Estimating density

Density is a fundamental property of populations

- Densities = number of individuals per unit area
- Density is thus calculated from abundance, but is useful for different things
  - Abundance is important for:
    - Population genetics
    - Risk of extinction
  - Density is important for:
    - Assessing habitat quality - high density often indicates high-quality habitat
    - Density-dependent changes in demographic rates, disease transmission rates

Approaches to estimating density

- Estimate abundance, divide by area sampled
  - Bounded area, if actually bounded
  - Effective area, if not bounded
- Count individuals within a known area
  - Count within discrete, bounded regions
  - Fixed-width transects
- Estimate density directly
  - Distance sampling methods

Using a population size estimate, divide by study area size

- We know how to estimate population size now, why not just divide by the study area size?
- Problem: what is the area occupied by the population estimated?
  - Mark/recapture work is labor intensive, done in a distinct study area
  - The study area boundaries don’t necessarily correspond to the edges of a population
  - Need to estimate the effective area sampled

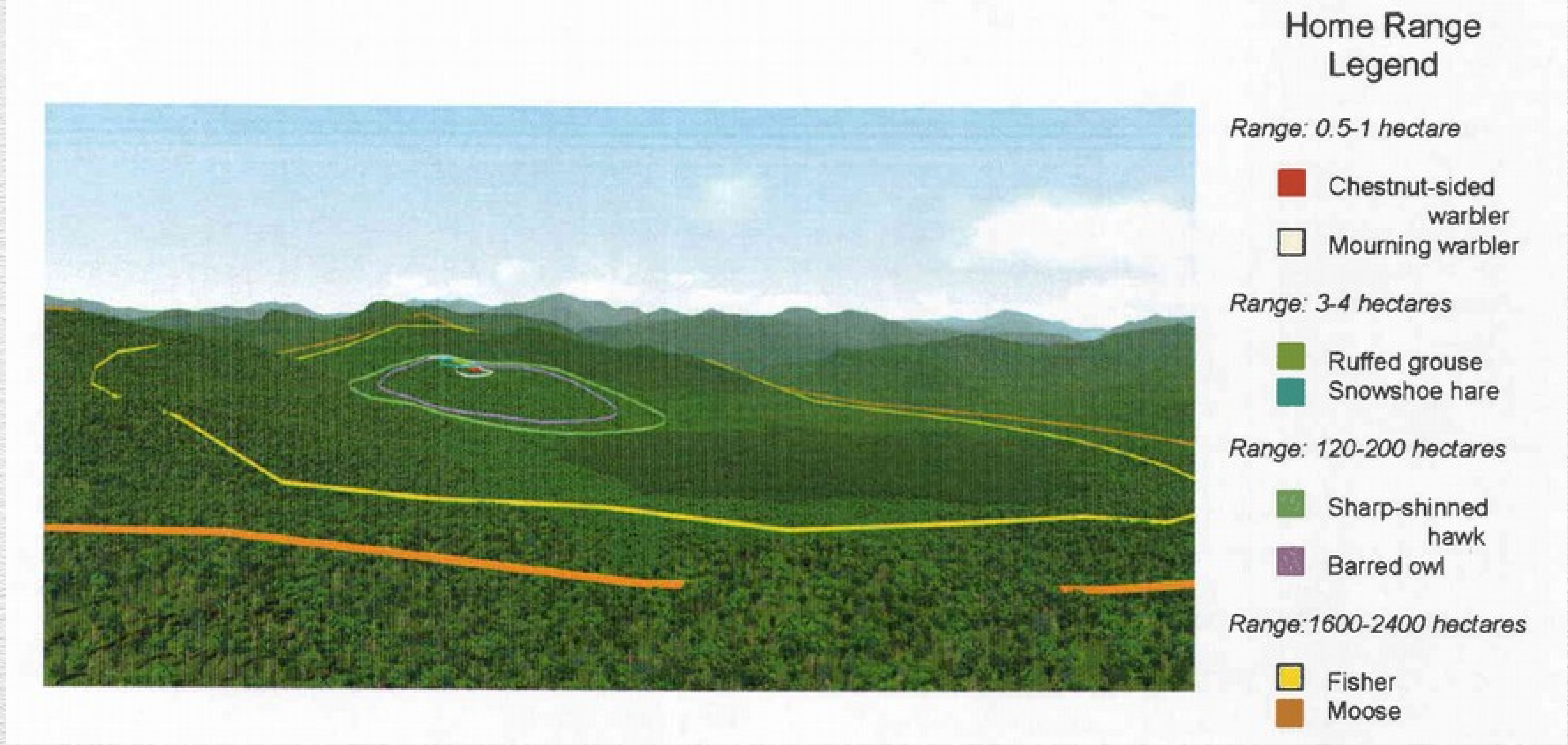
Effective areas of traps

- You have an estimate of abundance based on trapping
- How big an area does a trap sample? What is the Effective Trapping Area (ETA)?
- It depends on:
  - Species
  - Whether the trap is baited
  - How long it's left out
- Even if the traps are laid out in a grid, the effective area around the edges will have a big effect on the density estimate

