Efficiently estimating escapement uncertainty from systematic samples

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INTRODUCTION

- Non-replicated systematic sampling is often used to estimate annual escapement of anadromous Pacific salmon – e.g., counting towers or hydroacoustic counts.
- Sound management requires variance estimates of annual escapement that have low-bias and are efficient.
- No *unbiased* variance estimator exists for non-replicated systematic samples[1].
- The best variance estimator for non-replicated systematic samples depends on the underlying process being sampled[2].

OBJECTIVES: Using simulated* tower counts of sockeye salmon (*Onchorynchus nerka*) passage on the Kvichak River, AK, to estimate total escapement, we compare

- 5 variance estimators for non-replicated systematic samples to find the least biased,
- 5 systematic sampling designs to find the most precise.

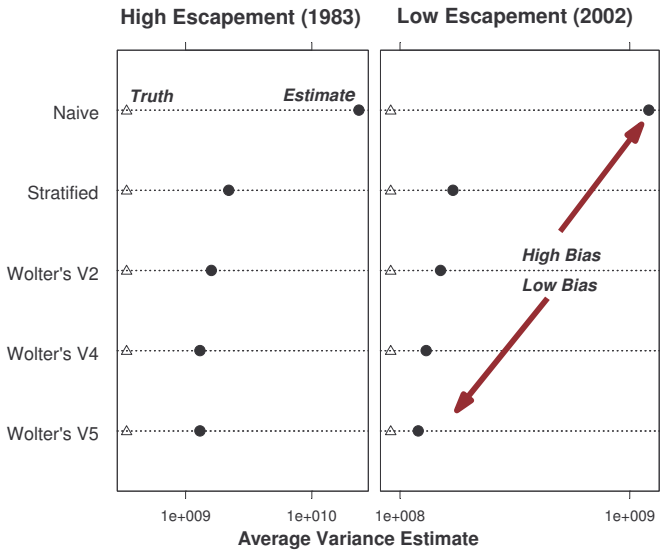
*- sample from census of 10 minute counts constructed from ADF&G tower data at Igiugig, 1983 and 2002.

OBJECTIVE 1: Least biased variance estimator, non-replicated systematic (NRS) samples

Method: simulate NRS sample 10 minutes / 1 Hour; 6 possible samples – for each, calculate the variance estimators in Table 1.

Table 1. Variance estimators for a NRS sample of n observations, $\{y_j\}$, where j indexes observation sequence; *f* is the proportion of the possible observations that were actually collected. Var(Total Escapement)=$\hat{V}(\hat{Y})$ = (Expansion)^2 x $\hat{V}(\bar{y})$, where *Expansion* is a multiplier determined by the NRS sampling effort and number of days sampled.

ESTIMATOR	VARIANCE ESTIMATE	ASSUMPTIONS/FEATURES
Naïve	$\hat{V}(\bar{y}) = \frac{(1-f)}{n}\sum_{j=1}^{n}(y_j-\bar{y})^2/(n-1)$	Simple random sample
V2	$\hat{V}(\bar{y}) = (1-f)(1/n)\sum_{j=2}^{n}a_j^2/2(n-1)$, where $a_j = y_j - y_{j-1}$	NRS sample, removes linear trends in process
V4	$\hat{V}(\bar{y}) = (1-f)(1/n)\sum_{j=3}^{n}b_j^2/6(n-2)$, where $b_j = y_j - 2y_{j-1} + y_{j-2} = (y_j - y_{j-1}) - (y_{j-1} - y_{j-2})$	NRS sample, removes process trends, autocorrelation, stratification effects.
V5	$\hat{V}(\bar{y}) = (1-f)(1/n)\sum_{j=5}^{n}c_j^2/3.5(n-4)$, where $c_j = y_j/2 - y_{j-1} + y_{j-2} - y_{j-3} + y_{j-4}/2$	
Stratified by time[3]	$\hat{V}(\bar{y}) = \sum_{Strata\,i=1}^{k} N_i^2(1-f_i)\frac{s_{Strata\,i}^2}{n_i}$, where $s_{Strata\,i} = \sqrt{\frac{1}{n_i-1}\sum_{j=1}^{n_i}(y_{i,j}-\bar{y}_{Strata\,i})^2}$	Stratified random sample with n_i units sampled from N_i in strata *I*; $f_i=n_i/N_i$.



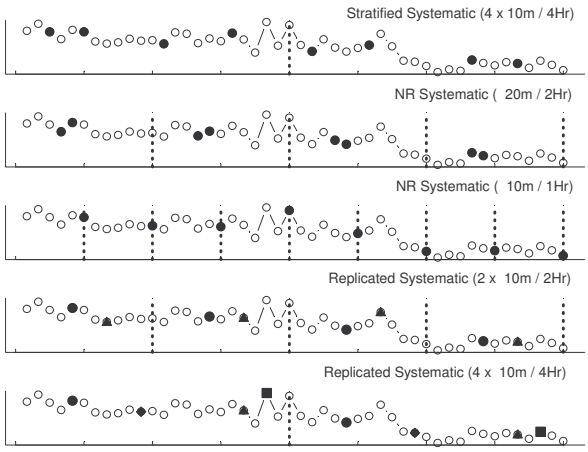
RESULTS

For high and low escapement years, estimators V2, V4, and V5 are least biased, giving variance estimates only 5-7% that from Naïve estimator.

V2 estimate is 23% > V5.

Similar pattern for NRS sampling 20 min / 2 Hr.

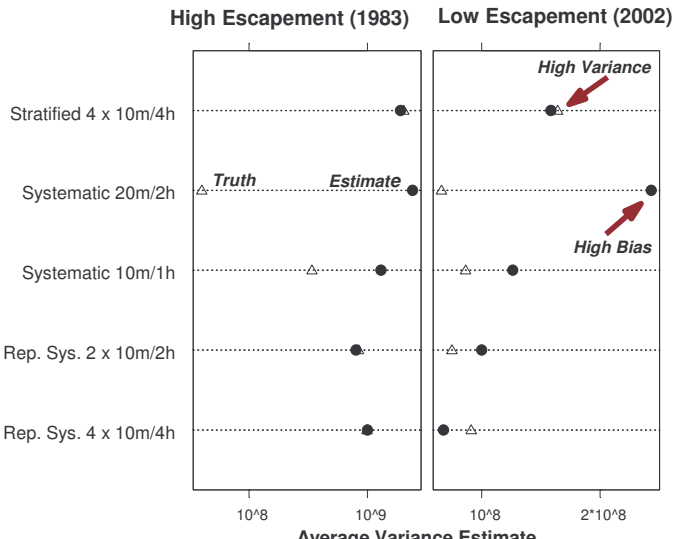
OBJECTIVE 2: Most precise systematic sampling design for estimating Total Annual Escapement. Method: simulate all possible systematic samples, or 250 randomly chosen ones, under each design. For each, calculate the best variance estimator then compare average estimated variance.



Designs (figure Left):
.Stratified Systematic Sample (+Vstratified): randomly select 4 times every four hours.
.Non-Replicated Systematic (+V5)
.Replicated Systematic (+VNaive): randomly select k systematic samples, calculate total escapement estimate from each sample then calculate variance of total escapement estimates.

RESULTS (BELOW):

Replicated Systematic sampling is potentially more precise and provides for an unbiased variance estimator compared to Non-Replicated Systematic sampling



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