kDirect Stream versus acclimated releases of spring Chinook Salmon in the Imnaha River

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Introduction

Hatchery-reared Chinook salmon (*Oncorhynchus tshawytscha*) released into the Imnaha River are held at the Gumboot Weir and Acclimation Site for a period of acclimation prior to their release. Acclimating smolts is expensive and results in them being imprinted on the area of the acclimation site, which has resulted in the adults being most likely to spawn in the region around the acclimation site (Hoffnagle et al. 2008). We would prefer that the adult hatchery salmon from this integrated hatchery program spawning in nature distributed themselves more widely—similar to that of natural salmon. Nez Perce Tribe has reported that direct release of hatchery Chinook salmon into Johnson Creek has resulted in a spawning distribution of hatchery Chinook salmon that does not differ from that of natural salmon in Johnson Creek (Gebhards and Rabe 2014).

The Oregon Department of Fish and Wildlife (ODFW) found no difference in smolt-to-adult return (SAR), survival rates, or stray rates between acclimated and direct released spring Chinook salmon from the 1990, 1992, and 1993 brood years released into the Imnaha River (ODFW unpublished data); however, there were not enough returns to accurately evaluate these years. Paired release experiments of hatchery steelhead between 1987 and 1996 into the Wallowa, Upper Grande Ronde, and Imnaha river basins suggests that acclimating juvenile steelhead (*O. mykiss*) produces significantly higher SAR rates (Clarke et al. 2010). This contrasts with other steelhead acclimation studies that found acclimation did not help achieve higher returns to release sites (e.g., Kenaston et al. 2001). These contrasting studies suggest that there may be minimal benefits to acclimating juvenile Chinook. If acclimation does not significantly benefit the hatchery salmon, it would be logical to halt its use, thereby improving the efficiency and decreasing the cost of the hatchery program.

Research and management biologists from the Oregon Department of Fish and Wildlife and Nez Perce Tribe have discussed directly releasing smolts into the river at a site upstream from the Acclimation Site. However, we are not able to access the river upstream of the acclimation site due to heavy snow during the time of release.

In a review of NE Oregon Lower Snake River Compensation Plan (LSRCP) Facilities, the Hatchery Review Team (HRT 2009) provided recommendations and programmatic alternative actions for improvements to LSRCP facility operations. One recommendation of the HRT was to evaluate release strategies for the Imnaha River (HRT 2009, pg 172) spring/summer Chinook.

Recommendation LR-SC6 (pg 142): *Weigh the benefits of the current acclimation and release strategy versus the risk of catastrophic loss, or the risk of releasing fish too early or too late.*

Evaluate acclimation and release alternatives such as: reducing the acclimation and/or release period, allow the fish to volitionally outmigrate at any point during acclimation, direct stream releasing all or a portion of the fish, increasing acclimation capacity, or reducing the program size. Consider acclimating only one group during optimum weather and stream conditions and direct stream releasing the other group during the same time the acclimated group is being released. The two groups should be differentially marked with coded wire tags and should include representative PIT tags for evaluation of survival, homing, and straying. Alternative release strategies should be comparatively evaluated (differential tagging) to determine which results in the best survival/contribution to broodstock and escapement.

Given these recommendations, our objective was to determine if survival differed between direct and acclimated releases of Chinook salmon smolts in the Imnaha River. To determine if the juvenile and adult survival differed between smolts that were acclimated prior to release and smolts that were released directly into the Imnaha River without a period of acclimation, the following parameters were compared between direct and acclimated releases of Chinook salmon smolts in the Imnaha River:

1) smolt survival to Lower Granite Dam;
2) smolt migration timing to Lower Granite Dam;
3) smolt-to-adult return rate (to the Imnaha River);
4) total smolt-to-adult survival rate.

<u>Methods</u>

Standard production size target for Imnaha River hatchery smolts is 18–23 g (i.e., 25–20 fish/lb). Collection and rearing procedures for the Imnaha River hatchery Chinook Salmon Program were described in Feldhaus et al. (2016). The primary difference between the rearing conditions in this study and Feldhaus et al. (2016) is that in this study there were no purposeful attempts to rear smolts within the same year to different sizes. Both hatchery-and natural origin Chinook Salmon adults were collected at the Imnaha River Weir and Acclimation Facility and transported to Lookingglass Fish Hatchery (LFH) where the adult salmon were spawned and the eggs were incubated and hatched. Juvenile salmon were reared at LFH for about one year before the yearling smolts were transported back to Imnaha River Acclimation Facility. In mid-February, about one month prior to release, a random sample of smolts was measured to the nearest fork length (mm; N=250) and weighed (g; N=50).

Smolts were released from the acclimation site in late March to mid-April to mimic natural smolt emigration timing and reduce interaction between natural and hatchery smolts in freshwater by minimizing the time that the hatchery smolts spend in the stream (Figure 1). Acclimated smolts were held in an acclimation pond for at least one week and allowed to volitionally emigrate for at least one week of volitional release before being forced into the river (Figure 1). Smolts released directly into the Imnaha River were released adjacent to the acclimation facility after the volitional release had started. Forced releases would occur in late afternoon or early evening.

Five to seven raceways of Imnaha stock fish are produced at Lookingglass hatchery for each brood year to meet the smolt release goal of 490,000 smolts. Number of smolts per raceway ranged from 55,069 to 89,504 (Table 1). For this study, the experimental unit is the raceway. All of the smolts in this study were marked with an adipose (AD) fin clip but not all raceways received smolts marked with coded-wire-tags (CWTs). For each year of the study, there were four raceways of CWT marked smolts (i.e, ADCWT) and 1-3 raceways of smolts that were not CWT marked. Each raceway of CWT marked smolts received a unique tag code and efforts were made to CWT mark 100% of the smolts in each raceway. However, in brood year 2013 there was only one direct stream raceway that was code-wire tagged. Due to this smolt production shortfall, the brood year 2013 smolts were comprised of five total raceways. Managers were concerned with meeting goals and decided to acclimate more raceways in concern that direct release raceways may not perform as well. Three raceways of ADCWT smolts were acclimated, one raceway of ADCWT smolts was direct stream (DS) released, and one raceway of smolts were direct stream released that were only marked with adipose fin clips (i.e., AD). Coded-wire tag data was used to calculate SAR and total survival rates.

