# Use of Adult Pacific Lamprey Passage Structures at Bonneville Dam
*2021 Letter Report*

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March 31, 2022

***On the cover:*** Washington Shore-AWS LPS exit slide with optical sensors.

Suggested citation for this letter report is:
Gibbons, K.M., P.L. Madson, and N.A. McClain. 2022. Use of adult Pacific Lamprey Passage Structures at Bonneville Dam 2021 Letter Report. U.S. Army Corps of Engineers, Portland District, Fisheries Field Unit. Cascade Locks, OR.

## Introduction

Here, we report the total number of adult Pacific Lamprey (*Entosphenus tridentatus*) that passed Bonneville Dam via conventional and alternative fishways designed to pass these fish. Three alternate Lamprey Passage Structures (LPSs) have been added to Bonneville Dam's fishways to increase upstream lamprey passage as they migrate to spawning grounds. Our objectives were to maintain the reporting of lamprey counts and improve lamprey LPS count accuracy. We provide corrected and validated lamprey passage counts obtained from mechanical counters at the Bradford Island AWS LPS (BI-AWS), Cascades Island Entrance LPS (CI-ENT), and the Washington shore AWS LPS (WA-AWS) and combine these counts with window counts to determine the total number of lampreys passing Bonneville Dam in 2021. In addition, we present data of the newly installed optical sensor counters at the WA-AWS exit.

The performance of the mechanical counters (i.e., paddles that are moved as lampreys pass them) has been inconsistent and variable from site to site and year to year (Cates et al. (2020), Gallion et al. (2017) and Zorich et al. (2019)). This has required increased video validation or acceptance of inaccurate counts (see Table 6 from Cates et al. 2020). Optical sensors have been used in applications such as canning lines as the standard for industrial counting and offer a possible alternative solution for LPS count accuracy. Unlike mechanical counters, optical sensors tally counts when the passing lamprey breaks a beam of infrared light as opposed to each passing fish physically contacting a paddle. The benefits of optical sensors over mechanical paddles include the elimination of incorrect counts due to physical malfunction as well as the potential injury or disease transfer to passing lampreys due to paddle contact.

## Lamprey Passage Structure Operations

The three LPSs at Bonneville Dam operated between 174 and 209 days in 2021. The BI-AWS and CI-ENT pumps were started 6 April and dewatered 1 November. The new pumps were installed for the WA-AWS and were started on 11 May and the structure was dewatered on 1 November. For a complete description of LPS locations, history, and methods please refer to Cates et al. (2020), Moser et al. (2010), and Zorich et al. (2019).

## Count Validation and Estimates

Count validation was calculated using two different methods. We used the average of correction factors calculated from 2018 to 2020 at BI-AWS and CI-ENT. However, at the WA-AWS, video validation was performed to calculate the correction factor and to compare counts with the optical sensors installed at the exit slide. To calculate the correction factor, we divided the number of lampreys that were observed passing in each video review period by the number of lampreys that were logged by the mechanical counter. Daily counts were multiplied by the correction factors to achieve the corrected counts. At each location, the computer program logger shut down occasionally creating gaps in the data. Linear interpolation was used to fill these gaps.

The Bonneville Dam LPS passage estimate during 2021 increased by 2,417 lampreys when corrected for mechanical counting error. Specific corrections indicate undercounting occurred at BI-AWS and the seasonal correction factor of 1% or 98 fish were added, thus we estimated a total of 9,870 lampreys passed. Undercounting also occurred at WA-AWS and 2,378 fish or 11% were added, thus

we estimated 23,998 lampreys passed. Overcounting occurred at CI-ENT and 60 fish or -6% were removed from the count, thus we estimated 928 lampreys passed. After correction we estimate 34,795 lampreys passed the system this year.

The estimated total lamprey escapement at Bonneville was 83,983. This count includes 44,773 lampreys passing the window (day (1 Jan – 31 Dec) and night (15 May - 30 Nov) counts), 34,795 lampreys passing through the LPSs and 4,415 lampreys that were collected for the translocation program by the Columbia River Inter-Tribal Fish Commission. For historical lamprey LPS counts refer to appendix tables A1-A3.

