Monitoring populations

An introduction

Ophélie Couriot
Postdoc at the Gurarie Wildlife Ecologie Lab
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ESF

Mark-Recapture

- Technique used to study the population vitals, by focusing on the individual
- Estimation of the population's:
  - Size
  - Survival rate
  - Growth rate
  - Recruitment rate…

How does that work?

- Capture of individuals at time *t*
  - In their reproduction area, their wintering area, along their migration route…
  - using traps, nets, tele-anesthesia…
- Mark the individuals
  - Using paint, ring, tag, collar, chip, transponder…
- Release the individuals at the capture site
- Re-capture the individuals at time *t+1*
  - Physically or visually
  - In the same area of the first capture either the same year or the next one

Challenges

- Delineating the study area: the spatial contours of the "*population*"

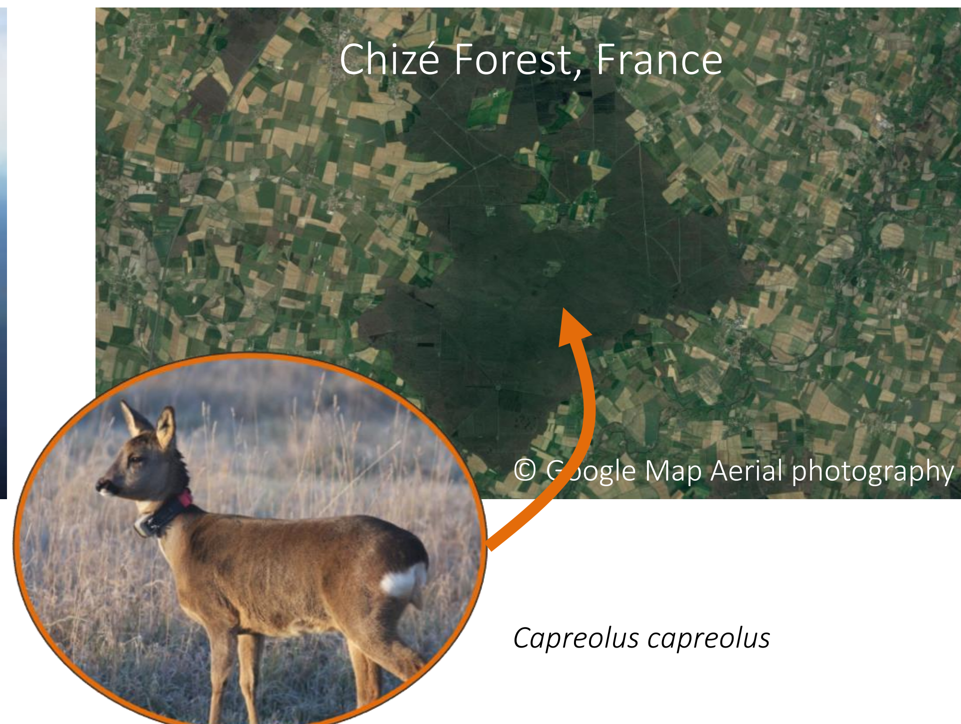
- **Population**: *A group of organisms of the same species occupying a particular space at a particular time [1], that live together and reproduce [2]*

[1] Krebs, Charles J. 1972. Ecology; the Experimental Analysis of Distribution and Abundance. Harper & Row. Biogeography. 694 pages.
[2] Gotelli, Nicholas J. 1998. Paradigms of Population Regulation. Ecology 79: 354-354.

Challenges

- Delineating the study area: the spatial contours of the “*population*”
  - Sometimes easy to determine (island, forest…)

