Monitoring Spring/Summer Chinook Salmon Spawning Migration in the Lostine River, Oregon: Summary Report of Radio Telemetry Tracking from 2008 through 2021

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Key Conclusions

- Radio-tagging adult Chinook Salmon and tracking their movement in the Lostine River enabled us to identify fish passage problems, prioritize restoration needs, and evaluate management actions using site-specific empirical data.
- We evaluated three irrigation diversions before and after being rehabilitated with a roughen-channel design; restoration increased upstream passage success, decreased passage duration, and improved access to critical spawning habitat.
- Despite improvements in fish passage at some irrigation diversion structures and progress in maintaining instream discharge during the spawning migration, low discharge and some irrigation diversion structures continue to hinder salmon migration. In particular, the Poley Allen Diversion is a partial barrier to upstream salmon migration, even when minimum flow agreement thresholds are met.

Plain-language Abstract

Low stream flows and irrigation diversion structures can delay or block adult Chinook Salmon from migrating upstream to critical spawning habitat in the Lostine River. A diverse group is working to keep more water in the river during the summer and improve irrigation diversions structures, so adult salmon and other fish can swim freely up the river. In this study, we captured and radio-tagged salmon near the mouth of the river and tracked their journey upstream from 2008 through 2021. We monitored 860 salmon in total, using this data to identify and address challenges, evaluate actions, and enhance fish-friendly conditions. We observed significant improvements in fish passage over three rehabilitated

diversion structures, and a minimum flow agreement improved flow conditions in a reach of the river that was chronically dewatered. Despite these improvements, low flows and some irrigation diversion structures continue to hinder salmon migration in the system. In particular, the Poley Allen Diversion is a partial barrier to upstream salmon migration, even when minimum flow agreement thresholds are being met at the site. Restoration of the Poley Allen Diversion is planned. We will continue to monitor the upstream migration of adult salmon in the Lostine River and use the data to inform and evaluate actions that aim to improve connectivity for salmon and other fish.

Introduction

The Lostine River provides critical spawning and rearing habitat for Snake River spring/summer Chinook Salmon. Chinook were nearly extirpated from the Lostine River in the mid-1990s (Tranquilli et al. 2004) and were listed as threatened under the Endangered Species Act in 1992. Declines in the Lostine and elsewhere in the Snake River Basin have been attributed to a combination of negative effects from the hydroelectric dams on the Snake and Columbia Rivers, over-harvest, habitat loss and degradation, hatcheries, invasive species, and climate change (Ruckelshaus et al. 2002, Hoekstra et al. 2007, Crozier et al. 2021). Within the Lostine River watershed, impaired riparian conditions in the valley bottom and disrupted connectivity to spawning and rearing habitat are primary concerns. Specifically, irrigation diversions contribute to low stream discharge and can impede adult fish migration (Harbeck et al. 2014).

Natural resource managers are attempting to address in-basin challenges for Chinook Salmon in the Lostine River through an integrated approach of water management, riparian/stream habitat restoration, harvest management, and hatchery supplementation. Maintaining hydrological connectivity for these fish is essential to the success of this approach. Accordingly, improving instream flow conditions has been a priority, especially while Chinook adults are attempting to migrate upstream to spawn. In 2004, The Freshwater Trust (TFT) initiated a minimum flow agreement that compensated irrigators for maintaining 15 cfs (cubic feet per second) of discharge in August and September through a section of the Lostine that was chronically dewatered. Instream flows have also been improved by leasing water rights for instream use and improving irrigation system efficiencies. In addition to efforts to improve discharge, three irrigation diversions structures were rehabilitated during this study (City of Lostine Diversion in 2012, Sheep Ridge Diversion in 2016, and Tulley Hill Diversion in 2017). Each project converted the instream portion of the diversions to a roughen-channel design, with goals to maintain irrigation functionality and improve conditions for fish passage (for all species and all life stages).

A radio-telemetry project was initiated in 2008 to monitor the spawning migration of adult Chinook Salmon in the Lostine River and evaluate the effects of low discharge and irrigation diversion structures on the upstream migration of these fish. In this report we summarize results from this project by evaluating: 1) fish passage at irrigation diversion structures before and after restoration, 2) passage at fixed monitoring sites relative to discharge, and 3) movement patterns of fish through the system from tagging at the weir to final spawning location.

Methods

Study area

The Lostine River is a 51-km-long stream originating in the Eagle Cap Wilderness and is a major tributary to the Wallowa River in northeastern Oregon (Figure 1). The river drains approximately 235 km^2 and ranges in elevations from 2225 to 916 m. The headwaters are primarily public-owned forestland, and the lower river valley is predominantly private-owned land developed for agriculture. Stream flows are primarily snowpack driven, with peak discharge typically occurring in May-June and base flows occurring in August-September. A core Chinook Salmon spawning aggregate occurs as the river drops out of the mountains and into the lower river valley (approximately river km 15-20). Below this area, 13 irrigation diversions contribute to low stream discharge and can impede adult fish migration (Harbeck et al. 2014). In addition to supporting Spring/Summer Chinook Salmon, the watershed also supports several other fish species including two additional species listed as threatened under the ESA (steelhead and Bull Trout), as well as two species reintroduced to the watershed (Coho Salmon and Pacific Lamprey).

Trapping/tagging

Adult Chinook Salmon were trapped at the Lostine River weir facility located approximately 1 km upstream of the river mouth and confluence with the Wallowa River (Figure 1). Fish were anesthetized and subsequently tagged with VHF radio tags manufactured by *Lotek Wireless*. We used three different models/sizes of radio tags over the course of this study (Table A1). Tagging techniques and anesthesia procedures evolved over the course of the study. Initially (2008-2010), all tags were equipped with surgical tubing bands or rubber o-rings to promote tag retention, but from 2011-2021 only the smaller (MCFT2-B) tags were equipped with surgical tubing bands. From 2008- 2012, fish were submerged into a vessel containing a buffered solution of tricaine methanesulfonate (MS-222) for anesthetization, and from 2013-2021, fish were placed into an electro-anesthesia trough. Tags were implanted into the anesthetized fish by gently inserting a tag through the mouth and into the stomach. From 2008-2010, tags were coated with glycerin and implanted using a PVC pipe as a trochar (Harbeck et al. 2014). We stopped coating tags with glycerin and using a PVC trochar in 2011 and started inserting tags with the aid of a small diameter wooden dowel (Figure A1). Immediately after tagging and recovery from anesthesia, fish were released upstream of the weir in slow moving water.

Fish were radio-tagged throughout the adult migration (June – Sept). Sample size goals ranged from 50 – 75 tagged fish per year, depending on the available number of radio tags. Fish were tagged proportional to average arrival timing of fish to the weir. Tagging goals were met in most years, with a few exceptions due to limitations in weir operations and other fisheries management priorities. We targeted hatchery-origin adult (Age 4 or older) fish for this study, but some jacks and natural-origin were also radio-tagged when hatchery adults were not available for tagging (Figure A2; Table A2). An even ratio of males and females were tagged each year.

Tracking/recovery

Radio-tagged fish were located using a combination of fixed antenna stations and mobile tracking. Four fixed sites were run continuously during the spawning migration each year of the study, except for 2008 and 2009 when only three sites were operated (Table 1). Each fixed site consisted of two 5-element Yagi antennas, with one pointed downstream and the other upstream. This configuration allowed us to determine direction of movement, whether fish successfully passed both antennas, and duration of time needed to pass the antennas. Fixed sites located at diversion structures were chosen to provide monitoring at least three years prior and three years after restoration, if possible. Caudle Lane, which did not have an irrigation diversion structure, was monitored each year to serve as a control site for evaluating restoration projects. Over the course of the study, two other fixed sites were located for the primary purpose of improving the efficiency of mobile tracking (i.e., Pole Bridge and Lostine Acclimation); these two sites were not included in passage success/duration analyses. Mobile surveys were conducted approximately weekly during the spawning migration; tracking was done either from foot or a vehicle using a portable antenna and receiver. Radio tags were recovered from salmon carcasses (or nearby) during Chinook Salmon spawning ground surveys or weekly mobile tracking.

