2015 Intensive Monitoring of Larval-Juvenile Lamprey Entrainment in the Yakima River Subbasin

Cover Photo: Overview of the area upstream of the fish screens at Bachelor-Hatton Diversion (Ahtanum Creek, river km 31.8) where over 10,000 larval lampreys were salvaged in 2015.

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ABSTRACT

Total larval lamprey numbers were estimated at three diversions with considerably high lamprey entrainment. The area immediately downstream of the fish screens at Sunnyside Diversion (Yakima River, river km 171.4), the area immediately upstream the fish screens at Wapato Diversion (Yakima River, river km 176.3), and the area immediately upstream and downstream of the fish screens at Bachelor-Hatton Diversion (Ahtanum Creek, river km 31.8) were our primary focus. At each location, surveys were conducted in representative areas of Type I and Type II habitat. The resulting Type I and Type II densities were then extrapolated over the area of the respective habitat type.

At Sunnyside Diversion (in the area immediately downstream of the fish screens), a total of 66 plots were surveyed in representative portions of Type I and Type II habitat between October 29, 2015 and February 25, 2016 covering five survey dates. On average, daily density in Type I habitat ranged between 4.3 and 10.1 lamprey/m^2 (average of 6.9 lamprey/m^2) and that in Type II habitat ranged between 2.1 and 3.3 lamprey/m^2 (average of 2.7 lamprey/m^2). Daily estimated lamprey numbers from electrofishing ranged from as low as 3,146 (December 14, 2015) to as high as 11,075 (October 29, 2015). Throughout the salvage/survey process, a total of 1,954 lampreys were salvaged and returned to the river, with 49 dead lampreys found along the bank (totaling 2,003 lampreys removed). Total estimated numbers (created from the addition of electrofishing estimates, other lamprey observations, and cumulative number of lampreys removed up to the previous survey date) ranged from 4,796 to 11,115.

At Wapato Diversion (in the area immediately upstream of the fish screens) a total of 12 plots were surveyed in representative portions of Type I and Type II habitat on October 27, 2015. From this, we estimated the total number of larval-juvenile lampreys (from electrofishing densities) to be 6,145 in this area. On average, high density Type I habitat contained 12.9 lamprey/m^2, medium density Type I habitat contained 5.2 lamprey/m^2, and low density Type I habitat near the fish screens contained 2.8 lamprey/m^2. The total estimated number of lampreys in the area immediately upstream of the fish screens at Wapato Diversion was 6,969. If we assume that the high density area potentially had 2 times as many fish at its peak on October 16, 2015, compared to October 27, 2015, based on our observation from electrofishing in high density areas, our estimated number of lampreys in this area increases to 8,075, based on this conservative adjustment (assuming that the density in other areas remained constant).

At Bachelor-Hatton Diversion, surveys were conducted between July 14, 2015 and January 28, 2016. Surveys occurred both immediately upstream and immediately downstream of the fish screens (seven and four survey dates, respectively). From electrofishing efforts, 10,698 lampreys, all live larvae, were captured and successfully returned to Ahtanum Creek. Average electrofishing densities above the fish screens ranged from 42.9-560.0 lamprey/m^2 (July 14, 2015 and October 6, 2015, respectively). Below the fish screens, electrofishing densities ranged from 9.0-25.0 lamprey/m^2 (July 14, 2015 and October 7, 2015, respectively). Identification of 564

larval lampreys (>50 mm in total length) showed that 97.3% were Pacific Lamprey. Also, a total of 1,518 dead (or mostly dead) lampreys were found on dewatered banks (n=8), on top of wetted habitat (n=810), or found on dredged material (n=700). During the dredging operation, which occurred on October 16-17, 2015, two pumps (50 gallon/min and 300 gallon/min pumps) were placed immediately upstream of the fish screens and used to draw down the water level. We estimate that approximately 1,188 larval lampreys have passed through these two pumps during approximately 500 minutes of run time (average of 142 lamprey/hour), resulting in approximately 16-25% mortality (~321 lampreys). At final tally, 13,404 larval lampreys were removed from the diversion (either through electrofishing, mortality, or pump). Upstream of the fish screens, daily total estimated lamprey numbers (sum total of daily electrofished number plus cumulative number of lampreys removed prior to the survey date) ranged from 5,536 (July 14, 2015) to 34,467 (October 17, 2015). Downstream of the fish screens, daily total estimated lamprey numbers ranged between 715 (July 14, 2015) and 1,248 (October 7, 2015).

In reality, these estimated numbers could be considerably larger, even exceeding the high range of our estimated numbers, as we are entirely uncertain how many lampreys remained unseen during the survey period either from survey inefficiency, predation, decomposition, or concealment in the dredged material. From our 2014 mark-recapture study in Wapato Diversion, we estimated only 19-45% capture efficiency using the standard electrofishing surveys.

The ratio of Pacific Lamprey (vs. Western Brook Lamprey) was comparatively high during the 2015-2016 survey period compared to previous years: At Sunnyside Diversion it was 14.2%, at Wapato Diversion it was 17.1%, and at Bachelor-Hatton Diversion it was 97.3%. It is likely that the offspring from the Ahtanum Creek translocation is contributing to this high ratio at Bachelor-Hatton Diversion and those fish are gradually reaching Wapato and Sunnyside diversions on mainstem Yakima River. During the 2014-2015 survey period, only ~7% were Pacific Lamprey at Sunnyside and Wapato diversions and no Pacific Lamprey were found at Bachelor-Hatton Diversion.

