U.S. Fish and Wildlife Service
Columbia River Fish and Wildlife Conservation Office

Monitoring the Entrainment of Juvenile Pacific Lamprey at Irrigation Canals of the Umatilla River

2023 Annual Report

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On the cover: Feed Diversion Dam during standard river discharge (above) and during a flooding event (dam obscured) in 2020 (below). Picture by William Simpson.

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Disclaimers

Monitoring the Entrainment of Juvenile Pacific Lamprey at Irrigation Canals of the Umatilla River 2023 Annual Report

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Abstract – Outmigrating juvenile Pacific Lamprey are inadvertently diverted from rivers and streams into irrigation diversions common to the arid interior of the Columbia River basin (entrainment), where fish can be trapped and killed. Lamprey may be particularly susceptible to entrainment and harm because fish screens associated with these structures were originally designed to rescue juvenile salmonids from canals, not lamprey that are morphologically and behaviorally different from salmonids. As a result, the entrainment of lamprey into intermittently operating irrigation canals where fish may interact with screen infrastructure is seen as a potential factor that limits lamprey in some environments. Entrainment of PIT (Passive Integrated Transponder)-tagged juvenile Pacific Lamprey was primarily monitored at Feed Diversion Canal on the Umatilla River using stationary and mobile PIT tag arrays to determine what factors (river flow, fish size) influence entrainment, and if fish leave the canal unharmed through rotary drum screen and bypass infrastructure common to the Columbia River basin. A large proportion of PIT-tagged juvenile Pacific Lamprey released upstream of the canal headgate was estimated as entrained into the canal in 2020 (54%, CI95 39–78%), but no fish were released in 2023 and no fish tagged in previous years were detected at the fixed array within the canal in 2023. No juvenile Pacific Lamprey were detected as stranded or killed within the irrigation canal during mobile PIT tag detection surveys. Mobile PIT detection surveys were highly efficient at detecting PIT tags seeded within the canal during water diversion and after dewatering, suggesting if significant numbers

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of PIT tags were liberated from dead juvenile lamprey they would be detected by these surveys. Juvenile bypass antenna detections of dead lamprey that were PIT tagged and released into the water column of the canal suggests that tagged fish that die outside of their burrows or on fish screens could be mistaken for live lamprey that are bypassed. Few PIT-tagged lamprey were redetected downstream in the Umatilla and Columbia Rivers after their entrainment, obscuring the fate of these fish. However, the PIT antenna at the bypass outfall detected most entrained salmonids in 2023, suggesting that the bypass of entrained juvenile lamprey is well documented. The number of fish detected as entrained inside of Feed Diversion Canal in previous years was negatively related to Umatilla River flows at their time of release upstream of the canal, and this lamprey entrainment did not appear to be size selective based on the size distributions of detected and undetected fish. Continued annual monitoring of lamprey entrainment may provide information managers can use to evaluate how river flows may be used to avoid short windows of potential entrainment during the outmigration of juvenile Pacific Lamprey and how successful entrained juvenile lamprey are at using screen and bypass infrastructure originally made to rescue salmonids from irrigation canals.

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Table of Contents

List of Tables

List of Figures

Introduction

Irrigation diversions are common within the arid interior of the Columbia River basin and can inadvertently trap fish. Juvenile Pacific Lamprey (*Entosphenus tridentatus*) are poor swimmers relative to juvenile salmonids (Dauble et al. 2006; Muller et al. 2006), and as a result, they may be particularly susceptible to diversion from rivers and streams into irrigation canals (entrainment) during their rearing and downstream migration (Moser et al. 2015). Rotary drum fish screens commonly found at irrigation canals in the Columbia River basin are generally designed to exclude juvenile salmonids from canals (McMichael et al. 2004), not juvenile lamprey. Once entrained, escaping from screened irrigation canals may be more difficult for juvenile lamprey than for salmonids due to differences in body size, body shape, swim performance, and behavior (Moser et al. 2015). Because of this uncertainty, the Bureau of Reclamation (Reclamation) wants to identify techniques to reduce entrainment, trapping, and mortality of lamprey at many of their diversion structures in the mid-Columbia River basin. This requires quantifying the aggregate loss of juvenile lamprey entrained into irrigation canals and how many fish pass the canal intakes unimpeded. To this end, Reclamation and their cooperators are conducting a collaborative research and monitoring effort in the Umatilla River basin that focuses on tracking lamprey implanted with PIT tags (Passive Integrated Transponders) as they move through the river network and encounter irrigation canals (Reclamation 2016). Long-standing PIT tag interrogation systems (PIT arrays) within irrigation canals originally designed to monitor steelhead entrainment will allow Reclamation to quantify the entrainment of juvenile lamprey, and recently installed PIT arrays in the Umatilla River can redetect entrained fish after they use screening and bypass infrastructure. Reclamation enlisted the Columbia River Fish and Wildlife Conservation Office to install and report on the maintenance, operations, and detections of PIT arrays in irrigation canals and their adjacent river arrays (Reclamation agreement # R20PG00060 and FWS# 4837-1374). The detections of lamprey at PIT arrays near Feed Diversion Dam, Maxwell Diversion Dam, and Three Mile Falls Diversion Dam (TMF) of the Umatilla River are indicative of the canal entrainment or the screening and bypass of juvenile lamprey. Therefore, the data gathered for this project were used to examine 1) how river discharge is related to the proportion of juvenile Pacific Lamprey entrained from groups of fish released upstream of the Feed Diversion Canal headgate, 2) how the entrainment timing of volitionally outmigrating juvenile lamprey relates to the timing of juvenile lamprey release groups, 3) if canal entrainment of juvenile Pacific Lamprey is size selective, 4) direct and indirect evidence of juvenile lamprey dying or becoming stranded within the irrigation canals, and 5) the proportion of juvenile lamprey documented inside the canals that successfully use the screening and bypass infrastructure to return to the river.

Study Sites

The Feed Diversion Dam and Canal is a Reclamation diversion structure located on the Umatilla River 2.4 km southeast of Echo, Oregon (Figure 1). The dam is constructed of concrete and rock and employs a timber weir with an embankment wing that raises the water level in the Umatilla River by 1.2 m. This furnishes surface water to a canal that extends to the Cold Springs Reservoir. Feed Diversion Canal has a maximum diversion capability of 6.2 m^3/sec (219 CFS). Water velocity testing at the rotary drum screen of Feed Diversion Canal was conducted shortly after its construction in 1994. Testing indicated the screen usually met 1994 NOAA criteria for salmonid smolts when canal discharge was 5.6 m^3/sec (ratio of sweep to approach velocity in front of the screen was two or more 91% of the time, and the approach velocity was usually ≤ 0.18 m/s; Cameron et al. 1997). The Feed Diversion Dam has an adult ladder and a slot in the dam structure to assist adult salmonids with upstream passage. A lamprey passage system is attached to the adult ladder to assist adult lamprey with upstream dam passage. During the 2023 water year, the headgate supplying water to Feed Diversion Canal opened intermittently beginning on December 28th, 2022 (Table 1). The canal headgate operates while juvenile Pacific Lamprey are known to move downstream. On April 8th, 2023 the canal was completely dewatered, essentially draining the water within the canal down to maintenance levels. Under maintenance conditions the headgate is left slightly open, only allowing enough water into the canal to keep its substrate wet between the headgate and the fish screen with the goal of

Table 1. First and last dates of operation for Feed Diversion Canal by water year. Canal operation within these dates can be intermittent. Mean diversion rate is only calculated over days the canal contained diverted water.