Environmental monitoring

Stream discharge was monitored for each fixed telemetry site to provide a covariate for fish passage assessments and to provide additional information for water managers. At most sites, we estimated discharge by deploying water level and barometric pressure sensors/loggers to estimate water level. We then manually measured discharge at varying wadable water levels to develop a water level-discharge relationship. We also used discharge estimates from long-term monitoring sites when the telemetry site was located adjacent (OWRD sites # 13330000, 13330050, & 13330300).

Stream water temperatures were monitored at each fixed telemetry site. Stream temperatures in the Lostine River were rarely above 20°C during this study (e.g., Figure A3). The few times temperatures did exceed 20°C, discharge was also very low. Because of the observed lack of acute thermal conditions for adult salmon and to avoid potential multicollinearity issues between discharge and stream temperature, we did not include stream temperature as a covariate in fish passage analyses. We recognize the effects warm stream temperatures can have on migrating adult Chinook Salmon (e.g., Strange 2012; Keefer et al. 2018; Teffer et al. 2018; Bowerman et al. 2021). We plan to further investigate thermal conditions and their potential effects throughout the freshwater migration corridor for Lostine River Chinook Salmon, but that is outside the scope of this technical report.

Analysis – Restoration effectiveness

We evaluated the effectiveness of three irrigation diversions rehabilitations using a Before-After-Control-Impact (BACI) analysis approach. We defined effect size as an estimate of the magnitude of the impact from each restoration (Osenburger et al. 1994). Differences in passage characteristics between control and impact sites were used to estimate effect size since the control and impact sites were sampled simultaneously (Stewart-Oaten et al. 1986). Specifically, we calculated the effect size of restoration on upstream fish passage success and passage duration as:

$$Effect\ size = (Treatment_{after} - Control_{after}) - (Treatment_{before} - Control_{before})$$

where *Treatment* equals median passage duration or passage success rate at the restoration site, *Control* equals median passage duration or passage success rate at the control site, calculated separately for all fish passage events occurring *before* or *after* restoration.

Statistical significance of the effect of restoration on passage duration was also evaluated using a linear mixed effects model with Site (treatment/control) and Period (before/after) as fixed effects, an interaction term between the two fixed effects, and year as a random effect. The significance of the interaction term between the fixed effects was of primary interest (Smokorwowski & Randall 2017). Passage duration was transformed with a log base 10 transformation because the data were extremely skewed. Each restoration project was evaluated separately using the *nlme* R package (Pinheiro et al 2022) and summarized using the *sjPlot* R package (Lüdecke 2023).

Analysis – Passage success and duration relative to stream discharge

We evaluated the relationship between stream discharge and upstream passage success using a logistic regression. We excluded data from years when restoration occurred because of complications/bias related to the restoration activities. Ultimately, most remaining sites and time periods were not evaluated using this approach because there were insufficient failed attempts (i.e., almost all the fish passage attempts were successful, Figure 4). However, there was sufficient data to evaluate Poley Allen and Tulley Hill (pre-restoration). Observations were pooled across years for each site. Passage attempts were linked to discharge estimates within the nearest 15 minutes. We analyzed each site separately using the *glm* function in R (R Core Team 2023).

We evaluated the relationship between stream discharge and passage duration using a simple linear regression. We limited this analysis to successful upstream passage events. Failed attempts may have taken much longer than successful attempts, but the configuration of the fixed antennas (one upstream of the diversion and one downstream) made it difficult to consistently estimate a duration for failed passage attempts. We again excluded data from years when restoration occurred because of complications/bias related to the restoration activities. We analyzed each monitoring site separately using the *glm* function in R (R Core Team 2023).

Fish sex and length were also evaluated as predictor variables in preliminary analyses of passage success and duration, but the variables explained little or no additional variation in response variables. Accordingly, stream discharge was the sole independent variable used in regression analyses for this report. Model assumptions and goodness of fit were evaluated for each regression.

Results and Discussion

Overall movement observations

Chinook captured and tagged at the weir earlier in the run were more likely to spawn further upstream than later arriving fish, but fish exhibited a range of movement patterns during the study (Figures 2 & 3). Most upstream passage attempts at fixed monitoring sites were successful (Figure 4), but the failures were critical in identifying locations and conditions worthy of additional scrutiny. Interannual variation in passage duration was minimal at most sites (Figure 5), except for those that were rehabilitated (see next section). Duration served as an important measure for evaluating before/after effectiveness of restoration, as well as effects of covariates, like discharge on fish passage at fixed sites.

Restoration effectiveness

Rehabilitating irrigation diversion structures with a roughened-channel design reduced passage duration time and increased passage success rate at all three sites (Table 2; Figures 6-8). Effect sizes for median passage duration ranged from -14 to -30 minutes, and effect sizes for passage success rate ranged from 0.03 to 0.15 (Table 2). The fixed effect of restoration and the interaction of restoration and control/treatment status were highly significant in the linear mixed effects modeling results for each site ($P < 0.001$, Table A3).

These fish passage improvements likely reduce the cumulative stress adult Chinook salmon experience during their spawning migration, and any reduction in stress can improve the chances of these fish successfully spawning and contributing to the recovery of this population. Salmon encountering irrigation diversions and low stream discharge in the Lostine River have already navigated fish passage at eight mainstem dams on the Columbia and Snake Rivers, multiple fisheries, and often adverse environmental conditions caused by anthropogenic factors (e.g., elevated water temperatures, degraded water quality). These stressors, especially in combination, can contribute to prespawn mortality (e.g., Bowerman et al. 2018; Teffer et al. 2018), which can have dire consequences to population dynamics (e.g., Spromberg and Scholz 2011). Improvements in fish passage, such as those evaluated in this report, contribute to reducing cumulative stress on migrating adults and are one of many actions needed to conserve and recovery Chinook in the Lostine River.

Stream discharge effects on passage

Stream discharge significantly affected the success rate of upstream fish passage at Poley Allen Diversion ($p < 0.01$, $pseudo\text{-}r^2 = 0.50$; Figure 9; Table 3). All failed passage attempts at this site occurred at discharges less than 27 cfs, with the number and proportion of failed attempts increasing as discharge decreased. Based on the logistic regression results, we estimated a 0.37 (0.25 - 0.52, 95% CI) upstream passage probability at 15 cfs. From 2018 through 2021, 15 cfs was the minimum flow agreement threshold for this reach of river. The annual minimum discharge in the Lostine River above the irrigation diversions ranged from 24 to 43 cfs for this same time period, with a mean of 34 cfs. Passage probability was 0.93 (0.67 – 0.99, 95% CI) at 34 cfs. Without rehabilitation of the Poley Allen Diversion[1], all of the stream's natural discharge would need to remain in-river to pass all (or nearly all) adult Chinook, and the site would still be a partial barrier in low flow years. Protecting and increasing stream discharge in this reach of the Lostine River continues to be essential for enabling adult Chinook passage.

Stream discharge was not a significant predictor of fish passage success at the Tulley Hill Diversion, pre-restoration (Table A3). Fish passage failures at this site occurred across a broad range of discharge (25 to 360 cfs). The pre-restoration fish passage dynamics at Tulley Hill remain somewhat uncertain. One hypothesis is the failed attempts were adult fish holding in pool/pocket water created downstream of the previous log-weir style diversion, and the fish could pass the site without issue. However, the new roughened channel design also has potential holding water for adult fish, yet the fish do not hold at the site and appear to proceed upstream through the diversion without delay.