Kanaloa kahoolawensis



Capreolus capreolus

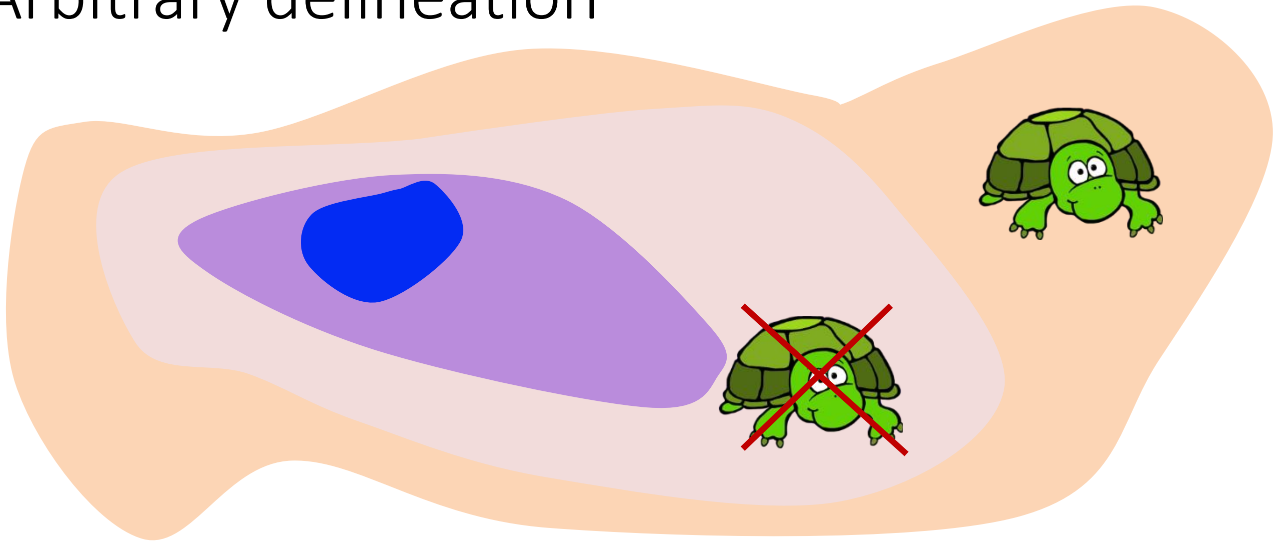
Challenges

- Delineating the study area: the spatial contours of the “*population*”
  - Most of the time it is hard (fragmented habitat)

Challenges

- Delineating the study area: the spatial contours of the *"population"*

  → Arbitrary delineation



The delineation of the spatial contours is done depending on the known presence of the species and the probability of detection of individuals in the area

Challenges

- Choosing the method of capture that is the least harmful for the animal

Nets

Tele-anesthesia

...

Traps

Challenges

- Choosing the type of marking that is the least invasive and the most appropriate to the study
  - Artificial marks

Challenges

- Choosing the type of marking that is the least invasive and the most appropriate to the study
  - Artificial marks





Challenges

- Choosing the type of marking that is the least invasive and the most appropriate to the study
  - Natural marks

Estimate population size

Using Mark Recapture

- When capturing individuals, we usually **underestimate** the number of individuals in the population: because it is very rare to be able to capture **ALL** the individuals from a population

