EVALUATION OF ADULT PACIFIC LAMPREY MIGRATION AND BEHAVIOR AT MCNARY AND ICE HARBOR DAMS, 2007

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by

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Preface

Pacific lampreys are native anadromous fishes of the Pacific Northwest. But unlike Pacific salmonids, lampreys have historically received limited attention by managers and researchers. Like all long distance migrants, Pacific lamprey must negotiate numerous challenges to achieve reproductive success and population sustainability. In the 1990’s, the US Army Corps of Engineers began funding investigations on adult lamprey behavior and passage at federally-operated hydropower dams on the lower Columbia River. These initial studies demonstrated low lamprey passage success at Bonneville Dam and other lower Columbia River dams. Further studies were conducted to determine specific mechanisms for poor passage and the development of structures and operations to improve adult lamprey passage at these lower river projects. We initiated evaluations of adult lamprey passage at McNary and Ice Harbor dams during 2005 and 2006.

This and related publications from the University of Idaho, Fish Ecology Research Lab can be found at www.cnr.uidaho.edu/uiferl/

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Abstract

During the 2007 Pacific lamprey migration, we used radio-telemetry and half-duplex PIT (HDX) monitoring to calculate passage efficiency and identify areas of difficult passage at McNary Dam. Dam passage efficiency was 89% with 12 of 14 lamprey that approached the dam successfully passing the dam. Median time from release to first approach a McNary Dam fishway was 7.6 d. Median time from first fishway approach to first fishway entrance was 0.01 d (24 min) with only one lamprey taking more than a day to enter a fishway. After entering fishways, lamprey passed quickly through the non-weired portions of fishways and through transition pools. Median time to pass this fishway segment was 0.38 d \( (n = 8) \) as was the median time from first transition pool record to last transition pool record \( (n = 6) \). Median time to pass from the last transition pool record to exit a fishway was 1.0 d. In all, median time from fishway entry to exit was 2.8 d \( (n = 7) \).

HDX antennas located within auxiliary juvenile passage channels in the pier walls of the Oregon-shore fishway indicated lamprey entered these passages and one fish apparently used a juvenile passage channel to enter the forebay.

Of the twelve lamprey believed to have passed McNary Dam, five fish were recorded at upstream dams through December 2007. Two lamprey were detected at Ice Harbor Dam on both telemetry and HDX systems and three lamprey were detected by telemetry receivers at Priest Rapids Dam. Both lamprey detected at Ice Harbor entered a fishway quickly \(< 3 \text{ h}\); passage times from fishway entrance to exit were 6.9 and 16.7 h. The three lamprey detected at Priest Rapids passed the McNary reservoir and Hanford Reach in 8.7, 16.6 and 39.7 d \( (4.3 – 19.4 \text{ km/d}) \).
Introduction

The Pacific lamprey (Lampetra tridentata) in the Columbia River Basin have suffered a widespread population decline in recent years. This is likely due to a similar combination of factors contributing to the decline of Columbia and Snake River salmon and steelhead stocks. Since construction of the Columbia and Snake River hydrosystems, counts of migrating adult Pacific lamprey have decreased dramatically and the distribution of juveniles in streams has been truncated.

Beginning in 1997, radiotelemetry studies were used to examine lamprey passage at lower Columbia River dams (Bonneville, The Dalles, and John Day; e.g., Moser et al. 2002; 2003; 2004; 2005) and later expanded McNary and Ice Harbor dams (Cummings et al. 2008; Keefer et al. in review). Results indicated that Pacific lamprey did not readily pass dams and poor passage could represent a critical limitation to migration, and ultimately, reproductive success (Close et al. 1995; Moser et al. 2002). Specifically, Moser et al. (2002, 2003, 2004, 2005) found that fishway entrances, collection/transition areas, diffuser gratings, and serpentine weirs impeded adult Pacific lamprey dam passage at lower Columbia River dams.

