Estimating population size

Estimating abundance

- There are many different methods because…
  - Differences in mobility of the organism
  - Differences in management practices
  - Need to account for varying complicating factors
- A complete count is a census
  - No estimation required
  - But, rarely practical
- All of the estimation methods are thus sample based, and we need to account for sampling variation

The simplest case: counting how many are seen

Elephants

Nesting egrets in S. Carolina

Black-headed gulls

Waterfowl on the Mississippi

When the simple case isn't so simple

Black-browed albatross

California poppies

Manatees

Migrating caribou

Complete counts are not common

- It isn't practical to count massive populations distributed over large areas
- We can count in smaller areas, then extrapolate totals to regions
- This isn't always perfectly straightforward if scaling isn't linear

Example: how many poppies in the field?

How many poppies in a 40 ha field?

Using a 1 m^2 quadrat, count 20 poppies

$$20\ poppies/m^2\ x\ 10{,}000\ m^2/ha \times 40\ ha = 8{,}000{,}000\ poppies$$

$$20\ poppies/m^2\ x\ 400{,}000\ m^2 = 8{,}000{,}000\ poppies$$

Total from a mean of a random sample

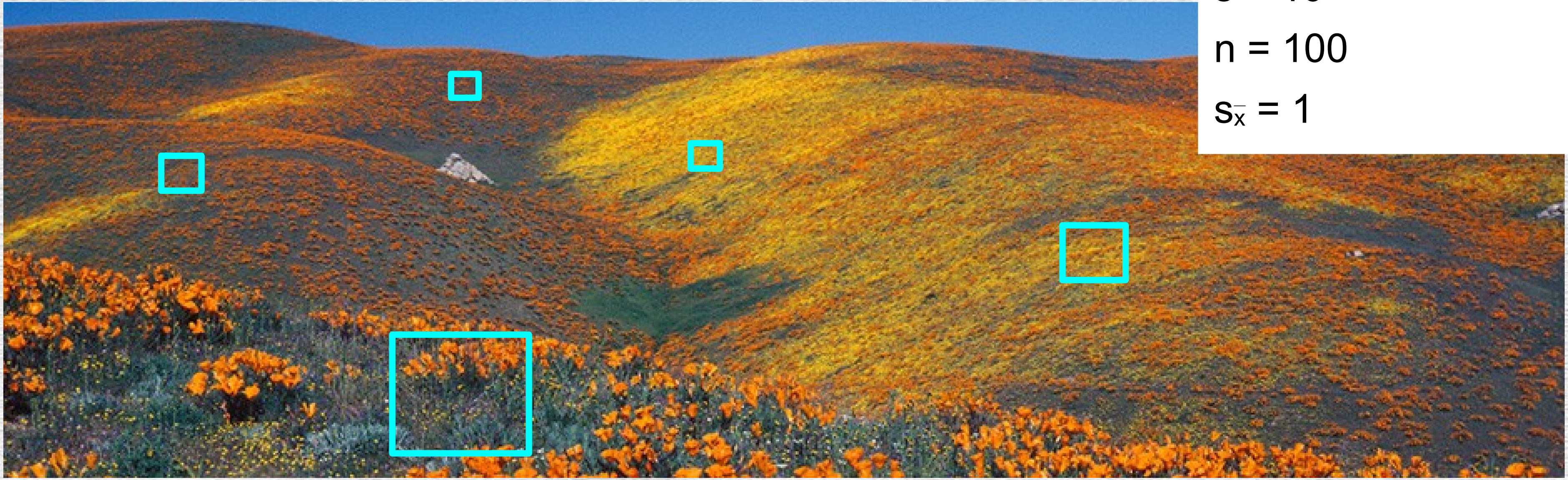
$$T = \bar{x} \times N = 20 \times 400{,}000 = 8{,}000{,}000$$