Water year	First Date		Last Date	Mean Daily Diversion Rate ($m^3/s \pm 2SE$)
2017	1/23/2017	–	5/12/2017	5.0 (± 0.2)
2018	11/29/2017	–	4/3/2018	5.5 (± 0.2)
2019	12/19/2018	–	4/29/2019	4.9 (± 0.3)
2020	1/22/2020	–	3/20/2020	5.2 (± 0.4)
2021	12/21/2020	–	4/2/2021	4.8 (± 0.3)
2022	1/10/2022	–	4/6/2022	5.0 (± 0.4)
2023	12/28/2022	–	4/8/2023	3.5 (± 0.4)

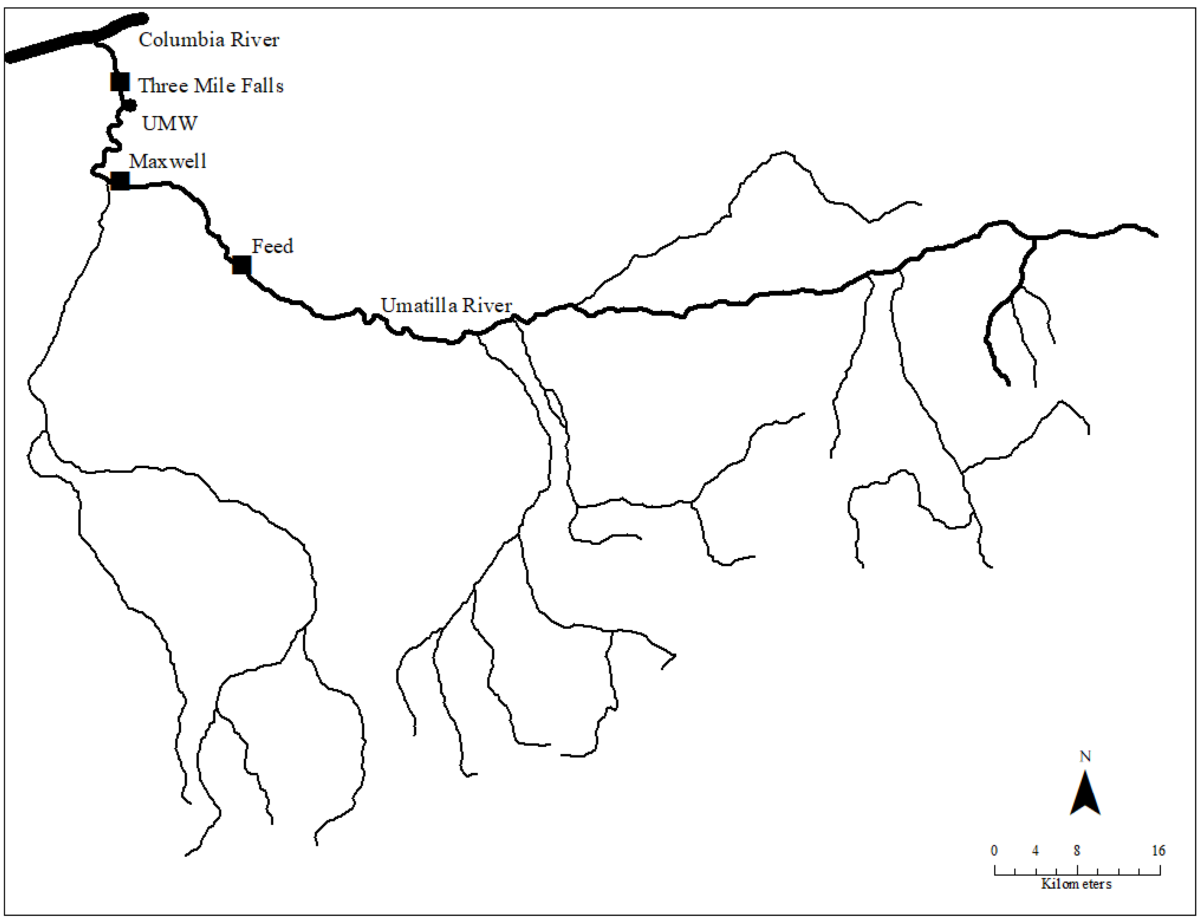

Figure 1. A map of the Umatilla River basin. Squares represent Bureau of Reclamation diversion dams and the diversion points of their associated canals. The circle marks the currently operating mainstem array site.

allowing any fish remaining within the canal to escape through the bypass system. The remaining patchwork of dry and pooled areas in the canal continue to dry out over the summer due to evaporation and vegetation growth within the canal.

Feed Diversion Canal has fixed antenna arrays in a pass-through orientation at upstream (Figure 2A) and downstream sites (Figure 2B) within the canal to detect PIT-tagged fish while they are entering and exiting the canal (Figure 3). The upstream and downstream antenna arrays are comprised of multiple (N = 6 and N = 5, respectively) individual antennas. Antennas in the upstream headgate array have a double loop design that performs better than a single loop design in the high electromagnetic interference (noise) environment surrounding the Feed Diversion Canal headgate. Due to water turbulence, velocity, and canal maintenance, PIT-tag antenna arrays were positioned 15 m downstream from the Feed Diversion Dam's headgate and 15 m upstream from the fish drum-screen structure. Finally, in late 2020 an additional array consisting of a single antenna was installed on the face of the Feed Diversion bypass outfall into the Umatilla River (Figure 4). PIT detection data are available for this site on the PTAGIS regional database (site code FDC; PSMFC 2021).

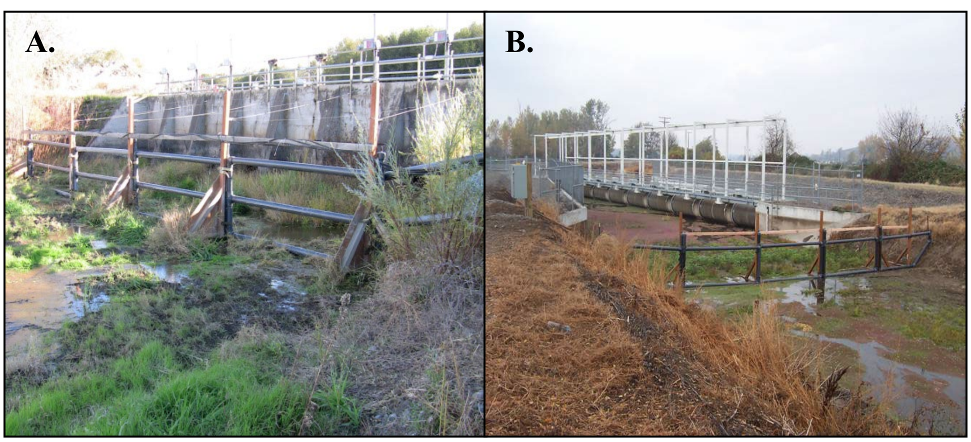

Figure 2. PIT arrays within Feed Diversion Canal. (A) Upstream PIT antenna array and the headgate. Instream posts and cables provide antenna support. The two parallel inductive loops of these antennas more evenly distribute the magnetic field generated by the antenna. As a result, the read range of PIT tags can be increased at sites that have high noise. (B) Downstream PIT antenna array upstream of the fish screening structure at Feed Diversion Canal.

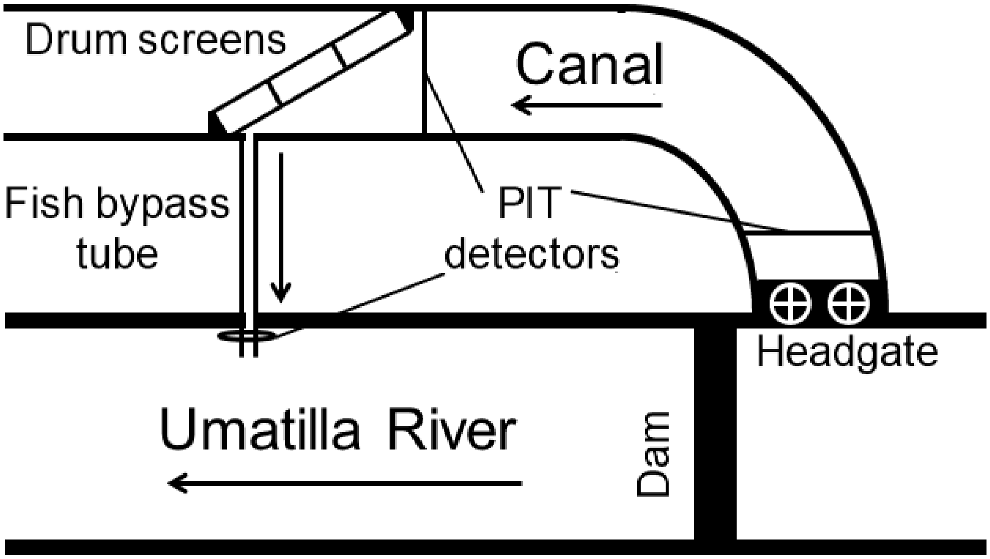

Figure 3. Diagram of Feed Diversion Dam. The diagram illustrates the headgate, screen, and bypass infrastructure of Feed Canal, and PIT detector arrays associated with those structures (modified from Simpson 2018).

Figure 4. Fixed PIT antenna at the bypass outfall of the Feed Diversion Canal.