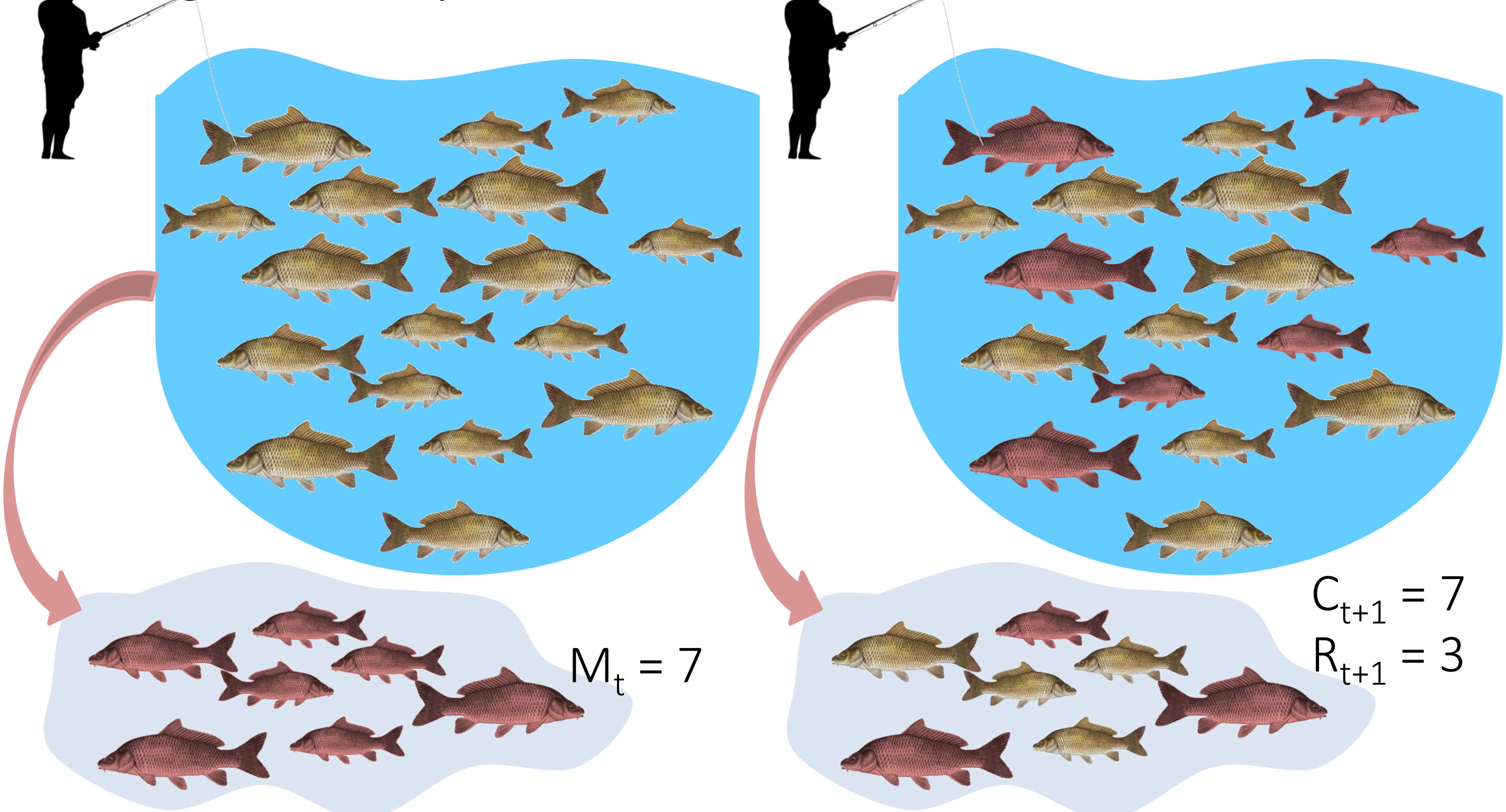
- **Lincoln-Petersen Index**:

$$N_{t+1} = \frac{(M_t * C_{t+1})}{R_{t+1}}$$

  - N_{t+1}: the estimated population size at t+1
  - M_t: the number of individuals captured and marked at t
  - C_{t+1}: the total number of individuals captured at t+1
  - R_{t+1}: the number of individuals marked at t, recaptured at t+1