Stream discharge had no apparent effect on upstream passage duration at the sites evaluated herein (Table 4). The only statistically significant regression result was at City of Lostine Diversion (post-restoration), but the slope of the regression was nearly zero (0.004) and the model explained almost no variation in passage duration ($r^2 = 0.09$). However, this does not mean stream discharge was not affecting fish movement in the system. From late July through late August, when discharge was the lowest in the system, fish moved little (e.g., Figure 2). In future analyses, we plan to further evaluate this relationship by comparing weekly fish movement rates to stream discharge.

[1] Analyses from this project provided information to local partners to prioritize rehabilitation of the Poley Allen Diversion. Nez Perce Tribe fisheries staff and partners worked with the landowner, and the diversion was rehabilitated with a roughened-channel design in October of 2023. We will monitor the impacts to fish passage using the same methods discussed in this report.

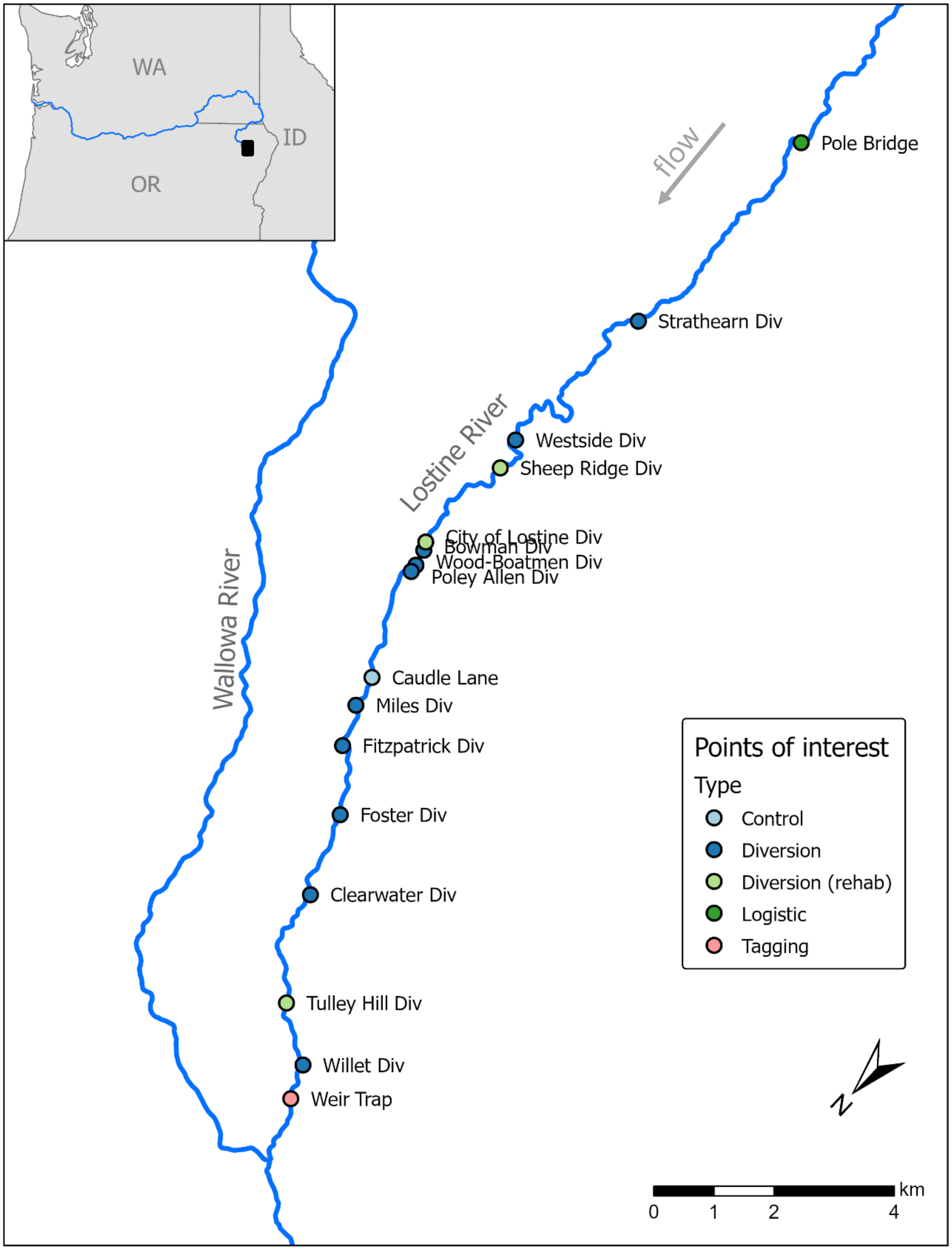

Figure 1. Telemetry study area with points of interest along the Lostine River, Wallowa County, Oregon. Reference map (upper left) indicates approximate study location (black box) and migration route for salmon (blue line).

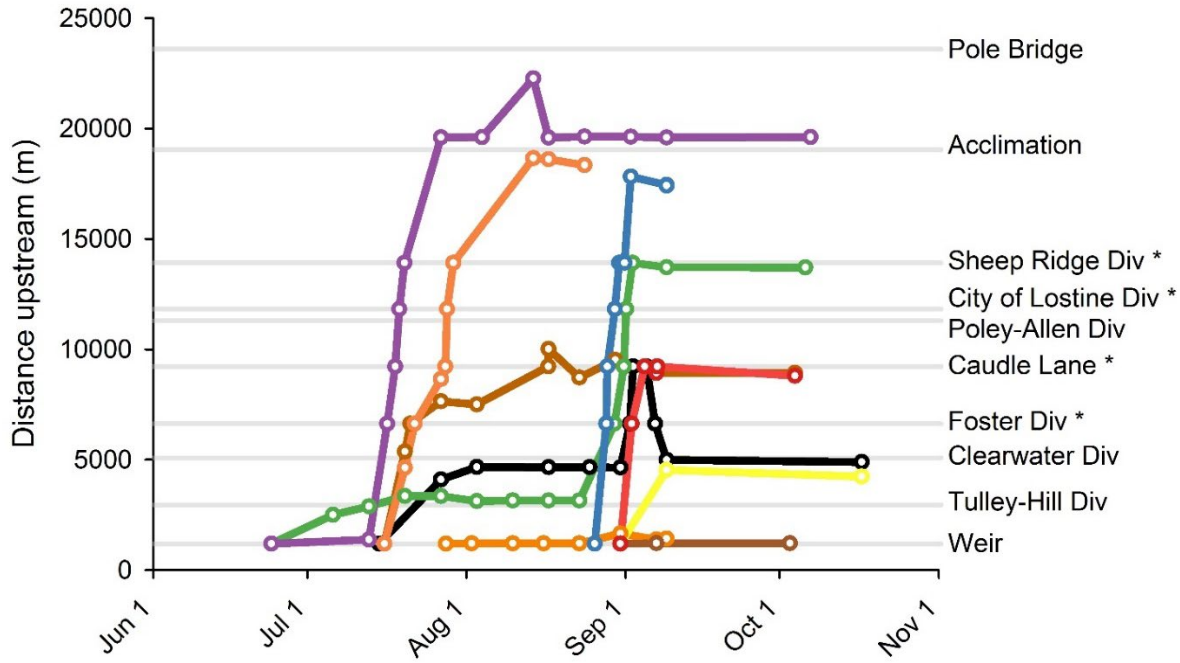

Figure 2. Example of Chinook movement patterns in the Lostine River in 2016. Colored lines and circles track the locations of 10 different fish from the time of tagging through tag recovery. Light gray lines indicate the location of diversion structures and other landmarks (* = monitored site in 2016). Mouth = 0 m.

