Sampling techniques for studying non-volant terrestrial mammals

ECM – T5

2024/2025 – Miguel Rosalino

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Sampling strategies

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Core research questions in Ecology and Conservation

- How animals occur throughout the landscape?
- How many individuals are there?
- Which is the population trend?
- Why populations evidence those trends?

Sampling strategies

Different resolution levels:

1. Where animals occur? **Distribution**
2.
3.
4.

Sampling strategies

ECM

Different resolution levels:

1. Where animals occur? **Distribution**

2. How many individuals are there? **Abundance**

Relative

It uses abundance indexes (e.g., number of signs of presence, visitation rates) that can be compared as a function of time or between areas

Absolut

It requires the use of counting methods (censuses) that allow estimating the number or density of individuals in the population

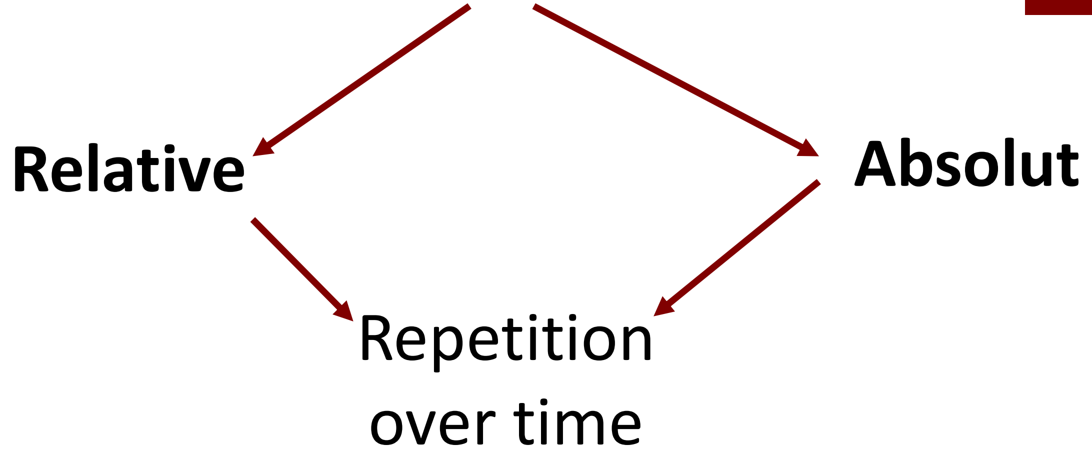
3.

4.

Sampling strategies

Different resolution levels:

1. Where animals occur? **Distribution**
2. How many individuals are there? **Abundance**

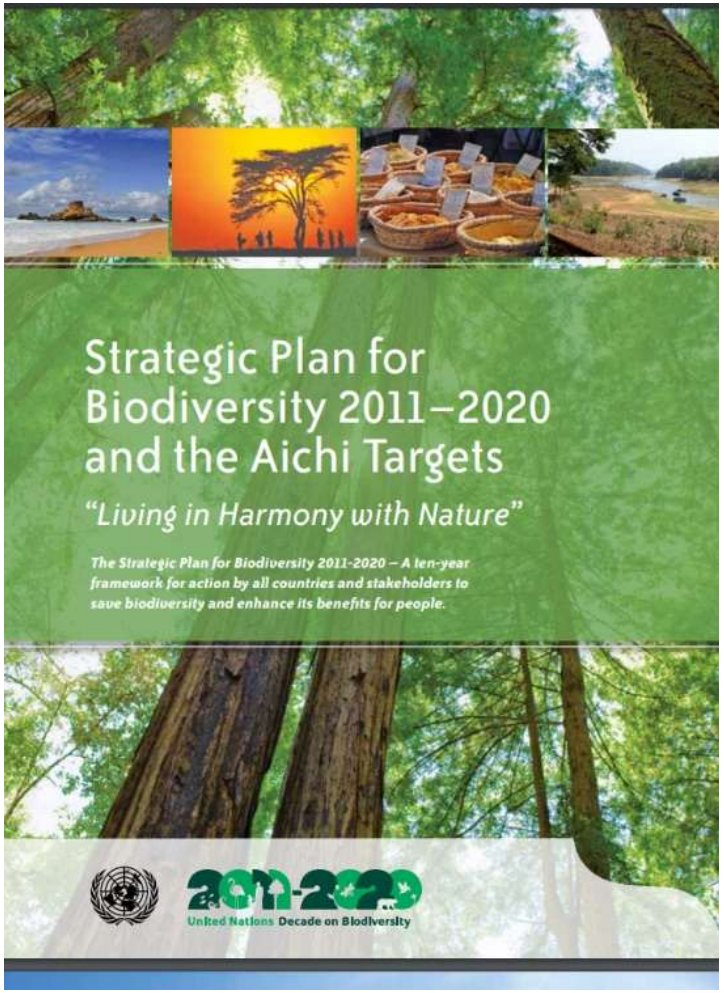


3. Which is the population trend? **Monitoring**
4.

Sampling strategies

Why monitoring animal populations is important?

- Only way to evaluate the effect of **impacts** and the effectiveness of **conservation programs**
- Needed to provide knowledge to conservation strategies at regional and national or global scales (e.g., United Nations Biodiversity Convention, Sustainable Development Objectives, Ecosystem Millenium Assessment)



Sampling strategies

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Conservations needs monitoring, and monitoring needs research

Monitoring	Research	Action	Monitoring
Detecting the problem →	What is the main cause? ↓ What is the solution? →	Test the solution ↓ Implement the solution →	Are the management measures suficient to revert the problem?

← New evaluation

Sampling strategies

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Different resolution levels:

1. Where animals occur? **Distribution**
2. How many individuals are there? **Abundance**
3. Which is the population trend? **Monitoring**

Population trend	**Objective**
Increase	Control
Stable	Sustainable exploitation
Decrease/ regression	Conservation

Management strategies → Sustainable exploitation

4.

Sampling strategies

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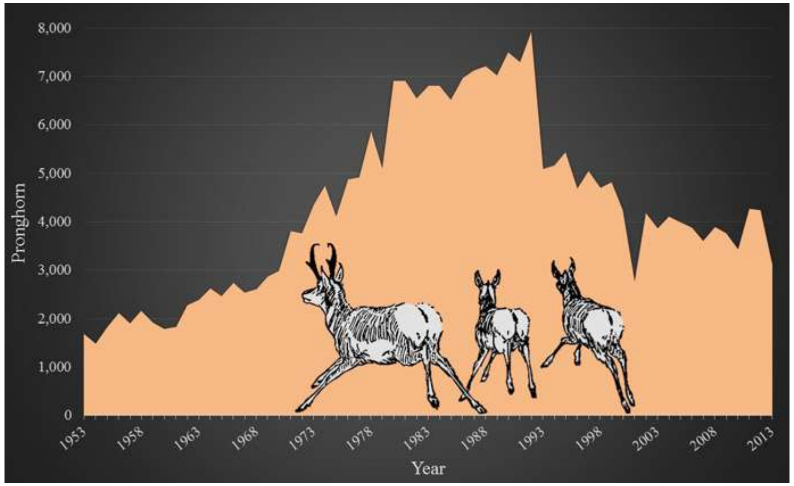
Different resolution levels:

1. Where animals occur? **Distribution**
2. How many individuals are there? **Abundance**
3. Which is the population trend? **Monitoring**
4. Why populations evidence those trends, i.e. why the stability or the change? (demographic processes) **Research**

↑ → ↓



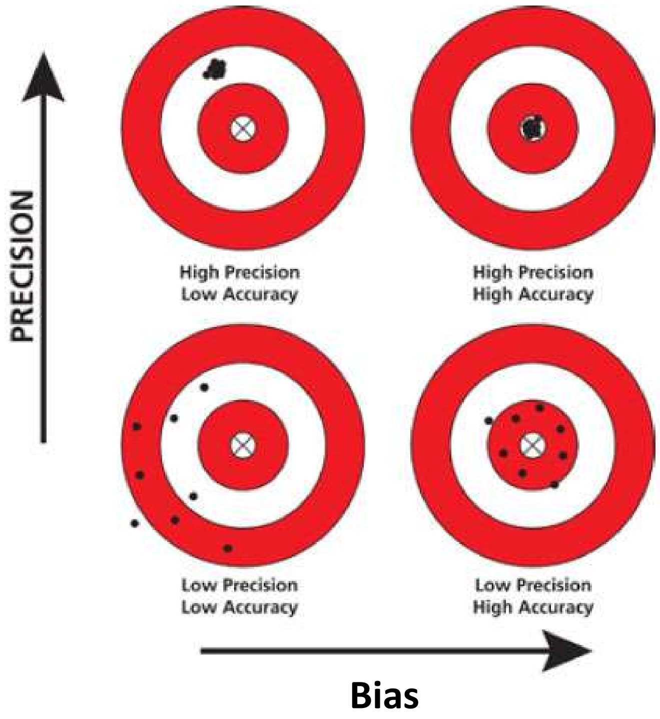
Sampling methods

ECM

Sampling methods may be direct or indirect and vary according to a gradient of:

- **Precision** (how similar are the measured values, e.g. SD values)
- **Bias** (how close is the estimate of the actual value)
- **Cost**

The selection of the method depends on the issue under analysis and the cost-benefit relationship



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Sampling methods

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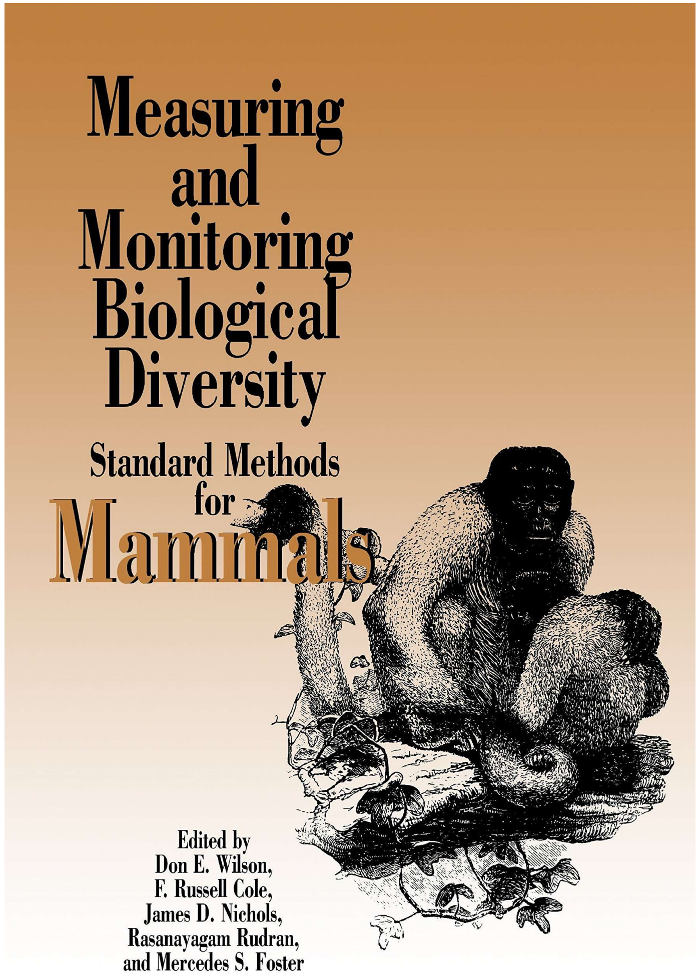
Three fundamental questions in method's selection:

- Probability of observation or capture
- Size of the study area (time and money investment are constraints)
- Available human resources



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Sampling methods

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Mammals can be difficult to study because they often:

- Evidence secretive behaviors
- Show nocturnal habits
- Occupy vast areas
- Prefer areas with high vegetation cover
- Live in low density

Complex census and monitoring approaches

Sampling methods - Indirect

ECM

Questionnaires – face-to-face/oral, written, online

Advantages: non-invasive method, applicable to different scales (including broad scale), low cost

Disadvantages: misidentification of species, reduced response rates, concentration of observations - e.g. along roads, in proximity to houses or areas of concentrated activity

Figure 1. Spotted skunk wanted poster.

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Sampling methods - Indirect

ECM

Questionnaires

Inquérito à População

Muitos fatores têm contribuído para que o lobo-ibérico *(Canis lupus signatus)* seja admirado por muitas pessoas, mas odiado por outras. A falta de esclarecimento, informação e proteção das pessoas tem contribuído para que este problema continue, colocando em risco, ao longo dos anos, a sobrevivência de um ícone da fauna portuguesa.
Um estudo mais elaborado sobre o conhecimento e atitudes do homem face ao lobo constitui assim um meio indispensável para a proteção e esclarecimento das populações, bem como para uma melhor gestão e conservação do lobo-ibérico e seu habitat.
Posto isto, este questionário, no âmbito da dissertação de mestrado em Ecologia Aplicada da aluna Diana Lopes, da Universidade de Aveiro, é uma ferramenta indispensável para o cumprimento destes objetivos.

Solicita-se assim a colaboração de todos para o seu preenchimento.

Idade: ____ Sexo: M☐ F☐ Localidade: ____________
Profissão: ______________ Freguesia: ____________
Habilitações Académicas: ________ Concelho: ____________
Tem gado doméstico? Sim☐ Não☐
(se respondeu 'não' avance para o **Grupo I**)
Tem cães de guarda/gado? Sim☐ Não☐

Grupo I - As seguintes perguntas são sobre experiências pessoais e conhecimento sobre o lobo.
Por favor, assinale a resposta que melhor descreve a sua.

1) Já avistou lobos na sua zona?	Sim	Não
2) Tem conhecimento de ataques de lobos a animais doméstico?	Sim	Não
3) Já sofreu perdas de animais domésticos por ataque de lobos?	Sim	Não
4) Tem conhecimento de ataques de lobos a humanos?	Sim	Não
5) Quando o lobo ataca um animal domestico, o proprietário é sempre compensado?	Sim	Não
6) Já houve reintroduções de lobos em Portugal?	Sim	Não
7) O lobo alimenta-se principalmente de animais de caça maior	Sim	Não
8) A população de lobos na sua zona tem aumentado	Sim	Não
9) O número de ataques de lobos a gado tem aumentado	Sim	Não
10) A presença do lobo na sua região pode implicar prejuízos financeiros?	Si	Não

Sampling methods - Indirect

Citizen-science – use data collected by citizens

Advantages: non-invasive method, applicable to different scales, low cost

Disadvantages: misidentification of species, concentration of observations - e.g. along roads, in proximity to houses or areas of concentrated activity

Sampling methods - Indirect

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Questionnaires

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Sampling methods - Indirect

Signs of presence – scent stations, track-plates, hair-traps, transects for scat collection and DNA fecal analysis

Advantages: non-invasive method, often high accuracy

Disadvantages: complexity, high cost (DNA analysis), and applicability only at lower spatial scales

Sampling methods - Indirect

Signs of presence

Scent stations

Sampling methods - Indirect

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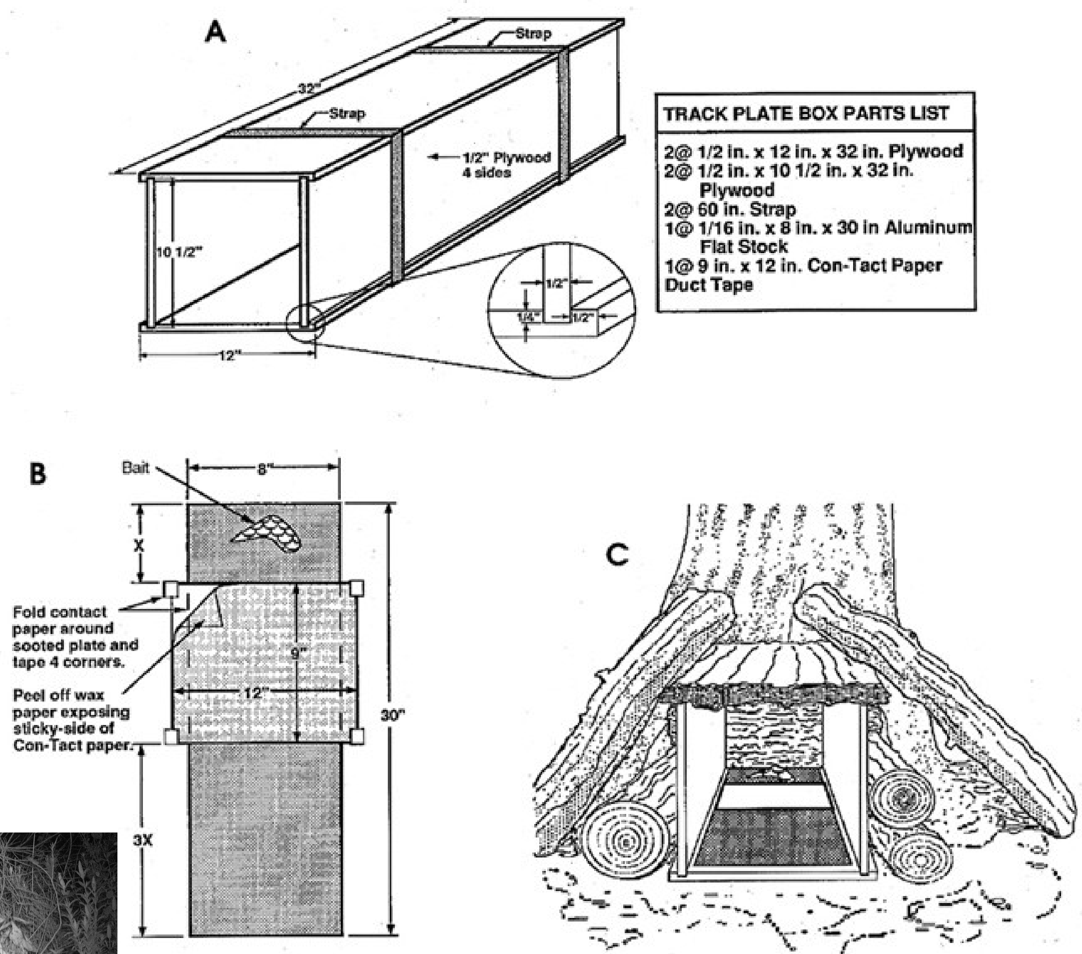
Signs of presence

Track-plates



Sampling methods - Indirect

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Signs of presence

Hair-traps

Sampling methods - Indirect

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Signs of presence

<u>Hair-traps</u>

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Sampling methods - Indirect

Signs of presence

Footprints and trails

Sampling methods - Indirect

Signs of presence

Criteria for identifying footprints

- Profile
- Size
- Shape
- Location

Sampling methods - Indirect

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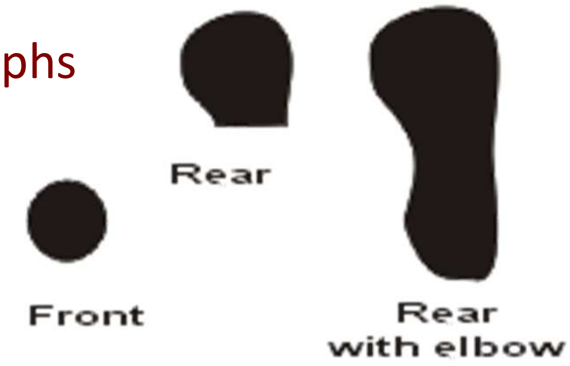
Signs of presence

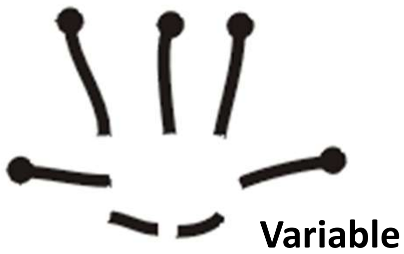
<u>Criteria for identifying footprints</u>

- Overall Profile

Lagomorphs



Rodents and
Eulipotyphla



Felids

Viverrids

Canids

Mustelids (others)

Herpestids

Mustelids

(Otter, badger)

Cervids

Suids

Sampling methods - Indirect

ECM

Signs of presence

Criteria for identifying footprints

- Size

0 1 2 3 4 5 6 7 8 9 10 cm

Eulipotyphla

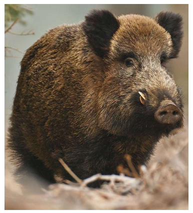
Rodentia

Lagomorpha

Carnivora

Cervidae

Suidae



Sampling methods - Indirect

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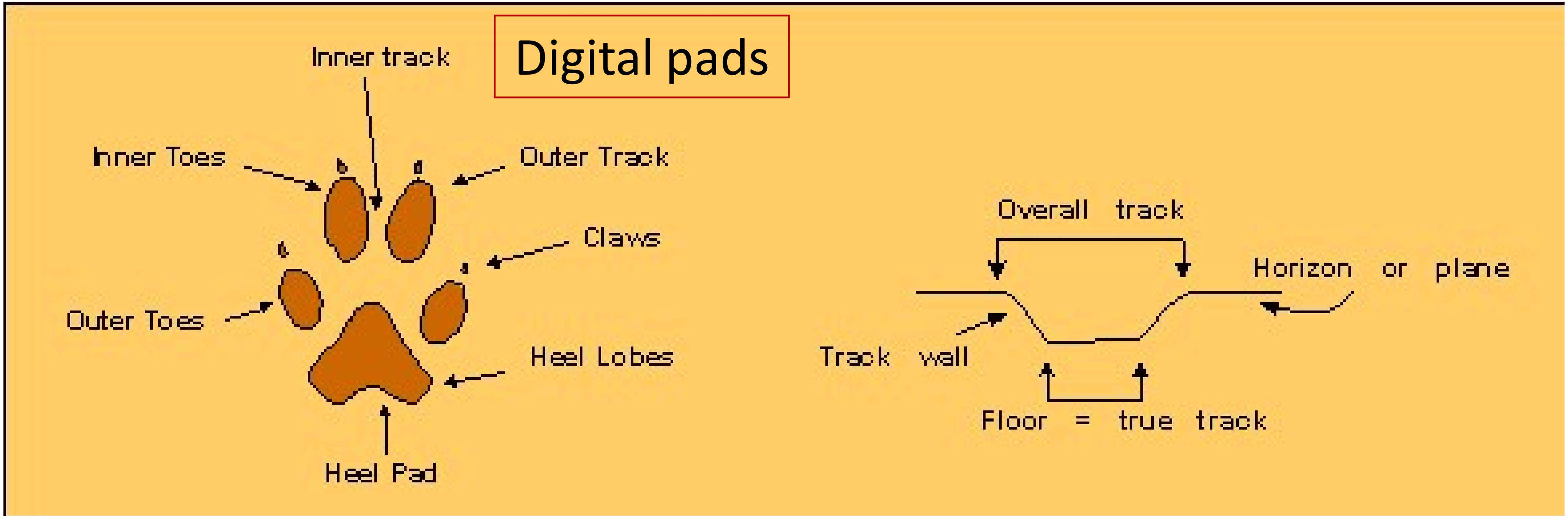
Signs of presence

Criteria for identifying footprints

- Shape – Digital and palmar pads



Palmar pads

Sampling methods - Indirect

ECM

Signs of presence

- There are 3 types of footprints:

I – Without any clear distinction between digital and palmar pads
RODENTS, EULIPOTYPHLA

II – With a clear distinction between digital and palmar pads
CARNIVORES, LAGOMORPHS

III – Hoof marks
CERVIDS, SUIDS

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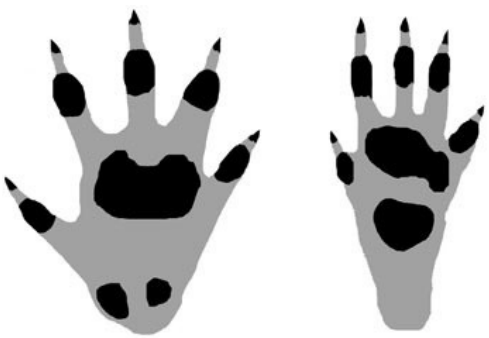
Sampling methods - Indirect

Signs of presence

RODENTS and EULIPOTYPHLA

5 finger in front and hind foot

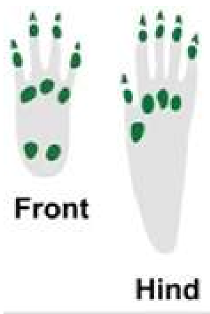
- Shrews (Soricidae)
- Moles (Talpidae)
- Hedgehogs (Erinacidae)



4 finger in front and 5 in hind foot

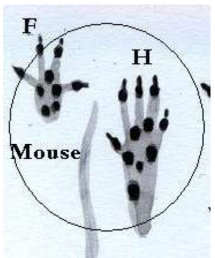
Front and hind foot of same or similar size

- Squirrels (Sciuridae)



Front and hind foot of different size

- Mice and rats (Muridae)
- Voles (Cricetidae)
- Garden dormouse (Gliridae)



Sampling methods - Indirect

Signs of presence

CARNIVORES and LAGOMORPHS

- **5 finger in front and hind foot**
  - **With visible claws**
    - **With digital membrane**: Otters (Mustelidae)

    - **Without digital membrane**: Weasel, stoat, polecat, mink, Stone and Pine marten, badger (Mustelidae); Mongoose (Herpestidae)

  - **Without visible claws**: Genet (Viverridae)

- **4 finger in front and hind foot**

  - **With visible claws**
    - **Well defined pad print**: Wolf, fox and dog (Canidae)

    - **Poorly or undefined pad print**: Hare and rabbit (Leporidae)