Estimate population size

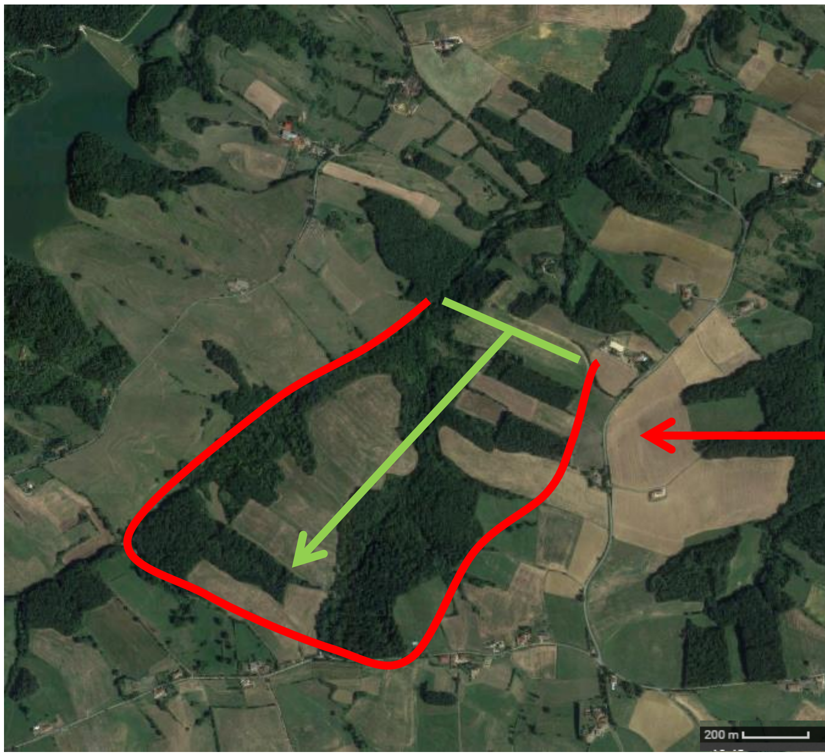
Using Mark Recapture

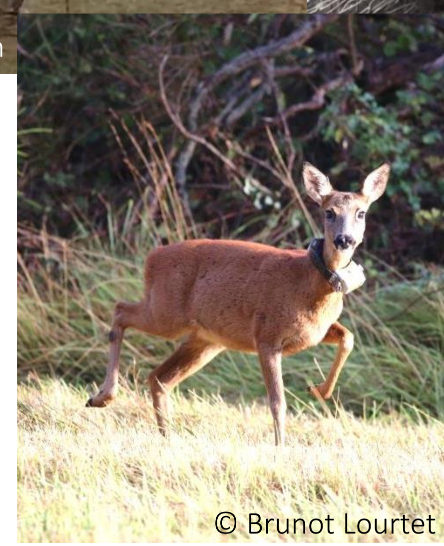


$$N_{t+1} = \frac{(M_t * C_{t+1})}{R_{t+1}} = \frac{(7 * 7)}{3} = 16.33 \rightarrow \text{No half fish! } \mathbf{N = 17}$$

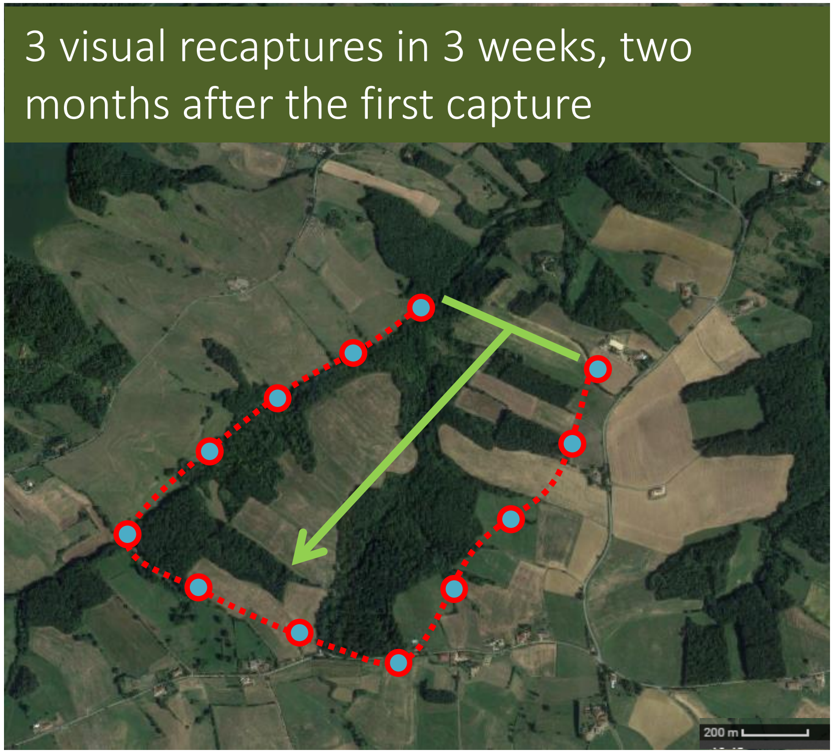
Example: Population density of Roe deer in the South of France

Roe deer (*Capreolus capreolus*) captured in an area using nets and equipped with GPS collars





Example: Population density of Roe deer in the South of France



2018

	M_t	C_{t+1}	R_{t+1}
Recapture 1	8	43	6
Recapture 2	8	30	5
Recapture 3	8	22	5

Example: Population density of Roe deer in the South of France

- Lincoln-Petersen Index:
- $N_{t+1} = \frac{(M_t * C_{t+1})}{R_{t+1}}$ $$D = \frac{N}{A}$$