Baiting increases detections, but attracts animals from a distance

https://youtu.be/hCg6uYXd3tM

Effective area depends on home range size



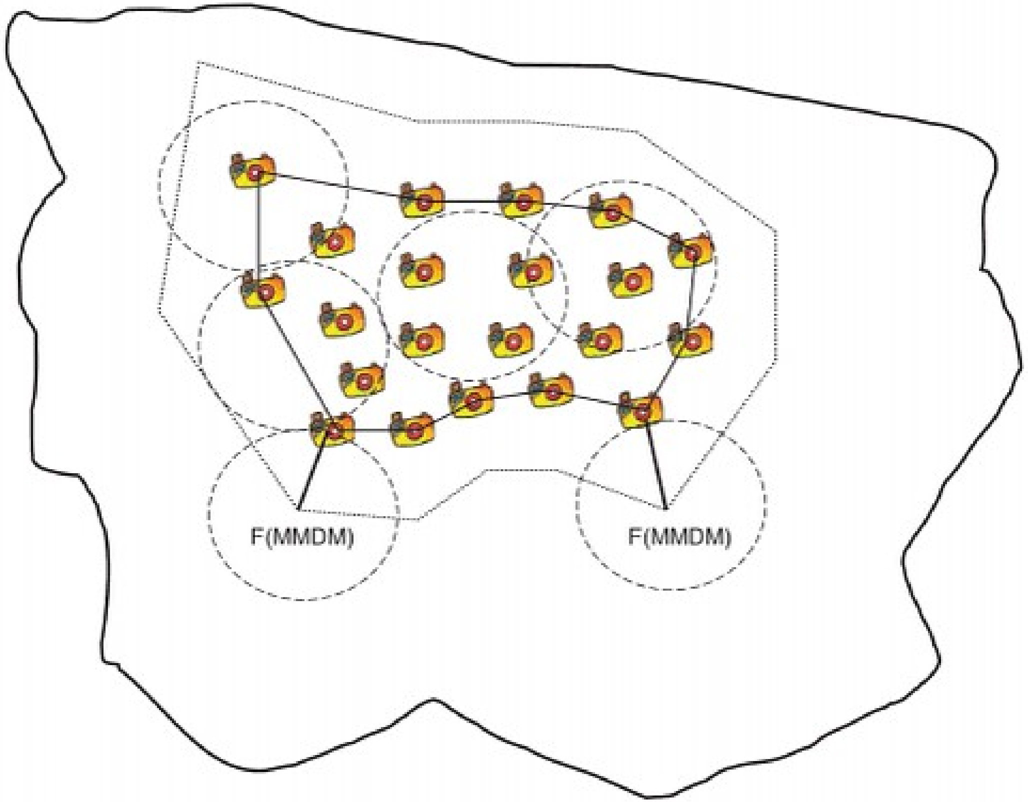


Fig. 6.4 Schematic array of camera traps and effective sampling area. A convex polygon of area A_{tp} is defined by connecting the camera trap points. Circular home ranges are calculated with radii expressed as some function $F\,(F=½,\ 1)$ of the mean maximum distance moved by individuals between camera traps for individuals captured more than once. F(MMDM) defines a length W specifying an area A_w that is added as a buffer around the convex polygon under the assumption that individuals with home ranges centered outside the convex polygon of trap points but within the buffer area fall within the sampled population. The effective sample area is then defined as $A(W)=A_{tp}+A_w$

In the middle camera traps have overlapping detection distances

At the edges the detection distance extends into surrounding area

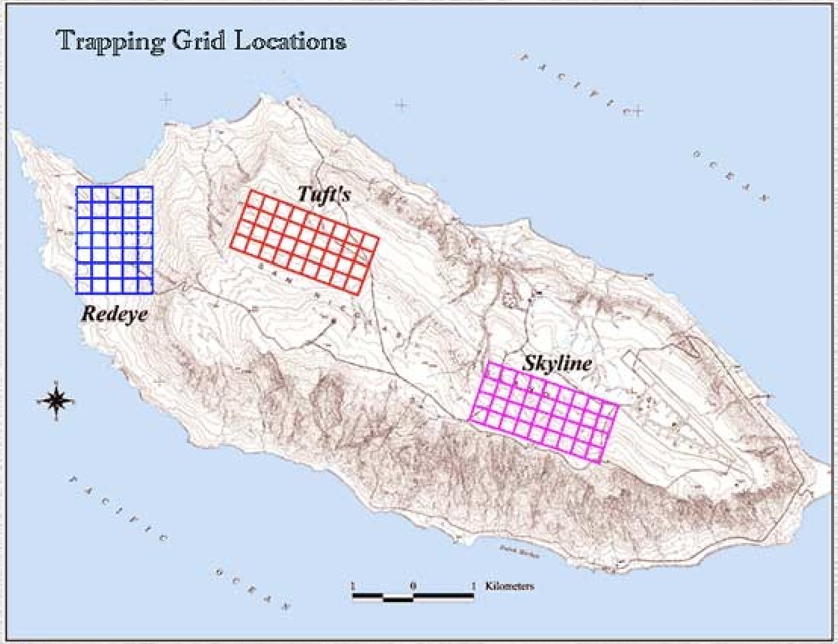
- Fewer cameras covering the area → lower detection probability for animals in edge areas