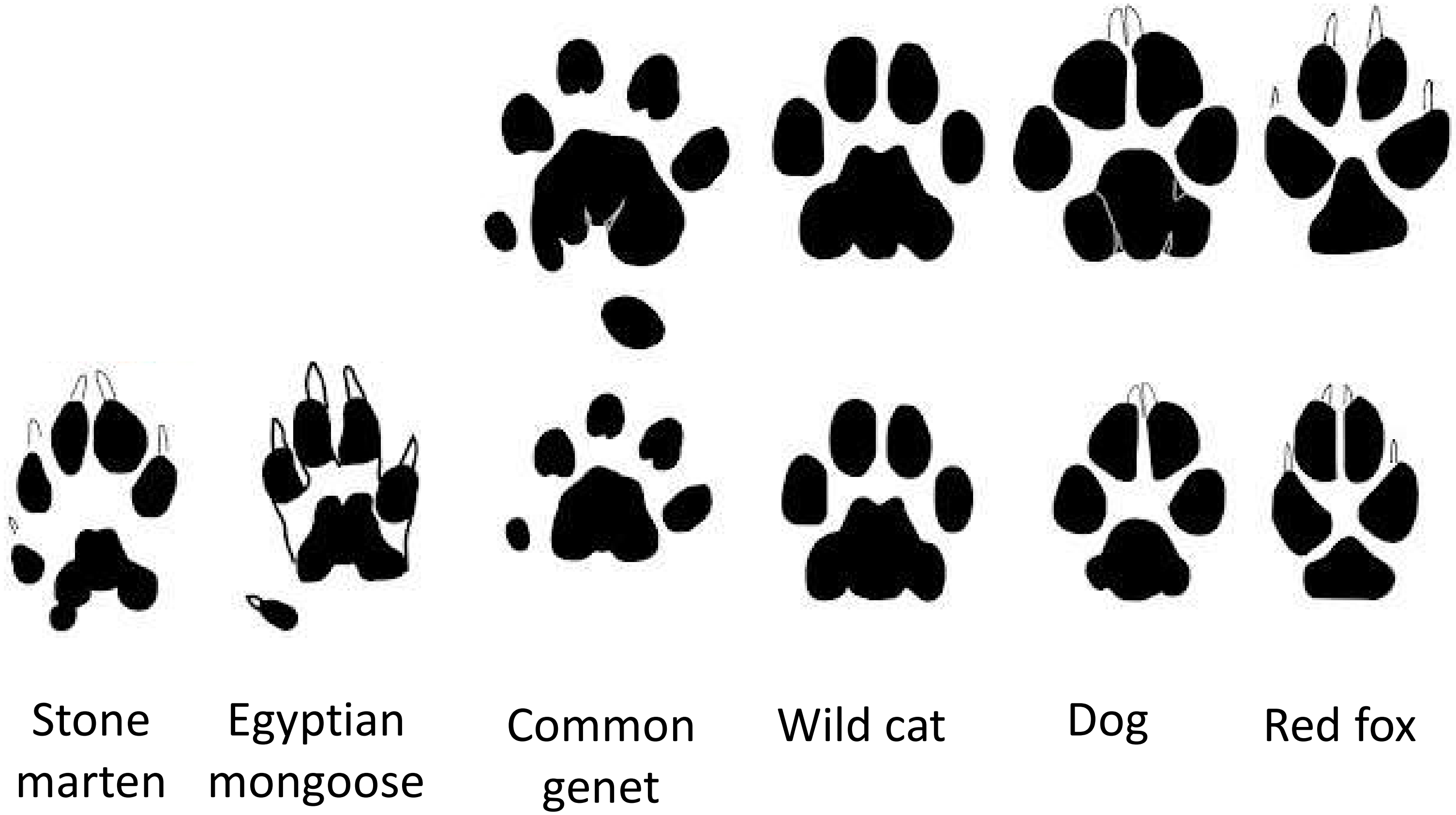
  - **Without visible claws**: Cat and Lynx (Felidae)

Sampling methods - Indirect

ECM

Signs of presence

CARNIVORES



Sampling methods - Indirect

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Signs of presence

UNGULATES

Footprints with an even number of hoofs

With 4 elements

Wild boar (Suidae)

With 2 elements

Rectangular silhouette

Red and fallow deer (Cervidae)

Heart silhouette

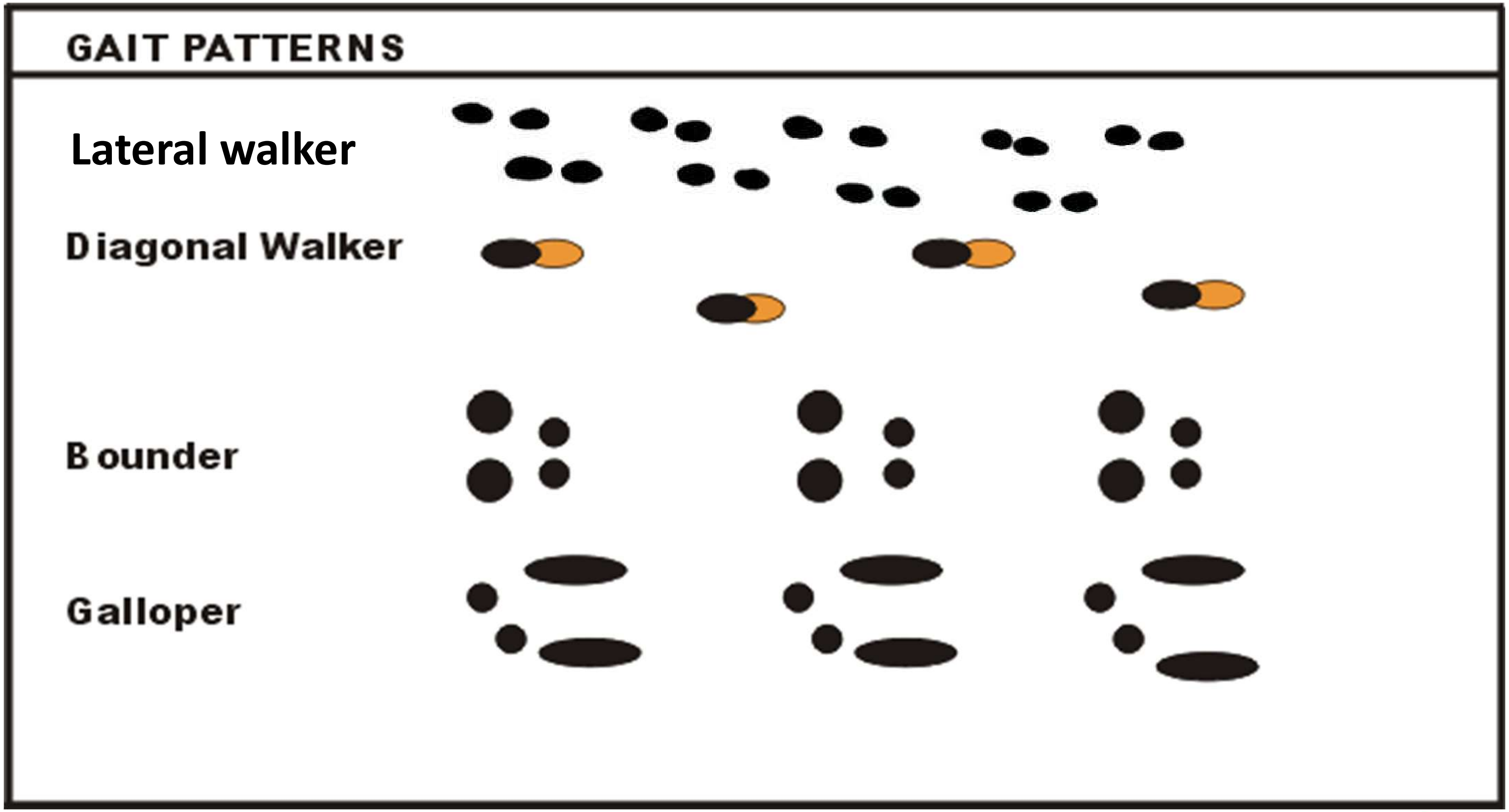
Roe deer (Cervidae)

Footprints with a odd number of hoofs

Horse (Equidae)

Sampling methods - Indirect

Signs of presence TYPES OF MOVEMENTS



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Sampling methods - Indirect

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Signs of presence TYPES OF MOVEMENTS

Lateral walkers

- Move the same side of the body at the same time (e.g. RF & RR)
- These animals have wide, rotund bodies.
- Most of the time these animals use this pattern. As speed increases, they change their pattern.

- e.g. badgers, skunk, porcupine opossum, raccoon, bear

Sampling methods - Indirect

ECM

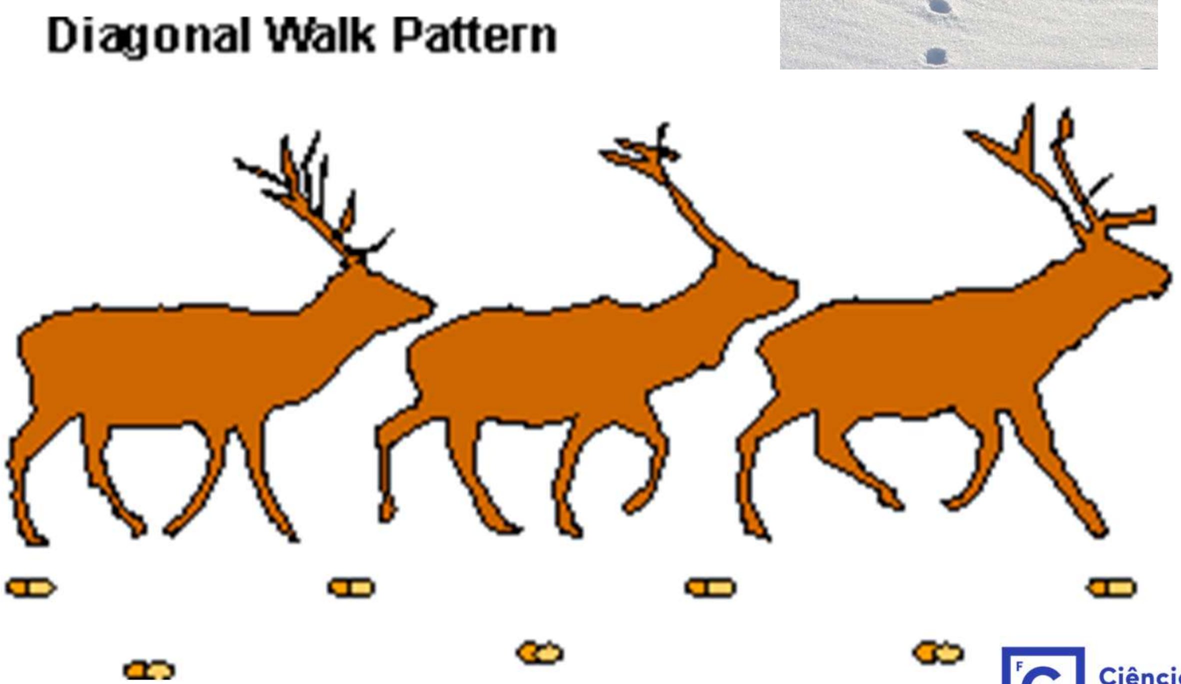
Signs of presence

TYPES OF MOVEMENTS

Diagonal walkers

- The animal moves the opposite sides of the body at the same time (e.g. RF & LR move simultaneously).

- e.g. Ungulates, canids, felids



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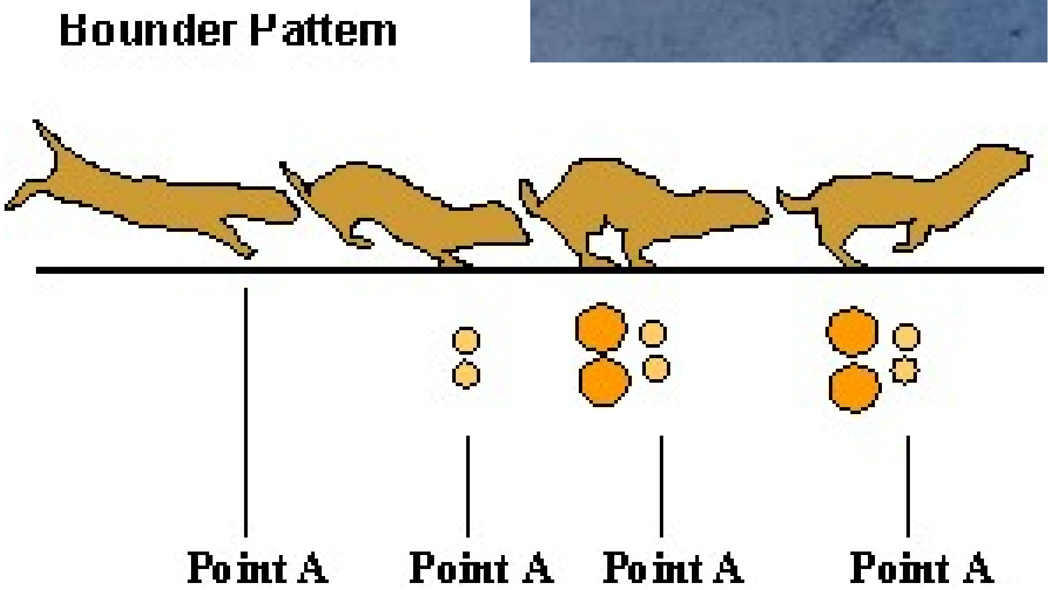
Sampling methods - Indirect

Signs of presence TYPES OF MOVEMENTS

Bound Walkers ("salto")

- The front feet land together, then the rear feet behind
- Most of the time these animals use this pattern even when moving slow or fast.



e.g. Mustelids - All members except skunks & badgers

Sampling methods - Indirect

ECM

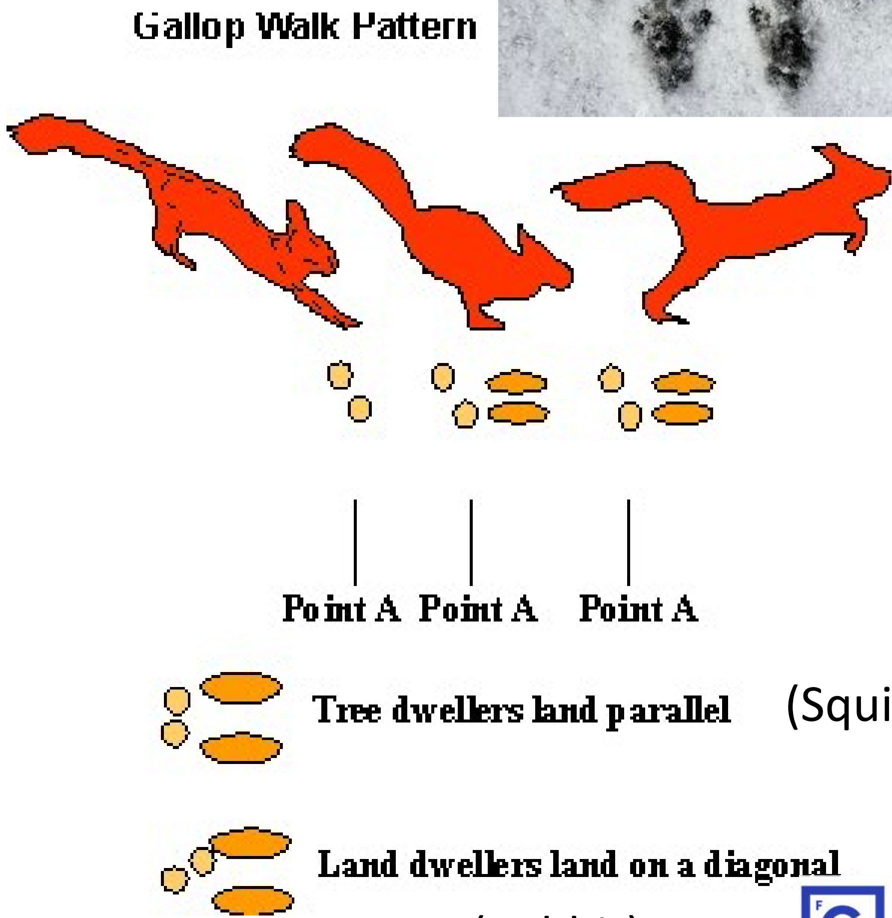
Signs of presence

TYPES OF MOVEMENTS

Gallop Walkers

- The front feet land first, then the rear feet come on the outside of the front feet and land ahead.
- Most of the time these animals use this pattern even when moving slow or fast. The pattern doesn't change with speed.
- The distance between sets of tracks increases with speed.

e.g. Lagomorphs, most Rodents



(Squirrel)

(Rabbit)

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Sampling methods - Indirect

ECM

Research Article

Can footprints of small and medium sized felids be distinguished in the field? Evidences from Brazil's Atlantic Forest

William Douglas de Carvalho[1,2,3*], Luís Miguel Rosalino[3], Júlio Cesar Dalponte[4], Bárbara Santos[1], Cristina Harumi Adania[1] and Carlos Eduardo Lustosa Esbérard[2]


Ocelot, *Leopardus pardalis* (8,5-16kg)

Abstract
Carnivores, particularly felids, face threats in many regions of the world. They are a crucial component of biodiversity with a functional role in the top of the food chain. Therefore, they have been the target of surveys and monitoring and ecological studies, most of which are based on footprint identifications, an efficient and low-cost method compared to other approaches. In these cases, species identifications may suffer from a high degree of bias due to the overlap in the size and shape of footprints among species. We experimented with small to medium captive wild felids of five species: ocelot, *Leopardus pardalis*, margay *L. wiedii*, oncilla, *L. guttulus*, domestic cat, *Felis catus*, and jaguarondi, *Puma yagouaroundi*).We tested for differences in footprint measurements, including main pad and toe pad sizes. We used humid sand as substrate and took measurements from several front and hind footprints of seven animals per species (except jaguarondi, for which only four animals were available). Our results showed that ocelot is the only species for which it is possible to obtain 100%-accurate footprint identifications, mainly because of its footprint area (*i.e.*, length x width). The remaining species presented a wide variation in measurements, making them almost impossible to distinguish based solely on footprint


Margay *Leopardus wiedii* (2,6-3,9kg)


Jaguarundi, *Puma yagouaroundi* (4,5-9kg)


Oncilla, *Leopardus guttulus* (1,8-3,5kg)

Ciências ULisboa

Sampling methods - Indirect

Signs of presence

Scats

Sampling methods - Indirect

ECM

Signs of presence

Criteria for identifying scats

- Size
- Shape
- Location
- Odour

Sampling methods - Indirect

Signs of presence

<u>Criteria for identifying scats</u>

- **Shape**
  - Tubular – Canidae, Ursidae
  - “Teardrop” – Felidae
  - “Rolled ribbon” – Mustelidae
  - “M&M” – Lagomorpha
  - Oblong (may have a tip at the end) - Cervidae
  - “Pencil lead” - Rodentia

(**Fox** - Tubular & tapered at both ends - between dog and cat)

Sampling methods - Indirect

ECM

Signs of presence

<u>Criteria for identifying scats</u>

- **Location**
  - Deposition site – soil, tuft of vegetation, tree branch, roof, near water, etc.)
- **Number**
  - Latrines or isolated scats
- **Type of habitat**
- **Positioning on the trail** - crossroads of paths, sett/den entrance, pit in the ground etc.)

Sampling methods - Indirect

ECM

Signs of presence

Criteria for identifying scats

Journal of Zoology ZSL

Journal of Zoology. Print ISSN 0952-8369

Factors affecting the (in)accuracy of mammalian mesocarnivore scat identification in South-western Europe

P. Monterroso[1,2,3], D. Castro[1], T. L. Silva[1,2], P. Ferreras[3], R. Godinho[1] & P. C. Alves[1,2,4]

Table 1 Red fox *Vulpes vulpes*, stone marten *Martes foina* and European wildcat *Felis silvestris* relative abundances and genetic results for the scats morphologically identified, collected at Cabañeros National Park (CNP) and Guadiana Valley Natural Park (GVNP), during the summer 2009 and winter 2010

						Proportion (%) of samples genetically identified as:				
Putative species	Season	Study area	TS	*n*	SGI (%)	Red fox	Stone marten	European wildcat	Polecat	Dog
Red fox	Summer/autumn	CNP	22.08 ± 22.04	26	64.00	**82.35**	17.65	0.00	0.00	0.00
		GVNP	4.16 ± 6.46	39	79.49	**93.55**	0.00	0.00	0.00	6.45
	Winter/spring	CNP	34.19 ± 34.68	54	77.78	**83.33**	11.90	2.38	0.00	2.38
		GVNP	2.27 ± 4.96	38	71.05	**85.19**	3.70	3.70	0.00	7.41
	Overall		16.78 ± 25.28	157	75.52	**86.32**	7.69	1.71	0.00	4.27
Stone marten	Summer/autumn	CNP	3.53 ± 5.72	30	90.00	7.41	**92.59**	0.00	0.00	0.00
		GVNP	1.63 ± 3.58	19	94.74	16.67	**72.22**	0.00	11.11	0.00
	Winter/spring	CNP	2.14 ± 3.83	32	75.00	45.83	**54.17**	0.00	0.00	0.00
		GVNP	6.26 ± 7.96	45	86.67	15.38	**84.62**	0.00	0.00	0.00
	Overall		3.34 ± 5.71	126	85.71	20.37	**77.78**	0.00	1.85	0.00
European wildcat	Summer/autumn	CNP	0.33 ± 0.99	1	100.00	100.00	0.00	**0.00**	0.00	0.00
		GVNP	2.56 ± 3.50	19	84.21	80.00	6.67	**13.33**	0.00	0.00
	Winter/spring	CNP	0.74 ± 1.95	0	–	–	–	**–**	–	–
		GVNP	1.89 ± 3.71	17	69.23	90.00	0.00	**10.00**	0.00	0.00
	Overall		1.29 ± 2.80	37	78.78%	84.62	3.85	**11.54**	0.00	0.00

Monterroso et al (2012) Factors affecting the (in)accuracy of mammalian mesocarnivore scat identification in South-western Europe. *Journal of Zoology*, **289**, 243-250.

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Sampling methods - Indirect

Signs of presence

Other signs of presence (e.g. dens, setts)

Sampling methods - Indirect

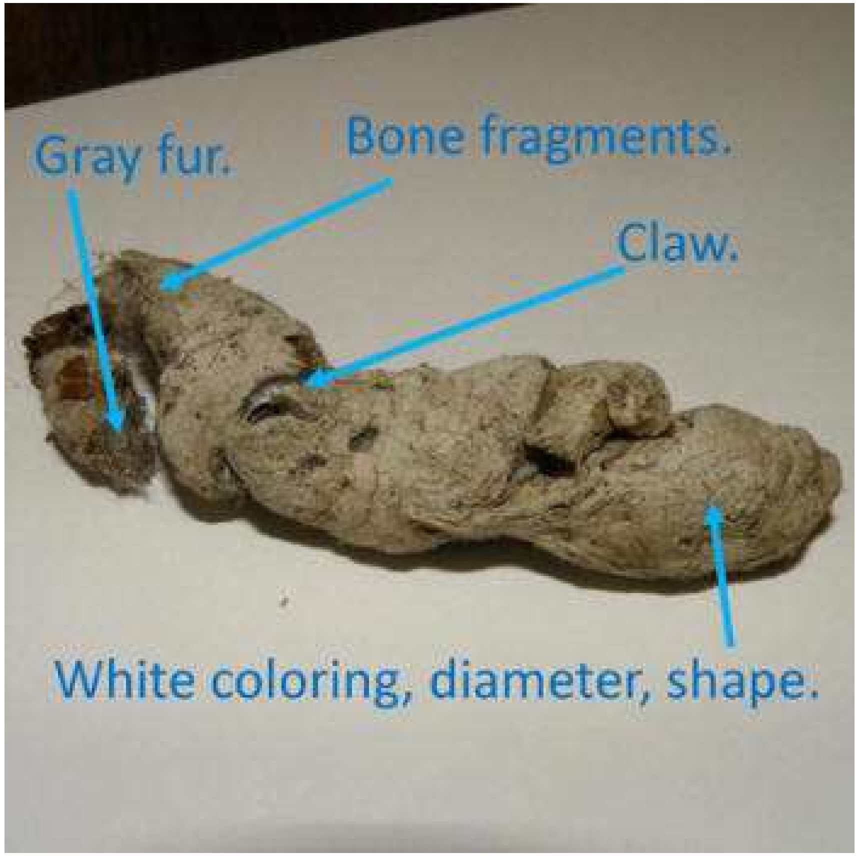
Signs of presence

<u>Other signs of presence (e.g. marks, tree scratches)</u>

Sampling methods - Indirect

Scat and pellet analysis

(e.g. carnivores, owl)



COMPLEMENTAR METHOD

Sampling methods - Indirect

ECM

Scat and pellet analysis

(e.g. carnivores, owl)

Advantages: non-invasive method, moderate accuracy (difficulty in locating the capture site), low cost, applicable to large scale studies

Disadvantages: time demanding, knowledge about the size of the predator's home range

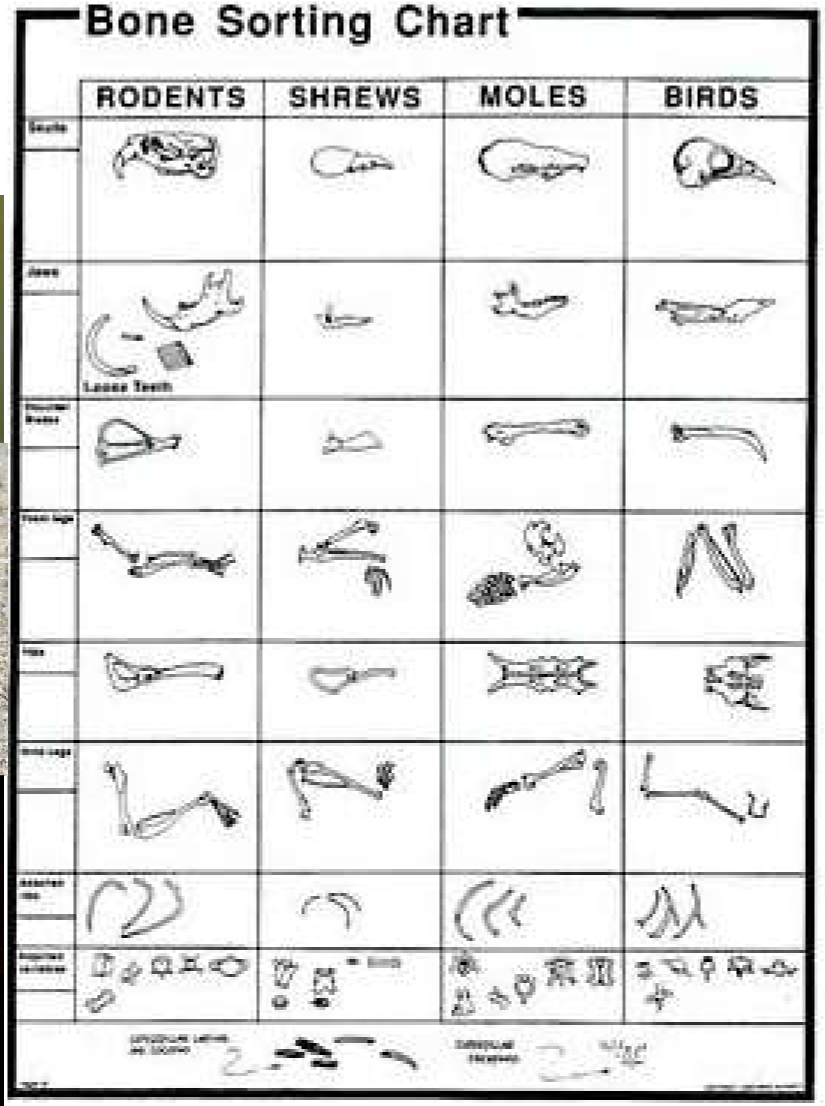
COMPLEMENTAR METHOD

Sampling methods - Indirect

ECM

Scat and pellet analysis

(e.g., carnivores, owl)