Two other Reclamation diversion structures on the Umatilla River that contain PIT tag detection infrastructure include Maxwell Diversion Dam and Canal and Three Mile Falls Dam/West Extension Irrigation District Canal. Maxwell does not divert water when PIT-tagged juvenile lamprey are released on the Umatilla River (January and February). Similarly, no water has been diverted in January and February at Three Mile Falls Dam since 2017. However, any PIT-tagged juvenile Pacific Lamprey that remains in the Umatilla after their release may have an opportunity to become entrained when annual canal operations begin in the spring.

Two PIT tag arrays have operated in the mainstem Umatilla River downstream of Feed Diversion Canal. These PIT tag arrays were placed in the Umatilla River to quantify juvenile lamprey that encounter diversion dams but do not become entrained and to detect downstream migrating fish after entrainment and successful bypass. The upstream mainstem array was located 45 m downstream of Feed Diversion Dam on the Umatilla River. All antennas from this stream spanning array were removed or buried in April 2019 due to flooding and have not been replaced (site code UMF; PSMFC 2021). The second downstream mainstem array is currently located adjacent to the Hermiston Recycled Water Facility owned by the City of Hermiston, which is 2.4 rkm upstream of TMF (Figures 1 and 5). This is the furthest downstream site on the Umatilla River known to have rock substrate suitable for the anchoring of antennas. The PIT array is made of a single row of up to four 6 × 1 m antennas, which covers more than the wetted width of the river at base flow (Figure 6). All four antennas are anchored in a pass over orientation to minimize damage by impacts from large wood and other debris. CANbus antenna cables are anchored between 0.7 and 1 m downstream of the antennas at this site. A battery switcher was installed to power the array in October of 2020 based on 2019 testing that suggest it may mitigate noise at the site. The PIT detection data for this site is available on the PTAGIS regional database (site code UMW; PSMFC 2021).

Figure 5. Interrogation site adjacent to the Hermiston Recycled Water Facility (UMW). The red rectangle on the aerial photograph indicates the location of the PIT array. The river flow is from the bottom to the top of the picture.

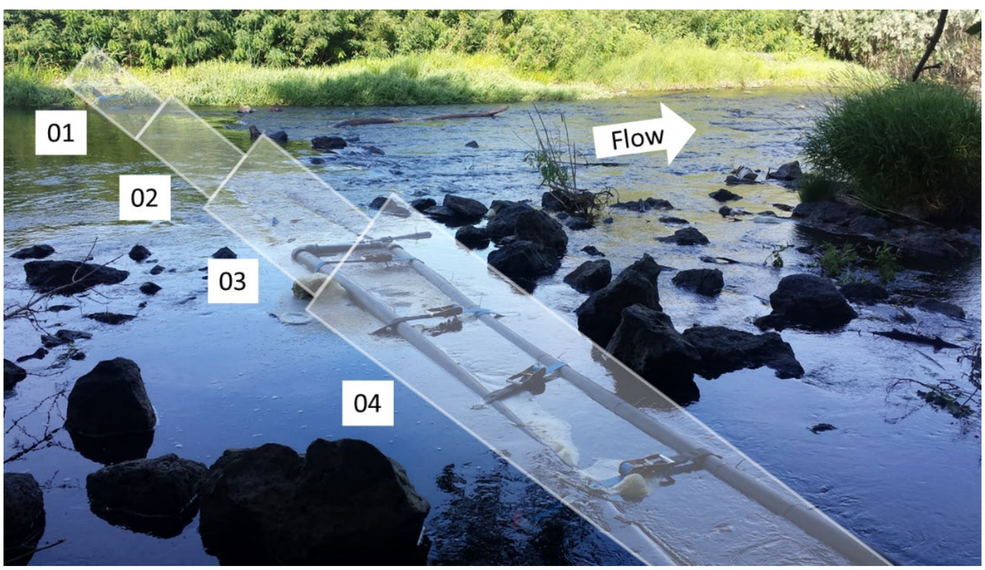

Figure 6. Umatilla River PIT array adjacent to the Hermiston Recycled Water Facility (UMW). The four individual antennas are numbered on the photograph.

PIT array Maintenance and Operations

The screen, headgate, and bypass array within Feed Diversion Canal operated the entire time the canal was diverting during the 2023 water year. Problems with the batteries in the battery switcher at the UMW array resulted in the antennas operating at least every other hour between September 21st and November 16th 2023 immediately followed by a tripped breaker and complete power outage between November 16th 15:45 and November 29th 12:13 2023 (Table 2). Antenna 2 at UMW was damaged in a previous year and it has not been replaced. The UMW array detected 1,585 salmonids in 2023 (Appendix A). The headgate and screen arrays in the Maxwell Diversion Canal operated throughout the diversion period, except for a transceiver malfunction from June 3rd 7:59 to June 6th 15:25 2023 at the screen array.

Table 2. The number of days (% days) each antenna in the UMW array operated in 2023.

Antenna	1	2	3	4
Days operated (%)	353 (97%)	0 (0%)	353 (97%)	353 (97%)

Methods

PIT-tagged Juvenile Lamprey.- Confederated Tribes of the Umatilla Indian Reservation (CTUIR) personnel have run a variety of screw traps on the Umatilla River between autumn and spring annually. This trapping indicates that the movement of outmigrating juvenile lamprey peaks during high river flows, including flooding or rain-on-snow events. CTUIR and its partners used a screw trap located approximately 2.8 rkm upstream of the river mouth to capture and tag juvenile Pacific Lamprey associated with these types of events on the Umatilla River in early 2017 and 2019 to 2020. Captured juvenile Pacific Lamprey were implanted with 8-mm or 10-mm FDX PIT tags and released in groups into the Umatilla River approximately 0.8 rkm upstream of the Feed Diversion Canal (FDC). The screw trap was not operated from 2021 to 2023; therefore, no release groups were placed upstream of Feed Diversion Canal in these years (Table

3). CTUIR personnel have also intermittently used electrofishing in the Umatilla River and Meacham Creek upstream of Feed Diversion Canal to capture and tag larval and juvenile Pacific Lamprey with 8-mm and 10-mm FDX PIT tags, after which these fish were released near their capture location. From late 2020 through early 2023 no lamprey were captured, tagged, or released upstream of the canal via electrofishing (Table 3). Since 2017 we have monitored fish detection at antenna arrays within Feed Diversion Canal, in the Umatilla River, and downstream in the Columbia River to estimate what percentage of juvenile Pacific Lamprey releases become entrained into the canal, how water conditions are related to entrainment, to monitor the size distribution of entrained individuals, and to document individuals that escaped the canal. Steelhead and Chinook Salmon PIT detections were examined to confirm the satisfactory operation of the canal and bypass fixed arrays in years when few or no larval Pacific Lamprey were detected.

Table 3. The number of PIT-tagged Pacific Lamprey released annually by CTUIR personnel for detection. Juvenile Pacific Lamprey were captured in screw traps, tagged, and released in groups upstream of the Feed Diversion Canal (release groups). Both larval and juvenile Pacific Lamprey were also captured by electrofishing and released in place (volitional). No larval or juvenile lamprey were captured and released in water years 2018, or 2021 – 2023.

Water year	Release type	Release groups (N)	Juvenile Pacific Lamprey (N)	Release date(s)
2017	Release group(s)	3	309	2/8/2017 – 2/9/2017
2017	Volitional	N/A	0	N/A
2019	Release group(s)	1	498	1/24/2019
2019	Volitional	N/A	536	10/10/2018 – 11/15/2018
2020	Release group(s)	4	1478	1/26/2020 – 1/28/2020
2020	Volitional	N/A	0	N/A

Planting PIT Tags in Feed Diversion Canal for Mobile Canal Surveys.- When PIT-tagged fish die in irrigation canals, including juvenile Pacific Lamprey, some of these fish presumably decompose and shed their PIT tag within the canal. PIT tags that are no longer associated with a living fish counterpart due to shedding or mortality are often called “ghost tags” (Bond et al. 2019; Stout et al. 2019). We conducted canal surveys annually between 2018 and 2023 with portable PIT-tag detection systems to find ghost tags associated with dead juvenile Pacific Lamprey and we estimated the detection efficiency of these efforts by seeding the canal with a known number of PIT tags before each survey. The length of the unscreened portion of the canal (between the headgate and the bypass adjacent to the fish screen) is approximately 212 meters long (Cameron et al. 1997). The canal was seeded by standing on the bank of the canal and tossing one PIT tag perpendicularly into the canal approximately every 12 to 13 m of the canal’s length between the headgate PIT array and the canal screen. The model and length of PIT tags differed by seeding year (2018,2019,2021: TXP148511B-8.5mm; 2022: Mini HPT8-8.4mm and Mini HPT10-10.3mm). The placement of the first tag was determined by a random start. Between 22 and 15 tags were seeded at least once annually while the canal was still diverting water, and again after the canal stopped diverting water (Table 4). Work restrictions due to COVID-19 did not allow for seeding the canal with PIT tags in 2020. The timing of annual tag seeding during water diversion ranged from 7 to 52 days before canal drainage. Most of the canal’s bottom is paved with large, roughly flat rocks, on top of which rests shallow and patchily distributed sediment. Just upstream of the fish screen the canal bottom consists of a flat concrete apron. Little sediment rests upon this apron after dewatering of the canal, and the apron begins 143.5 meters downstream from the canal headgate. Detection efficiencies for seeded tags were examined based on canal operations at seeding, the timing of tag seeding, distance of tag seeding from the headgate, and the type of canal bottom substrate the tag was seeded over. This information was used to better understand if juvenile Pacific Lamprey that are stranded or die in the canal and leave ghost tags are likely to be detected during canal PIT tag surveys. Sediment removal was conducted as part of canal maintenance at Feed Diversion in November 2022, so presumably some seeded tags were removed from the canal at that time.