INTRODUCTION

Irrigation diversions in the Yakima Subbasin entrain many thousands of larval and juvenile Pacific Lamprey (*Entosphenus tridentatus*) and Western Brook Lamprey (*Lampetra richardsoni*) each year both upstream and downstream of the fish screens. The entrained lampreys (buried in the fine sand, silt and clay sediments) become vulnerable to desiccation when the diversions are dewatered in the fall. Annual dredging operations (removal of fine sediments) also pose a serious threat to entrained lampreys. Dewatered electrofishing surveys conducted in 2015 revealed that tens of thousands of larval/juvenile lampreys were entrained in three irrigation diversions in the Yakima Subbasin; Sunnyside Diversion (Yakima River, river km 171.4), Wapato Diversion (Yakima River, river km 176.3), and Bachelor-Hatton Diversion (Ahtanum Creek, river km 31.8). During the irrigation season, Sunnyside Diversion diverts approximately 300-1300 cfs and Wapato Diversion diverts approximately 400-2000 cfs from Yakima River, and Bachelor Hatton Diversion diverts approximately 30-40 cfs from Ahtanum Creek. In the following report, we attempt to answer one primary question; 1) how many larval and juvenile lampreys are entrained in Sunnyside, Wapato, and Bachelor-Hatton diversions?

METHODS

Sunnyside, Wapato and Bachelor-Hatton diversions were intensively surveyed for larval lampreys during the 2015-2016 dewatering period. Larval lamprey surveys were focused in the following three areas: 1) immediately downstream of the fish screens at Sunnyside Diversion, 2) immediately upstream the fish screens at Wapato Diversion, and 3) immediately upstream and downstream of the fish screens at Bachelor-Hatton Diversion. Whereas 3) was a new focus for the intensive monitoring surveys, past electrofishing surveys have continuously shown that 1) and 2) accumulate a large number of larval/juvenile lampreys.

The distribution of Type I (preferred) and Type II (acceptable) larval lamprey habitat was mapped for each survey location using Google Earth 7. The resulting area of each habitat type was calculated on the Earth Point Website (http://www.earthpoint.us/shapes.aspx). In order to calculate the area of available (wetted) Type I and Type II habitat on each survey date, the daily wetted ratio of the overall habitat area was estimated and used to calculate available habitat areas.

Electrofishing surveys were performed using an AbP-2 Backpack Electrofisher (ETS Electrofishing Systems Inc., Madison, WI) using standard larval lamprey survey protocols (3 pulses/sec and fast stunning pulse of 30 pulses/sec, 25% duty cycle, 3:1 burst pulse train, and 125 volts) and focused on representative areas (plots) of available Type I and Type II larval lamprey habitat. Captured lampreys were identified to species (Western Brook Lamprey or Pacific Lamprey, if total length was greater than 50 mm). The number of missed lampreys was

tallied individually or calculated from an estimated ratio of captured to missed lampreys (when too numerous to count individually). The total number of lampreys observed from electrofishing was calculated for each survey (total of captured and missed). When both areas upstream and downstream of the fish screens were surveyed, a subsample of the captured lampreys were measured separately for both surveyed areas.

Resulting electrofishing densities were extrapolated over the wetted area of each habitat type and summed together to attain a daily estimated number of lampreys from electrofishing. In addition to electrofishing, dewatered fine sediment was searched for dead (or near dead) larval/juvenile lampreys, which were tallied separately. Total estimated numbers for each survey date were calculated from the addition of electrofishing estimates, all other lampreys observed and/or estimated, and cumulative number of lampreys removed (captured and desiccated lampreys) up to the previous survey date.

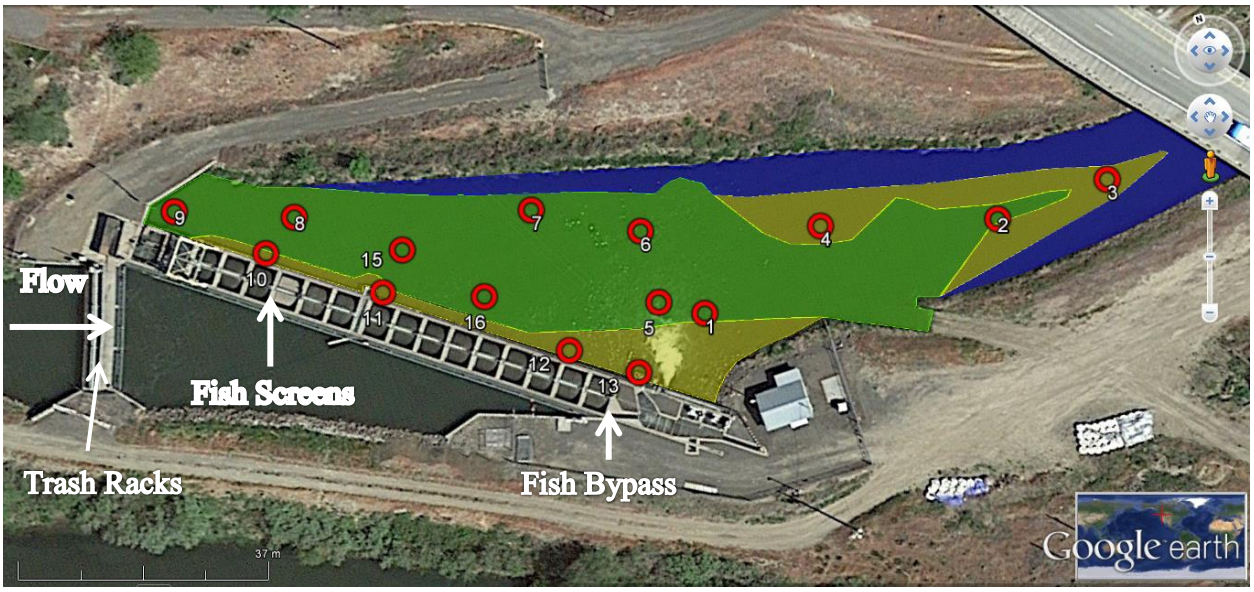
At Bachelor-Hatton Diversion, the dredging process (annual removal of fine sediments conducted by the Bureau of Reclamation) was closely monitored for impacts on entrained lampreys. Larval lampreys were searched for on the surface of dredged (removed) fine sediment and tallied separately from desiccated lampreys found within the diversion. In addition, during the dredging operation, two pumps (50 gallon/min and 300 gallon/min pumps) were placed immediately upstream of the fish screens and used to draw down the water level. Nets were placed under the outflow from each pump to sample the number of fish passing through. As a result, the number of lampreys removed by the pumps was estimated (from observed passage rates and total pump run time). Because the dredging and pumps operated during and after electrofishing took place, we did not include the number of lampreys observed or estimated from these two operations in the daily total estimated numbers (except in the cumulative number of lampreys removed) due to the potential of double counting some of the same lampreys from the electrofishing surveys.

