# Counting animals

## EFB 390: Wildlife Ecology and Management

Dr. Elie Gurarie

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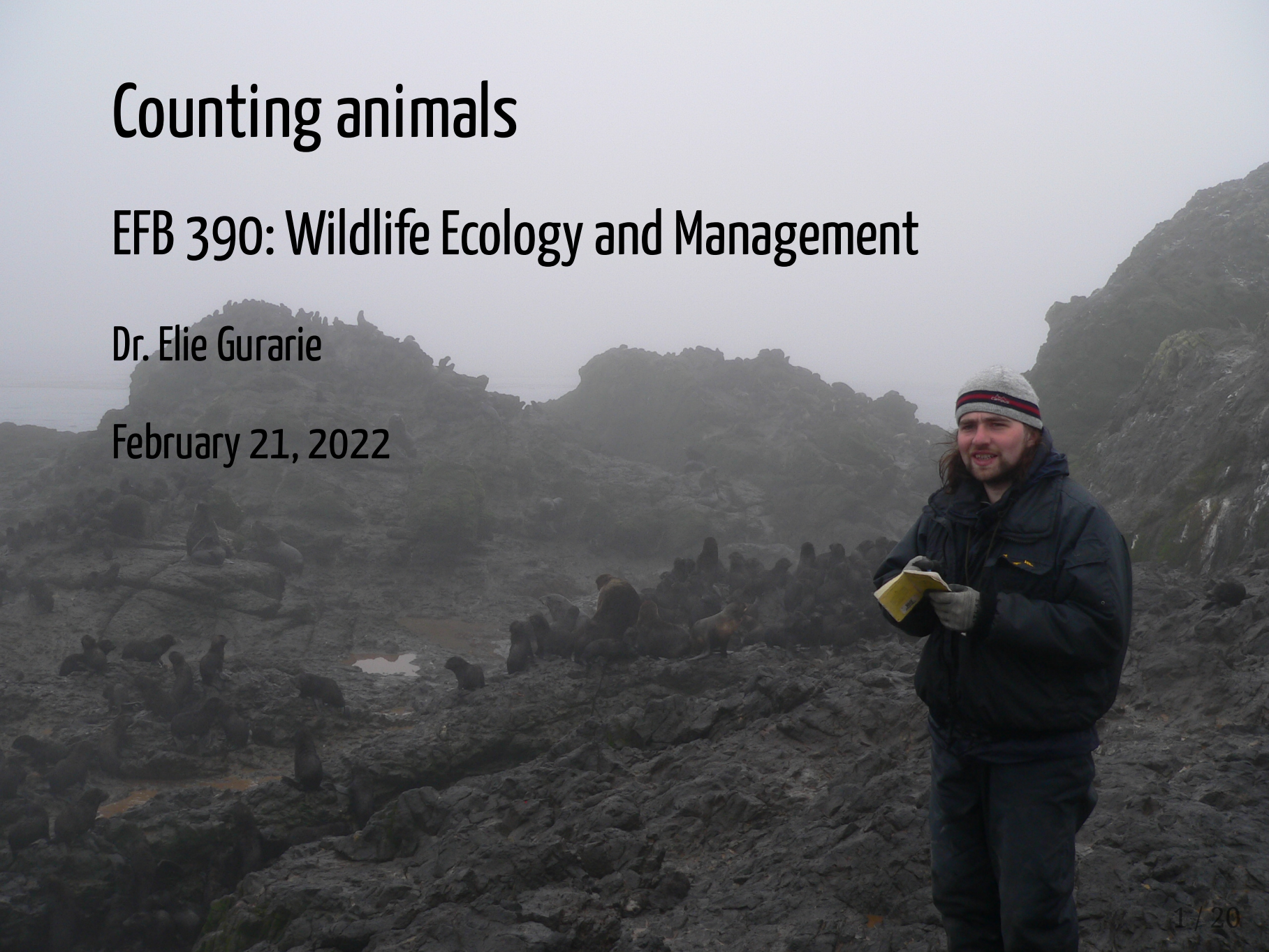