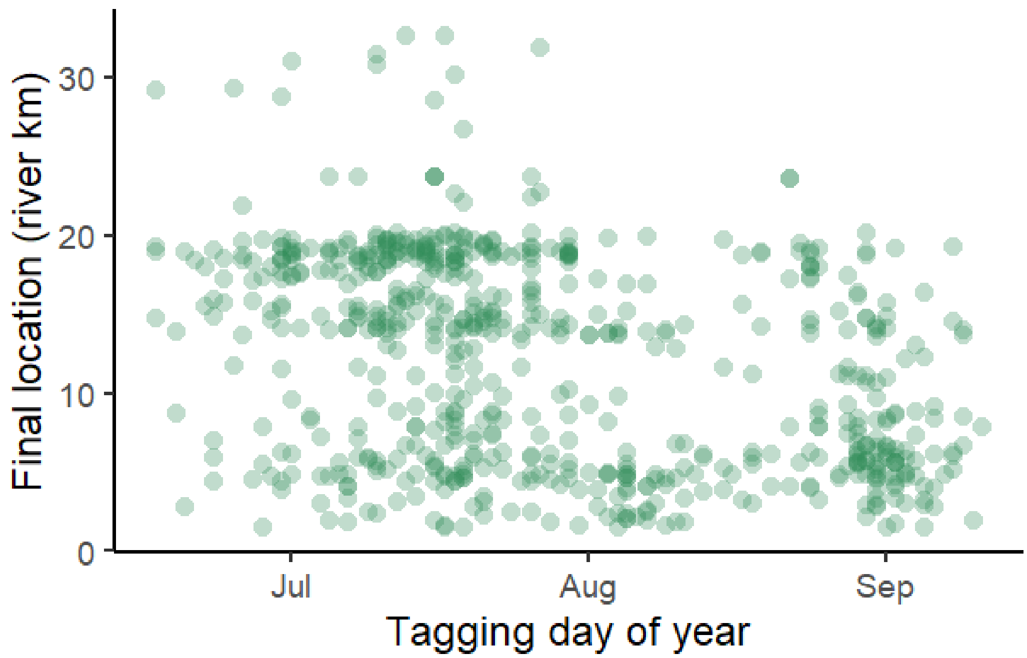

Figure 3. Final location of radio tags vs. date of tagging. All years combined. Each point is semi-transparent and represents a single fish. Overlapping points results in darker colors. Tags recovered near the weir were removed because of the likelihood of tag regurgitation skewing the data. Mouth = 0 km.

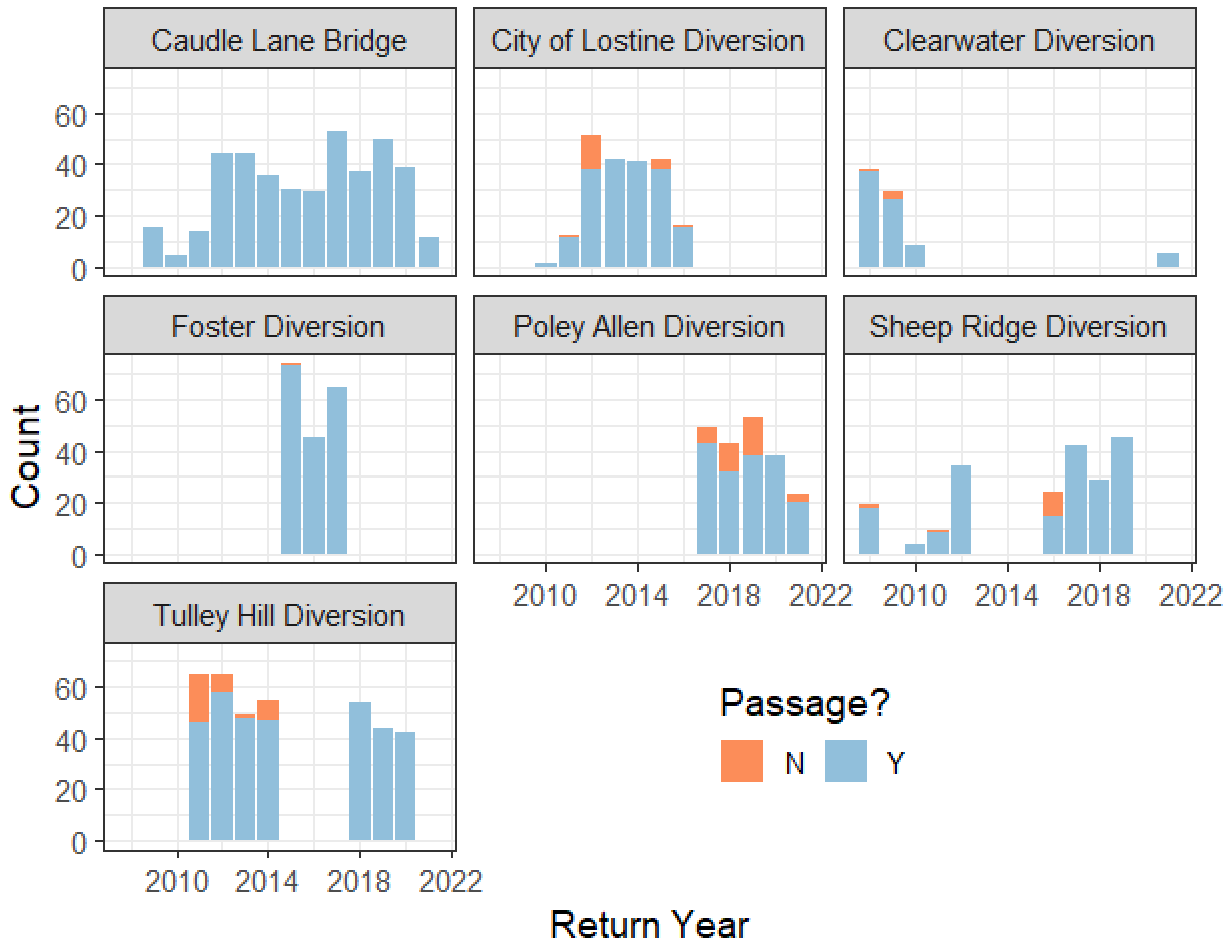

Figure 4. Upstream passage success of Chinook Salmon observed at fixed monitoring sites in the Lostine River from 2008 through 2021.