RESULTS

Sunnyside Diversion

A total of 66 repeat plot surveys were conducted in 12 representative plots of Type I and Type II habitat (Map 1) between October 29, 2015 and February 25, 2016 covering five survey dates at Sunnyside Diversion along Yakima River, river km 171.4 (Table 1). Although the headgate was closed on October 26, 2015, due to subsurface flow and small leakage in the headgate, the water level at Sunnyside needed to be pumped down to a surveyable level (assistance from the Bureau of Reclamation made this possible). Sometimes the pump was turned on only for a few days before we conducted the survey (such as for October 29, 2016, and December 14, 2016), whereas other times the pump ran continuously for 20 days or longer (such as for November 17,

2016, and February 25, 2016). Average lamprey densities were 2.5 times higher in Type I habitat than Type II habitat (Table 2 and 3, respectively). Daily estimated lamprey numbers from electrofishing (Type I and Type II) ranged from 3,146 (December 14, 2015) to 11,075 (October 29, 2015; Table 4). Throughout the salvage/survey process, a total of 1,954 lampreys were salvaged and returned to the river, with 49 dead lampreys found along the dried banks (totaling 2,003 lampreys removed). Total estimated numbers by survey date (created from the addition of electrofishing estimates, other observation/estimates, and cumulative number of lampreys removed up to the previous survey date) ranged from 4,796 to 11,115. Identification of 465 larval lampreys (>50 mm in total length) showed that 14.2% were Pacific Lamprey.



Map 1. Sunnyside Diversion overview map showing the distribution of Type I, II, III habitat (green, yellow and blue polygons, respectively) immediately downstream of the fish screens and the location of the 12 repeatedly surveyed plots in Type I and Type II habitat (red circles).

Table 1. Available (wetted) Type I and Type II habitat area on each of the five survey dates at Sunnyside Diversion immediately downstream of the fish screens.

Survey Date	Days Post Headgate Closure	Days Since Pump Operation	Overall Type I Area (m^2)	Overall Type II Area (m^2)	Overall Type III Area (m^2)	Overall Area Type I/II Habitat (m^2)	% Type I Habitat	% Type II Habitat	% Overall Type I/II Habitat Wetted	Daily Wetted Area Type I (m^2)	Daily Wetted Area Type II (m^2)
10/29/15	7	3	1897	749	701	2646	72%	28%	53%	997	394
11/04/15	13	9	1897	749	701	2646	72%	28%	47%	892	352
11/17/15	26	22	1897	749	701	2646	72%	28%	33%	630	249
12/14/15	53	3	1897	749	701	2646	72%	28%	33%	630	249
02/25/16	126	31	1897	749	701	2646	72%	28%	33%	630	249

Table 2. Daily estimated lamprey numbers from electrofishing estimated within Type I habitat at Sunnyside Diversion immediately downstream of the fish screens.

Survey Date	# of Plots Type I	Survey Area Type I (m^2)	# Captured Type I	# Missed Type I	Total # E-Fish in Type I	Density Type I (L/m^2)	Daily Est. # Lamprey E-Fish in Type I
10/29/15	9	40.0	327	87	405	10.1	10096
11/04/15	7	60.0	495	106	576	9.6	8565
11/17/15	7	65.5	310	135	431	6.6	4144
12/14/15	6	46.0	171	55	211	4.6	2889
02/25/16	9	67.0	238	71	289	4.3	2716
Total	**38**	**279**	**1541**	**454**	**1912**	**6.9**	**-**

Table 3. Daily estimated lamprey numbers from electrofishing estimated within Type II habitat at Sunnyside Diversion immediately downstream of the fish screens.

Survey Date	# of Plots Type II	Survey Area Type II (m^2)	# Captured in Type II	# Missed in Type II	Total # E-Fish in Type II	Density Type II (L/m^2)	Daily Est. # Lamprey E-Fish in Type II
10/29/15	6	20.5	42	9	51	2.5	979
11/04/15	5	44.0	112	25	137	3.1	1097
11/17/15	4	25.5	54	14	68	2.7	663
12/14/15	7	41.5	73	15	88	2.1	527
02/25/16	5	28.5	75	20	95	3.3	829
Total	**27**	**160**	**356**	**83**	**439**	**2.7**	**-**

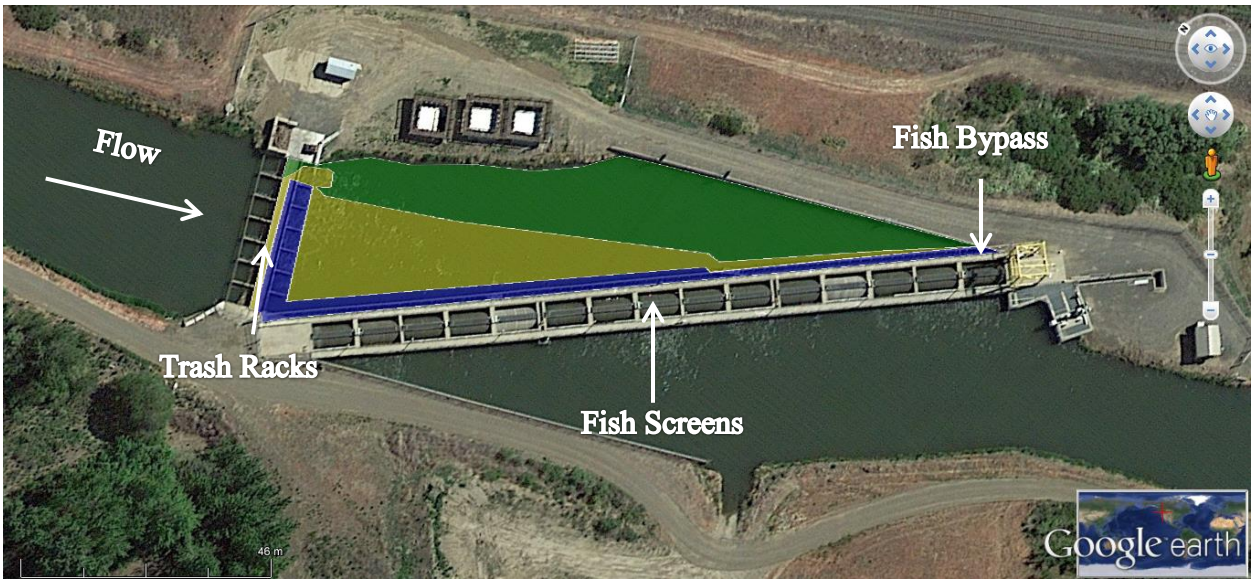
Table 4. Summary of lamprey assessment at Sunnyside Diversion immediately downstream of the fish screens.