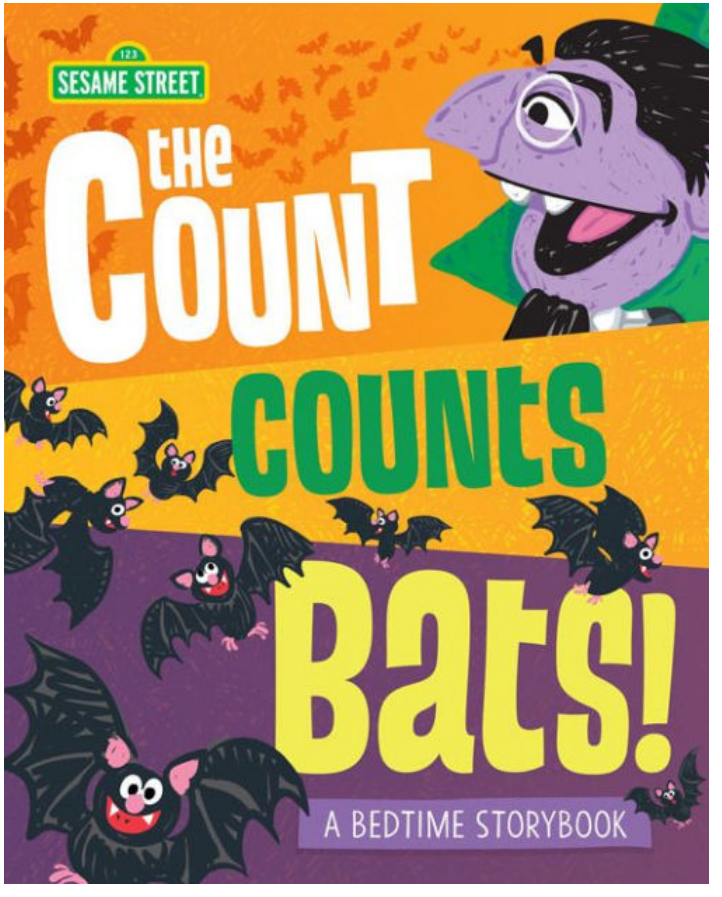
## Goals of wildlife management

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

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

The variance of the estimator can be written as

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

Component-wise,

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

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

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

and

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

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

Miller 2005 (Ph.D. dissertation)

# An observation

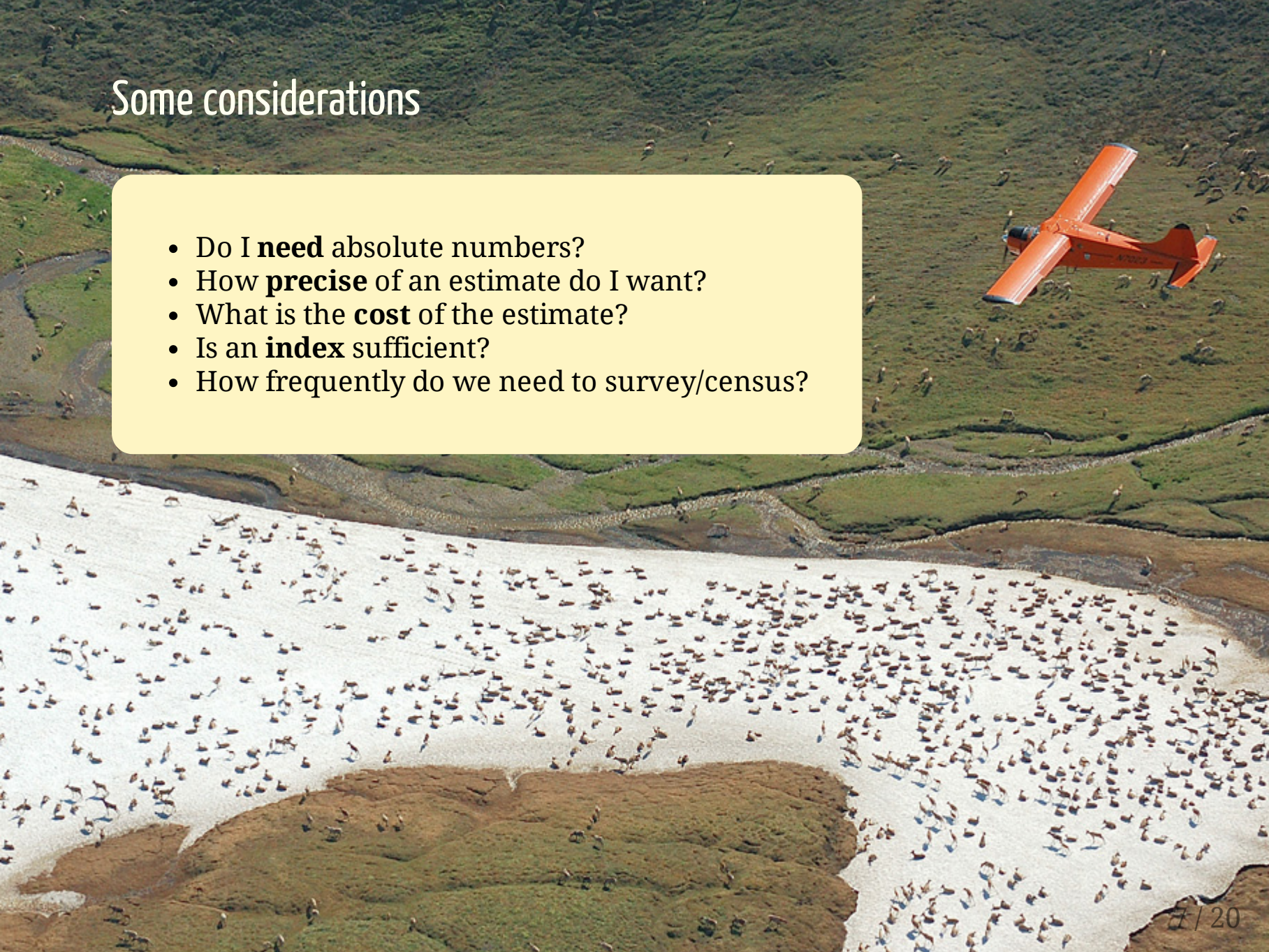
Counting **fish** is just like counting **trees**, except they're *invisible* and they *move* ...

