that any target tracking would have been possible (Figure 4). Since fish were schooling, the best approach to obtain an overall estimate of fish density was to echo integrate the data and come up with a relative density index. This was similar to what was done during studies at Roza Dam in 2006 and 2007, where sufficiently high densities of fish prevented us from developing fish tracks (Sullivan and Horn 2007).

One of the goals of the study was to try to observe broader scale behavior of smolts by scanning further out into the forebay of the reservoir. This proved ineffective, as we were not able to individually track fish and look at spatial differences in fish distribution. It is suggested that if there is a need to examine fish distribution further from the face of the dam, that a series of mobile boat surveys be conducted. This could be done in a manner so as to generate a density map of smolts to determine if they favor one particular portion of the reservoir during their approach to the bypass structure. Surveys could be conducted over several days and at different times to gain a more complete understanding of fish behavior.

Wind was a significant issue when trying to analyze data. Cle Elum typically became very windy each afternoon, with the dam located at the end of the reservoir receiving the maximum brunt of the wave action. Wave action acts to introduce microbubbles into the water column, which, while small on an individual basis, cumulatively produces a significant impact during echo integration (Figure 5). Wind-generated reverberation in the water column was a significant problem in 2013, and some of the biggest spikes in NASC were actually due to wind events, not fish (Figure 6).

While wind did cause extreme spikes in NASC, fish movement in general followed the expected patterns for sockeye smolts, thus allowing us to remove the impact of wind most days. Typically, as the day shifted from dusk to dark, smolt numbers increased dramatically across the zone monitored by the transducers, indicating movement toward the bypass structure (Figures 6 and 7). By this time of the day, wind had also died down significantly, which allowed clear delineation of these pulses of fish (Figures 6 and 7).

In 2013, we visually observed sockeye smolts leaving the reservoir within 45 minutes of opening the fish passage flume. By the time the hydroacoustic monitoring was in place on April 25, it was apparent significant numbers of fish had already emigrated (Figure 8). As sockeye smolt migrants appeared at Prosser Dam in significant numbers on April 26 (Figure 11), 4 days after the flume operations commenced, there was little or no delay in fish migration out of the reservoir. Fish migration appeared to fall off by the second or third week of May and, although the data show spikes in fish densities after that time (for example, see June 2-3 2013, Figure 8), visual observations were of schools of fish milling around in the forebay without any directed migration. These fish may have been schools of sockeye parr feeding, or smolts reluctant to migrate until night, when we could not visually observe them.

In 2014, we had one transducer fully operational on the first day. The 2014, data indicated that most fish migrated almost immediately and were probably out of the system within 10 days. The largest escapement of fish was during the first 48 hours of operation, with day 2 being a large number of fish. Fish were visually obvious in the forebay of the dam and along the face of the dam, and were observed far out into the reservoir pool, indicating significant numbers of juveniles were in migratory condition. After the first 10 days of operation, fish continued to move through, but after the third week of May, relative fish density had significantly dropped off (Figure 9). Large numbers of sockeye migrants were first observed at Chandler Juvenile Facility on May 16, only 3 days after the fish passage flume was opened.

Flume operations have been adjusted over time to using only a single, 11-foot-wide weir board for fish passage, with 2-5 feet of head passing over it, leading to discharges in the flume ranging from 150-300 cfs. This configuration has been found to maintain water velocity gradients within recommended guidelines (Vermeyen 2014). With 2 feet of head on the flume weir boards, the maximum near-surface velocity gradient was 0.79 ft/sec/ft. For 3 feet of head on the weir boards, the maximum near-surface velocity gradient was 1.01 ft/sec/ft. With these operations, velocity gradients are at or below 1.0 ft/sec/ft, which has been shown to cause avoidance behavior in migratory Atlantic and Chinook salmon smolts. This is a design consideration for the operation of juvenile fish passage facilities (Vermeyen 2014).

We were not able to look at the first couple of days' data in 2013, due to equipment malfunctions, but it is interesting which period of time fish passage occurred. While there are expected to be year-to-year differences, in both years, the numbers of fish passing appeared substantially diminished by late May, even though passage did not begin in 2014, until almost mid-May. This pattern suggests a large proportion of fish were "waiting" to migrate.

When given the opportunity to migrate earlier, as in 2011 (Figure 10), sockeye started migrating in large numbers in mid-April through mid-May, similar to results for the Columbia River (Chapman et al. 1995) at Rock Island Dam (Figure 12). Variations in outmigration timing from their natal lake can be affected by water temperatures, wind direction and its effects on the reservoir surface, and age, size, and physiological condition of the smolts (Burgner 1991). Migration typically occurs between sunset and sunrise with the migration period spread between late April and into early July, depending upon latitude and seasonal conditions (Johnson and Groot 1963). Data summaries indicate sockeye and coho smolts passing Bonneville Dam peaked around mid-May, with fish appearing from early- to mid-April through about the third week of June (Carter et al. 2009, Park and Bentley 1967).

