HOW IMPORTANT IS THE USE OF PRIOR INFORMATION FOR THE ESTIMATION OF FRESHWATER AND SMOLT-ADULT SURVIVAL RATES OF SALMONIDS USING DATA FROM PIT TAG STUDIES?

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Numerous studies in the Upper Willamette River have implanted juvenile salmonids with Passive Integrated Transponder (PIT) tags with aims to estimate dam passage survival or understand migration timing. These data can also be analysed to result in estimates of freshwater and marine survival rates that can be incorporated into life cycle models of ESA-listed spring Chinook salmon (Oncorhynchus tshawytscha) and winter steelhead (Oncorhynchus mykiss). One modelling approach is to use the Cormack-Jolly-Seber (CJS) model, which estimates the survival rate between release and detection locations by adjusting the numbers of PIT tag detections at each location for the probability of detection at each location. Estimates of river-smolt survival rate (φRSS) and smolt-adult survival rate (φSAS) can be obtained using releases of PIT-tagged juvenile fish into dam tailraces in each Willamette sub-basin and detection arrays at Sullivan Dam juvenile bypass facility (SUJ) and at the Willamette Falls adult ladder (WFF). Data from PIT tag studies can be sparse, and when few fish are detected at some locations, it can be challenging to understand whether low numbers of detections are due to low survival or low detection probability. This can result in high levels of uncertainty in CJS model parameter estimates, limiting their value.

Within a Bayesian modelling framework, uncertainty can be reduced by incorporating prior knowledge via prior probability distributions. Priors represent the degree of belief about values that model parameters can take and informative priors may be derived from expert knowledge, published data, or other analytical methods. Alternatively, where there is little or no information available, vague (uninformative) priors can still be used. To reduce uncertainty in CJS model parameter estimates, we used several data sources to develop informative priors specific to the Willamette for φRSS, φSAS, detection probability at SUJ (pSUJ), and detection probability at WFF (pWFF).

One concern with the use of informative priors is when they are more informative than the data. In these situations, the priors may overwhelm the data such that the posterior estimates reflect the prior and not the data, which may thus mask the true parameter values for the study population. This could lead to incorrect survival rate estimates being applied in life cycle models, affecting the ability to make predictions about their population dynamics. However, the problem of over-informative priors is difficult to diagnose as the conditions that lead to data being less informative than priors are usually unknown. We used simulation-estimation analysis to understand how the posterior estimates of φRSS and φSAS can be sensitive to the use of

informative priors versus vague priors and determine under which settings could the use of informative priors be important when analysing PIT tag data.

We simulated release-detection data and used a Bayesian CJS model with either vague (e.g., beta(1,1)) or informative priors to investigate the effects of both sample size of released fish and underlying true values of each model parameter. We applied two sample sizes (1,000 and 10,000 fish) based upon studies that either used beach seines to capture natural-origin juveniles, where <1,000 tagged fish were typical, or studies that released large numbers of hatchery-origin juveniles, where >10,000 tagged fish were typical. We determined a base case set of true parameter values (φRSS=0.4, φSAS=0.01, pSUJ=0.15, pWFF=0.98) and varied one parameter at a time to generate a set of 1,000 simulated datasets for each sample size and true value, across a potential range of values for each parameter.

When release size was only 1,000 fish, the model with vague priors resulted in biased estimates of all parameters (Figure 1). The model with informative priors performed better where estimated posterior mean values were close to the true value, except where the true values of the estimated parameters were in the upper tails of the prior distributions, e.g., for true φSAS values ≥ 0.05. The variation among posterior mean estimates was also reduced compared to that with vague priors. The informative prior on φSAS resulted in considerably less biased estimates for true values within the range of recent Chinook salmon φSAS estimates from both the Willamette (maximum since 2011 = 0.012, Welch et al. (2021)) and Snake River (maximum since 2011 = 0.029, McCann et al. (2022)). The informative prior on φRSS resulted in less bias for all true values except 0.2, although similar to the vague prior model, estimates for values >0.7 were poorly estimated. The informative prior on pSUJ resulted in estimates that were close to the true values across the range examined. The larger release size of 10,000 fish resulted in reduced bias in estimates from both vague and informative prior models (Figure 2). These findings have implications for researchers looking to use PIT tag data for estimation of survival rates where release sizes are relatively low, which is perhaps typical for those of natural-origin fish. In these situations, use of informative priors can help considerably to improve the reliability of survival rate estimates.

