Population estimation

Remember steps in strategic planning

- Where are we now?
- Where do we want to be?
- How do we get there?
- Did we make it?

Remember steps in strategic planning

- Where are we now?
    - What is the size of the population(s) of interest?
        - population estimation
    - What are the boundaries between populations and how firm are they?
        - population identity

Counting animals

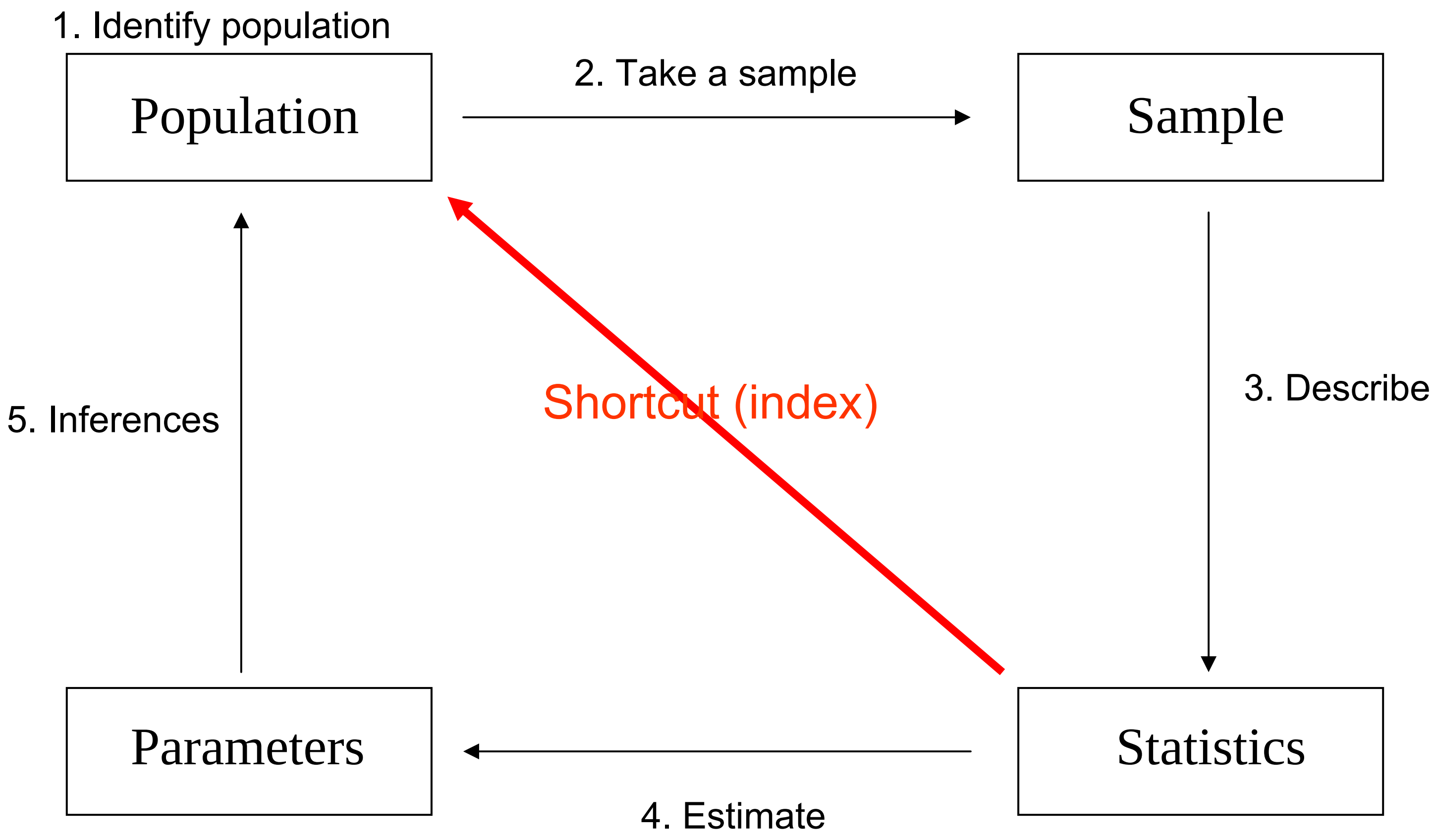
- Animals don’t always cooperate
- Logistical and financial constraints
- Three different approaches
  - Census
  - Index
  - Estimation

Census

- Complete enumeration
- Detection probability (p) = 1.00
  - Probability that animal is seen given that it is present
- Most applicable for small sampling units; otherwise not feasible

Index

- A statistic assumed to be related (correlated) to the true population parameter in some (unknown) way
- An incomplete count or measure of a related variable (covariate)
- Generally used for abundance
- p is unknown or assumed constant
- Useful only in comparisons between indices

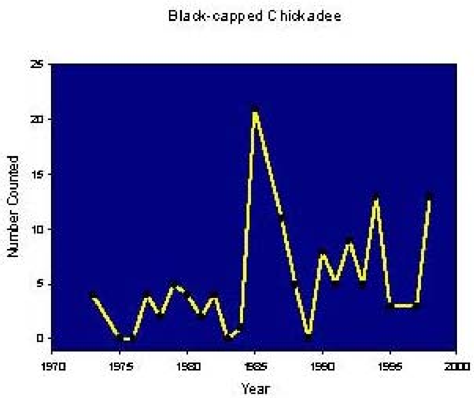

1. Identify population
Population
2. Take a sample
Sample
3. Describe
Statistics
4. Estimate
Parameters
5. Inferences
Shortcut (index)