In an effort to improve monitoring of Pacific lamprey in the basin, half-duplex (HDX) passive integrated transponder (PIT) tag monitoring sites were deployed at dams starting in 2005. PIT tags are relatively inexpensive and small, are uniquely identifiable, are not limited by battery life, and are easy to implant (Gibbons and Andrews 2004). Therefore, this technology can be used to monitor relatively large numbers of fish cost-effectively as they pass through constricted in fishways where detectors were installed. HDX tags were selected for Pacific lamprey passage evaluations to avoid potential tag collisions with the full-duplex (FDX) PIT tags used to monitor salmonids in the basin and because of their greater detection ranges.

In 2005 and 2006, studies at McNary and Ice Harbor dams evaluated adult lamprey dam passage times and efficiencies and identified areas at these dams that pose particular difficulties for migrating lamprey. In these two years, 190 adult lamprey were trapped and tagged with radio and/or HDX-PIT tags and released about 1 km below the dams. Using both monitoring systems, about half the tagged animals were detected as they approached the dam after release. Estimated passage efficiencies were about 62% at McNary Dam in both years and were 33% and 77% at Ice Harbor Dam in 2005 and 2006, respectively.

In 2007, we continued this study by tagging 61 adult lamprey and releasing them below McNary Dam. Their migration behavior was monitored with radiotelemetry and HDX-PIT systems at both McNary Dam and at Ice Harbor Dam on the Snake River. Radio-tagged lamprey were also detected by receivers at Priest Rapids Dam on the Columbia River and at Lower Monumental Dam on the Snake River. The objective of this work was to evaluate passage times and passage success and further define passage bottlenecks at the two dams.

Methods

Study area

Adult Pacific lamprey were captured in the Oregon-shore fishway at McNary Dam, Columbia River kilometer (rkm 470), and tagged at the Juvenile Fish Facility (Figure 1). Tagged fish were released on both shores of the river, approximately one kilometer downstream from McNary Dam. Fish were detected at HDX and radiotelemetry monitoring sites at McNary and Ice Harbor
Fish collection

Adult Pacific lamprey were trapped using one aluminum trap mounted on guides installed on the side walls of the Oregon-shore fishway and one portable aluminum trap that rested on top of a fishway weir but was not fixed to the wall. Traps were lowered into the ladder at approximately 2000 hrs each day and left overnight. Additional lamprey were dip-netted from the Oregon-shore fish ladder at a location approximately six weirs upstream from the fixed trap. Lamprey were removed from the traps at approximately 0700 h each day, moved to a tagging station and tagged, allowed to recover (~ 30 min), transported by truck, and released to the river.

Tagging procedure

All study animals were anesthetized in 60 ppm eugenol for 5-8 min. Lamprey were then moved to a 4 in diameter polyvinyl chloride (PVC) pipe with a sealed T-end. A portion of the pipe was cut away to expose the ventral surface of the fish for surgery. Lamprey were placed in the tube with the head facing the T-end and the head and gills were submerged in 60 ppm eugenol. An incision approximately three centimeters long was made to the left of the ventral midline in line with the
insertion of the first dorsal fin. If the animal was receiving both a radio and an HDX tag, the HDX tag (23 mm × 3.8 mm, 0.6 g in air) was inserted into the body cavity first. A catheter was then placed inside the body cavity and pushed through the musculature and skin approximately five centimeters posterior to the incision. The radio-tag antenna was threaded through the catheter and the catheter was removed by pulling it through the body wall, leaving the antenna protruding through the skin. The radio tag was then inserted into the body cavity and the incision was closed with two or three simple interrupted Vicryl™ sutures. The radio tags were model NTC-4-2L (Lotek Wireless Inc., Newmarket, Ontario) and weighed 2.1 g in air (18.3 mm × 8.3 mm) with a 5 sec burst rate.

