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MEMORANDUM

TO: Gary Fredricks, NOAA

FROM: Tom Berggren and Jerry McCann

DATE: October 23, 2007

RE: Simulations of the effects of increased detection probabilities at Bonneville Dam on the variability in reach survival estimates

Introduction

As you requested simulations were used to evaluate the effects of increased detection probability at Bonneville Dam, on the variance of PIT-tag reach survival estimates. In an effort to better quantify the possible effects of increased detection probability of proposed spillway PIT-detection systems at Bonneville Dam, we simulated the reach survival of PIT-tag juvenile salmon populations migrating from Lower Granite Dam to below Bonneville Dam. The results suggest that relatively large increases in precision can be achieved by increasing detection probability, when the starting population of PIT-tagged fish at Lower Granite Dam is relatively small (12,500) . However, with large starting populations at Lower Granite Dam, in the range of 100,000 tags, the benefit of increasing detection probability is not as dramatic. Increased starting population at Lower Granite had a larger effect on relative precision than increased detection probability. It may be that using the same technological breakthroughs applied to developing the Bonneville spillway detector array, could be used to better effect at the Lower Granite Dam RSW. Some discussion of possible management implications of using an alternate installation site such as the Lower Granite Dam RSW instead of the Bonneville Dam spillway is included for your consideration.

Methods

Simulated populations of PIT-tagged fish were generated using software developed within the Comparative Survival Study (Schaller et al 2007). The starting point for each simulated PIT-tag population is a common timing distribution at Lower Granite Dam (LGR) as illustrated in Figure 1. The simulated populations then migrate from dam to dam following the default travel time distributions used in Schaller et al 2007, and then arrive at Bonneville Dam (BON) approximately two weeks later (Figure 1). Each simulated inter-dam survival rate is constant over time in daily binomial draws that produce the number of surviving smolts to the reach's downstream dam. The collection probability of these PIT-tagged fish at each dam is also constant over time in daily binomial draws that produce the number of detected smolts. Input values for the reach survival and collection probabilities are shown in Table 1. Across the simulated populations created, a common set of reach survival and collection probabilities are used as shown in Table 1, except at BON where 5 separate levels of collection probability are run (*i.e.*, 0.125, 0.1875, 0.250, 0.375, and 0.500). Finally, there are four levels of starting population numbers at LGR in the various runs (*i.e.*, 12,500; 25,000; 50,000; 100,000). In order to account for the potential of some PIT-tagged fish detected and re-released at LGR being transported at LGS or LMN, we added a removal probability of 0.15 on the collected fish at those two sites.

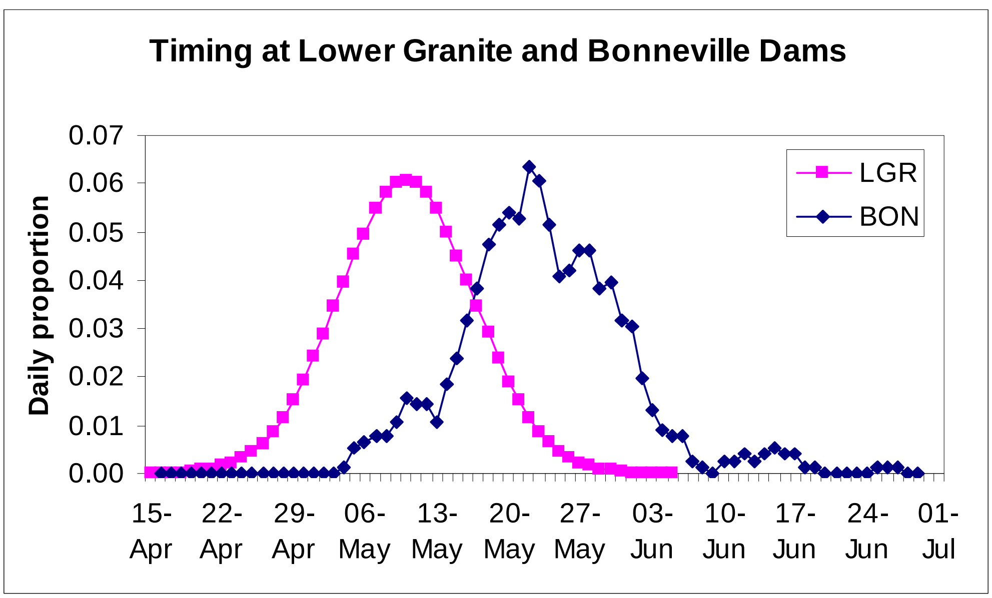

Figure 1. Arrival distribution of simulated PIT-tag population at Lower Granite and Bonneville dams.

Table 1. Probability inputs for parameters in binomial draws used in generating simulated data sets.