Additionally, the Imnaha River hatchery Chinook Salmon were part of the Comparative Survival Study and 21,000 smolts were tagged annually with PIT tags. These PIT tags were evenly distributed among randomly tagged smolts from each raceway and 5-7 raceways were used each year. After accounting for PIT tags found in dead smolts and shed PIT tags found on the bottom of the raceways prior to release, the percent of smolts released with PIT tags per raceway ranged from 3.9–6.4% with the number of PIT tags in a raceway ranging from 2,918–4,232 (Table 1). Probability of smolt survival from the release site on the Imnaha River to LGD was calculated by using PIT tag detections in a Cormack-Jolly-Seber multiple mark-recapture model (Cormack 1964; Jolly 1965; Seber 1965) in PitPro version 4.19.8 (Westhagen and Skalski 2009; www.cbr.washington.edu).

We analyzed brood years 2010–2017. Although there are additional years that can be used for this study, 2017 is the most recent brood year with completed returns (data for at least age-4 fish). Each raceway is an experimental unit. A mixed affects two-way ANOVA was used to compare the differences between acclimated and direct released smolts. Brood year was treated as a random affect. Size comparisons included weight (g) of smolts between acclimated and direct released smolts, acclimated and direct released AD CWT smolts, and AD CWT and AD only smolts.

Comparisons of juvenile survival of smolts to Lower Granite Dam included comparisons between: acclimated and direct released smolts, acclimated and direct released AD CWT smolts, and AD CWT and AD only smolts. Smolt-to-adult survival, stray rates, and adult return age composition were compared between both treatments using a mixed affects two-way ANOVA where brood year was treated as a random variable. Additionally, we tested whether juvenile survival rates were related to release timing and median travel time from the Imnaha weir to Lower Granite Dam.

Results

There was no difference in the mean weight of smolts between acclimated and direct released smolts ($P = 0.9$), acclimated and direct released AD CWT smolts ($P = 0.9$), and AD CWT and AD only smolts ($P = 0.9$; Figure 2). There was no difference in the mean survival of smolts to Lower Granite Dam between acclimated and direct released smolts ($P = 0.3$), acclimated and direct released AD CWT smolts ($P = 0.1$), and acclimated AD CWT and AD only smolts (*P* = 0.4; Figure 3).

Mean adult SAS rates were not significantly different between treatments (*P* = 0.6; Figure 6). Acclimated releases had a mean SAS that ranged from 0.20–1.82% (mean = 0.63%; Table 3; Figure 4) and direct releases had a mean SAS that ranged from 0.04–1.96% (mean = 0.61%; Table 3; Figure 4). When averaging SAS rates by brood year and then by treatment acclimated releases had a mean SAS of 0.64% (± SD = ± 0.14%; Figure 5) and direct releases had a mean SAS of 0.60% (± 0.17%; Figure 5).

Mean stray rates were not significantly different between treatments (*P* = 0.5). Composition of ages was not significantly different between treatments for age three (*P* = 0.6), age four (*P* = 0.6), or age 5 fish (*P* = 0.5; Figure 7). When averaging age composition by brood year and then by treatment acclimated releases had a mean composition of 24% (± SD = ± 14%) age three fish, 64% (± 15%) age four fish, and 12% (± 11%; Figure 8) age five fish. Direct releases had had a mean composition of 26% (± SD = ± 16%) age three fish, 59% (± 18%) age four fish, and 14% (± 12%; Figure 8) age five fish.

Juvenile survival to Lower Granite Dam was negatively related to juvenile release date ($P < 0.01$; Figure 9) and positively related to median number of travel days to Lower Granite Dam (*P* = 0.01; Figure 10).

Discussion

As no metric between acclimated and direct releases were significantly different, we suggest managers halt acclimated releases into the Imnaha river and instead use only direct releases. This will reduce the personnel time and cost to release fish into the Imnaha River while achieving the same result. Additionally, direct releasing fish may potentially reduce the number of smolts that will directly imprint on the acclimation location (i.e. Imnaha weir) and instead disperse themselves more throughout the system.

One factor that our study did not evaluate is if longer periods of acclimation would affect juvenile survival and adult returns. We assumed that our acclimation periods were sufficient to “reap the benefits” of acclimating fish. Another factor to consider is that in some years fish may have left sooner than others when they were volitionally released. A future study may want to determine if juvenile survival and adult returns differ with length of acclimation. What our study did evaluate was whether direct releasing fish differed than the current acclimated release strategy.

Although there was no significant difference overall in the mean SAS between the treatments, BY 2014 did have a large difference in SAS between the acclimated and direct releases. Direct release smolts from BY 2014 were infected with BKD, which is believed to have led to low survival rates, while the acclimated BY 2014 smolts were not infected with BKD.

Smolts that were released earlier and have more days in nature prior to arriving at Lower Granite Dam were significantly more likely to survive than fish that were released later and moved out of the system more quickly. This is counter-intuitive as most other streams in northeast Oregon have the exact opposite relationship between juvenile survival and both release timing and median travel days (ODFW unpublished data). Our release timing regression uses the first release date for acclimated releases. We also used the final date of release for acclimated releases and later release timing was also significantly negatively related to percent survival to Lower Granite Dam. Release timing and travel days also affects how many fish can make it onto barges at Lower Granite Dam rather than go through the juvenile bypass system (Figure 11). Fish arriving later to the dam may have a greater chance of survival because they are more likely to get on a barge, where their probability of survival is higher than the bypass system.

Within our evaluation of the effects of release time and migration time on smolt survival, it is important to note that brood year 2017 drives the relationships we observed. When removed from the analysis, release timing and median travel days are not a significant predictor of juvenile survival to Lower Granite Dam. However, brood year 2017 smolts were also the latest release group in our study period, with the beginning of the volitional release starting after the end or on the last day of acclimation for all but one other study year. The much later release timing represents a plausible mechanism explaining why this year “anchors” our regression relationships, and hence we did not discount it as an outlier. Indeed, learning from substantially later or earlier releases (whether the variation was experimentally intended or not), is an important reason for maintaining rigorous monitoring coupled with an adaptive management feedback loop.

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Table 1. Number of acclimated and direct raceways by brood year and last return year for raceways with smolts with both adipose fin clips and coded wire tags (AD CWT), and only adipose fin clips (AD). Total number of raceways, smolts, coded wire tagged (CWT) smolts, and PIT tags for each brood year are included.