**Monitoring coverage**

Telemetry coverage at McNary and Ice Harbor dams in 2007 consisted of both Yagi (aerial) and underwater antennas. Two Yagi antenna sites were located on opposite sides of the river approximately 2.5 km downstream of each dam and monitored fish movement into tailrace areas. Multiple underwater antennas monitored fish behavior near and just inside the fishway entrances, in transition pools, and at the fishway exits (Figures 1 and 2). Records at these antennas were used to identify when a fish made their first and subsequent approaches, entrances and exits at the fishway openings. Approaches were when fish were detected on outside antennas. An entrance occurred when a fish was detected on an outside antenna followed immediately by a detection on the associated inside antenna. Exits were the reverse of these two events. HDX antennas
monitored fish passage at fishway weirs (typically at the first weir that was never inundated by tailrace water) and at fishway exits. At McNary Dam, two additional HDX antennas monitored lamprey movement through auxiliary juvenile passage channels located inside the Oregon shore fishway pier wall that connected to the forebay (Figure 1). Study animals using the auxiliary passage channels would not pass telemetry or HDX fishway exit sites. HDX coverage at Ice Harbor included antennas at fishway entrances in addition to fishway weirs and exits (Figure 2). At Priest Rapids Dam, telemetry receivers were located near fishway exits and at Lower Monumental Dam telemetry receivers were at fishway entrances and exits.

Results

River environment and dam operation

Columbia River flow during the 2007 lamprey migration season was very similar to flows experienced in the previous two seasons of this research, though all three years were below long-term means (Figure 3).

Dam spill was initiated in late March and continued until the end of August with spill volumes fluctuating between 50 and 125 kcfs. This was slightly lower than volumes in the previous two years (range = 50 to 160 kcfs) (Figure 3).

Water temperature reached 20° C in the second week of July and generally remained above that temperature until mid September. On average, 2007 was slightly cooler than the previous two years though temperatures remained higher later in the season (Figure 3).

Fish Collection

The two traps in the Oregon-shore fishway were fished every night from 24 June to 13 September and caught 52 lamprey. An additional nine lamprey were dip-netted from the Oregon-shore fishway near the viewing window (Figure 4). Of the 61 lamprey tagged, 59 received both a radio and an HDX tag, one was radio tagged only and one was HDX-PIT tagged only. The 61 lamprey ranged in weight from 312 to 680 g (mean = 430.7 g). Total fish length ranged from 54 to 78 cm (mean = 64.7 cm) and girth ranged from 9.4 to 12.5 cm (mean = 10.5 cm) (Figure 5). These fish were slightly smaller than those collected in 2005 and 2006, although the differences were not significant.

Lamprey were released at two sites on opposite sides of the river approximately 1 km downstream of McNary Dam: 28 near the north shore and 33 near the south shore.

Dam passages and detection efficiencies at McNary Dam

Of the 60 radio-tagged lamprey released below McNary Dam, 17 (28%) were detected at McNary tailrace receivers, 14 (23%) were detected approaching fishways at the dam and 10 (16%) were detected inside a fishway entrance. Eight (13%) lamprey were detected by telemetry receivers at transition pools, and seven (11%) were detected at fishway exits. HDX systems detected seven (12%) lamprey passing fishway weirs (located just upstream of transition pool telemetry receivers) and nine (15%) passing fishway exit antennas (including those located within the auxiliary juvenile passage channel). One lamprey was detected upstream from McNary Dam without being detected by either PIT or radio antennas. Combining all sites and upriver detections, 12 (20%) of the 60 radio-tagged lamprey were known to have passed the dam (Table 1).
Figure 3. River flow, dam spill and water temperature at McNary Dam during the adult Pacific lamprey research seasons of 2005-2007.

There were no significant differences in the weight, length and girth of radio-tagged lamprey that did or did not pass McNary Dam (ANOVA, P value range 0.44 – 0.956). However, there was a significant (P < 0.001) difference in the release dates of lamprey that did or did not pass the dam. Lamprey that successfully passed the dam had a mean release date of 7August (SD = 16.2) while unsuccessful migrants had a mean release date of 21July (SD = 16.7)
Figure 4. Numbers of adult Pacific lamprey counted passing through fishways at McNary Dam (solid line) and the number captured and tagged during the 2007 research season. Asterisks denote dates of successful lamprey passage at McNary Dam.