Indices

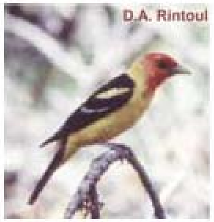
- Mammals?
  - Track counts in snow
- Birds?
  - Breeding bird surveys
  - Christmas bird count
- Fish?
  - Catch per unit effort

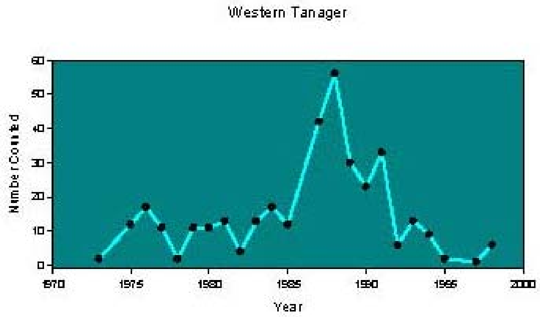
Examples from the Breeding Bird Survey Routes (Clinton, Montana)

- Black-capped Chickadee *Poecile atricapillus*



- Western tanager *Piranga ludoviciana*

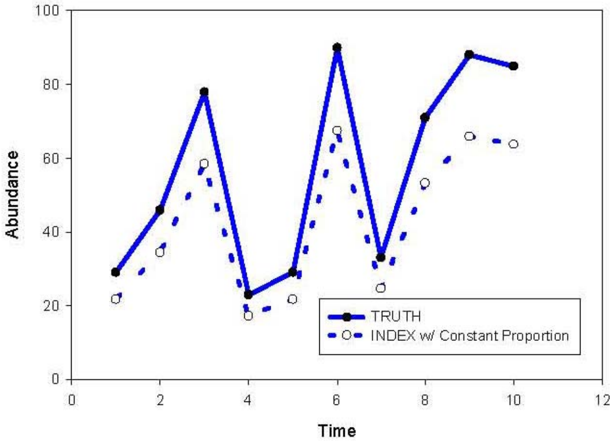




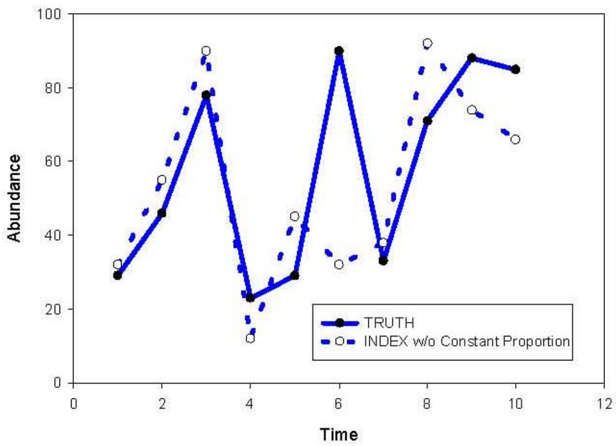
Assumptions

- Relative abundance is related to true abundance
- Index is a constant proportion of true value
- What affects this assumption?
- How can you maintain a constant proportion?
  - Standardize!
  - Measure covariates!

INDEX = 0.75 x TRUTH



INDEX = ? x TRUTH



Estimation--sampling

- Use statistics and estimators to obtain estimates of population parameters

$$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n}$$

- Estimate *p* and adjust statistics accordingly

$$\hat{N} = \frac{C}{\hat{p}}$$

  - Distance sampling
  - Double sampling

Some Major Methods

- For an index of abundance:
  (e.g, mean number of animals detected/visit)
  - Terrestrial songbirds, tree squirrels, chipmunks
  - Simple line transect
  - Fixed-width transect (belt transect)
  - Variable-width transect

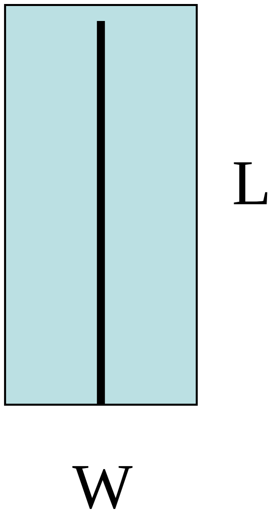
Simple Line Transect

- Simply walk a route and record all the animals of interest that you see or hear without regard to distance from transect route.

- Good for a species list and a very general assessment of relative abundance.

