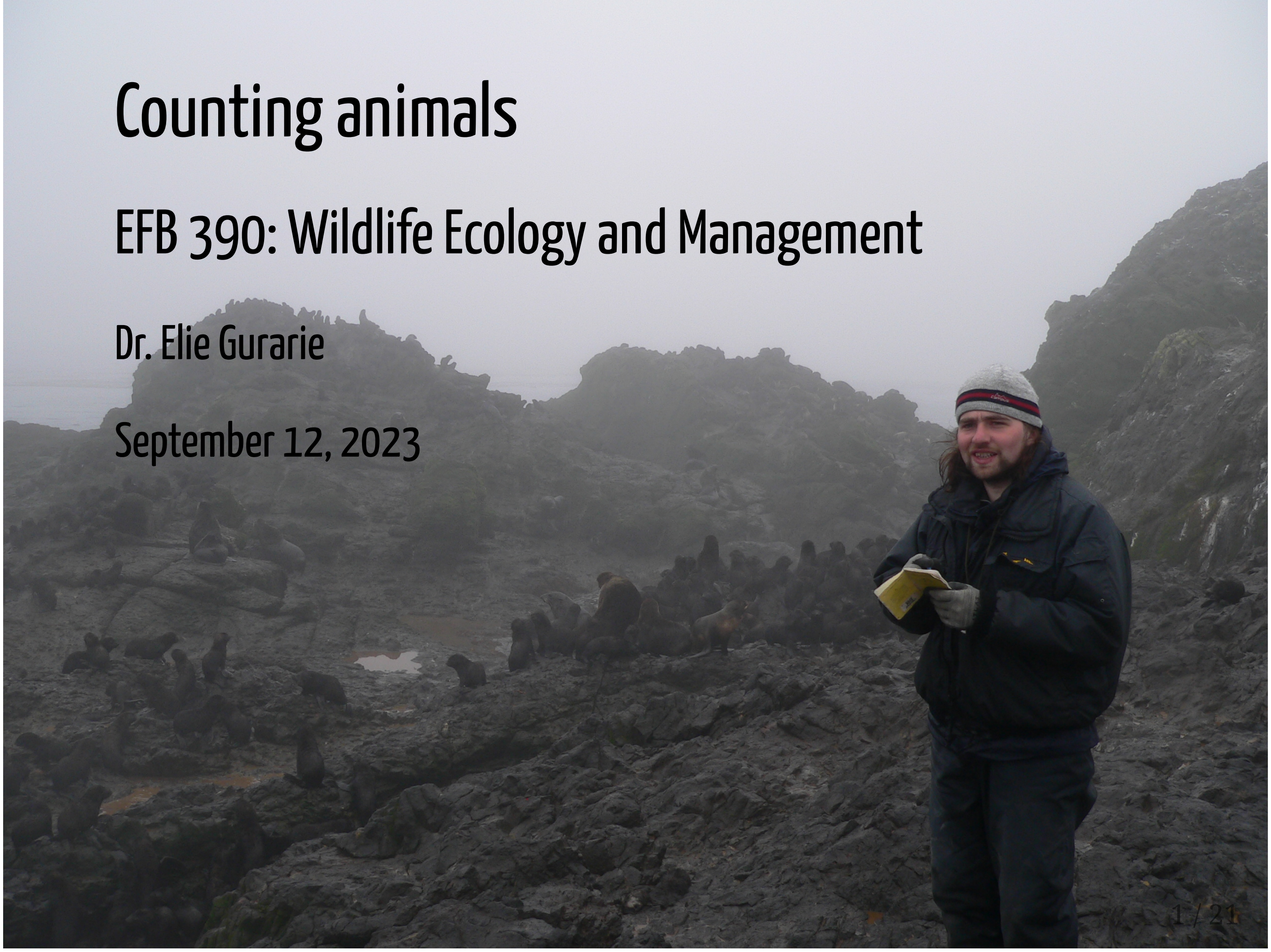


Counting animals

EFB 390: Wildlife Ecology and Management

Dr. Elie Gurarie

September 12, 2023

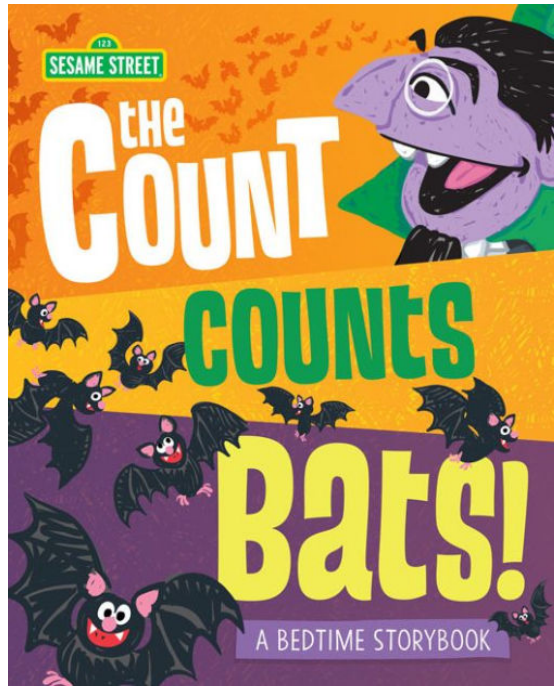
Goals of wildlife management

1. make them increase
2. make them decrease
3. keep them stable
4. do nothing - but keep an eye on them

What do we need to know!?

