Relationships between juvenile size, instream flow, emigration timing, downstream travel time, and age-at-return for a Columbia River Basin spring Chinook Salmon hatchery population

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Abstract

Pacific Salmon abundance is now heavily reliant on hatchery production. Hatchery culture, management practices, and environmental factors greatly influence release size and juvenile migration timing. These factors in turn influence important demographic characteristics in returning adults. While relationships between juvenile characteristics and subsequent survival to adulthood for Pacific Salmon have been studied, additional clarification of these relationships can result in new approaches to hatchery practices that might better achieve production goals. We analyzed a data set of more than 450,000 PIT-tagged spring Chinook Salmon juveniles detected exiting Cle Elum Supplementation and Research Facility (Yakima River, Washington, USA) acclimation sites over twelve brood years (2003-2014; juvenile migration years 2005-2016; adult return years 2006-2019) and evaluated juvenile size and migration timing relative to other factors. Except in very low flow years (drought conditions), flows did not appear to affect the date that juveniles volitionally exited acclimation sites. We observed a relationship between fork length at PIT-tagging and volitional exit timing of fish from acclimation sites, with larger fish tending to migrate earlier than smaller fish. Fish that left acclimation sites earlier had longer travel times to downstream detection sites than fish that migrated later. However, migrating juveniles had similar detection rates and generally arrived during the month of May at Bonneville Dam (500-530 km downstream of acclimation sites). In general, for fish surviving to adult return, those that returned at younger ages were earlier juvenile migrants and larger at release, whereas fish that were older at return were later juvenile migrants and were smaller at release. Our results support the need for additional research into artificial production factors such as growth and thermal regimes that affect the tradeoff between survival to adult return and size- and age-at-return.

Relationships Between Fish Size, Acclimation Site Exit Timing, Downstream Detects, and Age-at Return

Presented by:
Bill Bosch,
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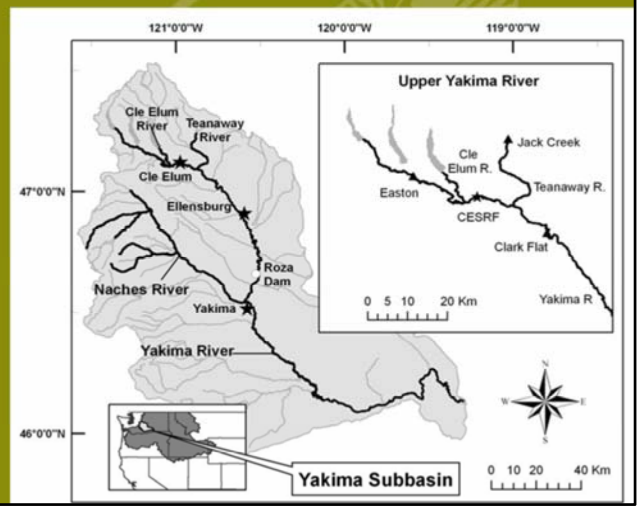
May 21, 2020
Update



Volitional release occurs between March 9 and May 16 annually. This talk discusses how what happens to a fish later in its life relates to its size and timing when it left the acclimation site – early: generally March, mid: Apr 1-23, or late: Apr 24-May 16.

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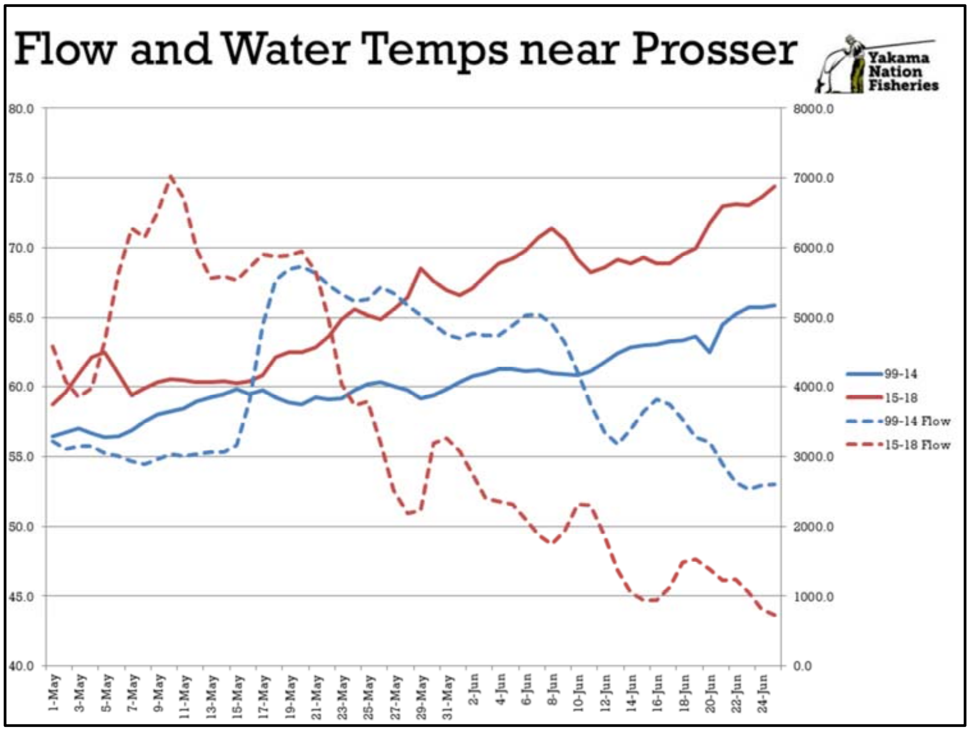
Thanks to all these folks who have helped with the design, planning and implementation of our fish restoration and evaluation efforts.



