CAN REDUCING DAM PASSAGE MORTALITY COMPENSATE FOR LOW MARINE SURVIVAL IN WINTER STEELHEAD (*Oncorhynchus mykiss*)?

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Understanding how dam passage efficiency and dam passage survival interact with other sources of mortality at different life stages of anadromous Salmonids, particularly marine survival, is important. Dam passage mortality can be reduced by management choices like releasing water at certain times of year. However, since most density dependent mortality happens before fish smolt and migrate past dams there is little to no increase in marine survival when dam passage mortality is high. Studies show that marine survival rates in Columbia River steelhead (*Oncorhynchus mykiss*) populations have declinedby about an order of magnitude over the last few decades. Thus, a question is can reducing dam passage mortality facilitate conservation goals or is marine survival so low that dam passage mortality cannot be increased enough to matter? To evaluate if dam passage mortality can be reduced enough, we looked at spawner recruit data and marine survival data for winter Steelhead in the Willamette River and tributaries. Then we fitted population dynamics models to the observations and used the models to run simulations and calculate performance metrics to assist in decision making. As a bonus result of the model, we evaluated the contributions of repeat spawners (which can be seen as another type of marine survival).

Methods

The steelhead IPA LCM was formulated specifically for the population components that spawn above the dams in the Upper Willamette River to evaluate the response of above dam populations to alternative dam passage measures. For full details on model structure, inputs, and model fitting procedures, see McAllister et al. (2022). The LCM includes survival through life cycle stages for juveniles above and below the dams, juvenile and sub-adult stages at sea, and adults below and above the dams. A key simplification is that we model only the female population, as data from the Willamette indicate that more females than males are present in the returning adults and >80% of repeat spawners are female (Clemens 2015; Jepson et al. 2015). The above dam survival of female juveniles is modelled using a single freshwater survival parameter, so spawning adults above dams result in Beverton-Holt density-dependent production of smolts that are available to pass the dam. These are assumed to all be age-2 steelhead, supported by data from tagging studies (Monzyk et al. 2017). Age-2 steelhead smolts above dams then attempt dam passage and, after successful passage, migrate downstream to Willamette Falls.

In the ocean, female steelhead smolts survive natural mortality (accounting for autocorrelation between years via a lag-1 autocorrelation function) before maturing into adults that return to freshwater at ages 4-6. The adults returning to dam tailraces are then outplanted above the dams as virgin spawners with fecundity equal to that observed for virgin spawners. A proportion of spawning adults survive a downstream migration as kelts and return as repeat spawners the next year, so the model also includes repeat spawners of age 5-7 with repeat spawners' fecundity.

Values for model parameters were obtained using studies conducted in the Upper Willamette that have been published in the literature, values from the expert workshops which were part of the 2015 COP (Zabel et al. 2015), and our own analyses of the data available. For example, we used published data (Clemens 2015) on the age structure of returning adults and iteroparity rates to calculate kelt-repeat spawner survival rate and construct an age structure for virgin and repeat spawners. We also used data from geographically local steelhead populations in the Columbia River. For example, we derived a marine survival rate time series using data from the Snake River (McCann et al. 2022) and Wind River (Wilson et al. 2021). The IPA LCMs also used as inputs dam passage efficiencies (DPE) and dam passage survival rates (DPS) provided by USACE from the Fish Benefits Workbook software (FBW). Uncertainty in many of these parameters was accounted for using prior probability distributions. The LCM was fitted to available time series of adult counts at Foster. The estimated parameters were freshwater survival and annual deviates in marine survival.