A count can be simple

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200



… or a count can be pretty darned complex

Variance on the estimator of the variance of a **Pacific cod** count based on on-deck observations of harvest in pots:

respectively. The expectation of Eq. 4.17 is

$$E\left({}_1\widehat{\boldsymbol{\Psi}}_k\right) = E_{s_w}\left\{\frac{M_k}{m_{2k}}\sum_{i=1}^{m_{2k}} E_{s_{L_i}}\left[\frac{N_{ki}}{n_{ki}} E_{s_O}\left(\frac{n_k}{n_{Ok}} E_{s_A}\left(\frac{N_{Om}}{n_{Am}}\psi_{Aki}\right)\right)\right]\right\}$$
$$= E_{s_w}\left\{\frac{M_k}{m_{2k}}\sum_{i=1}^{m_{2k}} E_{s_{L_i}}\left[\frac{N_{ki}}{n_{ki}} E_{s_O}\left(\frac{n_k}{n_{Ok}}\psi_{Oki}\right)\right]\right\}$$
$$= E_{s_w}\left[\frac{M_k}{m_{2k}}\sum_{i=1}^{m_{2k}} E_{s_{L_i}}\left(\frac{N_{ki}}{n_{ki}}\psi_{Lki}\right)\right] = E_{s_w}\left(\frac{M_k}{m_{2k}}\sum_{i=1}^{m_{2k}}\boldsymbol{\Psi}_{ki}\right) = \boldsymbol{\Psi}_k.$$

The variance of the estimator can be written as

$$V\left({}_1\widehat{\boldsymbol{\Psi}}_k\right) = \underbrace{V_{s_w}\left\{E_{s_{L_i}}\left[E_{s_O}\left(E_{s_A}\left({}_1\widehat{\boldsymbol{\Psi}}_k\right)\right)\right]\right\}}_{V_1} + \underbrace{E_{s_w}\left\{V_{s_{L_i}}\left[E_{s_O}\left(E_{s_A}\left({}_1\widehat{\boldsymbol{\Psi}}_k\right)\right)\right]\right\}}_{V_2}$$
$$+ \underbrace{E_{s_w}\left\{E_{s_{L_i}}\left[V_{s_O}\left(E_{s_A}\left({}_1\widehat{\boldsymbol{\Psi}}_k\right)\right)\right]\right\}}_{V_3} + \underbrace{E_{s_w}\left\{E_{s_{L_i}}\left[E_{s_O}\left(V_{s_A}\left({}_1\widehat{\boldsymbol{\Psi}}_k\right)\right)\right]\right\}}_{V_4}.$$

Component-wise,

$$V_1 = V_{s_w}\left(\frac{M_k}{m_{2k}}\sum_{i=1}^{m_{2k}}\boldsymbol{\Psi}_{ki}\right) = M_k\left(\frac{M_k}{m_{2k}} - 1\right)\frac{\sum_{i=1}^{M_k}\left(\boldsymbol{\Psi}_{ki} - \overline{\boldsymbol{\Psi}}_k\right)\left(\boldsymbol{\Psi}_{ki} - \overline{\boldsymbol{\Psi}}_k\right)^T}{M_k - 1},$$

$$V_2 = E_{s_w}\left[\left(\frac{M_k}{m_{2k}}\right)^2\sum_{i=1}^{m_{2k}} V_{s_{L_i}}\left(\frac{N_{ki}}{n_{ki}}\psi_{Lki}\right)\right]$$
$$= \frac{M_k}{m_{2k}}\sum_{i=1}^{M_k} N_{ki}\left(\frac{N_{ki}}{n_{ki}} - 1\right)\frac{N_{ki}\left[\operatorname{diag}\left(\mathbf{P}_{ki}\right) - \mathbf{P}_{ki}\mathbf{P}_{ki}^T\right]}{N_{ki} - 1},$$

$$V_3 = E_{s_w}\left\{\left(\frac{M_k}{m_{2k}}\right)^2 E_{s_{L_i}}\left[V_{s_O}\left(\sum_{i=1}^{m_{2k}}\frac{N_{ki}}{n_{ki}}\frac{n_k}{n_{Ok}}\psi_{Oki}\right)\right]\right\}$$
$$= E_{s_w}\left\{\left(\frac{M_k}{m_{2k}}\right)^2\sum_{i=1}^{m_{2k}} E_{s_{L_i}}\left[\left(\frac{N_{ki}}{n_{ki}}\right)^2 V_{s_O}\left(\frac{n_k}{n_{Ok}}\psi_{Oki}\right)\right]\right\}$$
$$+ E_{s_w}\left\{\left(\frac{M_k}{m_{2k}}\right)^2\sum_{i\neq j}^{m_{2k}}\sum E_{s_{L_i}}\left[\frac{N_{ki}}{n_{ki}}\frac{N_{kj}}{n_{kj}} Cov_{s_O}\left(\frac{n_k}{n_{Ok}}\psi_{Oki}, \frac{n_k}{n_{Ok}}\psi_{Okj}\right)\right]\right\}$$
$$= E_{s_w}\left\{\left(\frac{M_k}{m_{2k}}\right)^2\sum_{i=1}^{m_{2k}} E_{s_{L_i}}\left[\left(\frac{N_{ki}}{n_{ki}}\right)^2 n_k\left(\frac{n_k}{n_{Ok}} - 1\right)\frac{n_k\left[\operatorname{diag}\left(\mathbf{p}_{Lki}\right) - \mathbf{p}_{Lki}\mathbf{p}_{Lki}^T\right]}{n_k - 1}\right]\right\}$$
$$- E_{s_w}\left\{\left(\frac{M_k}{m_{2k}}\right)^2\sum_{i\neq j}^{m_{2k}}\sum E_{s_{L_i}}\left[\frac{N_{ki}}{n_{ki}}\frac{N_{kj}}{n_{kj}} n_k\left(\frac{n_k}{n_{Ok}} - 1\right)\frac{n_k\mathbf{p}_{Lki}\mathbf{p}_{Lkj}^T}{n_k - 1}\right]\right\}$$