Impetus for this study: Should we be forcing fish out of the acclimation sites earlier because of the warmer temperatures and lower flows that fish encounter downstream in May?

Key Questions

1. What are the relationships between size at time of tagging and migration timing?
2. To what extent do flows drive migration timing?
3. How do juvenile fish size and migration timing affect travel time and survival to downstream dams?
4. How do juvenile fish size and migration timing affect survival to adult return?
5. How do juvenile fish size and migration timing affect age-at-return?

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Methods – PIT Detections

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Brood Year	CFJ	ESJ	JCJ	Total
2003	12,883	12,951	13,009	38,843
2004	12,869	12,645	10,513	36,027
2005	13,037	12,931	13,110	39,078
2006	15,178	11,649	11,764	38,591
2007	15,265	11,679	11,663	38,607
2008	15,641	11,684	11,680	39,005
2009	15,650	11,610	8,927	36,187
2010	15,401	11,575	11,720	38,696
2011	15,018	11,478	11,654	38,150
2012	15,158	11,498	11,654	38,310
2013	15,106	11,503	11,642	38,251
2014	15,209	11,334	11,518	38,061
				457,806

Jack Creek Acclimation Site

Easton Acclimation Site

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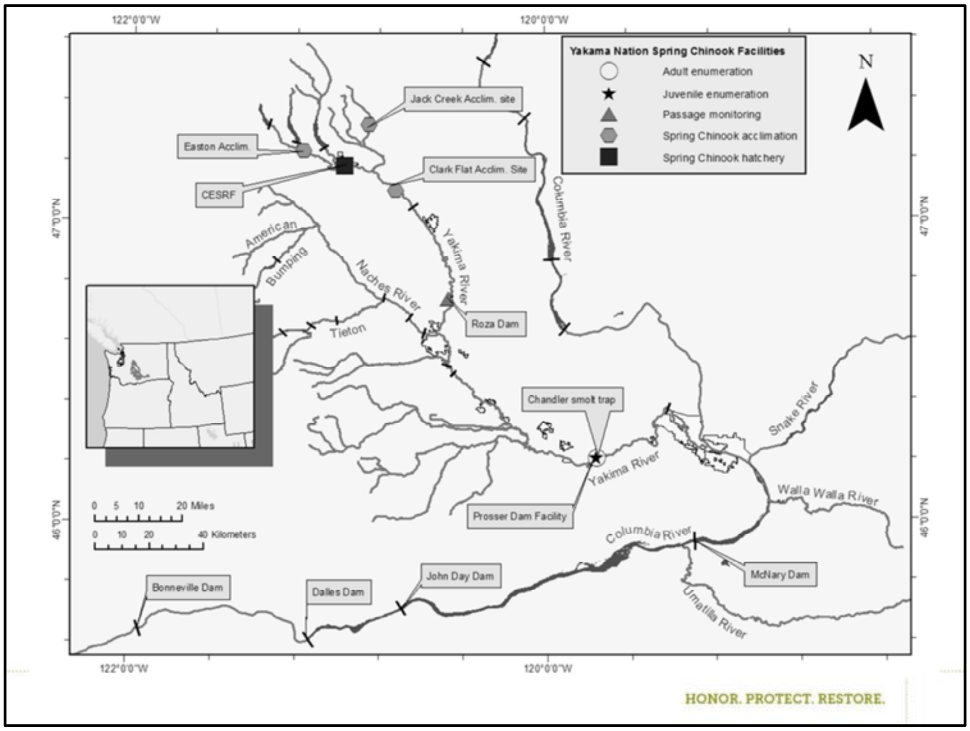
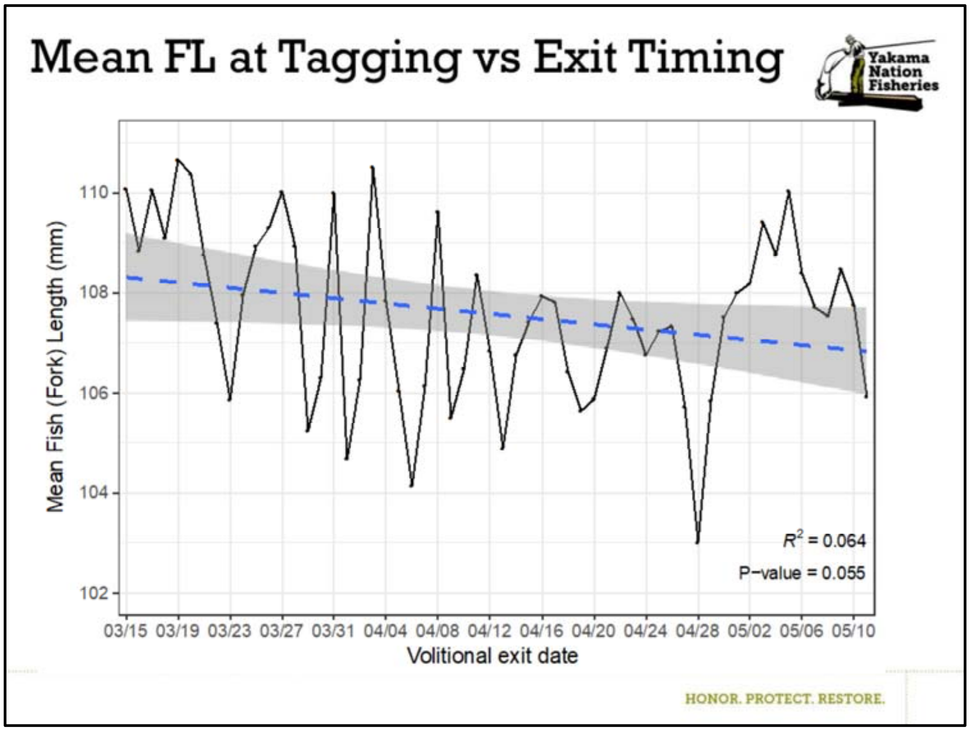
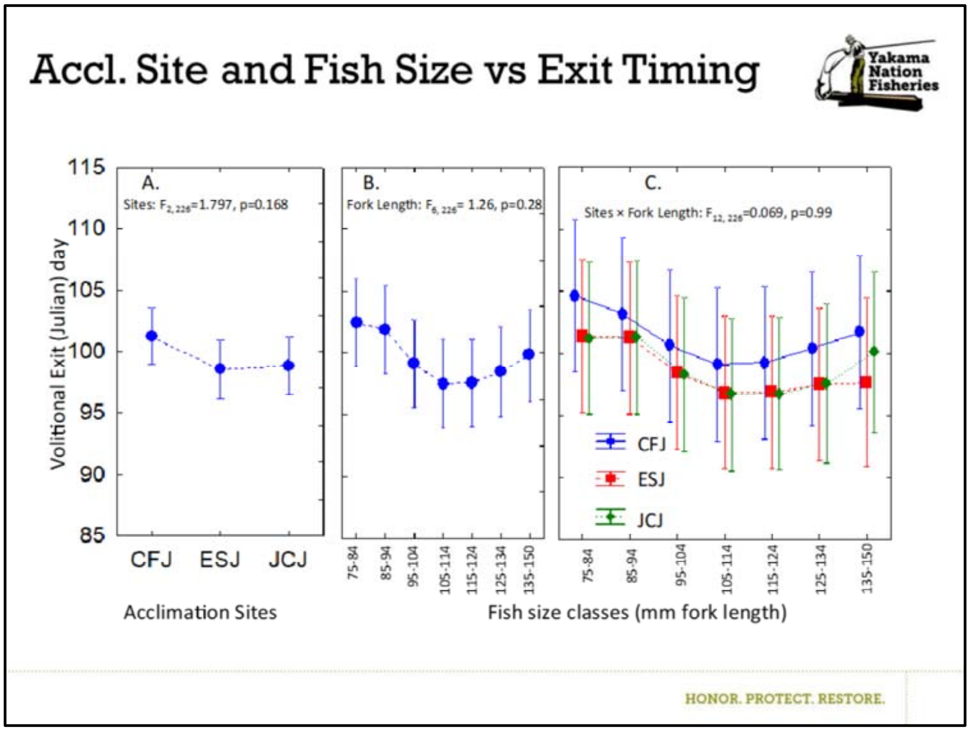
For each PIT-tag detected exiting an acclimation site, we have an associated fish size for this fish and an exit date. We used these data and detections at downstream dams to evaluate relationships relative to the key questions in the study.