Finally, during these studies, we observed significant numbers of sockeye smolt mortalities at the base of Cle Elum Dam (Figure 12). These observations were supplemented by observations of injured sockeye smolts found further downstream in the mainstem Cle Elum River (Tim Webster, WDFW, personal communication). Finding dead or injured fish so easily suggests there could be a significant mortality rate for fish in the interim fish passage flume. Fish are likely to be injured when they enter the Cle Elum River, as water velocities in the interim passage flume are nearly 40 feet/second (Figure 1-C). Fish may also be injured in the flume, as the spillway surface is rough and has been eroding.

Measuring flume passage mortality could be important for determining Cle Elum Reservoir sockeye production and productivity during the interim fish passage phase, as interim operations are expected to continue until permanent fish passage facilities are built at Cle Elum Dam.

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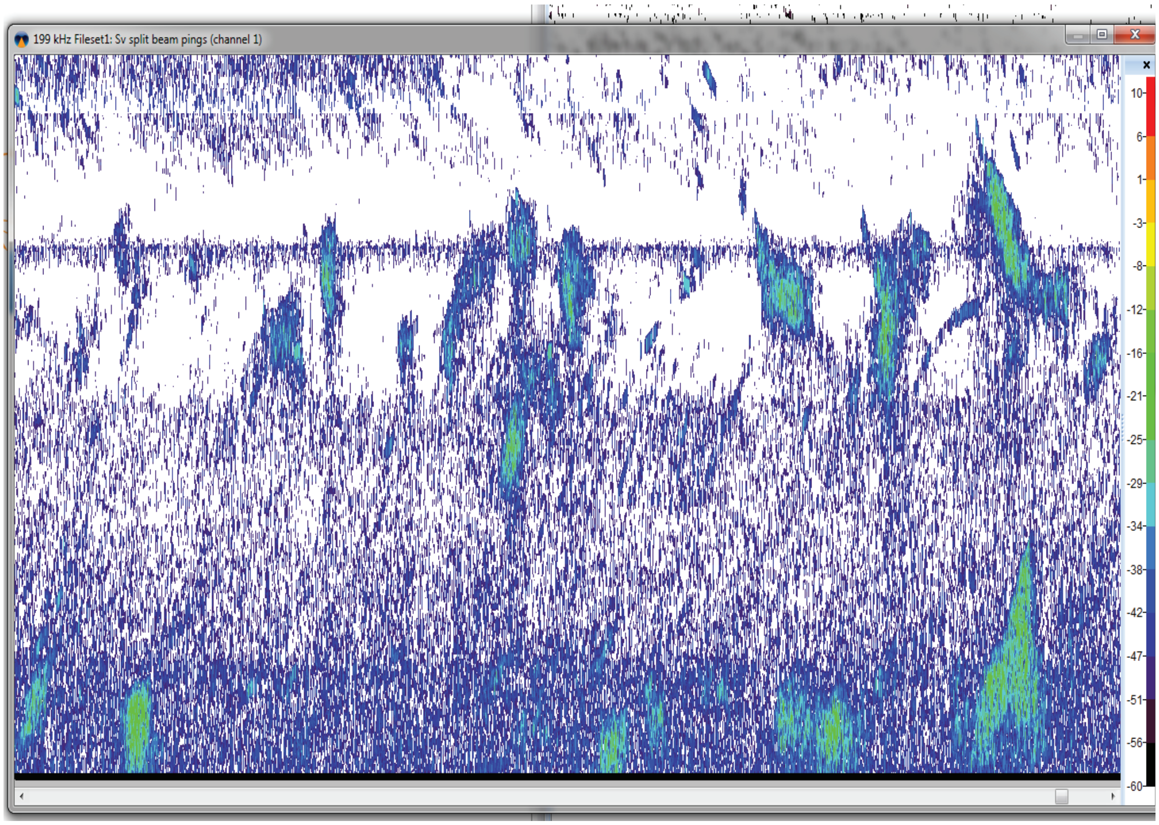


Figure 3. Typical echogram showing small groups of smolts as they pass the entrance to the flume.