# 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?

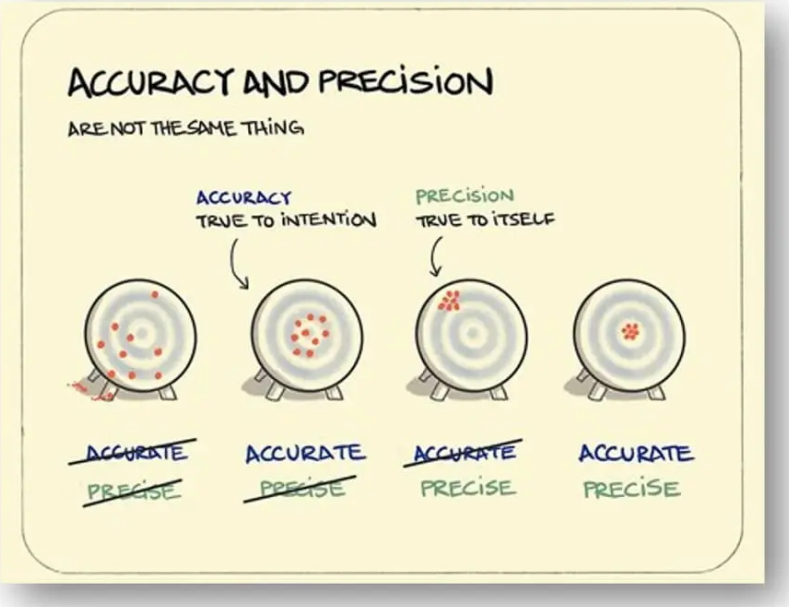


## Accuracy

Is the estimate **biased**?

Determined by **design**.

Can be difficult to assess.