Sampling methods - Indirect

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Molecular Tools

What ecological information can be obtained from molecular tools (just some examples):

- Identification of species, gender, and individuals from non-invasive samples (e.g., fur, scats).
- Behavioral patterns (e.g., interrelationship among group members, and paternity)
- Dispersal movements
- Spatial structure of the population (e.g., how home-ranges are spatially distributed)
- Population biology and dynamics (e.g., density, abundance)
- Diet and trophic networks (e.g., Metabarcoding)
- Conservation (assessing species responsible for cattle depredation)
- Host-parasite phylogeography
- etc…

Sampling methods - Direct

ECM

Direct observation, live captures

- Direct observation
- Spotlighting
- Live trapping
- Camera-trapping
- Video surveillance
- Drones

Advantages: high accuracy

Disadvantages: some invasive method (disturbance - e.g., headlamp, or handling), complexity, high cost and only applicable in small scale studies

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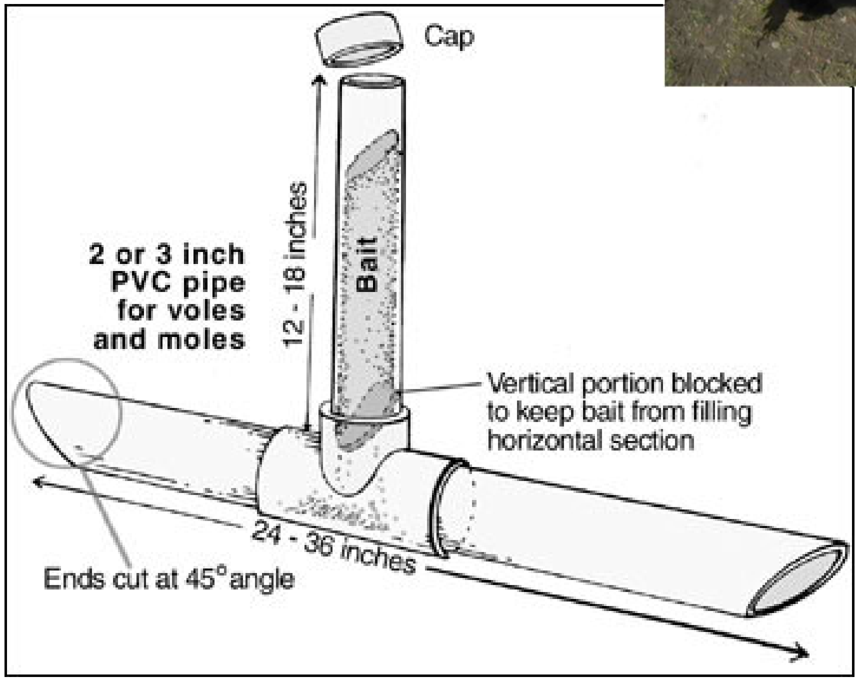
Sampling methods - Direct

Direct observation, live captures

<u>(Live) trapping</u>



Sampling methods - Direct

ECM

Direct observation, live captures

(Live) trapping

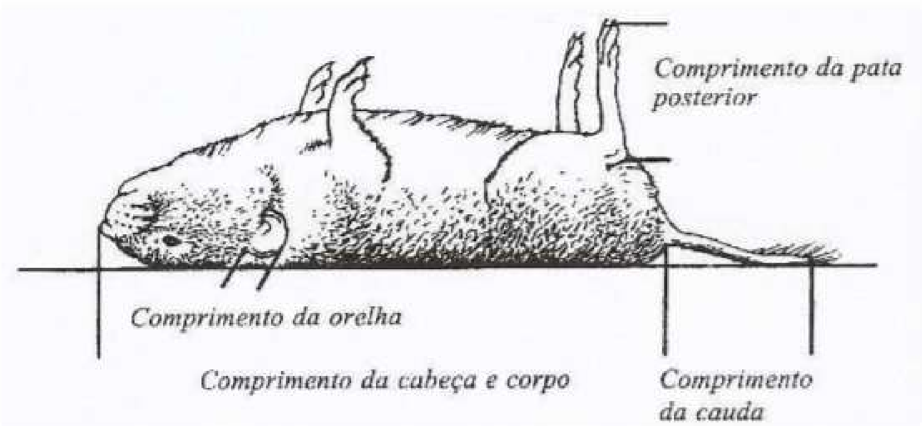
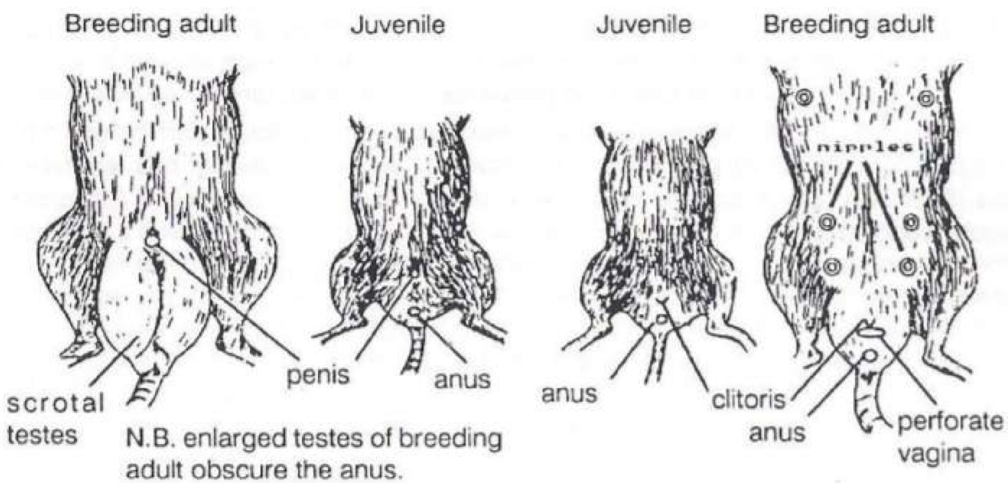


Fig. 9- Biometrias gerais de um mamífero (Fonte: Macdonald &



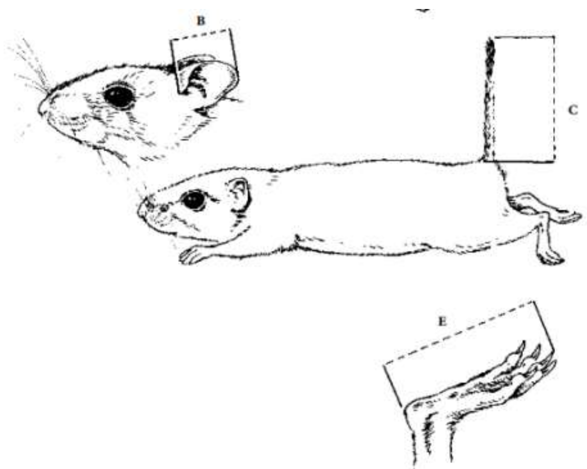


Fig.10- Características sexuais de machos (à esquerda) e fêmeas (à direita) (Fonte: Gurnell & Flowerdew, 1990).

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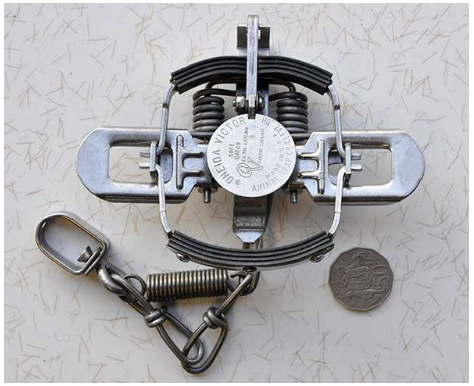
Sampling methods - Direct

ECM

Direct observation, live captures

Live trapping



Sampling methods - Direct

Sampling methods - Direct

ECM

Direct observation, live captures

Live trapping

Sampling methods - Direct

ECM

Direct observation, live captures

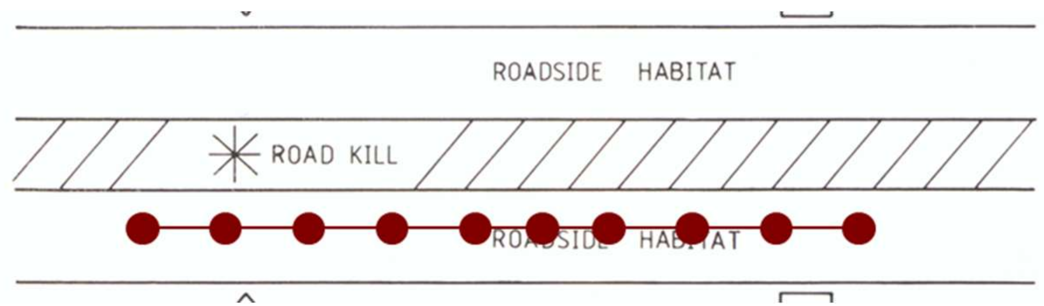
Live trapping

Sampling methods - Direct

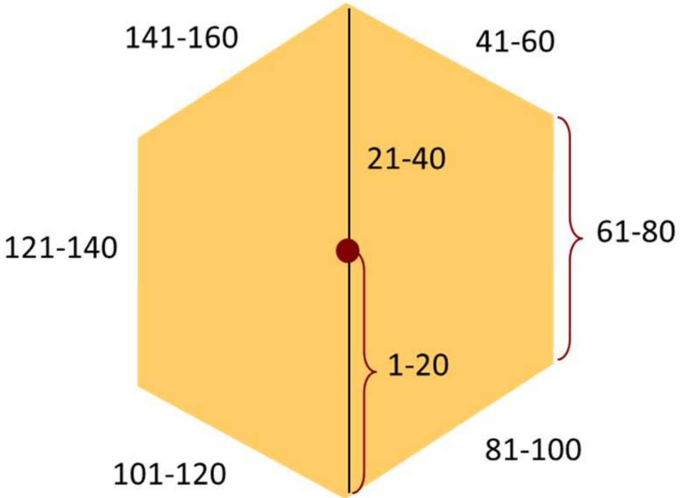
Direct observation, live captures

Live trapping

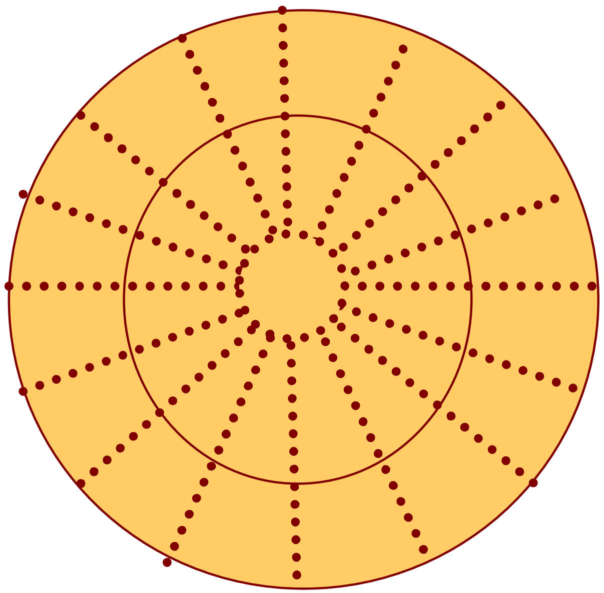
Trapping transect **Abundance**



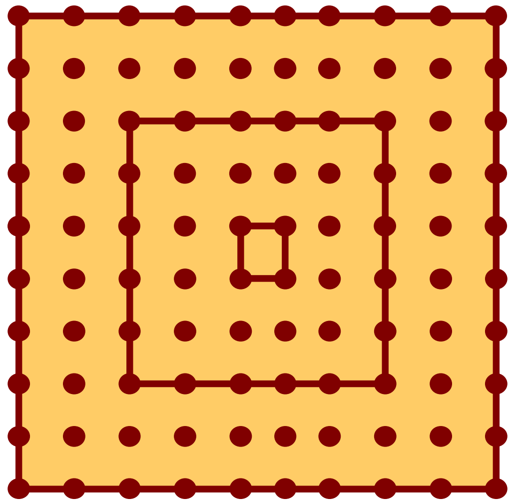
Trapping hexagon **Density**



Trapping web **Density**



Trapping grid **Density**



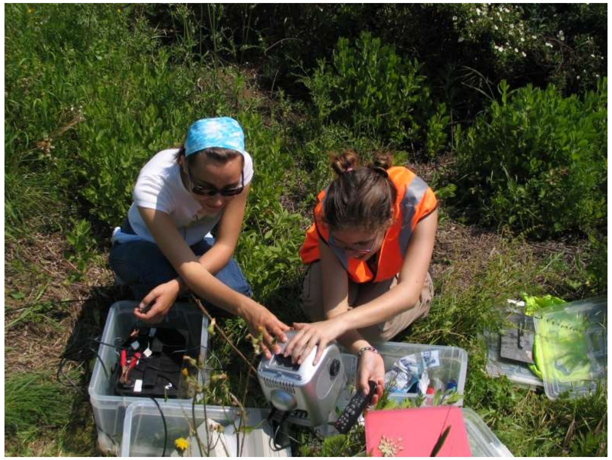
Sampling methods - Direct

ECM

Direct observation, live captures

Camera-trapping

Video surveillance



Sampling methods - Direct

Direct observation, live captures

Video surveillance

Sampling methods - Direct

ECM

Ciências ULisboa

Sampling methods - Direct

Direct observation, live captures

Video surveillance

Sampling methods - Direct

Direct observation, live captures

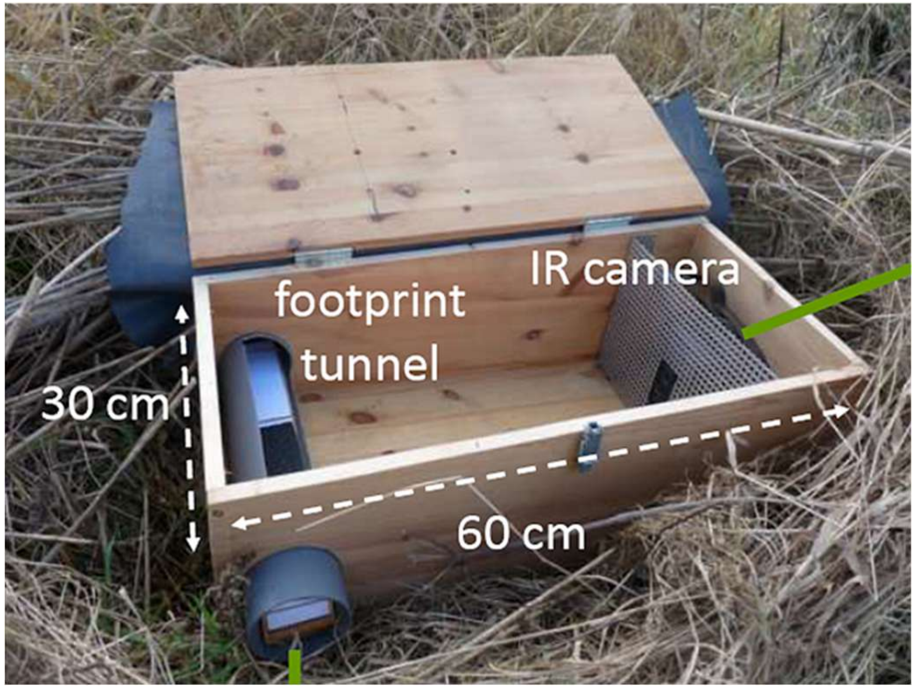
<u>Camera-trapping</u>

Sampling methods - Direct

ECM

Direct observation, live captures

<u>Camera-trapping</u> – Mostela-trap



Taxa – Small mammals and small carnivores

Sampling methods - Direct

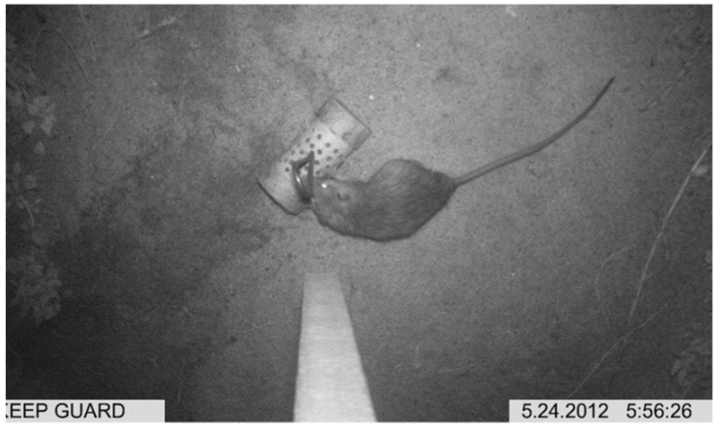
ECM

Camera-trapping – Mostela-trap

Sampling methods - Direct

ECM

Camera-trapping – Small mammals



Taxa – Small mammals

2024/2025 – Miguel Rosalino

Ciências ULisboa

Sampling methods - Direct

ECM

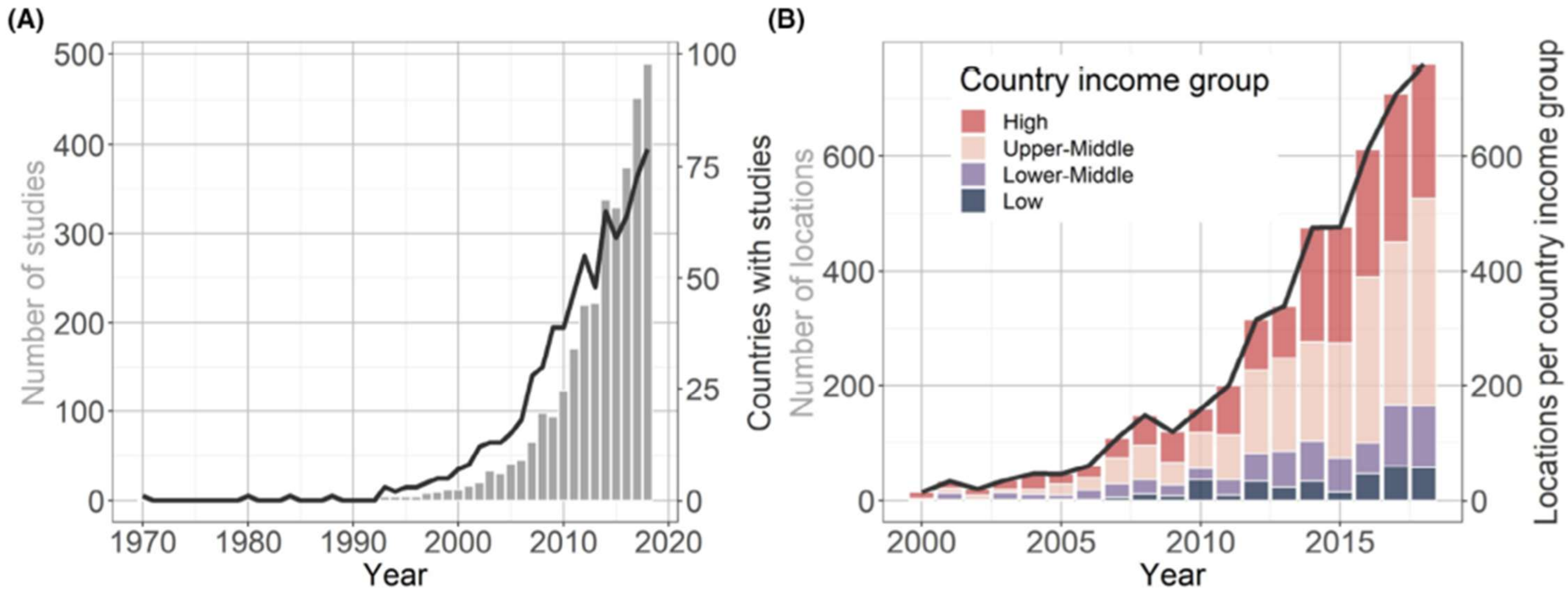


Figure 2. Temporal and spatial patterns of camera trap research. (A) Number of studies that used camera traps as a research tool (left axis and bar graph) and number of countries where the research was conducted (right axis and line graph) between 1970 and 2019. (B) Number of locations in the past two decades (right axis and line graph) compared among country income groups (left axis and stacked bar graph). (C) Global research locations before and after year 2000. (D) Number of studies that used camera traps as a research tool per country.

Mugerwa et al. (2023). Remote Sens Ecol Conserv.

Sampling methods - Direct

ECM

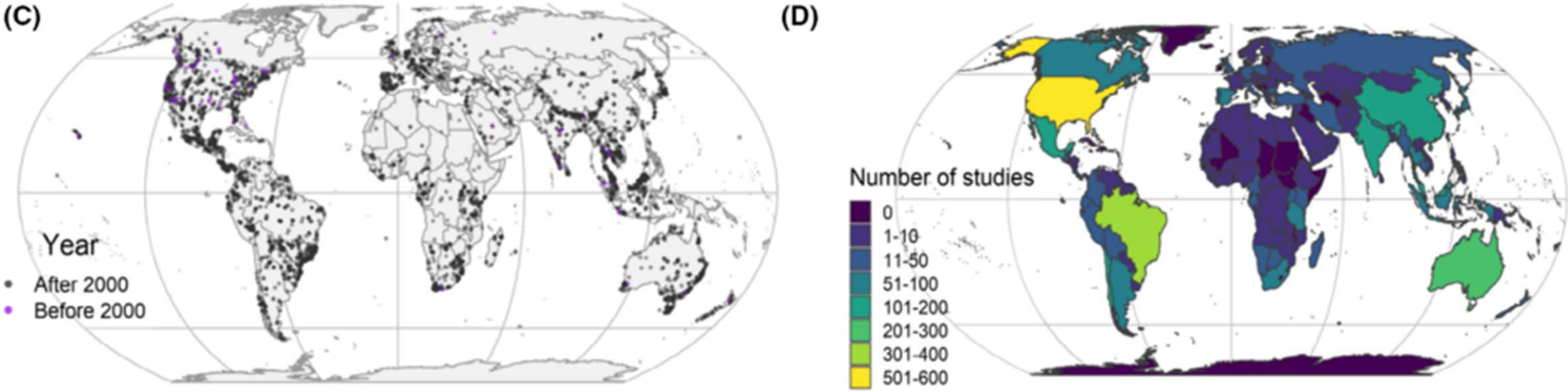
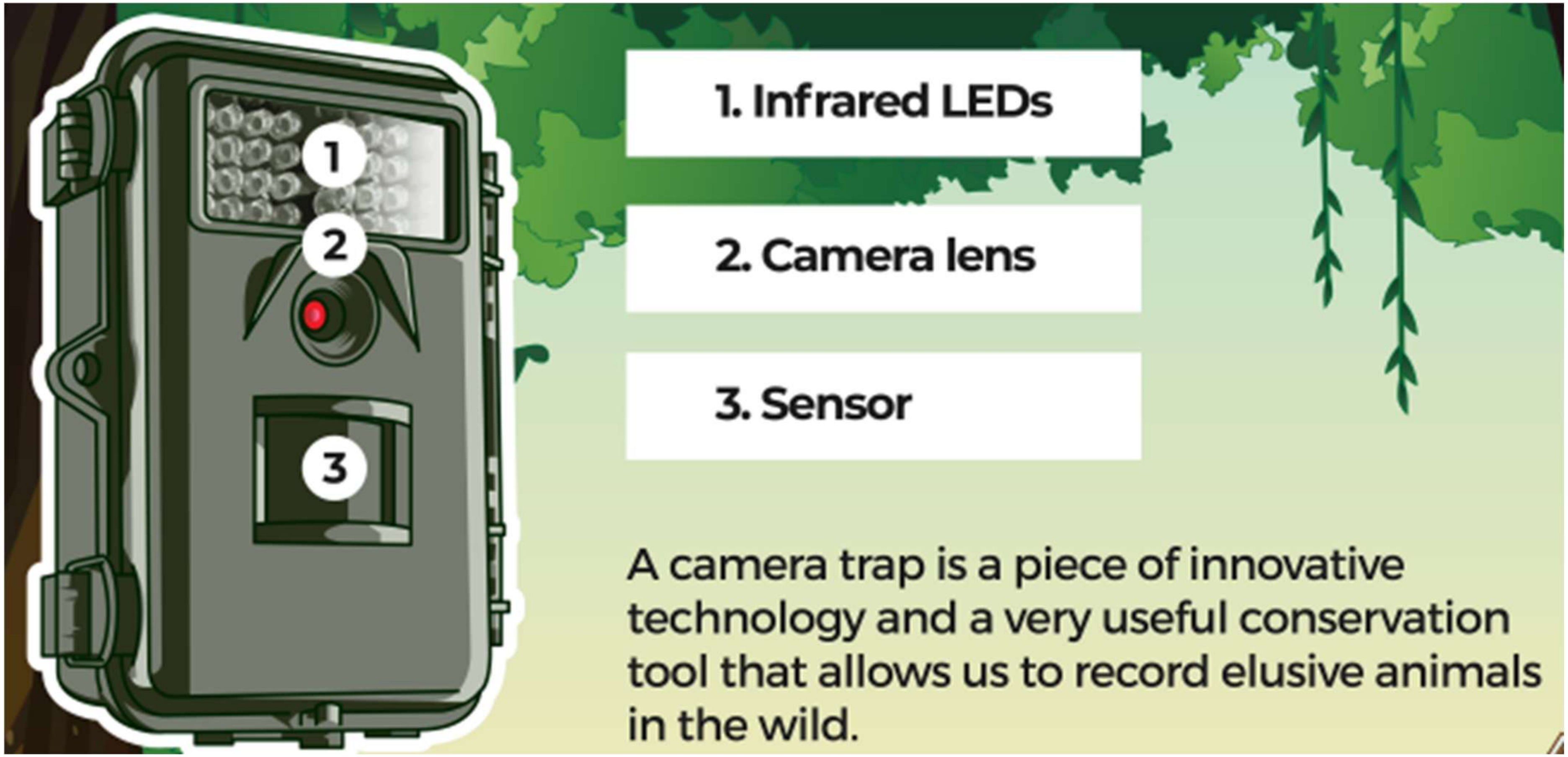


Figure 2. Temporal and spatial patterns of camera trap research. (A) Number of studies that used camera traps as a research tool (left axis and bar graph) and number of countries where the research was conducted (right axis and line graph) between 1970 and 2019. (B) Number of locations in the past two decades (right axis and line graph) compared among country income groups (left axis and stacked bar graph). (C) Global research locations before and after year 2000. (D) Number of studies that used camera traps as a research tool per country.