	M	*C*	*R*	*N*	*A (km²)*	*D (per km²)*
Recapture 1	8	43	6	57	2.15	26.51
Recapture 2	8	30	5	48	2.15	22.33
Recapture 3	8	22	5	35	2.15	16.28

D	*95%CI*	*MIN*	*MAX*
21.71	10.08	11.63	31.79

Estimate other parameters

- Gathering data over several years, with one capture session every year

- Capture-recapture history of an individual

0011011000

Animal not captured years 8, 9 & 10

Animal recaptured years 6 & 7

Animal not captured years 1 & 2

Animal recaptured year 4

Animal not captured year 5

Animal captured year 3

Mark-Recapture data

1	0 0 0 1 1 0 0 0 0 1
2	1 0 0 0 1 1 1 1 0 0
3	0 0 0 0 0 1 0 1 0 0
4	0 0 0 1 0 0 1 0 0 0
5	0 0 0 0 0 0 0 1 0 1
6	1 1 0 1 0 1 0 1 1 0
7	0 0 1 0 0 0 0 0 0 0
8	0 1 0 1 1 0 0 0 1 0
9	0 0 0 1 1 1 0 0 0 0
10	0 0 1 1 0 0 0 0 1 0
11	0 0 0 0 0 0 0 0 0 1
12	0 0 0 1 0 0 1 1 0 0
13	0 0 1 0 0 0 0 0 0 0
14	0 0 0 0 1 0 0 1 0 1
15	0 0 0 0 0 0 0 0 0 1

- Mark Recapture data on several years allows to estimate population size with a higher precision, but also:
  - Probability of detection
  - Probability of recapture
  - Survival rate
  - Growth rate
  - Recruitment rate…

For example: $\Phi_t = \frac{R_{t+1}}{N_t}$

Φ_t = Survival between t and t+1

N_t = Number of individuals captured and marked at t

R_{t+1} = Number of individuals marked at t, captured at t+1

Mark-Recapture data

1 0 0 0 1 1 0 0 0 0 1
2 1 0 0 0 1 1 1 1 0 0
3 0
4
5
6
7
8
9
10
11
12
13 0
14 0 0 0 0 1 0 0 1 0 1
15 0 0 0 0 0 0 0 0 0 1

- Mark Recapture data on several

The more data (number of animals captured and years of monitoring) the more accurate the estimations

For example: $\Phi_t = \frac{R_{t+1}}{N_t}$

Φ_t = Survival between t and t+1

N_t = Number of individuals captured and marked at t

R_{t+1} = Number of individuals marked at t, captured at t+1

Analysing Mark-Recapture data

- MARK (White and Burnham 1999)
- POPAN (Neil Arnason & Carl Schwarz)
- M/E-SURGE (J.D. Lebreton, R. Pradel, R. Choquet)
- JOLLY – JOLLYAGE (Pollock et al. 1990)
- CAPTURE (Rexstad & Burnham 1978)
- RELEASE (Burnham et a. 1987)
- DISTANCE (Laake et al. 1999)
- SURVIV – MSSURVIV –RDSURVIV –ORDSURVIV – TMSURVIV-MSSRVMIS
- MSSRVRCV – SPECHRICH, COMDYN (J.D. Nichols, W. l. Kendall & J. Hines)

Mark-Recapture

- Pros:
  - Allows to estimate life history traits without having to count every individuals in the area
  - Large diversity of models to estimate population dynamics
  - Can be used to study population dynamics of most species
- Cons:
  - Requires a large amount of data for model accuracy
  - Invasive

Distance sampling

- Method allowing to estimate population size and population density
- Relies on the visual capture of individuals, without identification
- Does not require the capture and marking of individuals

Distance sampling: “quadrats”

- Common method for population density estimation: placing quadrats randomly within a delineated area to estimate density within this area