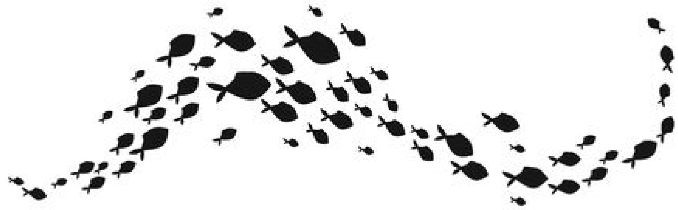
and

$$V_4 = E_{s_w}\left\{\left(\frac{M_k}{m_{2k}}\right)^2 E_{s_{L_i}}\left[E_{s_O}\left(V_{s_A}\left(\sum_{i=1}^{m_{2k}}\frac{N_{ki}}{n_{ki}}\frac{n_k}{n_{Ok}}\frac{N_{Om}}{n_{Am}}\psi_{Aki}\right)\right)\right]\right\}$$
$$= E_{s_w}\left\{\left(\frac{M_k}{m_{2k}}\right)^2 E_{s_{L_i}}\left[\sum_{i=1}^{m_{2k}} E_{s_O}\left[\left(\frac{N_{ki}}{n_{ki}}\frac{n_k}{n_{Ok}}\right)^2 V_{s_A}\left(\frac{N_{Om}}{n_{Am}}\psi_{Aki}\right)\right]\right.\right.$$
$$\left.\left. + \sum_{i\neq j}^{m_{2k}}\sum E_{s_O}\left[\frac{N_{ki}}{n_{ki}}\frac{N_{kj}}{n_{kj}}\left(\frac{n_k}{n_{Ok}}\right)^2 Cov_{s_A}\left(\frac{N_{Om}}{n_{Am}}\psi_{Aki}, \frac{N_{Om}}{n_{Am}}\psi_{Akj}\right)\right]\right]\right\}$$
$$= E_{s_w}\left\{\left(\frac{M_k}{m_{2k}}\right)^2\sum_{i=1}^{m_{2k}} E_{s_{L_i}}\left[\left(\frac{N_{ki}}{n_{ki}}\frac{n_k}{n_{Ok}}\right)^2 N_{Om}^2\left(\frac{N_{Om}}{n_{Am}} - 1\right)\frac{\left[\operatorname{diag}\left(\mathbf{p}_{Oki}\right) - \mathbf{p}_{Oki}\mathbf{p}_{Oki}^T\right]}{N_{Om} - 1}\right]\right\}$$
$$- E_{s_w}\left\{\left(\frac{M_k}{m_{2k}}\right)^2\sum_{i\neq j}^{m_{2k}}\sum E_{s_{L_i}}\left[\frac{N_{ki}}{n_{ki}}\frac{N_{kj}}{n_{kj}}\left(\frac{n_k}{n_{Ok}}\right)^2 N_{Om}^2\left(\frac{N_{Om}}{n_{Am}} - 1\right)\frac{\mathbf{p}_{Oki}\mathbf{p}_{Okj}^T}{N_{Om} - 1}\right]\right\}$$