Fixed-width Transect

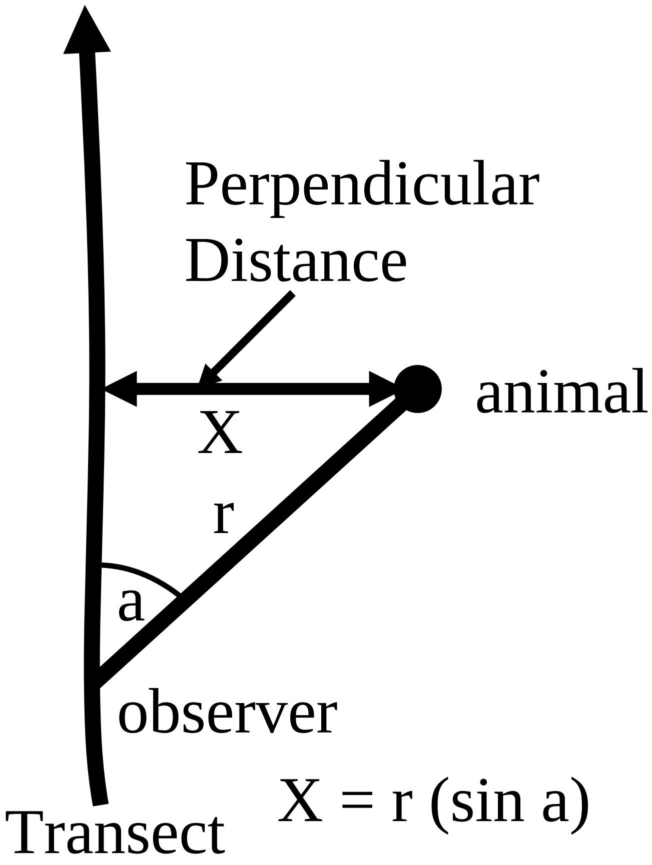
- Can calculate density (#/area)
- Some distance is predetermined to be the maximum sighting distance, W -- all animals within this distance can be seen
- The transect's length is known, L
- Density is = N/(L*W) (area)



Variable-width Transect

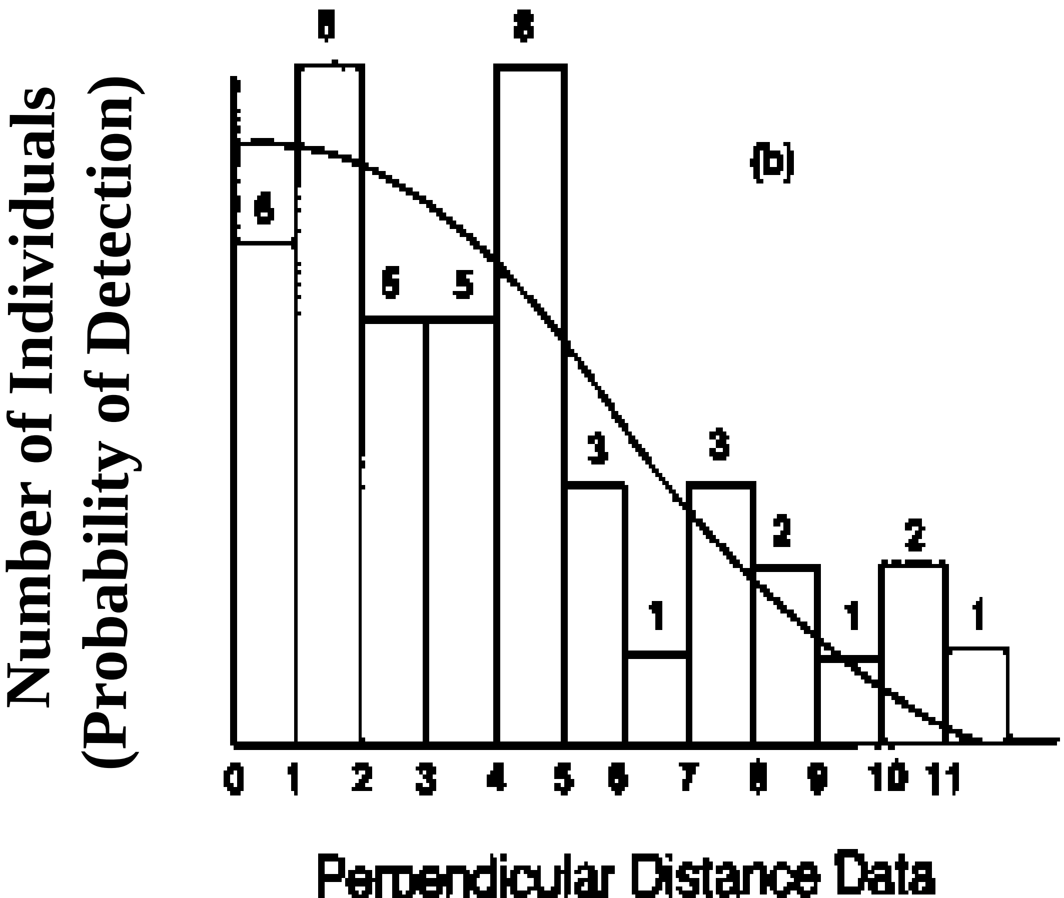
- Similar to fixed-width except you estimate distance to animals detected
- Distance estimation errors are very likely
- Density estimates require many calculations (computer programs are available)

Variable-width Transect



- Observer walks transect and records distances to sighted animals
- Assumptions
  - all animals on the line are detected
  - animals don't move before being sighted and none are counted twice
  - distances are measured accurately
  - sightings are independent