- Area being sampled is bigger than the area that contains cameras

From O'Brien, 2011

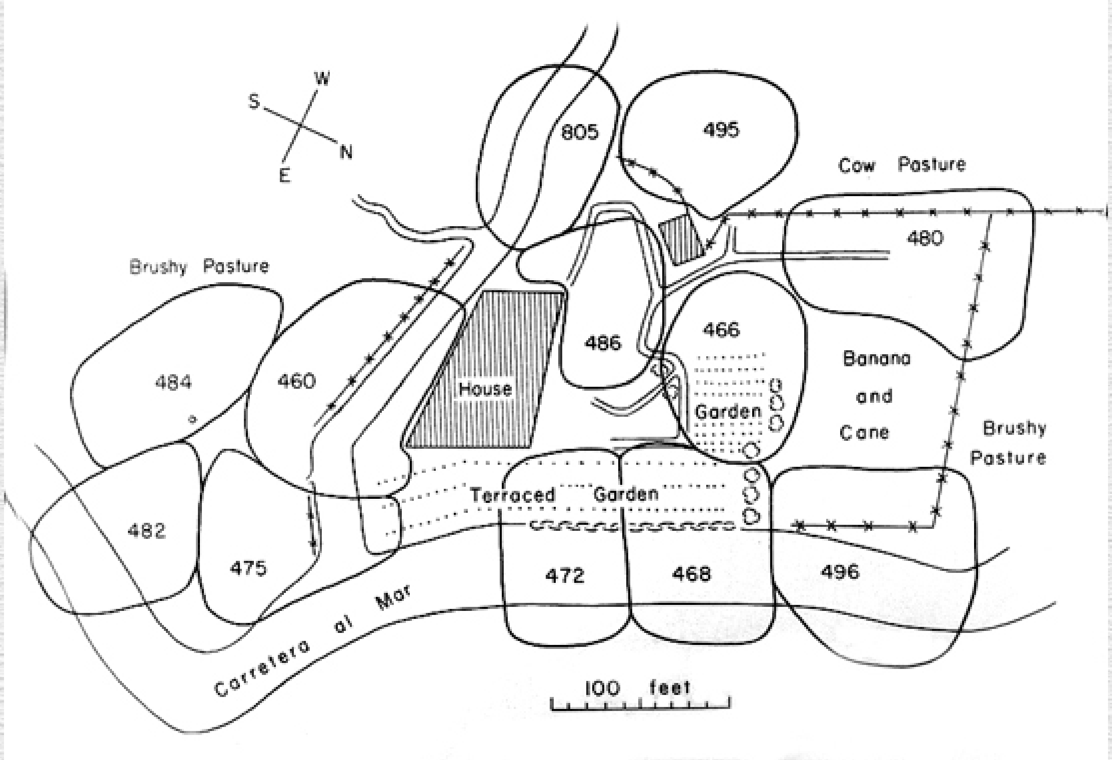
Counting within a fixed area

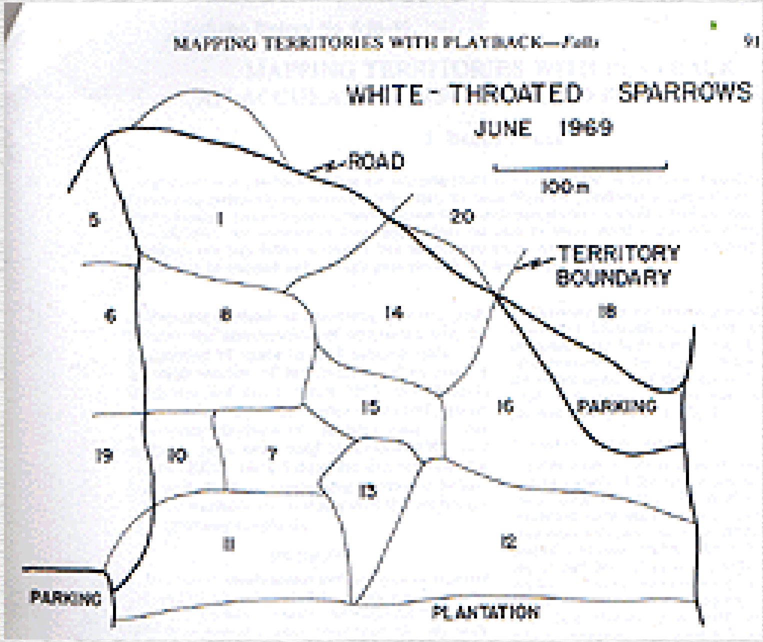
- We can move away from mark/recapture, and estimate density directly
  - Define a discrete area within which a count will be done
  - Count all of the individuals within the discrete area
  - Divide number counted by area
- For this to be accurate, we need:
  - A complete count of the population (or sub-population) of interest
  - No net movement into or out of the bounded area during the count


Trapping Grid Locations
PACIFIC
OCEAN
Tuft's
Redeye
Skyline
PACIFIC
OCEAN
1 0 1 Kilometers