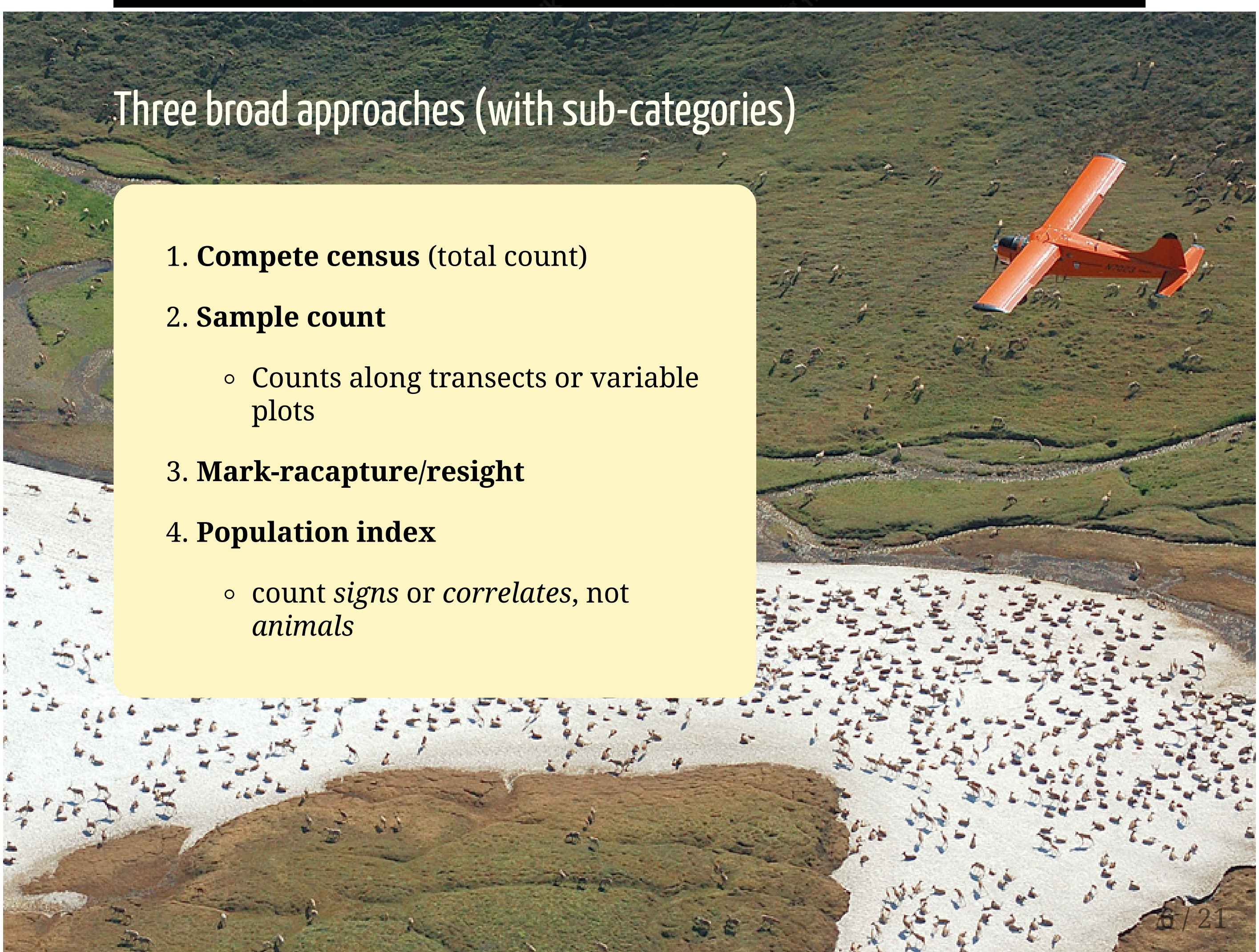
where $\mathbf{P}_{ki} = \boldsymbol{\Psi}_{ki}/N_{ki}$, $\mathbf{p}_{Lki} = \psi_{Lki}/n_k$ and $\mathbf{p}_{Oki} = \psi_{Oki}/N_{Om}$.

Miller 2005 (Ph.D. dissertation)

An observation



Counting **fish** is just like counting **trees**, except they're *invisible* and they *move* ...

