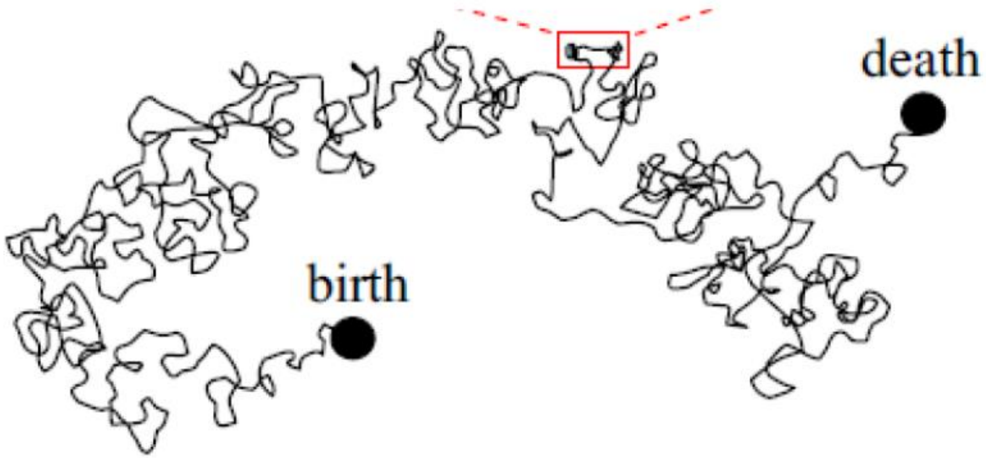
Wildtierkundekurs II

4. Introduction to Animal Movement



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Animal movement

Movement is defined as the change in spatial location of the whole individual in time

Animals move in response to multiple processes acting at various spatial and temporal scales

The fate of animals is determined by their interaction with their environment and hence their movements in space and time

Thus understanding animal movement is central to animal conservation and management

Nathan et al. 2008 , PNAS

Lecture overview

- General principles of animal movement
- Animal movement and the age of biologging
- Behavior that results in animal home ranges

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Fundamental questions of animal movement

Nathan et al. 2008, PNAS

1) Why to move?

Internal state of animal (e.g. food, seeking shelter, etc.)

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Fundamental questions of animal movement

Nathan et al. 2008, PNAS

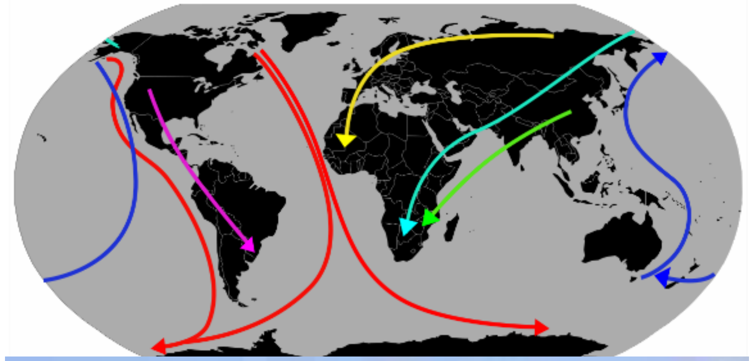
2) How to move?

The motion capacity of the animal (e.g. biomechanical predisposition to swim, fly or walk)

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Fundamental questions of animal movement

Nathan et al. 2008, PNAS



3) When and where to move?

Navigation capacity of the animal (response to cues, memory to previous experiences, genetic predispositions)

4) What external factors affect movement and how?

e.g. season or day/night, competing species, temperature, etc.

These components interact to produce movement

Tracking animal movement

How can we collect data on animal’s use of space?

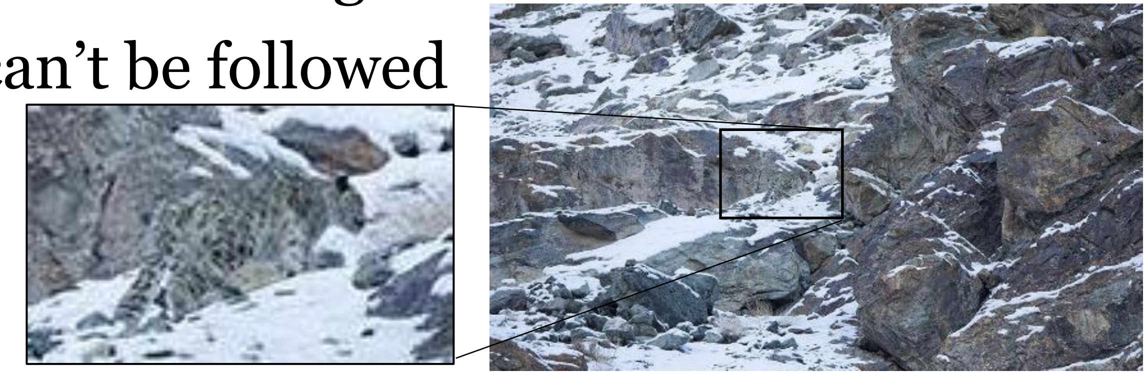
By following animals and record where they go.