		Acclimated # of Raceways		**Direct Stream # of Raceways**		**Smolt Release Metrics**			
Brood Year	Last return year	AD CWT	AD	AD CWT	AD	Total Raceways	Total smolts	CWT marked smolts	# PIT tags
2010	2015	2	3	2	0	7	469,807	253,635	20,819
2011	2016	2	2	2	1	7	390,703	220,089	20,896
2012	2017	2	2	2	0	6	346,702	223,570	20,816
2013	2018	3	0	1	1	5	331,702	250,791	20,862
2014	2019	2	2	2	0	6	516,802	319,480	20,950
2015	2020	2	2	2	1	7	491,126	267,626	20,688
2016	2021	2	2	2	1	7	490,510	256,948	20,875
2017	2022	2	3	2	0	7	511,337	266,026	20,871
2018	2023	2	2	2	0	6	397,917	239,097	20,772
2019	2024	2	2	2	1	7	511,261	236,769	20,701
2020	2025	2	2	2	1	7	505,872	233,640	20,956

Table 2. Juvenile survival to Lower Granite Dam for both acclimated and direct releases by brood year. Number of raceways (N) in each treatment for each brood year are included.

	Acclimated		Direct	
BY	Mean (±SD)	N	Mean (±SD)	N
2010	69.4% (±2.2%)	5	67.8% (±3.98%)	2
2011	73.2% (±7.01%)	4	69.9% (±8.85%)	3
2012	68.9% (±2.36%)	4	65.3% (±0.05%)	2
2013	64.7% (±10.98%)	3	72.9% (±2.68%)	2
2014	71% (±5%)	4	70.5% (±2.76%)	2
2015	61.6% (±5.92%)	4	59.6% (±3.72%)	3
2016	66.3% (±3.41%)	4	65.1% (±2.25%)	3
2017	60.8% (±2.47%)	4	55.6% (±2.48%)	3

Table 3. Adult smolt-to-adult survival rates for both acclimated and direct releases by brood year. Number of raceways (N) in each treatment for each brood year are included.

	Acclimated		Direct	
BY	Mean (±SD)	N	Mean (±SD)	N
2010	0.79% (±0.44%)	2	0.47% (±0.51%)	2
2011	1.82% (±0.07%)	2	1.96% (±0.25%)	2
2012	0.55% (±0.01%)	2	0.85% (±0.03%)	2
2013	0.47% (±0.12%)	3	0.44%	1
2014	0.55% (±0.01%)	2	0.04% (±0.05%)	2
2015	0.2% (±0.11%)	2	0.25% (±0.05%)	2
2016	0.36% (±0.12%)	2	0.41% (±0.08%)	2
2017	0.4% (±0.06%)	2	0.38% (±0.05%)	2

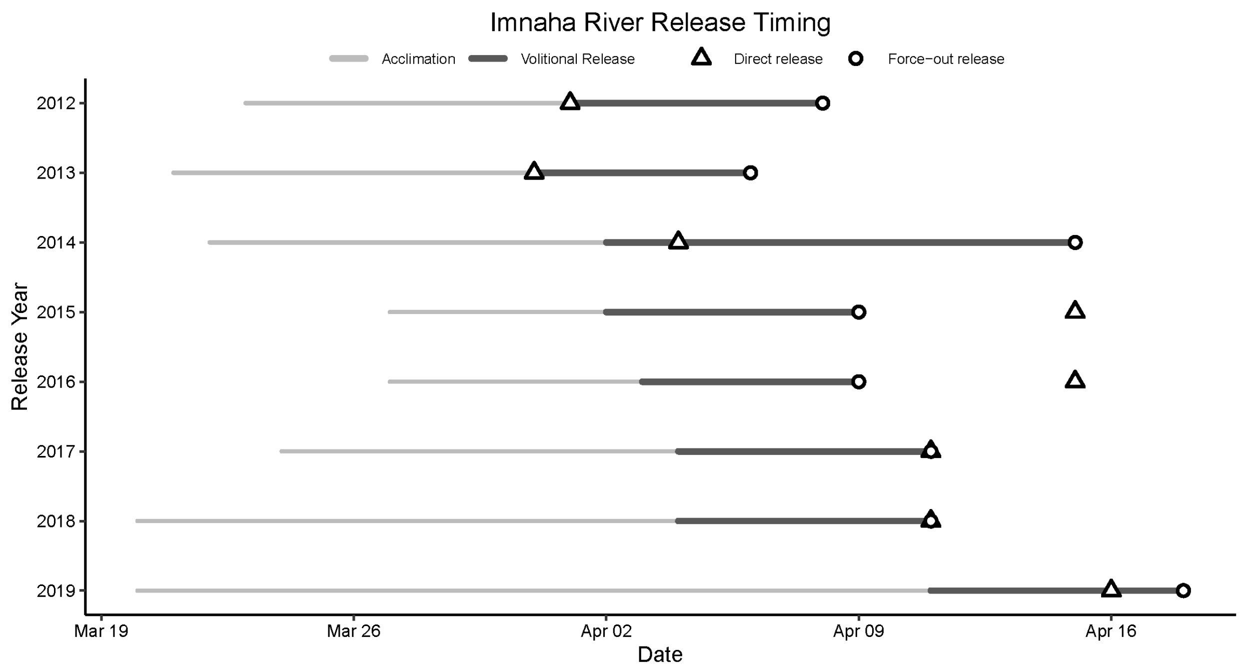

Figure 1. Release timing of Imnaha River acclimated and direct released smolts for release years 2012–2019 (brood years 2010–2017).

