Considering Dam Passage for Spring Chinook Salmon Populations in the Upper Willamette Within an Adaptive Management Modeling Framework

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A multi-stage life cycle model for Upper Willamette spring Chinook salmon (*Oncorhynchus tshawytscha*) was developed to evaluate the efficacy of alternative dam passage measures at high head dams in the McKenzie, Middle Fork, South Santiam and North Santiam sub-basins (Figure 1). Only the above dam breeding population components were represented in the population dynamics models developed; the population components that may spawn in river reaches below the dams were excluded from the models. In each sub-basin, six juvenile chinook salmon migrant types were represented. These were categorized into fry that either stayed in their natal streams until after their first summer (stayers) or moved from their natal stream before their first summer (movers). Movers became smolts either in their first spring or autumn or in the spring of the following year. Stayers either moved into the reservoir and became smolts in the first autumn, moved into the reservoir in the first autumn and became smolt the following spring or moved into the reservoir and also became smolts the following spring. Cohorts of each juvenile migrant type were tracked separately from each brood year.

Pre-spawn mortality of mature adults was represented both below and above dams. The contribution of hatchery origin adults to above dam spawning was represented where Hatchery and Genetic Management Plan (HGMP) guidelines allowed for this, and tended to be higher in sub-basins where the average abundance of natural origin (NOR) adults has been very low. Values for dam passage efficiency (DPE) and dam passage survival (DPS) rates were obtained from Corps runs of the Fish Benefits Work for particular dam passage options in each of the sub-basins. Estimates of tailrace to Willamette Falls survival rates and smolt to adult survival rates were obtained by fitting Cormack Jolly-Seber models to release and detection records from PIT tag studies in each of the sub-basins. Smolt-adult survival rates were reparameterized to separate average marine fishing and natural mortality rates at age based on stock assessment results from US-Canada Chinook Technical Committee reports. Egg-to-fry survival rates and PSM were modeled as density-dependent processes with parameter values obtained from the literature with the latter dependent also on the seven-day average maximum daily water temperature.

The life cycle models for each sub-basin were calibrated by freeing up natural mortality rate in the first year at sea and the proportion maturing at age. The life cycle models were fitted to time series records for NOR adults that returned to each dam tailrace and historic time series of spawner age compositions above the dams (Figure 2). The fitted models were projected for 30 years based on representations of recent passage and different permutations of historic records for hydrological conditions. Because model predictions for DPE, DPS and PSM depend on the hydrological attributes of a given year, a bootstrap of historic year records was applied to ensure consistency between simulated values for parameters and river flows, and temperatures above and below dams in a given future year. The projections incorporated uncertainties in numerous different parameter

values including reservoir survival rates, marine survival rates, egg-fry survival rates, dam passage survival rates, dam passage efficiency, tailrace to SUJ survival rates, and PSM.

Projections of NOR adult abundance based on hatchery origin out-planting guidelines and recent conditions predicted that above dam natural origin populations on average would continue to decline the South Santiam sub-basin, remain at very low abundance (approximately 100 spawners) in the McKenzie and Middle Fork (about 65 spawners) and remain stable at about 1000 spawners in the North Santiam sub-basin (Figs. 3-6). Considering dam passage options that involve primarily structural modifications the long-term NOR adult abundance was predicted to on average approximately double on the Middle Fork, and increase several-fold in the South Santiam, North Santiam and McKenzie sub-basins (Figs. 3-6). The widely differing trajectories and wide 95% bounds for the projected NOR abundance under the alternative dam passage option considered for each of the sub-basins indicated marked uncertainties in future projected NOR adult abundance. The uncertainties in evaluations of dam passage options are of course even greater given that there remain additional levels of uncertainty that remain to be accounted for, for example, in the DPE and DPS outputs from FBW.

It may therefore be appropriate to consider also an adaptive management approach that treated the implementation of dam passage options and also hatchery migration measures within a deliberately experimental framework. This would require a formal evaluation of which experimental designs for dam passage implementation and hatchery mitigation options could be most effective for informing and achieving long-term conservation objectives. In the experimental options considered, close monitoring of reservoir survival rates, DPE and DPS, NOR return rates would need to take place, and contingency plans and decision rules would be to be specified so that dam passage and hatchery mitigation measures could be deliberately modified depending on the future conclusions drawn from the data that were gathered.