**Optical Sensor vs Mechanical Paddle at WA-AWS**

For the 2020 lamprey passage season, three optical counters were installed at WA-AWS exit. The optical sensors sample at a rate of 3,500 Hz or 3,500 times each second. This can result in a single fish being counted multiple times if the light beam is broken, re-connects, and is broken again by a single passing lamprey. To alleviate this issue, one-shot timers were attached to each optical counter and set to three different time delays in seconds: 0.1, 0.5, 1.0 to increase count accuracy. When compared to the video counts in 2020 preliminary results indicated overcounting of all optical sensors as well as the mechanical paddle counter. We found that as the one-shot timer period was increased, overcounting decreased. To find the optimum setting for the one-shot timers, during the 2021 passage season we used delays of 1, 2, and 3 seconds. Results of the 2021 WA-AWS paddle and optical sensor comparisons to the video counts (Table 1) indicate that the accuracy of all three timer settings is well within the 15% precision goal.

Table 1. 2021 Bonneville Dam Washington Shore AWS LPS exit comparison of mechanical paddle and optical sensor counts with video review counts.

| | | | Optical Sensor | | |
|---|---|---|---|---|---|
| | Video | Paddle | 1 Second Timer | 2 Second Timer | 3 Second Timer |
| Count | 1,480 | 1,344 | 1,586 | 1,533 | 1,485 |
| Difference | | -136 | 106 | 53 | 5 |
| % Difference | | -9.2 | 7.2 | 3.6 | 0.3 |

**Conclusion**

The LPSs at Bonneville Dam were operated to encompass the seasonal run timing of lamprey. Window counts indicated that 10% of the run passed Bonneville Dam by 18 June and the run was 90% complete by 5 August. The duration of LPS operations (6 April – 31 October) successfully covered these dates, and we recommend continuing to operate LPSs during this time frame to provide additional routes of passage for early and late migrants.

Bonneville Dam LPSs continue to pass a substantial portion of the lamprey run. Overall, LPS passage for the 2021 monitoring season was 41% of the total lamprey escapement of 83,983. As in previous years, lampreys using the LPSs favored the WA-AWS which passed 69%, followed by BI-AWS 28%, and CI-ENT 2.7%. These LPS structures provide an alternate route of passage that has proven to be successful as 30-47% of the lampreys passing the dam typically use these

structures (Cates et al. (2020), Gibbons and McClain (2021), and Zorich et al. (2019)).

The optical sensors show potential for count accuracy improvement. In 2021, each of the three time-delay settings of the optical sensors outperformed the paddle counter at WA-AWS increasing in precision with each increase in time delay setting (Table 1). The accuracy of the optical sensors was within the 15% precision we strive to achieve, and we recommend adding optical counters at BI-AWS and CI-ENT for the 2022 lamprey passage season. While the 3-second time delay setting proved to be the best performer in 2021 at WA-AWS, differences in exit configuration at BI-AWS and CI-ENT require further investigation to identify the optimal time delay setting at these locations. In 2021, lamprey passage through the LPS's was 13.4% of the five-year average and concerns that the 3-second time delay may undercount fish during a larger run year need to be assessed. Therefore, we recommend modifying the time delay settings to 2, 2.5, and 3 seconds for 2022.

**Acknowledgements**

We thank the Bonneville Dam project personnel: Ben Hausmann, Andrew Derugin, Jeanette Wendler, Rebecca Cates for cooperative operation of the LPSs, including installing and removing pumps seasonally, conducting inspections, collecting water temperatures, removing, and reporting of mortalities. We would also like to thank Bjorn van der Leeuw, and Christine Brandtner from the USACE's Fisheries Field Unit for helping with field work and/or viewing hours of lamprey passage video to allow for adequate correction of the WA-AWS mechanical counter as well as improving previous versions of this report. Thanks to Kyle Tidwell and Bob Wertheimer for their review of the report. Thanks also goes to staff from Columbia River Inter-Tribal Fish Commission for sharing Bonneville Dam collection numbers with us.

**Literature Cited**

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## Appendix A. Annual lamprey passage tables for Bonneville Dam LPSs

**Table A1.** Annual lamprey passage estimates at Washington Shore auxiliary water supply Lamprey Passage Structure during 2007-2014 (Corbett et al. 2015), 2015-2016 (Gallion et al. 2016), 2017-2018 (Zorich et al. 2019), 2019 (Cates et al. 2020), 2020 (Gibbons and McClain 2021), and 2021.