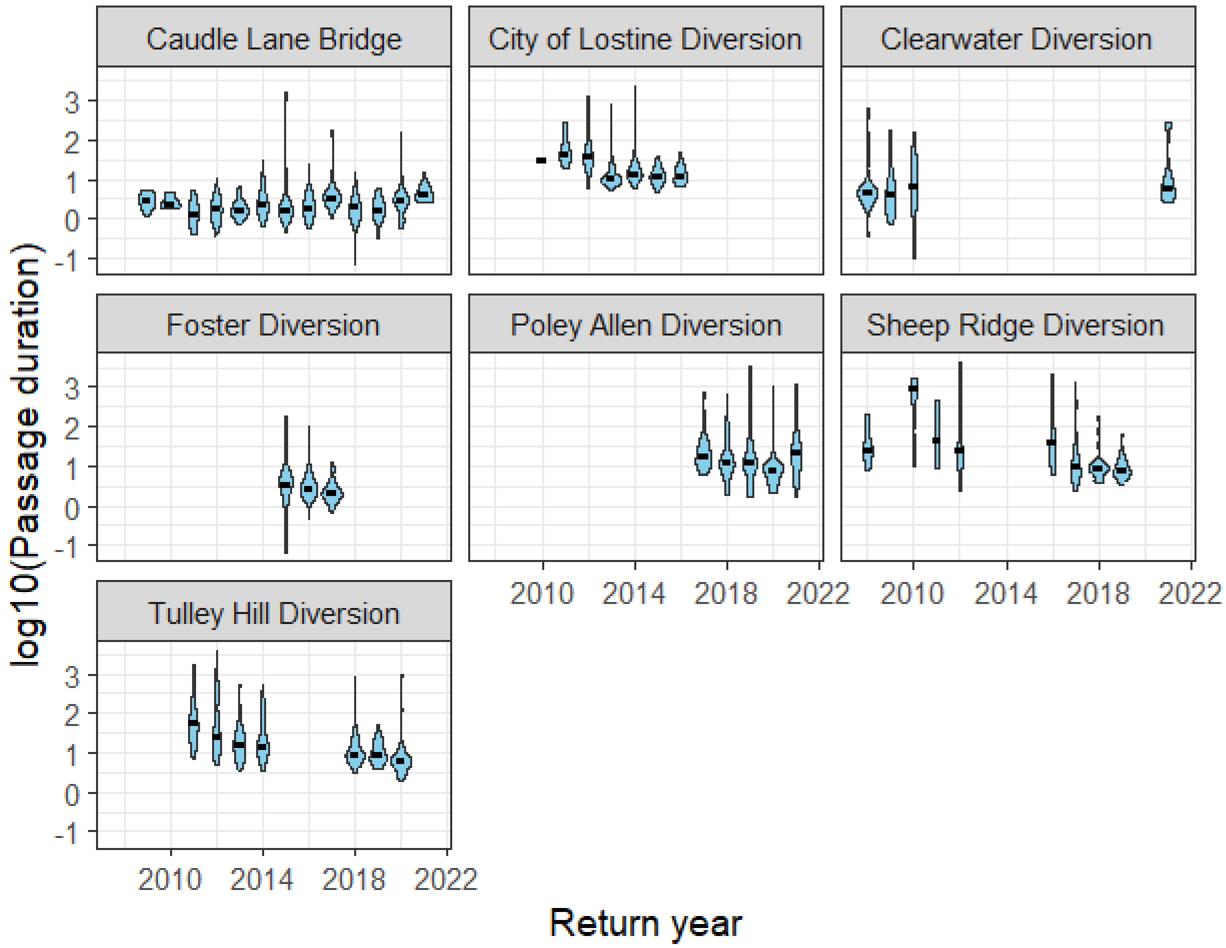

Figure 5. Violin plots of passage duration ($\log_{10}$ minutes) for Chinook Salmon successfully migrating upstream at fixed monitoring sites in the Lostine River from 2008 through 2021. Black dashes represent median passage duration for each site-year combination.

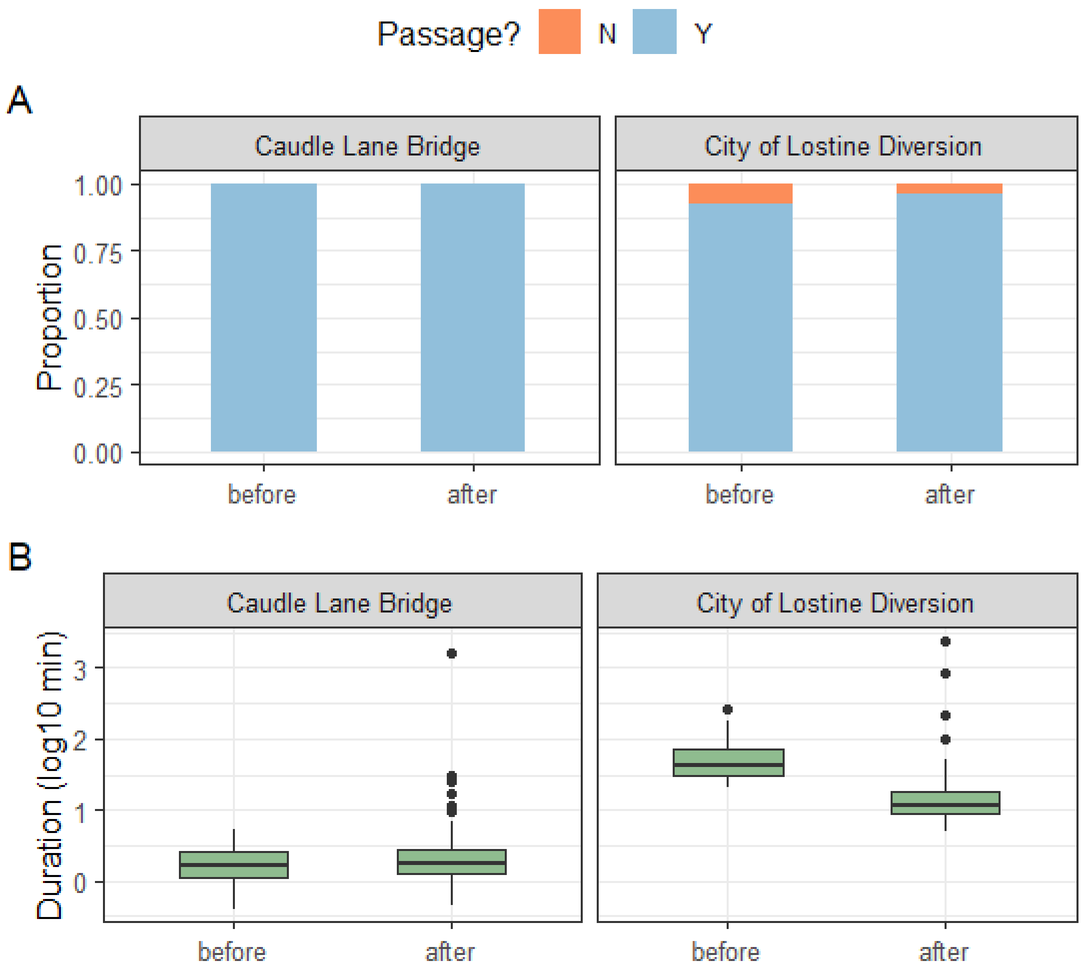

Figure 6. Passage success (A) and passage duration (B) before and after restoration at the City of Lostine Diversion. Data combined among years before (2010-2011) and after (2013-2016) the restoration which occurred in 2012. Only upstream passage events are included. Passage success displayed as proportion of upstream passage attempts that were successful (Y) or unsuccessful (N). See Wickham (2016) for details on boxplot statistics.

