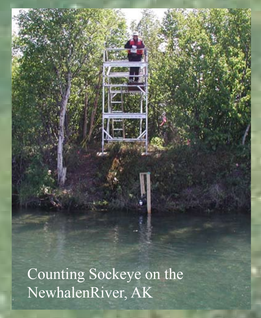
Efficiently Estimating Escapement Uncertainty from Systematic Samples

J. H. Reynolds[1], C. A. Woody[2], Nancy E. Gove[3], and Lowell F. Fair[3]
[1]US Fish and Wildlife Service, 1011 E. Tudor Rd., Anchorage, AK 99503
[2]US Geological Survey, Alaska Science Center, 4230 University Dr. Suite 201, Anchorage, AK 99508.
[3]Alaska Dept. of Fish and Game, Commercial Fisheries Division, 333 Raspberry Rd., Anchorage, AK 99518

INTRODUCTION

- **Annual escapement of anadromous Pacific salmon is often estimated using non-replicated systematic sampling – e.g., counting towers or hydroacoustic counts.**
- **Sound management requires low biased and efficient estimates of uncertainty associated with annual escapement estimates, e.g., a *good* variance estimator.**
- **No unbiased variance estimator exists for non-replicated systematic samples[1].**
- **The best variance estimator depends on features of the process being sampled[2].**



Counting Sockeye on the NewhalenRiver, AK

The Princess of Ping setting up hydroacoustic gear for ADF&G.

OBJECTIVES

Using simulated tower counts of sockeye salmon passage on the Kvichak River, Alaska, we compare

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

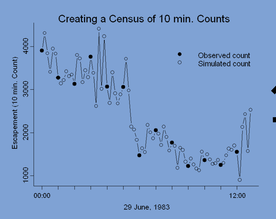
METHODS

Simulate samples from a 'census' of 10 minute Kvichak River tower counts created by stochastically filling in between observations:

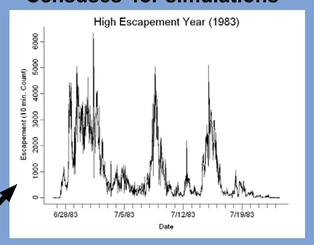
$$\text{Missing}_{\text{time } i+k/6} = \text{Data}_{\text{time } i} + (\text{Data}_{\text{time } i+1} - \text{Data}_{\text{time } i})*k/6 + \varepsilon,$$

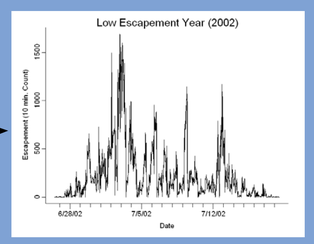
where

$$\varepsilon \sim \text{Uniform}(-|\text{Data}_{\text{time } i+1} - \text{Data}_{\text{time } i}|, |\text{Data}_{\text{time } i+1} - \text{Data}_{\text{time } i}|)$$



'Censuses' for simulations

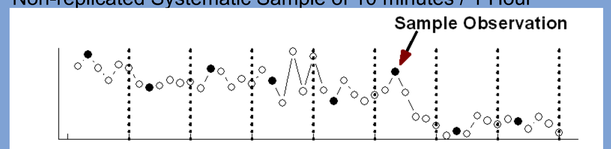




Objective 1: Compare Variance Estimators for Non-Replicated Systematic Samples of fish escapment.

Sampling Design:

Non-replicated Systematic Sample of 10 minutes / 1 Hour

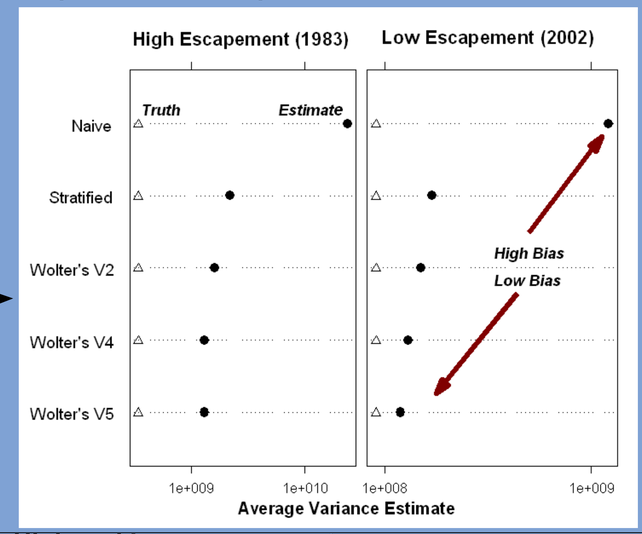


(sample unit = 10 minute count = circle; selected sample = filled)

6 possible samples – for each, calculate the variance estimators in Table 1.