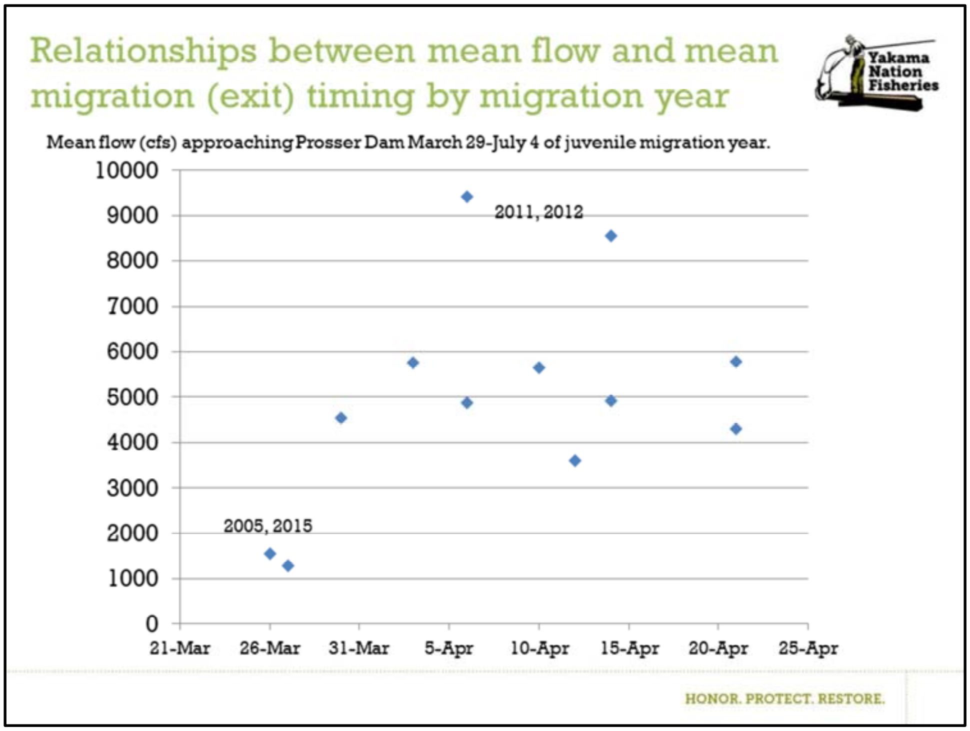
Map of Study Area.