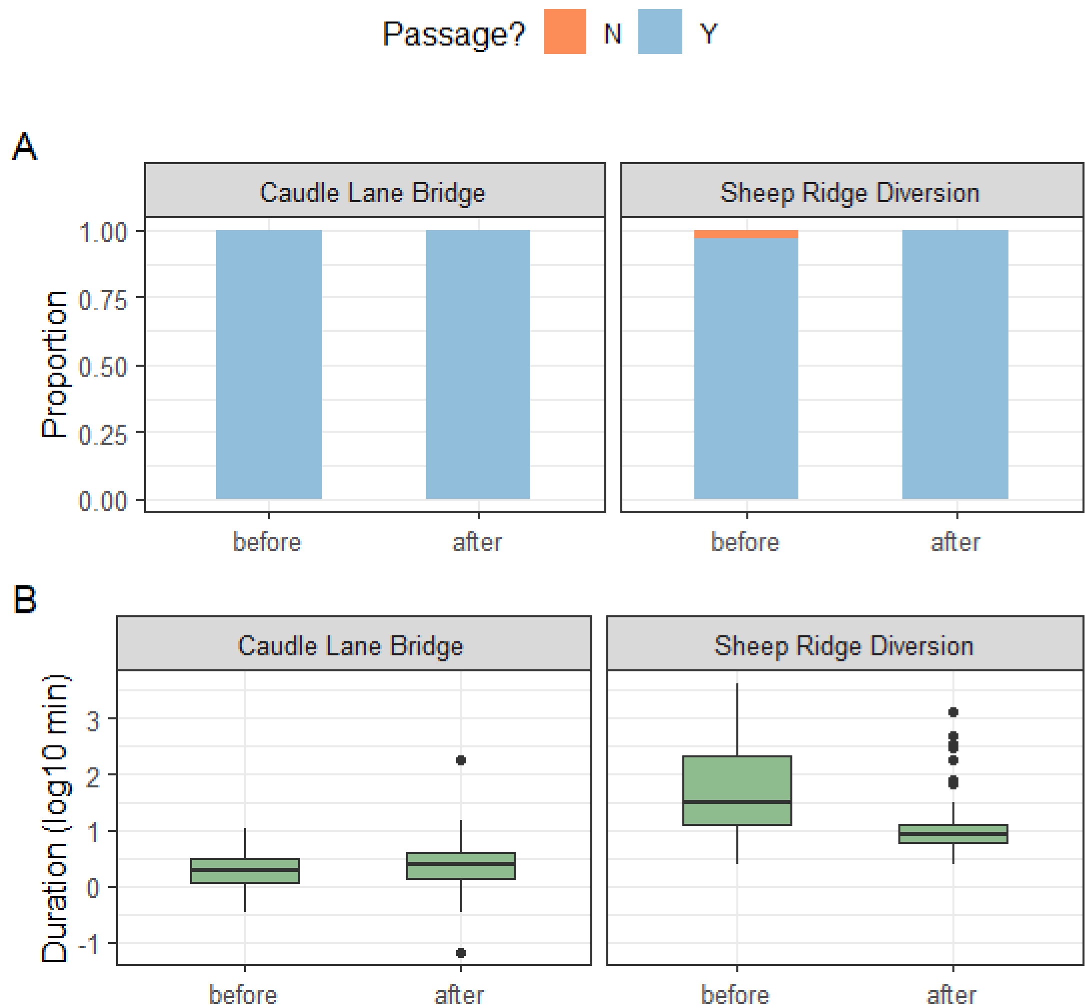

Figure 7. Passage success (A) and passage duration (B) before and after restoration at the Sheep Ridge Diversion. Data combined among years before (2008-2012) and after (2017-2019) the restoration which occurred in 2016. Only upstream passage events are included. Passage success displayed as proportion of upstream passage attempts that were successful (Y) or unsuccessful (N). See Wickham (2016) for details on boxplot statistics.

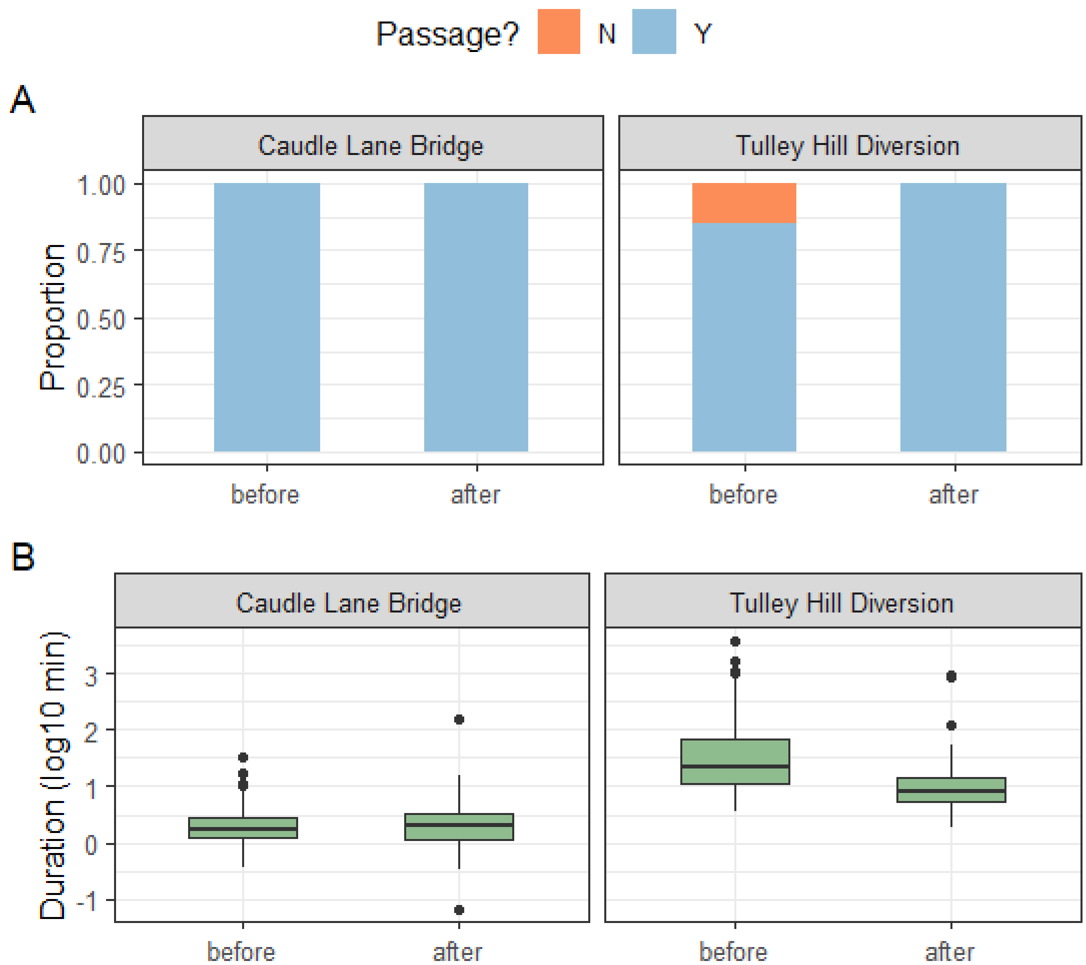

Figure 8. Passage success (A) and passage duration (B) before and after restoration at the Tulley Hill Diversion. Data combined among years before (2011-2014) and after (2018-2020) the restoration which occurred in 2017. Only upstream passage events are included. Passage success displayed as proportion of upstream passage attempts that were successful (Y) or unsuccessful (N). See Wickham (2016) for details on boxplot statistics.