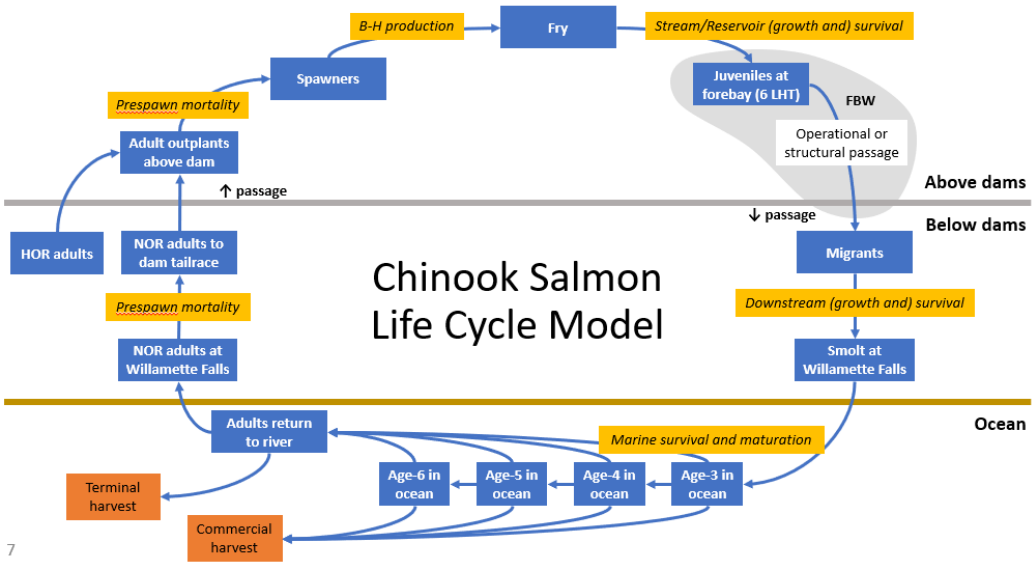

Figure 1. Schematic representation of a life cycle model for above dam populations of spring chinook salmon in the upper Willamette Basin.

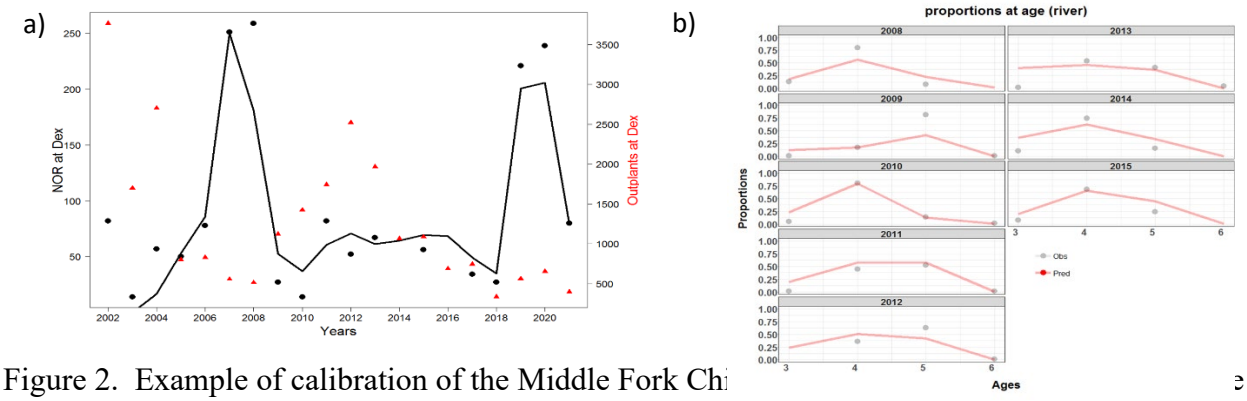

Figure 2. Example of calibration of the Middle Fork Chi e model predictions of (a) natural origin adult abundance (black line) was fitted to the counts of natural origin (NOR) Chinook salmon at the Dexter tailrace (black dots) by inputting the counts of adults outplanted to spawning streams above the Lookout Point Dam and adjusted for PSM (red triangles) and (b) proportion at age spawning (red line) to observed age composition of spawners above the Lookout Point Dam.