Survey Date	Total # of Plots	# Captured (E-Fishing)	# Captured (on Bank)	Daily # Removed	Cumul. # Removed	Daily Est. # Lamprey (E-Fishing)	Daily Est. # Lamprey (Combined)
10/29/15	15	369	40	409	409	11075	11115
11/04/15	12	607	0	607	1016	9661	10070
11/17/15	11	364	0	364	1380	4807	5823
12/14/15	14	261	0	261	1641	3416	4796
02/25/16	15	353	9	362	2003	3545	5195
Total	**67**	**1954**	**49**	**2003**	**-**	**-**	**-**

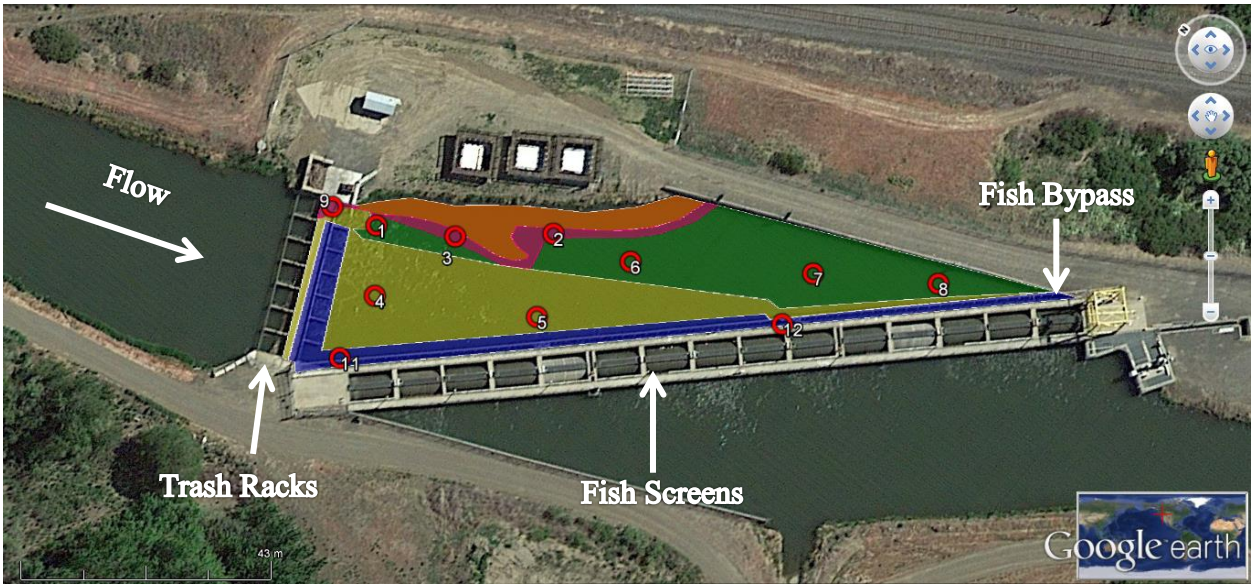
Wapato Diversion

A total of 12 plots were surveyed in representative portions of Type I and Type II habitat on October 27, 2015, at Wapato Diversion (along Yakima River, river km 176.3) in the area immediately upstream of the fish screens (Map 2 and Table 5). The headgate to the diversion

closed on October 16, 2015. During electrofishing surveys, large differences in densities were observed within Type I habitat. To account for these differences observed in density levels, Type I habitat was separated into high, medium, and low density areas and the number of lampreys in the Type I habitat was estimated separately for these areas (Table 6). On average, high density Type I habitat contained 12.9 lamprey/m^2, medium density Type I habitat contained 5.2 lamprey/m^2, and low density Type I habitat near the fish screens contained 2.8 lamprey/m^2. In Type II habitat, lamprey densities were 0.1 lamprey/m^2 with minimal differences among plots. From this, we estimated the total number of larval-juvenile lampreys (from electrofishing densities) to be 6,145 in this area (Table 10). If we add all previously removed lampreys to our electrofishing estimate (removed 824 lampreys during a survey on October 16, 2015, one day after the headgate closure), our estimated number of lampreys in the area immediately upstream of the fish screens at Wapato Diversion is 6,969. During our survey on October 16, 2015 (one day after the headgate closure) maximum lamprey densities within the high density area of Type I habitat were up to 50-60 fish/m^2 (along gently sloped, two converging fine sediment banks that were gradually drying up; Table 7). However, 12 days later on October 27, 2015, lamprey densities in this area only ranged between 20-30 fish/m^2 and the estimated number of lampreys in this high density area was 1,558. If we assume that the high density area potentially had 2.0 times as many fish at its peak on October 16, 2015, compared to October 27, 2015, our estimated number of lampreys in this area increases to 8,075, based on this conservative adjustment (assuming that the density in other areas remained constant). Identification of 158 larval lampreys (>50 mm in total length) showed that 17.1% were Pacific Lamprey.