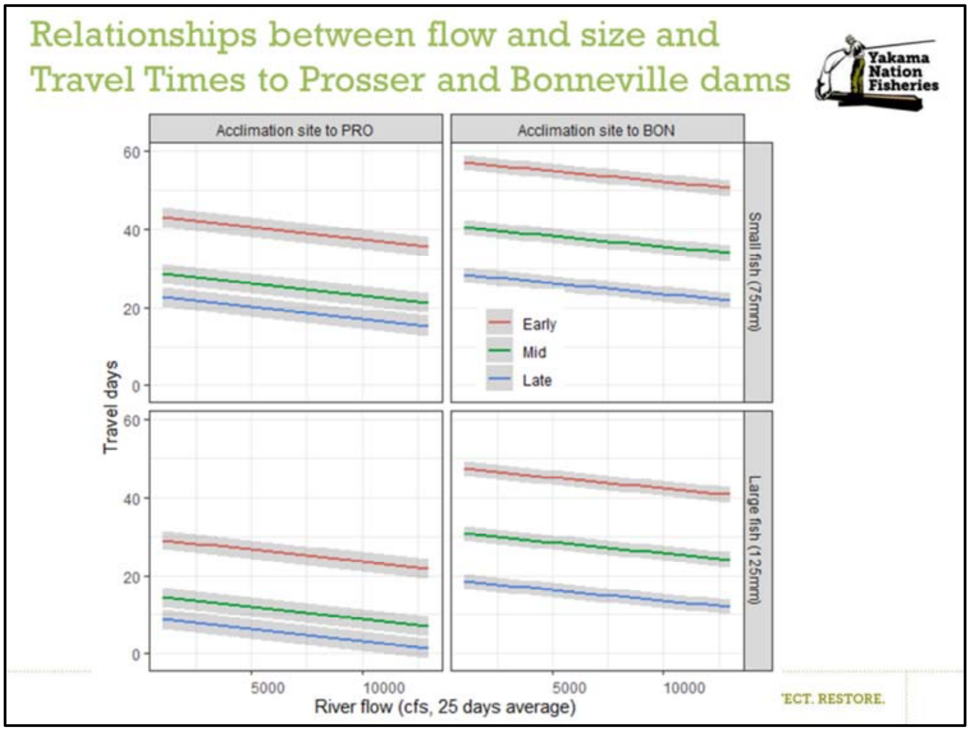
Larger (mm fork length) fish volitionally exited the acclimation sites significantly earlier than smaller fish



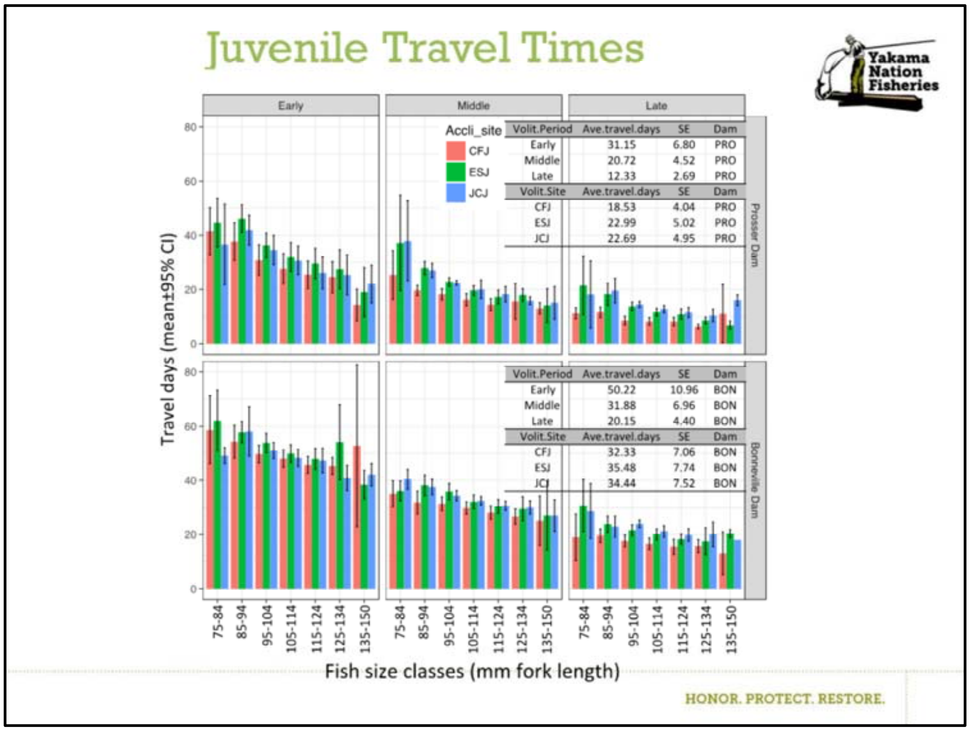
The fish from CFJ exited April 11 (Julian date 101.49 ± 1.15 (Mean ± SE)), whereas fish from ESJ and JCJ exited on April 8 (98.47 ± 1.26) and April 9th (99.12 ± 1.13), respectively. Volitional exit date for the CFJ acclimation site was slightly, but not significantly, later than exit dates at ESJ and JCJ (F = 1.80; df = 2, 226; P = 0.17; Figure A) and exit date was variable across the fish size classes, with smaller fish generally exiting later than larger fish but not significantly so (F = 1.26; df = 2, 226; P = 0.28; Table 3, Figure B). There was no interaction effect between acclimation site and fish size class on volitional exit date (sites × fish size class: F = 0.07; df = 12, 226; P = 0.99; Figure C), indicating that the magnitude of the effect of fish size class on the volitional exit date between the three acclimation sites did not vary.