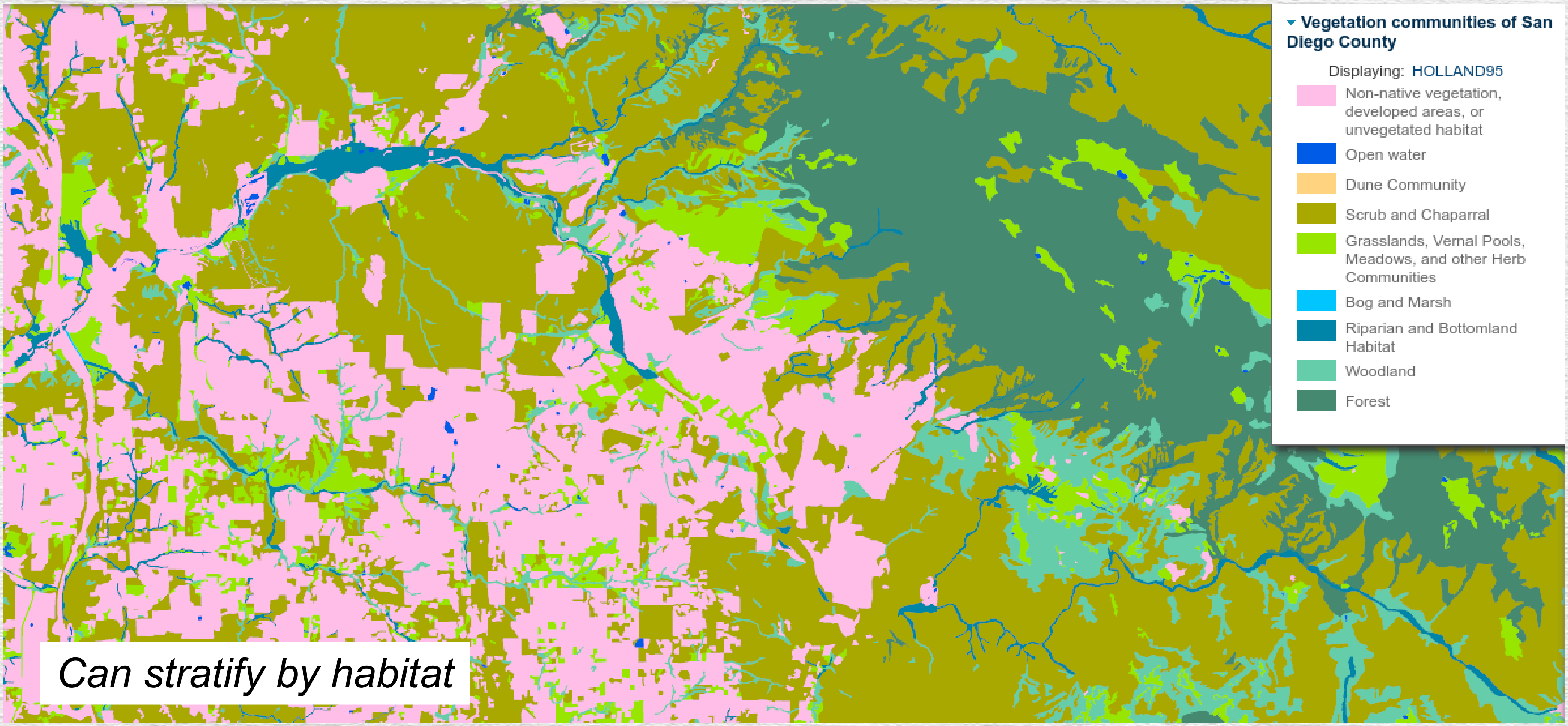

© Michael & Richard
Webster

Territory mapping in breeding birds





Within an area, or within suitable habitat within an area?



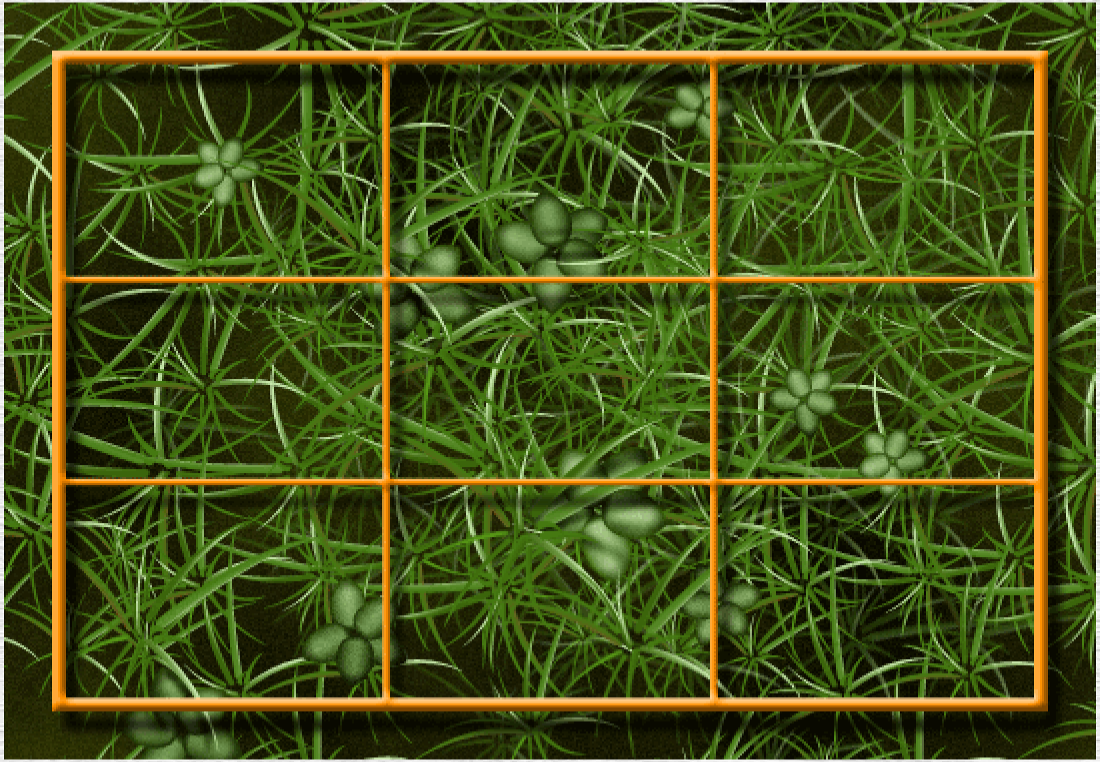
Methods for the very dense

- Species that reach really high density can't be counted over large areas
- Instead, many samples within small sampling areas (quadrats) are obtained
  - Number counted/area of quadrat is the density
  - Multiple quadrats → estimate of standard error, confidence interval

In or out?

Individuals per unit area, so don't want to count the same individual in two different plots

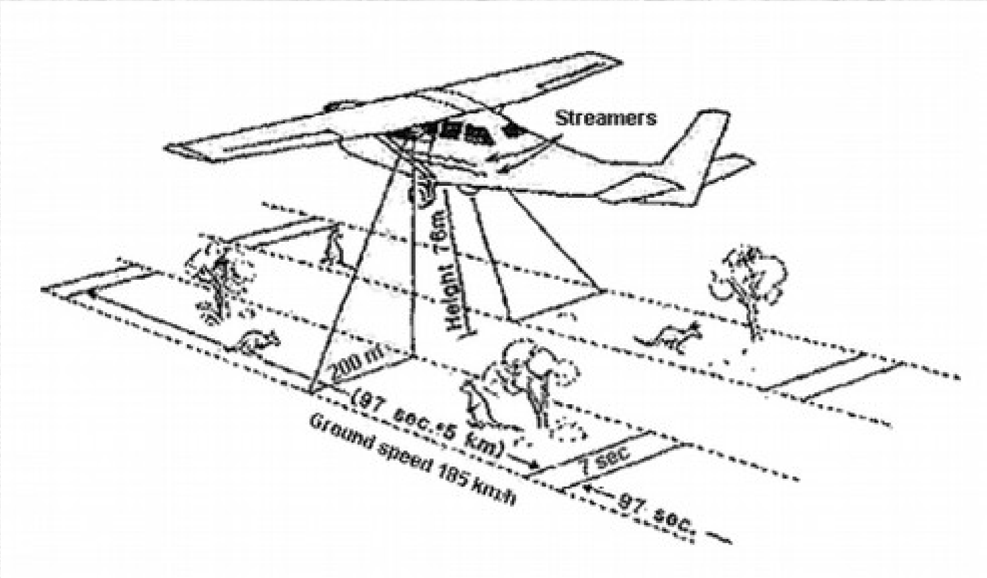
Need rules for deciding a) what's an individual?, and b) is it in or out?