Mugerwa et al. (2023). Remote Sens Ecol Conserv.

Sampling methods - Direct

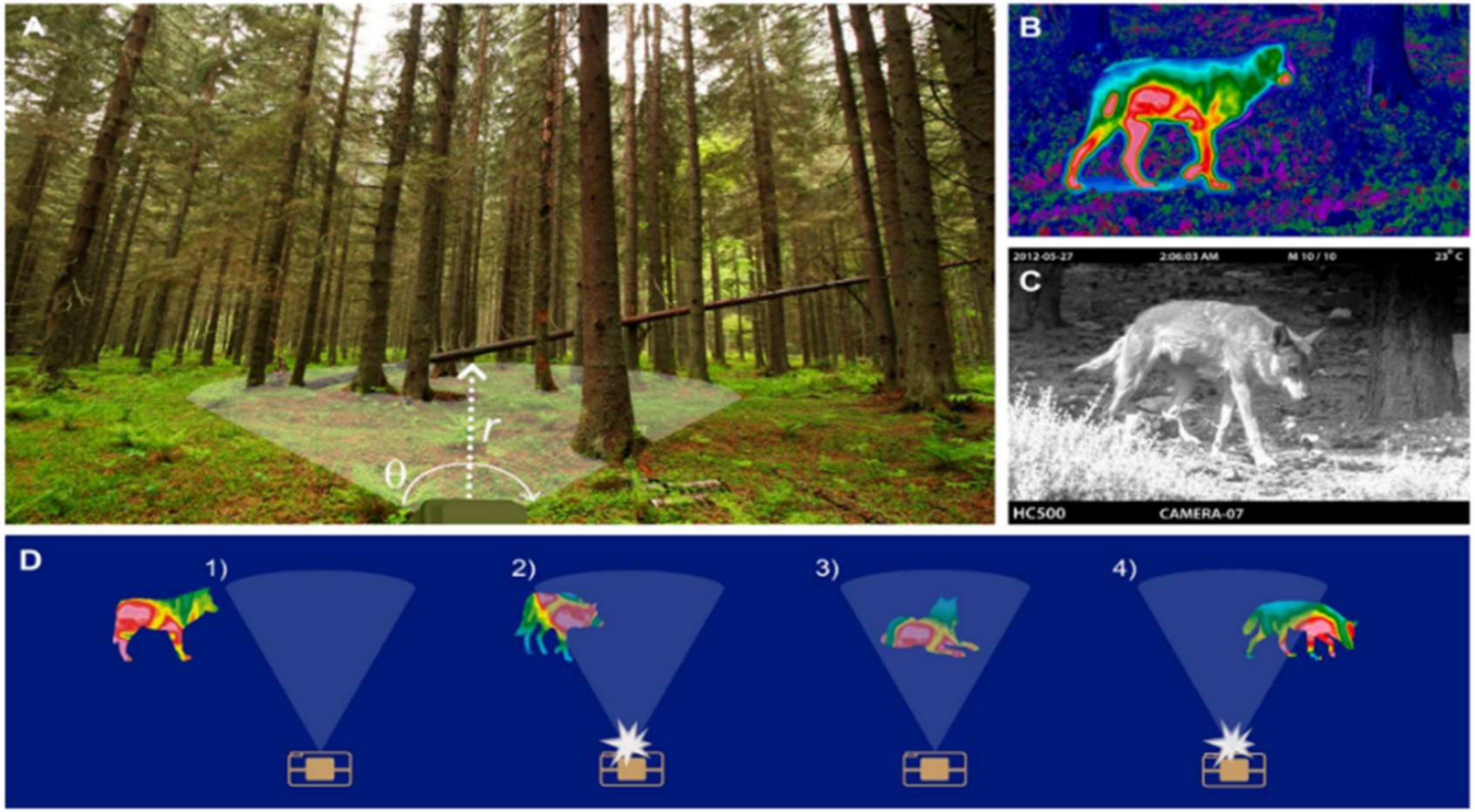
What is a camera-trap?



Sampling methods - Direct

ECM

- Camera traps (CT) have a detection zone, defined by the **radius, r and angle, θ** (A);
- CT monitor the surface temperature within the detection zone - warm-blooded animals stand (B);
- But they also have to be moving (C);
- The combination triggers the camera trap, including the infrared flash if ambient lighting is poor;
- An animal will only trigger the camera if it is moving inside the detection zone (D, 2 and 4);
- An immobile resting animal (3) may not trigger the camera.

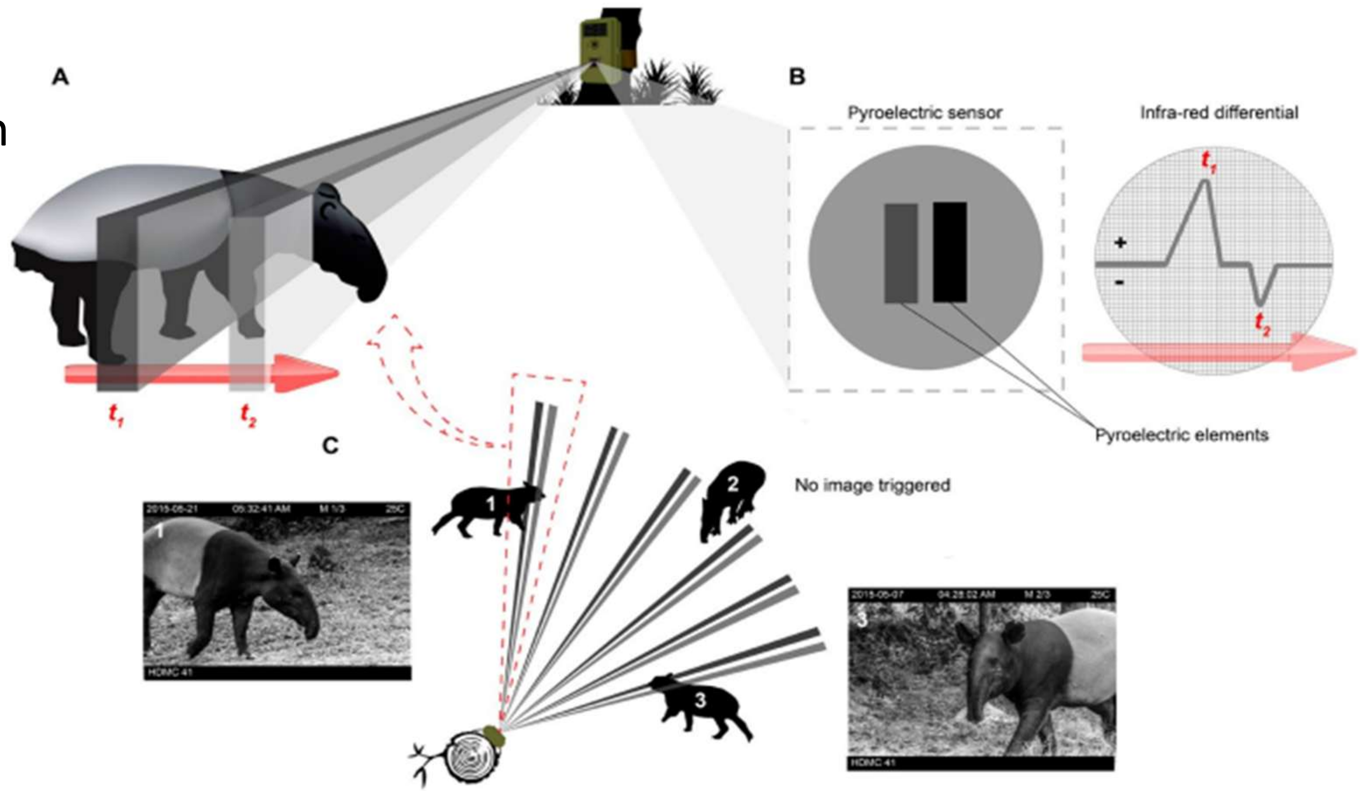


Wearn, O. R., & Glover-Kapfer, P. (2017). Camera-trapping for conservation: a guide of best-practices. Woking, United Kingdom: WWF-UK.

Ciências ULisboa

Sampling methods - Direct

- The detection zone of the modern camera trap is composed of one or more detection windows;
- When an animal moves across a detection window (A), the pyroelectric sensor registers a difference in the amount of infrared radiation received by the two elements (B);
- If this differential is greater than a certain threshold, an image is triggered;
- Most camera traps have multiple detection windows (C) - six detection windows in (C);
- Animals that approach a camera trap straight on (e.g. C-2) will often fail to be registered.



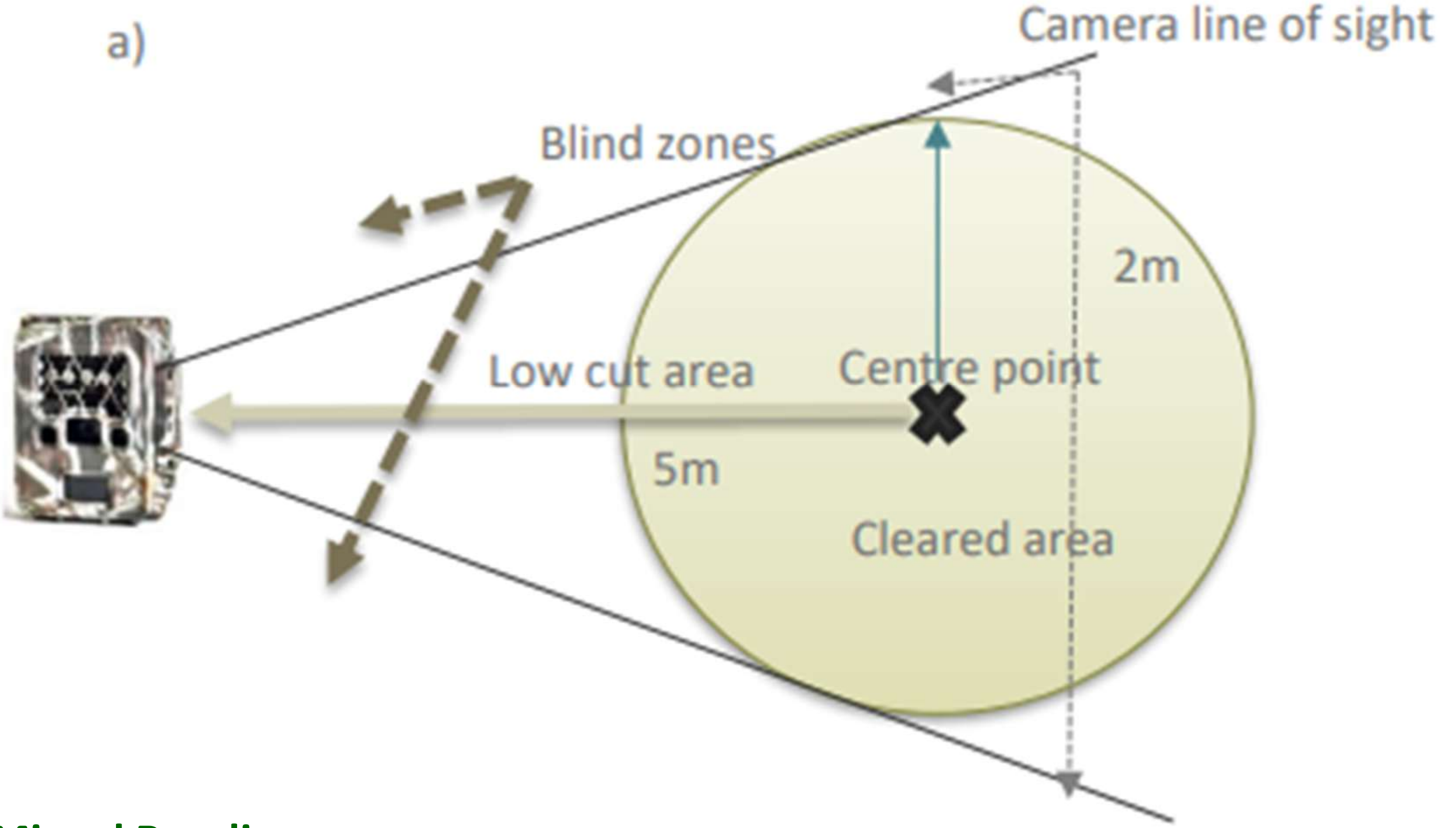
Wearn, O. R., & Glover-Kapfer, P. (2017). Camera-trapping for conservation: a guide of best-practices. Woking, United Kingdom: WWF-UK.

Sampling methods - Direct

ECM

How to set a camera-trap?

- **Clear vegetation in front of the camera** - minimize vegetation movement and the obstruction of the photographs (cleared to ground level).
- When baits, lures or attractants are used they should be placed at the centre point



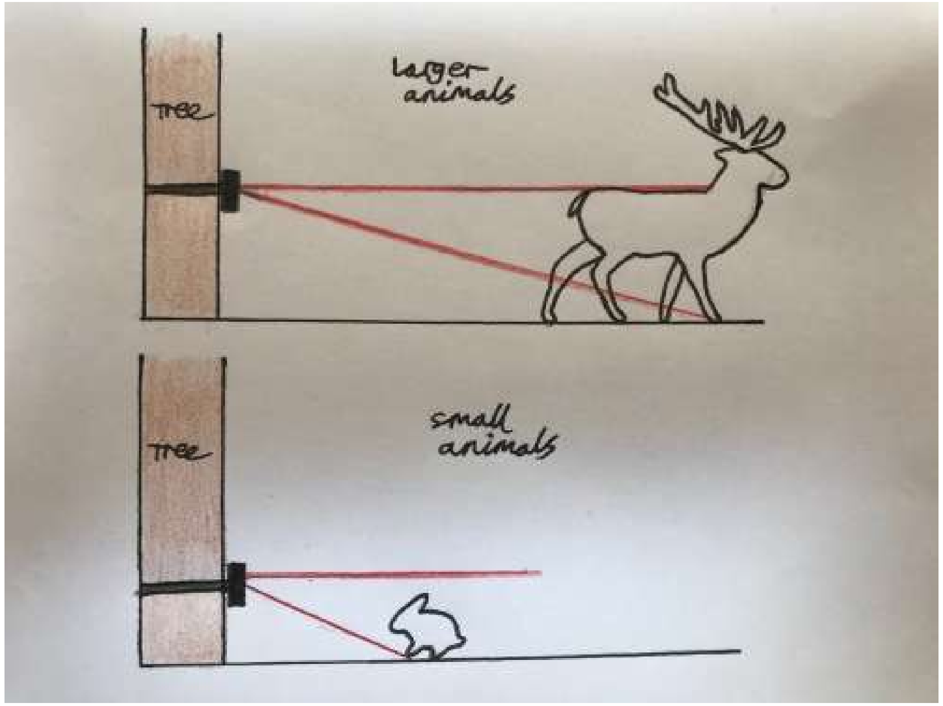
Ciências ULisboa

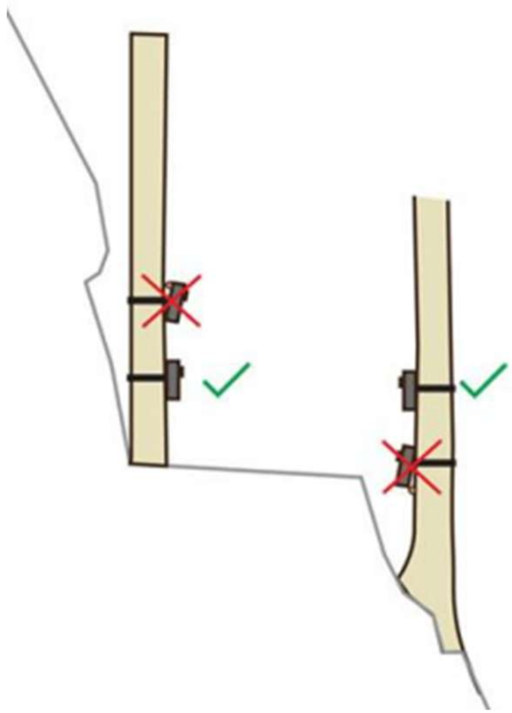
Sampling methods - Direct

ECM

How to set a camera-trap?

- **Camera sensor height**
  - 20-50 cm between the camera sensor and the ground
  - shoulder height of your focal species
  - height at which your species emits the most infrared radiation (i.e. heat)





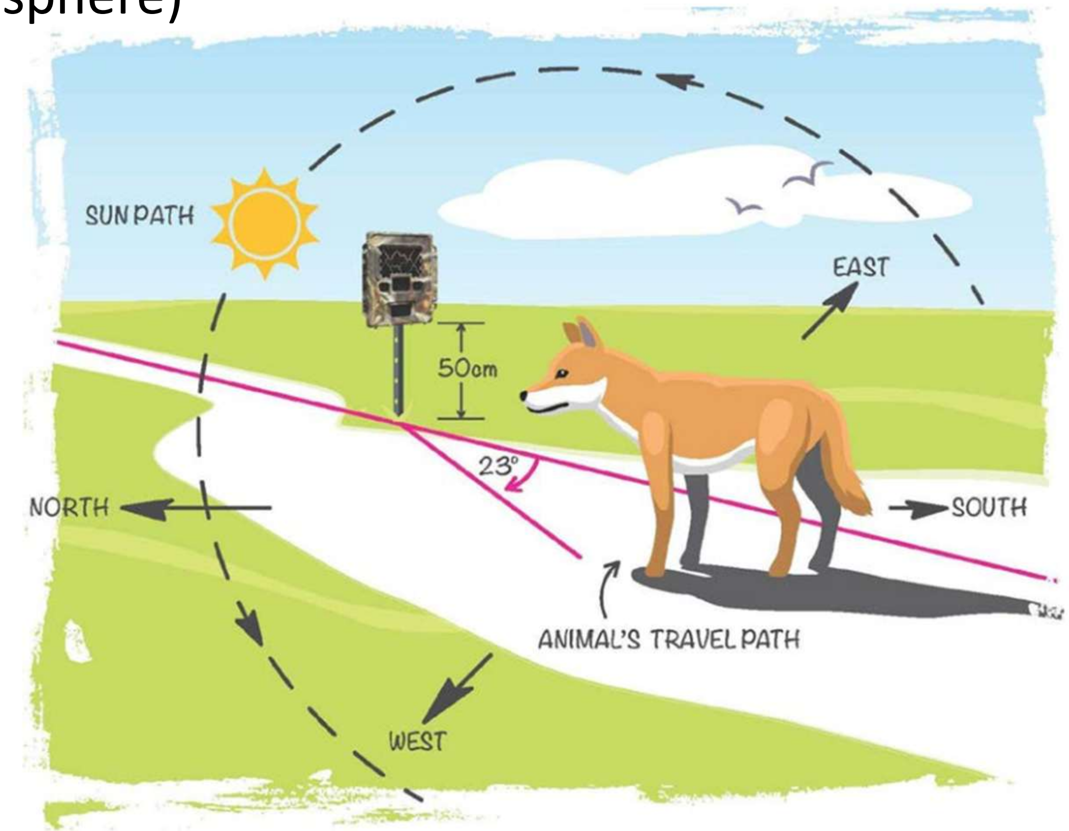
Ciências ULisboa

Sampling methods - Direct

ECM

How to set a camera-trap?

- Cameras position
  - **Facing N** (in the northern hemisphere)
  - **Facing S** (in the Southern hemisphere)



Southern hemisphere

Sampling methods - Direct

ECM

How to set a camera-trap?

- Passive infrared sensor should be:
  - perpendicular to the expected direction of animal travel.
  - perpendicular to the ground surface in front of it

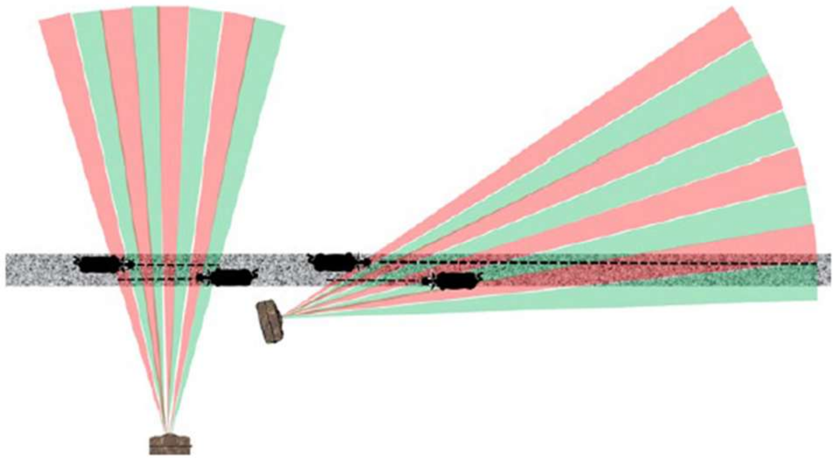


FIGURE 4 A camera trap aimed across a track has the maximum sensitivity, but targets are in the detection zone and field of view for only a short distance and time, which increases the chances that they will move out of view during the trigger delay. A camera at an obtuse angle to the track has a directional bias, but animals moving away from it can be videoed for an increased distance and time [Colour figure can be viewed at wileyonlinelibrary.com]

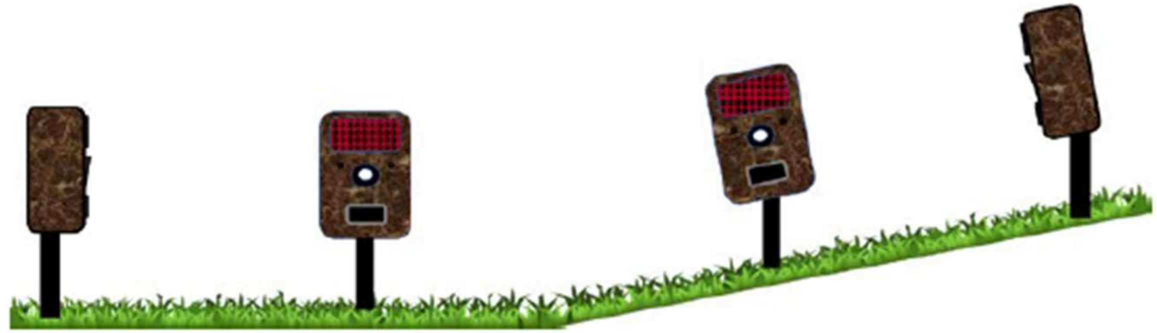


FIGURE 5 For maximum detections, camera traps must be angled to match the slope of the ground [Colour figure can be viewed at wileyonlinelibrary.com]

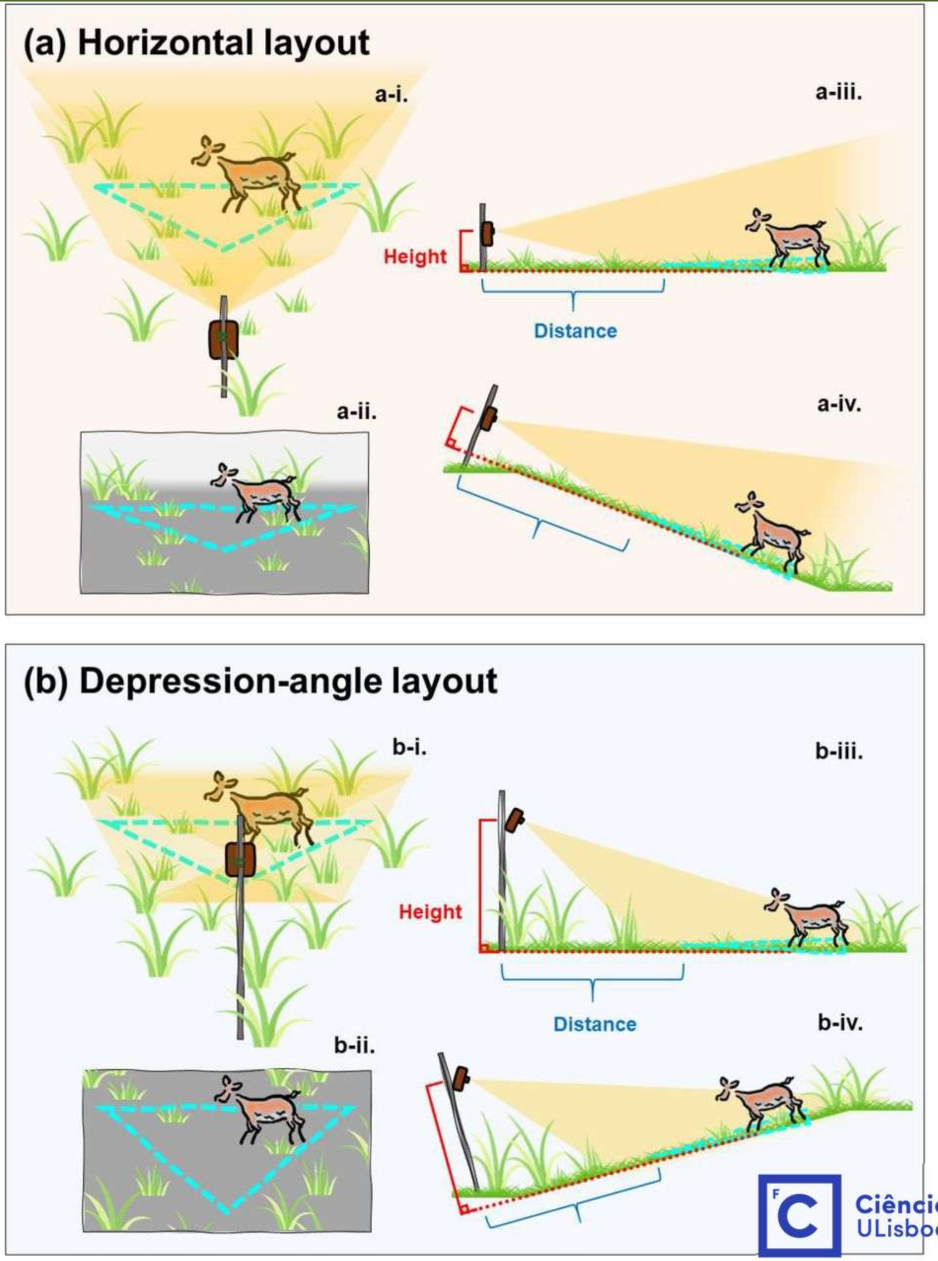
Apps & McNutt (2018). *African Journal of Ecology, 56*(4), 702-709

Sampling methods - Direct

ECM

How to set a camera-trap?