Summary Results

The LCM was able to fit the adult counts at the Foster Dam fairly well with initial abundance and the freshwater survival rate parameter freed up and annual deviates from inputted assumed marine survival rates estimated from past to present (Figure 1). A nonlinear relationship is observed between marine survival, dam passage survival and key performance metrics. This highlights how important considering full life cycle dynamics is when investigating the impacts of reducing mortality at a particular life stage. If survival is high enough the river habitat gets full and the population approaches carrying capacity. Marine survival impacts abundance in a subtle way since a single cohort spawn in multiple years. The fact that spawners can return in different years and can return, rarely, to spawn multiple times effectively averages marine survival over multiple years. Thus a few years of high marine survival followed by a few years of average marine survival can build up abundance, but an abnormally low marine survival year will have less impact. In looking at the isopleth diagrams (Figures 2-7) it should be noted that they show the average of 5000 trajectories of the simulated population dynamics. All of the performance metrics showed considerable sensitivity to uncertainty in marine survival rates and to the product of DPE and DPS. Sensitivity of outcomes to uncertainty in marine survival rates became dominant at intermediate and larger values for the product of DPE and DPS.

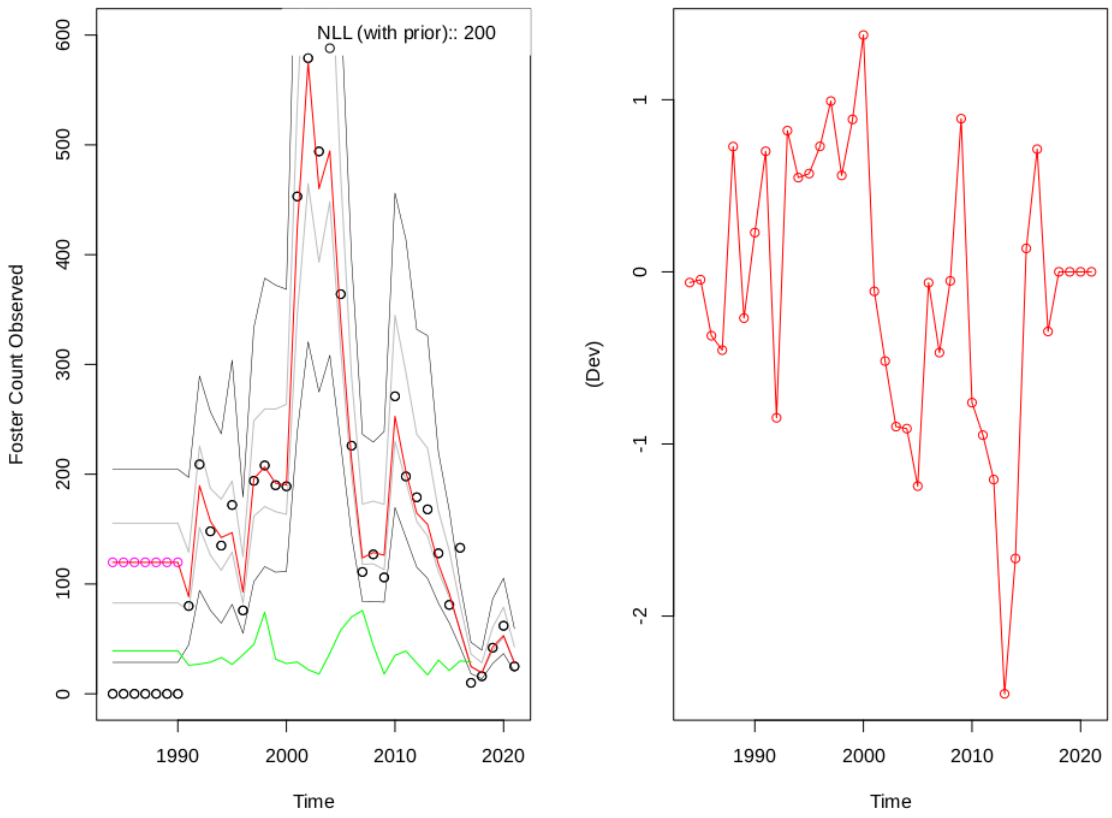

Figure 1. LCM fits to adult counts from the Foster Dam (left panel) and estimates of deviates from inputted marine survival rates of winter steelhead in the Upper Willamette River (right panel).