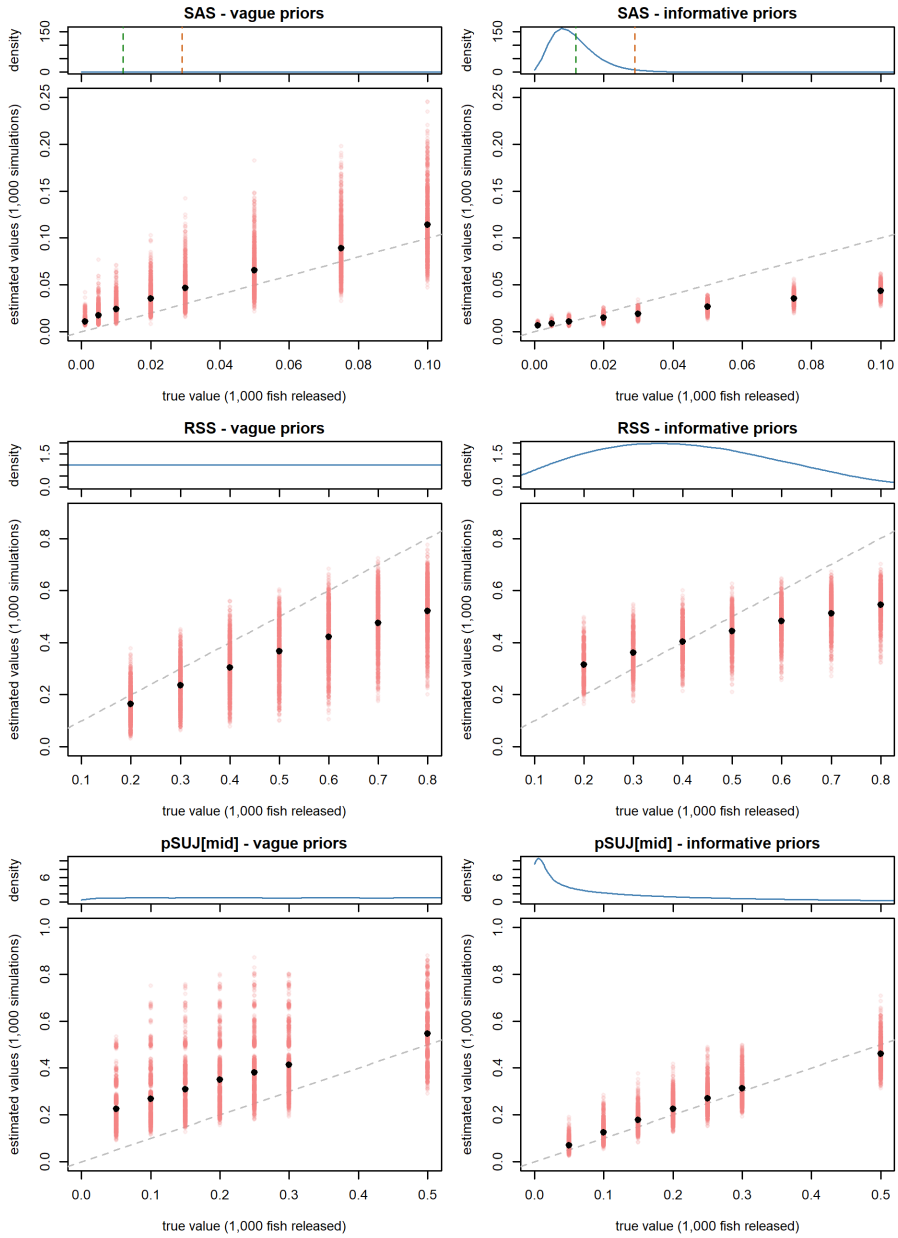

Figure 1 (overleaf). Estimated posterior mean values from 1,000 simulations plotted against a range of 'true' values used to generate each PIT tag dataset given a release size of 1,000 fish. Black circles show the mean values across simulations. Dashed grey lines show 1:1. Left panels show results from a model where vague priors, i.e., Beta(1,1), were used for all parameters. Right panels show results from a model where informative priors (see Appendix H of report) were used for all parameters. Top row shows results where the true smolt-adult survival (SAS) values were varied while other parameters remained at base case values, middle row shows results where true release-smolt survival (RSS) values were varied, bottom row shows results where true detection probability at SUJ under mid-flow (20-35 kcfs at Willamette Falls) conditions (pSUJ[mid]) was varied. Maximum observed values for SAS are shown for smolt years since 2011 from Willamette River (green dashed line, estimated from coded-wire tags by Welch et al. (2021)) and Snake River (orange dashed line, estimated by PIT tags by McCann et al. (2022)).