- Camera trapping on a slope:
  - Cameras should be pointing across a slope, not up or down it
  - But is better to set facing downwards than facing up to the sky
  - Facing down - may shorten the detection zone, leading to missed detections at longer ranges
  - Facing up - greater opportunity for concealment by increasing the effect of on-ground structures; the sky in photos may affect its quality



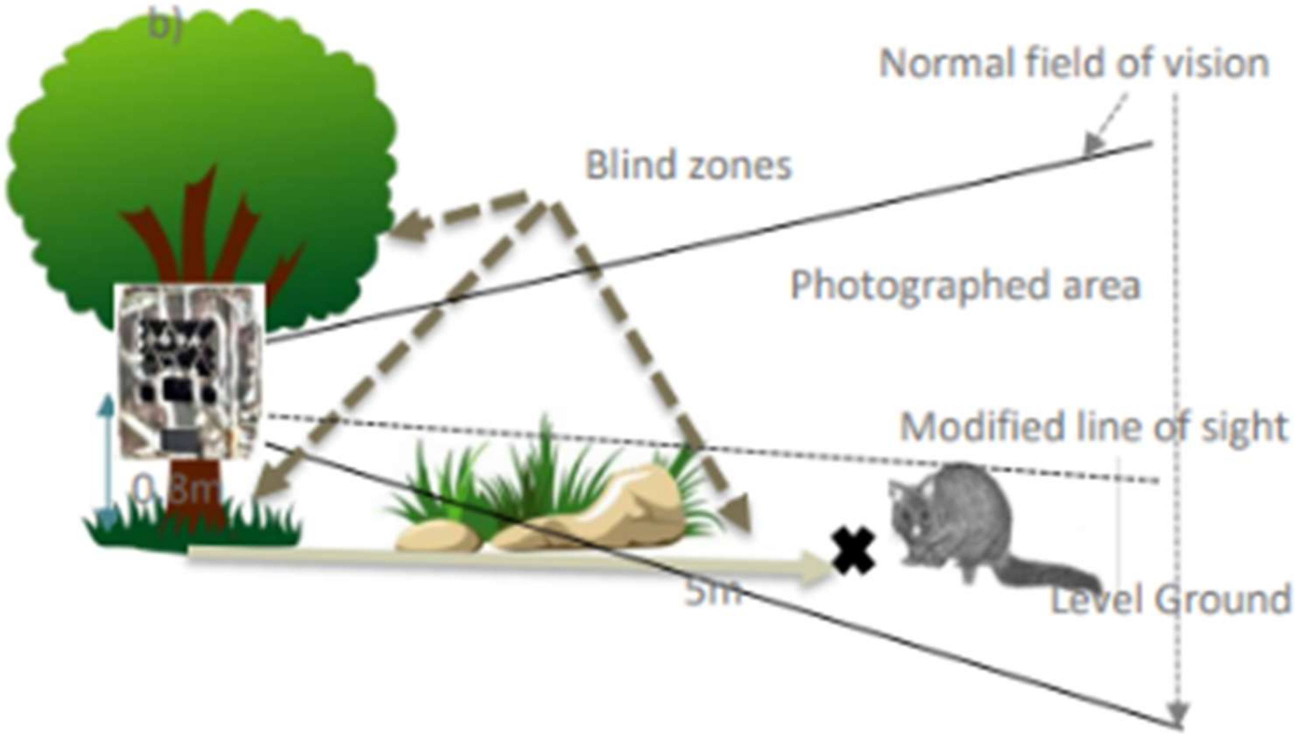
Ciências ULisboa

Sampling methods - Direct

How to set a camera-trap?

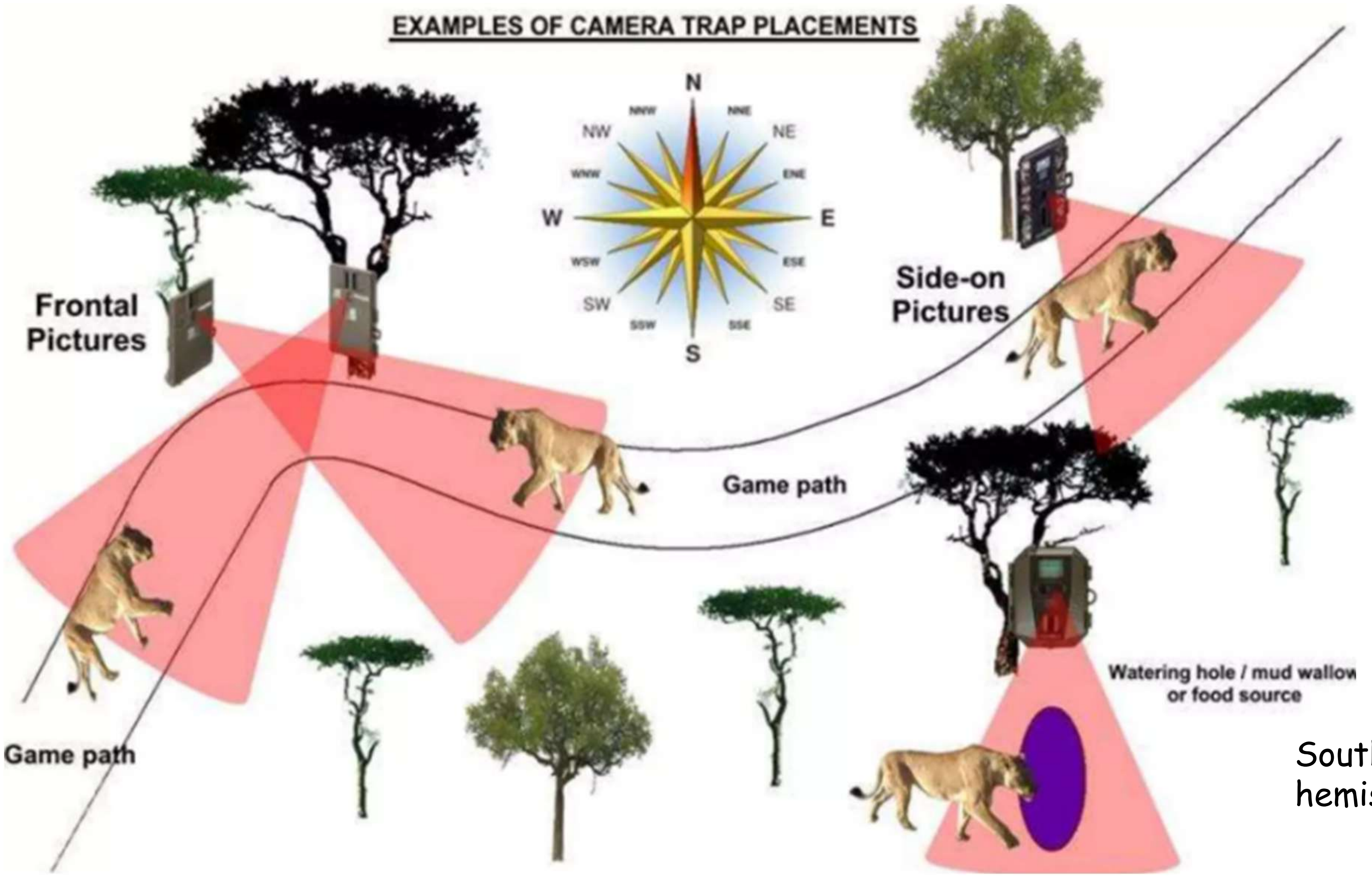
Be aware:

- Ground structures obscuring subjects



Sampling methods - Direct

How to set a camera-trap?



Southern hemisphere

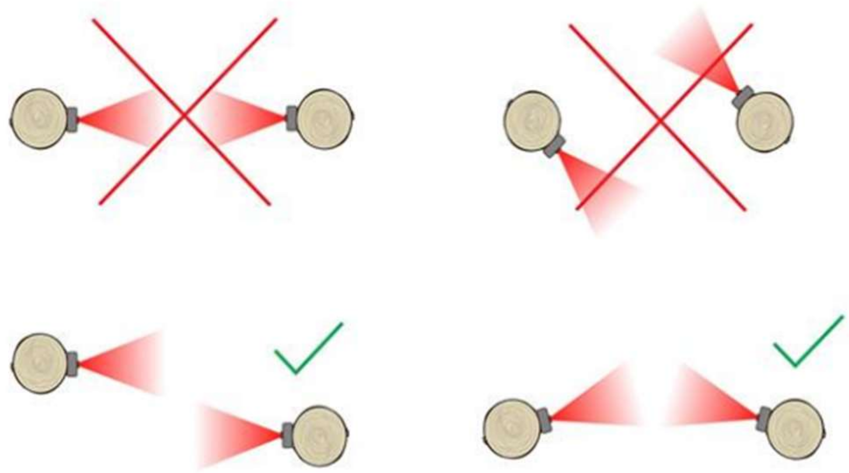
Sampling methods - Direct

ECM

How to set a camera-trap?

Use of two cameras per site:

- Increases the probability of individual identification



Picture 9: Opposing cameras should be directed into the same point on the trail, but not directly facing one another (to avoid overexposed photos).

Sampling methods - Direct

ECM

How to set a camera-trap?

Bait

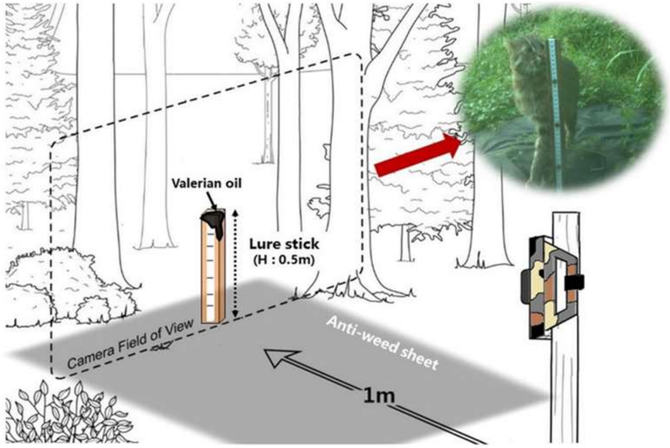


Fig. 2 Survey design of a baited camera trap to effectively capture leopard cat images

Park et al. (2019). Journal of Ecology and Environment 43: 39

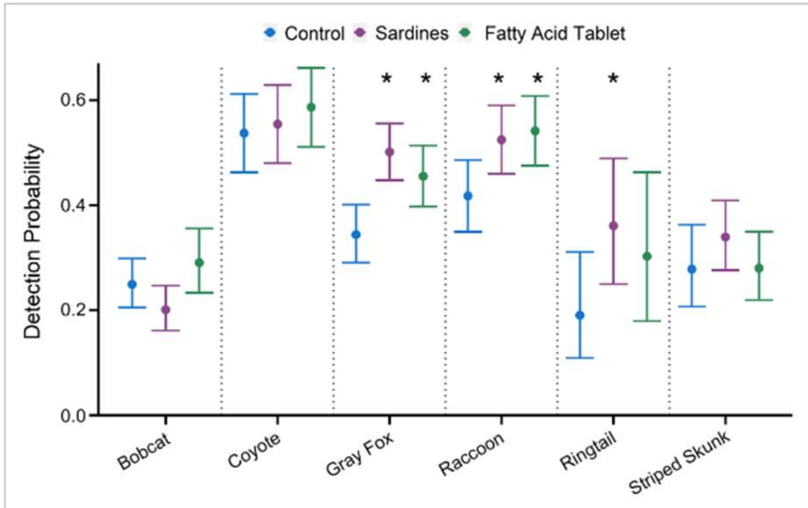
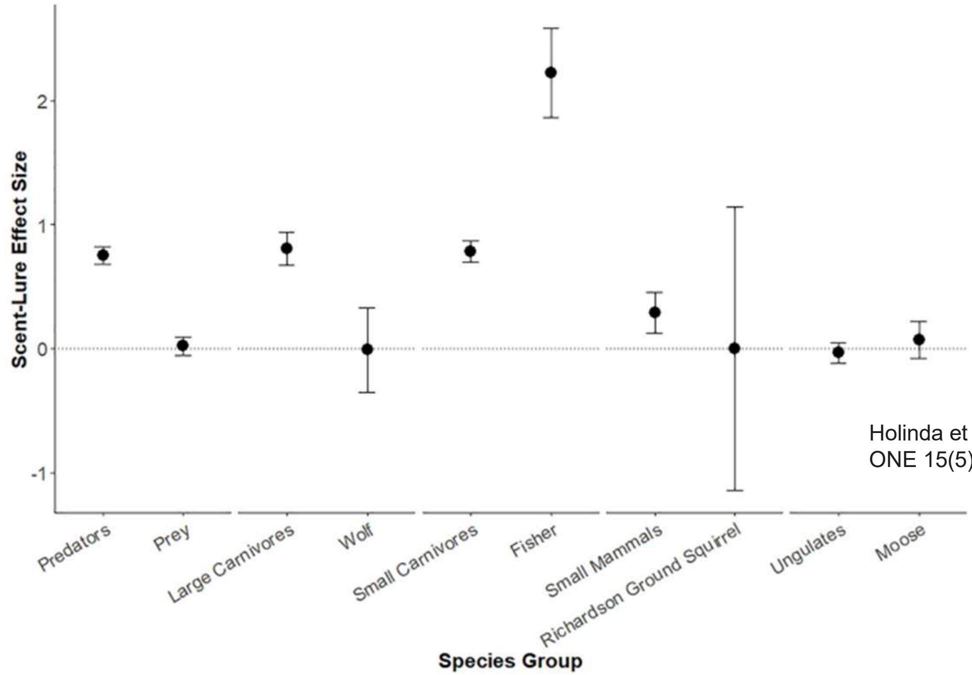


Fig. 2 Open in figure viewer | PowerPoint

Probability of detection (point) by species and lure type with 95% confidence intervals (bars). An asterisk indicates significant differences in detection probability from control (no lure). Based on occupancy model for each species.

Avrin et al. (2021). *Ecosphere* 12(8):e03710.



Holinda et al. (2020). PLOS ONE 15(5): e0229055

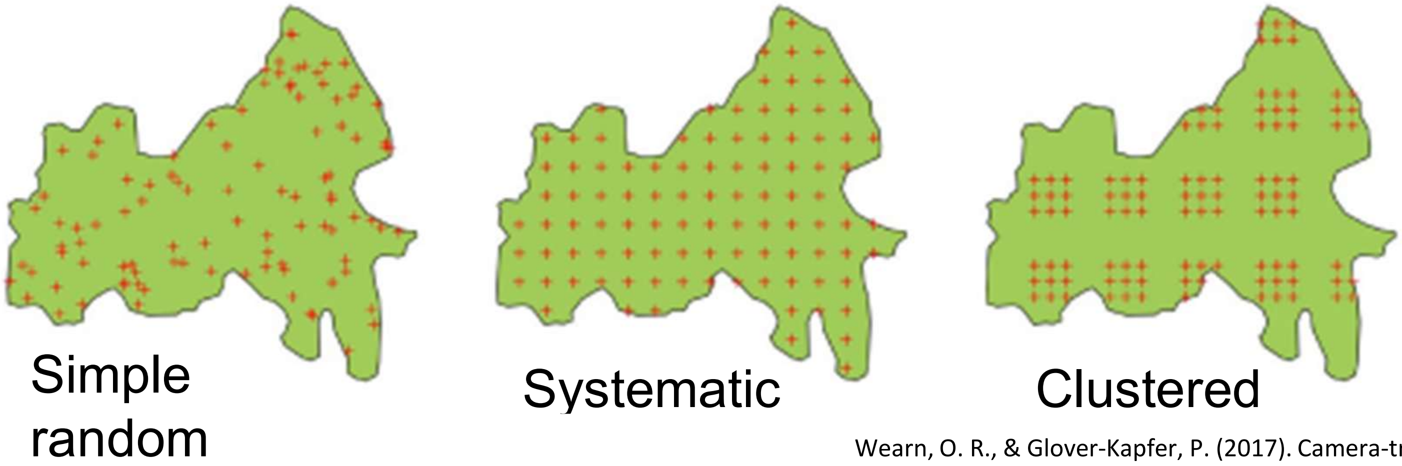
Fig 5. Effect of scent lure on detections of different species and groups. Mean effect (± SE) estimated from generalized linear mixed models of camera trap detections across lured (n = 404) and unlured (n = 440) stations in Alberta, Canada. Zero (no effect) is indicated by a horizontal dotted line.

Ciências ULisboa

Sampling methods - Direct

<u>How to set a camera-trap?</u>

Random - Sample units are selected at random using a simple random design
Systematic - sampling locations are arranged in a regular pattern, such as a grid or checkerboard pattern (**<u>Preferred</u>** - the variance in detection probabilities and abundance across sampling points will be lower).
Clustered - a more efficient sampling design where accessibility is difficult, because multiple cameras can be deployed quickly once a cluster has been reached (cluster centres are located at random/systematic, and then sample units within each cluster are also located at random/systematic).



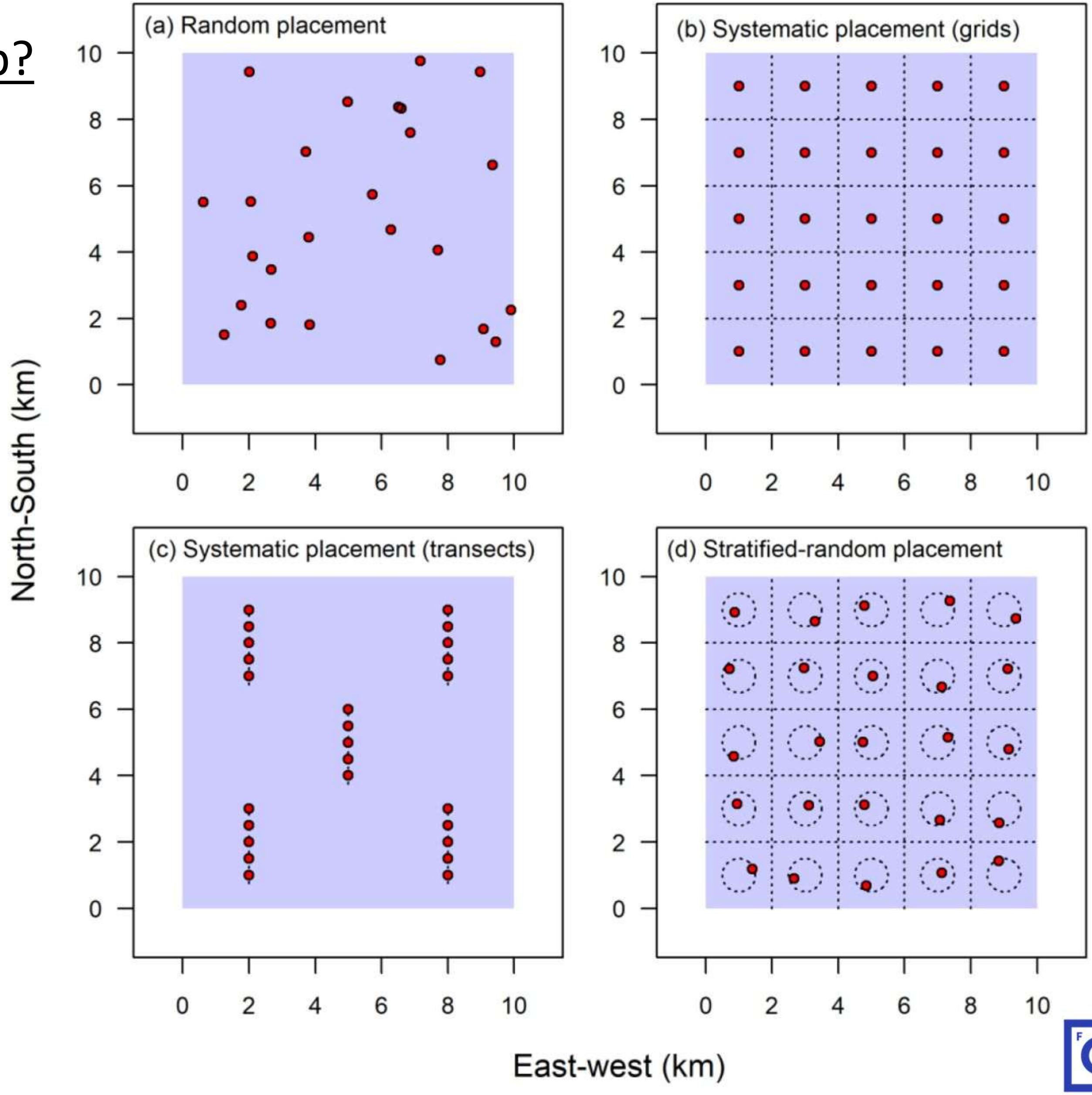
Wearn, O. R., & Glover-Kapfer, P. (2017). Camera-trapping for conservation: a guide of best-practices. Woking, United Kingdom: WWF-UK.

Sampling methods - Direct

ECM

How to set a camera-trap?

Schematic maps of four suitable camera placement designs



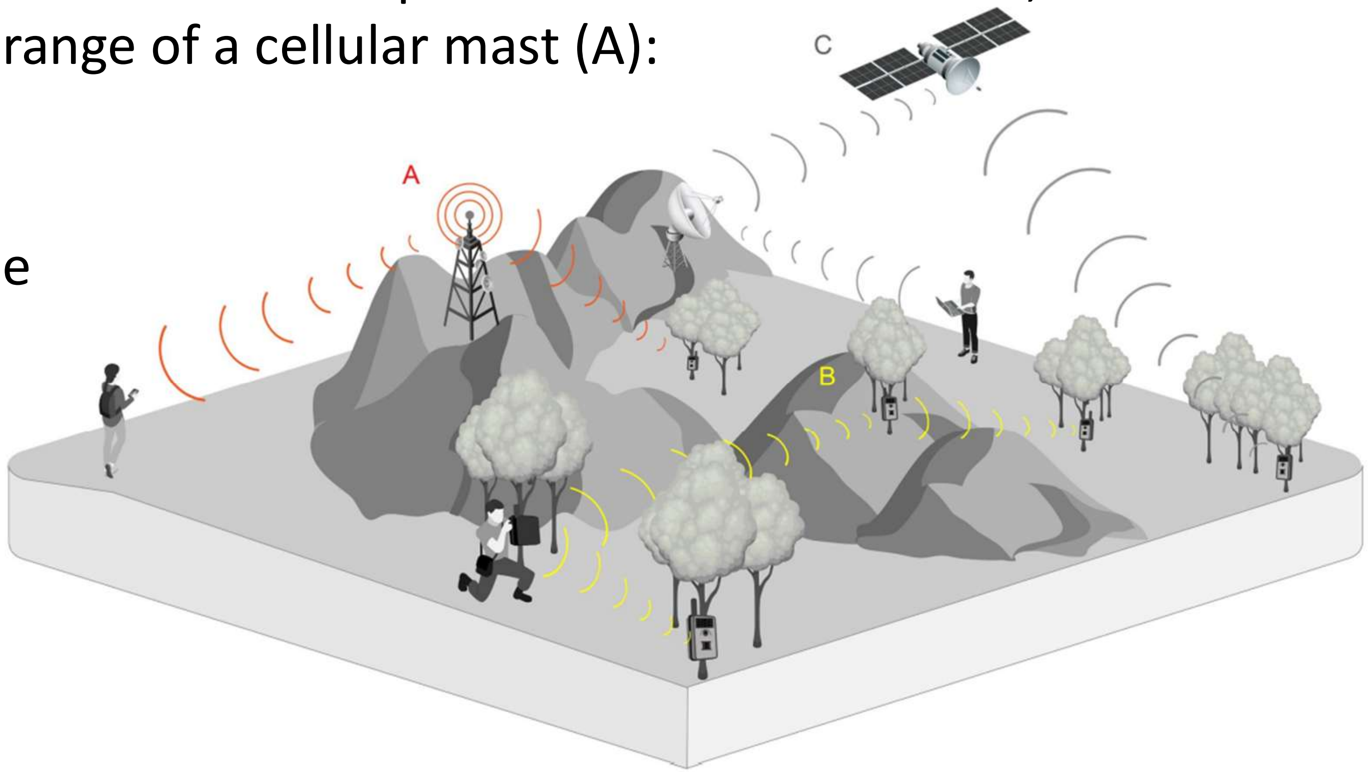
Ciências ULisboa

Sampling methods - Direct

ECM

How to set a camera-trap?

