Mark-Recapture
for monitoring populations
An introduction

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How do we monitor populations?

- Distance sampling
- Mark-Recapture

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

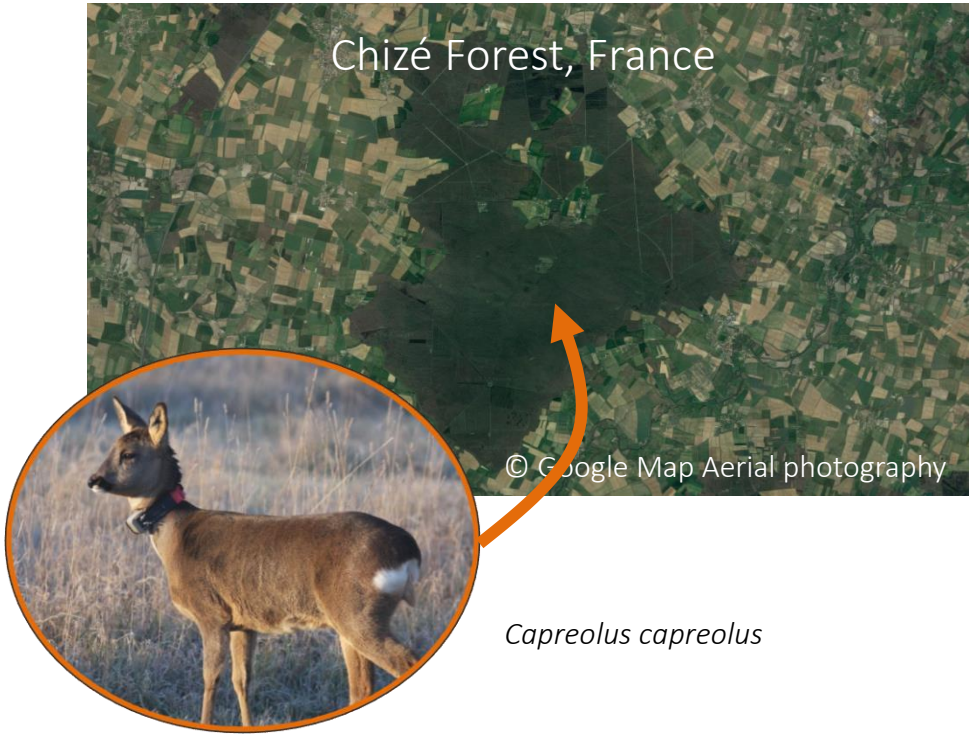
- Delineating the study area: the spatial contours of the "*population*"

- **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…)