In 2023 tags were seeded in the canal during and after water diversion as in previous years. However, to determine how ghost tags that remain within the body of dead lamprey move within the canal, the detection rates of seeded tags were compared

Table 4. The number of PIT tags seeded within the unscreened portion of Feed Diversion Canal. Various size and models of tag were seeded, and seeded tags were exposed to the operating canal for different durations, after the canal had been drained of water, and some tags were implanted into sacrificed Pacific Lamprey larvae prior to seeding.

Seeding Date	Tag size/Model	Diverted water exposure (d)	Canal status	Tags seeded (N)	Tagged fish seeded (N)
3/27/2018	8.9mm TXP148511B	7	diverting	15	0
4/30/2018	8.9mm TXP148511B	0	drained	15	0
3/8/2019	8.9mm TXP148511B	52	diverting	15	0
5/15/2019	8.9mm TXP148511B	0	drained	15	0
3/17/2021	8.9mm TXP148511B	16	diverting	15	0
4/21/2021	8.9mm TXP148511B	0	drained	15	0
3/24/2022	10.3mm Mini HPT10	51	diverting	11	0
3/24/2022	8.4mm Mini HPT8	51	diverting	11	0
3/24/2022	10.3mm Mini HPT10	13	diverting	11	0
3/24/2022	8.4mm Mini HPT8	13	diverting	11	0
4/21/2022	10.3mm Mini HPT10	0	drained	11	0
4/21/2022	8.4mm Mini HPT8	0	drained	11	0
3/29/2023	10.3mm Mini HPT 10	10	diverting	22	26
5/1/2023	10.3mm Mini HPT 10	0	drained	22	0

to rates of detection for dead larvae that were tagged and released into the canal. Young Pacific Lamprey were collected in 2022 from the Umatilla River near Pendleton, OR, PIT tagged, sacrificed in a lethal dose of MS-222, and frozen. These tagged fish (N = 26) were thawed and released into the diverting canal on the same day tags were seeded in 2023. Some tagged young lamprey (N_{larvae} = 14, $N_{transformer}$ = 1) were released every 7 meters on the left side of the canal using a random start, and the remaining fish (N_{larvae} = 10, $N_{juvenile}$ = 1) were release on the right side of the canal either at the upstream end of each drum screen or just upstream of each screen panel. Fish were released by placing them in a cup attached to a 2.9 meters telescoping pole, which was lowered into the canal to approximately half water depth before the fish was released.

PIT Tag Survey within Feed Diversion Canal.- Surveys at Feed Diversion Canal for planted PIT tags and PIT tags associated with stranded or dead juvenile lamprey were conducted after annual water diversion activities ceased and the canal was dewatered in 2018 (April 30th), 2019 (May 15th), 2021 (April 22nd), 2022 (April 21st), and 2023 (May 1st). A survey for PIT tags within Feed Diversion Canal was conducted in 2018 for PIT-tagged lamprey entrained in 2017 because PIT tags associated with entrainment are often detected within canals for multiple years (Simpson 2018). Feed Canal was not seeded with PIT tags in 2020 and no canal surveys were conducted that year. No release groups of PIT-tagged juvenile lampreys were placed upstream of Feed Diversion Canal in 2023. Canal surveys were simultaneously conducted by two people, both equipped with a portable PIT-tag detection system (PITpack; Hill et al. 2006). Both PITpacks were constructed from an IS1001-ACN PIT tag reader (Biomark), a Windows-based tablet for user interface, a lithium-ion battery, and a detection wand made of wire loop and PVC (Figure 7). Starting at the canal headgate, the biologists scanned all areas where PIT tags from trapped or stranded fish were likely to be located and proceeded slowly in a downstream direction until the fish screens were reached. Biologists also scanned piles of fine sediment located just downstream of the fish screens for PIT tags associated with lamprey.

Figure 7. An IS1001ACN-based mobile PITpack reader system. (A) The PITpack reader is comprised of a waterproof Pelican case, a Windows-based tablet mounted in a harness, a detection alarm, and a lithium-ion battery. (B) Scanning a drained Feed Diversion Canal with a PITpack detection wand, 2015.

Results

Detection of Entrained Juvenile Lamprey Using Fixed PIT Arrays within Feed Canal.- No PIT-tagged juvenile lamprey were detected as entrained within Feed Canal in 2023. Canal detections of juvenile lamprey in previous years and their travel time through the canal are detailed in Tables 5 and 6. The proportion of released juvenile lamprey that were entrained in previous years and the size distribution of those fish are shown in Figures 8 and 9.

During the 2023 water year many Chinook Salmon (N = 65) and steelhead (N = 9) were detected within Feed Canal (summarized in Appendix B). Most of these fish were detected at the bypass outfall ($N_{Chinook}$ = 62, $N_{steelhead}$ = 7). The detection efficiency of the bypass outfall array appeared to be high for fish tagged with 12-mm PIT tags (Chinook and steelhead) since the highest number of unique fish detections occurred at the bypass outfall, and 28 of 29 fish (97%) detected both within the canal and downstream of the canal were also detected at the bypass outfall.

Pacific Lamprey detections at irrigation canals in the Umatilla River basin are largely limited to Feed Diversion Canal. One juvenile Pacific Lamprey released in 2020 was detected at the bypass of the West Extension Diversion Canal (at Three Mile Falls Dam) on April 19th, 2020. No lamprey has been detected at Maxwell Diversion Canal.

Mobile PIT Tag Surveys for Stranded Juvenile Lamprey within Feed Diversion Canal.- The canal was seeded with PIT tags before surveys were conducted to estimate the efficiency of the mobile PIT tag detectors and if any PIT tags released from dead lamprey were likely to move through the canal. The detection efficiency of mobile surveys for PIT tags during the same year they were seeded within the canal were relatively high ranging from 43–93% (Table 7). The same year detection efficiency of these surveys was similar or higher for PIT tags seeded after the canal was dewatered compared to tags that were seeded while the canal was diverting water (Table 7). In the first four survey years (2018–2019, 2021–2022), 72% of tags were detected in the year they were first seeded (n = 113), 10% of tags were first detected a year or more after they were first seeded (n = 15), 10% of tags were never detected despite having

Table 5. The annual detection of PIT-tagged juvenile Pacific Lamprey released in groups upstream of the Feed Diversion Canal. Included are the total number of unique detections of juvenile Pacific Lamprey (total documented entrainment) in the canal and the percentage of released fish that represents (minimum percent of fish entrained), the number of unique fish detected at each antenna array (headgate and screen), the detection efficiency of the headgate array, the number of fish entrained from expanding the unique headgate detections by the detection efficiency of the headgate array and the percentage of released fish that represents, and the number and percentage of fish detected as entrained that were later detected downstream after escaping the canal. No larval or juvenile lamprey were captured and released in water years 2018, or 2021 – 2023.

Water year	Canal detections (N, %)	Headgate detections (N)	Detection efficiency (%, 95CI)	Headgate expanded lamprey entrainment (N, 95CI, %)	Screen detections (N)	Downstream detections (N, %)
2017	34, 11%	28	N/A	N/A	6	3, 9%
2019	11, 2.2%	7	N/A	N/A	5	0, 0%
2020	260, 18%	162	20.3, 14.1–28.4	799, 571–1149, 54%	123	50, 19%

Table 6. The time to detection for PIT-tagged juvenile Pacific Lamprey from their release in groups upstream of the Feed Diversion Canal. Also included is the travel time between the headgate and screen antenna arrays (units in minutes unless otherwise noted as days [d]). No larval or juvenile lamprey were captured and released in water years 2018, or 2021 – 2023.