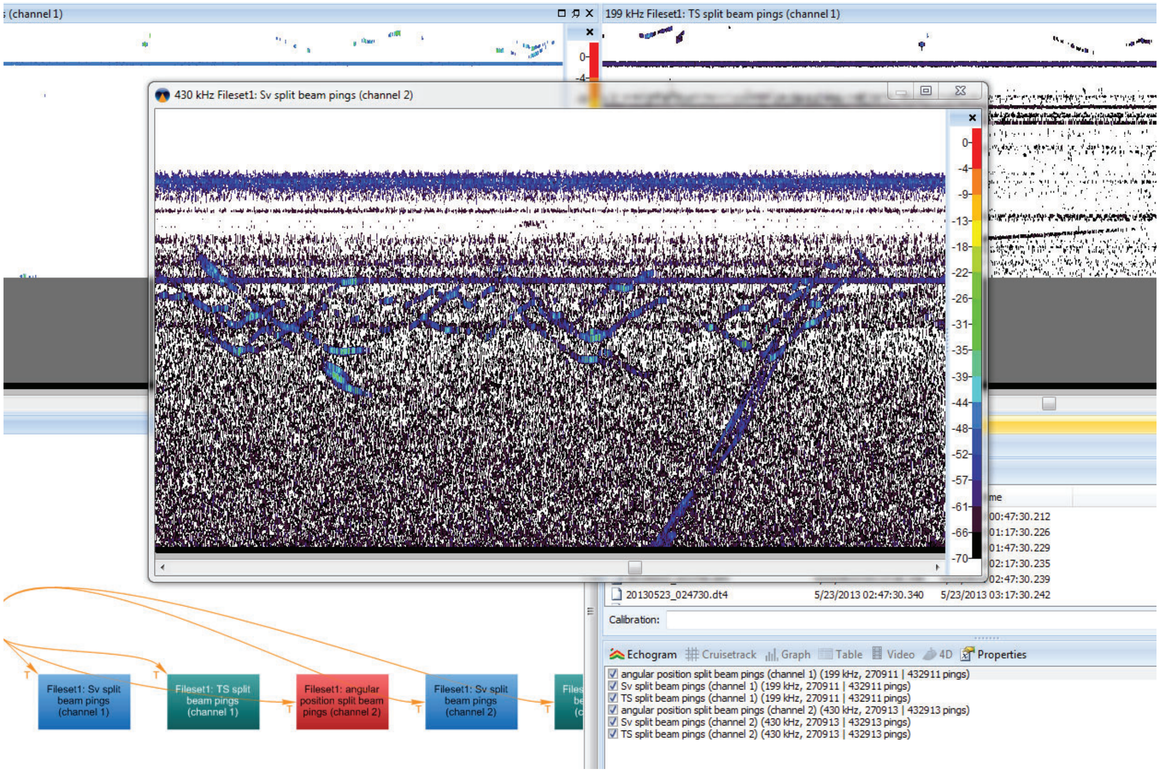


Figure 4. Only occasionally could individual fish traces be observed, such as from this echogram from later in the season when fewer fish were present.