- **"Cellular" camera traps** - connect to mobile phone networks and allow camera trap images to be sent to mobile phones or e-mail accounts, but cameras must be within range of a cellular mast (A):
- **Wi-Fi** - camera traps connect over a local network to a central base station, which securely stores the images in an accessible location until they are manually retrieved (B).

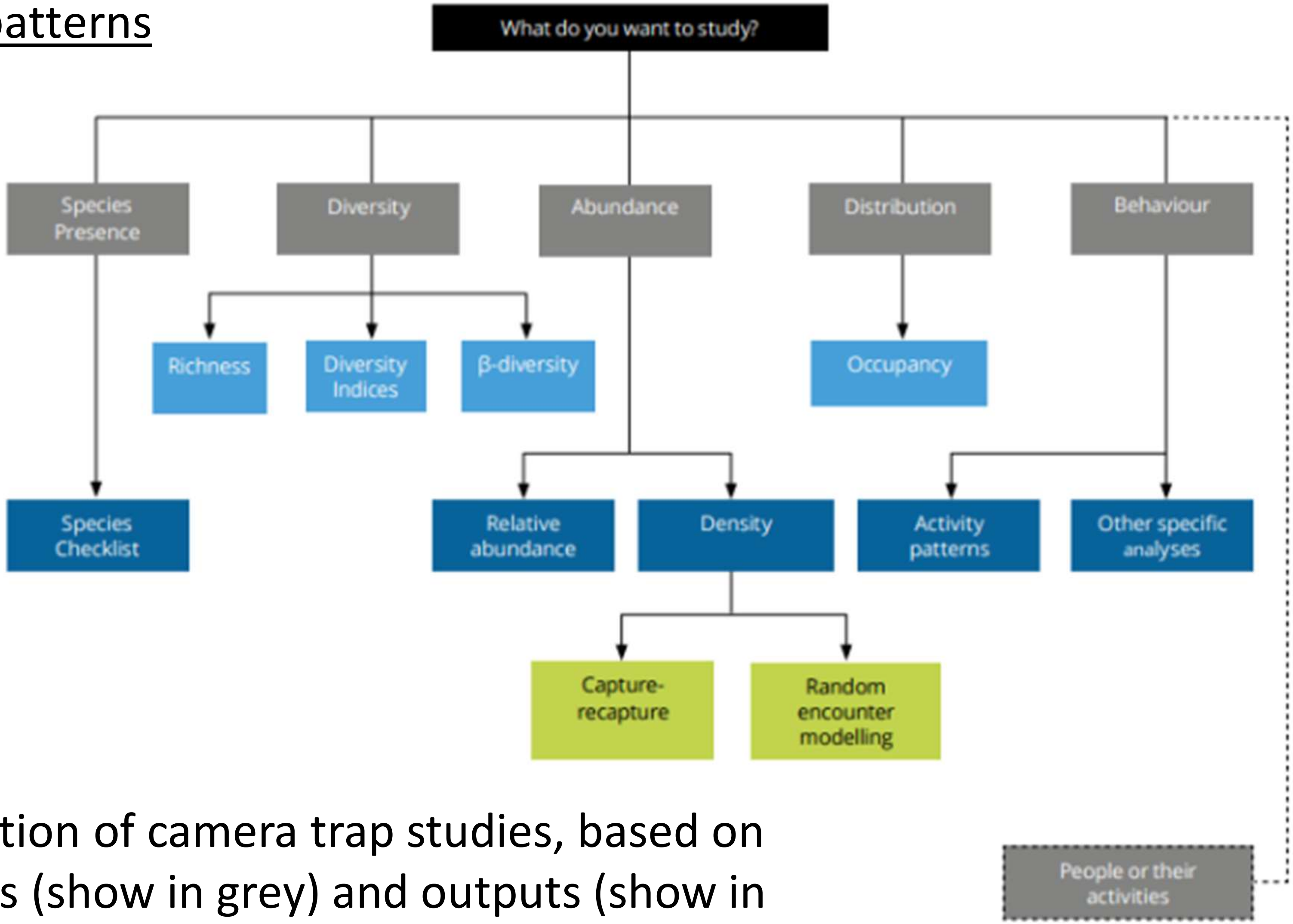


- In areas with no mobile or Wi-Fi networks, it is technically possible for camera traps to send images over satellite phone networks (C),

Wearn, O. R., & Glover-Kapfer, P. (2017). Camera-trapping for conservation: a guide of best-practices. Woking, United Kingdom: WWF-UK.

Sampling methods - Direct

Studied patterns



Classification of camera trap studies, based on their aims (show in grey) and outputs (show in blue colours).

Wearn, O. R., & Glover-Kapfer, P. (2017). Camera-trapping for conservation: a guide of best-practices. Woking, United Kingdom: WWF-UK.

Sampling methods - Direct

ECM

Type of batteries

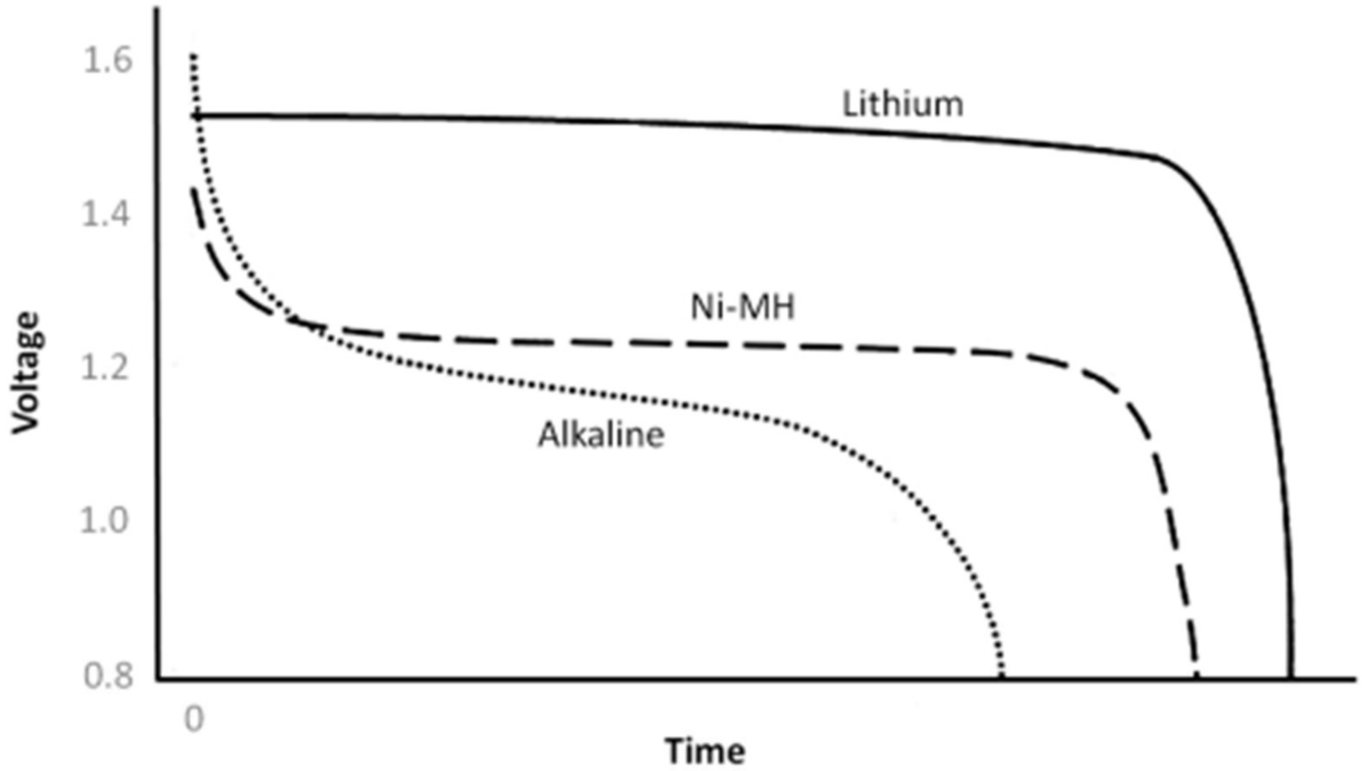


Figure 10-1. Example battery discharge curves for the three main types of AA battery currently used in commercial camera traps. Real data may show considerable variation around these idealised patterns. Adapted from van Berkel (2014).

Wearn, O. R., & Glover-Kapfer, P. (2017). Camera-trapping for conservation: a guide of best-practices. Woking, United Kingdom: WWF-UK.

Sampling methods - Direct

Spotlighting sampling

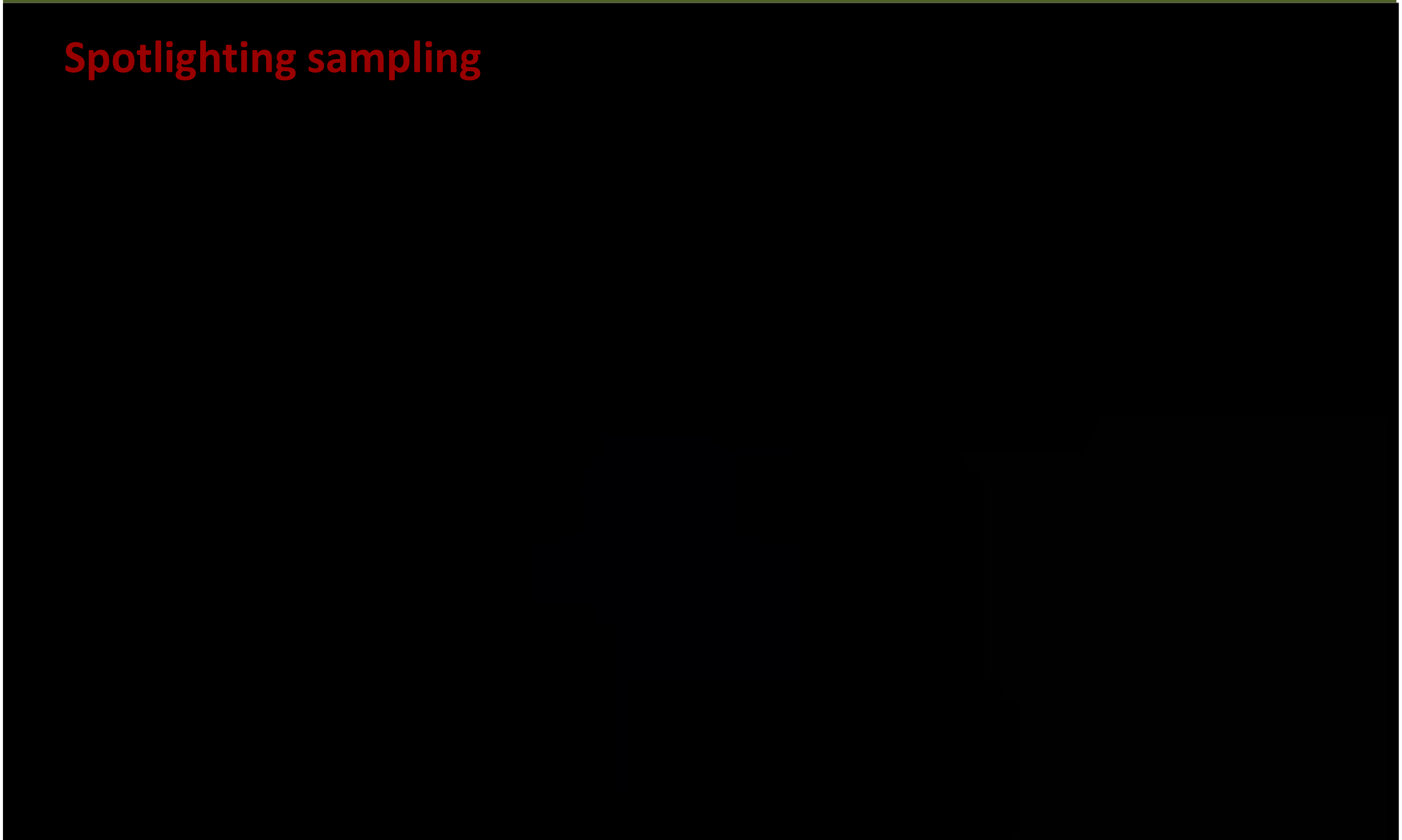

Advantages: Less-invasive method, moderate accuracy (difficulty in locating due to distance and lighting conditions), low cost, applicable to local scale

Disadvantages: need for human resources, knowledge about species behavior, good visual acuity

Sampling methods - Direct

ECM

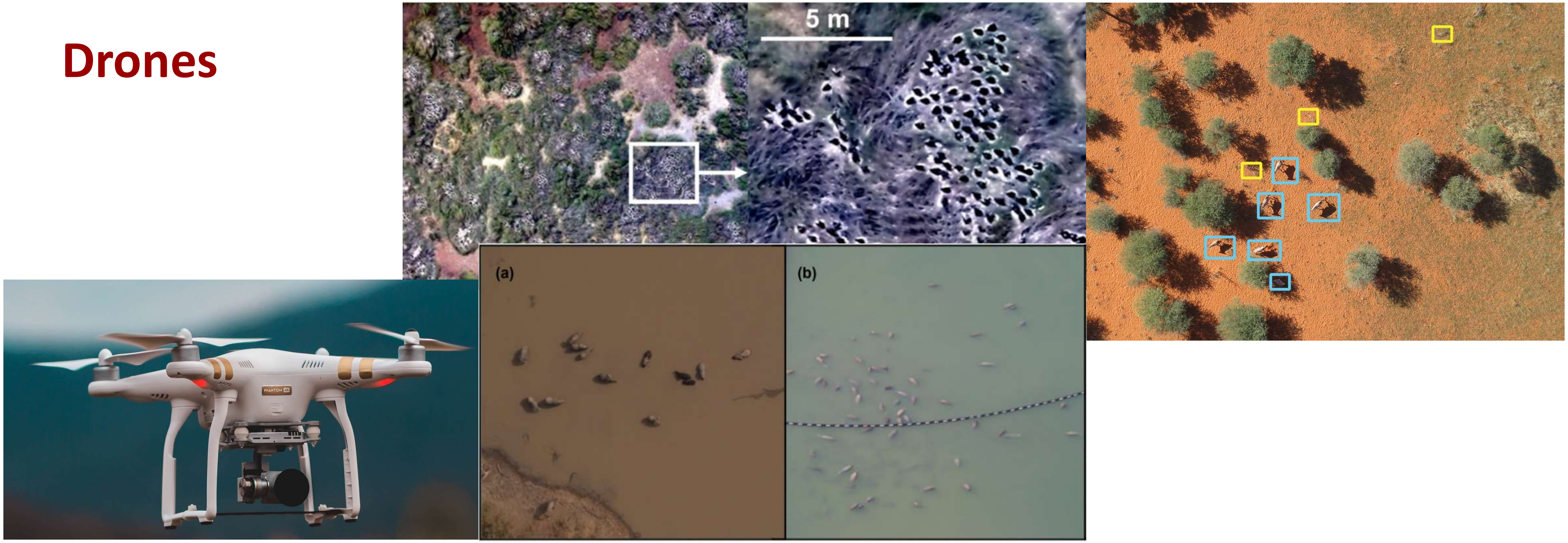
Spotlighting sampling



Sampling methods - Direct

ECM

Drones



Advantages: moderate accuracy (more efficient for large sized mammals), able to cover wide areas with lower effort

Disadvantages: cost of the drones, need for specialized human resources to maneuver the drones, only applicable to open areas, restricted autonomy

Sampling methods - Direct

ECM

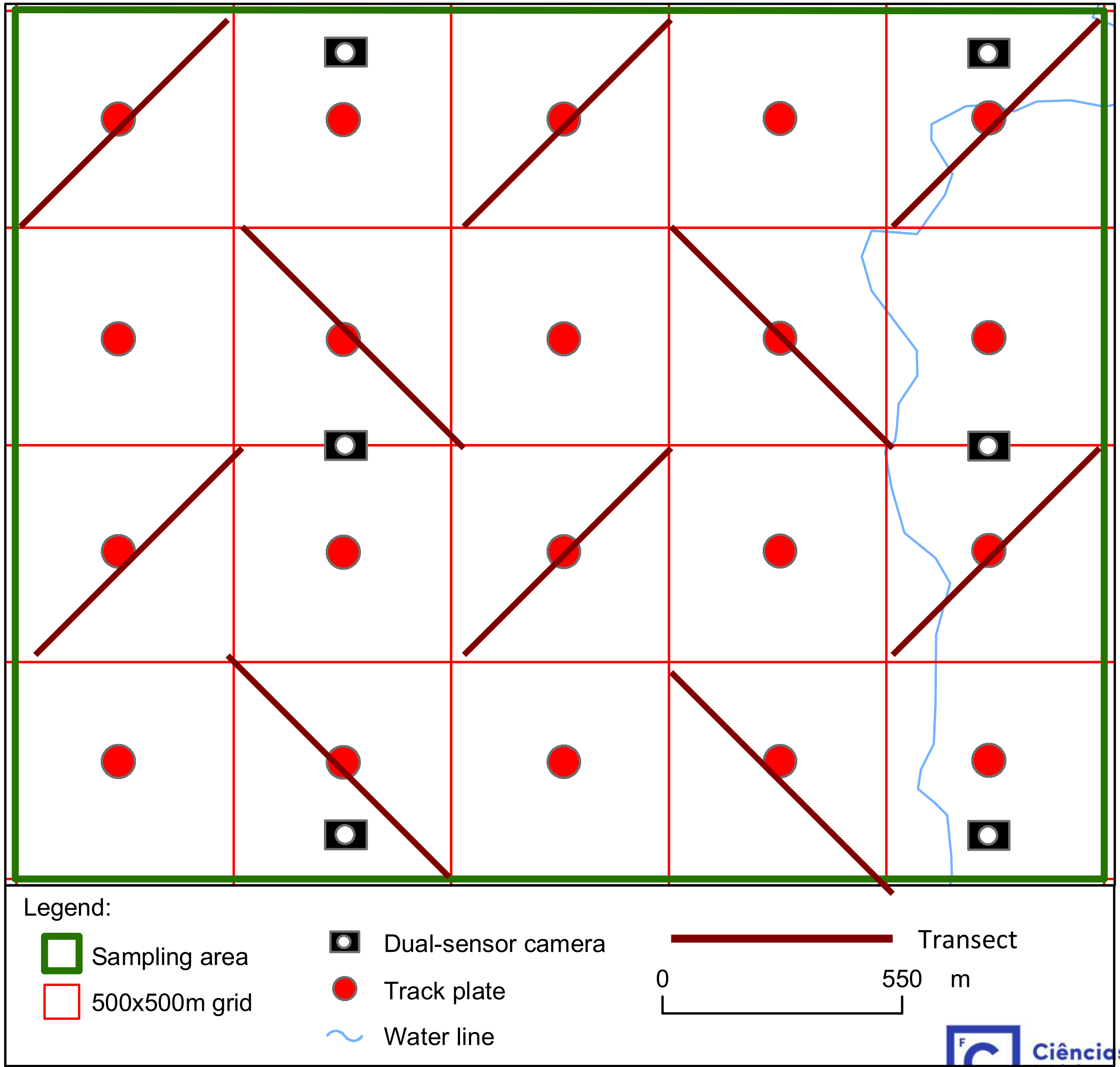
Sampling methods - Direct

ECM

Sampling methods

Combined strategies

They produce better results especially in situations of low density



Sampling methods

ECM

Combined strategies

Ciências ULisboa

Sampling methods

Radio-tracking

- Movements
- Estimation of home-ranges
- Behavior (e.g. circadian rhythms)
- Patterns of resource use (e. g. habitat preferences)

Advantages: moderate to high accuracy

Disadvantages: invasive method (envolves animal’s capture and handling), complexity, high cost and mostly applicable to small scale studies

Sampling methods

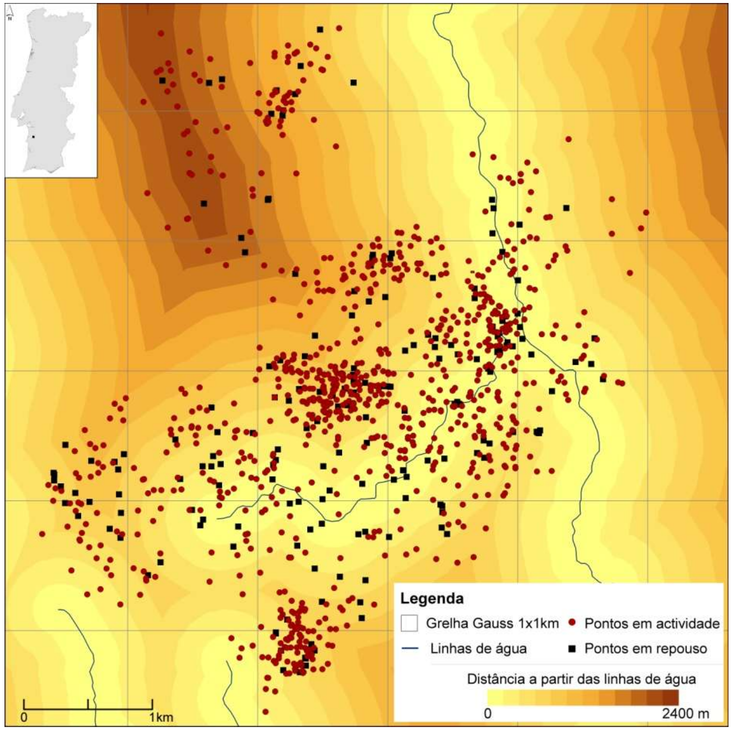
Radio-tracking

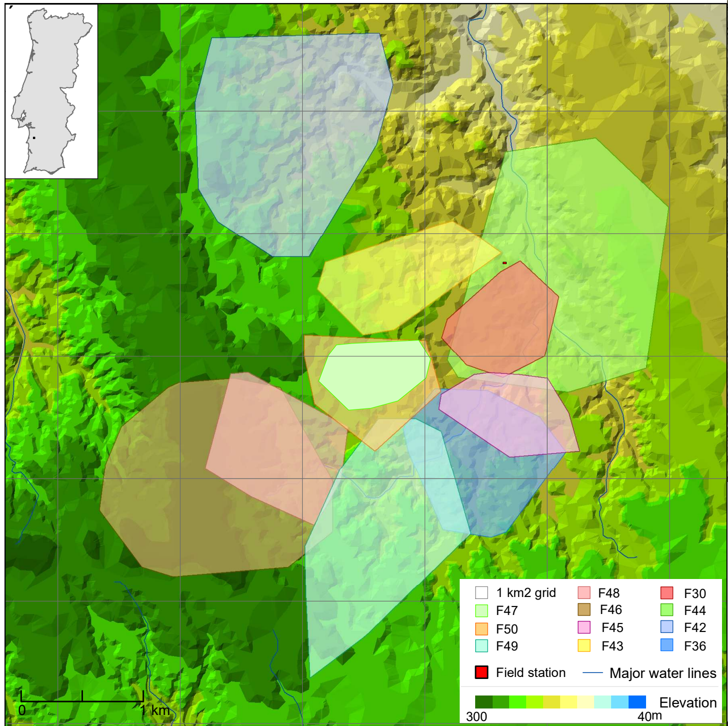
- Transmitters emitting on a single frequency, placed on a collar, harness or intraperitoneally through a surgical intervention
- Each location has an associated vector (x, y, t), where x and y are the spatial coordinates and t the time coordinate.
- Attributes associated with the vector, e.g., weather conditions, signal intensity, location description, habitat, and behavior (active / inactive) of the animal at location time, etc.