Distance sampling

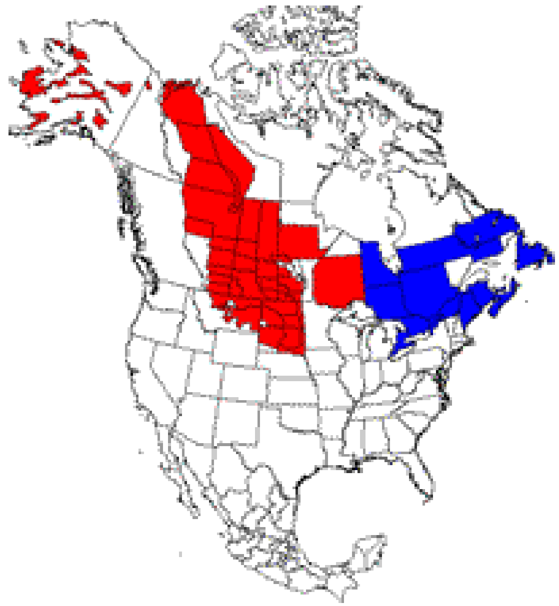


- Distance Data are Used to Determine Likelihood of Observing an Animal of Given Distance from the Line
- Distance Function is fit to distance data to calculate the average detection probability (for range of distances recorded) , P_w
- $N = C/P_w$
- Computer programs use calculus (integration) to solve for P_w

Aerial surveys

- Good for large mammals in northern climates
- Need open habitat, snow cover and flat light
- Moose: count number seen along flight path
- Variation: apply distance sampling to aerial observations
- Caribou: take aerial photos and count animals later
- FLIR: forward-looking infrared
  - Gives heat image of animal
  - Possible to use in heavy cover
  - Bears, deer, moose

Estimating waterfowl populations: breeding grounds surveys



Strata surveyed by USFWS air crews during the Waterfowl Breeding Population and Habitat Survey. Strata depicted in blue have been gradually added to the survey since 1990.

- Two-person aerial crews
- Fly transects, 29km x 400m, 50m above ground
- Pilot flies, observer counts
- Count hens w/ offspring only
- In areas w/ ground access counts by ground crews are used to estimate sightability correction factor by species