## Precision

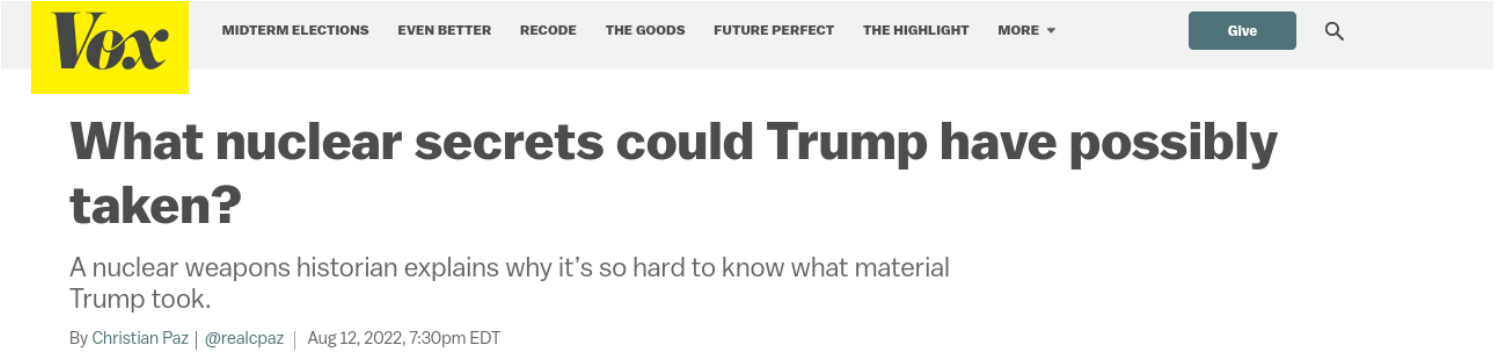
What is the *error* or *variance* or *spread* on the resulting estimate?

Quantified with **Confidence Intervals (C.I.)** or **Coefficients of Variation (C.V.)**

Generally determined by **effort** and computed with **fancy statistics**.

Generally **smaller** the bigger the **sample**.

# Very accurate, but very imprecise:




*"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.*

# Goal

Increase both **accuracy** and **precision**

- (maybe, generally, a higher premium on **accuracy** ... which is harder).

***or***

Maybe it's just enough to know how things are *changing*.

# Total Count, aka. **Census**

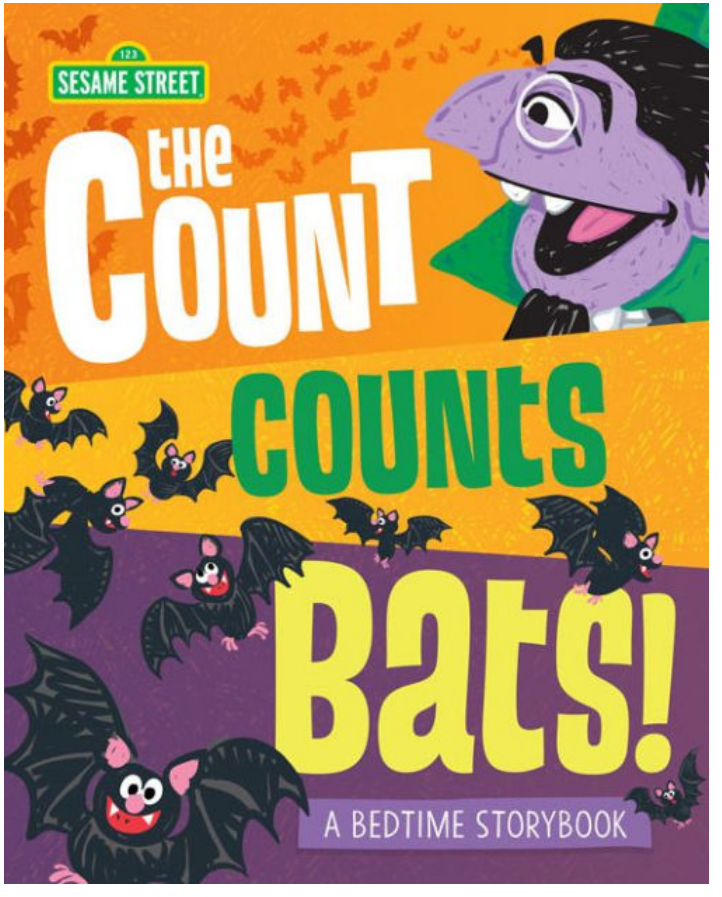
**Pros**

- Simple to explain!
- Simple math (*arithmetic*)!
- Very precise (no "confidence interval")

**Cons**

- Usually - VERY difficult to perform!
- Only possible for certain kinds of animals
- Accuracy?