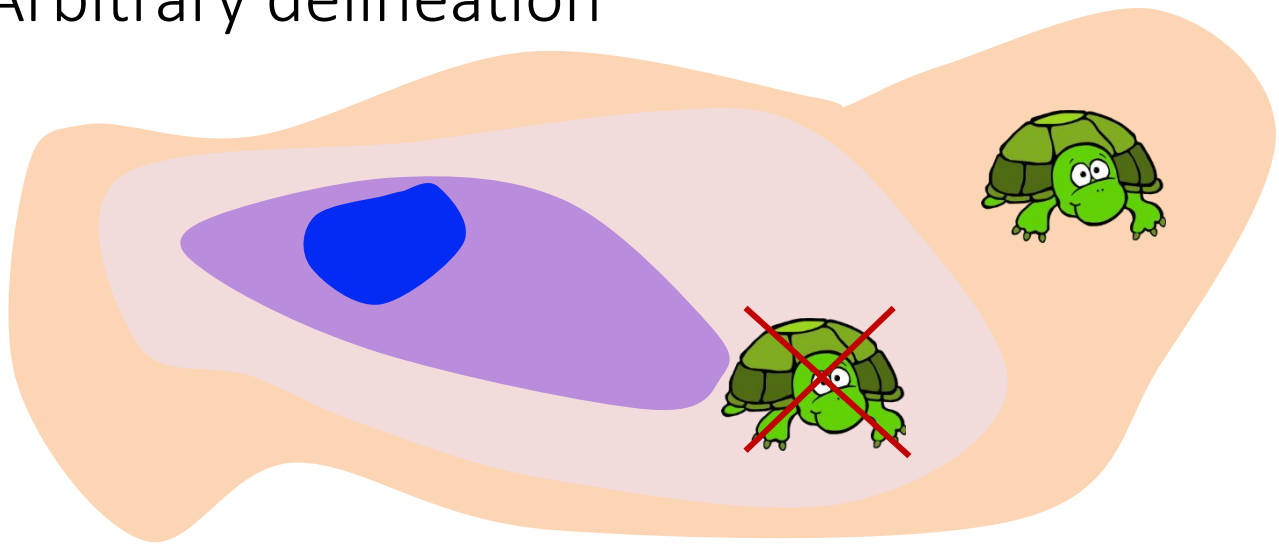
Challenges

- 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

Tele-anesthesia

...

Traps

Challenges

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

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Challenges

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





Estimating 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

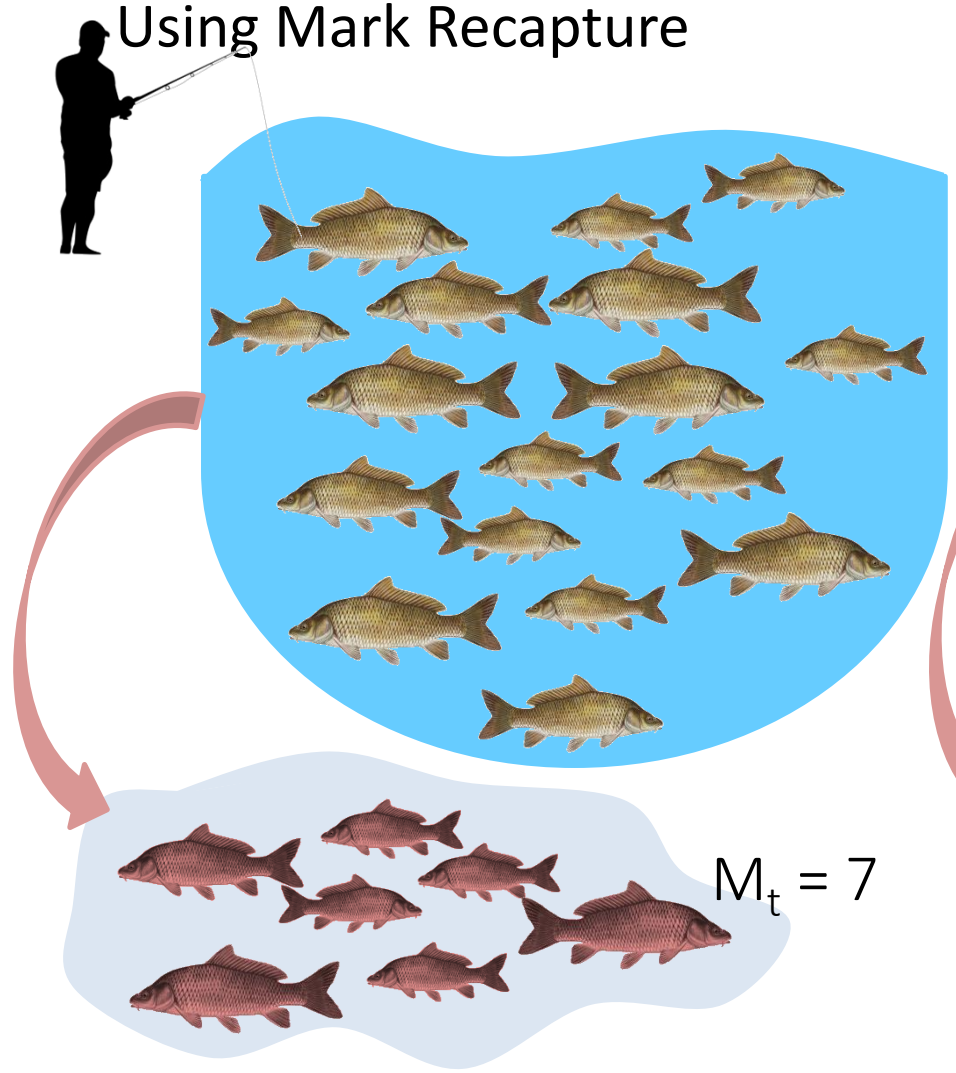
- **Lincoln-Petersen Index**:

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

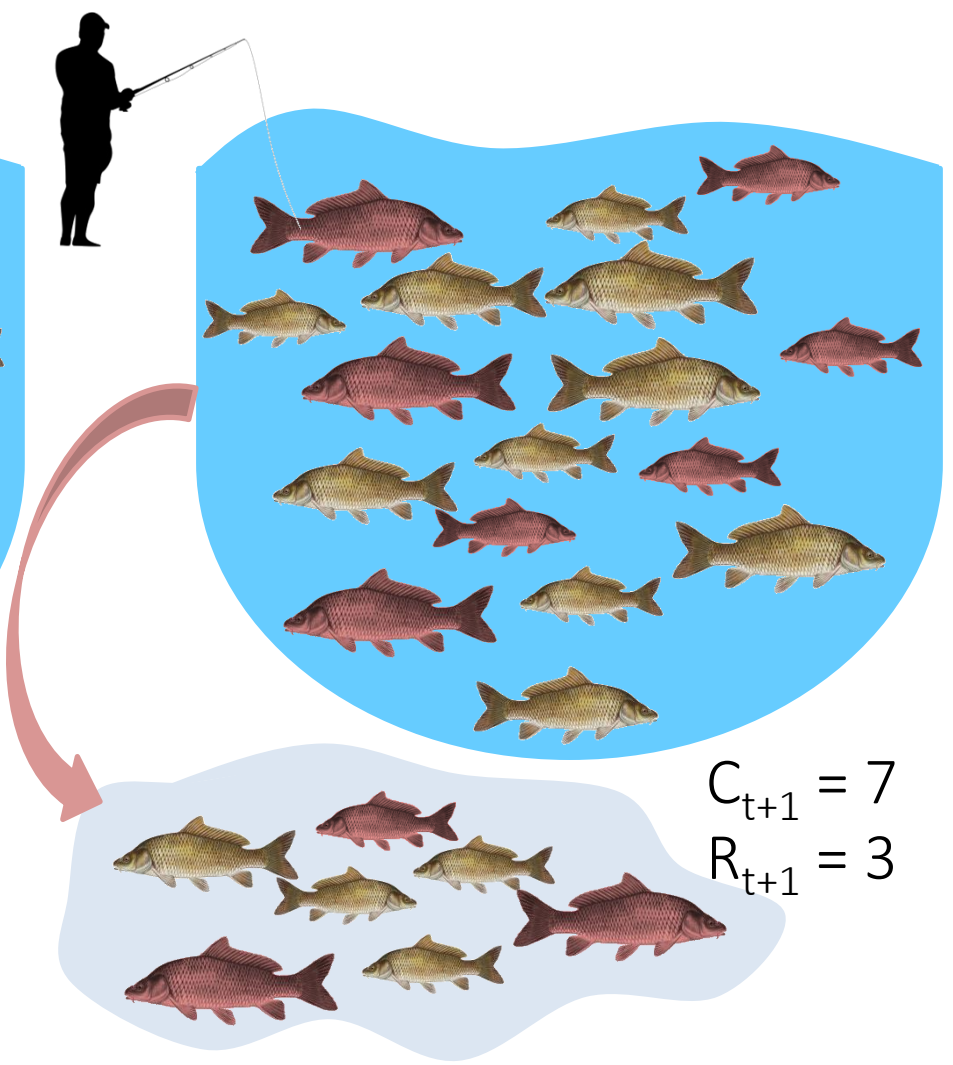
  - N_{t+1}: the estimated population size at t+1
  - M_t: the number of individuals captured and marked at t
  - C_{t+1}: the total number of individuals captured at t+1
  - R_{t+1}: the number of individuals marked at t, recaptured at t+1