| Year | Dates Operated | # Days | Estimated Passage |
|---|---|---|---|
| 2007 | 25 June – 22 October | 119 | 2,517 |
| 2008 | 13 May - 28 October | 168 | 1,985 |
| 2009 | 26 May – 2 November | 160 | 1,199 |
| 2010 | 8 June – 25 October | 139 | 2,961 |
| 2011 | 26 May – 9 November | 167 | 6,345 |
| 2012 | 2 June – 11 November | 162 | 5,686 |
| 2013 | 16 May – 16 October | 153 | 18,329 |
| 2014 | 8 May – 29 October | 174 | 29,756[1] |
| 2015 | 30 March – 28 October | 212 | 38,069[1] |
| 2016 | 5 April – 27 October | 202 | 40,880[1] |
| 2017 | 1 May – 31 October | 184 | 90,377[1] |
| 2018 | 25 April – 31 October | 189 | 31,432[1] |
| 2019 | 11 April – 31 October | 204 | 13,819[1] |
| 2020 | 1 April – 2 November | 215 | 11,116[1] |
| 2021 | 11-May – 1 November | 174 | 23,998[1] |

1: Corrected for mechanical count error

**Table A2.** Annual lamprey passage estimates at Bradford Island auxiliary water supply lamprey passage structure during 2007-2014 (Corbett et al. 2015), 2015-2016 (Gallion et al. 2016), 2017-2018 (Zorich et al. 2019), 2019 (Cates et al. 2020), 2020 (Gibbons and McClain 2021), and 2021.

| Year | Dates Operated | # Days | Estimated Passage |
|---|---|---|---|
| 2004 | Unknown | NA | 7,490 |
| 2005 | Unknown | NA | 9,242 |
| 2006 | Unknown | NA | 14,975 |
| 2007 | 8 May – 22 October | 167 | 7,387 |
| 2008 | 13 May – 28 October | 168 | 6,441 |
| 2009 | 26 May – 2 November | 160 | 3,302 |
| 2010 | 4 June – 25 October | 143 | 1,933 |
| 2011 | 26 May – 9 November[1] | 154 | 7,476 |
| 2012 | 2 June – 9 November[2] | 144 | 4,392 |
| 2013 | 16 May – 16 October[3] | 141 | 13,066 |
| 2014 | 8 May – 20 October | 165 | 17,587[5] |
| 2015 | 30 March – 28 October | 212 | 13,986[5] |
| 2016 | 5 April – 27 October[4] | 205 | 12,115[5] |
| 2017 | 5 April– 31 October | 210 | 28,843[5] |
| 2018 | 8 March – 31 October | 237 | 28,105[5] |
| 2019 | 18 April – 31 October | 197 | 6,538[5] |
| 2020 | 16 April – 2 November | 200 | 9,467[5] |
| 2021 | 6 April – 1 November | 209 | 9,870[5] |

1: 13 days of data gaps; 2: 16 days of data gaps; 3: 12 days of data gaps; 4: 2 days of data gaps; 5: Corrected for mechanical count error. In 2006 a second collection ramp was added to the east side of the AWS.

**Table A3.** Annual lamprey passage estimates at Cascades Island entrance lamprey passage structure during 2007-2014 (Corbett et al. 2015), 2015-2016 (Gallion et al. 2016), 2017-2018 (Zorich et al. 2019), 2019 (Cates et al. 2020), 2020 (Gibbons and McClain 2021), and 2021.

| Year | Dates Operated | # Days | Estimated Passage |
|---|---|---|---|
| 2009 | 26 May – 3 September[1] | 73 | 106 |
| 2010 | 31 May – 10 September[2] | 75 | 48 |
| 2011 | 6 June – 15 September[3] | 94 | 485 |
| 2012 | 23 May – 20 September[3] | 113 | 2,472 |
| 2013 | 24 June – 4 October[3,4] | 95 | 155 |
| 2014 | 14 May - 30 October[5] | 167 | 2,832 |
| 2015 | 6 April – 30 September | 177 | 72[6] |
| 2016 | 8 April – 27 October | 202 | 3,851[6] |
| 2017 | 5 April– 31 October | 210 | 3,027[6] |
| 2018 | 25 April – 31 October | 186 | 882[6] |
| 2019 | 16 April – 31 October | 199 | 774[6] |
| 2020 | 1 April – 2 November | 215 | 1,220[6] |
| 2021 | 6 April – 1 November | 209 | 928[6] |

1: Experimental flow testing was conducted; system was operated weekdays only; 5 days of data gaps; 2: LPS was operated weekdays only; 3: 7 days of data gaps; 4: CI LPS was extended to the forebay using mostly PVC pipe prior to 2013 operation; 5: two days of data gaps; 6: corrected for mechanical count error.