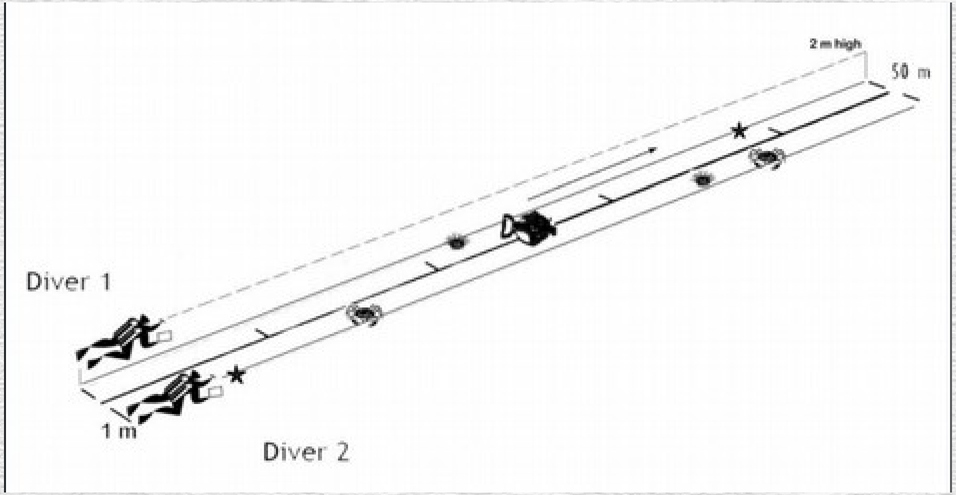
Estimating densities of less abundant organisms

- Organisms that are less dense can be estimated by counting numbers over a larger area
- The area has to be large enough to include a reasonable number of individuals
  - Avoid 0's
  - Larger area → more consistent counts
- To estimate density within a habitat, the size of the sampled area is restricted by the sizes of the habitat patches

Fixed width surveys



$$\hat{D} = \frac{n}{L\,2\,w}$$



Elephant census video

https://youtu.be/imvehfydUpc

Problem: detectability

- Surveys almost never count every single individual
- Chance of detection declines as distance from the observer increases

How many deer?

Problem: net movements in or out of the area

- Don’t want more animals entering than leaving during the count, or vice versa
- This can be a problem if:
  - They are migrating
  - The observer is affecting their movements (flushing)
- Best if counts are instantaneous, or at least are done over as short a time as possible

Distance sampling

- Another way of estimating density uses the fact that detection probability tends to drop off with distance
  - For each individual seen, record the distance from the transect line
  - Find a function that describes the drop-off in detections with distance, correct the count for missed animals
- Advantage of distance sampling
  - Direct estimate of density
  - Does not require a fixed area to be defined

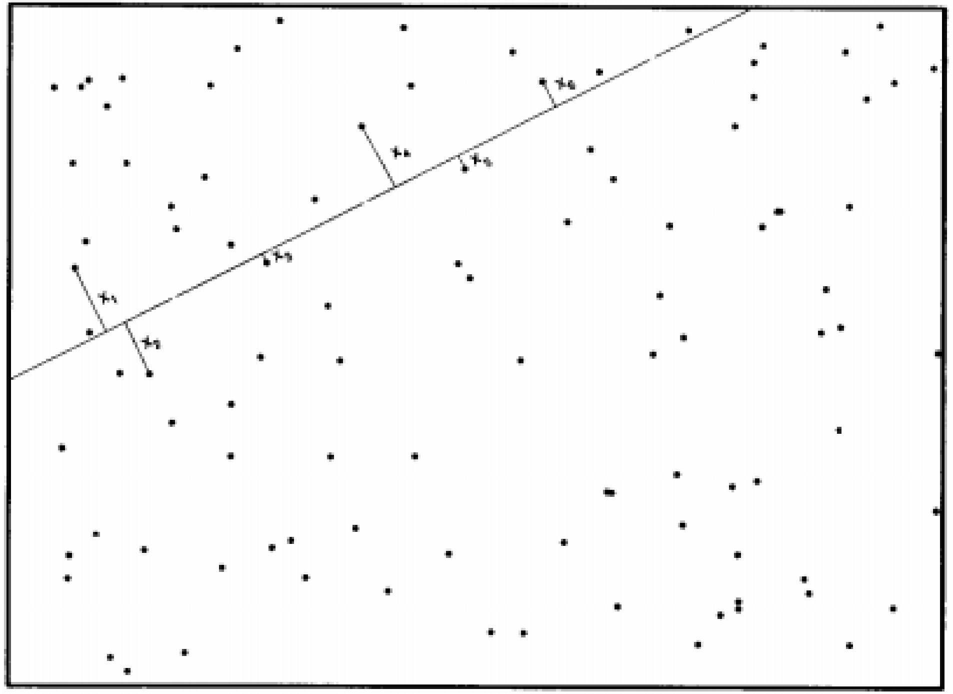


Fig. 1.2. Line transect sampling approach with a single, randomly placed, line of length L. Six objects ($n = 6$) were detected at distances $x_1, x_2, \ldots, x_6$. Those objects detected are denoted by a line showing the perpendicular distance measured. In practical applications, several lines would be used to sample the population.