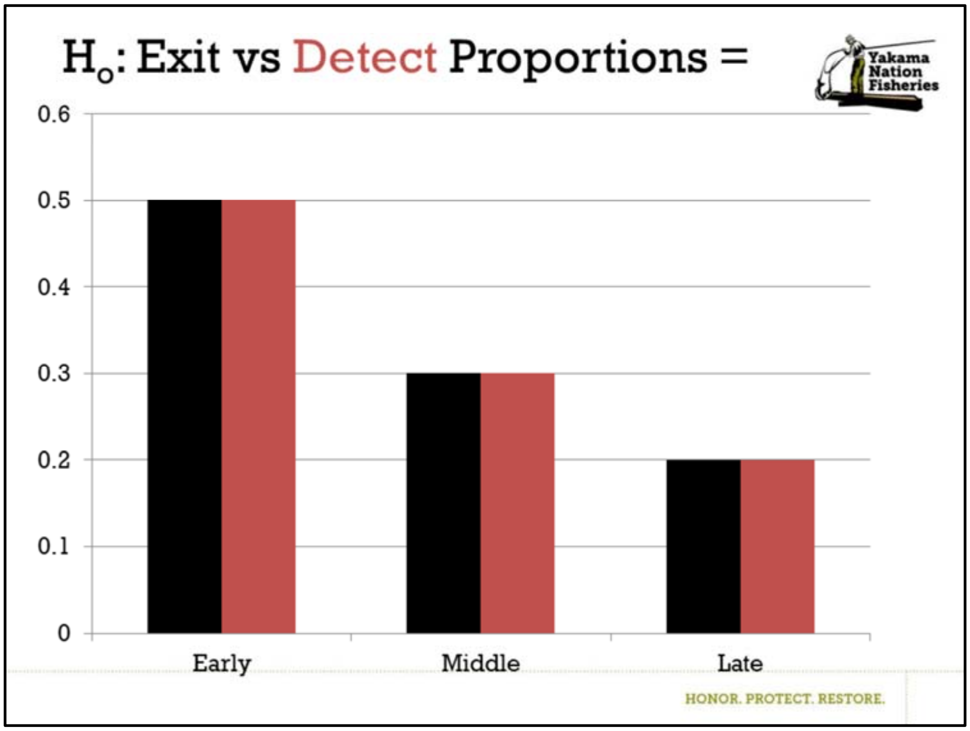
Two juvenile migration years within the study (2005 and 2015; brood years 2003 and 2013, respectively) were associated with major droughts and had the two lowest mean flows approaching Prosser Dam (approximately 160 to 210 km downstream of the acclimation sites), and these two years demonstrated the two earliest mean dates of exit from the acclimation sites. For the other years, however, mean daily flows approaching Prosser Dam showed no association with mean date of exit from the acclimation sites, indicating no effect of river flow on acclimation site exit date under most flow conditions.



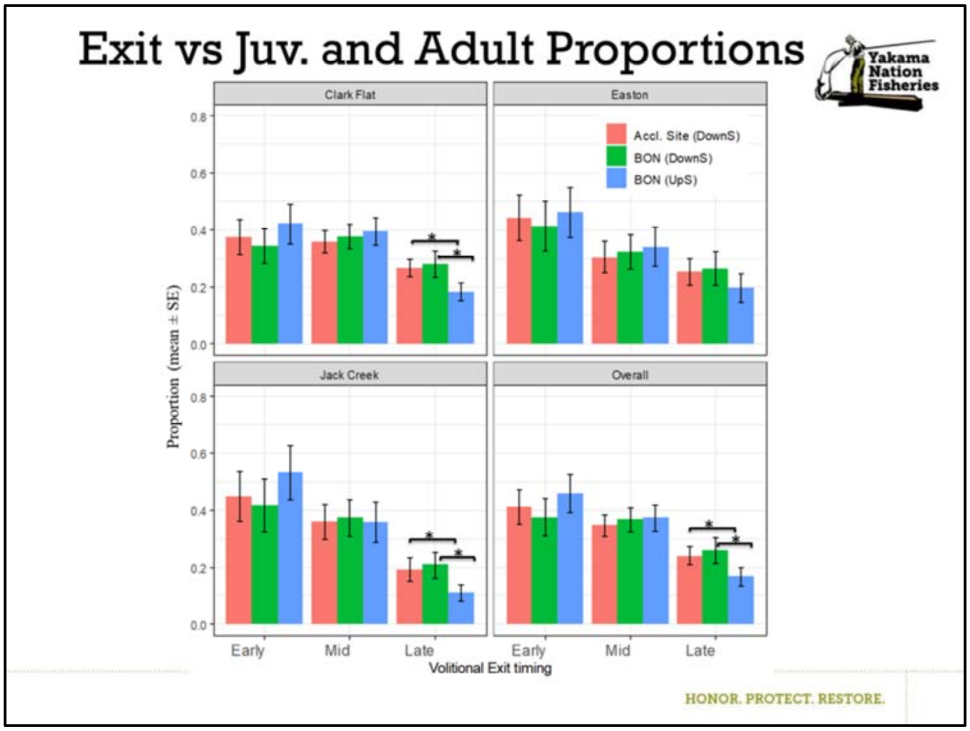
Higher flow = faster travel time; larger fish = faster travel time