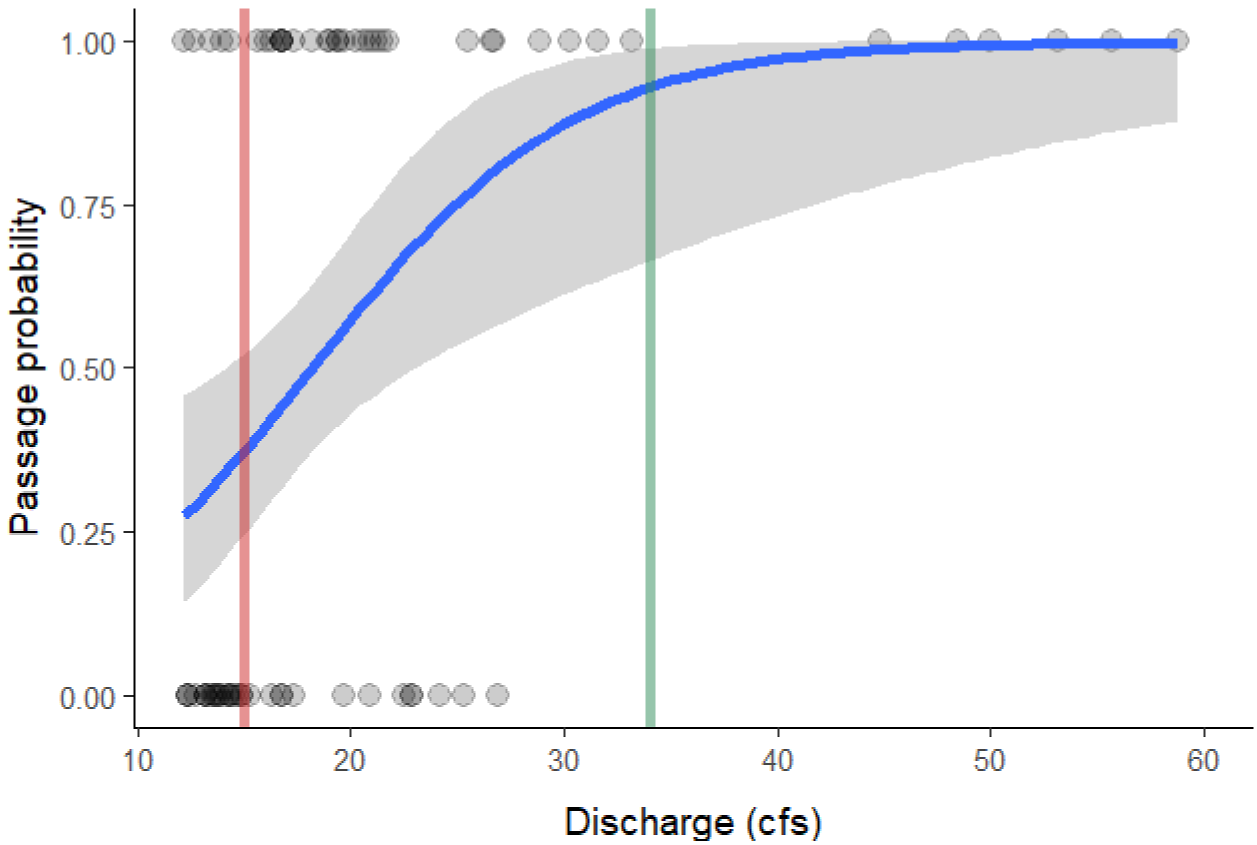

Figure 9. Success of upstream passage attempts as a function of stream discharge at Poley-Allen Diversion from 2017 through 2021 (n = 162). 1 = successful passage. 0 = failed passage. Blue line represents a logistic regression with 95% confidence limits shaded in grey. The red line indicates the 15 cfs minimum flow agreement threshold from 2018 – 2021; the threshold was 20 cfs in 2017. The green line indicates the median minimum flow recorded during this same time period at a gage upstream of the irrigation diversions (OWRD site # 13330000). All passage attempts greater than 60 cfs were successful and excluded from the graph.

Table 1. Location and schedule of monitoring using fixed sites. River kilometer 0 equals the mouth. Symbols indicate construction years (⛏), post-construction monitoring (☻), and all other monitoring (X).

		Year													
Site	River km	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Tulley Hill Diversion	2.9				X	X	X	X			⛏	☻	☻	☻	
Clearwater Diversion	4.8	X	X	X											X
Foster Diversion	6.6								X	X	X				
Caudle Lane Bridge	9.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Poley Allen Diversion	11.3										X	X	X	X	X
City of Lostine Div.	11.8			X	X	X, ⛏	☻	☻	☻	☻					
Sheep Ridge Div.	13.8	X		X	X	X				X, ⛏	☻	☻	☻		
Lostine Acclimation	19.5													X	X
Pole Bridge	23.6						X	X	X						

Table 2. Descriptive statistics and effect sizes for BACI restoration evaluations. n = number of upstream passage attempts for each group.

Restoration	Site	Before/After	Success Rate (%)	Median Passage Duration (minutes)	n
City of Lostine	Treatment	Before	0.92	41.6	18
		After	0.97	11.9	141
	Control	Before	1.00	1.7	13
		After	1.00	1.8	139
		Effect Size	**0.05**	**-29.8**	
Sheep Ridge	Treatment	Before	0.97	31.8	66
		After	1.00	8.6	116
	Control	Before	1.00	2.0	77
		After	1.00	2.4	140
		Effect Size	**0.03**	**-23.6**	
Tulley Hill	Treatment	Before	0.85	21.4	235
		After	1.00	7.9	140
	Control	Before	1.00	1.8	138
		After	1.00	2.1	126
		Effect Size	**0.15**	**-13.8**	

Table 3. Logistic regression analysis of upstream fish passage success[1].

Site	Coefficent Independent variable	*b*	*se*	*z ratio*	*p*	Model *psuedo* r^2	*df*
Poley Allen Diversion	Stream discharge[2]	0.163	0.057	2.872	0.004	0.503	160
Tulley Hill Diversion (pre-restoration)	Stream discharge[2]	0.001	0.001	0.686	0.493	0.003	232

[1]Dependent variable was passage success such that 1 = success and 0 = failure.

[2]Stream discharge units were cubic feet per second.

Table 4. Linear regression analysis of upstream fish passage duration[1] as a function of stream discharge[2].

	Intercept	Slope			Model	
Site	Estimate	Estimate	CI	p	R2	n
Caudle Lane	0.35	0.00	0.00 – 0.00	0.78	0.00	273
Clearwater Div.	0.65	0.00	-0.01 – 0.01	0.50	0.01	99
Foster Div.	0.44	0.00	0.00 – 0.00	0.96	0.00	138
Poley Allen Div.	1.36	0.00	0.00 – 0.01	0.63	0.00	70
City of Lostine Div. (before)	1.49	0.00	-0.01 – 0.02	0.46	0.08	9
City of Lostine Div. (after)	0.97	0.00	0.00 – 0.01	**<0.01**	0.09	102
Sheep Ridge Div. (before)	1.97	0.00	-0.02 – 0.01	0.50	0.01	57
Sheep Ridge Div. (after)	0.90	0.00	0.00 – 0.01	0.57	0.01	31
Tulley Hill Div (before)	1.43	0.00	0.00 – 0.01	0.53	0.00	118
Tulley Hill Div. (after)	0.98	0.00	0.00 – 0.01	0.45	0.01	65

[1]Dependent variable was upstream passage duration minutes log^{10} transformed.

[2]Stream discharge units were cubic feet per second. Analysis limited to upstream passage events that occurred at less than 100 cfs.

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Appendix

Table A1. Specifications of Lotek radio tags used in this study.

Model	Dimensions (mm)	Weight air (g)	Weight water (g)
SR-Series	16 x 53	17	7.5
MCFT-3A	16 x 46	16	6.7
MCFT2-B	14 x 37	9	4

Figure A1. Wooden dowel used as a trochar for the esophageal insertion of radio tags.

Table A2. Summary statistics of radio-tagged Chinook Salmon lengths.