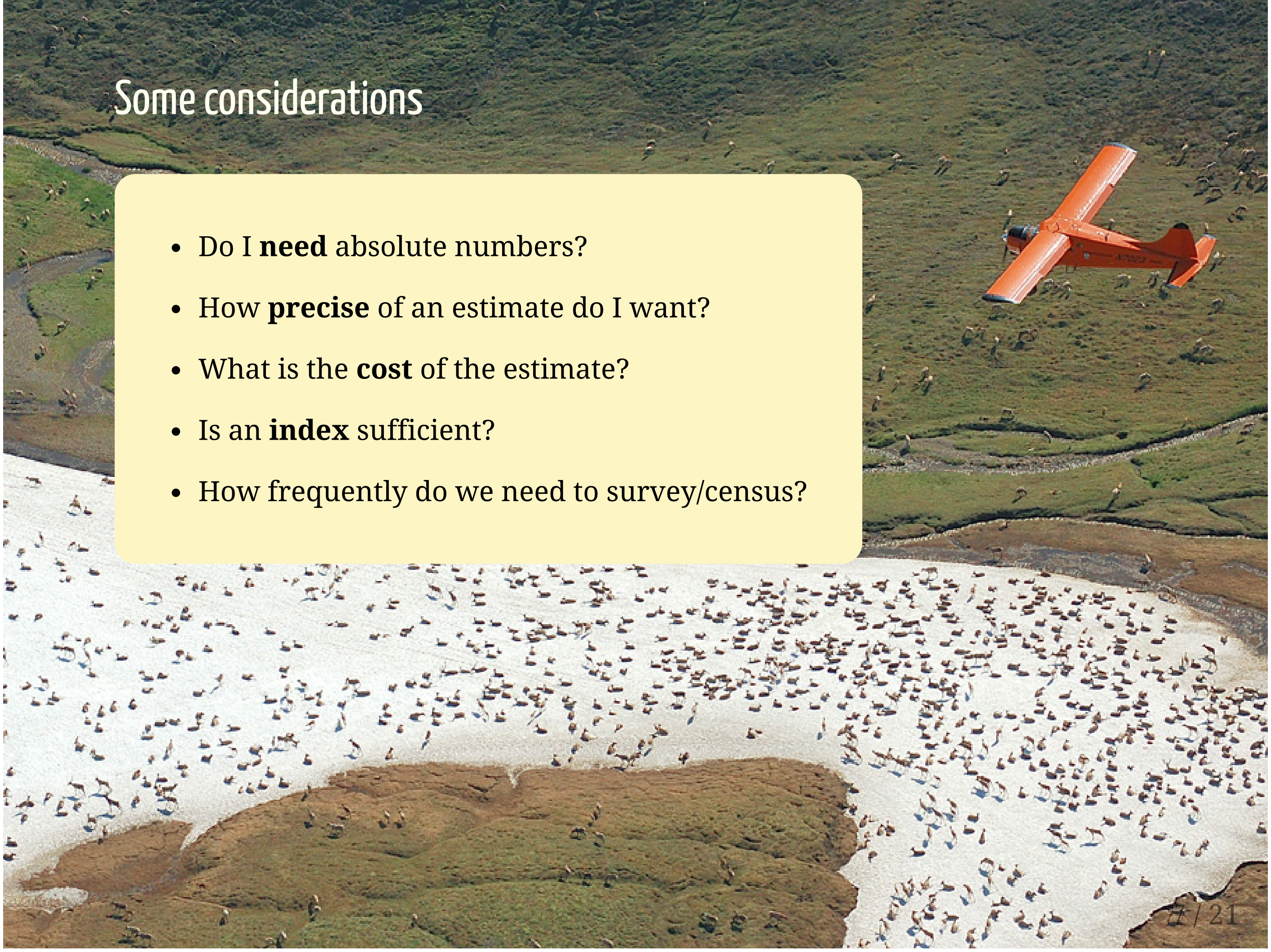


Three broad approaches (with sub-categories)

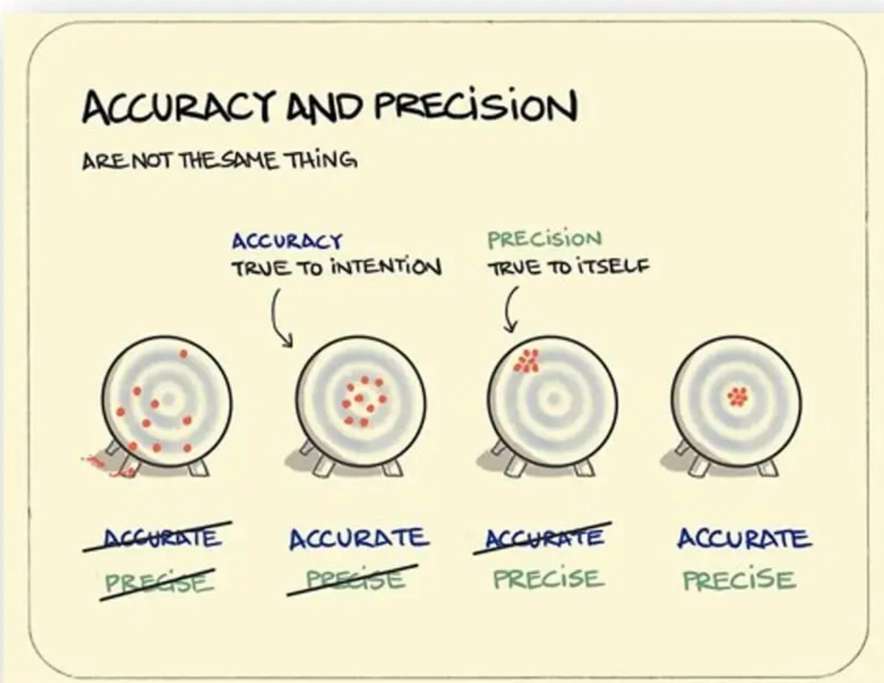
1. **Compete census** (total count)
2. **Sample count**
    - Counts along transects or variable plots
3. **Mark-racapture/resight**
4. **Population index**
    - count *signs* or *correlates*, not *animals*

Some considerations

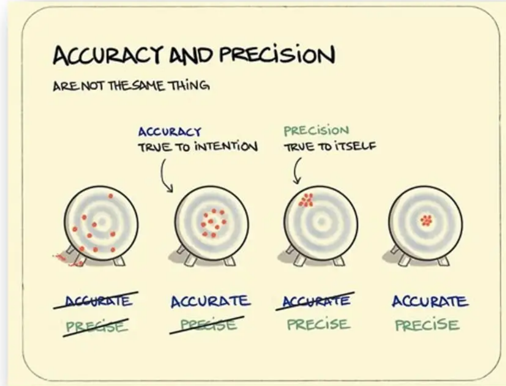
- Do I **need** absolute numbers?
- How **precise** of an estimate do I want?
- What is the **cost** of the estimate?
- Is an **index** sufficient?
- How frequently do we need to survey/census?



Two important considerations:



Accuracy



Is the estimate **biased**?

- On average, on target

Determined by **design**.

- how well you throw the dart?

Can be difficult to assess.

- beacuse there isn't usually a dartboard!