Water year	**Time to headgate (median, range)**	**Time to screen (median, range)**	**Travel time (median, range)**
2017	265, 15–1.4d	200, 111–42d	N/A
2019	6, 4–25	15, 12–31	7, N/A
2020	604, 22–8.8d	618, 19–1.6d	4, 3–5

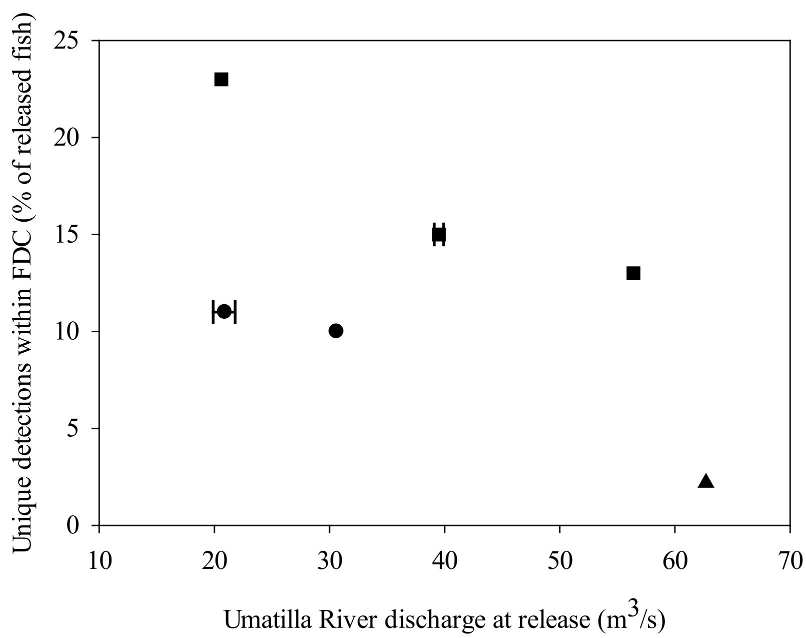

Figure 8. Relation between Umatilla River discharge and lamprey detected in Feed Diversion Canal. Discharge (m^3/sec) was measured adjacent to Feed Diversion Canal (UMUO gage) during lamprey releases. The percentage of released juvenile lamprey detected as entrained is shown for 2017 (●), 2019 (▲), and 2020 (■). Detections are unexpanded and represent the minimum number of fish entrained. When multiple releases occurred in a single day (see Table 3) release groups were pooled by day and the range of discharge at the releases are depicted using horizontal bars.

Table 7. PIT tag detection efficiency of mobile canal surveys within 2 months of tag seeding. Tags were seeded in the canal while the canal was diverting water and after the canal was drained of water.

Water year	All PIT Tags seeded in canal (detected % [N])	PIT Tags seeded during diversion (detected, %)	PIT Tags seeded in drained canal (detected % [N])
2018	63% (19)	53% (8)	73% (11)
2019	43% (13)	33% (5)	53% (8)
2021	90% (27)	87% (13)	93% (14)
2022	82% (54)	80% (35)	86% (19)
2023	93% (41)	91% (20)	95% (21)

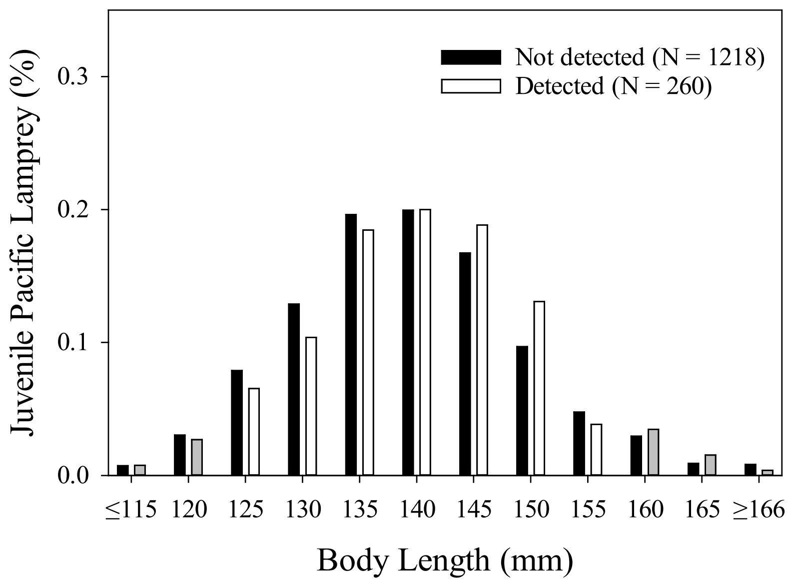

Figure 9. The size distribution at tagging of juvenile Pacific Lamprey by FDC detection in 2020. Distributions are compared between fish that were detected (entrained) shortly after their release, and those lamprey that were not detected as entrained into Feed Diversion Canal.

the opportunity to be detected in surveys of subsequent years (n = 16), and 8% of tags were never detected in the year of their seeding and had no subsequent opportunity to be detected prior to sediment removal in the canal (n = 12).

We also examined if the detection of seeded tags in any of the first four survey years are related to if the canal was diverting water at the time of seeding, the canal substrate upon which the tag was seeded (rock pavers/concrete apron), PIT tag size and model, and the number of days water was diverted in the two months after the tag was seeded. The linear distance between where PIT tags were seeded and the canal headgate is a measure of tag distribution within the canal and the substrate over which the tag was seeded (Figure 10). Over multiple annual surveys tags seeded on the canal apron during water diversion were detected 67% of the time (n = 20), but tags seeded on the apron while the canal was dewatered were detected at similar percentages (86%, n = 19) as tags seeded upstream of the apron both during (83%, n = 49) and after (89%, n = 40) water diversion. However, there were not significant differences in the proportion of seeded tags detected based on canal operations (diverting/not diverting) during seeding or the canal substrate over which the tag was seeded (Fishers Exact Test $P > 0.05$). A greater proportion of the Mini HPT10 pit tags were detected (93%, n = 30) over multiple annual surveys compared to the TXP148511B 8.9mm tags (82%, n = 74) and the Mini HPT 8 PIT tags (73%, n = 24), but these differences were not significant either (Fishers Exact Test $P > 0.05$). For tags seeded during water diversion, a smaller percentage of tags were detected when tags were placed in the canal 51-52 days before dewatering (65%, n = 24), compared to when tags were seeded within 16 days of dewatering (87%, n = 45; Fishers Exact Test $P \leq 0.05$). Despite sediment removal from the canal in autumn 2022, 47 seeded tags (of 156 total) from previous years were detected during the 2023 mobile canal surveys. Only one of the 26 PIT tags implanted in dead larval lamprey released in 2023 were detected during mobile surveys.

Few seeded tags were detected moving past the screen and bypass fixed arrays. Seeded PIT tags were not detected crossing the fixed screen array upstream of the apron between 2018 and 2022. In 2023 a seeded tag from 2021 passed the screen array. In 2022, 2 PIT tags that were previously seeded on the concrete apron just upstream of the bypass tube were detected at the bypass array, indicating they had passed through the bypass structure and tube. One tag was seeded in 2022 while water was being diverted through the canal and the other was seeded in 2021 after the canal had been dewatered. One tag seeded in 2023 just upstream of the screen bypass entrance was detected at the bypass outfall in 2023. The screen array detected 2 of the 8 PIT tags implanted in young dead lamprey that were released upstream of the screen array in 2023. A total of 12 of the 26 PIT tags associated with the young dead lamprey released into the canal were detected at the bypass outfall. Four of these fish were released directly in front of the drum screen. Eleven of these tags were detected within a day of the lamprey release, but one was detected twelve days later. Ultimately half of the dead lamprey that were released into the canal were detected at the outfall or during mobile surveys. We did not detect any PIT tags associated with the 2017, 2019, or 2020 release of tagged living lamprey upstream of Feed Diversion Canal screen during mobile antenna surveys conducted after canal dewatering.