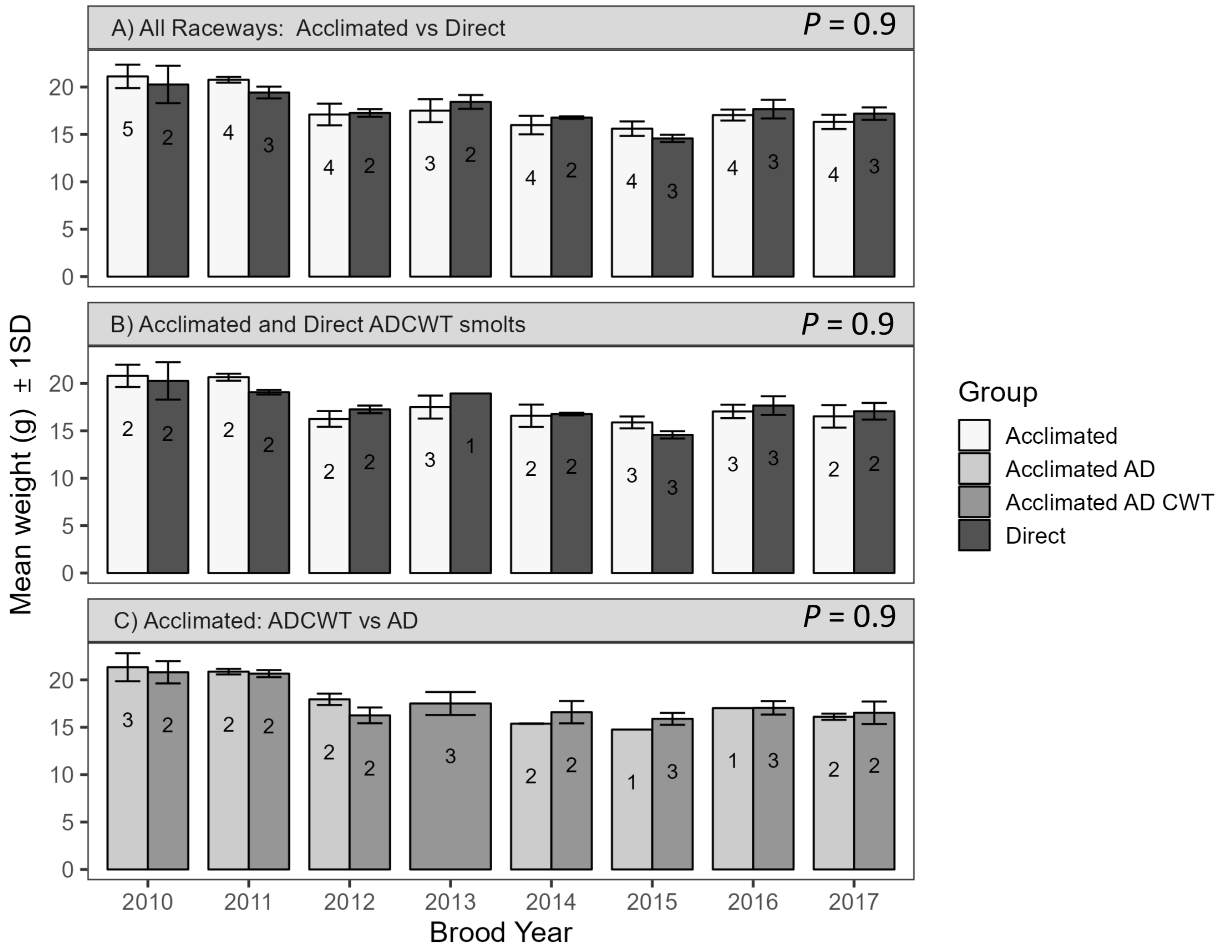

Figure 2. Bar graph comparing mean weight (g) and standard deviation of Imnaha River smolts for brood years 2010–2017 by: A) All raceways for both acclimated and direct released smolts; B) Raceways with only coded wire tags for both acclimated and direct released smolts; C) Only acclimated raceways. Number on bars represent the number of raceways.

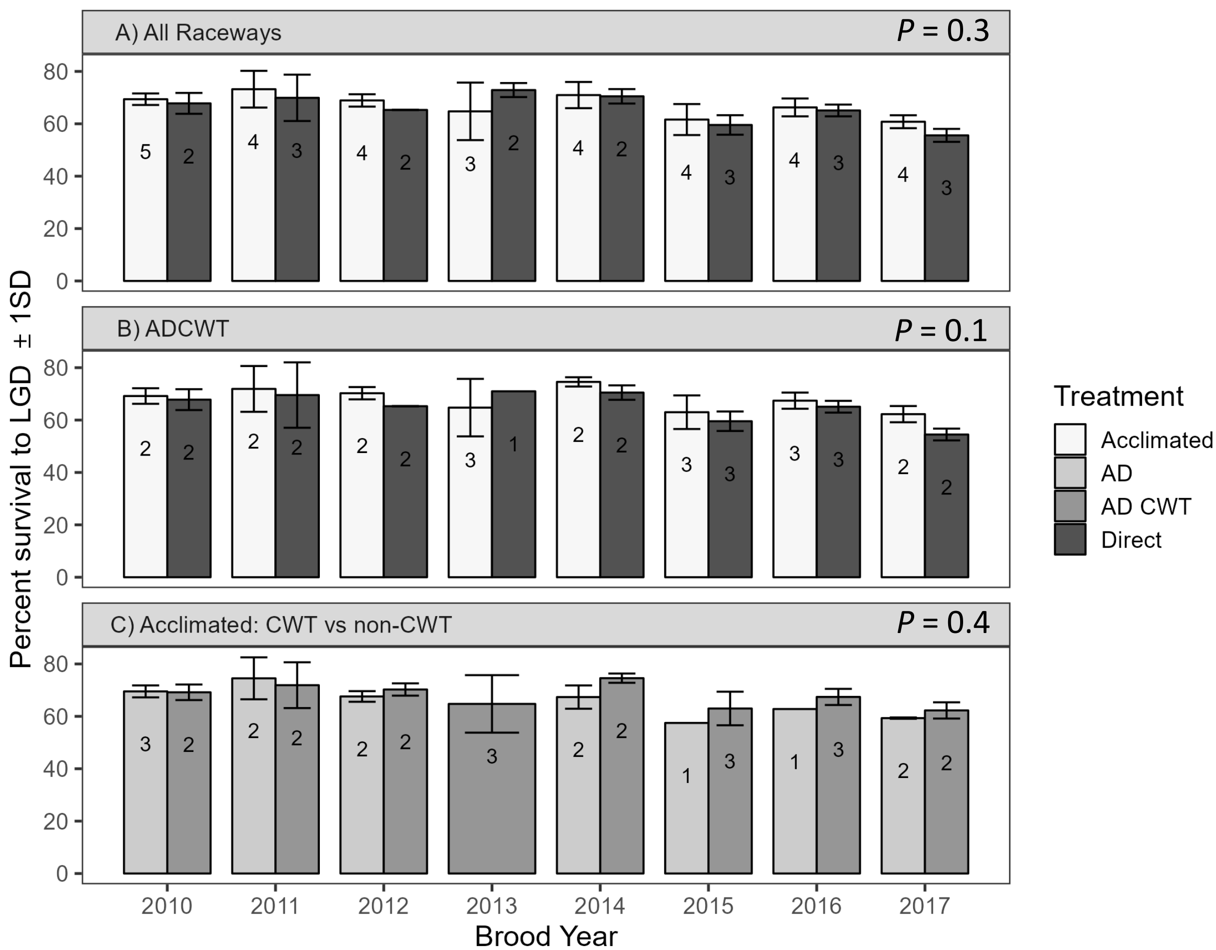

Figure 3. Bar graph comparing mean juvenile survival and standard deviation of Imnaha River smolts to Lower Granite Dam for brood years 2010–2017 by: A) All raceways for both acclimated and direct released smolts; B) Raceways with only coded wire tags for both acclimated and direct released smolts; C) Only acclimated raceways. Number on bars represent the number of raceways.