Inter-dam survival rate		Dam collection probability	
Parameter	**Input value**	**Parameter**	**Input value**
Release to LGR (S_1)	0.999 (maximum)	LGR (P_2)	1.000 (maximum)
LGR-to-LGS (S_2)	0.90	LGS (P_3)	0.45
LGS-to-LMN (S_3)	0.88	LMN (P_4)	0.30
LMN-to-MCN (S_4)	0.90	MCN (P_5)	0.35
MCN-to-JDA (S_5)	0.85	JDA (P_6)	0.15
JDA-to-BON (S_6)	0.85	BON (P_7)	Varies across runs: 0.125 0.1875 0.250 0.375 0.500
BON-to-TWX	0.03 (joint survival and collection probability)		
Removals at LGS	0.15 of collected fish		
Removals at LMN	0.15 of collected fish		

Results

Twenty simulated data sets were created based on the four levels of starting populations at LGR and five levels of collection probability at BON. The total LGR-to-BON reach survival rate ($S_R = S_2 \cdot S_3 \cdot S_4 \cdot S_5 \cdot S_6$) is the parameter of interest in this evaluation. Table 2 shows how precision of S_R is affected by changes in PIT-tag collection at BON for different size PIT-tag populations. The relative increase in precision of S_R as BON collection probability increases is higher for smaller populations than larger populations. A doubling of BON collection probability reduces the standard deviation of average S_R by approximately one-half for the smaller populations evaluated, while reducing the standard deviation by approximately one-third for larger populations evaluated.

Table 2. Simulated populations of smolts with underlying LGR-to-BON reach survival rate of 0.515 and resulting CJS estimate and precision relative to changes in PIT-tag collection probability at Bonneville Dam and starting number of smolts entering the reach at Lower Granite Dam (average and standard deviation of 1000 bootstrap replicates).

Collection prob. Bonneville Dam	Smolts re-released at Lower Granite Dam (detected plus initial tagged fish)							
	N = 12,500		N = 25,000		N = 50,000		N = 100,000	
	Avg.	Std.dev.	Avg.	Std.dev.	Avg.	Std.dev.	Avg.	Std.dev.
0.1250	0.677	0.1732	0.507	0.0730	0.551	0.0616	0.494	0.0354
0.1875	0.517	0.0952	0.489	0.0544	0.472	0.0357	0.541	0.0310
0.2500	0.579	0.0809	0.466	0.0406	0.497	0.0306	0.504	0.0235
0.3750	0.508	0.0504	0.519	0.0349	0.539	0.0299	0.529	0.0199
0.5000	0.527	0.0424	0.504	0.0259	0.526	0.0203	0.529	0.0145

If a goal of maintaining a precision of approximately 5% or lower coefficient of variation, then a combination of having larger population sizes of PIT tags available as well as higher collection probabilities at BON would be necessary (Table 3). A larger population number of PIT-tagged smolts with known date of passage at LGR could be attained by increasing the detection probability at LGR. Table 3 shows a 4-fold increase in number of smolts at LGR tends to cut in half (approximately) the coefficient of variation of S_R.

Table 3. Coefficient of variation for CJS estimated LGR-to-BON reach survival rates for simulated datasets in Table 1 (CV of 1000 bootstrap replicates; CV of approximately 5% or lower are shown in red).

Collection prob. Bonneville Dam	Smolts re-released at Lower Granite Dam (detected plus initial tagged fish)			
	N = 12,500	N = 25,000	N = 50,000	N = 100,000
0.1250	0.256	0.144	0.112	0.072
0.1875	0.184	0.111	0.076	0.057
0.2500	0.140	0.087	0.062	0.047
0.3750	0.099	0.067	0.055	0.038
0.5000	0.080	0.051	0.039	0.027

Discussion

As demonstrated with the simulated data sets, an increase in the precision of the estimated LGR-to-BON reach survival rate (S_R) is possible by increasing the collection probability of PIT-tagged fish at BON (Figure 2). This will also improve the precision of estimated reach survival rates of PIT-tagged fish originating outside the Snake River basin from tributaries such as the Wind, Hood, Deschutes, John Day, Klickitat, Umatilla, Yakima, Wenatchee, Entiat, Methow, and Okanagon rivers, as well as mainstem tagged fish in the Hanford reach or at Columbia River dams.