Map 4. Wapato Diversion overview map showing the overall distribution of Type I, II and III larval habitat immediately upstream of the fish screens (green, yellow and blue polygons, respectfully).



Map 2. Wapato Diversion overview map showing survey locations in Type I (high, medium and low densities) and Type II habitat immediately upstream of the fish screens (red circles). The dewatered Type I habitat bank is highlighted brown. The high density Type I habitat is highlighted pink, the medium density Type I habitat is highlighted green, and small area of low density Type I habitat is covered by surveys 11 and 12. Type II habitat is highlighted yellow and Type III habitat is highlighted blue.

Table 5. Available (wetted) Type I and Type II habitat area on October 27, 2015, at Wapato Diversion immediately upstream of the fish screens.

Survey Date	Days Post Headgate Closure	Overall Type I Area (m^2)	Overall Type II Area (m^2)	Overall Type III Area (m^2)	Overall Type I/II Area (m^2)	Wetted Type I Area (m^2)	Wetted Type II Area (m^2)	% Type I Habitat	% Type II Habitat
10/27/15	12	1221	920	411	2141	973	920	51%	49%

Table 6. Daily estimated number of lampreys from electrofishing in high density Type I habitat (Type I – H), medium Type I habitat (Type I – M), low density Type I habitat (Type I – L), and Type II habitat on October 27, 2015, at Wapato Diversion immediately upstream of the fish screens.

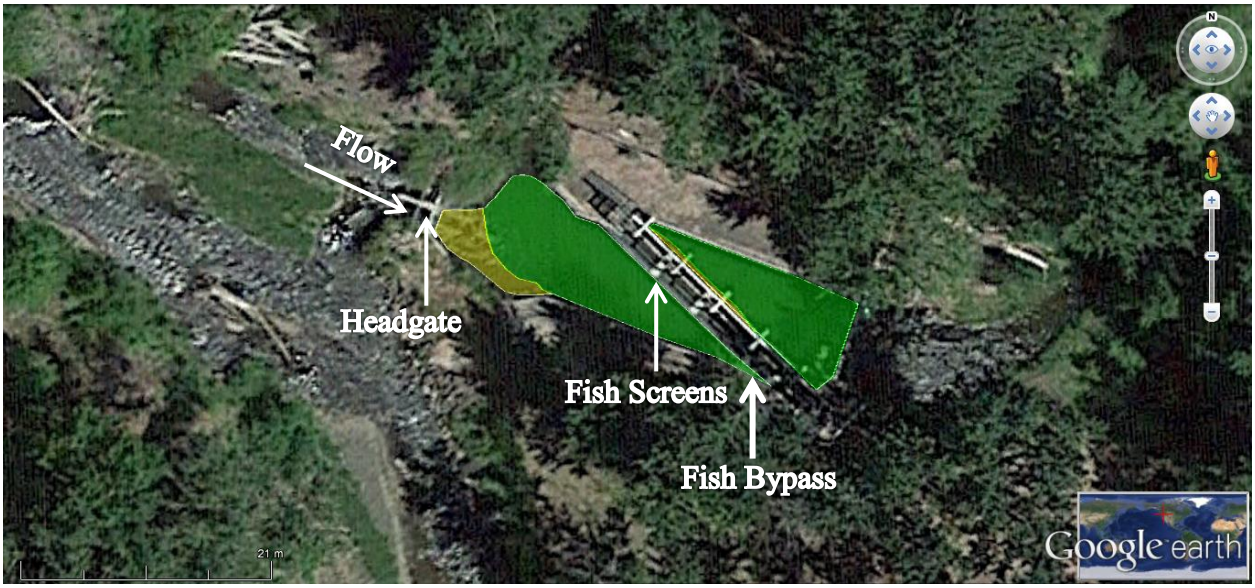
Survey Date	Larval Habitat Category	Total Area (m2)	# of Plots Surveyed	Survey Area (m2)	# Captured	# Missed	Total # E-Fish	Density (L/m2)	Daily Est. # Lamprey E-Fish
10/27/2015	Type I - H	121	3	16.0	160	46	206	12.9	1558
10/27/2015	Type I - M	852	4	19.0	79	20	99	5.2	4439
10/27/2015	Type I - L	2.5	2	2.5	6	1	7	2.8	20
10/27/2015	Type II	920	2	21.5	3	0	3	0.1	128

Table 7. Summary of lamprey assessment at Wapato Diversion immediately upstream of the fish screens.

Survey Date	Total # of Plots	# Captured (E-Fishing)	# Captured (on Bank)	Daily # Removed	Cumul. # Removed	Max E-Fish Density (#/m^2)	Daily Est. # Lamprey (E-Fishing)	Daily Est. # Lamprey (Combined)
10/16/15	1	452	372	824	824	60	7703	8075
10/27/15	12	248	0	248	1072	30	6145	6969

Bachelor-Hatton Diversion

Surveys for larval lampreys were conducted between July 14, 2015 and January 28, 2016 within Type I and Type II habitat at Bachelor-Hatton Diversion along Ahtanum Creek, river km 31.8 (Map 3). The diversion headgate closed on July 10, 2015. Surveys occurred both immediately upstream and immediately downstream of the fish screens (seven and four survey dates, respectively; Table 11). Average electrofishing densities above the fish screens ranged from 42.9-560.0 lamprey/m^2 (July 14, 2015 and October 6, 2015, respectively). Below the fish screens, electrofishing densities ranged from 9.0-25.0 lamprey/m^2 (July 14, 2015 and October 7, 2015, respectively). Daily estimated numbers of lampreys from electrofishing were highest above the fish screens (ranged from 5,536 to 26,656) compared to below the fish screens (ranged from 715 to 900). From electrofishing efforts, 10,698 lampreys, all live larvae, were captured and successfully returned to Ahtanum Creek (25m downstream of the diversion headgate). Identification of 564 larval lampreys (>50 mm in total length) showed that 97.3% were Pacific Lamprey. Size class distributions of captured larval lampreys immediately upstream and downstream of the fish screens are shown for surveys conducted on July 14, 2015, and August 20, 2015 (Figure 1 and 2). During the initial survey on July 14, 2015, most of the lampreys captured and observed were larger ones (average size was ~80 mm), whereas most were smaller ones (average size was ~30 mm) during the later survey on August 20, 2015.