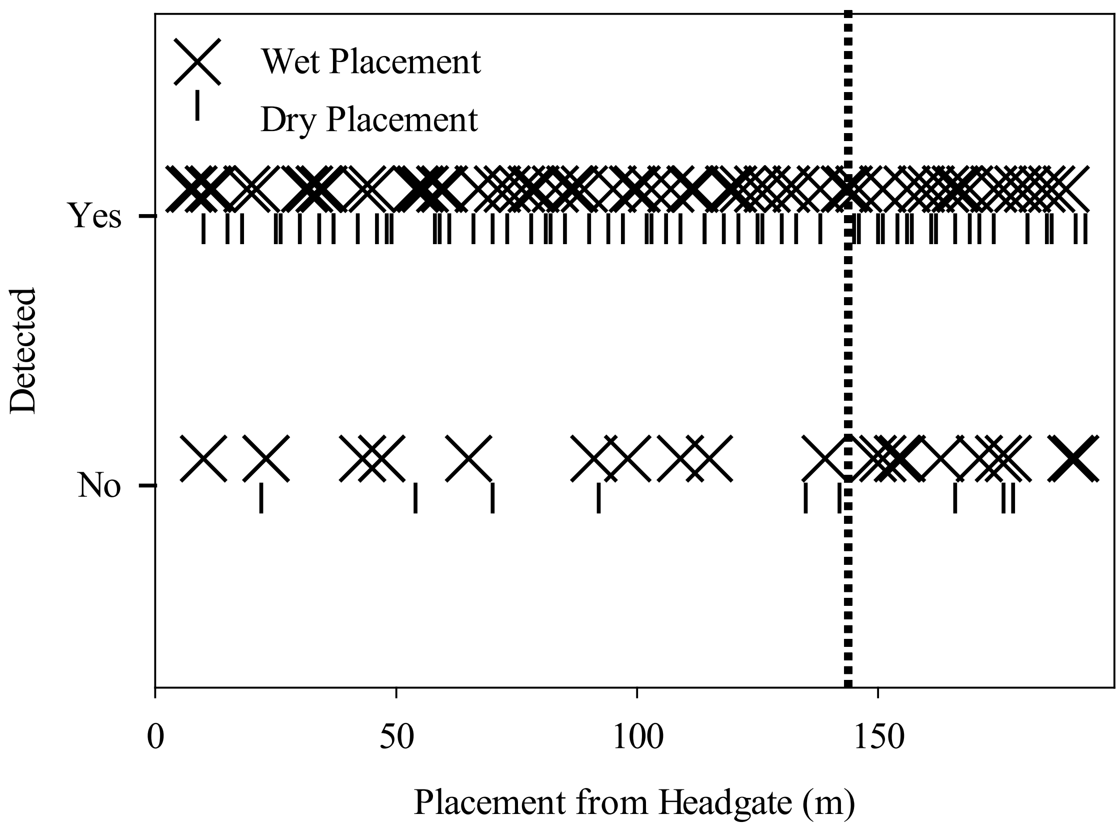

Figure 10. The detection of seeded PIT tags based on tag placement within Feed Diversion Canal. PIT tags were seeded while the canal was diverting water (wet placement) or after the canal was dewatered ('dry' placement) and at various distances from the Feed Canal headgate that correspond with different canal bottom substrates (rock pavers vs concrete apron, divided by the vertical dotted line at 143.5 m). Tag seeding and mobile antenna surveys for tag detection were conducted over four years (2018, 2019, 2021, 2022). Some tags were detected in surveys conducted after the year of their seeding.

Discussion

The entrainment of lamprey into intermittently operating irrigation diversions and their subsequent interaction with salmonid centric screen infrastructure is seen as a threat to lamprey and one of many potential factors limiting lamprey in freshwater environments of the Columbia River basin. Fish screening and the operation of screens is a fish conservation action common to the Pacific Northwest of the United States, yet the effectiveness of these actions is rarely evaluated in terms of the number of fish affected or how these structures affect fish populations (Moyle and Israel 2005). Developing a better understanding of factors that influence lamprey entrainment and screen effectiveness is thought to be an important component of lamprey conservation (Luzier et al. 2011; Clemens et al. 2017; Clemens et al. 2020).

One potentially effective method of addressing the trapping or stranding of juvenile Pacific Lamprey within irrigation canals is to prevent their diversion from rivers and streams into canals (entrainment). Canals with headgates that angle more perpendicularly to a river thalweg and face river flow directly are associated with greater larval lamprey entrainment than canals with headgates that divert water at a more parallel angle to the river thalweg and face river flow obliquely (Lampman and Beals 2019). Canals with a relatively large capacity to divert water tend to remove a greater proportion of discharge from streams and rivers, which is often related to more fish entrainment (Walters et al. 2012). Determining how multiple factors influence the entrainment risk of various life stages of lamprey is important since opportunities to change irrigation canal operations (diversion timing, average rate, or volume) can be limited. Methods to minimize Pacific Lamprey entrainment may be developed using information on how the diversion of these fish are related to biotic factors (e.g., fish size and age), abiotic factors (e.g., stream flow and temperature), and the interaction of these factors (e.g., fish physiology and behavior).

How river flows relate to the canal entrainment of juvenile Pacific Lamprey remains unclear. The outmigration of juvenile Pacific Lamprey is more variable and temporally dispersed compared to outmigration of juvenile salmonids with most individuals leaving during high spikes in river flows and rain events (Goodman et al.

2015). Similarly, the initiation of outmigration in juvenile River and Sea Lamprey of Europe is related to low water temperatures, high stream discharges, and turbidity during the appropriate seasons (largely in winter and spring) and is often multimodal with peaks in both winter and spring (Baer et al. 2018). As a result, many outmigrating juvenile lamprey may encounter diversions during spikes in river flow when they may be less likely to become entrained. The association of spikes in river flow with juvenile lamprey migration may also provide a window to minimize entrainment through short reductions or suspensions of water diversion. Exactly when these windows occur might be difficult to predict for juvenile Pacific Lamprey (Moser et al. 2015), but discharge spikes in January and February may have potential for mitigation (Baer et al. 2018).

Factors that influence juvenile lamprey entrainment were examined in this study by observing patterns in PIT tag detection after their release. Although river flows during lamprey entrainment events were within the range observed for the entrainment of spring-emigrating juvenile steelhead (Simpson and Peterson 2016), the proportion of emigrating juvenile Pacific Lamprey entrained after their release upstream of the Feed Canal headgate was greater than the known range of annual entrainment rates exhibited by outmigrating juvenile hatchery steelhead at Umatilla River canals (0–32%, Simpson and Peterson 2016) after accounting for the detection efficiency of the antenna arrays. This may be expected since juvenile Pacific Lamprey are weaker swimmers than juvenile steelhead. Also, since lamprey are thought to be more bottom oriented during outmigration due to their lack of a swim bladder, headgate structures that typically open from the bottom of streams could leave lamprey more vulnerable to entrainment. However, caution should be used when comparing entrainment between steelhead and lamprey since most steelhead entrainment on the Umatilla River occurred at Maxwell and West Extension Diversion Canals where canal-specific characteristics could drive differences in the percent of fish entrained (e.g., headgate orientation and location; Simpson and Ostrand 2012), as could the differences in mortality experienced between the various release and entrainment sites used in these studies. Unfortunately, a useful expanded estimate of entrainment was only generated at Feed Diversion Canal in 2020. This year three entrained PIT tags were detected associated with Pacific Lamprey tagged as larvae during the 2019 water year. These detections occurred in close temporal proximity to detections from the 2020 release groups, suggesting that these volitionally-entrained fish may be juvenile lamprey. If so, this would support the findings of other studies that the majority of juvenile lamprey migrate during high flow events, and the timing of group releases likely represent the experience of volitionally migrating juvenile lamprey. In general, detections of entrained lamprey appear to be negatively related to river discharge at release, suggesting that when lamprey encounter diversion headgates they are less likely to be entrained under high flow conditions. The rate of water diversion into Feed Canal is fairly consistent, so when the Umatilla River is experiencing higher flows, a relatively smaller proportion of the river is often diverted into the canal. A better understanding of the relation between river flow and entrainment could be achieved by continuing the comparison of flow to the total number (expanded) of fish entrained, and by obtaining a finer scale understanding of how environmental conditions relate to when volitionally migrating fish encounter irrigation diversions. The entrainment of juvenile Pacific Lamprey did not appear size selective across the lengths of released PIT-tagged juvenile lamprey and at river discharges experienced after their release (22–62 m^3/sec). In this analysis, undetected juvenile lamprey were assumed not to be entrained, but poor detection efficiency within the canal makes it likely that some undetected fish were actually entrained.