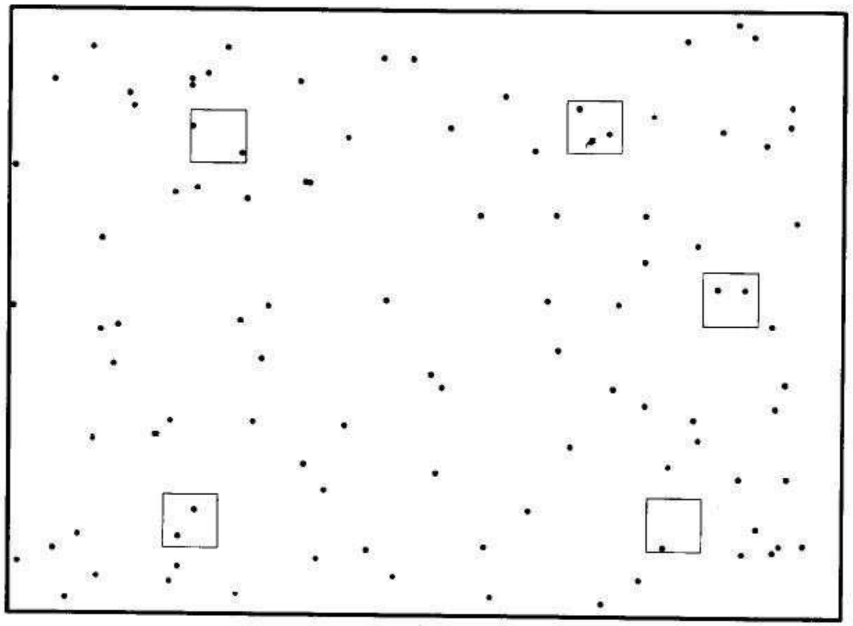


Fig. 1.1. Finite population sampling approach with five 1 m square quadrats placed at random in a population containing 100 objects of interest. $\Sigma a_i = 5$, $\Sigma n_i = 10$, and $\hat{D} = 2$ objects/m^2. In this illustration, the population is confined within a well-defined area. [3]

$$\widehat{D} = \frac{n}{a}$$

$\widehat{D}$: Density
n: number of individuals counted in the quadrats
a: total area of the quadrats in the study area

$$N = \widehat{D} * A$$

N: Population size
$\widehat{D}$: Estimated population density
A: Surface of the total area

[3] Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London. 446pp.

Distance sampling: “line transect”

- Lines are randomly placed within a delineated area to estimate density or population size within this area

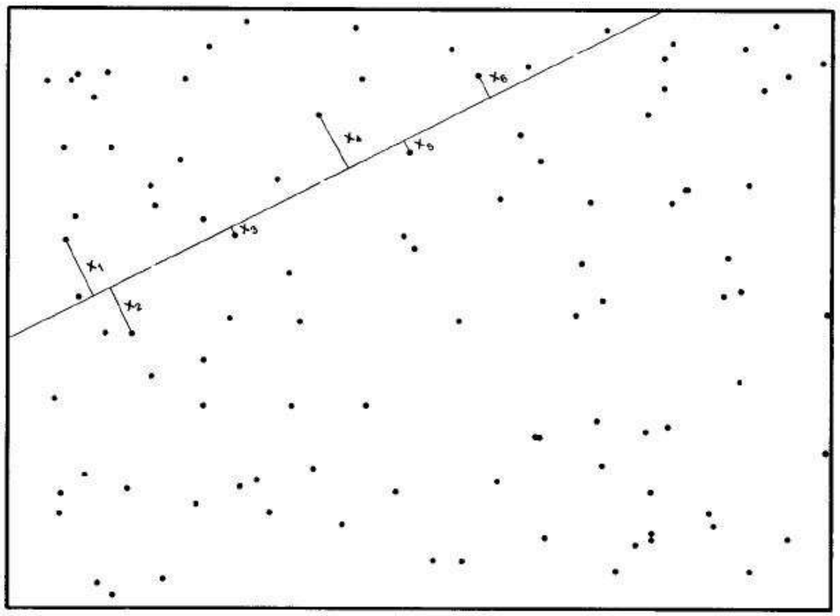
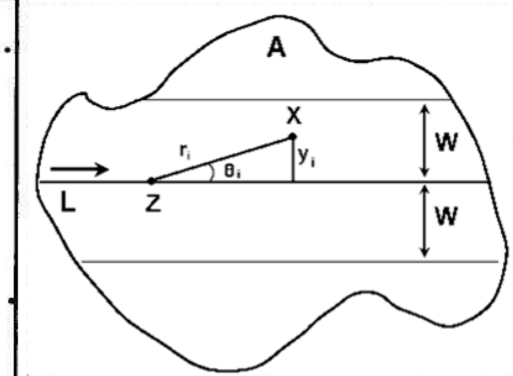