Map 3. Bachelor-Hatton Diversion overview map showing the distribution of Type I and Type II larval habitat (green and yellow polygons, respectively). *The displayed color-coding is for dates preceding October 16, 2015 (habitat distribution may have been altered after the dredging maintenance operation on October 16-17, 2015).

Table 8. Available (wetted) larval habitat area (combination of Type I and Type II) on each survey date upstream and downstream of the fish screens at Bachelor-Hatton Diversion. Daily electrofishing survey details and total estimated number of lampreys from electrofishing are also shown for both survey locations.

Survey Date	Survey Location Relative to Fish Screens	Overall Type I/II Habitat Area (m2)	% Available Habitat Wetted	Daily Area of Type I/II Habitat	Days Post Dewatering	Surveyed Area (m2)	# Captured	# Missed	Total # E-Fishing	Density (L/m2)	Est. # of Lamprey E-Fish
7/14/15	Upstream	136	95%	129.2	4	40	420	1294	1714	42.9	5536
7/16/15	Upstream	136	90%	122.4	6	40	1233	6165	7398	185.0	22638
7/17/15	Upstream	136	85%	115.6	7	50	1140	7980	9120	182.4	21085
7/21/15	Upstream	136	70%	95.2	11	50	3320	9960	13280	265.6	25285
8/20/15	Upstream	136	70%	95.2	41	4	200	800	1000	-	-
10/6/15	Upstream	136	35%	47.6	88	15	2100	6300	8400	560.0	26656
10/7/15	Upstream	136	70%	95.2	89	7	330	1460	1790	255.7	24344
10/7/15	Upstream	136	65%	88.4	89	35	900	8100	9000	257.1	22731
1/28/16	Upstream	136	90%	122.4	202	40	700	2800	3500	87.5	10710
7/14/15	Downstream	80	98%	78.4	4	48	220	213	433	9.0	707
7/17/15	Downstream	80	60%	48.0	7	25	106	318	424	17.0	814
8/20/15	Downstream	80	60%	48.0	41	-	14	500	514	-	-
10/7/15	Downstream	80	45%	36.0	89	3	15	60	75	25.0	900

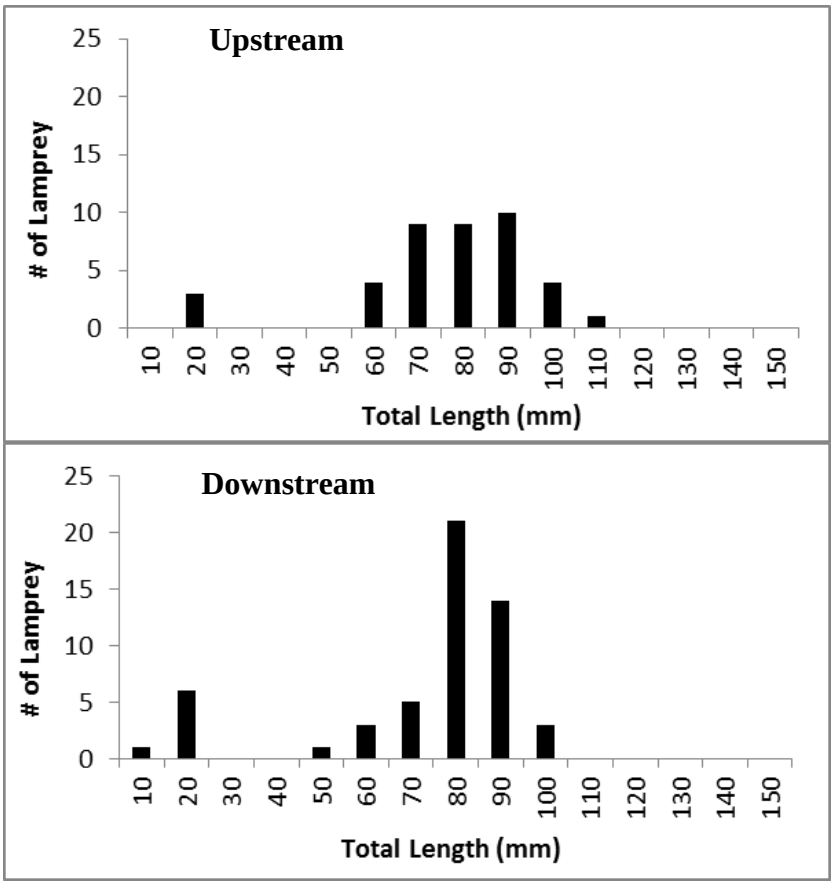


Figure 1. Frequency histograms displaying size class distribution of captured lampreys immediately upstream and downstream of the fish screens at Bachelor-Hatton Diversion on July 14, 2015. The shown size class distributions represent only captured lampreys and may not accurately represent all lampreys observed from electrofishing (higher emphasis was given to capturing larger lampreys).