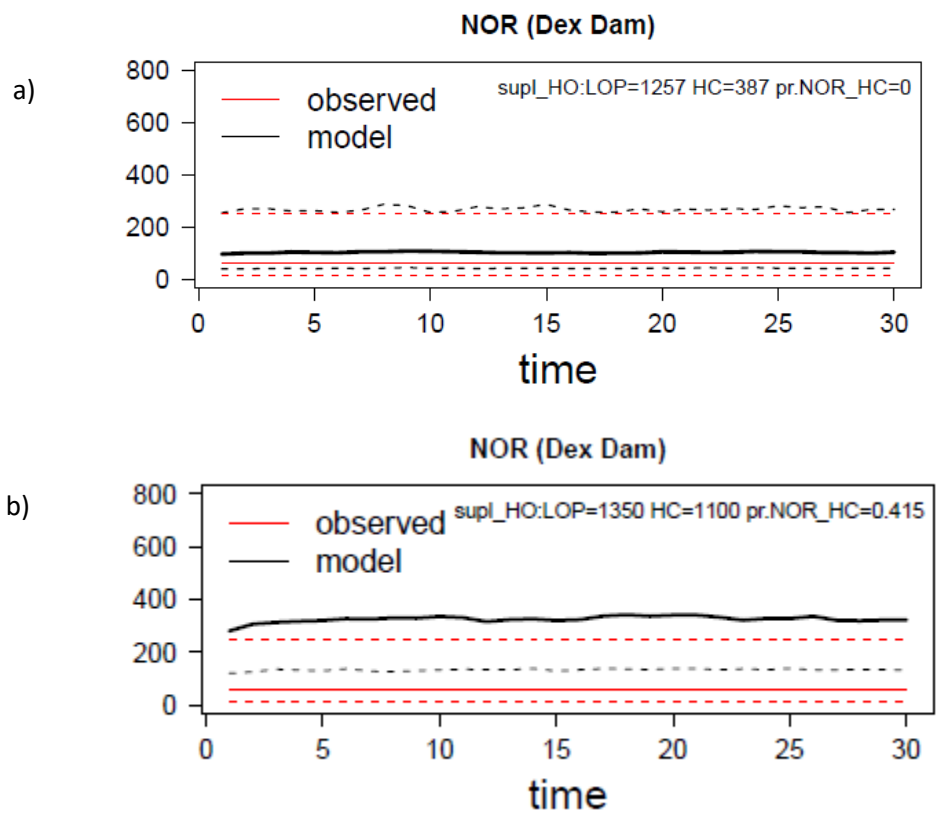

Figure 3. Projected natural origin abundance under a) recent conditions and b) a structural passage option on the Lookout Point and Hills Creek Dams on the Middle Fork River. Black lines show the median, black dotted lines show 95% upper and lower bounds of the projections, and red dashed and solid lines show the 95% bounds and median from the historic counts of NOR.