***What kinds of animals can we census?***

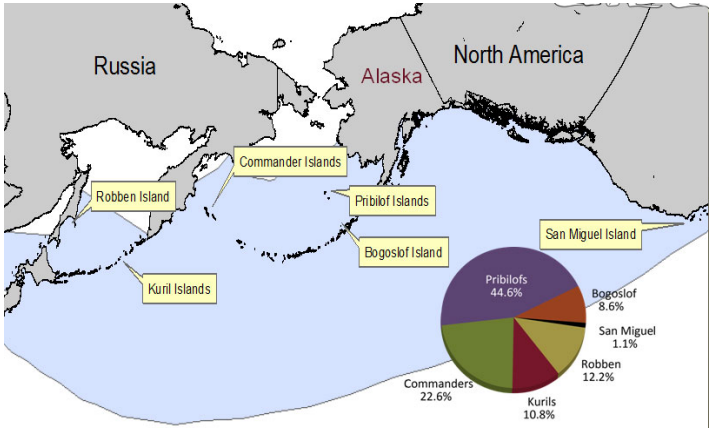


# Census Examples

- 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!

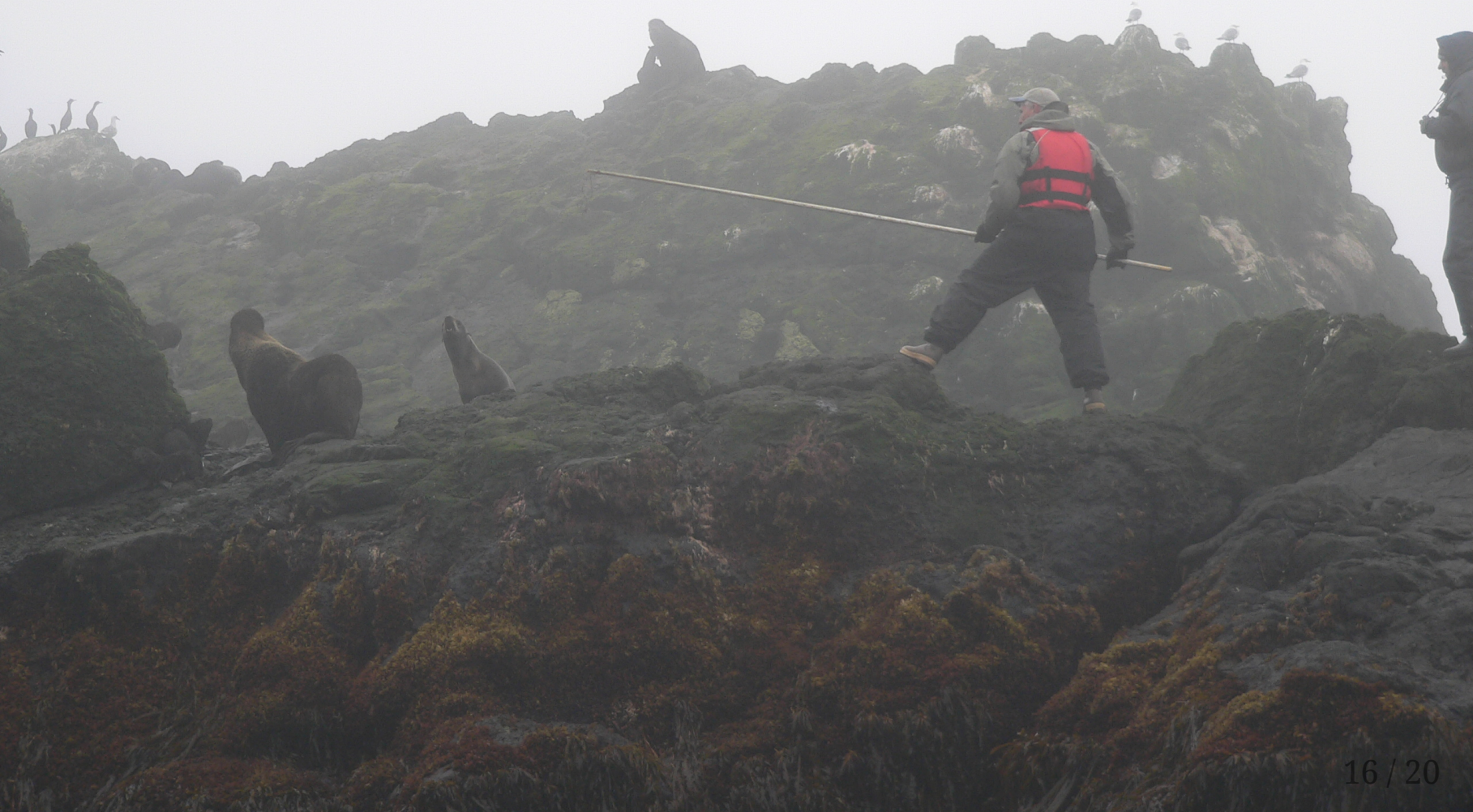
Tyuleni Island

# Lovushki Island Fur Seal Pup Count

**technology:** Count