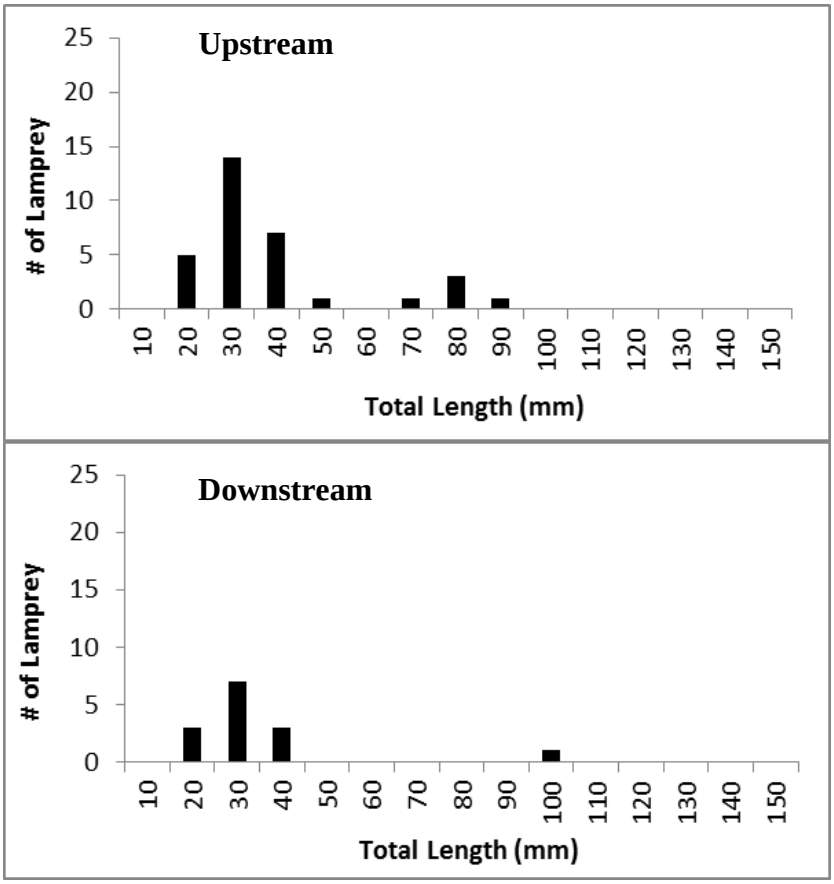


Figure 2. Frequency histograms displaying size class distribution of captured lampreys immediately upstream and downstream of the fish screens at Bachelor-Hatton Diversion on August, 20, 2015. The shown size class distributions only represent captured lampreys and may not accurately represent all lampreys observed from electrofishing.

During the survey period, a total of 1518 dead (or mostly dead) lampreys were found on dewatered banks (n=8; all from downstream of the fish screens), on top of wetted habitat (n=810; all from upstream of the fish screens), or found on dredged material (n=700) (Table 12). Lampreys in the dredged material pile (all sizes but primarily small larvae) were all found on the fine sediment surface from approximately 2 hours of salvage time (2-3 people). We searched through approximately 60-70% of the surface area, but we did not have time to search deeper inside the pile. We documented some larvae trapped inside the deeper sediment when the bulldozer dug inside the dredged pile. We also noticed that it took some time for many of the larvae to rise to the surface after the dredged material was initially laid down; most of the larvae appeared to the surface approximately 20 minutes after the material was laid down. During the dredging operation, which occurred on October 16-17, 2015, two pumps (50 gallon/min and 300 gallon/min pumps) were placed immediately upstream of the fish screens and used to draw down the water level (Table 13). On both dredging dates, nets were placed at the outflow of each pump to sample the number of fish passing through. On the first salvage date (October 16, 2015), only the 50 gallon/min pump was running and 300 larval lampreys were observed from 30 minutes of netting (a rate of 10 lamprey/min). On the second salvage date (October 17, 2015), both pumps

were used; a total of 80 lampreys were observed passing through the 50 gallon/min pump from 187 minutes of netting (a rate of 0.4 lamprey/min) and 72 lampreys were observed passing through the 300 gallon/min pump in 141 minutes of netting (a rate of 0.5 lamprey/min). The dredging operation was in close proximity to the pumps running on October 16, 2015 (gradually moving away from the pumps), potentially explaining the high number of lampreys observed passing through the pump used that day. We observed approximately 16 and 25% mortality from the 50 gallon/min pump on October 17 and October 16, 2015, respectively, and approximately 56% mortality from the 300 gallon/min pump on October 17, 2015. We estimate that approximately 1,188 larval lampreys have passed through these pumps during approximately 500 minutes (8.3 hours) of total running time (average of 142 lamprey/hour), resulting in approximately 321 lamprey mortalities.

Table 9. The number of dead lampreys found at Bachelor-Hatton Diversion (totaled for upstream and downstream of the fish screens) for each survey date. *This tally excludes dead lampreys found from the water pumps.

Survey Date	# of Bank Morts	# of Wet Morts	# of Dredge Morts	Total # Morts (no pump)
7/14/15	8	0	0	8
7/16/15	0	0	0	0
7/17/15	0	0	0	0
7/21/15	0	410	0	410
8/20/15	0	0	0	0
10/6/15	0	0	300	300
10/7/15	0	400	400	800
1/28/16	0	0	0	0
Total	**8**	**810**	**700**	**1518**

Table 10. Observed and estimated number of larval lampreys that passed through two different sized water pumps used to draw down the water during the dredging operation on October 16-17, 2015 at Bachelor-Hatton Diversion.

Pump Run Dates	Pump Location Relative to Fish Screens	Pump Size (gallons/ min)	Pump Total Run Time (min)	Time Net Under Pump (min)	# of LIVE Lamprey Through Pump	# of DEAD Lamprey Through Pump	Total # of Lamprey Through Pump	% Pump Mortality	Rate of Lamprey through Pump (L/min)	Est. # of Lamprey Through Pump
10/6/15	Upstream	50	100	30	225	75	300	25%	10.0	1000
10/7/15	Upstream	50	200	187	67	13	80	16%	0.4	86
10/7/15	Upstream	300	200	141	32	40	72	56%	0.5	102

At final tally, 13,404 larval lampreys were removed from the diversion (either through electrofishing, mortality, or pump; Table 14). Upstream of the fish screens, total estimated lamprey numbers (sum total of estimated lampreys from electrofishing, mortalities from dry banks and in-water and the cumulative number of lampreys, live and dead, removed prior to the survey date) ranged from 5,536 (July 14, 2015) to 34,467 (October 17, 2015). Downstream of the fish screens, daily total estimated lamprey numbers ranged between 715 (July 14, 2015) and

1,248 (October 7, 2015). In reality, these estimated numbers could be considerably larger, even exceeding the highest estimated number of 34,467, as we are entirely uncertain how many lampreys remained unseen during the survey period either from survey inefficiency, predation, decomposition, or concealment in the dredged material.