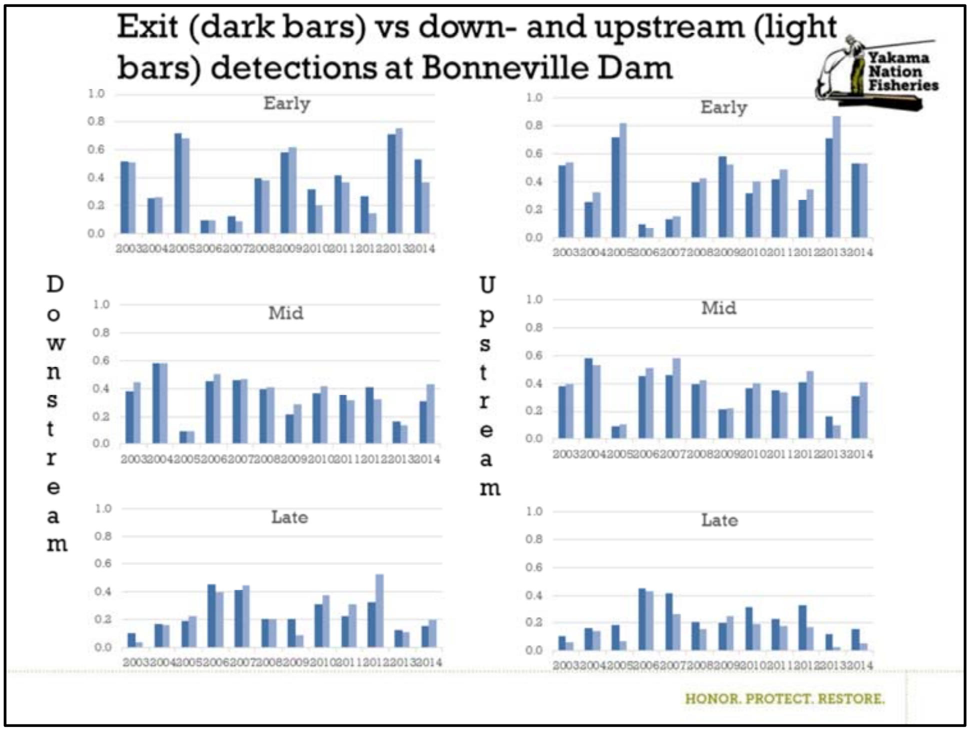
Mean travel times from acclimation sites to Prosser Dam ranged from 19 to 23 days (CFJ: 18.5 ± 4.0; ESJ: 23.0 ± 5.0; JCJ: 22.7 ± 5.0). The fish exiting acclimation sites early required 31.2 ± 6.8 days to travel to Prosser Dam, whereas the fish exiting during the mid and late time-periods took about 20.7 ± 4.5 and 12.3 ± 2.7 days, respectively. Similarly, mean travel times from acclimation sites to Bonneville Dam ranged from 32 to 35 days with fish exiting early taking 50 days on average to travel this distance, whereas late emigrating fish made the journey in about 20 days. For fish from all three acclimation sites and exit time periods, fish that were smaller generally took more time to travel, both to Prosser Dam and to Bonneville Dam, than fish that were larger.



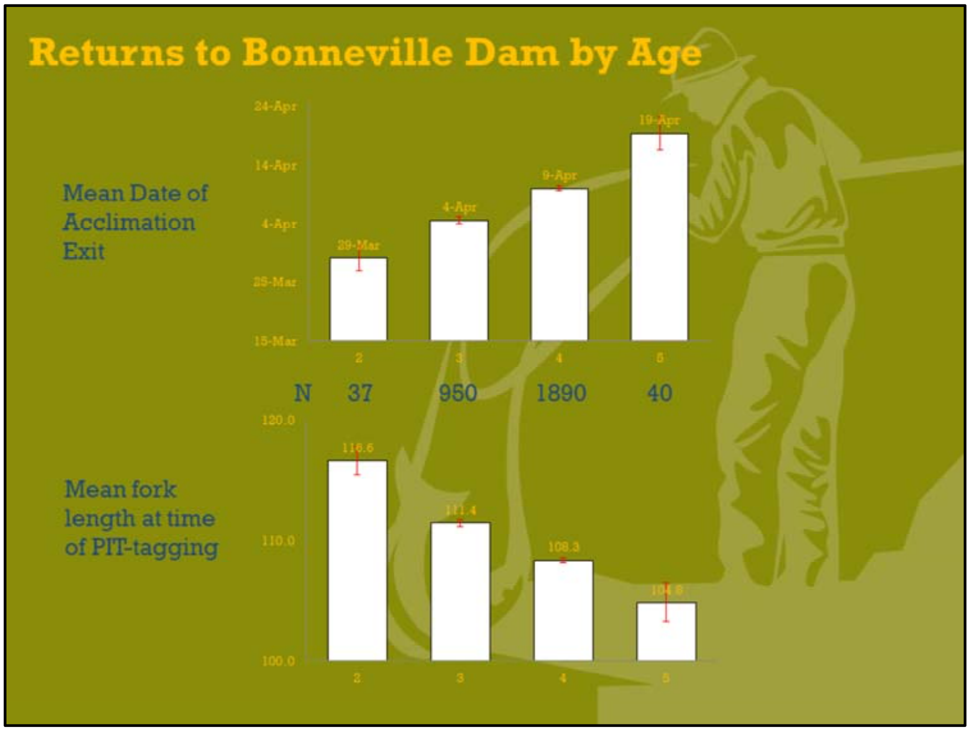
Assume that detection proportions at volitional exit from the acclimation sites and at downstream detection sites (whether fish are migrating downstream or upstream) will be equal regardless of volitional exit timing. In other words, the null hypothesis is that fish survival is equal throughout a fish's life regardless of when it left the acclimation site.



