Division of Statistics
Master's Thesis Defense

BOOTSTRAP ESTIMATES OF SIGHTABILITY CORRECTED AERIAL SURVEY ESTIMATORS

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ABSTRACT

Sightability corrected estimates of wildlife population parameters are commonly used to reduce the visibility bias (non-response) that occurs during aerial surveys. The probability of seeing a group (sighting probability) of animals is estimated, then used to 'correct' observed counts. The population total (τ) estimate produced by a sightability corrected aerial survey is a modified Horvitz-Thompson estimator (T). Three random mechanisms generate the sampling variance of the modified Horvitz-Thompson estimator: survey design, Bernoulli events of non-response, and estimation of a sighting probability model.

Formula estimates of Var(T) exist, but the statistical properties of the variance estimator are unknown. Furthermore, alternatives to these estimation techniques, such as the bootstrap, have not been studied. The objectives of this study were to 1) develop bootstrap estimates of population total and sample variance of the population total estimate; 2) determine if the bootstraps produce population total and standard error estimates with less bias and less root mean squared errors (RMSE) than traditional formula calculations.

Historic data was used to create 2 elk populations; one had a smooth distribution of group sizes, the other also had a smooth distribution, plus a single outlier group of 78 animals. Monte Carlo simulations were used to sample and estimate population total and variance parameters. Estimator performance was evaluated under 3 different sampling assumptions. The first assumed perfect sightability and contained only survey design error. The second assumed imperfect but known sightability and contained non-response and survey design error. The third assumed imperfect and unknown sightability, it contained sightability estimation error, non-response, and survey design error. A semi-parametric bootstrap, a non-parametric bootstrap, and a modified without replacement bootstrap (BWO) were used to estimate Var(T). Naïve and re-scaled semi- and non-parametric bootstraps were used to account for finite sampling. For each sampling assumption, formula estimates of τ contained the least bias and smallest RMSE, regardless of population structure. When groups were seen with perfect sightability, the formula and re-scaled bootstrap produced Var(T) estimates with small bias and similar RMSE. The naïve bootstrap produced biased estimates of Var(T), with large RMSE values.

When groups were seen with imperfect but known sightability, the semi-parametric bootstrap produced the least biased estimates of Var(T), but the modified BWO produced the smallest RMSE. The result held for both populations. The modified BWO also produced intermediate biases for both populations. The formula estimates produced intermediate and constant bias and RMSE, regardless of population structure. The semi- and non-parametric bootstraps produced the largest RMSE.

When groups were seen with imperfect and unknown sightability, formula estimates of Var(T) produced the smallest bias and RMSE while the bootstrap estimators performed poorly. On rare occasions, the modified BWO produced enormous Var(T) estimates that had great influence on the bias and RMSE. When these rare simulations were omitted, the modified BWO produced less bias than the formula for both populations; and less RMSE than the formula for the smooth population. The greater RMSE for the semi- and non-parametric bootstraps may have been due to variable sighting probabilities. When sighting probabilities vary among groups, samples of animal groups do not originate from identically distributed random variables. In the case of the modified BWO, the problem of non-identically distributed random variables may have been circumvented by embedding the sighting probability into the overall inclusion probability.