De-water Mortality Computation for a Population of Developing Chinook Salmon Eggs

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Fluctuations in flow during incubation of salmon eggs has the potential to de-water, and expose one or more redds. Dewatering is only of concern if in-stream flows during the incubation period are less than the flow at the time of spawning. When this occurs, there is an increased risk of mortality. The magnitude of this effect is related to the differences in flows and the particular hydraulic considerations of the spawning area.

Although flow variability is the principle driver of this risk, there are additional conditions that modulate the effect in the upper Sacramento River. From greatest-to-least influence, these are:

1. Maximum drop in flow between spawning and emergence. Steady and/or rising flows do not create this hazard.
2. Configuration of the Anderson Cottonwood Irrigation District (ACID) dam which can have "boards in" or "boards out" which indicates the positions of gates that affect water-levels upstream.
3. Run of Chinook (Fall, Late-Fall, or Winter) due to inter-specific differences in spawning behavior (e.g. variability in egg-pocket depth).

An empirical relationship for risk (USFWS 2006) is used since there is no closed-form for this calculation. The risk tables provide the risk for a specific combination of spawning flows and the minimum flow experienced before emergence. Note that there are several additional caveats:

1. A cohort is a group of redds built in the same reach, and attributed to the same day.
2. Each redd in a cohort has identical risk.
3. The dewater percentage applied on a cohort-by-cohort basis is a valid method to apply within the entire population.
4. The risk is independent of the total number of redds.
5. The risk of dewatering is identical for the entire incubation period regardless of developmental state of the eggs/alevins.
6. The magnitude of the minimum flow (Q_{MIN}) is necessary and sufficient for computing the risk, regardless of the duration of the Q_{MIN}.
7. Spring Chinook use the Winter Chinook tables.
8. Any out-of-study-region redds, i.e. downstream of Battle Creek, are assumed to have the same risk as their upstream counterparts for calculation of population-level dewatering mortality risk.

Requirements:

1. Timeseries of flows at all locations in the river where there are redds. KWK gage data are used, unless provided.
2. Timeseries of redd creation at each location in the river. Aerial or carcass survey data are used, unless provided.
3. Configuration of the boards (in or out) at the ACID dam.
4. Look-up tables of the probability of dewatering for distinct flows for these species: Fall, Late-Fall, or Winter Chinook (USFWS 2006). The risk table applies to all locations in the spawning area. An example look-up table for Fall Chinook redds with boards-in at ACID dam is illustrated in Figure 1.

Definitions and algorithm:

L,D = a location (L) and a day of year (D)

$C_{L,D}$ = a cohort of redds

$R_{L,D}$ = number of redds in a cohort

$Q_{L,X}$ = Flow at location L on day-of-year X

$S_{L,D}$ = Spawning day-of-year for cohort

$E_{L,D}$ = Emergence day-of-year for cohort

$Qmin_{L,D}$ = Minimum flow experienced by $C_{L,D}$ during incubation

= $\min(Q_S , Q_{S+1} , \ldots Q_E)_{L,D}$

$PDW_{L,D}$ = Percentage of $C_{L,D}$ dewatered

= Value-from-table { $Q_{L,D}$, $Qmin_{L,D}$, species, dam configuration }

$$\text{Dewater Mortality} = \frac{\sum_{L,D} R_{L,D} \times PDW_{L,D}}{\sum_{L,D} R_{L,D}}$$

References:

USFWS. 2006. Relationships between flow fluctuations and redd dewatering and juvenile stranding for Chinook salmon and steelhead in the Sacramento River between Keswick Dam and Battle Creek. https://www.noaa.gov/sites/default/files/legacy/document/2020/Oct/07354626849.pdf

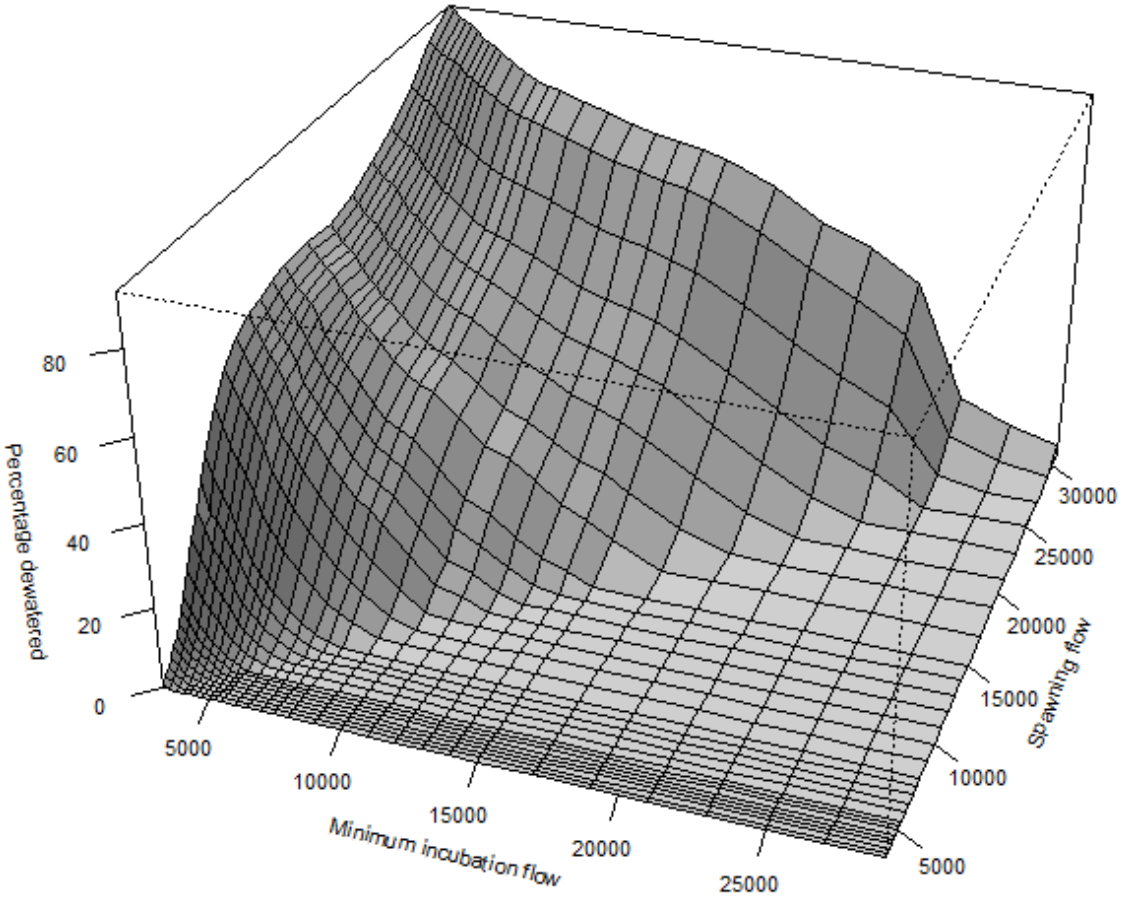

Figure 1 Fall Chinook redd dewater percentage based on spawning flow and minimum flow during incubation with boards-in at Anderson Cottonwood Irrigation District dam (redrawn from USFWS 2006 data).