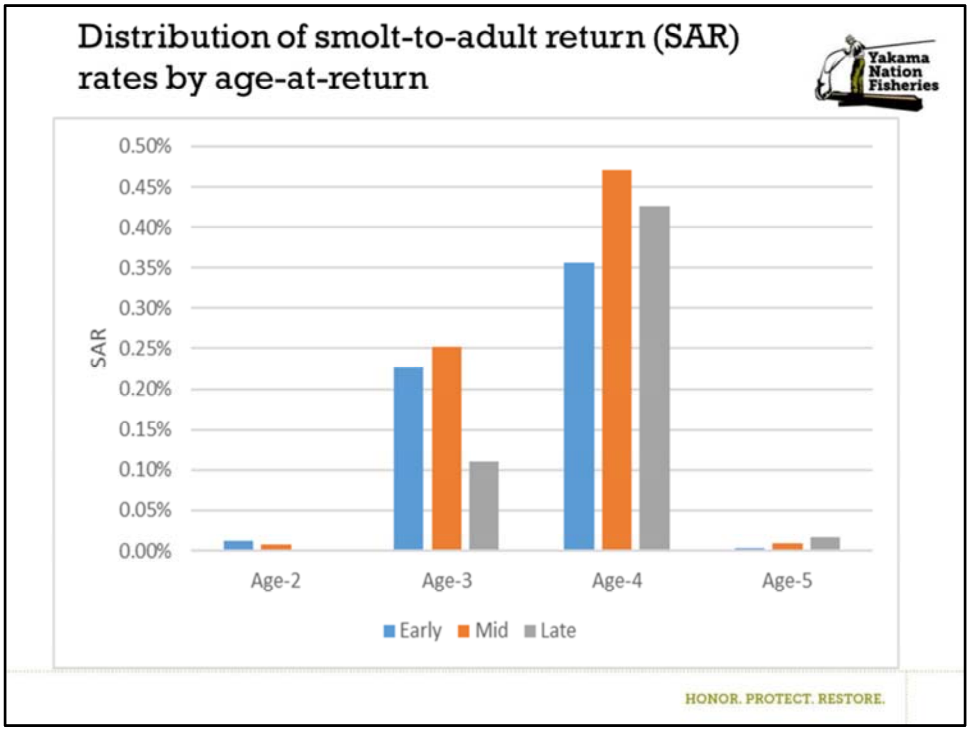
We found no significant differences between overall mean detection proportions leaving the acclimation sites (red bars) by brood year during the early, mid, and late emigration periods and mean detection proportions of juveniles (green bars) arriving at Bonneville Dam (P = 0.68, 0.74, and 0.75 for early, mid, and late emigration periods, respectively). There were slight differences between mean detection proportions leaving the acclimation sites (red bars) by brood year during the early, mid, and late emigration periods and mean detection proportions of these same groups for upstream migrating fish (blue bars) returning to Bonneville Dam. The differences were not significant with the exception of fish emigrating during the late time-period for the Clark Flat, Jack Creek, and overall populations which were marginally significant (F = 0.28; df = 1, 22; P = 0.12).



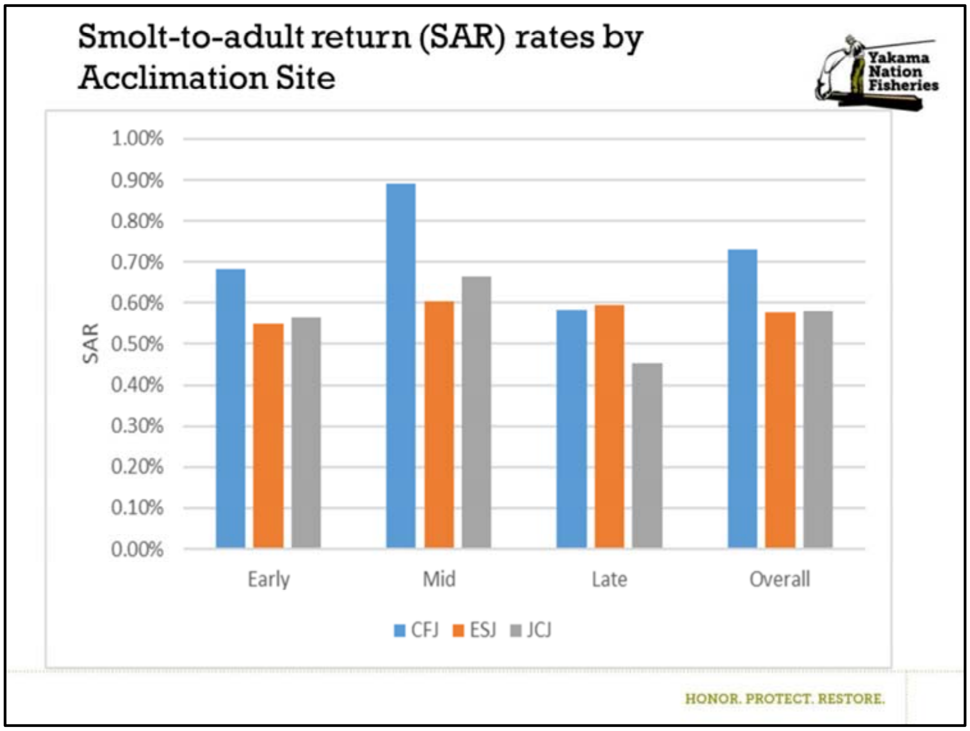
For early period emigrants, mean proportions of juveniles arriving at Bonneville Dam (light bars) were less than mean proportions at acclimation exit (dark bars) in eight of the twelve brood years (left panel). For early emigrants in four of these brood years (2007, 2010, 2012, and 2014), the difference between mean exit proportions and mean Bonneville Dam juvenile detection proportions was substantial, with 42-81% fewer fish detected as juveniles at Bonneville Dam than were expected.
The early emigrants were detected migrating upstream (light bars) at Bonneville Dam in greater proportions than expected (exit detections; dark bars) in most years (right panel). However, for late period emigrants, mean proportions of returning fish (light bars) arriving at Bonneville Dam were less than mean proportions at acclimation exit (dark bars) in eleven of the twelve brood years (39% ± 6% (mean ± SE) fewer returning fish than expected; right panel).