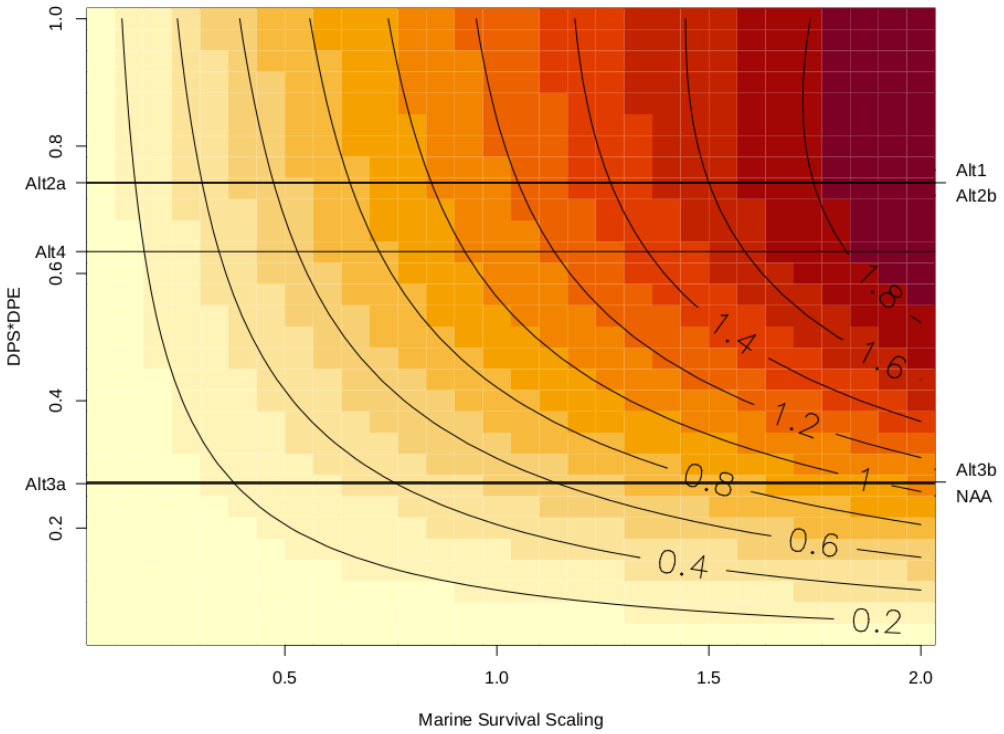

Figure 2. Isopleth of Foster recruits per spawner (R/S) across a range of marine survival and dam passage rates. The horizontal lines show the mean DPE*DPS for the different EIS alternatives.