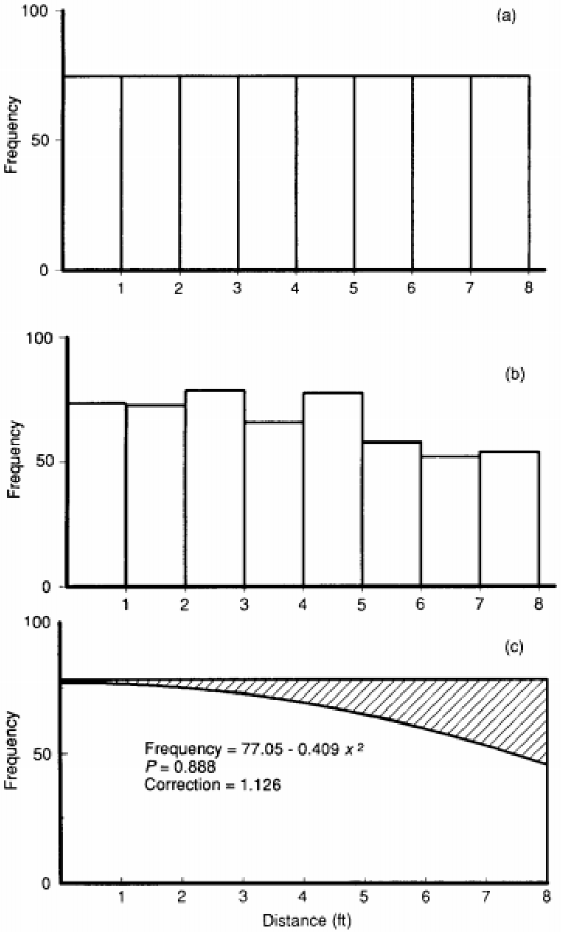


Fig. 1.10. Conceptual basis for line transect sampling: (a) the expected number of objects detected in eight distance classes if no objects were left undetected; (b) real data where a tendency to detect fewer objects at greater distances from the line can be noticed; (c) simple methods can be used to estimate the proportion of the objects left undetected (shaded area). The proportion detected, P, can be estimated from the distance data.

Assumptions of distance sampling

- Assumptions needed for the detection function to be accurate:
  - Either:
    - Probability of detection on the line is 1, or…
    - The probability of detection on the line is known
  - The population sampled around the line has the same density as the population on the line
  - Animals do not approach or flee from the observer
  - Individuals are independently sampled
- If these are true, distance sampling gives unbiased estimates of population density

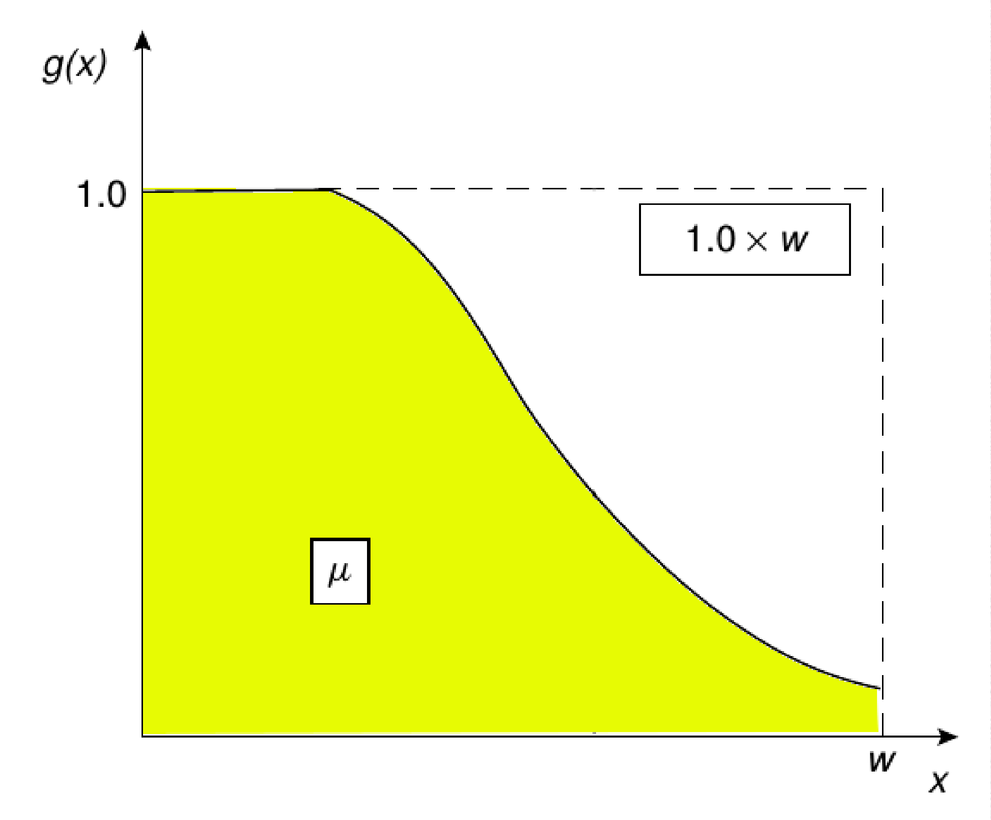
The model

g(x) is the probability of a detection at distance x, set to 1 at g(0)