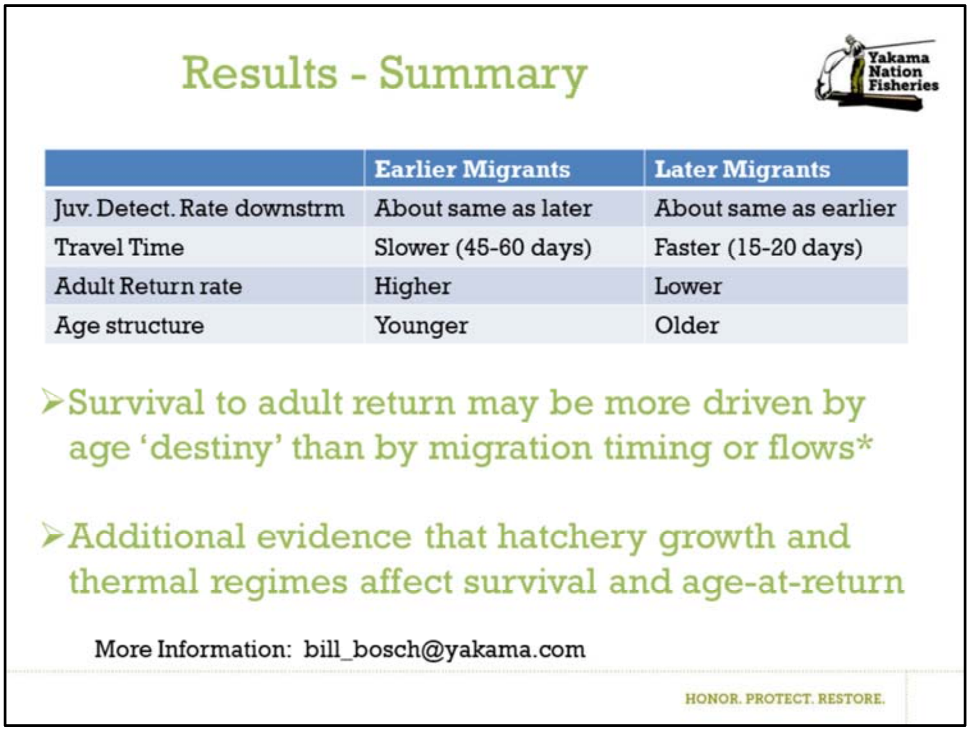
When PIT-tag detection data were pooled across all twelve years of the study, we found that age-at-return of fish returning to Bonneville Dam increased with increasing mean date of volitional exit from the acclimation sites (Adjusted $r^2 = 0.94$, slope = 5.32, $P = 0.01$). We also found that juvenile fish size was inversely correlated with age-at-return for fish that survived to adult return to Bonneville Dam (Adjusted $r^2 =$ 0.91, slope = -4.62, $P = 0.02$).



For PIT-tag detection data pooled across all twelve years of the study, fish from the early emigration time-period returned at younger ages, while fish from the mid and late emigration periods demonstrated better survival to older ages



Fish exiting the Clark Flat acclimation site had higher return rates for the early and middle emigration time periods, and overall, while fish exiting the Jack Creek acclimation site during the late emigration time period showed a lower return rate, relative to fish exiting the other acclimation sites during these same time periods. Fish from CFJ were larger at tagging (108.23 ± 0.02 mm) than fish from JCJ (108.15 ± 0.02 mm) which were larger than fish from ESJ (106.75 ± 0.03 mm); all of these differences were statistically significant ($P \leq 0.01$).



Results - Summary

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	Earlier Migrants	Later Migrants
Juv. Detect. Rate downstrm	About same as later	About same as earlier
Travel Time	Slower (45-60 days)	Faster (15-20 days)
Adult Return rate	Higher	Lower
Age structure	Younger	Older

- Survival to adult return may be more driven by age 'destiny' than by migration timing or flows*
- Additional evidence that hatchery growth and thermal regimes affect survival and age-at-return

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* Except in really low flow years; Or in other words, did fish that left later return to Bonneville at lower rates than expected because of flow/temperature/estuary arrival timing or because they were "destined" to be age 5 fish from early in their lives and therefore suffered a higher mortality burden by staying in the ocean longer?