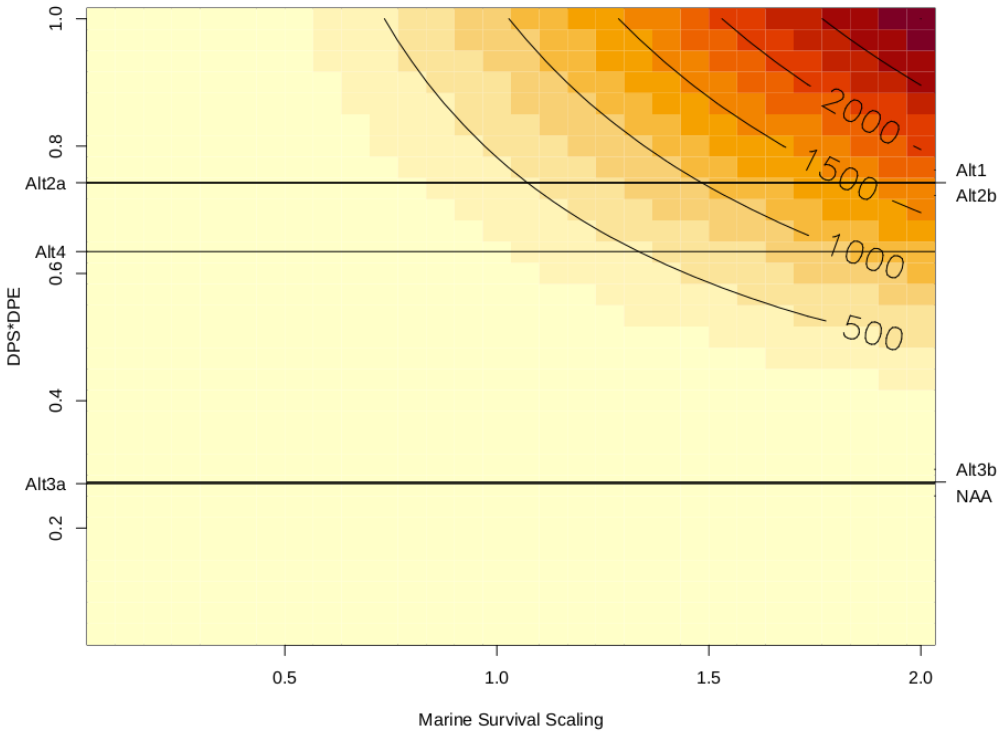

Figure 3. Isopleth of Foster spawner abundance across a range of marine survival and dam passage rates. The horizontal lines show the mean DPE*DPS for the different EIS alternatives.

Green Peter

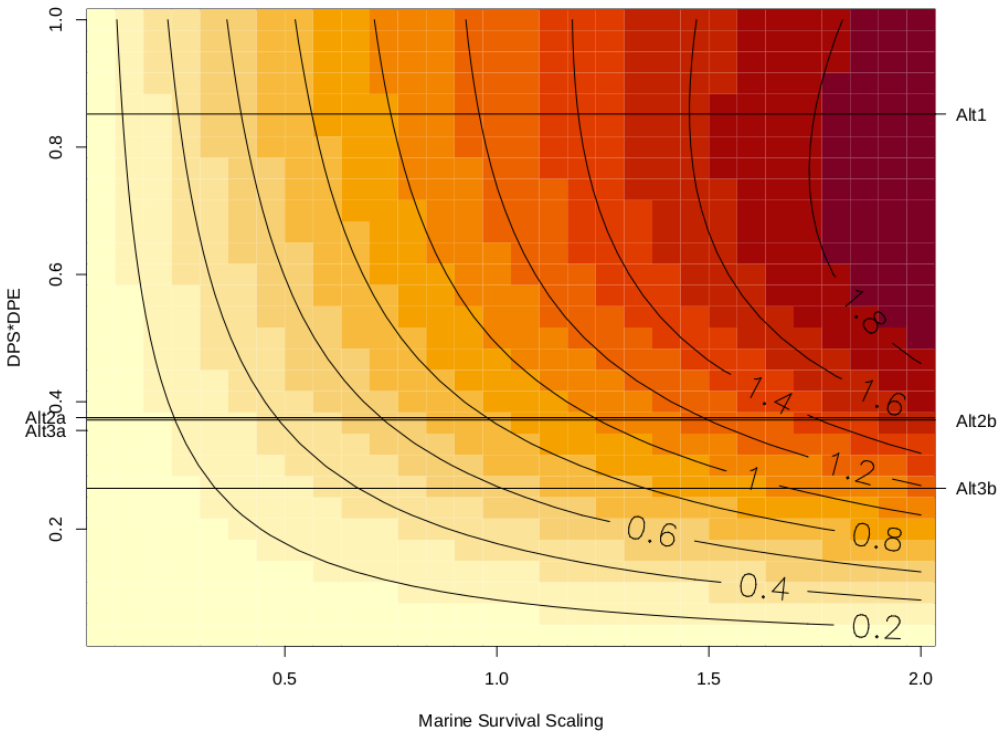

Figure 4. Isopleth of Green Peter recruits per spawner (R/S) across a range of marine survival and dam passage rates. The horizontal lines show the mean DPE*DPS for the different EIS alternatives.