But

→ animals might be affected by presence of observing researchers

→ animals may go to places where they can’t be followed

→ observers have to rest sometimes



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Tracking animal movement

Other possibility: **Transect or camera trap surveys**

But result in relatively few observations and often lack behavioral context.
Tell us little about range size if individuals can't be identified individually

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Tracking animal movement

Other possibility: **Radio telemetry**

Radio telemetry allowed monitoring individual animals with less interference to individuals followed

→ Enabled acquiring information from animals living in inaccessible environments

→ Enabled to simultaneously monitor survival and reproduction giving the opportunity to link movement to individual performance

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Tracking animal movement

Radio telemetry has been the most common technique to follow and record animal movement since beginning of VHF transmitters in 1960's

→ But still issue remained that animals can't be followed all the time everywhere

→ Trade offs between size of transmitters and performance limited and still limit size of animals that can be followed and for how long

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Biologging – a new Science

Combined advances in

- Miniaturization of radio transmitters
- Global positioning system
- Cellular and satellite networks
- Inprovement in battery performance
- Development of new sensors such as acoustic, temperature, heart-rate etc.

… opened new opportunities in tracking animals and increased our understanding of what drives animal movement and how this relates to individual and population level performance→ **Biologging** as a new science emerged

Today we can follow animals comfortably from behind our desk without biasing animal behavior by our presence

Rescue fawns with technology?

Every year fawns are killed during mowing

→ 5’000-15’000 fawns

→ Animal welfare & economical issue

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Rescue fawns with technology?

Huge effort to prevent mowing accidents every year

→ No scientific evaluation of different methods

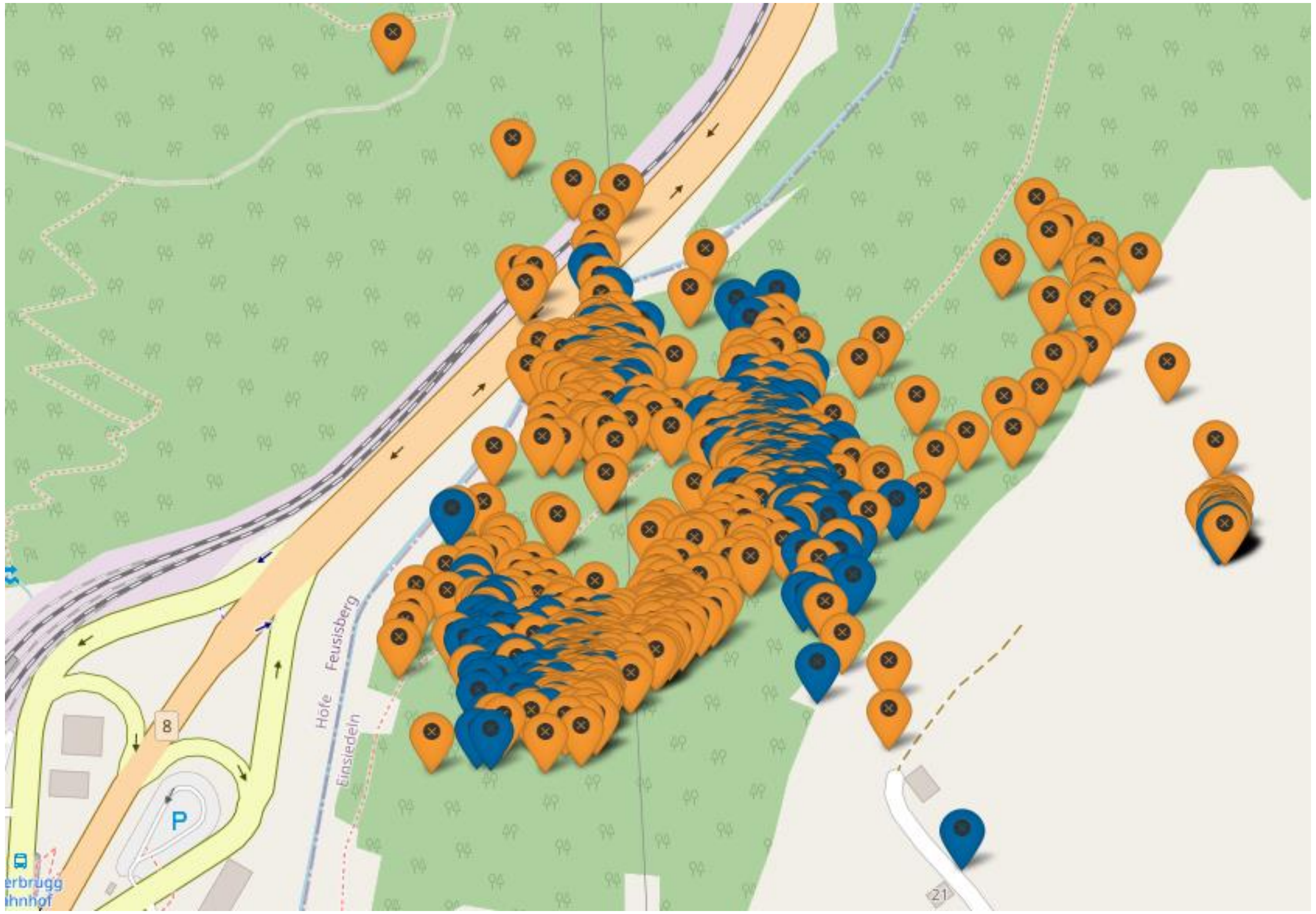




Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Rescue fawns with technology?