Estimate population size

Using Mark Recapture



$M_t = 7$

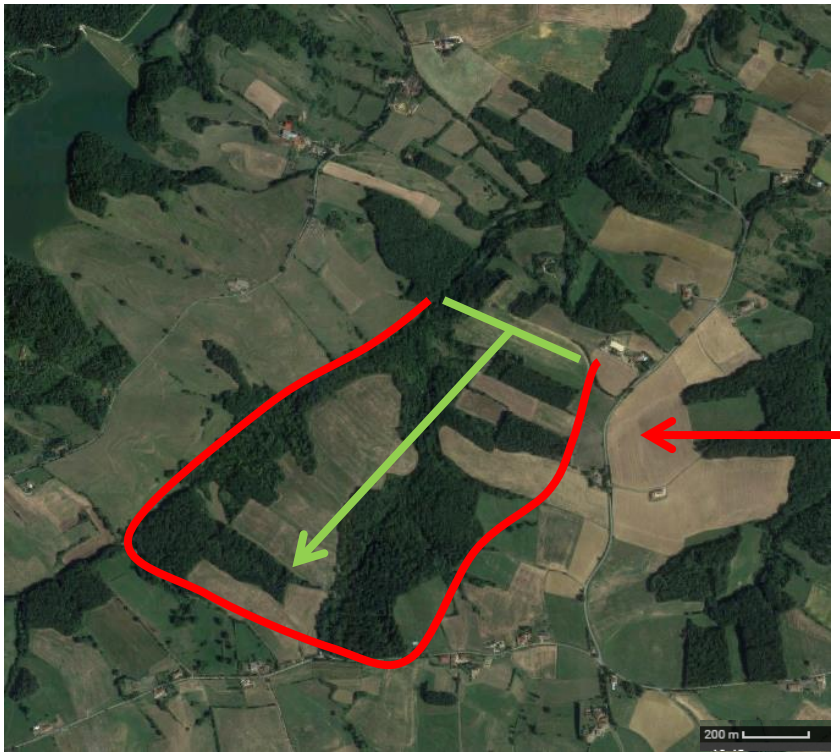


$C_{t+1} = 7$

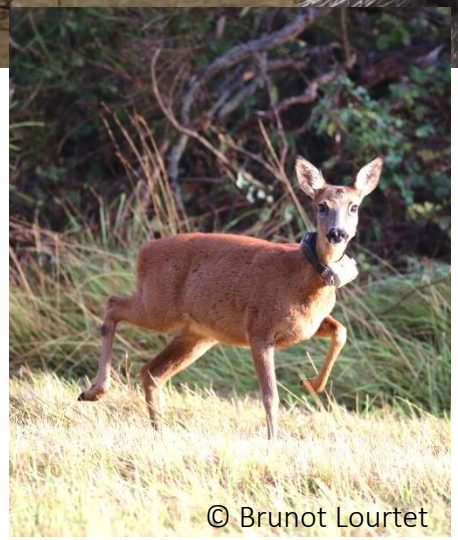
$R_{t+1} = 3$

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

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



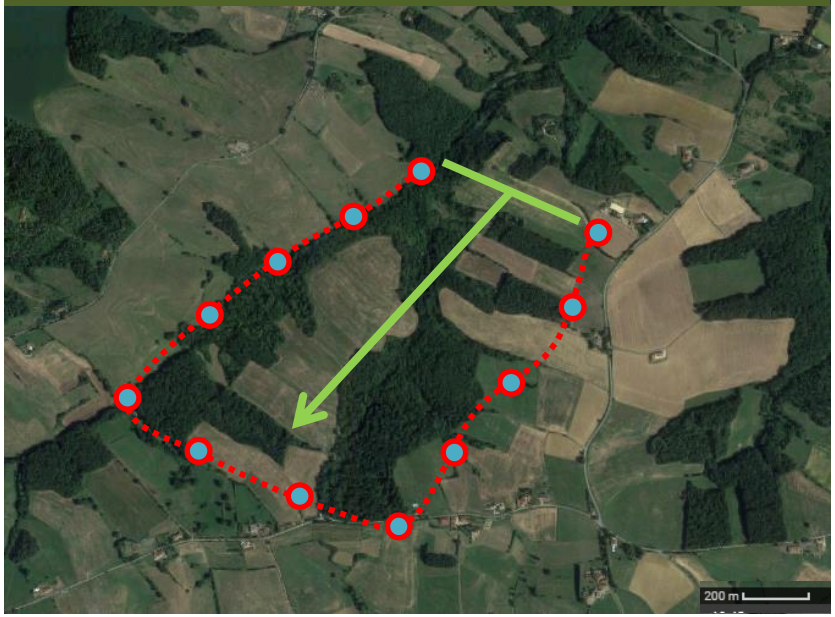
Roe deer (*Capreolus capreolus*) captured in an area using nets and equipped with GPS collars



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

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