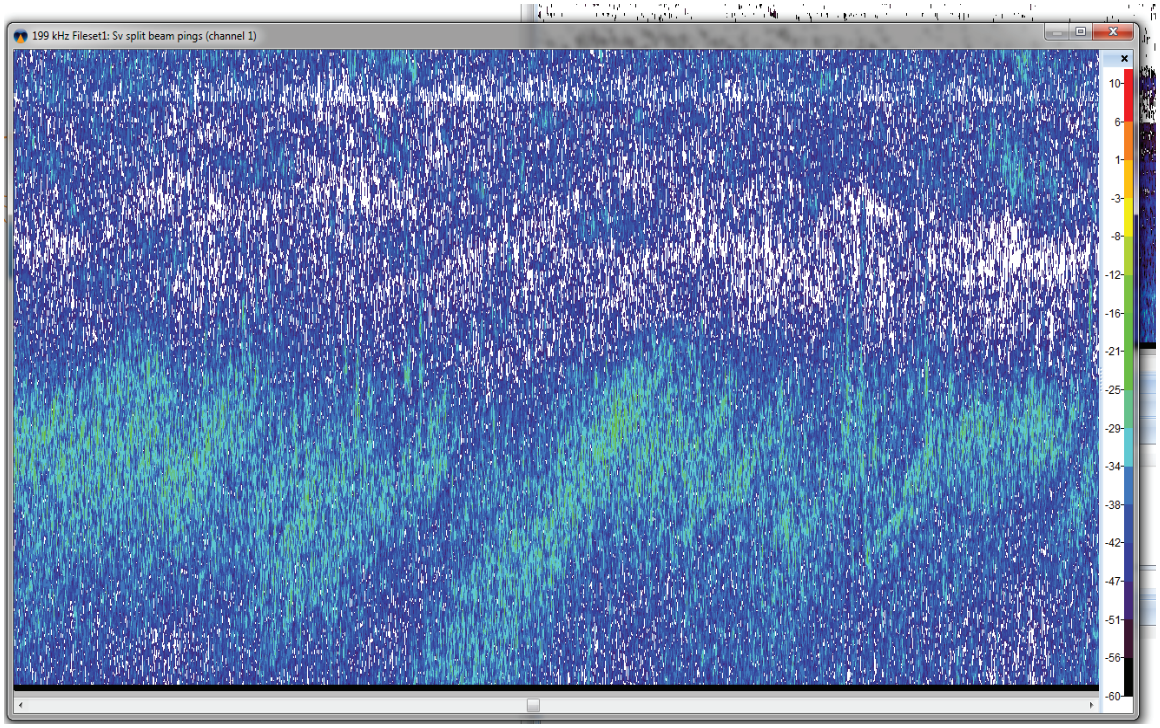
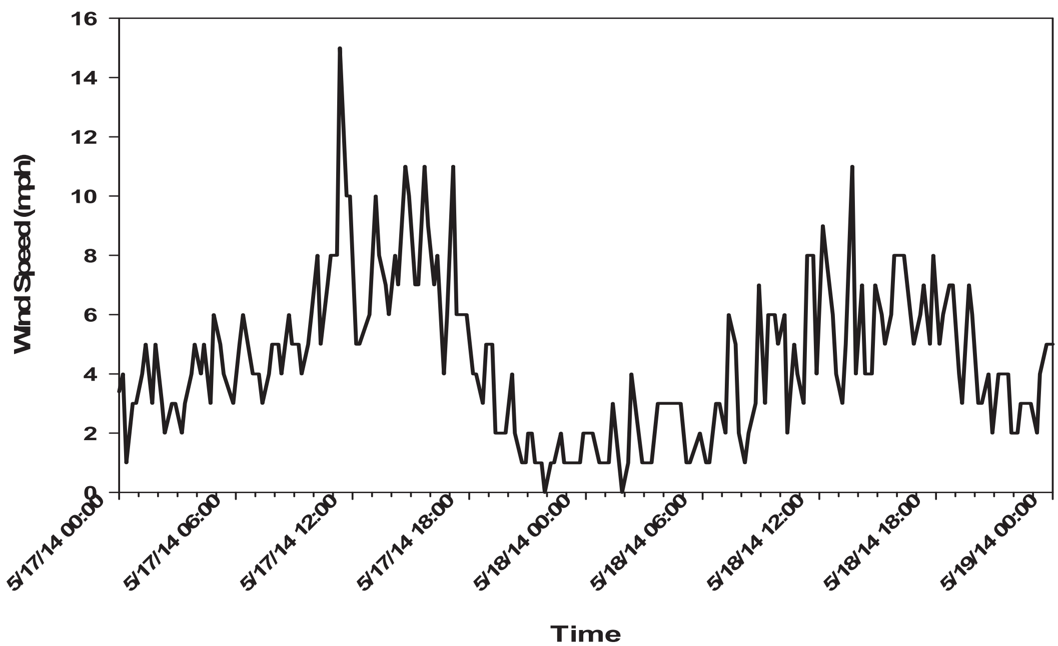
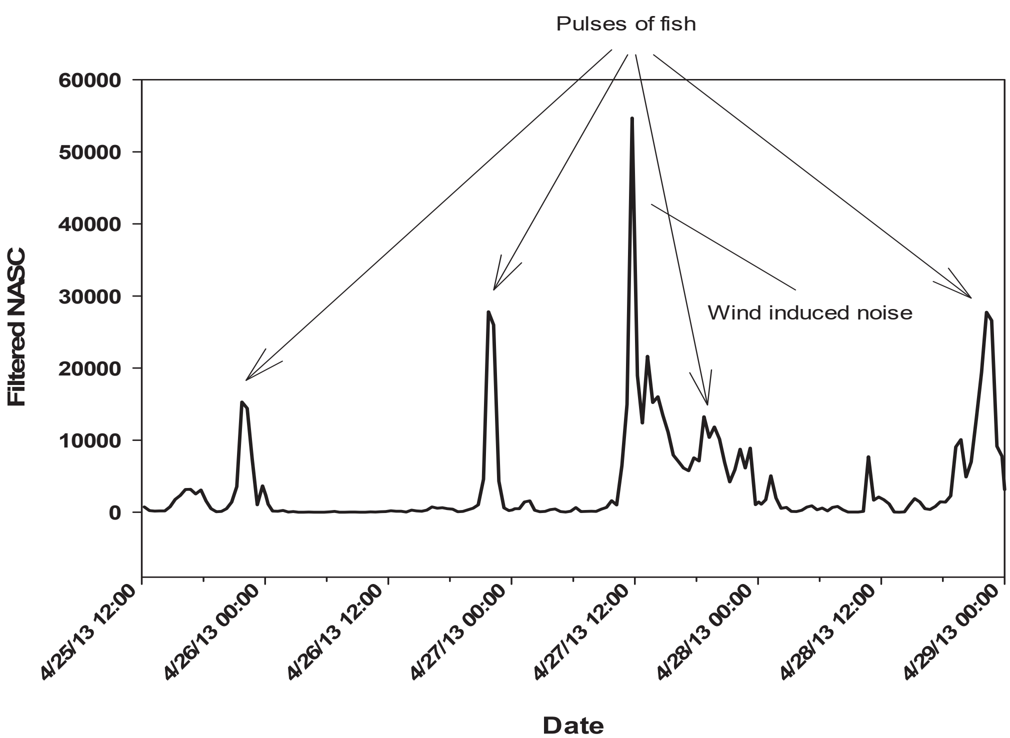


Figure 5. In this figure the effects of wind induced noise can be seen on the echogram. A high degree of thresholding would be needed to remove this noise. In extreme cases, the data was not usable due to intense wave action on those days, completely obscuring fish.



A.



B.

Figure 6. Typical daily wind pattern at Cle Elum. Panel A shows wind accelerating around midday, often abating around dusk. The lower panel B shows the impact of an extreme wind event upon NASC on 4/27/2014.

