Memo: Method to determine redd distributions from Sacramento River Winter Run Chinook Salmon (WRCS) carcass survey data.

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Background

The location of Winter Run Chinook Salmon (WRCS) redds in the upper Sacramento River is important for evaluating their susceptibility to temperature-dependent mortality. Water temperatures can change dramatically along the river, so there is spatial variability in temperature-dependent mortality, development rate, and other thermal processes secondary to the temporal thermal regime. Redds are distributed among reaches (Figure 1) of river between two landmarks. New redds are also distributed in time, with a protracted spawning season from May through July.

The spatial and temporal distributions of WRCS redds are known by two methods: 1) direct observation of redds from aerial surveys, and 2) modeled (expanded) predictions from carcass surveys. Aerial surveys of the spawning grounds began in the 1981 and were conducted across eight reaches extending as far downstream as Red Bluff Diversion Dam. While aerial surveys are a rapid method of surveying an extended area, accurate counts can be hampered by high flows, turbidity, and bad weather. Carcass surveys began in 2000 on the upper Sacramento River, with modern enumeration and logging beginning in 2004. The carcass surveys cover four upper reaches of the Sacramento River.

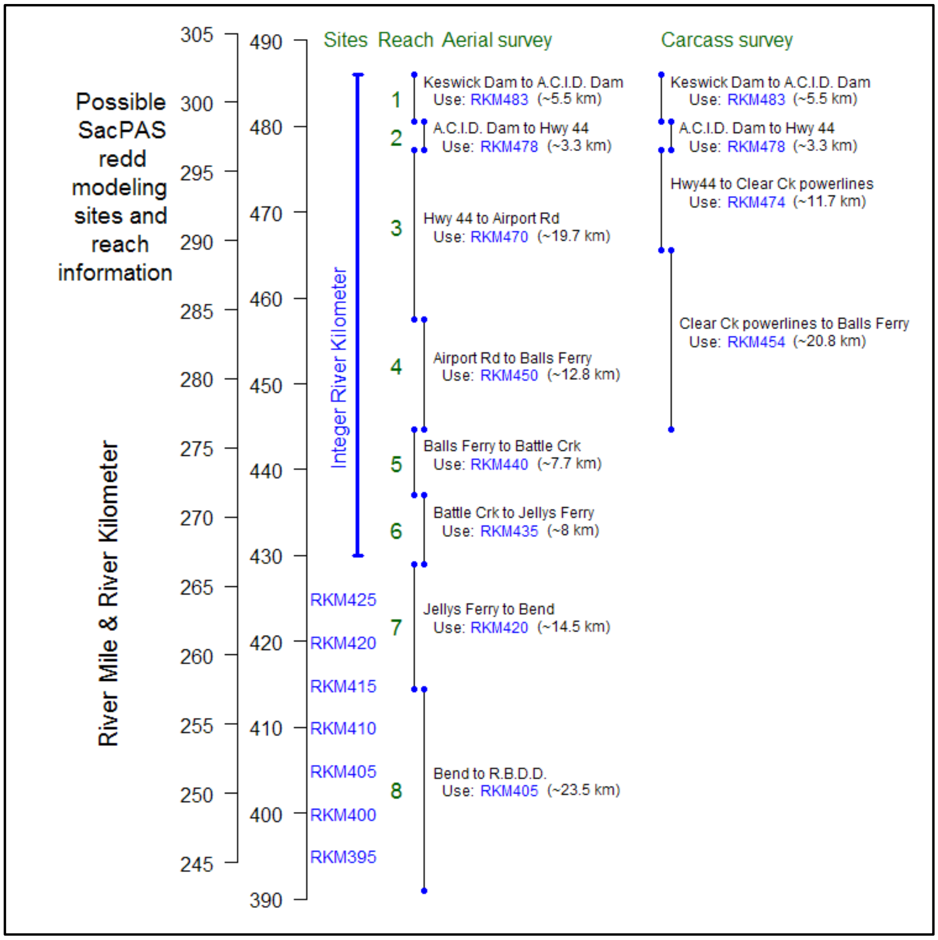

Figure 1. Sites (blue dots) and reaches (lines between blue dots) associated with aerial and carcass surveys for Winter Run Chinook Salmon redds. Diagram is also available at: http://www.cbr.washington.edu/sacramento/fishmodel/spawning.Xref.png

Methods

Estimating redd distributions from carcass data involves five steps. The first two steps are based on CDFW methods for enumerating spatial distribution (Killam, Doug, CDFW pers. communication October 1 2021). The next two steps are proposed methods for obtaining the temporal distribution. The final step associates the redds with a specific location.