Sampling methods

ECM

Radio-tracking

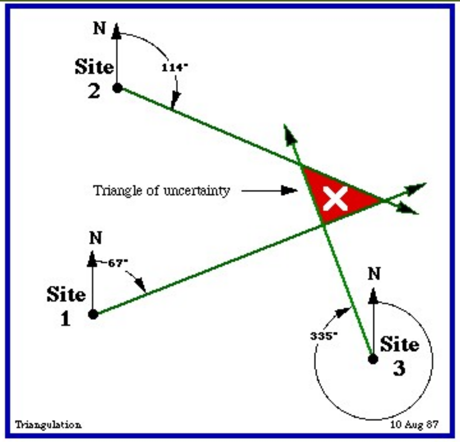




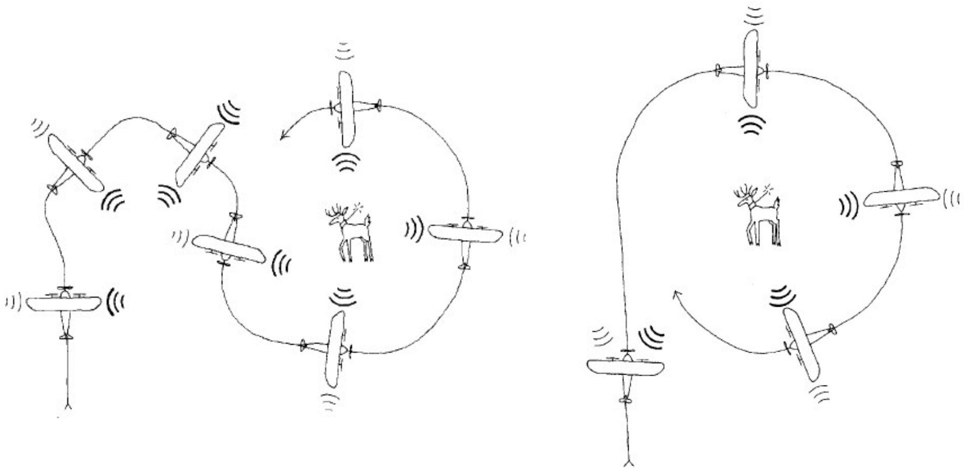
Sampling methods

ECM

Radio-tracking - VHF



- Triangulation
- Homing
  - Location of the animal on foot and within walking distance
- Plane



Ciências ULisboa

Sampling methods

Radio-tracking

Sampling methods

ECM

Radio-tracking

Sampling methods

ECM

Radio-tracking

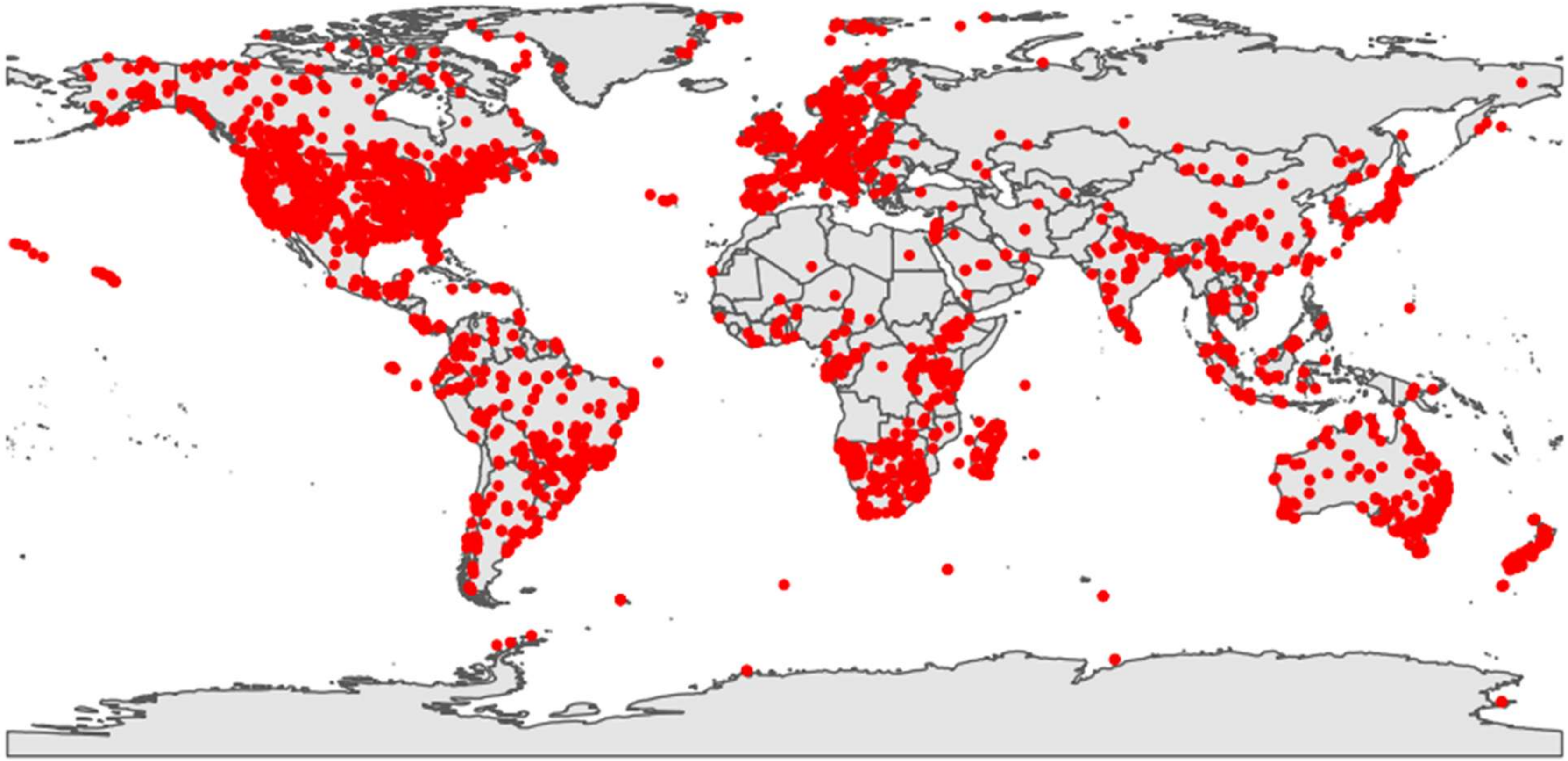


FIGURE 3 Distribution of the locations of the home-range studies included in the *HomeRange* database (n = 75,611)

Broekman et al. (2023) Global Ecology and Biogeography, 32, 198–205

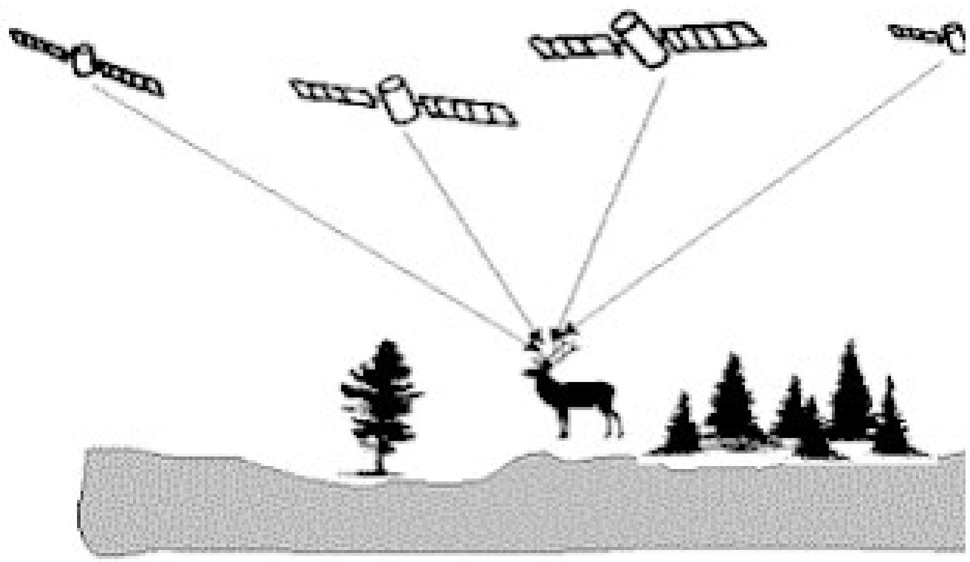
Ciências ULisboa

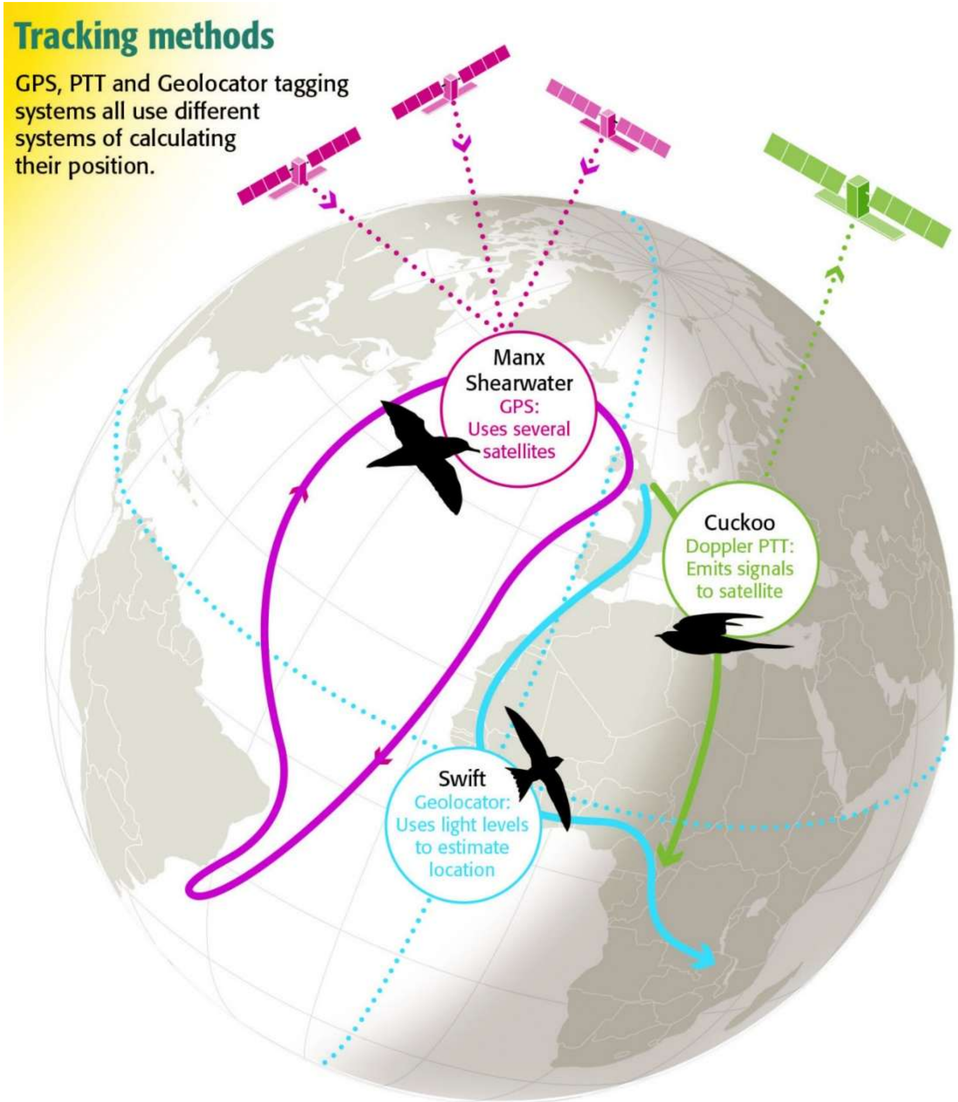
Sampling methods

ECM

Radio-tracking - satellites

1. PTTs (Argos Platform Transmitter Terminals)
2. GPS
3. Reverse GPS



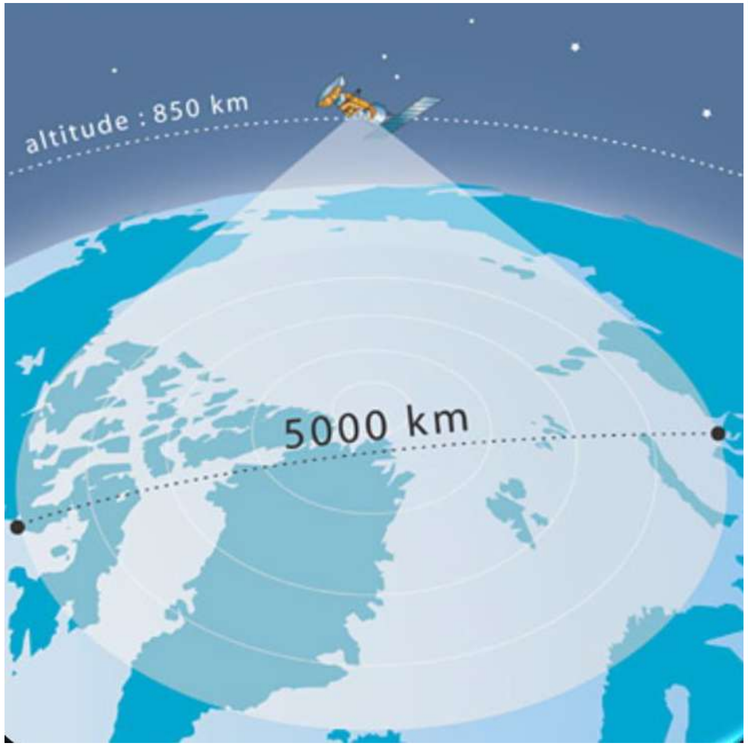


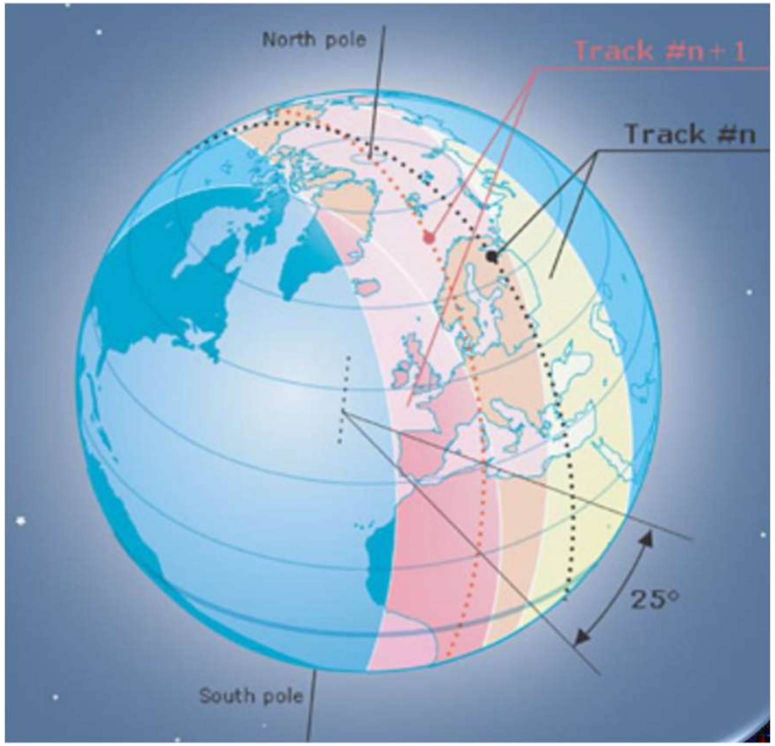
Sampling methods

ECM

1. PTTs (Argos Platform Transmitter Terminals) - Passive location using satellites

Argos system – a series of polar-orbiting satellites





Altitude: 850 km
Footprint diameter: 5000km
10m per pass

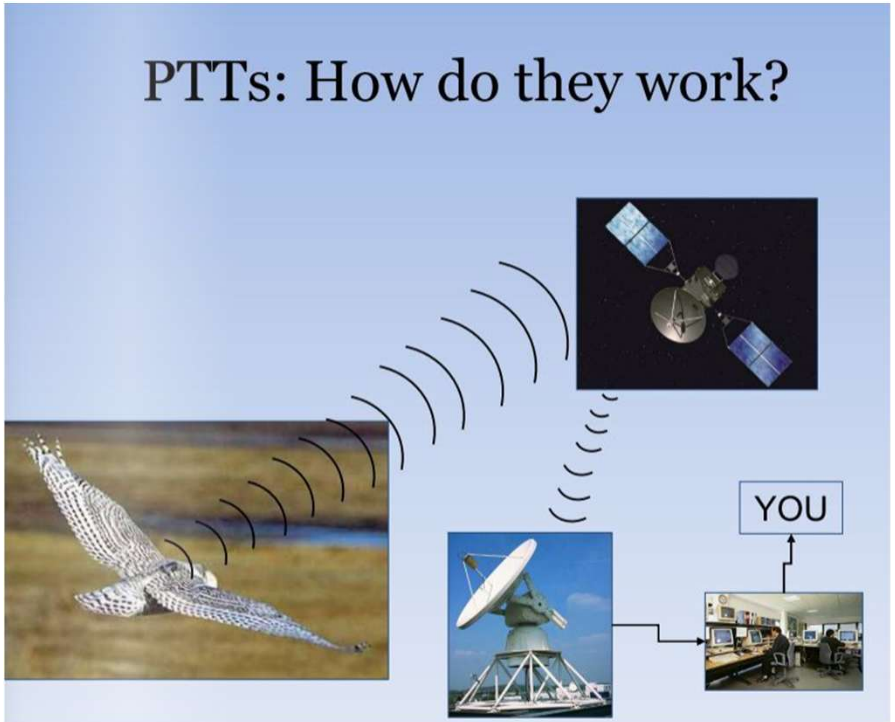
Each transmitter can be located 14 times a day

Sampling methods

1. PTTs (Argos Platform Transmitter Terminals) - Passive location using satellites

Argos system – a series of polar-orbiting satellites

- A platform (transmitter) transmits periodic messages characterized by the following parameters:
- Transmission Frequency, which must be stable as the location is computed on the basis of Doppler effect measurements
- Repetition period, which is the interval of time between two consecutive message dispatches, varying between 90 and 200 seconds
- The transmission of each message takes less than one second.

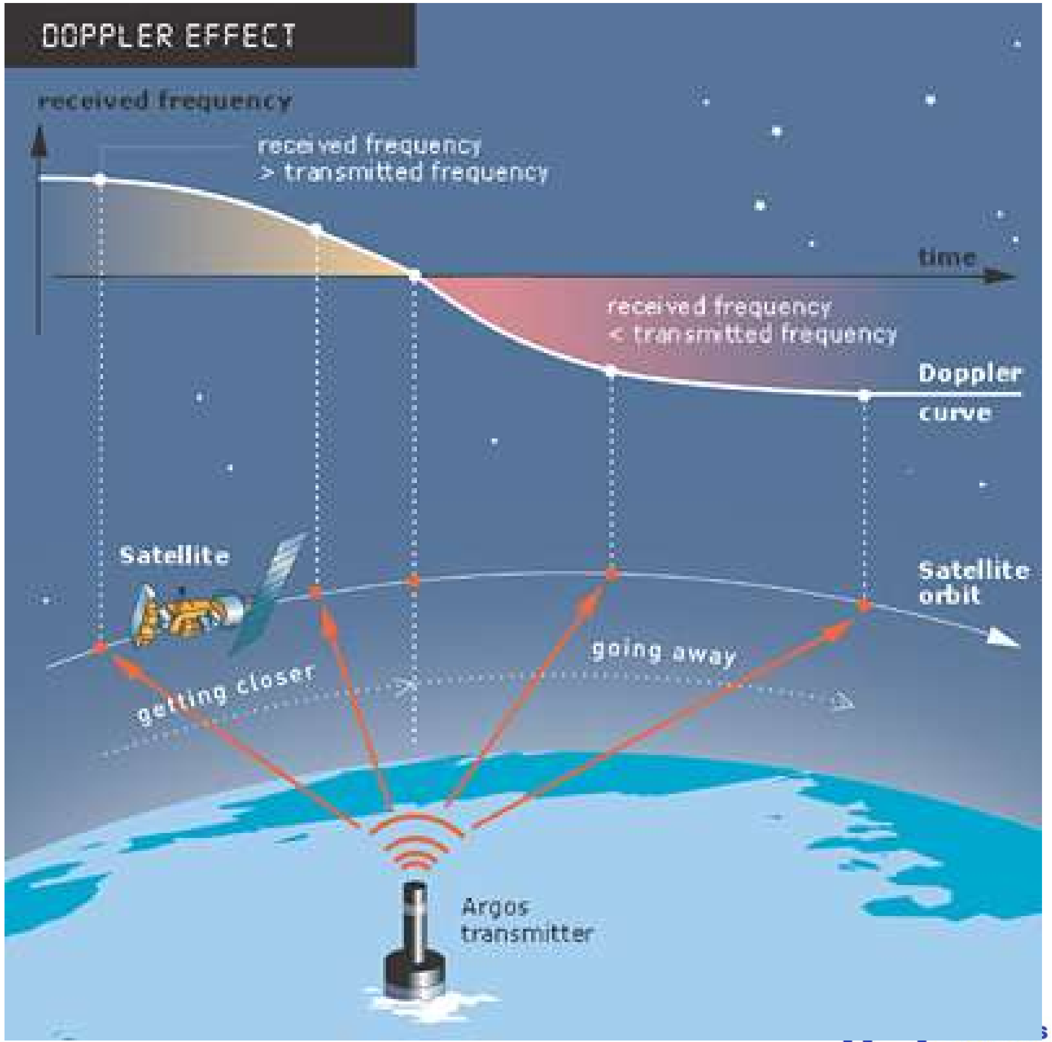


Sampling methods

1. PTTs (Argos Platform Transmitter Terminals) - Passive location using satellites

Argos system – a series of polar-orbiting satellites

- How it works?
- 'Doppler PTTs' – when a satellite comes into view whilst these tags are transmitting, the satellite will 'hear' the signal at a slightly different pitch as it passes towards and away from the tag (the 'Doppler effect')
- It estimates location using the change in the satellite's position, its speed and distance from Earth, and the change in frequency of an electromagnetic wave when the transmitter and receiver are in motion relative to each other

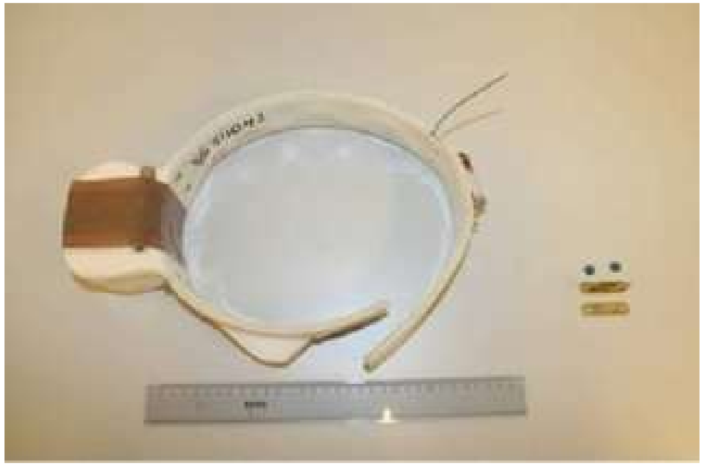


Sampling methods

1. PTTs (Argos Platform Transmitter Terminals) - Passive location using satellites
Argos system – a series of polar-orbiting satellites

- <u>Advantages</u>
  - Wider movements (dispersal and migration paths)
  - Moderate errors (0.25-1.5km)
  - Allows assessing habitat use patterns

- <u>Disadvantages</u>
  - Few transmissions per day
  - Expensive (2500-3500 USD)
  - Heavy transmitters
  - High data transmission costs



Sampling methods

2. Global Positioning Systems (GPS)

Figure 1. Remote data transfers for GPS-based tracking systems use a GSM link, a satellite-based link, or a handheld terminal.

Other broadly similar systems

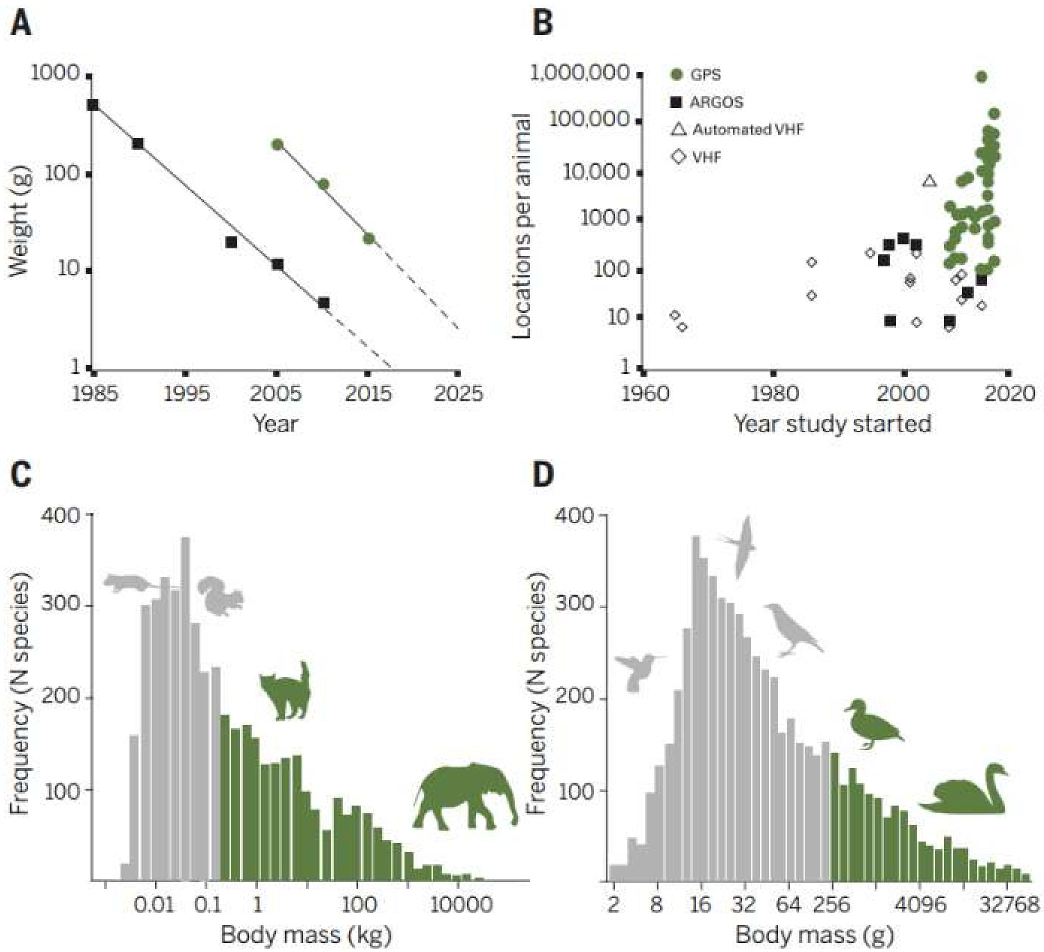
- GLONASS (Russia)
- BeiDou (China)
- Galileo (Europe)

Sampling methods

2. Global Positioning Systems (GPS)

Technological development allowed:

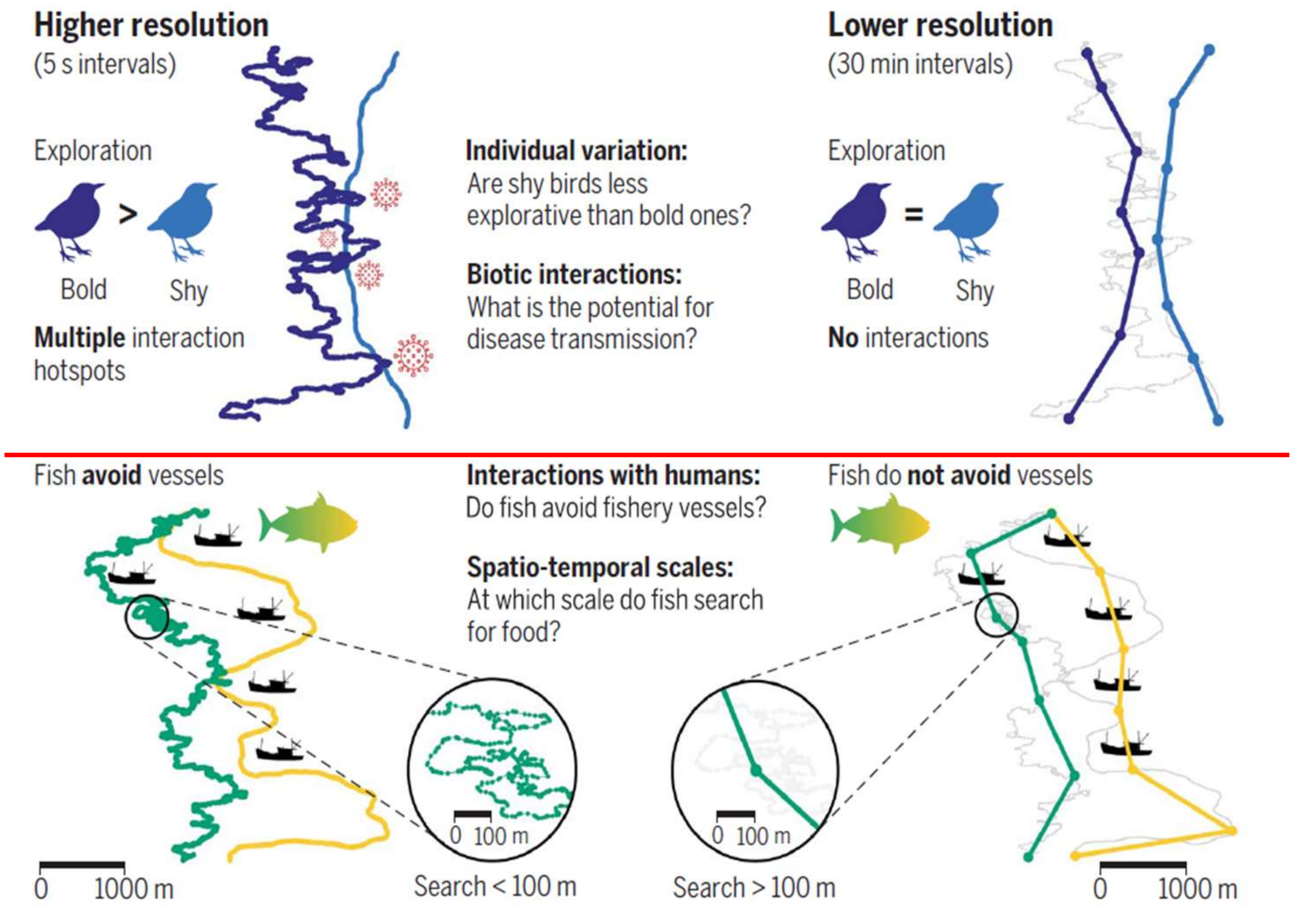
- decrease the size of GPS transmitters (A)
- increase the amount of data collected by each of the transmitters (B)
- to monitor species of lower body mass, namely mammals (C) and birds (D) - Grey bars



Sampling methods

2. Global Positioning Systems (GPS)

- Why do high-resolution data movement data matter?