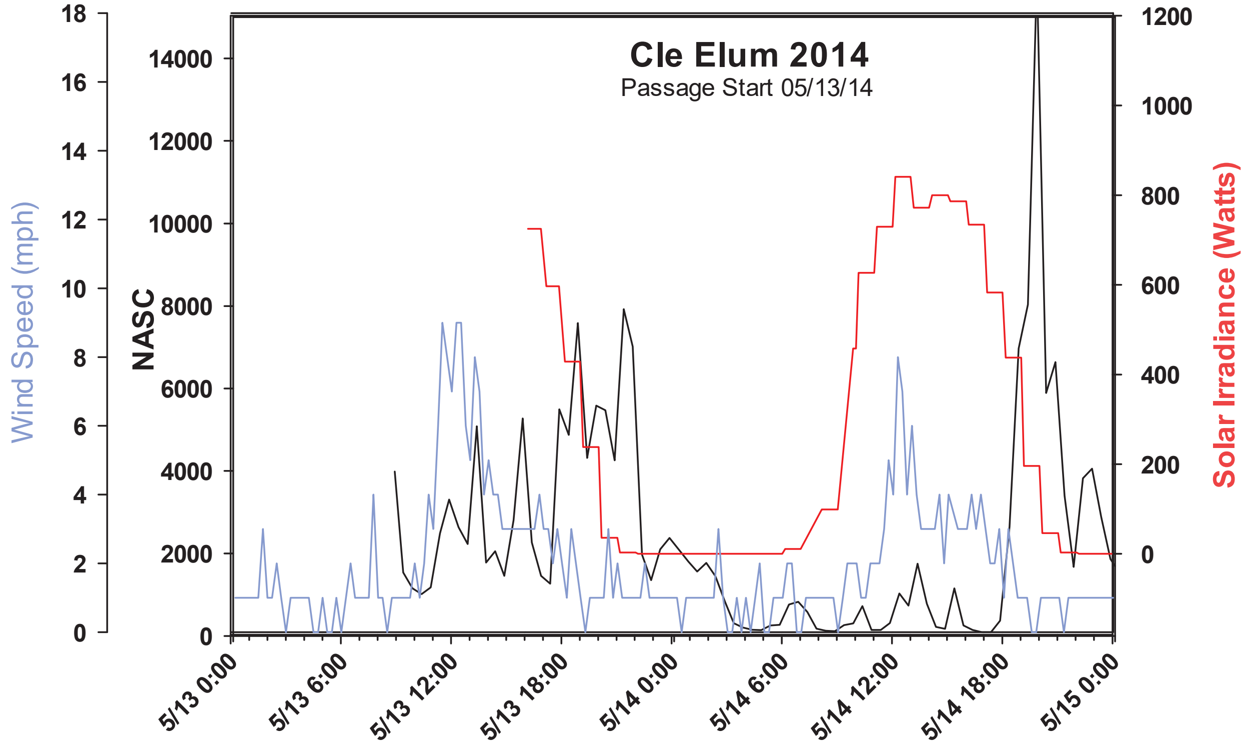


Figure 7. Timing of fish movement into the flume based on diel patterns. The black line represents an index of fish abundance, the red line is solar radiation, and the blue line is wind speed. Fish movement consistently started around dusk with an initial pulse, then lower numbers throughout the night. Higher wind on 5/13 generated a few false peaks prior to movement starting after 1800 hrs.