Mean = 20 poppies/m^2

s = 10

n = 100

$s_{\bar{x}}$ = 1



$$var(T) = s_{\bar{x}}^2 N^2 = \frac{100}{100} \times 400{,}000^2 = 160{,}000{,}000{,}000$$

$$s_T = \sqrt{var(T)} = 400{,}000$$

$$95\% \text{ CI} = T \pm 1.96\, s_T$$

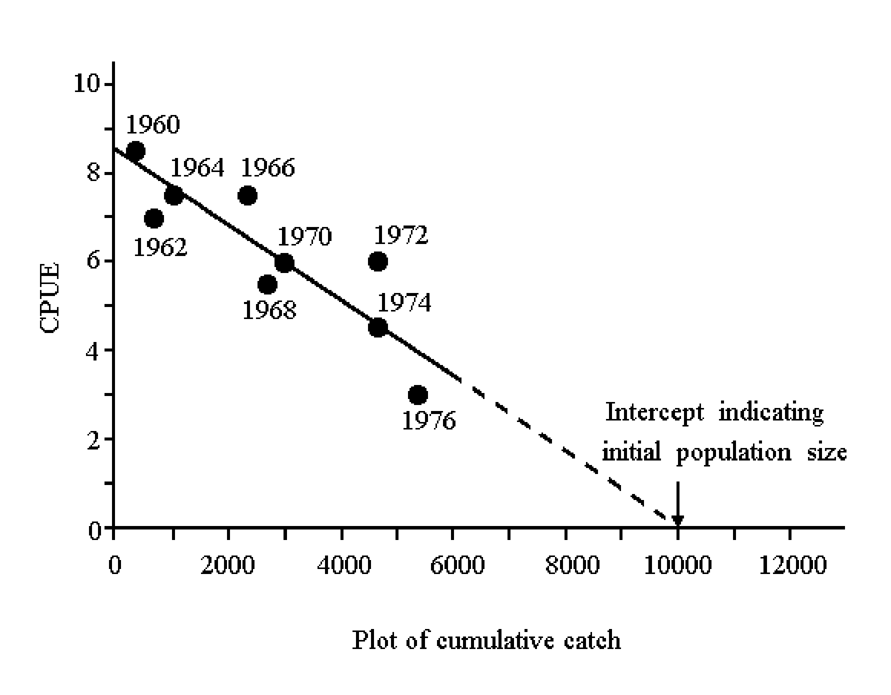
$$\text{LL} = 8{,}000{,}000 - 784{,}000 = 7{,}216{,}000$$
$$\text{UL} = 8{,}000{,}000 + 784{,}000 = 8{,}784{,}000$$

Approaches to estimating abundance for mobile organisms

- Methods that don’t require marking
  - Removal methods
- Most methods require capture, mark, release, and recapture
  - Classic methods with two (Lincoln-Petersen) or more (Schnabel) capture periods
  - Maximum likelihood estimation based on capture histories

Removal methods

- Best for harvested populations (whales in this case)
- Plot catch per unit effort against cumulative catch (a Leslie plot)
- X-intercept is the original population size
- Advantage: no live capture and marking needed
- Disadvantage: need to deplete the population to estimate its initial (former) size