		Fork length (mm)		
Year	n	mean	min	max
2008	56	765	510	1015
2009	62	791	690	875
2010	27	777	720	825
2011	70	718	490	960
2012	75	767	483	1020
2013	52	695	519	932
2014	75	737	633	894
2015	63	765	549	870
2016	78	774	662	915
2017	88	764	662	896
2018	59	726	660	830
2019	67	730	635	860
2020	52	741	650	860
2021	36	754	700	815

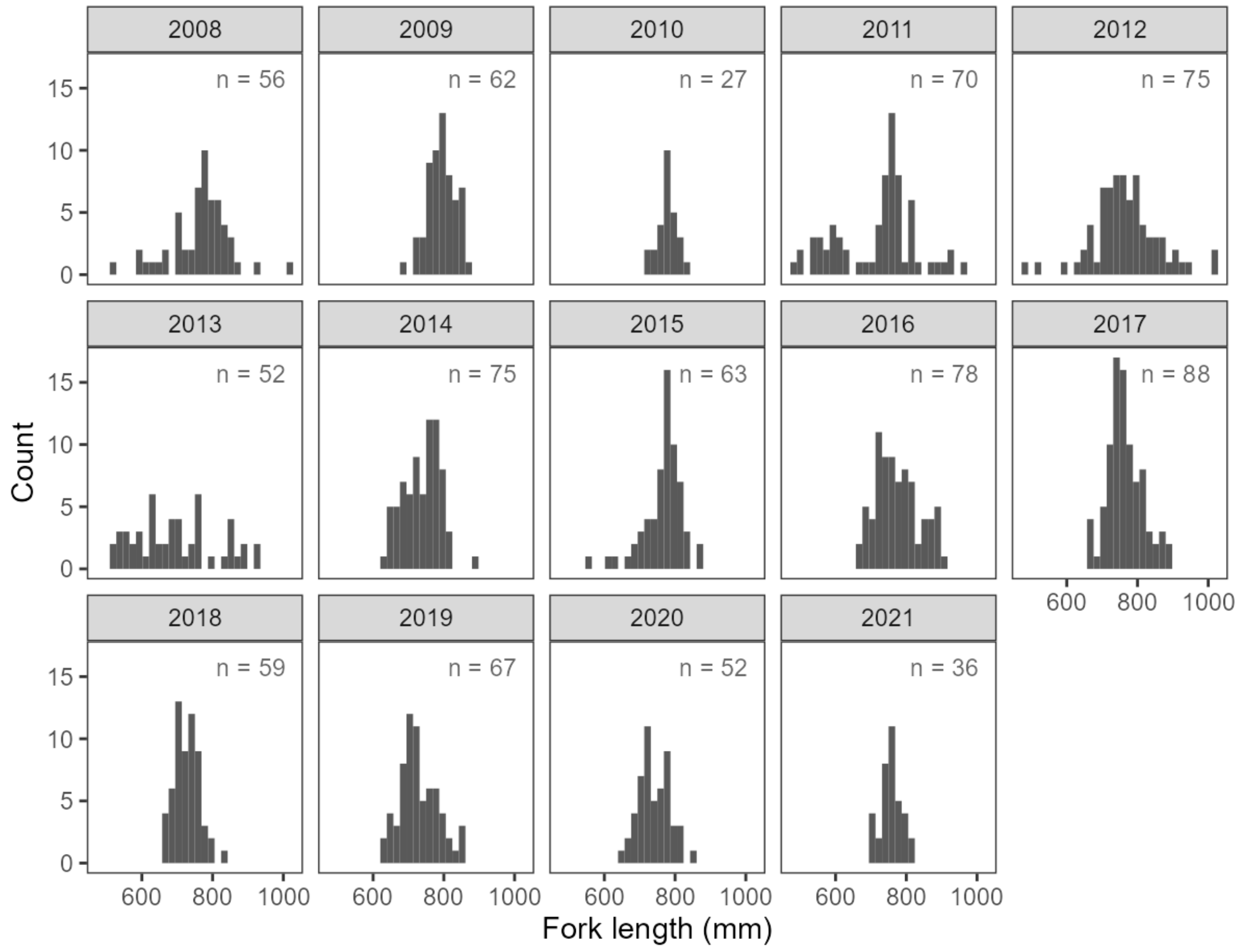

Figure A2. Length frequency distribution of Chinook Salmon radio-tagged in this study. Annual sample size indicated in each panel.

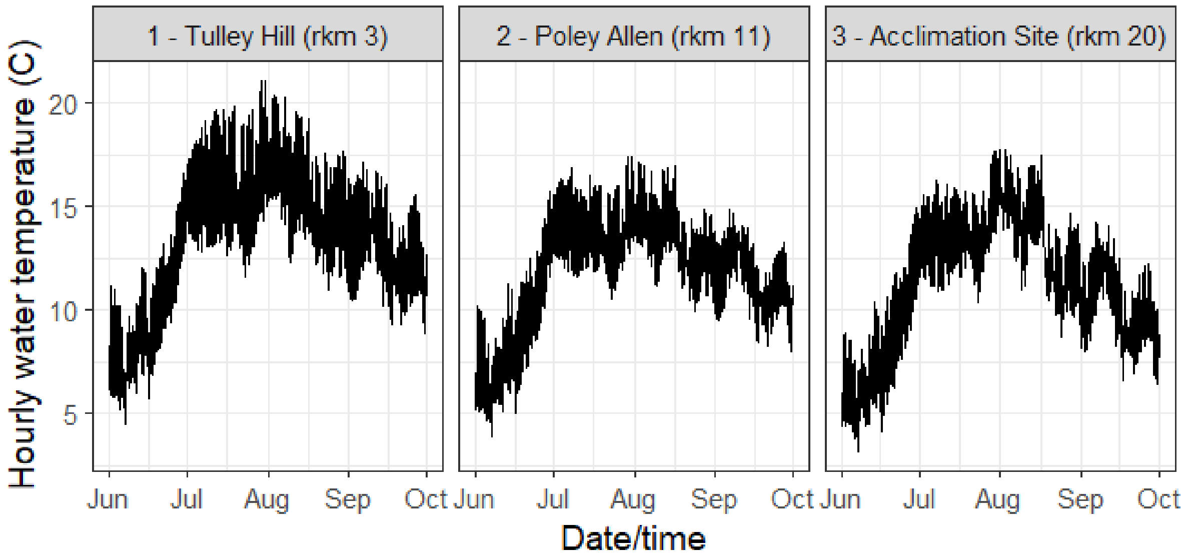

Figure A3. Hourly stream water temperature observations at three sites (one in the lower, middle, and upper focus area of the study). Observations are from 2021, the warmest summer during this study. River kilometer (rkm) is the distance upstream from the mouth.

Table A3. Linear mixed effects model results of restoration effects on passage duration at Sheep Ridge, Tulley Hill, and City of Lostine Diversion. Caudle Lane was the control site for each.

Sheep Ridge Diversion			
	Duration (min log 10)		
Predictors	*Estimates*	*95% CI*	*p*
Intercept	0.35	0.11 – 0.59	**0.005**
Period (before/after)	-0.07	-0.47 – 0.34	0.702
Site (treatment/control)	0.67	0.56 – 0.78	**<0.001**
Period x Site	0.89	0.68 – 1.09	**<0.001**
Random Effects			
σ^2	0.21		
$\tau_{00\ Year}$	0.04		
ICC	0.16		
N_{Year}	8		
Observations	395		
Marginal R^2 / Conditional R^2	0.554 / 0.627		

Tulley Hill Diversion Restoration			
	Duration (min log 10)		
Predictors	*Estimates*	*95% CI*	*p*
Intercept	0.3	0.16 – 0.45	**<0.001**
Period (before/after)	0.01	-0.24 – 0.26	0.949
Site (treatment/control)	0.66	0.55 – 0.77	**<0.001**
Period x Site	0.53	0.38 – 0.68	**<0.001**
Random Effects			
σ^2	0.21		
$\tau_{00\ Year}$	0.01		
ICC	0.05		
N_{Year}	7		
Observations	601		
Marginal R^2 / Conditional R^2	0.559 / 0.581		

City of Lostine Diversion			
	Duration (min log 10)		
Predictors	*Estimates*	*95% CI*	*p*
Intercept	0.33	0.25 – 0.41	**<0.001**
Period (before/after)	-0.12	-0.41 – 0.17	0.322
Site (treatment/control)	0.81	0.72 – 0.90	**<0.001**
Period x Site	0.7	0.41 – 0.98	**<0.001**

Random Effects	
σ^2	0.14
$\tau_{00\ Year}$	0
ICC	0.02
N_{Year}	6
Observations	305
Marginal R^2 / Conditional R^2	0.594 / 0.602