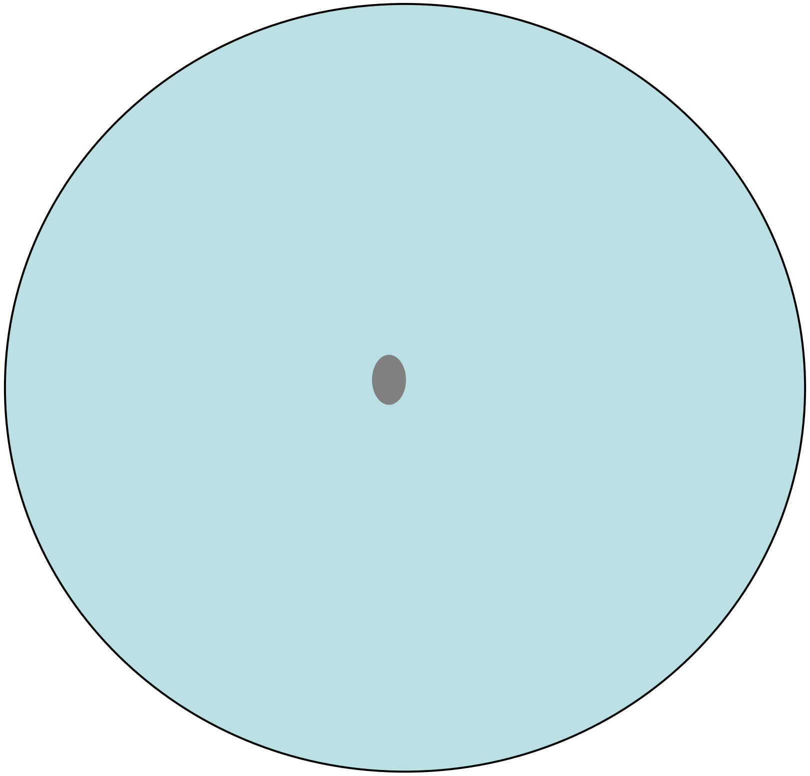
http://birdmaps.fws.gov/home.aspx

Point Counts

1. Simple point count
2. Fixed-radius point count
3. Variable-radius point count

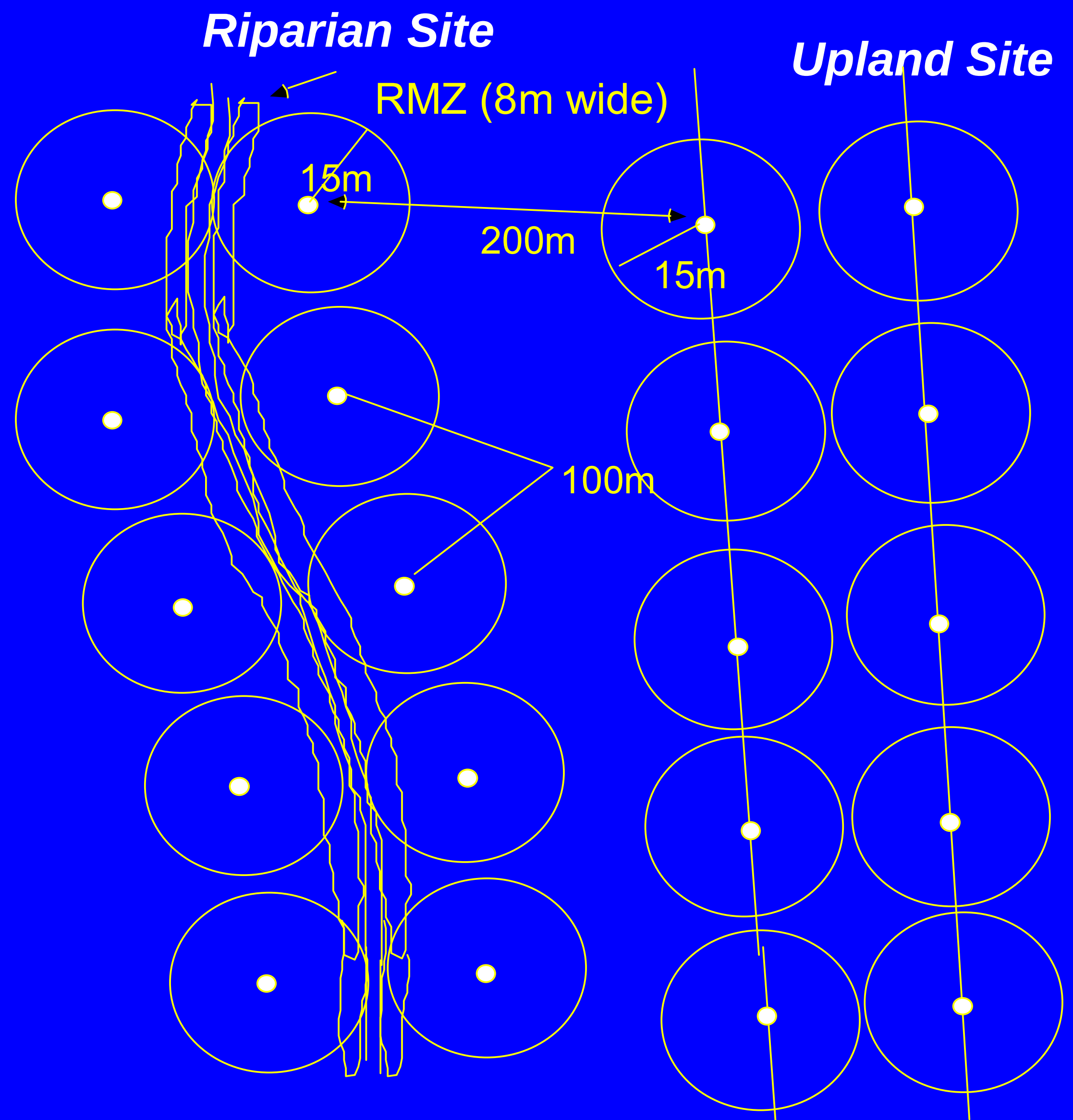
Simple Point Count

- Good for obtaining index of abundance



Fixed-radius Point Count

- Fixed radius usually 50m
- Widely used
- Good for abundance index, could get density estimate for species with small territories, but need many points



Array of bird sampling points in the riparian and upland sampling areas.

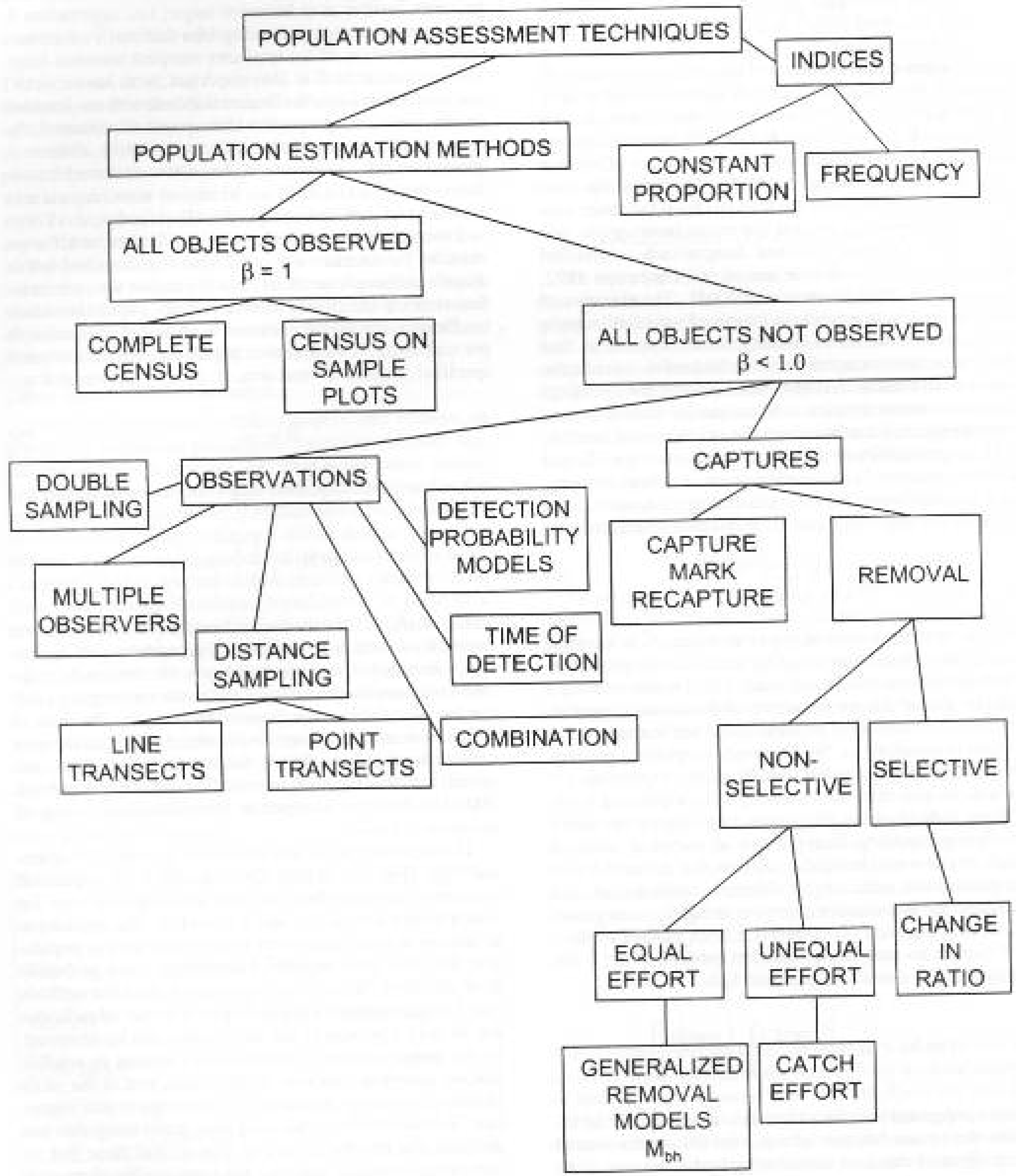
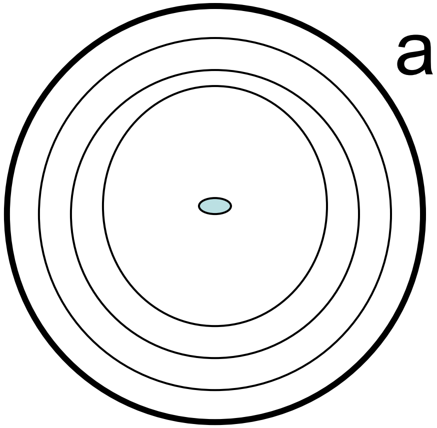