w is the maximum distance observable

The area under the curve in yellow, μ, are the detections

μ/w = P = the probability of a detection of an animal in the count

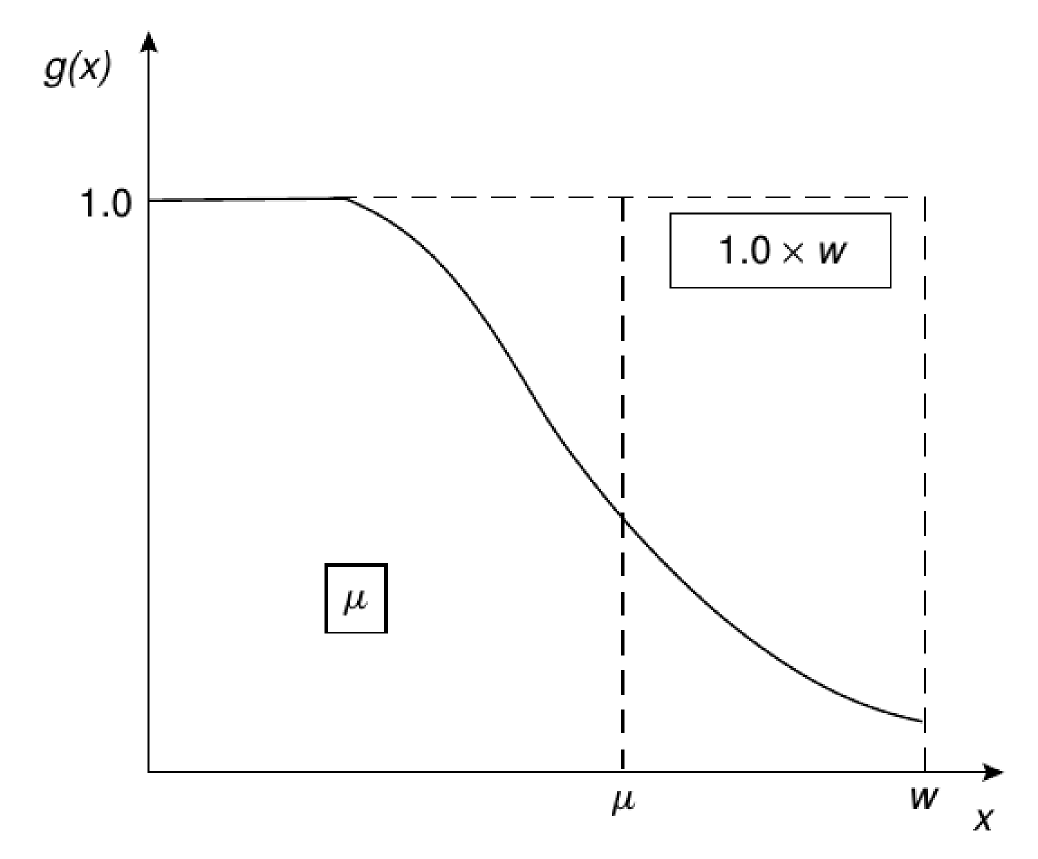


μ is also the effective transect width

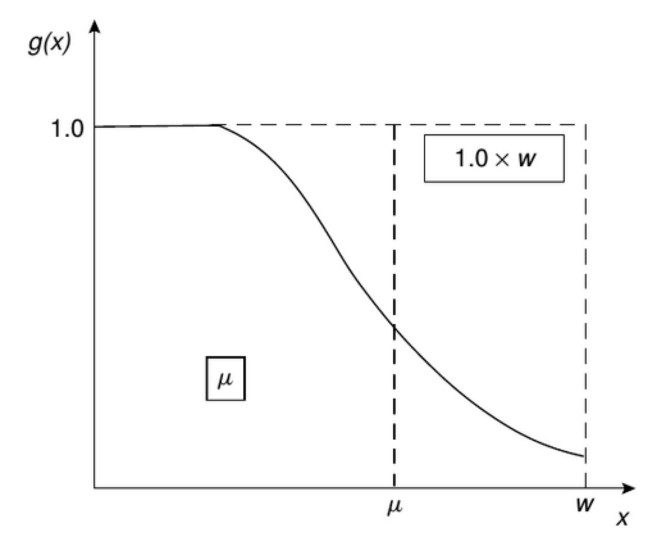
μ is the effective transect width = equivalent width of a transect with perfect detectability

$$\hat{D} = \frac{n}{L\,2\hat{\mu}}$$

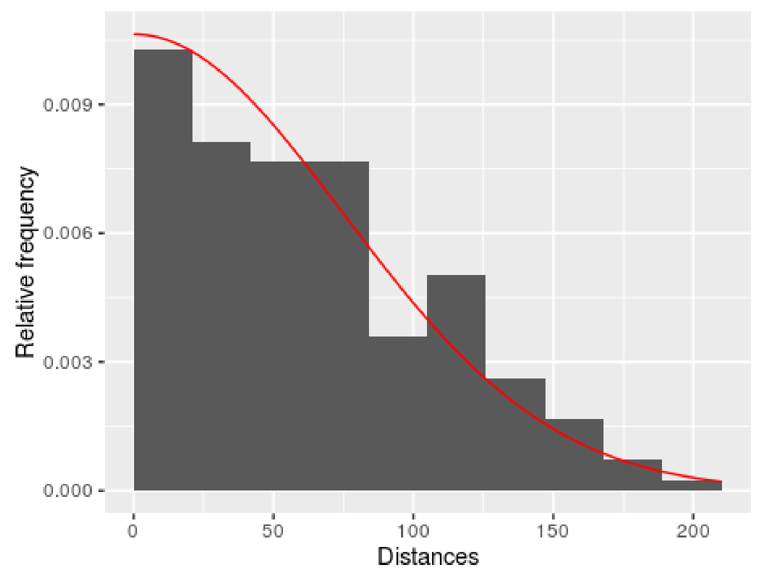
Simple enough, but how do you know μ?