Fig. 1.2. Line transect sampling approach with a single, randomly placed, line of length L. Six objects ($n = 6$) were detected at distances $x_1, x_2, \ldots, x_6$. Those objects detected are denoted by a line showing the perpendicular distance measured. In practical applications, several lines would be used to sample the population.[3]



A: Delineated area
L: Total transect line
Z: Position of observer
X: Position of object
W: Strip width (maximum pre-determined distance)
R_i: Sighting distance
$\boldsymbol{\theta_i}$: Sighting angle
Y_i: Perpendicular distance

$$\widehat{D} = \frac{n}{2LW}$$

$$N = \widehat{D} * A$$

[3] Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London. 446pp.

Distance sampling: "line transect"

- Can have several parallel lines within the area
- In that case $L = \sum_{i=1}^{n} l_i$

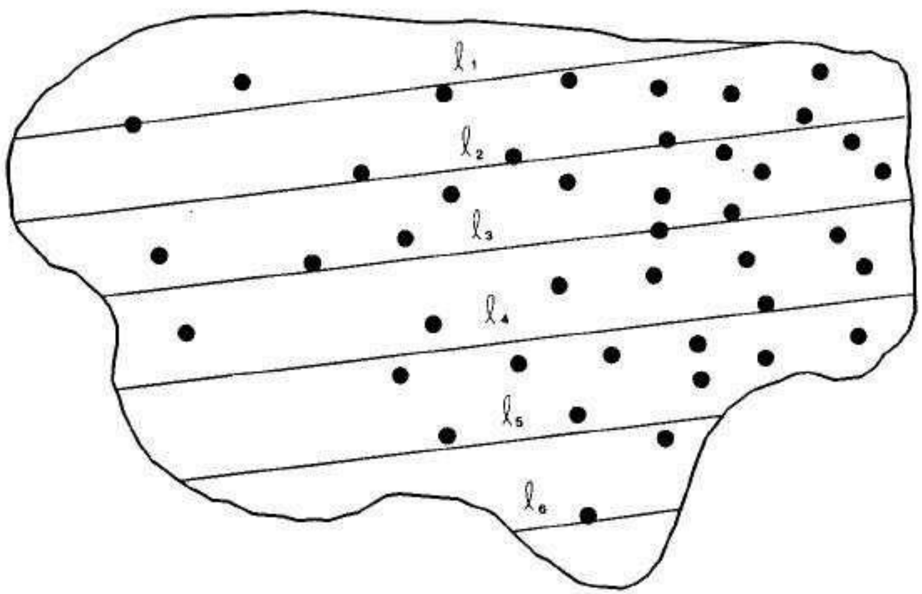


Fig. 1.4. A population of objects with a gradient in density is sampled with lines parallel to the direction of the gradient. In this case, there are $k = 6$ lines of length $l_1, l_2, \ldots, l_6$, and $\sum l_i = L$.[3]

$$\hat{D} = \frac{n}{2LW}$$

$$N = \hat{D} * A$$

[3] Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London. 446pp.

Distance sampling: “point transect”

- Random points within the delineated area
- The observer record the distance from the each sighted individual and the point from where the observation has been done

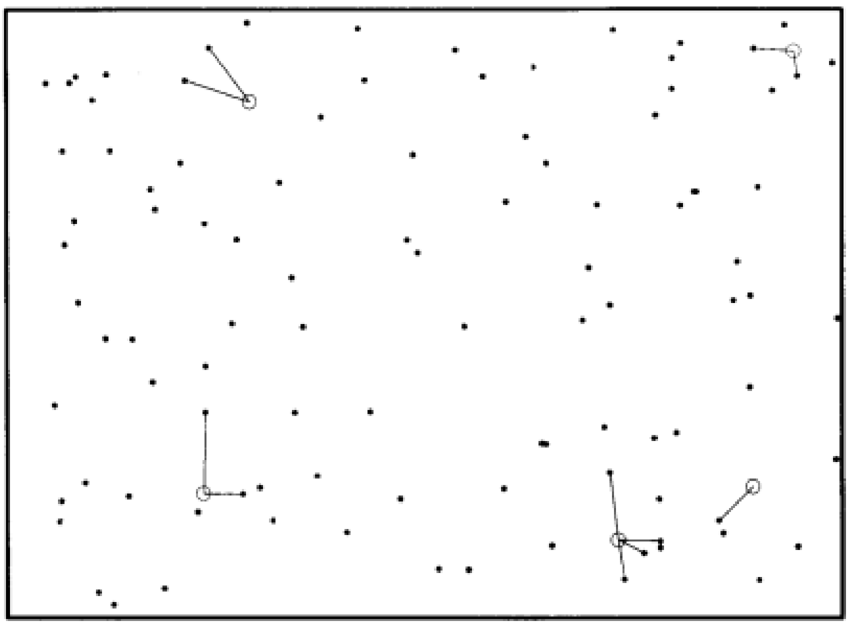
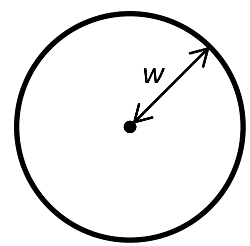