Fig. 3. The relationship among population estimation approaches.

Variable-radius Point Count

- Variable-radius circular plot



Must estimate distance between observer and animal; large error possible

Double sampling

- Often used for aerial surveys
- Based on detection probability (*p*): probability that an individual is detected given that it is present
  - Sightability correction factor

$$\hat{N} = \frac{C}{\hat{p}}$$

- Conduct extensive and intensive counts
  - Extensive: count all sampling units at normal intensity
  - Intensive: count subsample of units at high intensity
    - Assume all individuals counted (or known percentage)
- Correct extensive counts by adjusting for *p*

Assumptions

- Detection probability for intensive sampling is 1.00 or known
- Detection probability estimated for intensively sampled plots is the same for all other plots

Computations

- Estimate *p* from extensive/intensive count areas

$$\hat{p} = \frac{\hat{C}_e}{C_i}$$

$\hat{C}_e$ ← extensive count

C_i ← intensive count

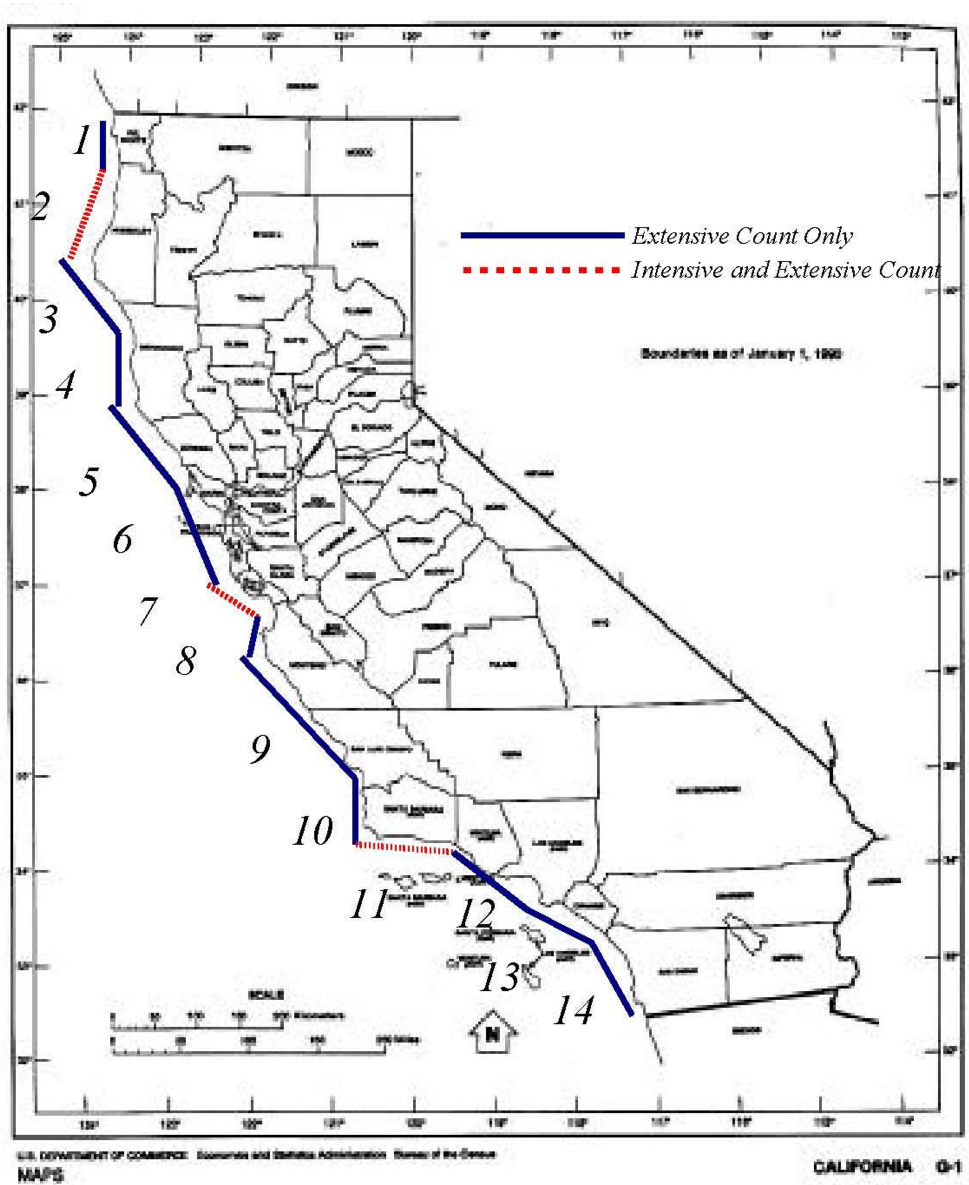
- Estimate *N* for all extensive count area