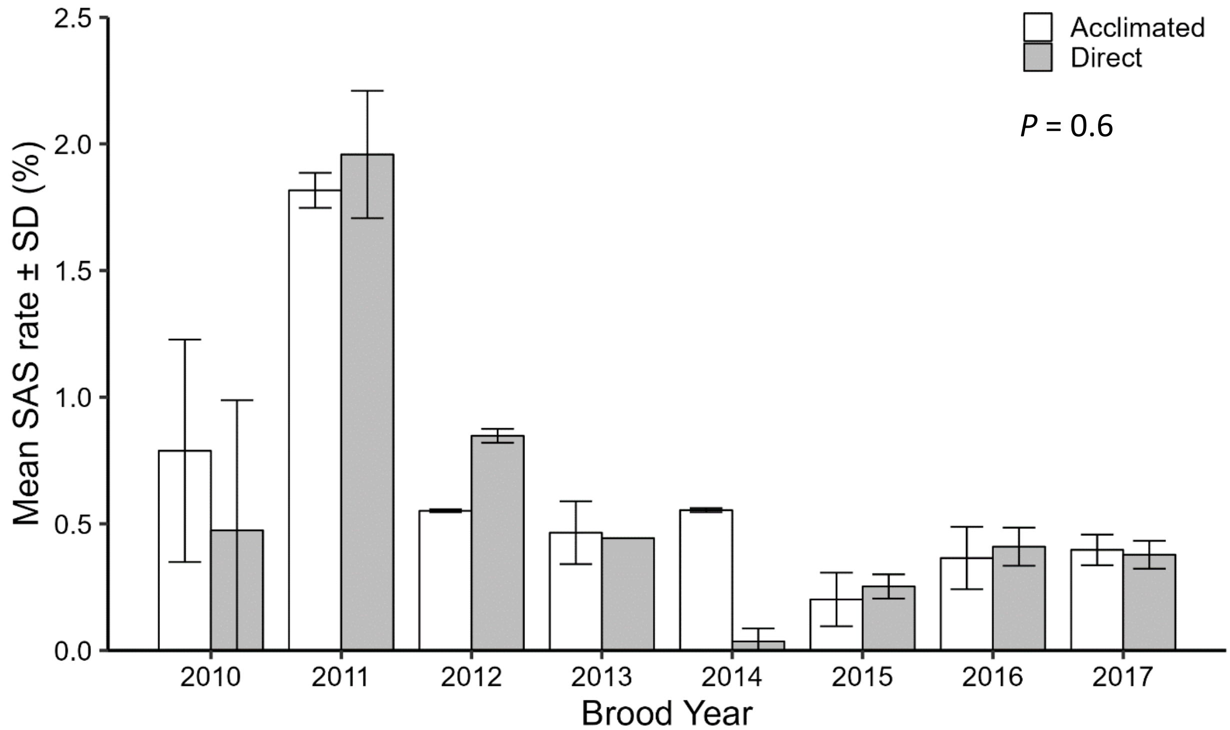

Figure 4. Bar graph comparing mean smolt-to-adult survival (SAS) and standard deviation between acclimated and direct released raceways for brood years 2010–2017.

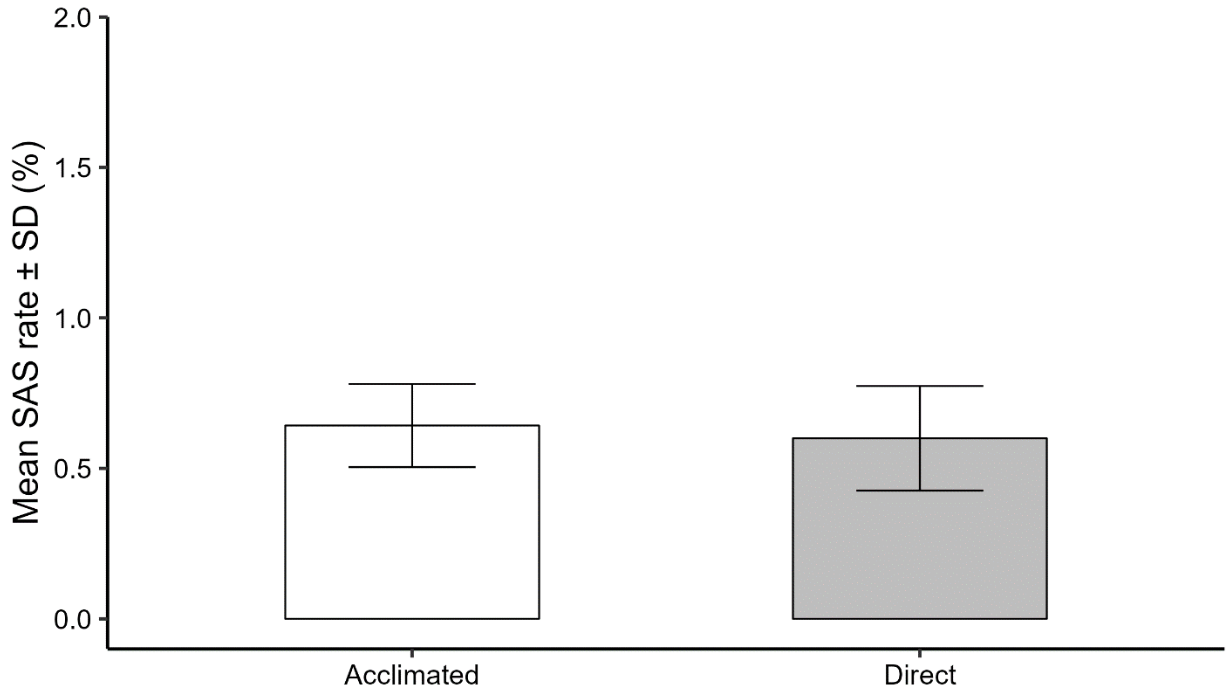

Figure 5. Bar graph comparing mean yearly smolt-to-adult survival (SAS) and standard deviation between acclimated and direct releases.