Another potential method to prevent the stranding and trapping of juvenile Pacific Lamprey in canals is the use of fish screens designed to return (bypass) fish back into the river after their entrainment. Like much of the Pacific Northwest, the fish screen and bypass infrastructure that lampreys encounter in the Umatilla River basin are designed to return juvenile salmonids to their river of origin. The interstitial spaces in these fish screens can be too large to successfully bypass small and narrow lamprey, allowing them to pass through screens instead of being diverted back into the river. In fact, the distribution of small larval lamprey within irrigation canals appears to be more related to the location of deposited fine sediment than the location of fish screens (Lampman and Beals 2019). However, a vertical traveling screen (2.0 m wide channel) was proven very effective at bypassing larger juvenile Pacific Lamprey released directly upstream due to the small pore size of the screen relative to body size of the lamprey (100%, Goodman et al. 2017). Few fish screens are evaluated for lamprey exclusion and bypass, so little is known about how the size and configuration of these fish screens affect bypass success for lamprey. Furthermore, it is unknown if increasing the distance of fish screens from the point of water diversion negatively affects the ability of juvenile lamprey to reach a screen and be bypassed. Although, juvenile lamprey may not hold in fine sediment upstream of fish screens the same way larval lamprey often do, bypass detections of PIT-tagged juvenile Pacific Lamprey can be more common when fish are released just upstream of the rotary drum screens (82%, Lampman and Beals 2019), compared to when they are released near the headgate in an irrigation canal (3–19%). This illustrates that little is understood about the fate (i.e., killed or stranded pre-bypass, bypassed, removed from the population by passing through the fish screen) of individual juvenile lamprey once they enter irrigation canals that have fish screens installed downstream of their point of diversion.

The detection efficiency of PIT-tagged lamprey at the fixed arrays within Feed Diversion Canal was low. Few entrained juvenile lamprey were detected at both fixed arrays within the canal over all three years of monitoring release groups, which can be indicative of poor detection of 8-mm and 10-mm PIT tags at both arrays within the canal. Only 20% of entrained juvenile lamprey were detected at the headgate array, based on results from the only year we could estimate detection efficiency (2020). Many entrained salmonids with larger 12-mm PIT tags were detected at the fixed arrays within Feed Diversion Canal in 2023 (Appendix B). The annual detection efficiencies observed for juvenile steelhead with 12-mm PIT tags at the fixed Feed Canal arrays was relatively high (2016; headgate = 44%, screen = 80%). Presumably this poorer detection efficiency is driven by the smaller sized tags used for implantation in juvenile lamprey. However, other differences between salmonids and lamprey could also contribute to differences in detection efficiencies, such as their position in the water column, the orientation of their body (and PIT tag) while they move downstream, or how long lamprey remain in the detection field of the antenna.

Most of the 8 to 10-mm PIT tags seeded within the canal were detected at least once during our four mobile surveys (82%), and movement of seeded tags in the canal appeared uncommon. Only one seeded tag was detected moving past the fixed array upstream of the screen, no tags were detected in sediment piles just downstream of the drum screen, and 3 PIT tags seeded on the concrete apron were detected as passing through the bypass pipe to the outfall. Any PIT tags liberated from dead lamprey were likely available for detection by mobile surveys barring their mechanical destruction. Since the three tags detected at the bypass outfall were seeded in the canal just upstream of the bypass tube, PIT tagged lamprey that die near the bypass screen could be mistaken for live fish returning to the river.

Any PIT-tagged larval or juvenile lamprey that die outside of their burrow, including on fish screens, and retain their PIT tag may be detected at the bypass outfall based on the results of this study. Such detections at the bypass outfall could also be mistakenly assigned to live lamprey. Most dead fish released into the water column were detected within a day of their release, suggesting more frequent movement through the canal compared to seeded PIT tags. Although lamprey have no swim bladders, air can become trapped in the oral hood of larval lamprey, artificially increasing their buoyancy (Jolley et al. 2015). Future evaluations that examine the mobility of PIT-tagged larval and juvenile lamprey in an operating canal will release fish at the substrate surface and confirm the buoyance of lamprey by expelling any trapped air from their mouthparts prior to their release.

Canal entrainment of juvenile Pacific Lamprey from the release groups occurred before the bypass outfall antenna was installed. Few canal-entrained juvenile Pacific Lamprey were documented returning to the Umatilla River through screen and bypass infrastructure via redetection at mainstem Umatilla and Columbia River arrays (19%), so the ultimate fate of most entrained fish is unknown. Confirmed escapees detected downstream of the canal were rarely observed at multiple locations, suggesting a poor ability to redetect tagged lamprey downstream. No PIT tags associated with lamprey were detected during mobile surveys within the canal despite the high detection efficiencies of these surveys (43–93%). Previous electrofishing surveys by the Bureau of Reclamation found no juvenile lamprey upstream of the fish screen (Sutphin et al. 2012; Sutphin et al. 2013). As a result, it is unlikely that most entrained juvenile Pacific Lamprey from the release groups held in sediment upstream of the canal screen, but instead were bypassed into the Umatilla River after which they were never redetected.

Although it is possible some of these PIT tagged juvenile lamprey passed through the drum screen, other studies have shown that few lamprey greater than 100 mm (e.g., juveniles) pass through drum screens (Lampman and Beals 2019), and the Bureau of Reclamation also found no larval or juvenile lamprey downstream of the screens during the same electrofishing surveys at Feed Diversion Canal. Based on bypass detections of juvenile steelhead and Chinook Salmon between 2021 and 2023, the fixed antenna on the bypass outfall of Feed Canal will likely be effective at detecting PIT tags associated with any future juvenile lamprey release groups leaving the canal. Such improvements should allow the direct documentation of juvenile lamprey that return to the Umatilla River and allow comparisons of lamprey bypass success at Feed Diversion Canal to the bypass success for juvenile lamprey encountering other types of infrastructure (e.g., louvers and vertical traveling screens; Goodman et al. 2017).

Additional Actions in 2024

Next year we will continue to examine if PIT-tagged lamprey that die in the canal can move downstream before decomposition and become detectable within the canal or at the bypass. Since Pacific Lamprey have no swim bladder and are thought to exhibit benthic movement, we will adjust our release methods next year to examine the buoyancy of fish before their release, and fish will be released directly on the substrate of the canal in the future.

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Literature Cited

Bond, RM, CL Nicol, JD Kiernan, BC Spence. 2019. Occurrence, fate, and confounding influence of ghost passive integrated transponder tags in an intensively monitored watershed. Canadian Journal of Fisheries and Aquatic Science 76:286–298.

Dauble, DD, RA Moursund, MD Bleich. 2006. Swimming behavior of juvenile Pacific Lamprey, *Lampetra tridentata*. Environmental Biology of Fishes 75:167–171.

Cameron, WA, SM Knapp, and RW Carmichael. 1997. Evaluation of juvenile salmonid bypass facilities and passage at water diversions on the lower Umatilla River. Bonneville Power Administration, Final Report, Portland, OR.

Clemens, BJ, and 20 others. 2017. Conservation challenges and research needs for Pacific Lamprey in the Columbia River basin. Fisheries 42(5):268–280.

Clemens, BJ, K Anlauf-Dunn, M Weeber, T Stahl. 2020. Coastal, Columbia, and Snake Conservation Plan for Lampreys in Oregon. Oregon Department of Fish and Wildlife, Salem, Oregon. 192 pp.

Goodman, DH, SB Reid, N Som, W Poytress. 2015. The punctuated seaward migration of Pacific Lamprey (*Entosphenus tridentatus*): environmental cues and implications for streamflow management. Canadian Journal of Fisheries and Aquatic Sciences 72:1–12.

Goodman, DH, SB Reid, RC Reyes, BJ Wu, BB Bridges. 2017. Screen efficiency and implications for losses of lamprey macrophthalmia at California's largest water diversions. North American Journal of Fisheries Management 37:30–40.

Hill, MS, GB Zydlewski, JD Zydlewski, JM Gasvoda. 2006. Development and evaluation of PIT tag detection units: PITpacks. Fisheries Research 77:102–109.

Lampman, R and T Beals. 2019. Exploring techniques to reduce lamprey and salmonid entrainment into canals. Yakama Nation Pacific Lamprey Project Final Progress

Report (Project ID No. 2621). Prepared for the U.S. Department of Interior, Bureau of Reclamation, Boise, ID.

Luzier, CW, HA Schaller, JK Bronstrom, C Cook-Tabor, RD Nelle, K Ostrand, B Streif. 2011. Pacific Lamprey (*Entosphenus tridentatus*) assessment and template for conservation measures. U.S. Fish and Wildlife Service, Portland, Oregon. 282 pp.