Precision

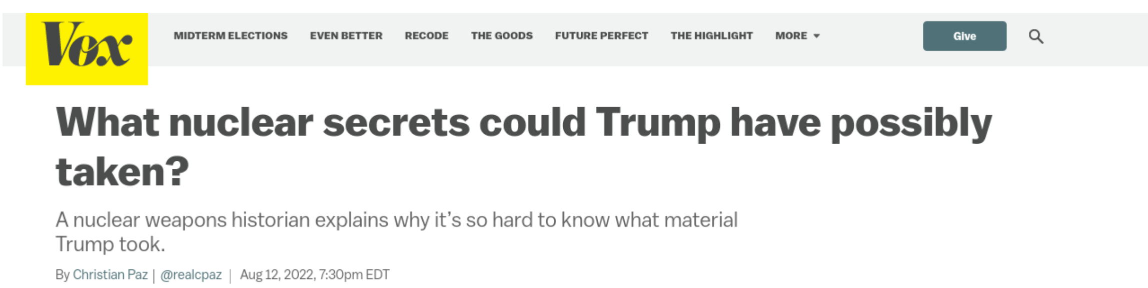
What is the *error* or *variance* or *spread* on the resulting estimate?

Quantified with **Confidence Intervals (C.I.)** (or coefficients of variation (C.V.))

Determined by **effort** and computed with (sometimes very fancy) **statistics**.

Generally: bigger the **sample** = smaller **error** = higher **precision**.

Very accurate, but very imprecise:


Vox | MIDTERM ELECTIONS | EVEN BETTER | RECODE | THE GOODS | FUTURE PERFECT | THE HIGHLIGHT | MORE | Give

What nuclear secrets could Trump have possibly taken?

A nuclear weapons historian explains why it's so hard to know what material Trump took.

By Christian Paz | @realcpaz | Aug 12, 2022, 7:30pm EDT

> *"It could be anything ranging from **something that would endanger the lives of hundreds of millions** of people to something that **has no impact on anything whatsoever**. That's how vague the classified categorization is," Alex Wellerstein, a historian of science and nuclear weapons, told me.*

General Goal of Abudance Estimation

Increase both **accuracy** and **precision** as contraints on **effort** (& costs).

Generally, there a higher premium on **accuracy**

- (i.e. better an unbiased but imprecise estimate, than a highly precise but biased estimate).

When might BIAS not be so important?

If the bias is consistent, repeated measures can tell you how things are *changing*

Method I: Total Count, aka. **Census**

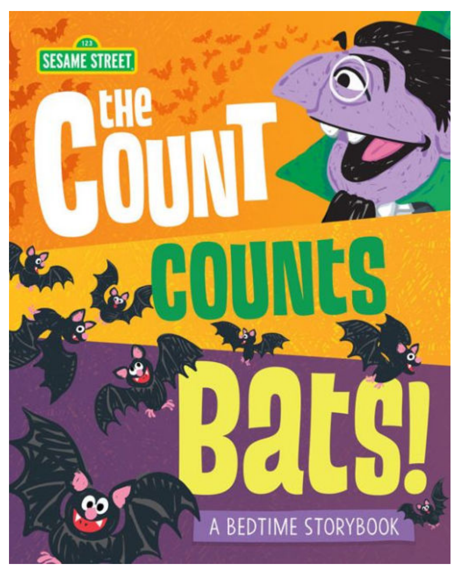
Pros

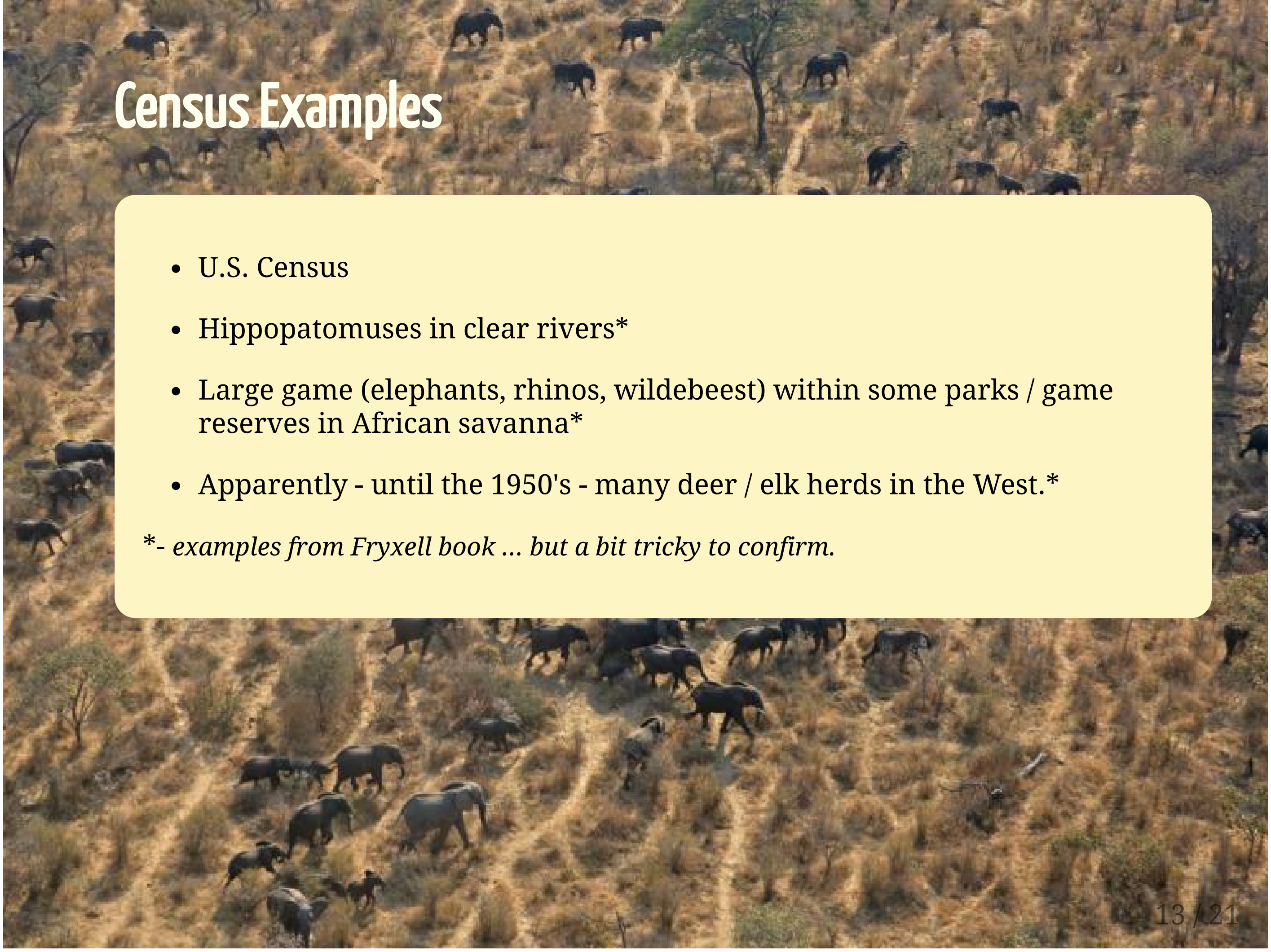
- Simple to explain!
- Simple math (*arithmetic*)!
- Very precise