Figure 5. Weight, length and girth measurements with means (SD) for adult Pacific lamprey captured at McNary Dam from 2005 to 2007.
Table 1. Individual lamprey detected by radio-telemetry and HDX antennas at McNary Dam in 2007. See Figure 1 for a description of each site. RT = radio tag, HDX = PIT detections.

<table>
<thead>
<tr>
<th>Site</th>
<th>N</th>
<th>Percent of total</th>
<th>South Fishway</th>
<th>North Fishway</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT Approach</td>
<td>14</td>
<td>23</td>
<td>9 (64)</td>
<td>5 (36)</td>
</tr>
<tr>
<td>RT Entrance</td>
<td>10</td>
<td>16</td>
<td>7 (70)</td>
<td>3 (30)</td>
</tr>
<tr>
<td>RT Trans pool</td>
<td>8</td>
<td>13</td>
<td>6 (75)</td>
<td>2 (25)</td>
</tr>
<tr>
<td>HDX Weir</td>
<td>7</td>
<td>11</td>
<td>6 (86)</td>
<td>1 (14)</td>
</tr>
<tr>
<td>RT Exit</td>
<td>7</td>
<td>11</td>
<td>6 (86)</td>
<td>1 (14)</td>
</tr>
<tr>
<td>HDX Exit</td>
<td>9</td>
<td>15</td>
<td>7 (78)</td>
<td>2 (22)</td>
</tr>
<tr>
<td>Known past dam</td>
<td>12</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Lamprey showed a clear preference for the Oregon-shore fishway at McNary Dam with nearly two-thirds of all first approaches by unique fish occurring there. In addition, 78% of all fish that passed the dam used the Oregon-shore fishway (Table 1). Of the 33 total approaches to McNary Dam made by radio-tagged lamprey, 20 were at Washington-shore fishway entrances, and 13 were at Oregon-shore fishway entrances. Lamprey approached a fishway a median of 1 time before entry (mean = 2.4). Two lamprey were detected exiting the Washington-shore fishway and nine were detected exiting the Oregon-shore fishway (Table 1). Of the nine that passed the Oregon-shore fishway, five were detected on HDX antennas within auxiliary juvenile passage channels.

The median times for radio-tagged lamprey to pass from the release site to first approach at McNary Dam fishway entrance was 7.6 d (range = 0.7 – 42.5 d). Time from release to first entrance into a fishway was 6.9 d (range = 0.7 – 42.5 d). Median time from first approach to first entrance at a fishway was 0.001 d (range = 0.001 – 0.06 d) and from first entrance to exiting a fishway was 2.8 d (range = 0.2 – 8.2 d). Median time from release to exiting a fishway was 10.9 d (range = 3.6 – 20.7 d) (Table 2).

Table 2. Passage times for radio-tagged lamprey at McNary Dam in 2007.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Median (d)</th>
<th>Range (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release to approach</td>
<td>14</td>
<td>7.6</td>
<td>0.7 – 42.5</td>
</tr>
<tr>
<td>Release to entrance</td>
<td>10</td>
<td>6.9</td>
<td>0.7 – 42.5</td>
</tr>
<tr>
<td>Approach to entrance</td>
<td>10</td>
<td>0.001</td>
<td>0.001 – 0.06</td>
</tr>
<tr>
<td>Entrance to exit</td>
<td>7</td>
<td>2.8</td>
<td>0.2 – 8.2</td>
</tr>
<tr>
<td>Release to exit</td>
<td>11</td>
<td>10.9</td>
<td>3.6 – 20.7</td>
</tr>
</tbody>
</table>
Detection efficiency for the telemetry system was 64%. Seven of the eleven radio-tagged lamprey known to have passed through the fishways were detected at one or more telemetry receivers. Efficiency for the HDX system was 82%, with nine of the eleven lamprey known to have passed through the fishways detected. One lamprey was detected upriver without detection on either system, suggesting that it may have passed the dam via the navigation lock or some other unmonitored route.