Roxana Sadre Orafai



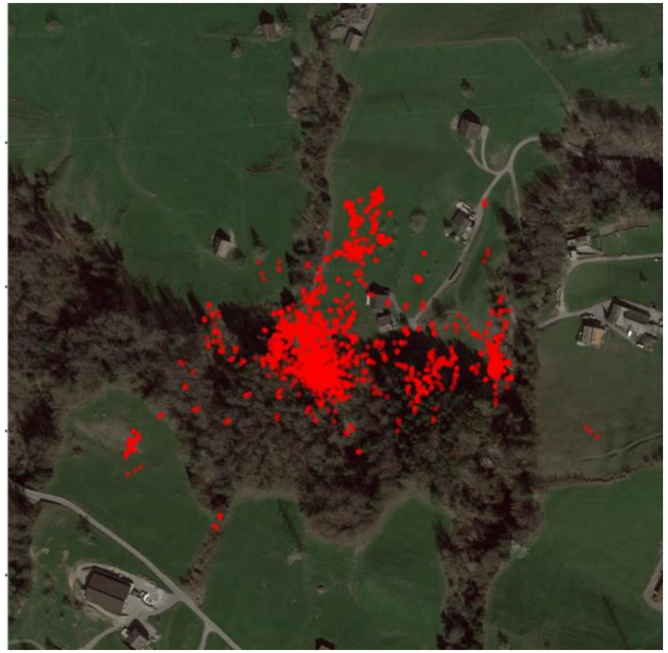
Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Wildtier Schweiz

Rescue fawns with technology?

Rescue fawns with technology?

Record GPS location every 2 minutes - fawns move far…



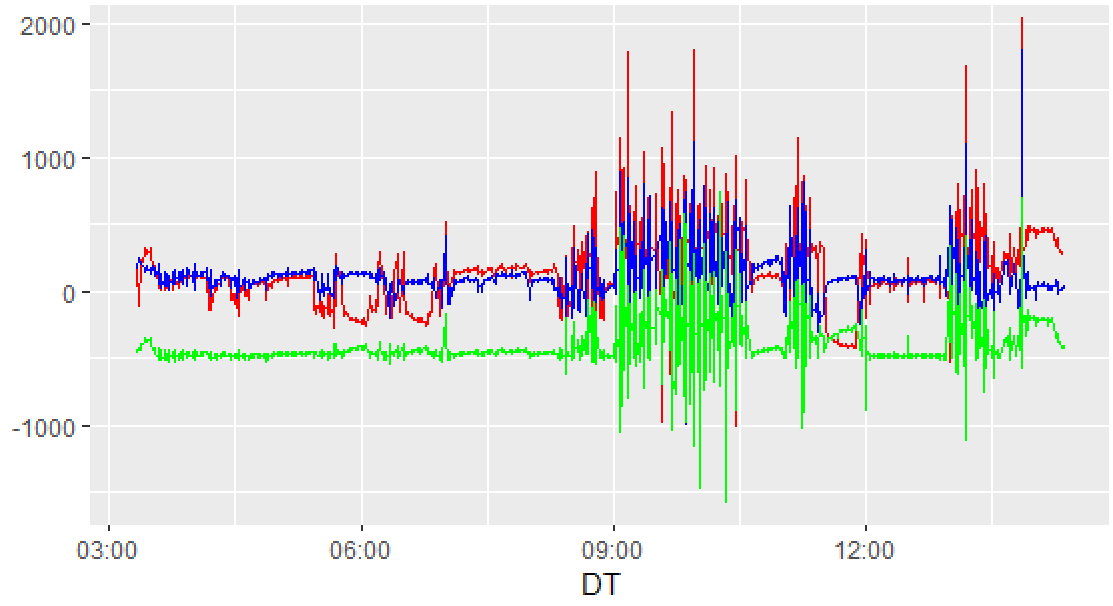
Kitz 9231 – 5 days

Kitz 9850 – 7 days

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Rescue fawns with technology?