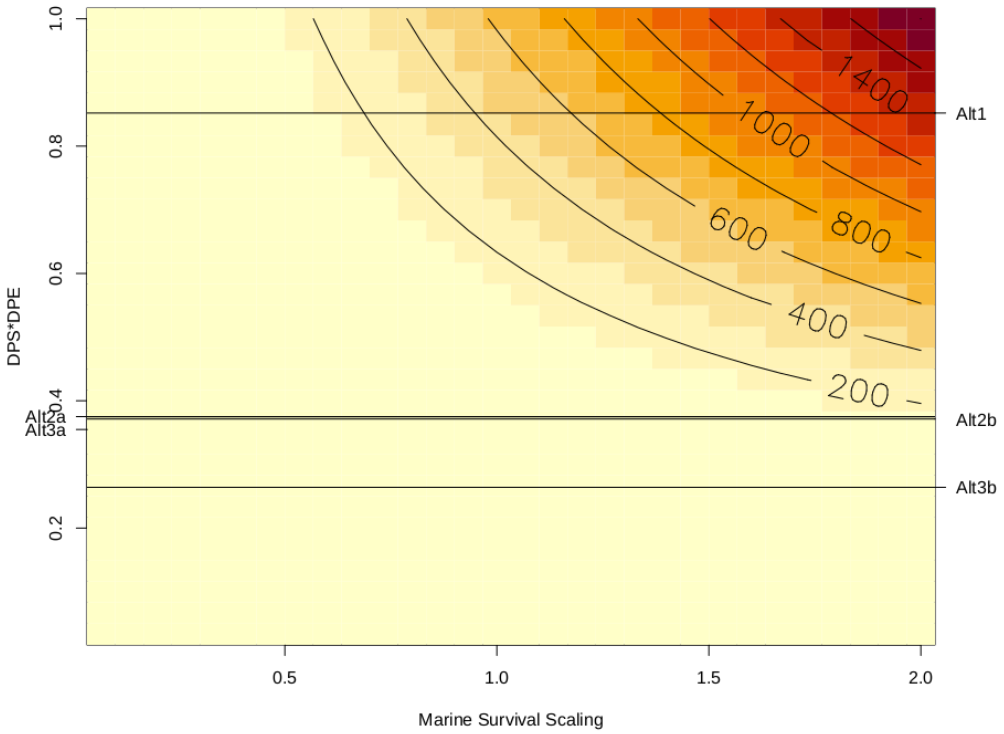

Figure 5. Isopleth of Green Peter spawner abundance across a range of marine survival and dam passage rates. The horizontal lines show the mean DPE*DPS for the different EIS alternatives.