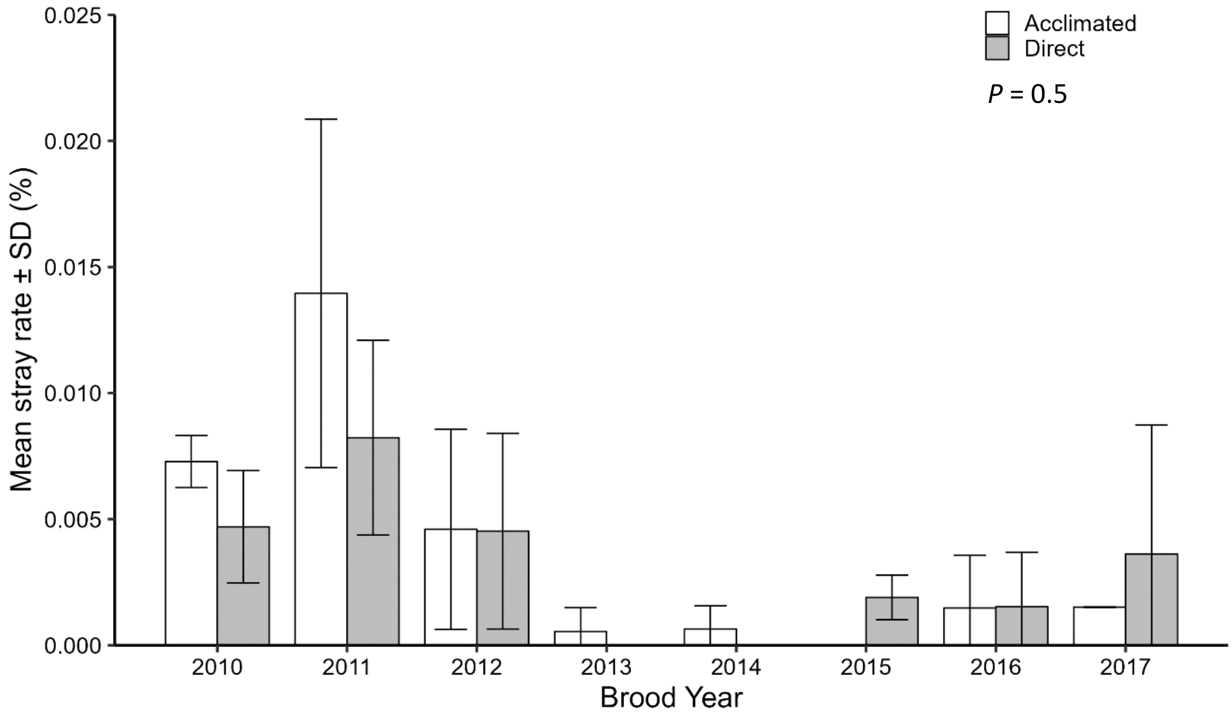

Figure 6. Bar graph comparing mean stray rates and standard deviation between acclimated and direct released smolts for brood years 2010–2017.

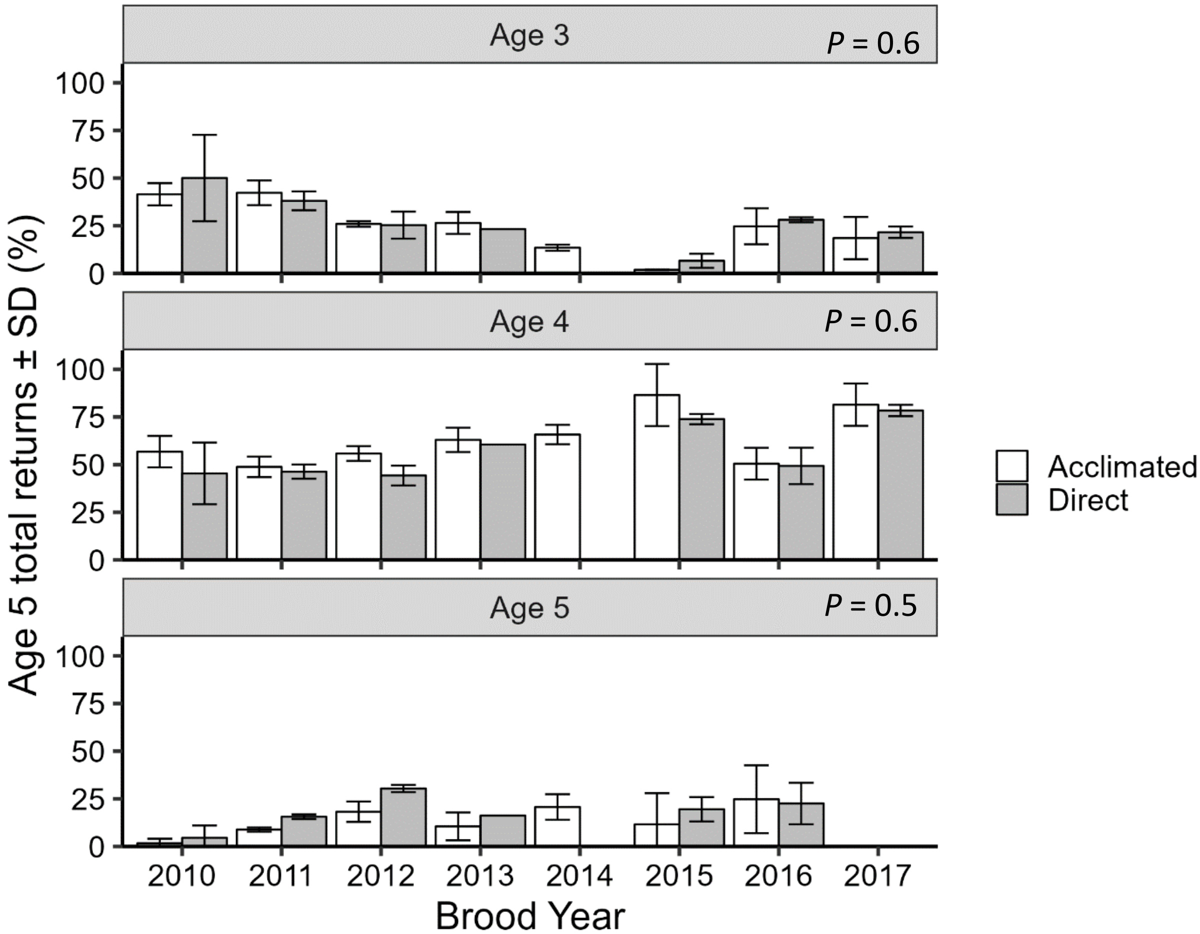

Figure 7. Bar graph comparing age composition between both acclimated and direct releases for brood years 2010–2017.