Step 1: The number of fresh female spawners (FFS) in each reach are counted on each survey day. At the end of the season the total number of FFS per reach is then known, and one redd is attributed to each FFS.

Step 2: Because carcasses naturally drift downstream, FFS per reach is adjusted to correct for this known downstream bias in carcass locations relative to redd locations. The drift rate of FFS is used to adjust the numbers allocated to each reach (Table 1).

Table 1. Adjustment matrices for correcting FSS observations on a reach-by-reach basis. Percentage values above and parameter names below. The subscripts on the fractions (*f*) denote the source reach first and the recovery reach second.

FFS Drift Rate SUMMARY Percents of all years combined				
	Tagged in			
Recaptured in	Reach 1	Reach 2	Reach 3	Reach 4
Reach 1	86.8%			
Reach 2	11.8%	77.8%		
Reach 3	1.2%	21.3%	96.5%	
Reach 4	0.2%	0.9%	3.5%	100.0%

Notation for calculations				
	Tagged in			
Recaptured in	Reach 1	Reach 2	Reach 3	Reach 4
Reach 1	f_{11}			
Reach 2	f_{12}	f_{22}		
Reach 3	f_{13}	f_{23}	f_{33}	
Reach 4	f_{14}	f_{24}	f_{34}	f_{44}

The Adjusted-FFS (FFSA) for each reach is computed beginning with R1 and moving down through each reach in turn, where "R" represents reach and the numeral denotes which reach, counting downstream from Keswick Dam.

The number of adjusted fresh fish spawner (*A*) of each fish in reach *R* is :

(1.1) $A_R = FFSA_R$ (for the Adjusted FFS in the reach R = 1,2,…,4)

The number of observed fresh fish spawners (X) in reach *R* is:

(1.2) $X_1 = FFS_{R1}$, etc. (for the FFS in the reach R = 1,2,..,4)

Then:

(1.3) $$A_1 = \frac{X_1}{(1 - f_{12} - f_{13} - f_{14})}$$

(1.4) $$A_2 = \frac{(X_2 - A_1 f_{12})}{(1 - f_{23} - f_{24})}$$

(1.5) $$A_3 = \frac{(X_3 - A_2 f_{23} - A_1 f_{13})}{(1 - f_{34})}$$

(1.6) $$A_4 = X_4 - A_3 f_{34} - A_2 f_{24} - A_1 f_{14}$$

All FFSA values must be positive, so A_4 and A_3 may be rounded up to zero in certain years.

Step 3: The FFSA are distributed in time proportional to the fraction of carcasses in the observed temporal distribution. Thus, the fraction of FFSA associated with a survey date is the same as the fraction of FFS for that same date.

For each survey day (*D*) in each reach (*R*),

$$(1.7) \qquad FFSA_{D,R} = \left(\frac{FFSA_R}{FFS_R} \right) FFS_{D,R}$$

In practice, steps 2 and 3 can generate fractional fish. $FFSA_{d,r}$ is computed in steps for each survey date (d) and fractional fish are allocated to day *D* as needed, but then subtracted from the FFSA for the next survey day. When the expansion fraction is <= 0, there is no expansion for the reach and the FFSA = 0 on every day. In practice, there is a small discrepancy between FFSA totals and FFS totals because of ignoring negatives and fractional fish handling. The range of differences is 1 to 10 redds, with a median = 3. No further corrections are made.

Step 4: New redd timing is computed by assuming that 7 days pass between redd completion and detection of the expired female spawner so the number of redds created on day *d* in reach *r* (now considered a *cohort*) is:

$$(1.8) \qquad Redds_{D,R} = FFSA_{D,R} - 7$$

Step 5: For subsequent analysis, the cohorts need to have a specific location along the river in order to identify the associated thermal regime. Each redd within a cohort is handled identically during further processing and analysis. The specific locations (in Rkm) are currently predefined at, or near, the center of each reach (Figure 1). The thermal regime locations in R1 and R2 are the same for aerial and carcass surveys. The carcass survey reaches R3 and R4 are slightly different, with the carcass survey boundary about 8 km upstream of the aerial survey boundary. To accommodate for this, the thermal regime locations for R3 and R4 are stipulated to be 4 km upstream of the aerial survey locations.