Detroit

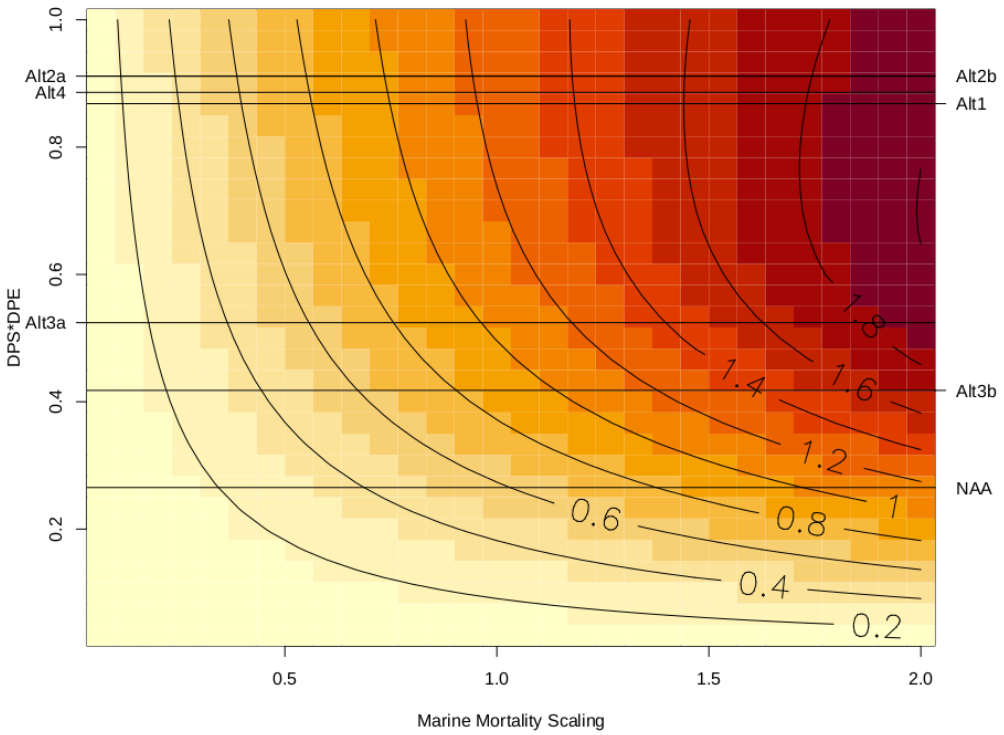

Figure 6. Isopleth of Detroit recruits per spawner (R/S) across a range of marine survival and dam passage rates. The horizontal lines show the mean DPE*DPS for the different EIS alternatives.

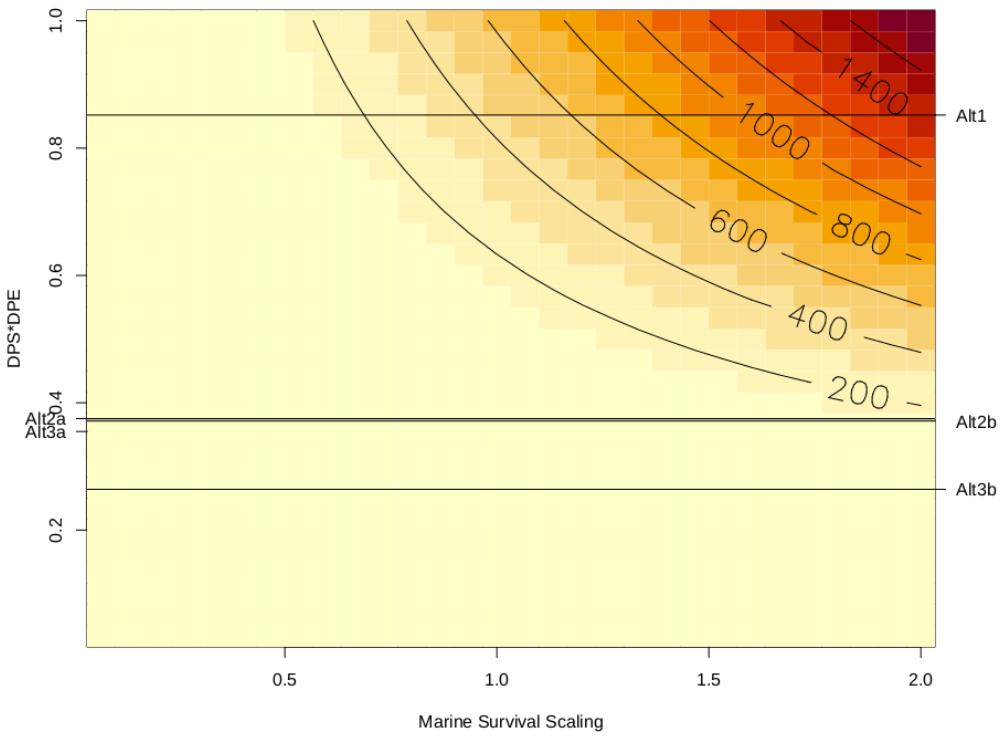

Figure 7. Isopleth of Detroit spawner abundance across a range of marine survival and dam passage rates. The horizontal lines show the mean DPE*DPS for the different EIS alternatives.

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