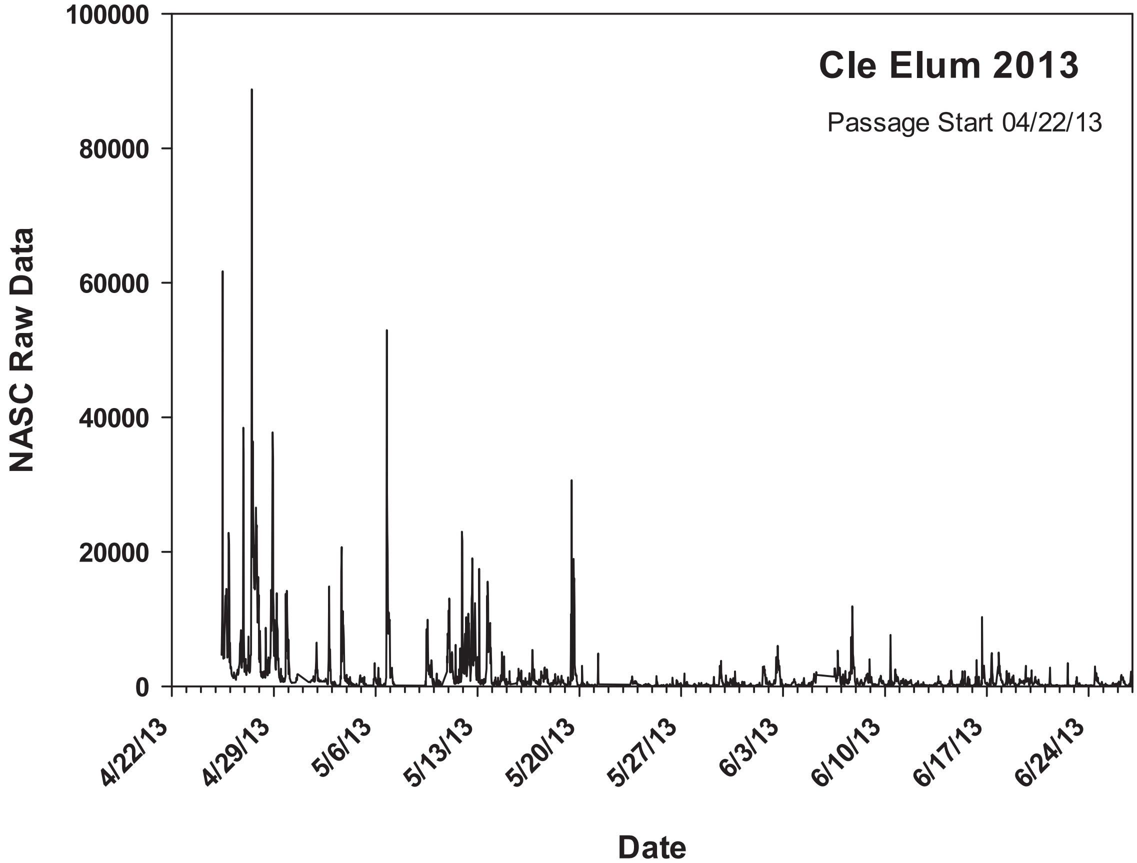


Figure 8. Pattern of NASC as measured at Cle Elum Dam during 2013. There appeared to be several pulses of fish, but the majority passed by about May 15. The large pulse on May 19 was a wind event and not fish.

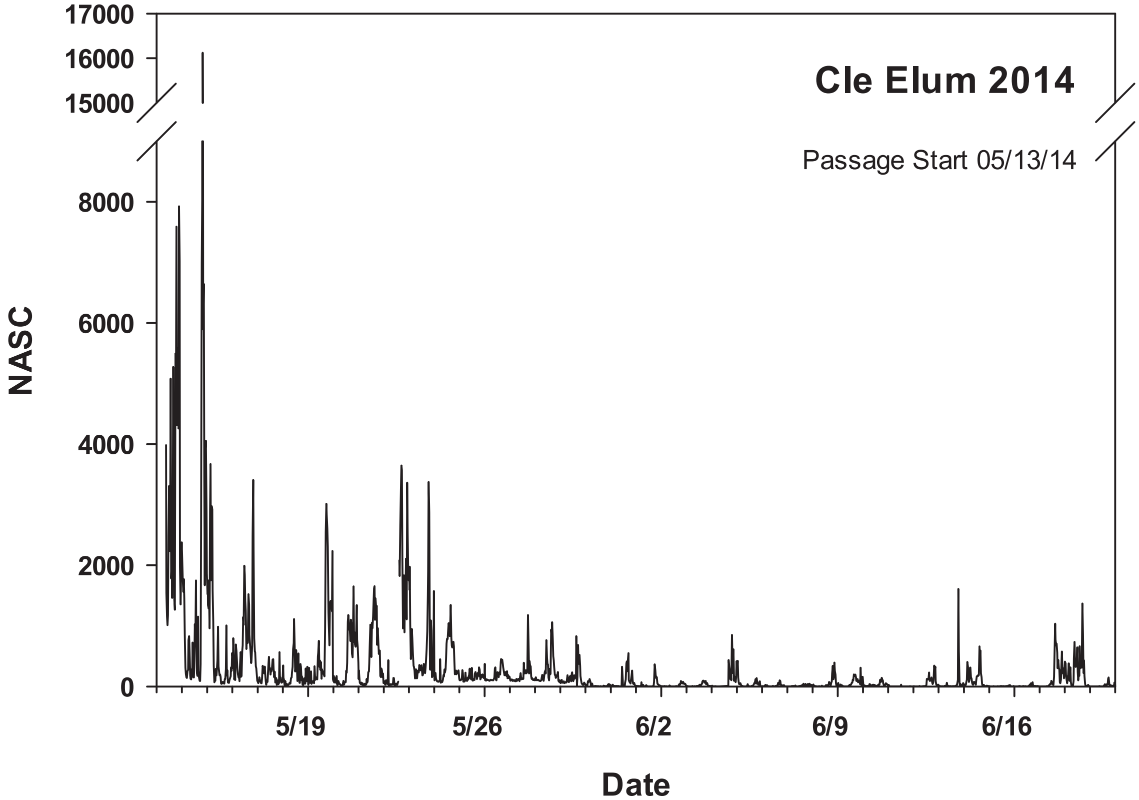
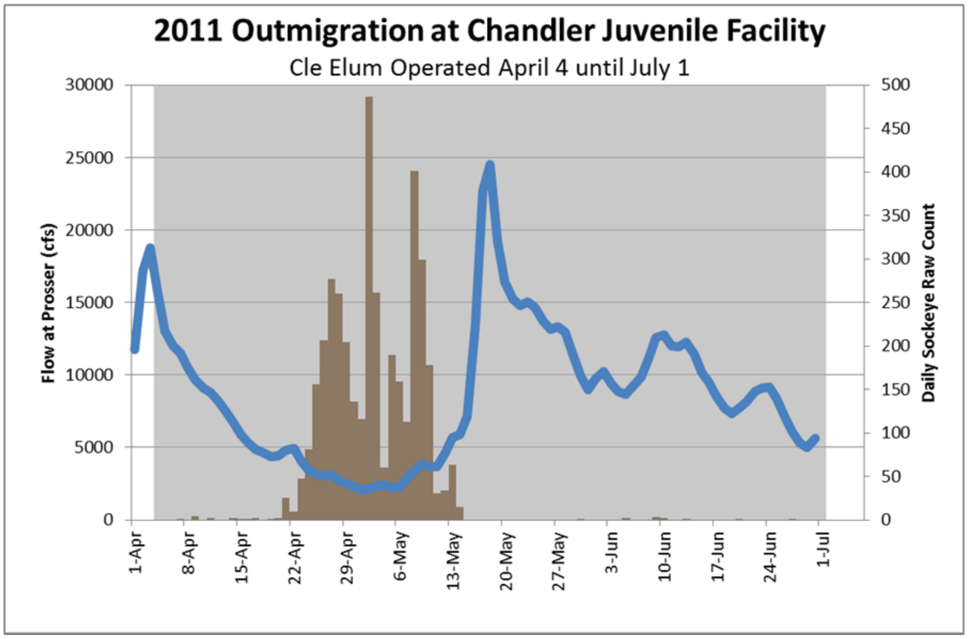