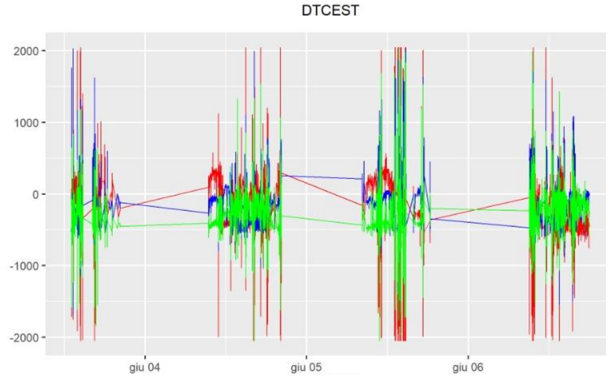
Record activity every 10s at 30Hz…



… we can monitor them without watching

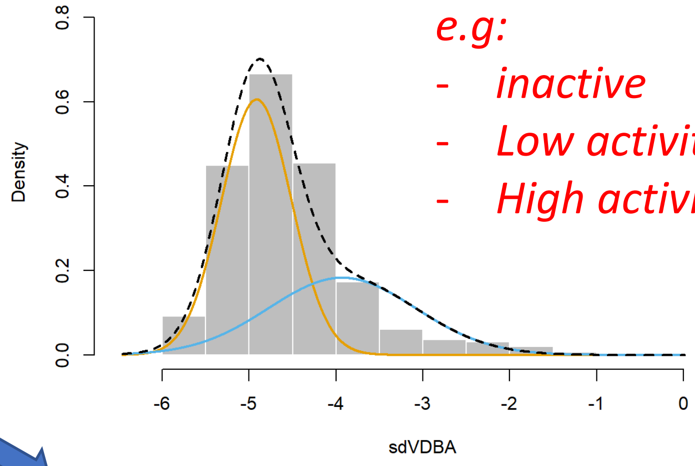
Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Rescue fawns with technology?



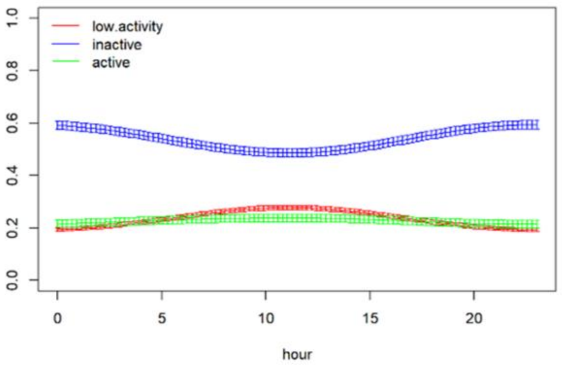
Accelerometer data from fawn

HMM modelling



Behaviors e.g:

- *inactive*
- *Low activity*
- *High activity*



MSc Adeline Bognalia, UZH

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Wildtier Schweiz

Methods to understand animal movement

Enormous increase in quantity and quality of collected data comes at a cost though

→ Need to develop new data management systems, computational power and methods to analyze large amounts of data

→ Newly developed tools and methods to analyze animal movement increasingly gained complexity

→ However with enormous progress in newly developed methods we begin to understand the individual processes from which animal movement emerges

Animal movement data

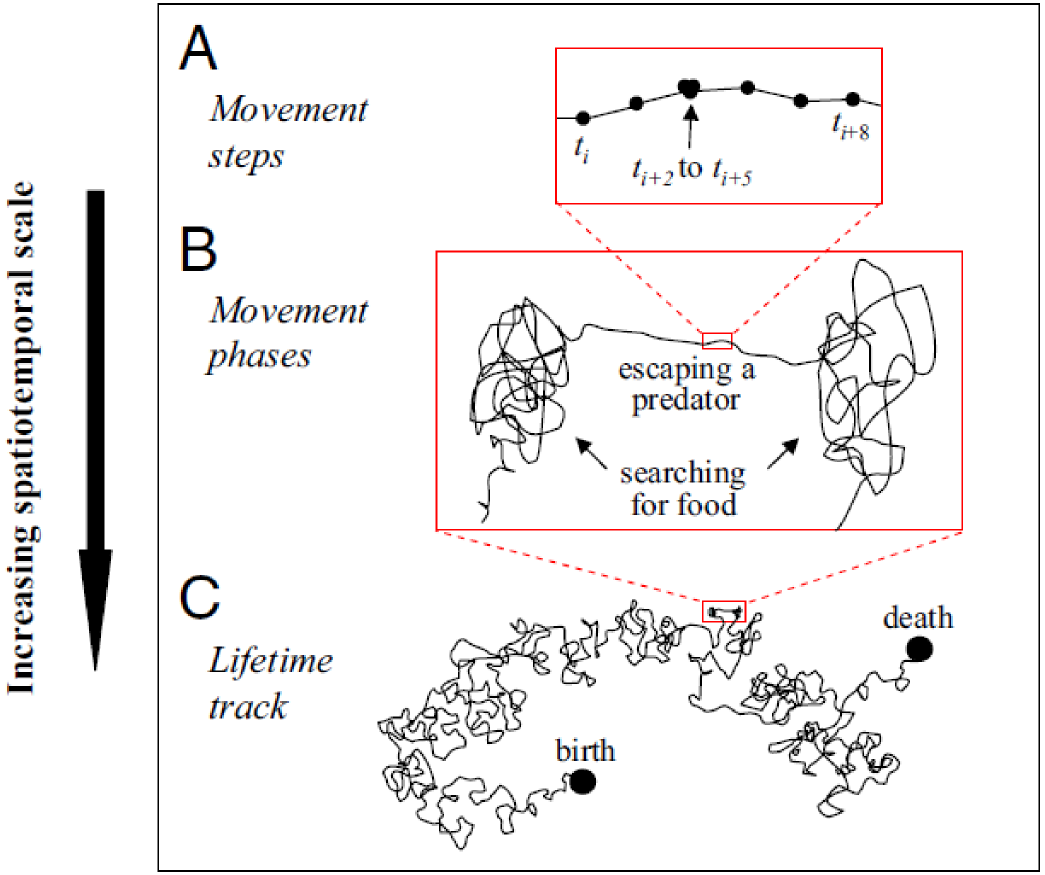
Movement data constitutes a temporal sequence of recorded locations of animals building a movement path (a trajectory)