Clickers | Notepad

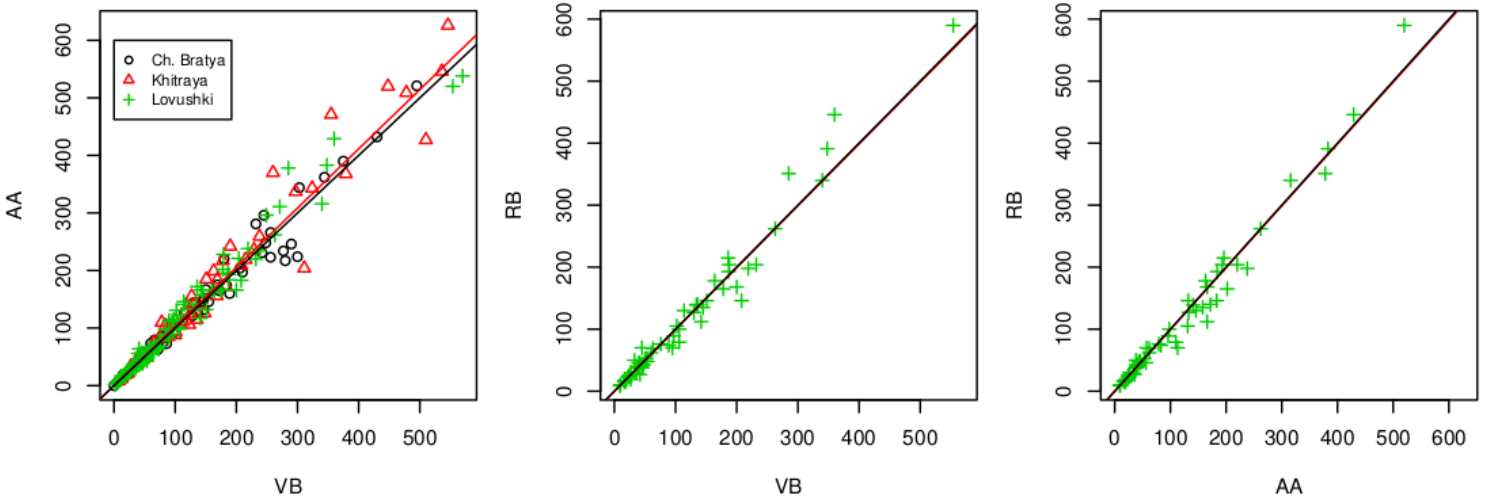
# Lovushki Island Fur Seal Pup Count

**technology:** Bamboo poles for self-defense



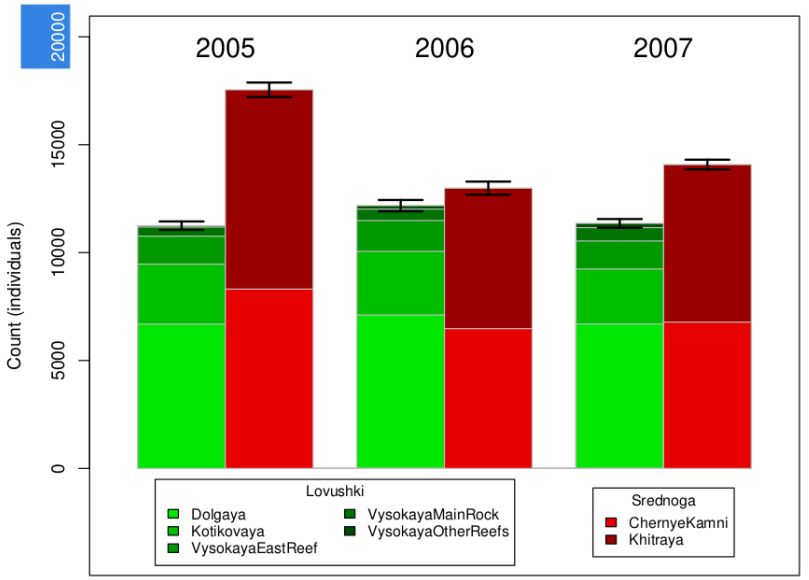
# Fur seal count: Source of variation?

## 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?