An integrated population model for estimating the relative effects of natural and anthropogenic factors on a threatened population of steelhead

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Assessing the degree to which at-risk species are regulated by density dependent versus density independent factors is often complicated by incomplete or biased information. If not addressed in an appropriate manner, errors in the data can affect estimates of population demographics, which may obfuscate the anticipated response of the population to a specific action. We developed a Bayesian integrated population model that accounts explicitly for interannual variability in the number of reproducing adults and their age structure, harvest, and environmental conditions. We apply the model to 41 years of data for a population of threatened steelhead in the Skagit River basin using freshwater flows, ocean indices, and releases of hatchery-born conspecifics as covariates. We found compelling evidence that the population is under strong density dependence, despite being well below its historical population size. In the freshwater portion of the lifecycle, we found a negative relationship between productivity (offspring per parent) and peak winter flows, and a positive relationship with summer flows. We also found a negative relationship between productivity and releases of hatchery conspecifics. In the marine portion of the lifecycle, we found a positive correlation between productivity and the North Pacific Gyre Oscillation. Furthermore, harvest rates on wild fish have been sufficiently low to ensure very little risk of overfishing. The evidence for density dependent population regulation, combined with the substantial loss of juvenile rearing habitat in this river basin, suggests that habitat restoration could benefit this population of at-risk steelhead. Our results also imply that hatchery programs for steelhead need to be considered carefully with respect to habitat availability and recovery goals for wild steelhead. If releases of hatchery steelhead have indeed limited the production potential of wild steelhead, there are likely significant tradeoffs between providing harvest opportunities via hatchery steelhead production, and achieving wild steelhead recovery goals.