$$\hat{N} = \frac{C_e}{\hat{p}}$$

- If extensive count area is a proportion *a* of total area,

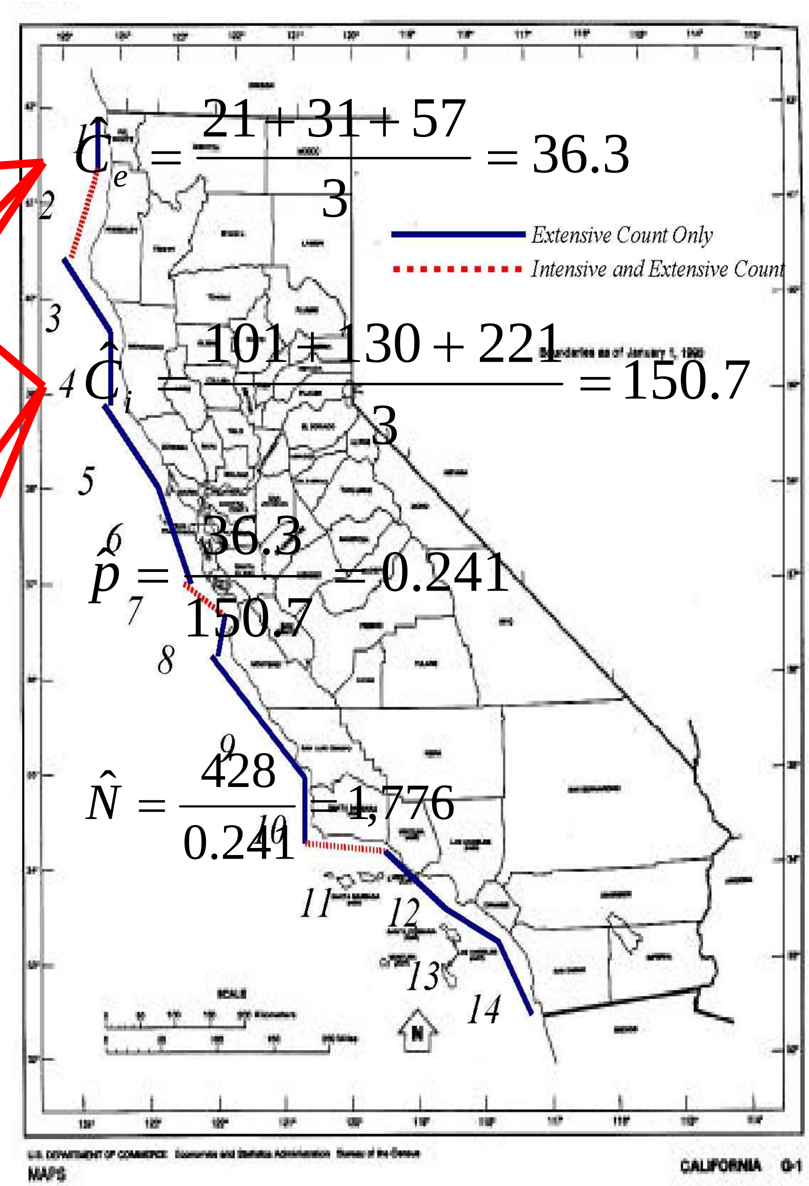
$$\hat{N} = \frac{C_e}{a\hat{p}}$$

California sea otter survey



Transect	Extensive count (Ce)	Intensive count (Ci)
1	33	
2	21	101
3	45	
4	78	
5	43	
6	19	
7	20	
8	31	130
9	24	
10	2	
11	57	221
12	36	
13	12	
14	7	