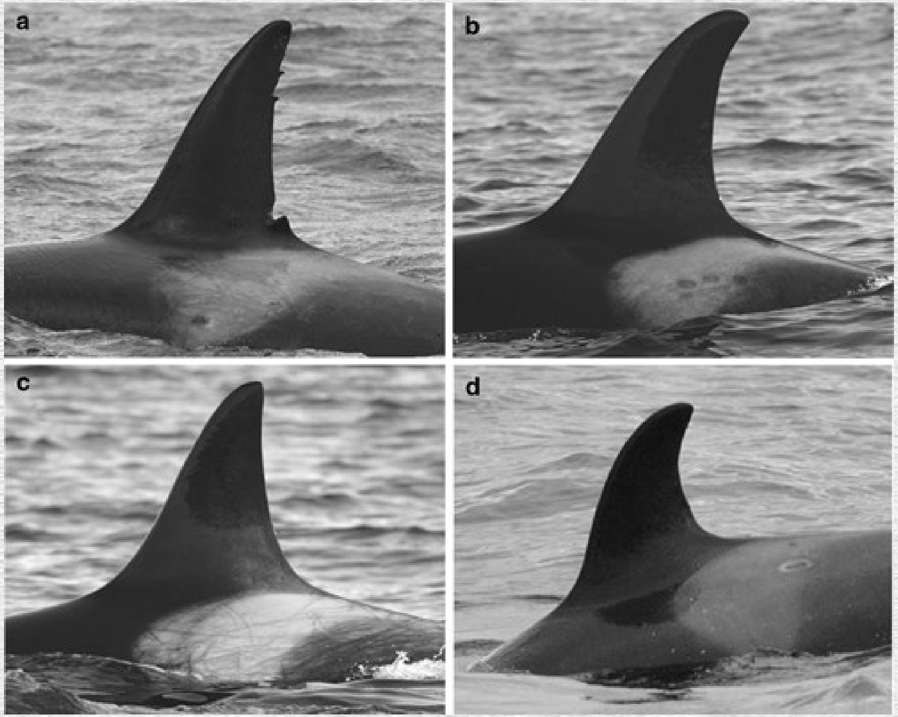
Mark-release-recapture methods

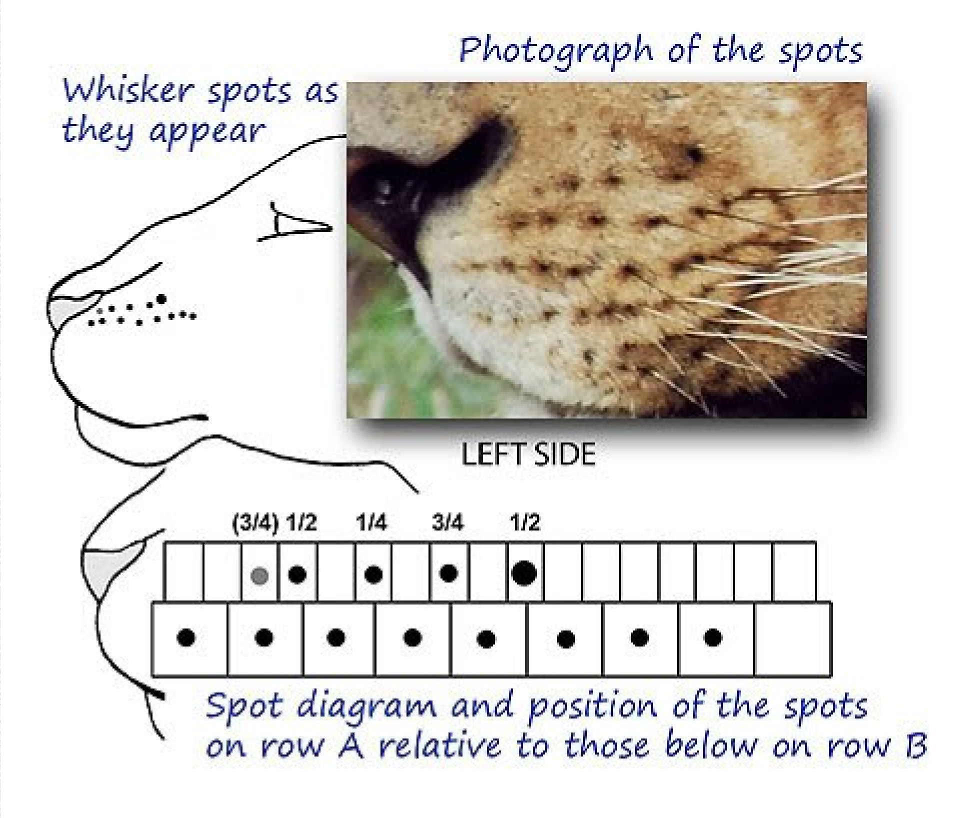
- Most methods of estimating abundance require:
  - An animal is initially captured
    - Marked and released back into the population
  - A second sample is taken at a later time
    - Size of second sample, and the number captured with marks recorded
- There can be more than one recapture period
- Some methods don't require the marks to be individually identifiable (**batch** marks)
- **Recapture** doesn't have to be an actual capture – resighting is okay if the marks are clearly visible

Capture

Marking

Using natural marks





If natural markings are individually identifiable, they can be used in place of artificial marks

No initial capture is needed!

Lincoln-Petersen estimator – the simplest method

Two periods – mark and recapture

All individuals captured the first time are marked – M

Count marked (r) and total captures (c) in the second period

Batch marks are fine – don't need individual ID

$$\hat{N} = \frac{Mc}{r} = M\,\frac{c}{r}$$

Do we need to re-sight every marked individual?