Different segments within a path can be attributed to different behavioral phases of an individual, each associated with a specific goal such as feeding, resting, searching for mate, etc.

The complete sequence of steps of an individual from birth to death constitute the «lifetime track»

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Animal movement data



Nathan et al. 2008 , PNAS

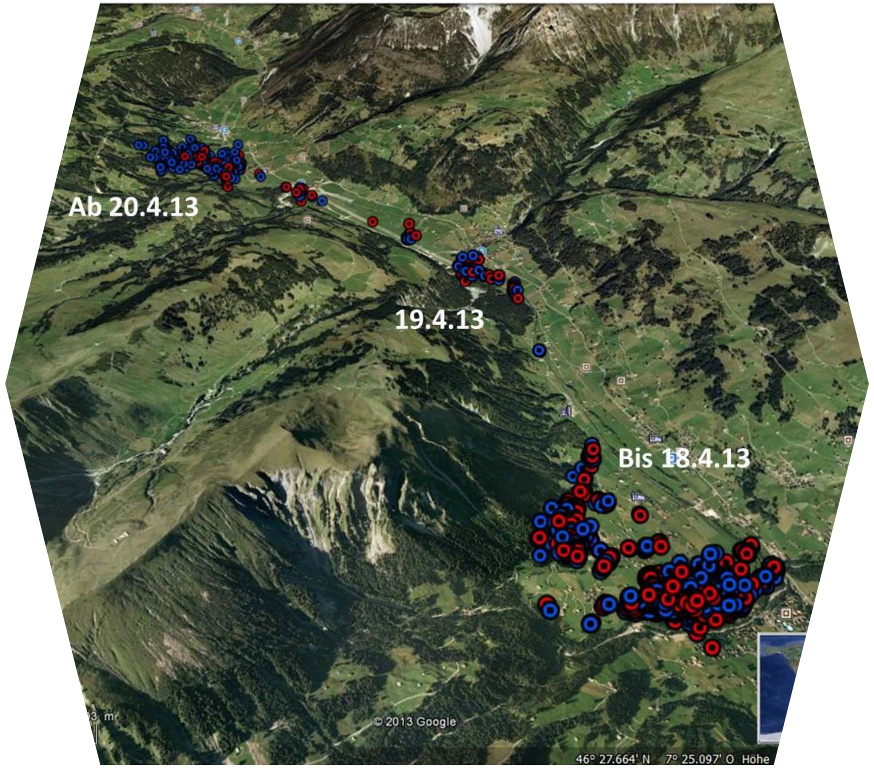
Animal movement data

Animal movement data must be interpreted at the right **spatial** and **temporal scale**

→ the frequency (i.e. resolution) of locations within a movement path will determine at what scale we can understand drivers of movement

We need to collect data about the environment (biotic and abiotic) in which animals move (e.g. tree density and occuring species or temperature and precipitation)

Non-independence among animal locations pose challenges (and opportunities!) to the statistical analysis of movement data



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Lecture overview

- General principles of animal movement
- Animal movement and the age of biologging
- Behavior that results in animal home ranges

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Area-restricted movement

Most animals restrict their movements to areas that are smaller than they could feasibly exploit given their movement capacity

Home range is traditionally defined as the area used for feeding, sleeping, finding mates, and raising young

More recently → area in which an animal has a probability of occurrence over a specific time window

Burt, 1943, p351 / Kernohan, 2001, p. 125-166

Home range behavior results in area-restricted movement

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Home range analysis

Why do animals have home ranges?