Figure 9. 2014 pattern of smolt passage across Cle Elum Dam. The greatest passage occurred the first couple of days. Numbers dropped after that time, lasting through the third week of May.



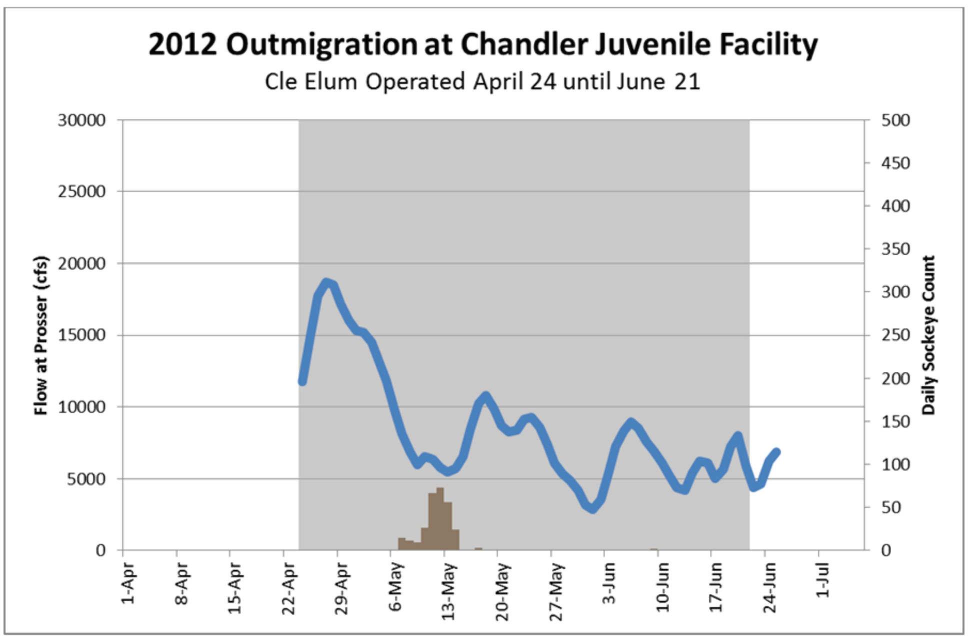
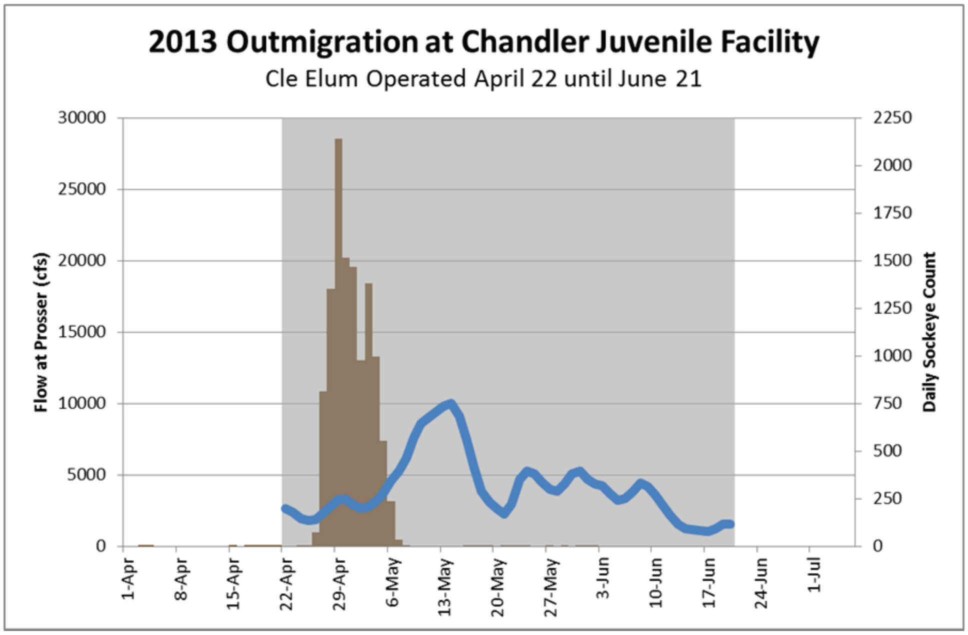


Figure 10. Raw counts of sockeye smolt migrants at the Chandler Juvenile Fish Trap located at Prosser Dam on the Yakima River (Yakama Nation Fisheries, unpublished data), along with Yakima River flow and Cle Elum Fish Passage operational data, 2011 and 2012. . Trap has not been calibrated for wild sockeye, and raw counts indicate migration timing, but not actual numbers of migrants.