Lamprey behavior after passing McNary Dam

Of the twelve lamprey believed to have passed McNary Dam, five were detected at upstream dams through December 2007. Two lamprey were detected at Ice Harbor Dam (rkm 538) on both telemetry and HDX systems and three lamprey were detected by telemetry receivers at Priest Rapids Dam (rkm 639).

The two lamprey detected at Ice Harbor Dam travelled the 68 km from McNary Dam in 5.9 and 19.1 d (11.5 and 3.6 km/d). At Ice Harbor Dam, both fish were detected by telemetry as they approached and entered the south-shore fishway within 3 h. After entering the fishway, both lamprey were detected by telemetry and HDX systems. Travel time from fishway entrance to exit were 6.9 and 16.7 h. One lamprey that passed Ice Harbor was detected in the tailrace of Lower Monumental Dam (rkm 588) having passed through the reservoir in 5.7 d (9.0 km/d). The other lamprey fell back at Ice Harbor Dam approximately 3 h after exiting the fishway and was last recorded in the Ice Harbor tailrace.

The three lamprey that were detected at Priest Rapids dam passed the McNary reservoir and free-flowing Hanford Reach of the Columbia River in 8.7, 16.6, and 39.7 d (4.3 – 19.4 km/d).

Discussion

While only 17 of 61 (28%) tagged lamprey were detected in the McNary tailrace after release, dam passage efficiency at McNary Dam for 2007 was 86%, with 12 of the 14 lamprey detected approaching fishways at the dam eventually passing the dam. Thus, fewer radio-tagged lamprey were detected in 2007 after release than 2005 and 2006 (mean = 49%), but a higher proportion of the fish that approached an entrance passed the dam than in the previous two years (mean = 62% for two years). At Bonneville Dam, the proportion of radio-tagged lamprey that approached the dam after tagging and release in 2007 was also low (68%) compared to previous years (82-92%, Moser et al. 2002).

The cause for the decrease in re-approaches during 2007 is unknown. Past performance and current testing of the transmitters do not indicate that tag failure would account for the perceived poor performance. Tagging effects, which would include loss of fish as a result of handling stress and/or a diminished tendency to resume migration following release downstream from the dam may have been a potential cause. In 2007, we switched to using a smaller transmitter so as to reduce potential tagging effects. We determined that gaps in the existing telemetry coverage (receivers that temporarily stop operating from malfunction or loss of power) did not result in significant number of potential approaches being missed. There was concern, however, that the underwater antennas used to monitor fish approaching fishway entrances did not detect all fish with these transmitters that approached. The telemetry receiver system at McNary Dam (and other dams) was designed to monitor radio-tagged adult salmon which carry much larger and more powerful transmitters and are more likely to approach the fishway while swimming closer to the surface. Lamprey may be approaching the fishway entrance from the periphery and from
lower in the water column making them more difficult to detect. This difference in behavior may partially account for the low proportion of lamprey detected after release at both McNary and other dams (see Keefer et al. in review). Low detection rates outside fishway entrances may also explain the relatively high reported passage efficiency. To address this issue, we plan to install a second radio receiver and Yagi aerial antenna near fishway entrances at Bonneville, The Dalles, John Day, McNary, and Ice Harbor dams prior to lamprey tagging in 2008. These antennas would have a much larger reception range and should help to resolve this question.

Fish we sampled in 2007 were smaller on average than in previous years (see Figure 5), which could be an indication of the overall condition of the returning adult lamprey population. If so, our results may represent an actual decreased in performance for adult migrants this year relative to past evaluations. Since all fish contained HD PIT tags in 2007, we will continue to scan for these study animals during winter and early spring to determine if they pass he projects after the period when their radio transmitters would be operating.