3 visual recaptures in 3 weeks, two months after the first capture



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:

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

$$D = \frac{N}{A}$$

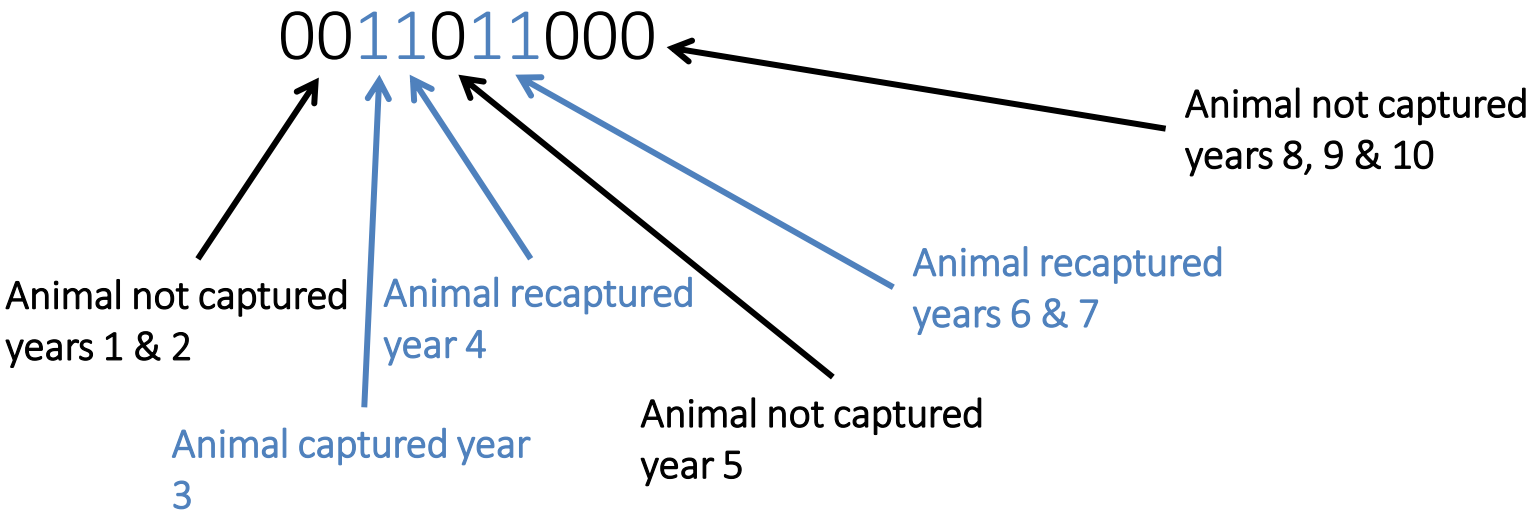
	M	*C*	*R*	*N*	*A (km²)*	*D (per km²)*
Recapture 1	8	43	6	57	2.15	26.51
Recapture 2	8	30	5	48	2.15	22.33
Recapture 3	8	22	5	35	2.15	16.28

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



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