However, increasing the number of PIT-tagged fish detected at LGR, which will also increase the precision of the estimated S_R, may have more utility for future evaluations of interest to fishery managers. Currently, we can only detect PIT-tagged smolts that enter the bypass channels at dams. Determination of a known number of fish passing a non-bypass/collector route, particularly through spill, would be very beneficial. This would allow direct comparisons between bypassed and spilled fish at LGR relative to their corresponding LGR-to-BON reach survival rate on a temporal basis, and potentially smolt-to-adult survival rates (SAR) if the number of PIT-tagged smolts available is large enough. Therefore, it may be prudent to consider installation and evaluation of the spillway PIT-tag detection system at LGR rather than BON. Also, it may prove more feasible for installation and operation at LGR within a spillway that contains a removable-spillbay-weir (RSW) rather than at BON in a convention spillway. If and when the technologies to monitor PIT-tags passing through spill bays is perfected to a high enough detection capability to warrant the expense of future installations, then the addition of spillway PIT-tag monitors at other dams would be useful for future evaluations of spillway passage benefits.

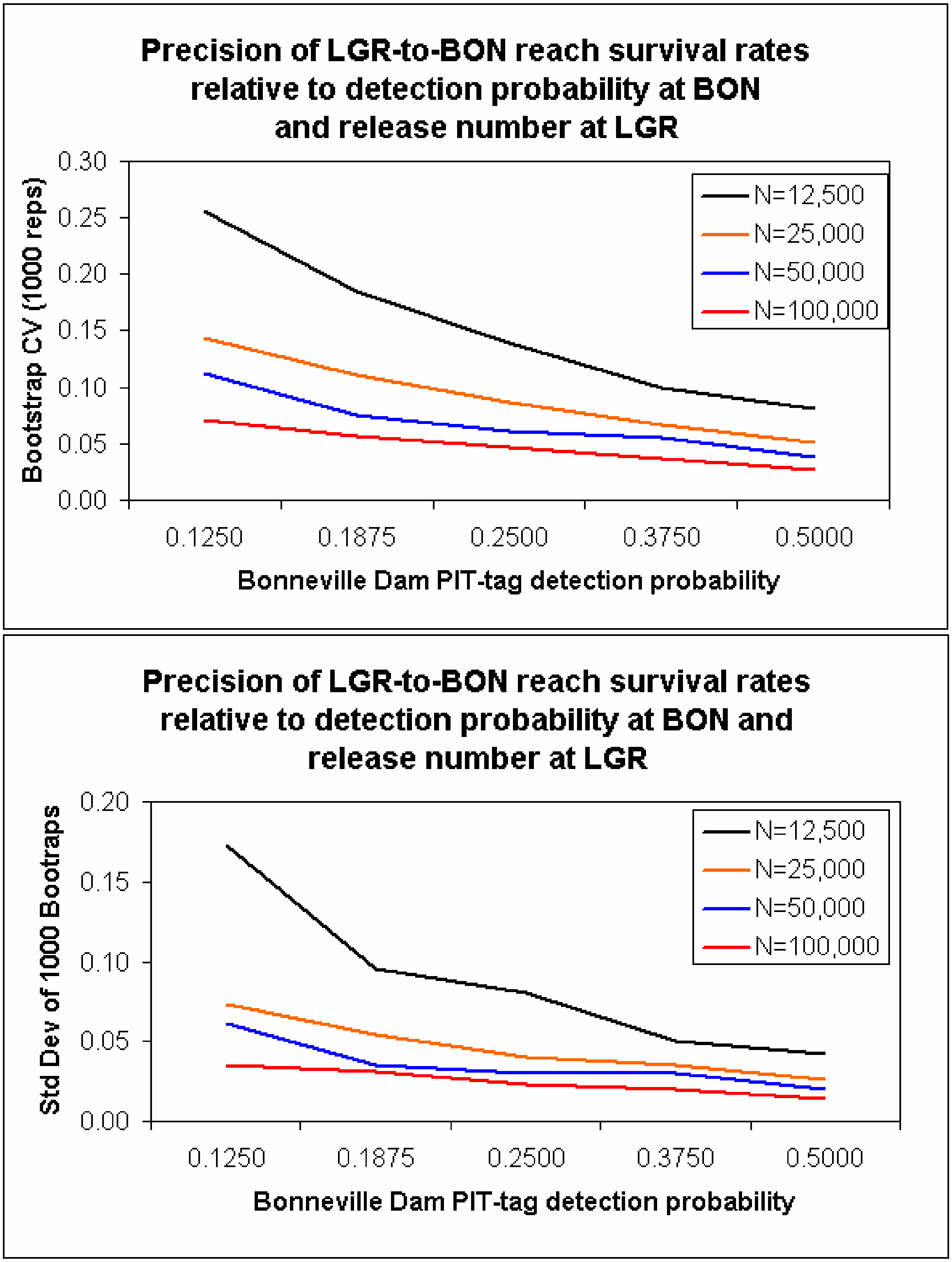

Figure 2. Trend in precision of LGR-to-BON reach survival rates (S_R) as PIT-tag detection probability increases at BON for various PIT-tag population sizes (upper plot is coefficient of variation of S_R and lower plot is standard deviation of 1000 bootstrap estimates of S_R).