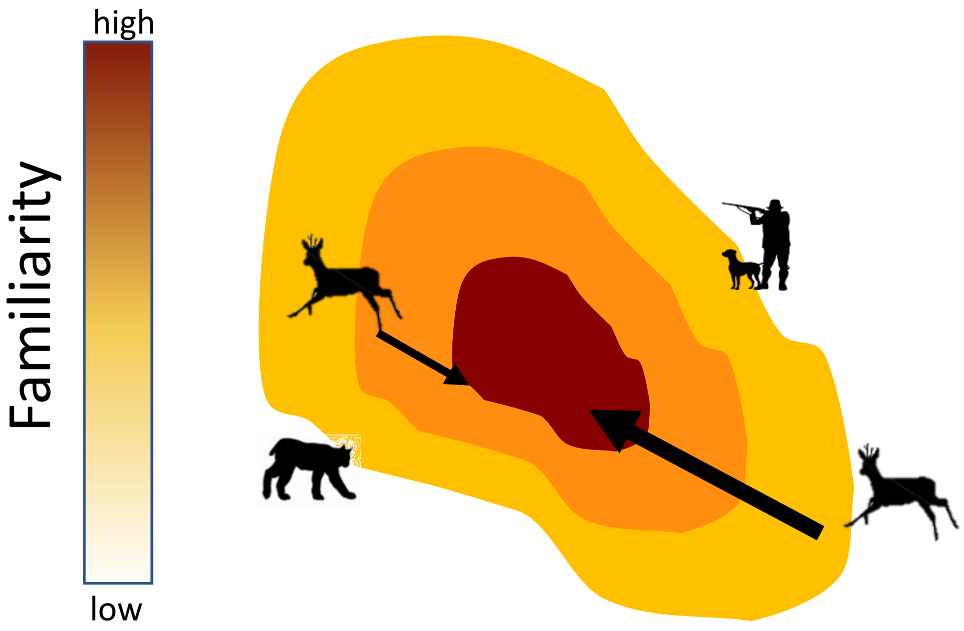
- Characterizing and memorizing of previously visited locations
  - animals with prior knowledge about resource distribution are more efficient in resource aquisition
  - Site-familiarity can help evade predators

- Home range behavior will emerge whenever site-specific knowledge is valuable

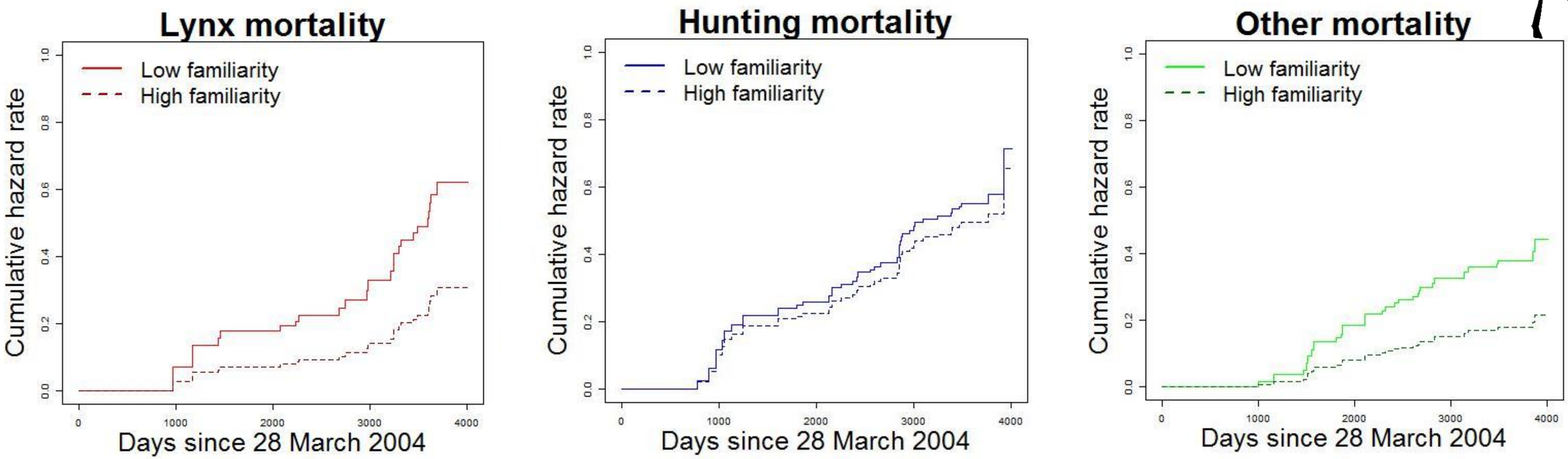
- Home range behavior is expected to increase individual fitness

Why it's good to know your home range

Why it’s good to know your home range



Why it's good to know your home range



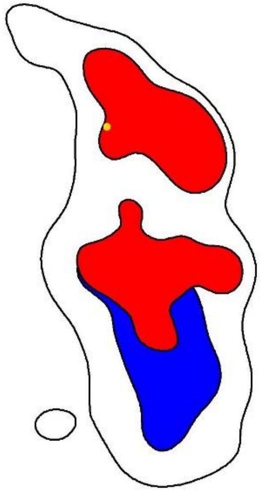
Gehr et al., JAE (2020).