McMichael, GA, JA Vucelick, CS Abernathy, DA Neitzel. 2004. Comparing fish screen performance to physical design criteria. Fisheries 29(7):10–16.

Moser, ML, AD Jackson, MC Lucas, RP Mueller. 2015. Behavior and potential threats to survival of migrating lamprey ammocoetes and macrophthalmia. Reviews in Fish Biology and Fisheries 25:103–116.

Moyle, PB, and JA Israel. 2005. Untested assumptions: effectiveness of screening diversions for conservation of fish populations. Fisheries 30(5):20–28.

Muller, RP, RA Moursund, MD Bleich. 2006. Tagging juvenile Pacific Lamprey with passive integrated transponders: methodology, short-term mortality, and influence on swimming performance. North American Journal of Fisheries Management 26:361–366.

PSMFC (Pacific States Marine Fisheries Commission). 2021. The Columbia basin PIT-tag information system (PTAGIS). PSMFC, Portland, Oregon. Available: www.ptagis.org. (December 2021).

Simpson, WG. 2018. The entrainment and screening of returning and postspawning adult salmonids at irrigation canals of the Umatilla River, Oregon. Journal of Fish and Wildlife Management 9:285–295.

Simpson, WG, DP Peterson. 2016. Fisheries monitoring system: Umatilla Project facilities. Annual report to Bureau of Reclamation, Hermiston, OR.

Simpson, WG, KG Ostrand. 2012. Effects of entrainment and bypass at screened irrigation canals on juvenile steelhead. Transactions of the American Fisheries Society 141:599–609.

Stout, JB, MM Conner, P Budy, PD Mackinnon. 2019. We ain't afraid of no ghosts: tracking habitat interactions and movement dynamics of ghost tags under differing flow conditions in a sand-bed river. North American Journal of Fisheries Management 39:1337–1347.

Sutphin, Z, E Best, S Camp. 2012. Presence of early life-stages of Pacific Lamprey above and below water intake screens in Bureau of Reclamation canals in the Umatilla River basin. U.S. Bureau of Reclamation, Pacific Northwest Regional Office, Technical Memorandum No. 86-68290-12-03. 37 pp.

Sutphin, Z, E Best, S Camp. 2013. Presence of early life-stages of Pacific Lamprey above and below water intake screens in Bureau of Reclamation canals in the Umatilla River basin: year 2. U.S. Bureau of Reclamation, Pacific Northwest Regional Office, Technical Memorandum No. 86-68290-13-2. 14 pp.

U.S. Bureau of Reclamation (Reclamation). 2016. Exploring techniques to reduce lamprey and salmonid entrainment into canals. Proposal to Science and Technology Program, Research and Development Office, Bureau of Reclamation.

Walters, AW, DM Holzer, JR Faulkner, CD Warren, PD Murphy, MM McCluer. 2012. Quantifying cumulative entrainment effects for Chinook Salmon in a heavily irrigated watershed. Transactions of the American Fisheries Society 141:1180–1190.

APPENDIX A: PIT-tagged Fish Detected at the mainstem Umatilla River array UMW in 2023

Fish species/run	Capture/tagging site	Release site	Dates released	Dates detected	Unique fish (N)
Steelhead/Summer	Birch Creek	Birch Creek	6/26/2022 – 5/22/2023	1/2/2023 – 5/31/2023	40
Steelhead/Summer	Irrigon Hatchery	Pendleton Acclimation Pond	4/13/2023	5/1/2023 – 6/12/2023	41
Steelhead/Summer	Meacham Creek	Meacham Creek	4/23/2022 – 5/21/2023	1/3/2023 – 5/28/2023	6
Steelhead/Summer	Minthorn Acclimation Pond	Minthorn Acclimation Pond	1/13/2023	4/1/2023	1
Steelhead/Summer	Umatilla River	Umatilla River	9/26/2022 – 4/16/2023	1/27/2023 – 5/24/2023	8
Steelhead/Summer	Three Mile Falls Dam	Umatilla River	3/28/2023 – 6/5/2023	3/28/2023 – 12/19/2023	1101
Steelhead/Summer (Adult)	Birch Creek	Birch Creek	2/16/2020 – 5/22/2022	4/17/2020 – 11/10/2023	13
Steelhead/Summer (Adult)	Bonneville Adult Fish Facility	Bonneville Adult Fish Facility	7/20/2022 – 9/19/2022	1/1/2023 – 4/15/2023	5
Steelhead/Summer (Adult)	Irrigon Hatchery	Imeques Acclimation Pond	4/21/2021	4/9/2023	1
Steelhead/Summer (Adult)	Irrigon Hatchery	Pendleton Acclimation Pond	4/28/2022	11/10/2023	1
Steelhead/Summer (Adult)	Lower Granite Dam	Lower Granite Dam	8/9/2022 –11/6/2022	3/20/2023 –5/14/2023	7
Steelhead/Summer (Adult)	Meacham Creek	Meacham Creek	2/2/2020	3/18/2023	1
Steelhead/Summer (Adult)	Priest Rapids Dam Adult Ladder	Priest Rapids Dam Adult Ladder	9/8/2022 –7/24/2023	4/7/2023 –9/6/2023	2
Steelhead/Summer (Adult)	Three Mile Falls Dam	Three Mile Falls Dam Tailrace	4/8/2021 – 5/21/2022	11/11/2023 –12/5/2023	2
Steelhead/Summer (Adult)	Three Mile Falls Dam	Umatilla River	4/18/2020 – 5/15/2022	5/10/2020 – 12/13/2023	16
Chinook/Fall	Bonneville Hatchery	Pendleton Acclimation Pond	3/3/2022 – 3/7/2022	3/5/2023 – 4/8/2023	268

Fish species/run	**Capture/tagging site**	**Release site**	**Dates released**	**Dates detected**	**Unique fish (N)**
Chinook/Spring	Umatilla Hatchery	Imeques Acclimation Pond	4/6/2023	4/7/2023 - 4/10/2023	39
Chinook/Spring	Umatilla Hatchery	Thornhollow Acclimation Pond	4/6/2023	4/7/2023 – 4/21/2023	18
Chinook/Spring	Umatilla River	Umatilla River	9/13/2022 – 2/8/2023	1/8/2023 – 4/10/2023	5
Chinook (Adult)	Bonneville Adult Fish Facility	Bonneville Adult Fish Facility	4/25/2023 –5/11/2023	5/4/2023 – 5/22/2023	7
Chinook/Spring	Irrigon Hatchery	Pendleton Acclimation Pond	4/5/2021	5/21/2023	1
Coho	Three Mile Falls Dam	Three Mile Falls Dam Tailrace	5/8/2023	9/26/2023 – 10/13/2023	1
Coho (Adult)	Cascade Hatchery	Lostine River Weir	3/30/2022	10/7/2023	1

APPENDIX B: PIT-tagged Salmonids Detected at Arrays within the Feed Diversion Canal (FDC) for Water Year 2023

Fish species/run	Capture/tagging site	Release site	Dates released	Dates detected	Unique fish (N)
Steelhead/Summer	Birch Creek	Birch Creek	6/26/2022 – 3/29/2023	1/6/2023 – 3/31/2023	2
Steelhead/Summer	Irrigon Hatchery	Pendleton Acclimation Pond	4/13/2023	4/30/2023 – 5/1/2023	1
Steelhead/Summer	Umatilla River	Umatilla River	10/6/2022 – 11/7/2022	1/6/2023 – 4/1/2023	4
Steelhead/Summer (Adult)	Minthorn Acclimation Pond	Minthorn Acclimation Pond	1/13/2023	4/1/2023	1
Steelhead/Summer (Adult)	John Day River	John Day River	5/14/2020	4/7/2023	1
Chinook/Fall	Bonneville Hatchery	Pendleton Acclimation Pond	3/3/2023 – 3/7/2023	3/4/2023 – 4/13/2023	24
Chinook/Spring	Irrigon Hatchery	Imeques Acclimation Pond	4/6/2023	4/7/2023 4/8/2023	25
Chinook/Spring	Meacham Creek	Meacham Creek	3/15/2023 – 3/25/2023	3/22/2023 – 4/5/2023	3
Chinook/Spring	Irrigon Hatchery	Thornhollow Acclimation Pond	4/6/2023	4/7/2023	6
Chinook/Spring	Umatilla River	Umatilla River	9/24/2022 – 3/26/2023	2/26/2023 – 4/11/2023	7

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