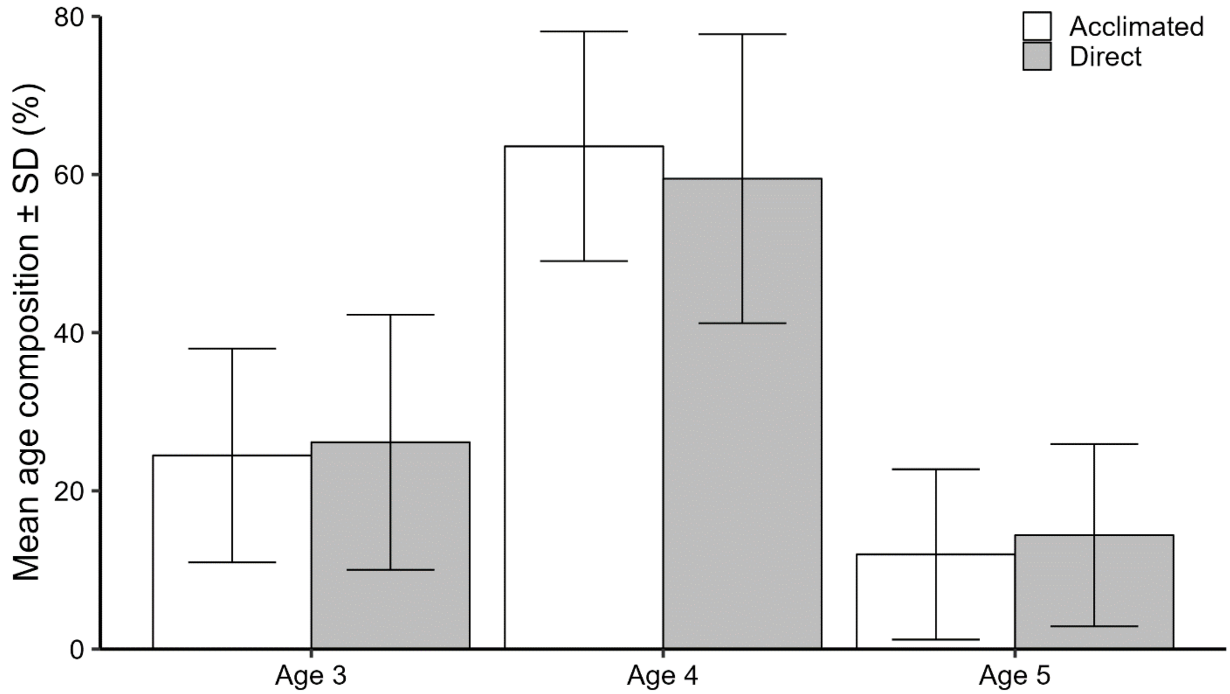

Figure 8. Bar graph comparing mean yearly age composition and standard deviation between acclimated and direct releases.

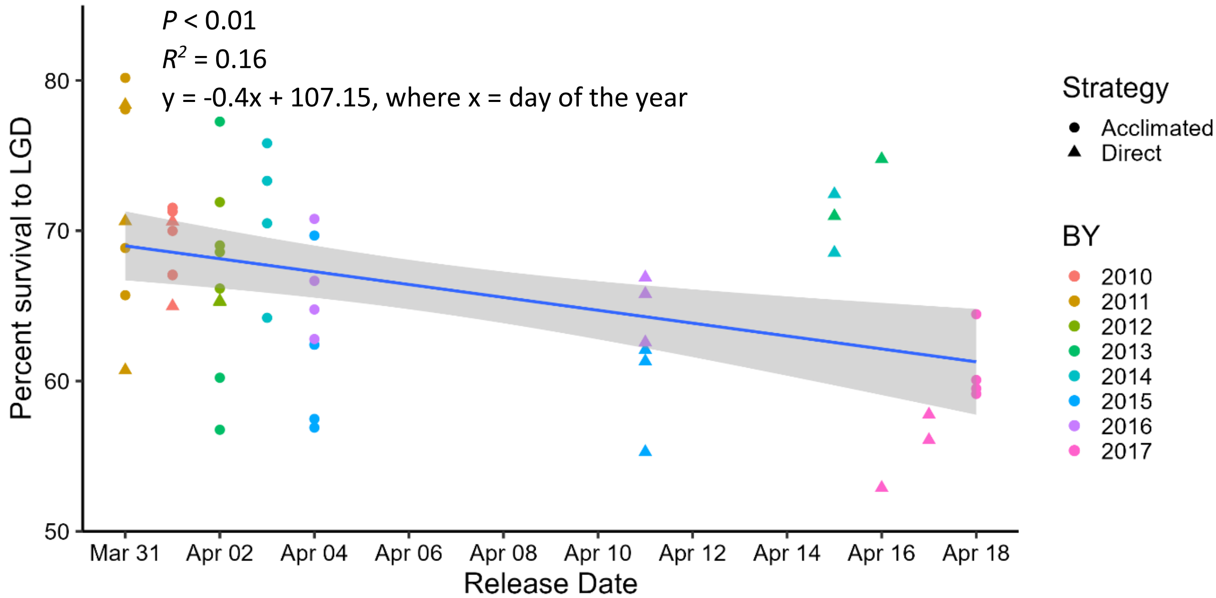

Figure 9. Regression (blue line) of percent survival of Imnaha River smolts to Lower Granite Dam (LGD) by brood year and release strategy as a function of release date at the Imnaha River Weir. Shaded area represents 95% confidence interval.