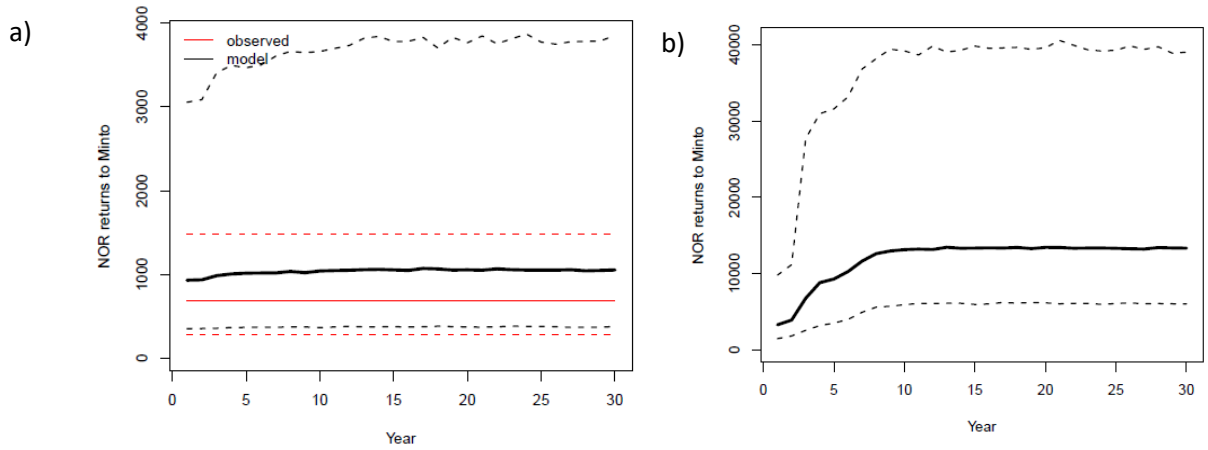

Figure 4. Projected natural origin abundance under a) recent conditions and b) a structural passage option above the Detroit Dam on the North Santiam River. Black lines show the median, black dotted lines show 95% upper and lower bounds of the projections, and red dashed and solid lines show the 95% bounds and median from the historic counts of NOR.

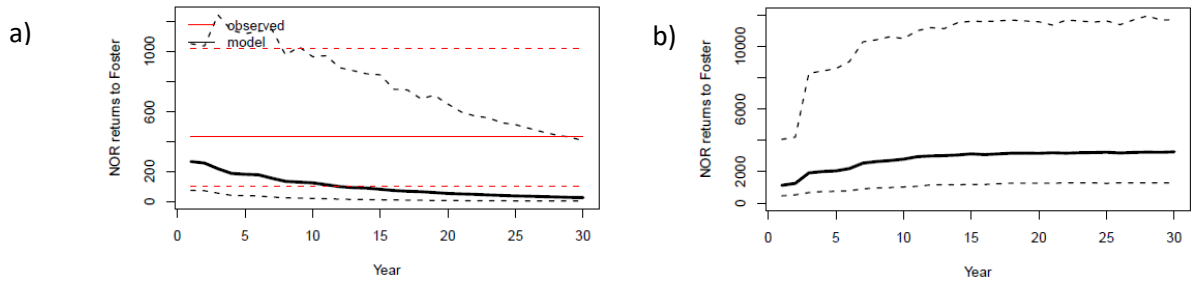

Figure 5. Projected natural origin abundance under a) recent conditions and b) passage structure measures taken on the Foster and Green Peter Dams on the South Santiam River. Black lines show the median, black dotted lines show 95% upper and lower bounds of the projections, and red dashed and solid lines show the 95% bounds and median from the historic counts of NOR.

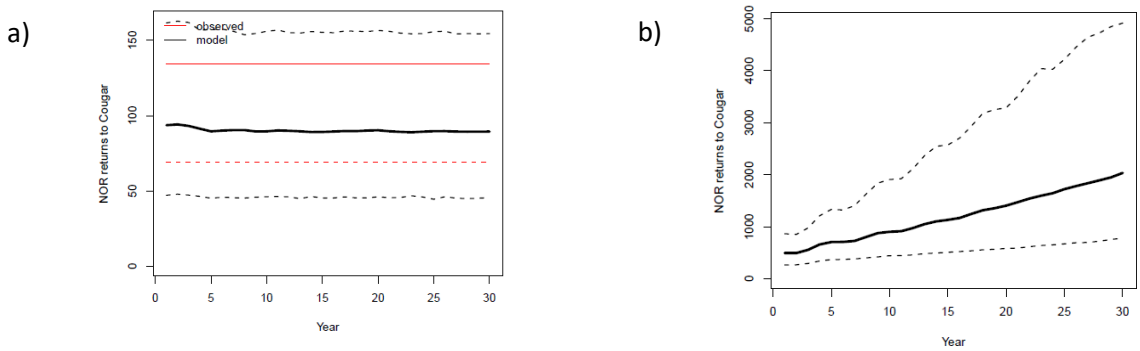

Figure 6. Projected natural origin abundance under a) recent conditions and b) a structural passage option above the Cougar Dam on the McKenzie River. Black lines show the median, black dotted lines show 95% upper and lower bounds of the projections, and red dashed and solid lines show the 95% bounds and median from the historic counts of NOR.