The median passage time from release to first approach McNary Dam (7.6 d) was similar to the 6.6 d estimates for 2005 and 2006 and also within the range of estimates at Bonneville Dam from 1997 to 2002 (4.0 – 7.8 d) (Moser et al. 2005). After lamprey approached a fishway at McNary Dam, all entered the fishway shortly thereafter. Median time from first fishway approach to first entrance (24 min) suggests lamprey did not have difficulty entering a fishway after locating it. Four lamprey exited the fishway (two of them twice) back into the tailrace, with three of these four fish subsequently re-entering and passing the dam.

After entering fishways, lamprey passed quickly through the non-weired portion of the fishway and through transition pools (medians = 0.38 d). Median time to pass from the last transition pool record to exit a fishway was 1.0 d, and the median full-dam passage time was 2.8 d. These times were comparable to a mean passage times of 2.0 d measured in 2005 and 2006 at McNary Dam, and 2.1 d at The Dalles Dam during 2000 and 2001, but faster than the 4.0 d at Bonneville Dam in 2000 and 2001.

As in past years, there was a clear preference by lamprey for the Oregon-shore fishway, with nearly two thirds of all unique first approaches occurring there. Likewise, 78% of all successful dam passages were via the Oregon shore, similar to past years. It is likely that this was due to the physical structure of the dam. The entrance to the Washington-shore fishway is adjacent to the spillway and lamprey may have difficulty finding the entrance in the turbulence generated by spill at the dam. Most (80%) of the fishway entrances by tagged lamprey occurred during spill conditions.

The addition of HDX antennas to the auxiliary juvenile passage channels on the Oregon-shore fishway pier wall indicated that these channels were used by lamprey. The openings of these channels are unit with relatively low velocity flow. Given the cryptic and photo-negative behaviors of lamprey use of these sites was not surprising. Of the nine lamprey believed to have passed via the Oregon-shore fishway, four were detected on these antennas. One fish was later detected at upriver sites without being detected at the fishway exit by either telemetry or HDX systems, indicating it may have exited into the forebay through these channels. Of the three other lamprey detected by juvenile channel antennas, one was later detected at the fishway exit by radiotelemetry and the other two were not subsequently detected by either monitoring system. It is possible that these juvenile channels, while feasible points of egress to the forebay, also pose a potential hazard to lamprey. The condition of these channels cannot be examined and some orifices opening into the forebay appear to be plugged with debris (Brad Eby, USACE, personal communication). Given that lamprey appear to have no difficulty negotiating the last portion of
the fishway and exiting into the forebay conventionally, it may be beneficial to block these channels to prevent potential passage bottlenecks.

Of the twelve lamprey believed to have passed McNary Dam, five were detected at upriver sites: two at Ice Harbor Dam and three at Priest Rapids Dam. Migration rates through the McNary pool to Ice Harbor Dam and through the pool and the Hanford Reach to Priest Rapids Dam ranged from about 4 km/d to more than 19 km/d. Interestingly, the most rapid migration rate (19.4 km/d) was for a lamprey detected at Priest Rapids Dam that had passed the free-flowing Hanford Reach. There appears to be a great deal of variability in the exigence of upstream migration for individual lamprey. It is believed that lamprey are not site-specific spawners, potentially cueing on pheromones released by juveniles or some other attractant (Bjerselius et al. 2000). Therefore, the speed and duration of the spawning migration may be influenced as much by physiological fitness and available energy reserves at a given stage of their migration as by the need to reach a certain spawning area.

To date, a central challenge to determining passage efficiencies and bottlenecks at McNary Dam has been collecting enough study animals to provide meaningful information. In 2007, we collected just 61 lamprey in more than two months of trapping. This, coupled with a low rate of detection after release, limited the amount of information available for lamprey passage evaluations at McNary Dam and at upstream dams. To address this in future research we have made modifications to our trapping systems as well as increased radiotelemetry coverage near fishway entrances. We also plan to track radio-tagged lamprey in the tailrace from boats in an effort to determine the fate of tagged lamprey that do not re-approach the dam. These efforts, as well as the addition of fixed-site radio receivers near the mouths of tributaries and the installation of HDX antennas at Priest Rapids Dam, should provide a better understanding of lamprey behavior, distribution, and survival.
References