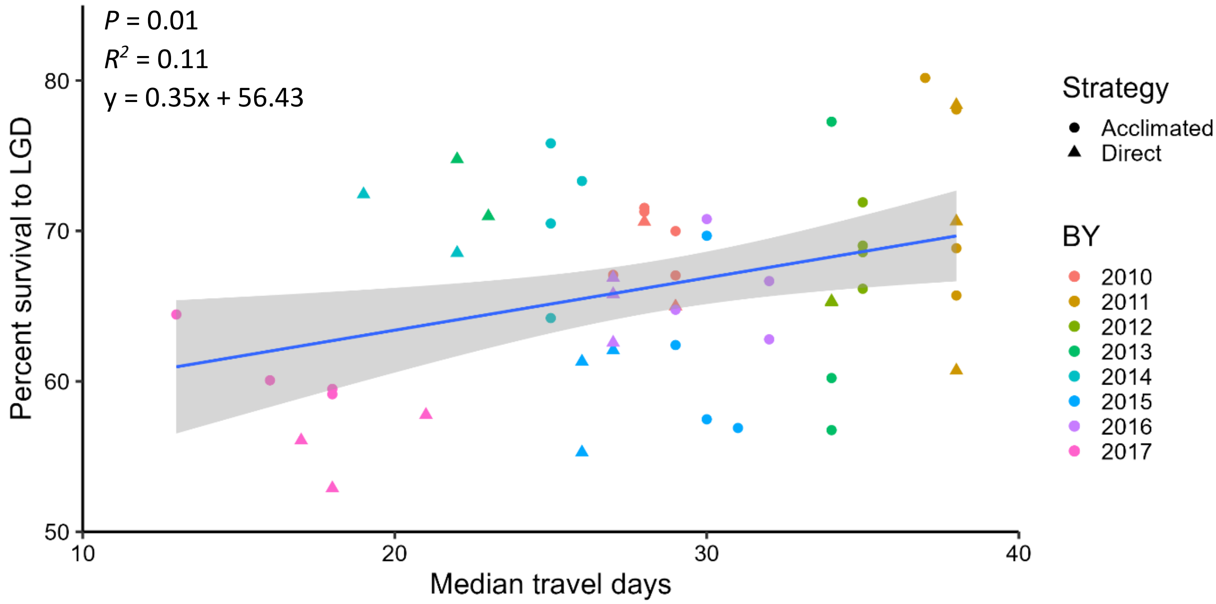

Figure 10. Regression (blue line) of percent survival of Imnaha River smolts to Lower Granite Dam (LGD) by brood year and release strategy as a function of median travel days from the Imnaha River Weir to LGD. Shaded area represents 95% confidence interval.

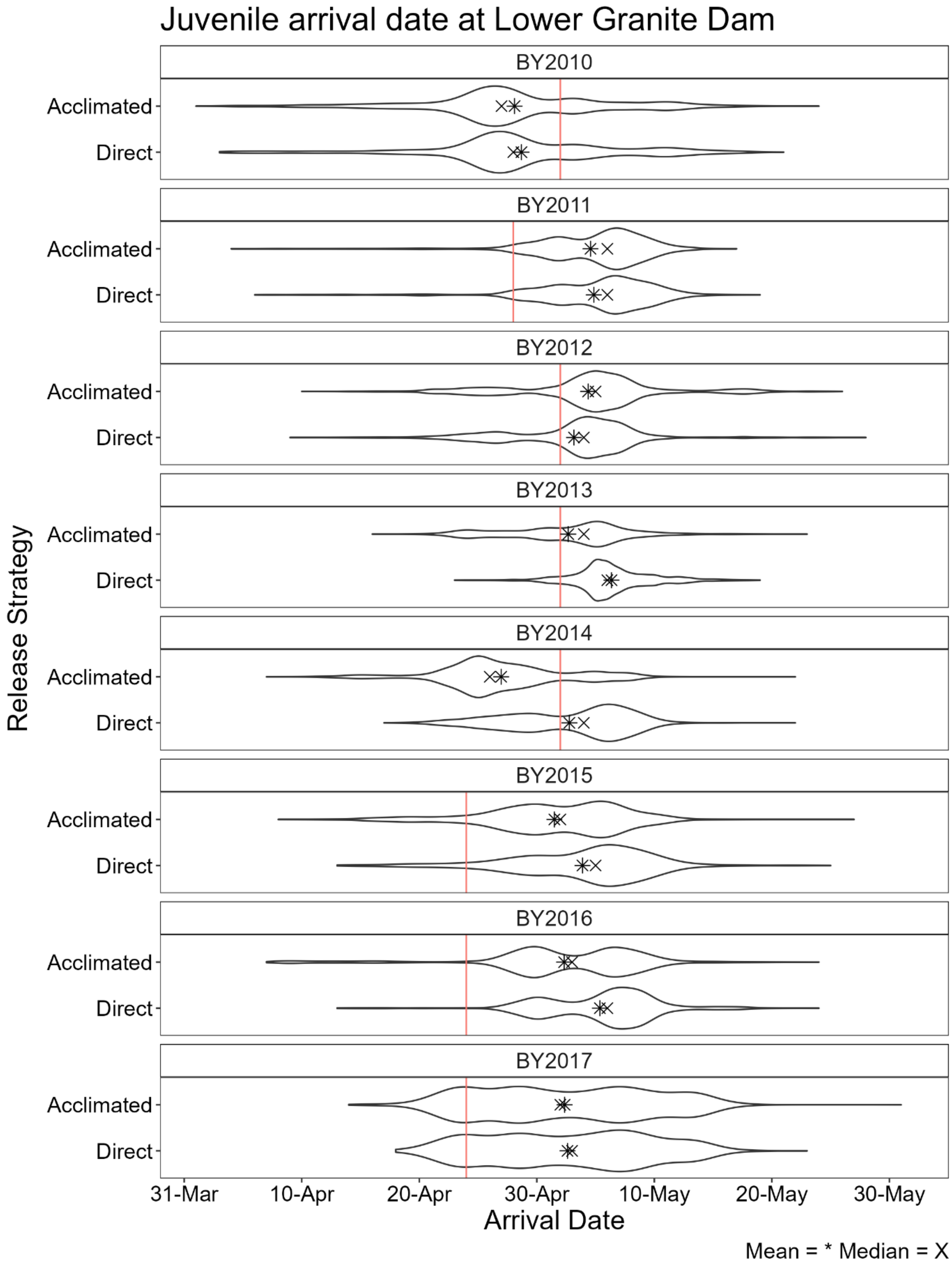

Figure 11. Violin plots comparing juvenile arrival date at Lower Granite Dam between acclimated and direct releases for brood years 2010–2017. Red lines signify the start of barging.