What does r do to precision?

$$var\left(\hat{N}\right) = \frac{\left[\left(M+1\right)\left(c+1\right)\left(M-r\right)\left(c-r\right)\right]}{\left[\left(r+1\right)^2\left(r+2\right)\right]}$$

Assumes this relationship is true: $\dfrac{M}{N} = \dfrac{r}{c}$

$$95\%\ \text{CI for } \hat{N} = \hat{N} \pm 1.96\sqrt{var\left(\hat{N}\right)}$$

Example LP estimate

$$\hat{N} = \frac{Mc}{r} = \frac{100 \times 200}{50} = 400$$

$$var\left(\hat{N}\right) = \frac{\left[(M+1)(c+1)(M-r)(c-r)\right]}{\left[(r+1)^2(r+2)\right]} =$$

M = 100

r = 50

c = 200

$$\frac{\left[(100+1)(200+1)(100-50)(200-50)\right]}{\left[(50+1)^2(50+2)\right]} = 1125.73$$

$$\text{Lower limit: } = \hat{N} - 1.96\sqrt{var\left(\hat{N}\right)} = 400 - 1.96 \times \sqrt{1125.73} = 334.2$$

$$\text{Upper limit: } = \hat{N} + 1.96\sqrt{var\left(\hat{N}\right)} = 400 + 1.96 \times \sqrt{1125.73} = 465.8$$

Assumptions of LP

- The basic model is: $\frac{r}{c} = \frac{M}{N}$
  - The ratio of marked individuals in the recapture sample is the same as the ratio of marked individuals in the entire population
- LP assumptions are the conditions needed to make this relationship true
  - The population is closed (N is constant, no M leave or die)
  - All individuals have the same chance of capture in the first sample
  - Marking doesn't affect resighting probability in second sample
  - Animals don't gain/lose marks before second sample
  - Complete mixing before second sample

Closed populations

- Closed populations are not changing over time
  - No deaths
  - No births
  - No immigration
  - No emigration

Demographic closure

Geographic closure

- The only way to ensure this is to sample over brief periods, and under conditions when movements are least likely

Mark-recapture with multiple recapture periods

- The Schnabel estimator – an extension of LP
- It is often possible to have more than one sampling period (multiple surveys over time)
- The first sampling period is just like LP – all animals caught are marked
- The second through second to last sampling period
  - All marked individuals are recorded as captured with marks, re-released
  - All unmarked are counted as unmarked at capture, marked, and released
- The last sampling period is like the recapture for LP – count all marked and unmarked

Schnabel estimator

$$\hat{N} = \frac{\sum M_t c_t}{\left(\sum r_t\right) + 1}$$

$$var\left(\hat{N}\right) = \frac{\left(\sum \left(M_t c_t\right)\right)^2}{\sum r_t}$$

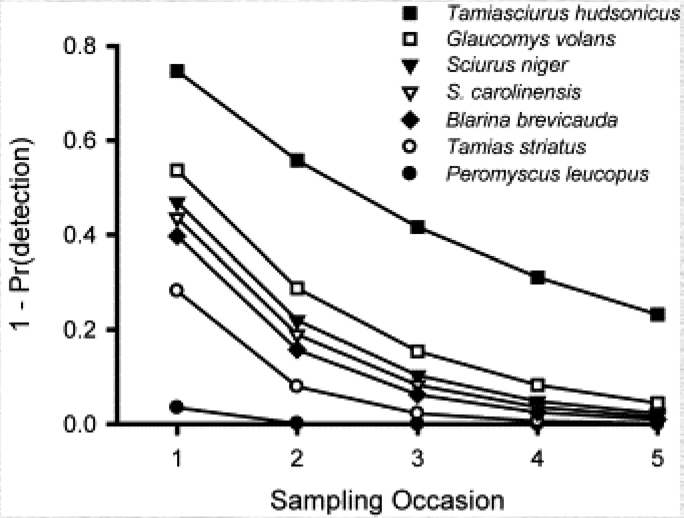
- Multiple capture periods
  - r_t = number of individuals in the sample at time t that were already marked
  - c_t = total individuals caught at time t
  - M_t = number of marked animals available for capture at time t (sum of animals marked before t)
  - N = population size
- Precision increases as the number of recaptures increases

Occurrence

- Sometimes occurrence is all you need to know
  - A species occurs in an area if at least one individual is found (0 individuals means it doesn't occur, ≥1 individual it does)
  - Recorded as a presence/absence binary variable (often 0,1)
  - If the species occurs at fewer sites over time they are probably declining
- Encounter probability is still an issue
  - Observing 1 or more individual is definitive – the presences are reliable
  - Need to observe frequently enough to be confident about absences
  - Failing to detect a species that does occur will result in a "pseudo-absence" – a 0 that's not really an absence
  - Multiple visits may be needed – but how many?

Number of visits

- How many visits are needed, when encounter probability isn't 1?
  - If the probability of detection is high, a single visit may be adequate
  - If detection probability is low, longer observation periods, or more visits may be needed
- Can determine empirically – re-visit the same sites until new detections stop occurring



From Gu and Swihart 2004