Table 11. Summary of lamprey assessment at Bachelor-Hatton Diversion. Daily electrofishing estimates are combined with lampreys observed through other means plus the cumulative number of lampreys removed up to the previous surveyed date to arrive at a combined estimated number of lampreys for each survey date at Bachelor-Hatton Diversion.

Survey Date	Survey Location Relative to Fish Screens	# Captured	# Est. Through Pumps	# of Morts	Daily # Removed	Cumul. # Removed	Est. # of Lamprey E-Fish	Daily Est. # Lamprey (Combined)
7/14/15	Upstream	420	-	-	420	420	5536	5536
7/16/15	Upstream	1233	-	-	1233	1653	22638	23058
7/17/15	Upstream	1140	-	-	1140	2793	21085	22738
7/21/15	Upstream	3320	-	410	3730	6523	25285	28488
8/20/15	Upstream	200	-	-	200	6723	-	-
10/6/15	Upstream	2100	1000	300	3400	10123	26656	33679
10/7/15	Upstream	330	86	-	416	10539	24344	34467
10/7/15	Upstream	900	102	800	1802	12341	22731	34127
1/28/16	Upstream	700	-	-	700	13041	10710	23005
7/14/15	Downstream	220	-	8	228	228	707	715
7/17/15	Downstream	106	-	-	106	334	814	1042
8/20/15	Downstream	14	-	-	14	348	-	-
10/7/15	Downstream	15	-	-	15	363	900	1248
Total	**-**	**10698**	**1188**	**1518**	**13404**	**-**	0	**-**

DISCUSSION

Tens of thousands of larval and juvenile lampreys were estimated to reside in the intensively monitored survey areas at Sunnyside, Wapato and Bachelor-Hatton diversions. The estimated number of entrained lampreys at Sunnyside (immediately downstream of the fish screens) ranged from 4,796 to 11,115 during the entire irrigation off-season. At Wapato Diversion (immediately upstream of the fish screens), the number of estimated lampreys was estimated to be 6,969 - 8,075 (mostly immediately after dewatering). At Bachelor-Hatton Diversion, estimates of entrained lampreys ranged from 5,546 to 34,467 lampreys immediately upstream of the fish screens and ranged from 715 to 1,248 immediately downstream of the fish screens during the entire irrigation off-season. In reality, these estimated numbers could be considerably larger, even exceeding the high range of our estimated numbers, as we are entirely uncertain how many lampreys remained unseen during the survey period either from survey inefficiency, predation, decomposition, or concealment in the dredged material. From our 2014 mark-recapture study in Wapato Diversion, we estimated only 19-45% capture efficiency using the standard electrofishing surveys.

Approximately 3-5 times more entrained larvae were estimated at Bachelor-Hatton Diversion compared to Sunnyside and Wapato diversions; this was especially unexpected as we have found hardly any entrained larvae in past years of monitoring at this site and it is such a small diversion compared to Sunnyside and Wapato diversions (diverts only 2-3% of the Wapato and Sunnyside diversion flow rates). This shows that even small diversions can entrain many larvae depending on the site specific conditions. In the case of Bachelor-Hatton Diversion, the headgate is built perpendicular to the thalweg current of a side channel which has a lot of slow-flow, larval lamprey habitat. This likely allows much of the fine sediment in the stream system to flow into the diversion and causes many of the lampreys to be entrained, as a result.

The ratio of Pacific Lamprey (vs. Western Brook Lamprey) was comparatively high during the 2015-2016 survey period compared to previous years: At Sunnyside Diversion it was 14.2%, at Wapato Diversion it was 17.1%, and at Bachelor-Hatton Diversion it was 97.3%. It is likely that the offspring from the Ahtanum Creek translocation is contributing to this high ratio at Bachelor-Hatton Diversion and those fish are gradually reaching Wapato and Sunnyside diversions on mainstem Yakima River. During the 2014-2015 survey period, only ~7% were Pacific Lamprey at Sunnyside and Wapato diversions and no Pacific Lamprey were found at Bachelor-Hatton Diversion. In addition, two Pacific Lamprey macrophthalmia were captured at Sunnyside Diversion this year (one each on November 17, 2015, and December 14, 2015). Over the several years of diversion sampling, many Western Brook Lamprey transformers have been captured at several diversion facilities within the Yakima Subbasin, but this was the first time a Pacific Lamprey macrophthalmia was captured during the dewatering season. One macrophthalmia was captured in lower Yakima River (river km 71.4 just downstream of Prosser Dam) during the larval lamprey survey in October, 2015, and many macrophthalmia have been sampled at Chandler Juvenile Fish Monitoring Facility during the winter and spring season over the years. For more information on the Pacific Lamprey versus Western Brook Lamprey ratio from the remainder of the diversions in the Yakima Subbasin, see Appendix Report F1 (2015 Summary Assessment of Larval/Juvenile Lamprey Entrainment in Irrigation Diversions within the Yakima Subbasin).

At Sunnyside Diversion, Mr. Mark Briggs helped with the lamprey salvage by coordinating the pump on and off schedule. At Bachelor-Hatton Diversion, Mr. George Marshall (Ahtanum Irrigation) helped with the lamprey salvage by opening the headgate (a few inches) to clear the turbid water for survey. In addition, during the irrigation off-season between July, 2015, and January, 2016, he allowed a few cfs to flow through the screen area (by forcing water through the bypass route using dam boards installed downstream of the fish screens). This helped provide fresh water to the entrained lampreys and likely enhanced lamprey survival both upstream and downstream of the fish screens. He suggested that if many lampreys are moving past the fish screens (into Bachelor and Hatton creeks), allowing a small amount of flow past the fish screens during the irrigation off-season (August through April) may be conducive for the entrained larval lampreys.