APPROACHES TO MODELLING PRE-SPAWN MORTALITY IN EVALUATION OF DAM PASSAGE OPTIONS FOR SPRING CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*)

Tom Porteus, Roberto Licandeo, Eric Parkinson, Mairin Deith, Murdoch McAllister
University of British Columbia, Vancouver, BC, Canada
taporteus@outlook.com

Life cycle models can be used to evaluate dam passage options on Upper Willamette River spring Chinook salmon (*Oncorhynchus tshawytscha*) by forecasting population trajectories into the future. An important factor in Chinook salmon population viability is pre-spawn mortality (PSM). PSM is comprised of two mortality sources 1) en route mortality, experienced after adults return to the river during the migration upstream to spawning grounds, 2) and onsite mortality, when adults die on the spawning grounds before reproduction. A life cycle model focused on the above dam population of Chinook salmon should include both sources, where en route mortality is considered 'below dam' PSM and onsite mortality is 'above dam' PSM. There are a number of factors that can influence PSM, so the challenge is to utilize previous studies conducted on PSM in the Willamette to appropriately model both below and above dam processes.

Onsite PSM has been studied through carcass surveys by ODFW and Normandeau Associates/EAS in each of the four Upper Willamette sub-basins (North Santiam, South Santiam, McKenzie, Middle Fork). Statistical modelling of these data by Bowerman et al. (2018) determined significant effects of temperature and the percentage of hatchery-origin spawners (pHOS) on onsite mortality. Importantly, the Bowerman model was fitted only to below dam data. We applied the Bowerman model to predict PSM above dams in each future year as a function of temperature, by bootstrapping historical 7-day maximum of average daily temperatures (7dADM); and pHOS, using the ratio of hatchery- to natural-origin adults outplanted above each dam. Under this model, PSM increases where temperature and pHOS are high, but initial predictions were not consistent with the observed data from above dams (as all were above the upper ranges of PSM estimates from the ODFW and Normandeau Associates/EAS carcass surveys). Our examination of the above dam carcass survey data indicated a different relationship with pHOS, such that PSM was reduced where pHOS was high. Confounding these results, sub-basins where temperatures are warmer were also those with outplanting of only natural-origin adults, which prevented further modelling of these data. As a result, we instead reduced the size of the pHOS effect in the Bowerman model such that PSM was mainly driven by temperature effects. This modified model resulted in PSM predictions that were more consistent with the above dam data and so was built into the life cycle model.

En route PSM in the mainstem Willamette has been studied through radio telemetry of adults tagged at Willamette Falls to the below dam spawning grounds in each sub-basin (Keefer et al. 2017). This study found body condition and injuries sustained during upstream migration were better predictors of PSM than temperature. We incorporated this radio-telemetry estimate of en

route mortality into the life cycle model as a single component of below dam PSM and computed a set of performance metrics under each dam passage option from 10,000 simulations. These metrics included the numbers of natural-origin returns (NOR), recruits per spawner (R/S) and probability of quasi-extinction (P<QET).

Under alternative dam passage options, the temperature regime downstream of each dam may vary considerably. As this may have variable effects on en route mortality, we further developed the life cycle model to account for an additional component of below dam PSM. Predictions of below dam temperatures under each alternative were made available to us for different flow year types. These indicated that options with spring drawdown resulted in the highest temperatures, as there would be limited availability of cooler reservoir water to release in the summer to lower river temperature. Use of these temperature data to predict PSM should consider the return timing of the adults to each sub-basin. For example, if most of the adults have returned to the dam tailrace by the end of July, they will have been outplanted above the dam before they experienced the highest temperatures after that date, so PSM based upon temperatures below dams through to September would be overpredicted and so should not be used. We thus used data on daily adult returns across sub-basins and flow year types to determine the maximum date to use in calculating 7dADM temperature. We accounted for this additional component of below dam PSM using the Bowerman model and built this into the life cycle model. We then computed a further set of performance metrics for a sensitivity analysis.

Accounting for PSM between the mainstem and dam tailraces as a function of maximum predicted temperatures resulted in additional below dam mortality of >50% depending on the sub-basin and dam passage option. This obviously led to reduced numbers of predicted NORs and R/S relative to life cycle model predictions that did not explicitly include it. However, the effects on extinction risk varied by sub-basin; in some it increased but in others remained similar. The smolt-adult return rate estimated when the life cycle model was fitted to NOR count data was necessarily increased relative to the model without this additional below dam PSM component to compensate for the additional mortality of adults. While we recommend modelling this additional below dam PSM component to account for the effect of variable temperature, we note that the mortality predictions may be too large due to our use of an onsite PSM model to predict en route PSM. The above dam population is migrating through the below dam reaches, rather than remaining in them for a prolonged period to spawn, and thus may not be as susceptible to factors such as increased temperature as would be predicted by the onsite model coefficients that were conditioned on data from below the dam. Further field studies, e.g., using radio-telemetry to monitor returning adult Chinook salmon above dams until they reach spawning grounds, would be necessary to better inform a model of en route mortality.

References

Bowerman, T., Roumasset, A., Keefer, M.L., Sharpe, C.S., and Caudill, C.C. 2018. Prespawn Mortality of Female Chinook Salmon Increases with Water Temperature and Percent Hatchery Origin. Transactions of the American Fisheries Society **147**(1): 31–42. doi:https://doi.org/10.1002/tafs.10022.

Keefer, M.L., Jepson, M.A., Naughton, G.P., Blubaugh, T.J., Clabough, T.S., and Caudill, C.C. 2017. Condition-Dependent En Route Migration Mortality of Adult Chinook Salmon in the Willamette River Main Stem. North American Journal of Fisheries Management **37**(2): 370–379. doi:10.1080/02755947.2016.1269032.