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Home range analysis

Many different ways of defining a home range:

- minimum convex polygon (MCP)
- Utilization distribution (UD)
  - Kernel Density Estimation (KDE)
  - Brownian bridge
  - Biased random bridge
  - Local convex hulls (LoCoH) and T-LoCoH
    - Clustering methods



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

MCP home range

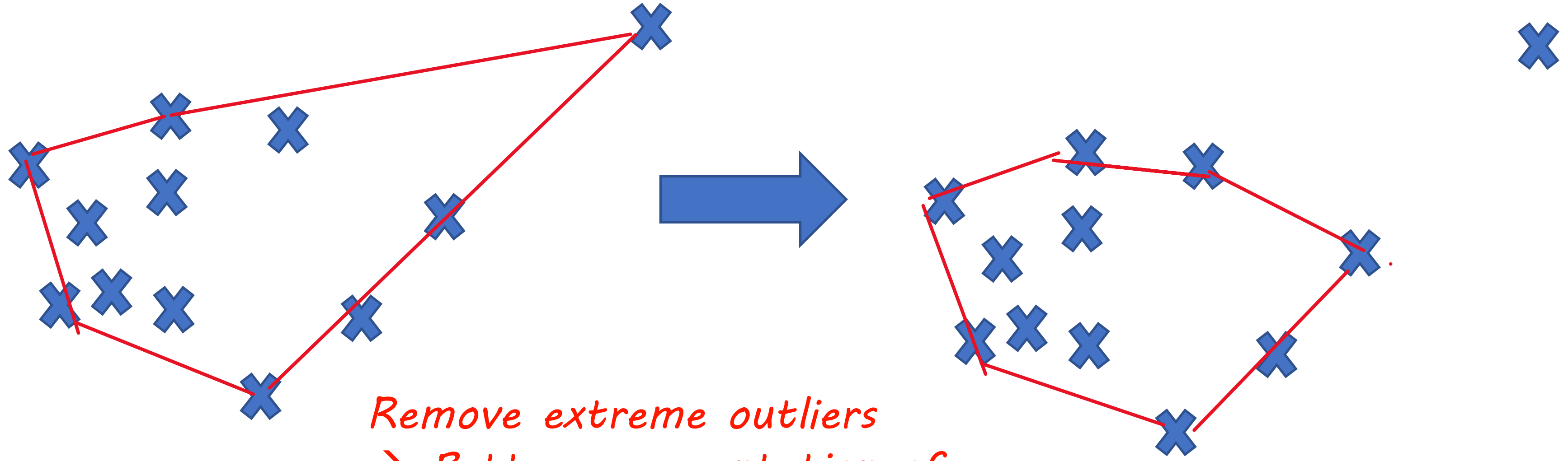
The **minimum convex polygon (MCP)** is the simplest and still frequently used method to define an animals home range.

→ Calculating the smallest polygon encompassing all animal locations

MCP home range

MCP's are very susceptible to outliers

→ Solution: often extreme points are excluded (e.g. 5% of points furthest away from centroid of relocation cloud)