$\Sigma = 428$



$$\hat{C}_e = \frac{21+31+57}{3} = 36.3$$

$$\hat{C}_i = \frac{101+130+221}{3} = 150.7$$

$$\hat{p} = \frac{36.3}{150.7} = 0.241$$

$$\hat{N} = \frac{428}{0.241} = 1{,}776$$

Change-in-ratio

- Sampling with removal
- Uses relative ratio of abundance of 2 classes of individuals (sex)
- Allows hunters to do the sampling for you through harvest
- Males after hunt = $(D_b K_b – K_d)/(D_a – D_b)$
  - D_b = # females per male before hunt
  - K_b = Male kill
  - K_d = Female kill
  - D_a = # females per male after hunt
- Assumptions
  - Observed proportions are unbiased
  - Closed population (except for removals)
  - All removals are known
  - Proportion removed differs from proportion in population, otherwise, the technique fails

Example

- Moose survey pre-hunt yields 2.8 ♀♀:♂
- Males-only harvest yields 86
- Moose survey post-hunt yields 3.5 ♀♀:♂
- # males after hunt = (2.8*86 – 0)/(3.5 – 2.8) = 344
- # females after hunt = 3.5*344 = 1204
- N = 1548

Example with either-sex hunt

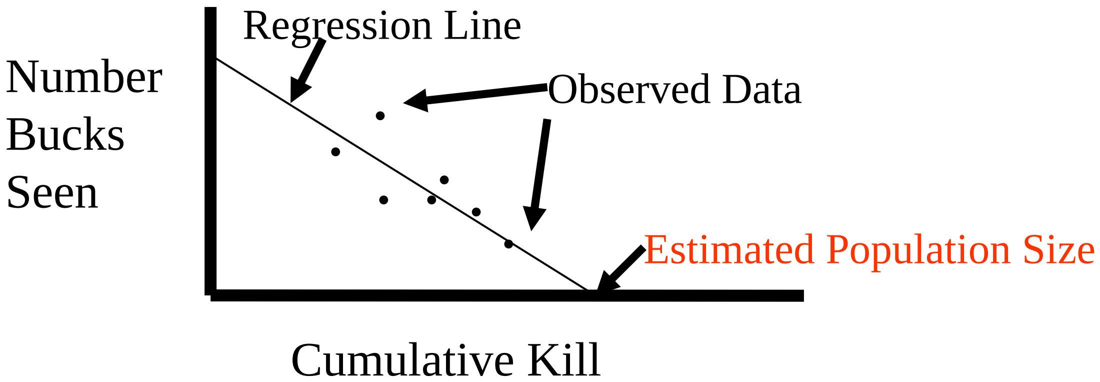
- Conner et al. (1986)
- 54 pre-hunt and 52 post-hunt road counts

	Antlered	Antlerless
Pre-hunt surveys	120	1126
Harvest	56	54
Post-hunt surveys	43	1086

- 120/1246 = 0.0963
- 43/1129 = 0.0381
- $\hat{N}_1 = \dfrac{R_x - R\hat{P}_2}{\hat{P}_1 - \hat{P}_2} = \dfrac{56 - 110(0.0381)}{0.0963 - 0.0381}$
- = 890 (SE = 149)
- # males = $\hat{P}_1 \hat{N}_1 = 0.0963(890)$
- = 86 (SE = 14)

Reduction in Number to Be Caught with Increasing Removal

- Plot Number Surveyed on Y axis versus Number Removed on X axis



- Assumptions
  - Population is “closed” (no birth, death, immigration, or emigration)
  - All animals have equal chance of removal
  - All removal are known

Capture-Mark-Recapture

- Simplest Form is the Lincoln - Peterson Model
- A sample n_1 is captured and marked
- Later, a second sample, n_2, is captured
  - some of this sample, m_2, are marked from first capture
- $m_2/n_2 = n_1/N$ or $N = n_1 n_2/m_2$

Example

- Night 1: Capture and mark 26 mice (n_1)
- Night 2: Capture 31 mice (n_2), 12 of which were captured on Night 1 (m_2)
- $N = n_1 n_2 / m_2 = (26 \times 31)/12 = 67.2$

Schnabel estimator

- For >1 recapture events
- has all assumptions of Lincoln-Peterson
- C_t = # animals caught at time t
- R_t = 3 individuals caught at time t that are already marked
- M_t = # marked animals in population prior to time t

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

$$Va\hat{r}\left(\frac{1}{N}\right) = \frac{\sum R_t}{\sum \left(M_t C_t\right)^2}$$

- Precision is increased by increasing total recaptures

Example

Trapping event	Captures (C_t)	Recaptures (R_t)	Total # marked prior to t (M_t)	M_tC_t	N
1	42	0	0	0	--
2	50	12	42	2100	162
3	54	21	80	4320	189
4	38	20	113	4294	198

Open Population Models

- Jolly-Seber Model
  - Incorporates births, deaths, immigration, and emigration in your estimates of population size
  - Basically adjusts number of marked animals at time of sample by mortality and emigration.
  - Allows projection to future times by calculating b, d, e, and i

Is There a Best Counting Method?

- No, it depends on precision needed, terrain covered, and type of animals surveyed
  - Higher precision requires census or well calibrated counts (good estimate of p)
  - If animals are hunted then removal methods are useful
  - If animals are difficult to see, then mark-recapture estimates are most useful
  - If animals are easily detected then transects, point counts, or aerial surveys with second counter on ground are efficient