Nathan et al. (2022) Science 375, 734

Sampling methods

2. Global Positioning Systems (GPS)

- Advantages
  - High precision of the locations (error < 100m)
  - More frequent animal location
  - Continuous monitoring (characterization of the movement patterns)
  - No tracking costs (if no satellite stations are used)

Sampling methods

2. Global Positioning Systems (GPS)

- Disadvantages
  - Heavy (+70g)
  - Costly: GPS alone (1000-2000 USD); with PTT (3000-4000 USD)
  - GPS alone: recapture needed or regular visits to the study area to retrieve data
  - GPS + PTT: greater tracking/data acquisition costs
  - Difficult miniaturization which restricts the range of species that can be monitored
  - Short duration of the batteries if the recording is continuous or almost continuous

Sampling methods

3. Reverse GPS

- Unlike the conventional GPS system, reverse GPS architecture places the emitters at the objects to be tracked and the receivers at fixed (earth) stations
- The emitters can be made very simple and most of the intelligence of the system is located at the receivers.
  - The hardware to be placed on the tracked objects can thus be reduced to a minimum.

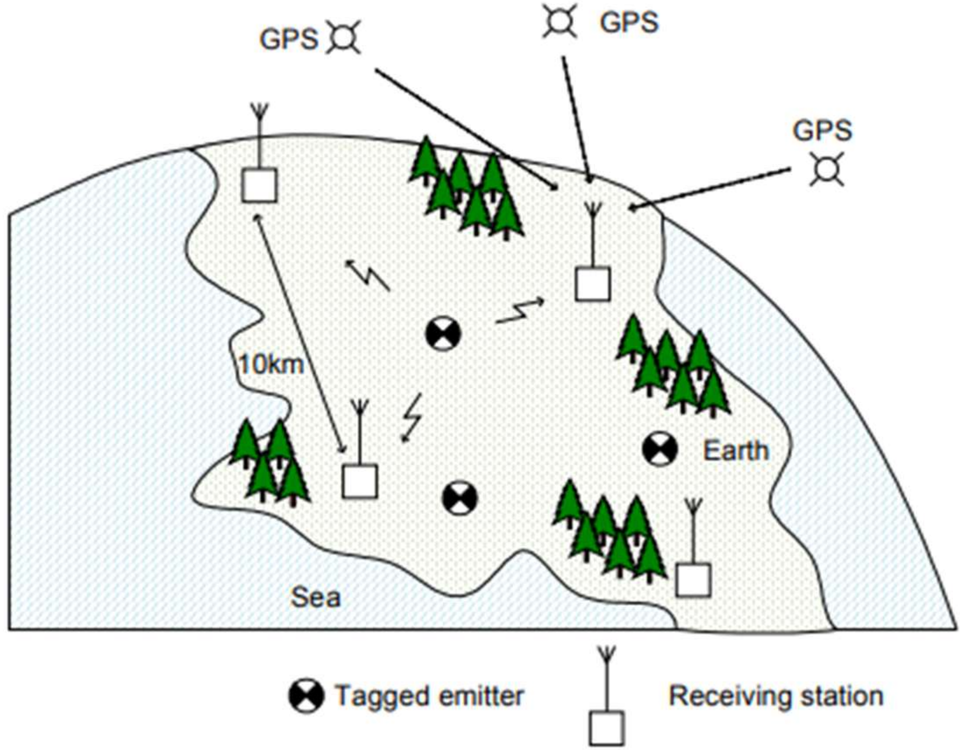
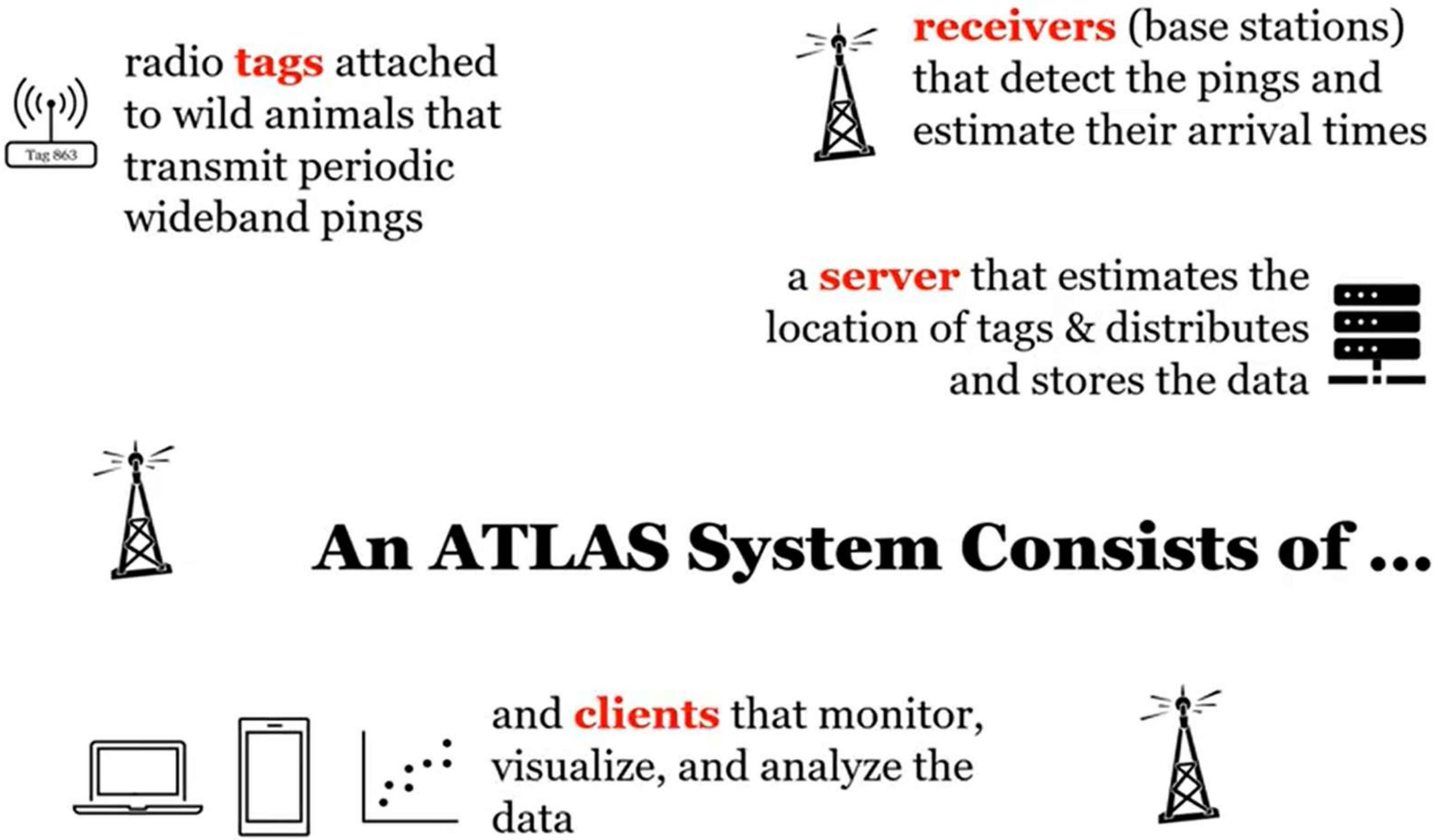


Figure 1 - Inverted GPS conceptual overview

Andrade et al. (2011). IEEE 2011 International Conference on Localization and GNSS (ICL-GNSS)

Sampling methods

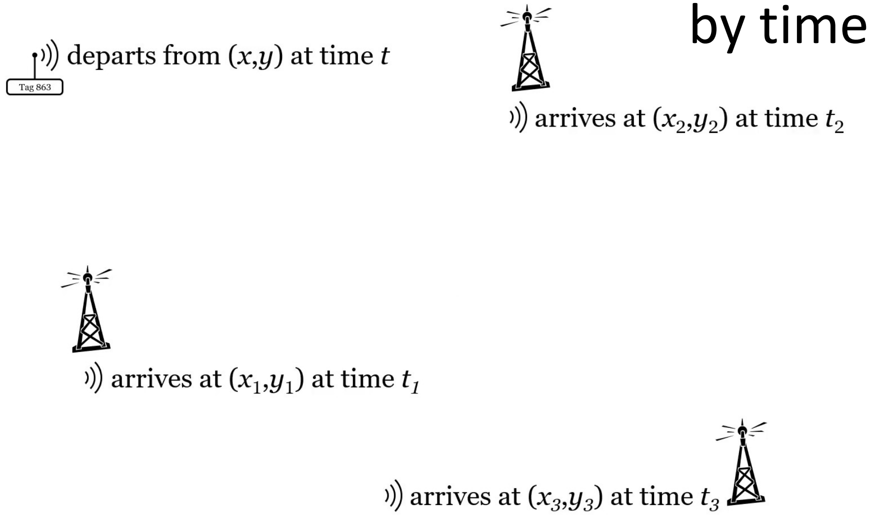
3. Reverse GPS

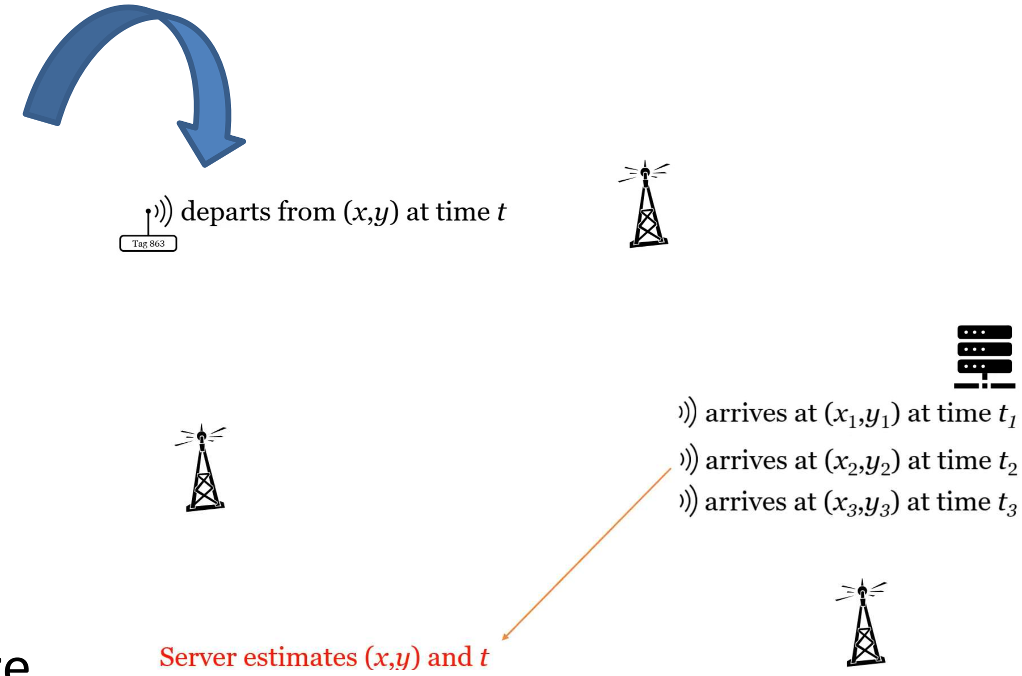


Sampling methods

3. Reverse GPS

- Track transmitting tags through an array of receivers by time-of-arrival estimation (trilateration).

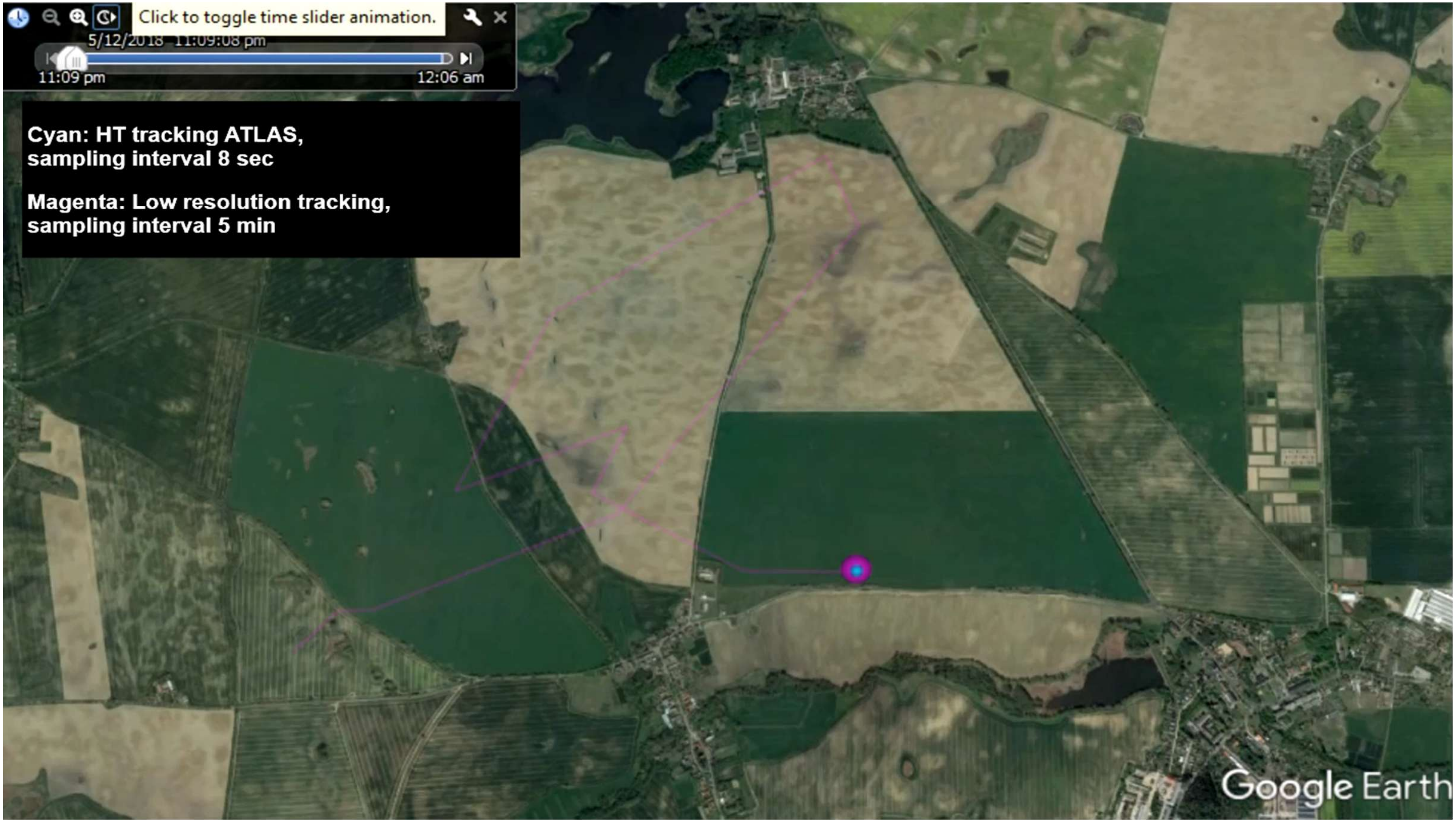




https://www.youtube.com/watch?v=LKNCAsG7sg4

- Their main limitations are relatively restricted range (≤100 km) and installation costs.

Sampling methods



Ciências ULisboa

Sampling methods

Radio-tracking – Effects on Mammals

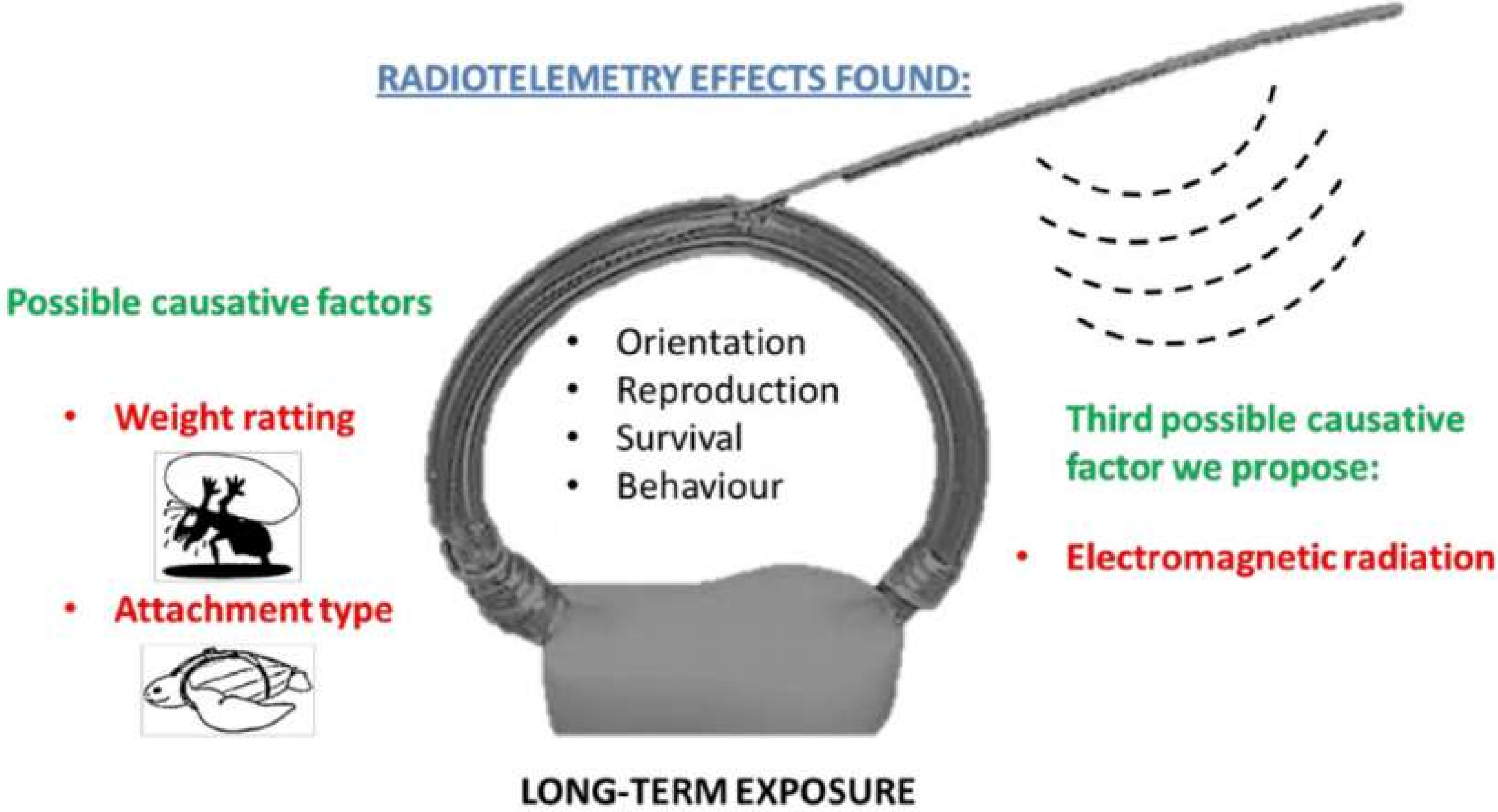


Fig. 1. Radiotelemetry effects found and possible causative factors.

Balmori A. (2016). Radiotelemetry and wildlife: Highlighting a gap in the knowledge on radiofrequency. Sci Total Environ 543: 662-669.

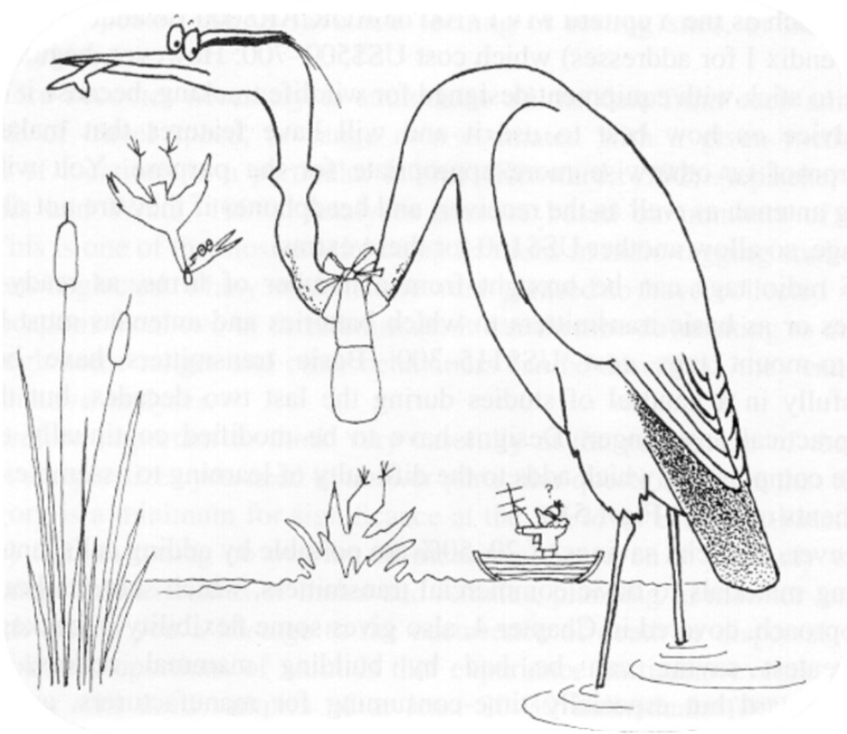
Sampling methods

ECM

Radio-tracking – Effects on Mammals

Weight rating

- It is recommended that the total radio transmitter and associated devices should not exceed 2–5% of the the body weight
- Can affect:
  - Behaviour
  - Movements
  - Reproduction
  - Survival



Sampling methods

ECM

Radio-tracking – Effects on Mammals

Type of attachment

- various types of attachments might have severe effects such as:
  - impaired survival
  - altered behavior
  - lower reproductive rate
- back-mounted or harness-attached transmitters may cause pathological lesions
- Mortality is more common in implants, harnesses, collars; with no mortality (or rare) reported in studies using tail mounts and glue

Sampling methods

ECM

Radio-tracking – Effects on Mammals

The importance of considering time

- Studies that found no adverse effects - ran for a few weeks/year
- No studies assessed the cumulative/long-term effects
- Generally, the damage is long-term, and the presence of pathological lesions was significantly associated with the length of time animals had been carrying their radio transmitters

Sampling methods

Radio-tracking – Effects on Mammals

<u>Non-ionising electromagnetic radiation</u>, i.e. radiofrequency radiation, RFR, from transmitters emitting the signals necessary for tracking

- RFR can cause sublethal physiological disruptions
  - Increase in stress proteins synthesis
  - Calcium channels - increased flow calcium into the brain (Physiology impacts)
  - Immune system
  - Nervous system and behavioural effects (e.g. cognitive function, sleep and electrical brain (EEG) response)
  - Genotoxic effects and potential carcinogenicity
  - Fertility, reproduction, offspring viability and sex ratio (e.g. oxidative stress and free-radical might affect fertility and reproduction)
  - Navigational disruption

How to design the sampling strategy

- **Factors to consider:**

- The study temporal scale
- What are the characteristics of the environment to be sampled (e.g., homogeneous vs. heterogeneous, terrestrial vs. aquatic)
- What is the question we want to answer?
- The study spatial scale
- Which is(are) the object(s) of study (physical characteristics and prior knowledge of its biology and ecology)

- Which is(are) the most appropriate study method(s)
- Which is the most appropriate sample design?