Fig. 1.3. Point transect sampling approach with five randomly placed points (k = 5), denoted by the open circles. Eleven objects were detected and the 11 sighting distances $r_1, r_2, \ldots, r_{11}$ are shown. [3]



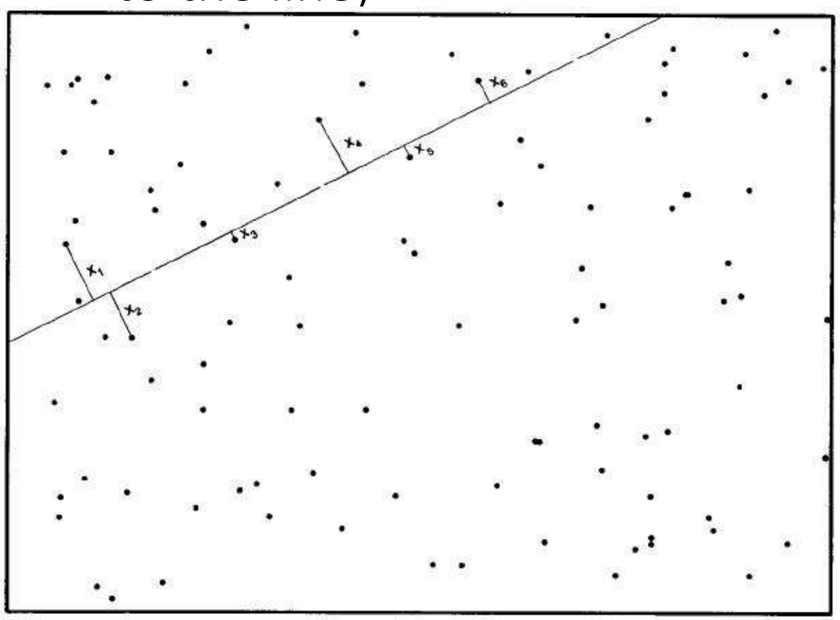
$$\hat{D} = \frac{n}{\pi w^2}$$

$$N = \hat{D} * A$$

[3] Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London. 446pp.

Distance sampling: detection function

- Based on the data, a probability density function f(x) can be developped (the probability of detecting an object given its distance to the line)



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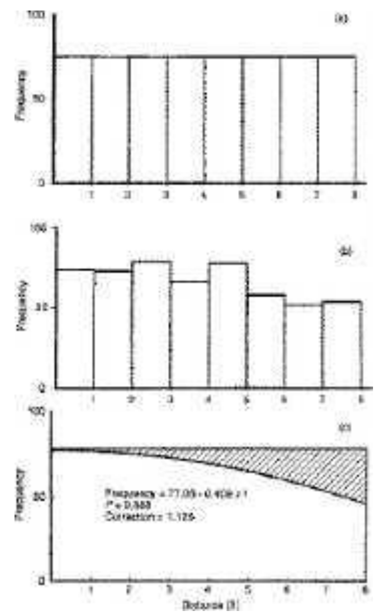

The detection is the same whatever the distance

The detection decreases with distance to the line

Detection function

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

$$N = \hat{D} * A$$

[3] Buckland, S.T., Anderson, D.R., Burnham, K.P. and Laake, J.L. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London. 446pp.

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