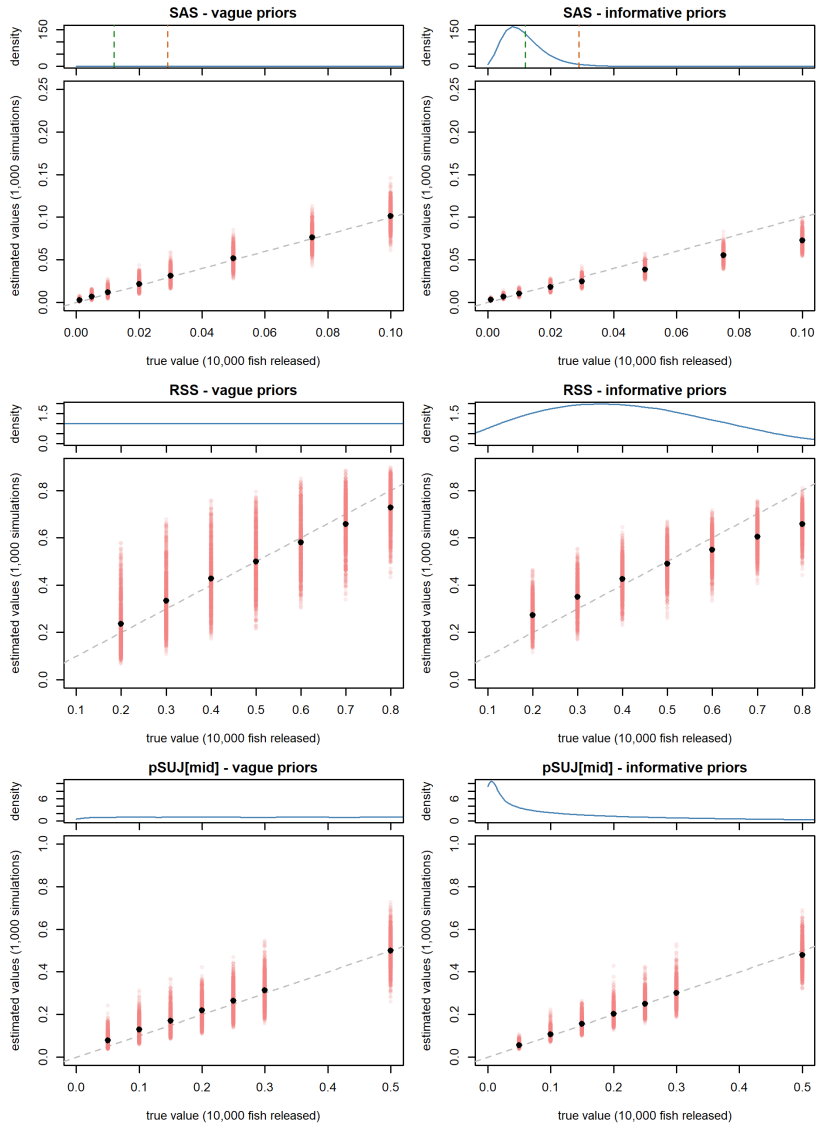

Figure 2 (overleaf). Estimated posterior mean values from 1,000 simulations plotted against a range of 'true' values used to generate each PIT tag dataset given a release size of 10,000 fish. Black circles show the mean values across simulations. Dashed grey lines show 1:1. Left panels show results from a model where vague priors, i.e., Beta(1,1), were used for all parameters. Right panels show results from a model where informative priors (see Appendix H of report) were used for all parameters. Top row shows results where the true smolt-adult survival (SAS) values were varied while other parameters remained at base case values, middle row shows results where true release-smolt survival (RSS) values were varied, bottom row shows results where true detection probability at SUJ under mid-flow (20-35 kcfs at Willamette Falls) conditions (pSUJ[mid]) was varied. Maximum observed values for SAS are shown for smolt years since 2011 from Willamette River (green dashed line, estimated from coded-wire tag data by Welch et al. (2021)) and Snake River (orange dashed line, estimated from PIT tag data by McCann et al. (2022)).

References

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