Finding $\hat{\mu}$



Detection function, g(x) – maximum at 1, area under curve is $\hat{\mu}$



Probability distribution, f(x) – area under curve is 1

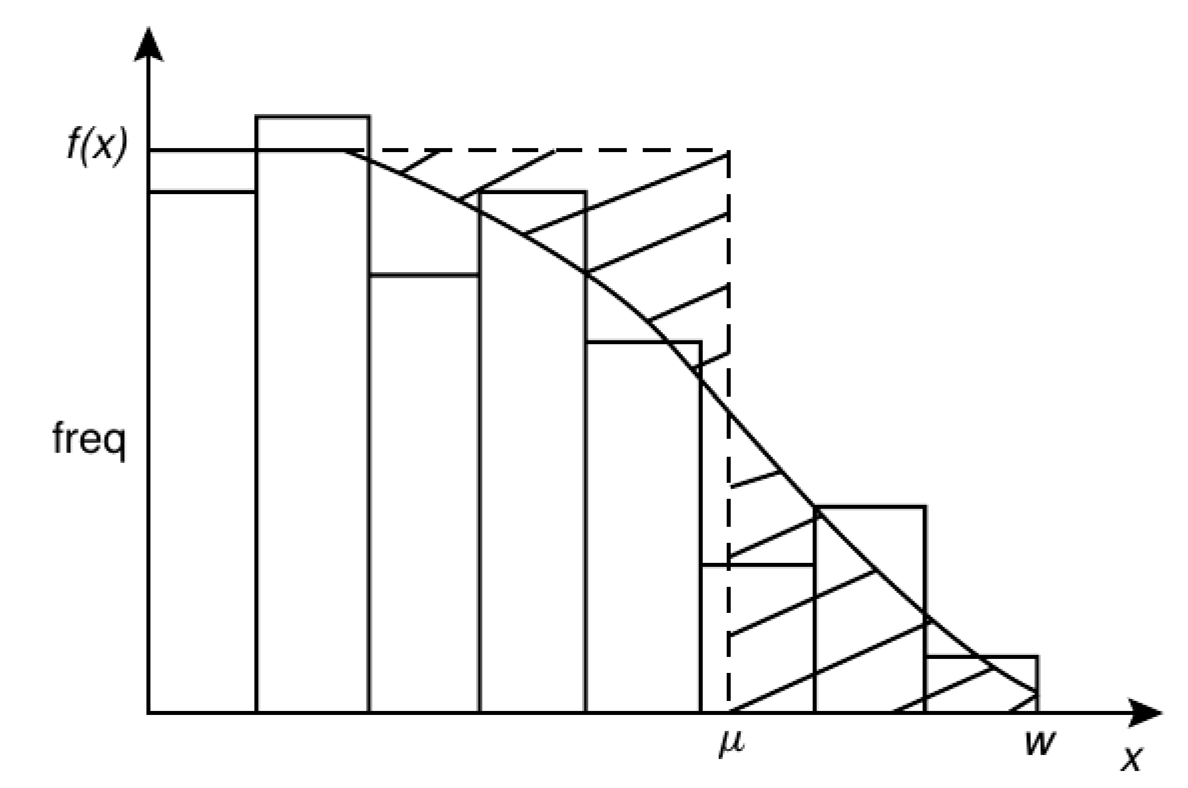
$$\frac{g(0)}{\hat{\mu}}=\frac{f(0)}{1},\ \ \frac{1}{\hat{\mu}}=f(0),\ \ \hat{\mu}=\frac{1}{f(0)}$$

The estimator

$$\hat{D} = \frac{n f(0)}{2L}$$

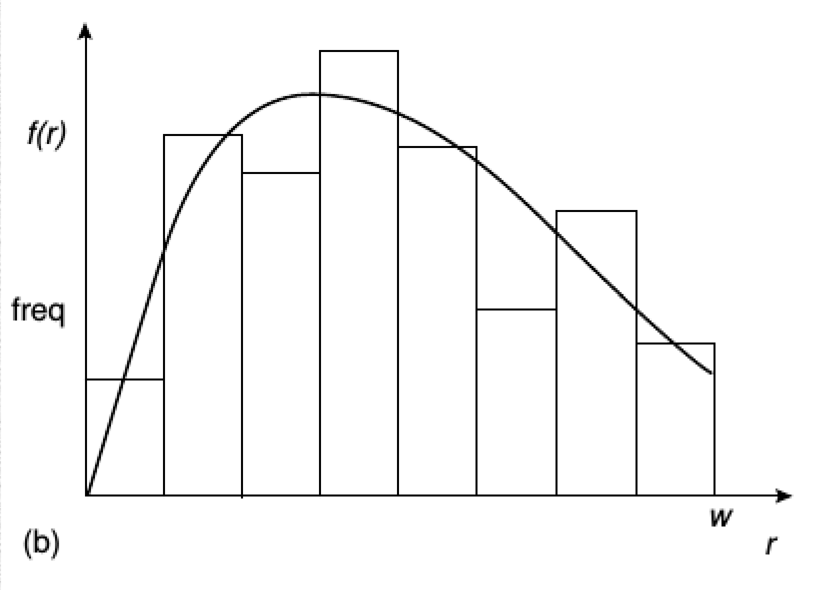
Once f(x) fitted, evaluate at 0 to estimate the density

Estimate the effective width as 1/f(0)



Distance sampling at points

- Area sampled is a circle around the center, rather than a rectangle
- The probability of detection at the point center is 1
- But, the center of the plot is a point, with area of 0
- Even though the probability of detection declines with distance, the area sampled increases



- This leads to a peak in detections some distance from the center

Densities at points

$$\hat{D} = \frac{n}{k \pi w^2 P}$$

n is total detections

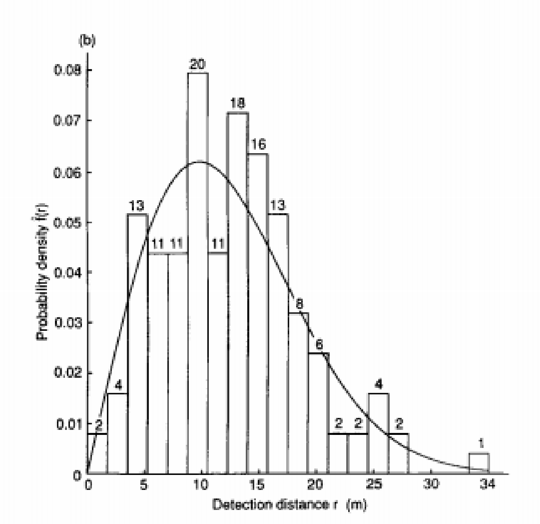
k is the numbers of points sampled

w is the maximum detection distance

P is the probability of detection

$$\hat{D} = \frac{n \hat{f}'(0)}{2 \pi k}$$

First derivative of the probability density function



Measuring the distances

- How, exactly?
  - Move/hide
  - Acoustic detections
- Distance sampling still improves on fixed-width transects if the distance measures are not very good
- Perpendicular distance needed, but can measure distance and direction, calculate perpendicular later
- Can use:
  - Tape measure
  - Pace
  - Optical range finder
  - Educated guess (usually binned distances)