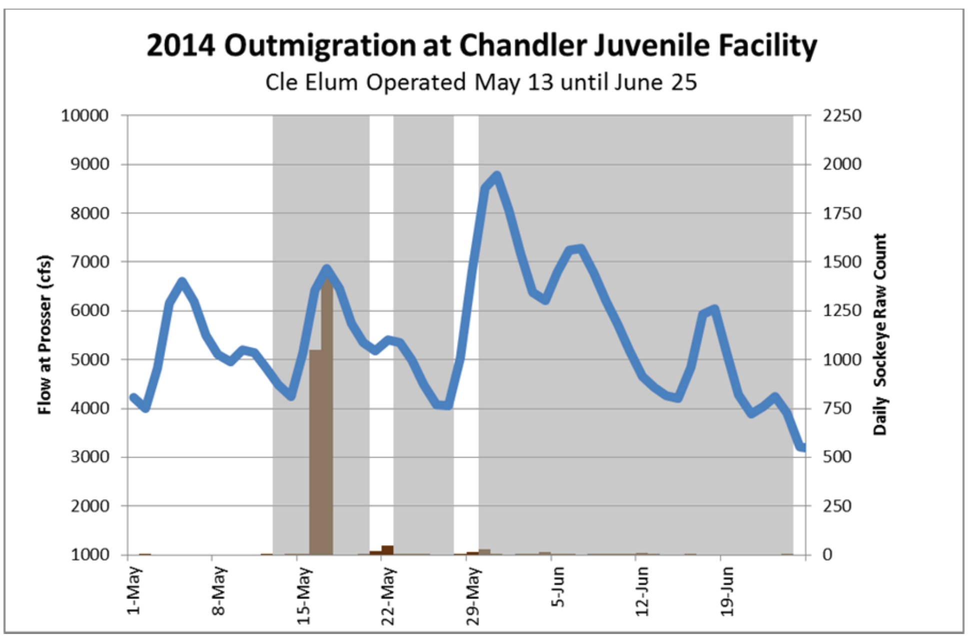


Figure 11. Raw counts of sockeye smolt migrants at the Chandler Juvenile Fish Trap located at Prosser Dam on the Yakima River (Yakama Nation Fisheries, unpublished data), along with Yakima River flow and Cle Elum Fish Passage operational data, 2013 and 2014. In 2014, the flume was shut down May 21-22 and 28-29 for repairs. The Chandler trap has not been calibrated for wild sockeye and raw counts indicate migration timing, but may not indicate actual numbers of migrants.

Figure 12. Injured sockeye smolts collected from the Cle Elum River by Washington Department of Fish and Wildlife crews during 2013. Photos by Tim Webster.

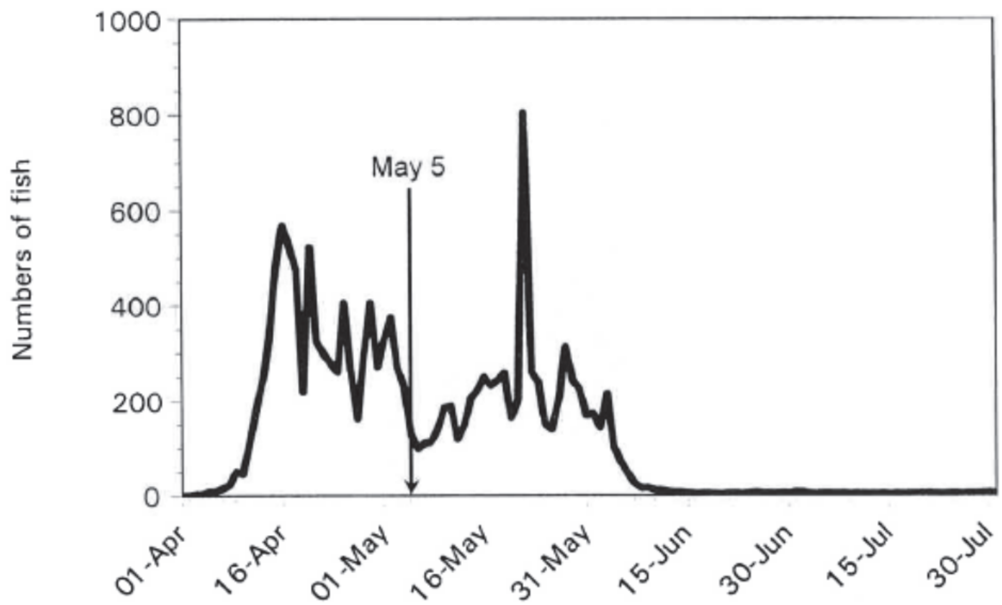


Figure 13. The average (1985-1994) time of passage for sockeye smolts at Rock Island Dam on the Columbia River (Chapman et al. 1995).