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Design-Unbiased Trapezoid Area-Under-the-Curve Estimators for Estimating Salmon Escapement

In the latest statistical review of methods for the estimation of salmon escapement (Parsons and Skalski, 2010), area-under-the-curve (AUC) methods were one of the recommended methods. Perhaps the most common AUC method is the trapezoid AUC (TAUC) method, which linearly interpolates periodic counts of live salmon and calculates the area under the interpolated curve to form the numerator of the escapement estimator. TAUC is the most popular approach to AUC estimation because it is straightforward to implement and it is immune to model misspecification due to its non parametric nature.

Despite these advantages, there is not currently any statistically founded recommended practice for the selection of the sampling times. In fact, for sampling times selected deterministically, it has been shown that the TAUC estimator cannot be unbiased for the AUC (unless all the days are sampled.) In practice, the sample size is often very small due to budget constraints and therefore the bias can be consequential.

An important perspective that has yet to be explored is to eliminate this bias by considering probabilistic mechanisms for selecting the sampling days. In this work, we show that a judiciously chosen probabilistic sampling mechanism (systematic sampling, simple random sampling or Bernoulli sampling) combined with a judicious choice of end-adjustments for the TAUC estimator allows unbiased estimation of the AUC. In addition, a variance estimator is proposed. The theoretical results are supported by a simulation study and illustrated on salmon counts collected in the Pacific Northwest.

Overall, this work provides guidance to fisheries managers on how to optimally sample their count data to avoid bias and optimize the accuracy of TAUC estimators for the estimation of salmon escapement. Moreover, it challenges Parsons and Skalski's (2010) conclusion that it is preferable to estimate the AUC by averaging the counts rather than using a TAUC estimator because this conclusion was drawn under the previous understanding that TAUC estimators could not be unbiased.