Cons

- Usually - VERY difficult / expensive to perform
- Only possible for certain kinds of animals
- Almost always biased!

What kinds of animals can we census?



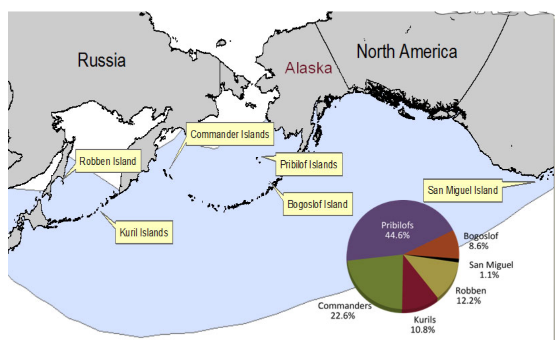


Census Examples

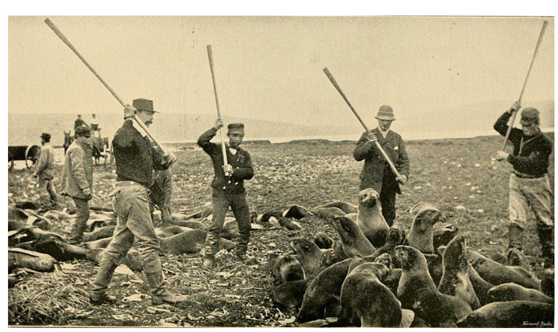
- U.S. Census
- Hippopatomuses in clear rivers*
- Large game (elephants, rhinos, wildebeest) within some parks / game reserves in African savanna*
- Apparently - until the 1950's - many deer / elk herds in the West.*

*- *examples from Fryxell book ... but a bit tricky to confirm.*

Northern Fur Seals *Callorhinus ursinus*



- Once extemely abundant
- VERY heavily harvested
- Paid off 1867 purchase Alaska in 30 years
- Reproduce (essentially) in only 6 **rookeries** worldwide
- At heart of the first international wildlife management treaty.



Count 'em!