Table 1. Variance estimators for non-replicated systematic samples (formulas on handout).

Estimator (Ref.)	Assumptions / Features
Naive (1)	Treat as Random Sample of Independent observations
V2 (2)	Uses sequential differences to remove linear trends
V4 (2)	Uses higher order differences to remove trends, autocorrelation, or stratification in underlying process
V5 (2)	
Stratified by Time (3)	Treat as Stratified Random Sample

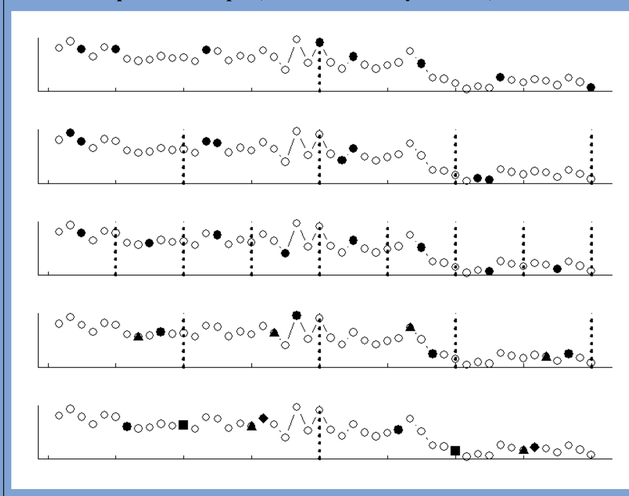


For both High and Low escapement years:
⇒ ***estimators V2, V4, and V5 are least biased and***
⇒ ***give estimates < 10% of the Naive estimator.***
⇒ ***Similar results for Non-replicated Systematic 20 min / 2 Hr***

Objective 2: Compare Systematic Sampling Designs for most Efficiently Estimating Total Annual Escapement

Sampling Designs:

Generate all possible samples, or 250 randomly selected, under each design.



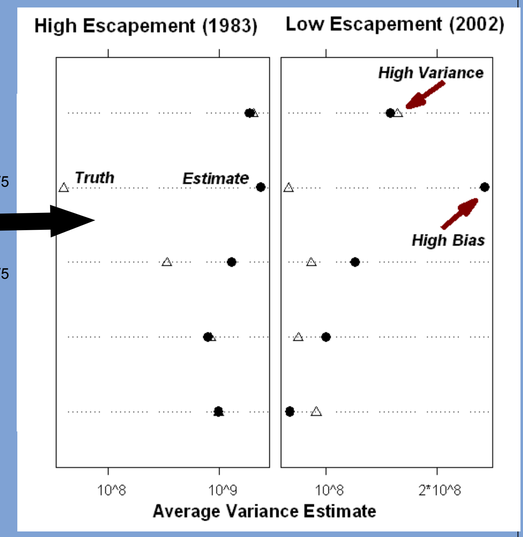
Systematic Stratified + $\text{Var}_{\text{Stratified}}$ (4 x 10 min / 4 Hr)

Non-replicated Systematic + Var_{V5} (20 min / 2 Hr)

Non-replicated Systematic + Var_{V5} (10 min / Hr)

Replicated Systematic + $\text{Var}_{\text{Naive}}$ (2 x 10 min / 2 Hr)

Replicated Systematic + $\text{Var}_{\text{Naive}}$ (4 x 10 min / 4 Hr)



Compared to the usual Non-Replicated Systematic Design,
⇒ ***Replicated Systematic Designs offer potentially smaller,***
⇒ ***less biased variance estimates of Total Annual Escapement.***

REFERENCES
1 - Cochran, W. G. 1977. *Sampling Techinques*. **Wiley & Sons.**
2 - Wolter, K. M. 1985. ***Introduction to Variance Estimation.*** **Springer-Verlag.**
3 - Skalski et al. 1993. ***Can. Jrnl. Fish. and Aq. Science*** **50(6): 1208-1221.**

Support provided by U. S. Fish and Wildlife Service, USGS-BRD, and Alaska Dept. of Fish and Game.
Background photo: Tom Kline