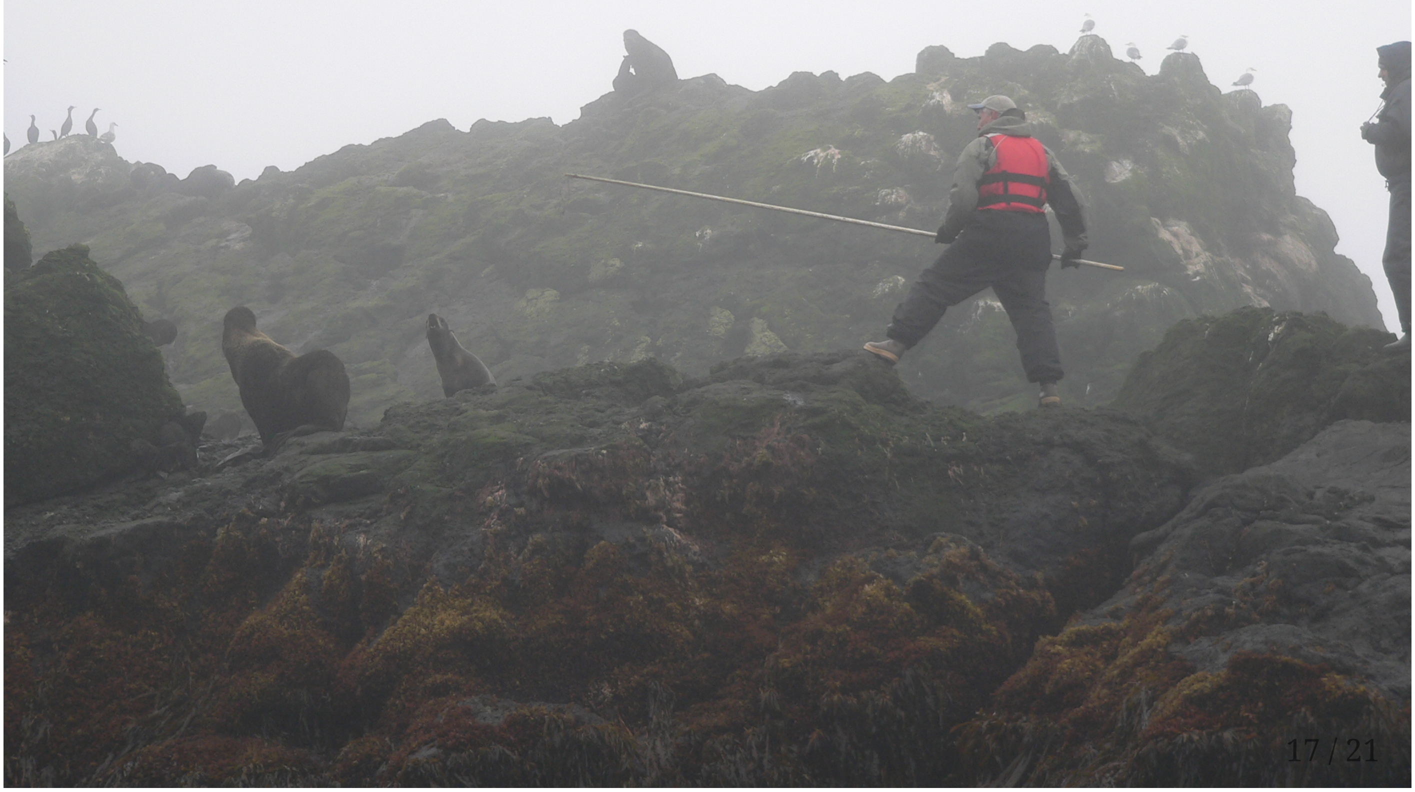
Tyuleni Island

Lovushki Island Fur Seal Pup Count

technology: Count Clickers | Notepad

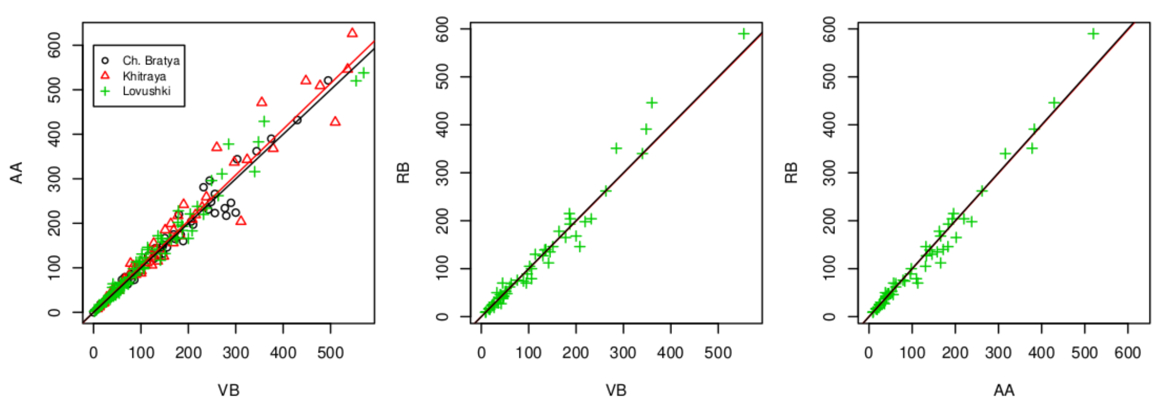
Lovushki Island Fur Seal Pup Count

technology: Bamboo poles for self-defense



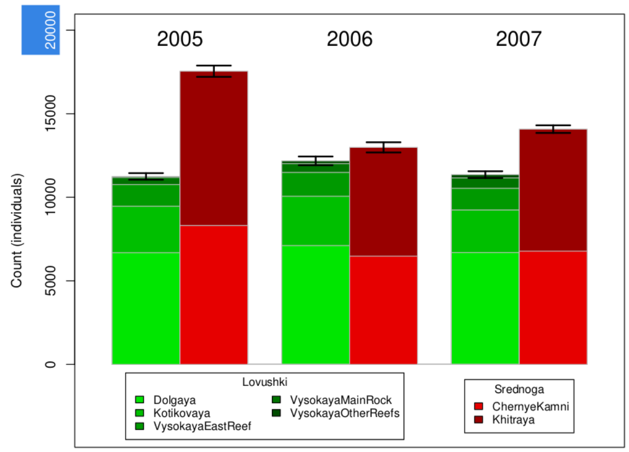
Fur seal count: Source of variation?

Individual counters



Pretty good agreement.

Fur seal count: High Precision!



Point Estimate:
$\widehat{N} = 28,792$

Standard Error (s.e.):
$\sigma_e = 216$

95% Confidence Interval
$\widehat{N} \pm 2\sigma_e = (28,630 - 29,220)$

Coefficient of variation
$\frac{\sigma_e}{\widehat{N}} = 0.75\%$

Fur seal count: what about accuracy?

What are potential sources of *error* (bias)?

What *direction* is that bias in?

Fur seal count: Ecological question?

What does **the number of pups** really tell you about a population?