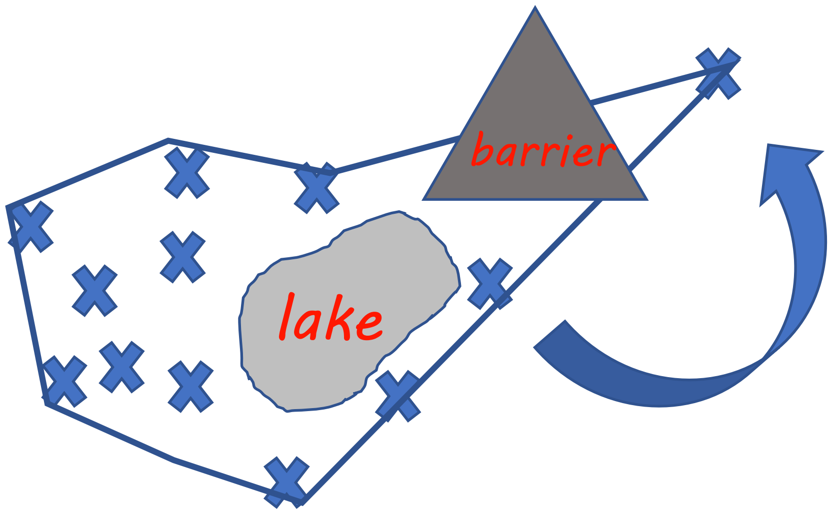


Remove extreme outliers
→ Better representation of area used

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

MCP home range

MCP's ignore potential barriers or unused areas within the home range

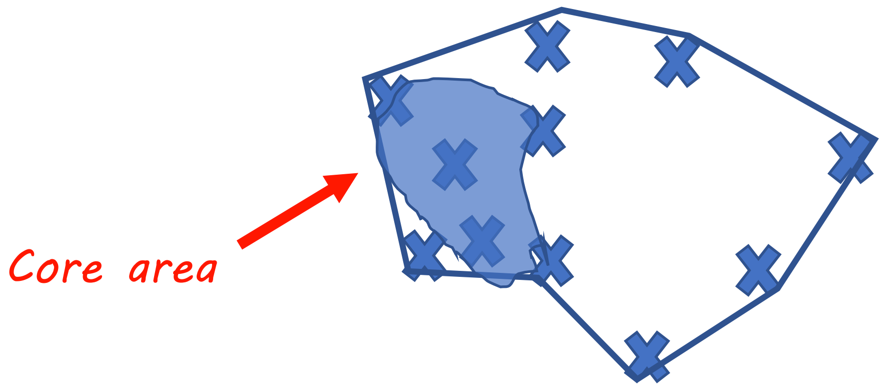


Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

MCP home range

MCP's ignore differences in intensity of use

→ animals don't spend equal amount of time in all areas within their home range



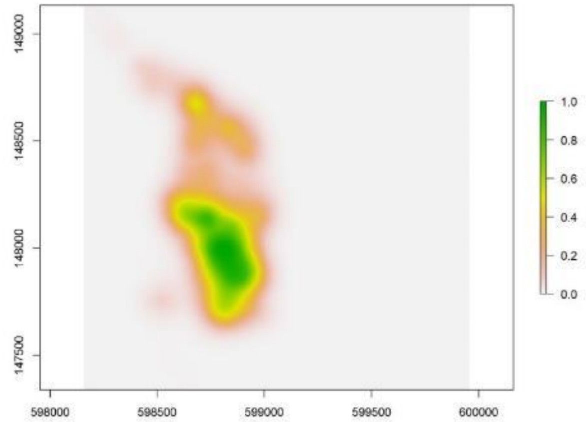
The utilization distribution

animals use space within their home range unevenly
→ intensity of use increases where key resources occur, or certain types of behaviours emerge

Borger et al. 2008

→ the **utilization distribution** describes the smoothed probability density of relocations defining an animal's home range

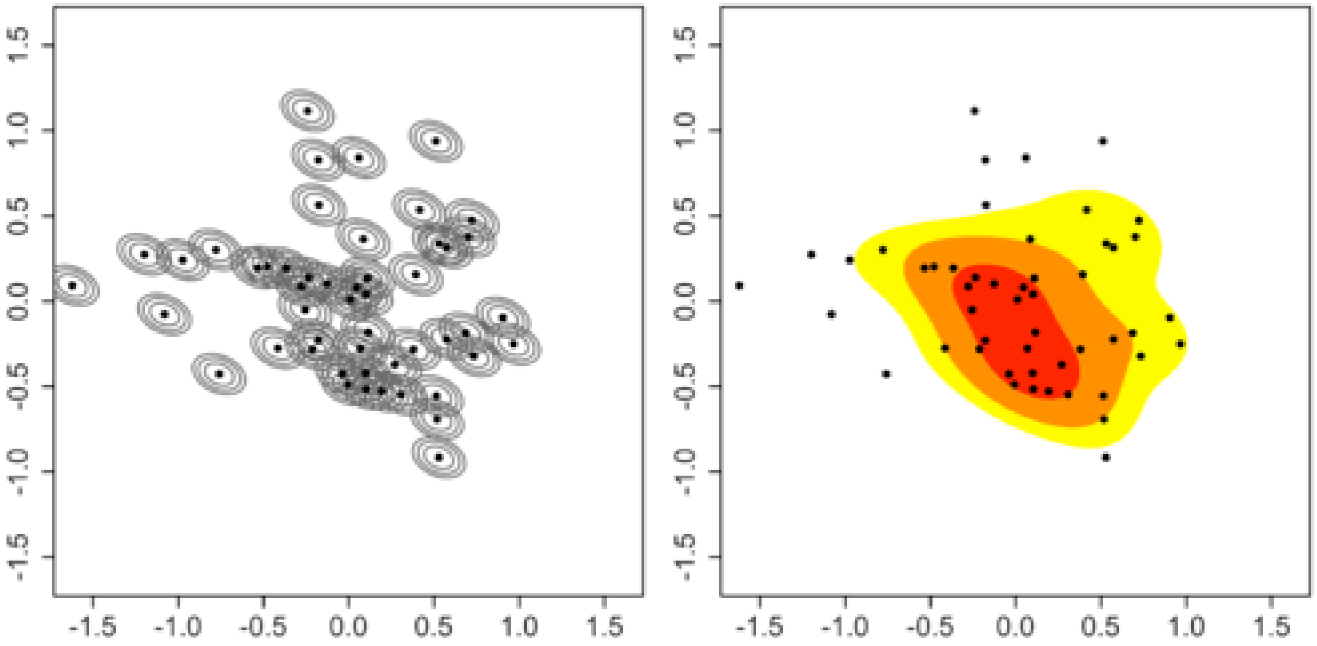
What's the probability of finding an animal at a given location?



Kernel density estimation (KDE)

A common way to calculate probability density is the Kernel density

→ a bivariate **kernel function** is placed over each relocation, and the values of these functions are averaged together.



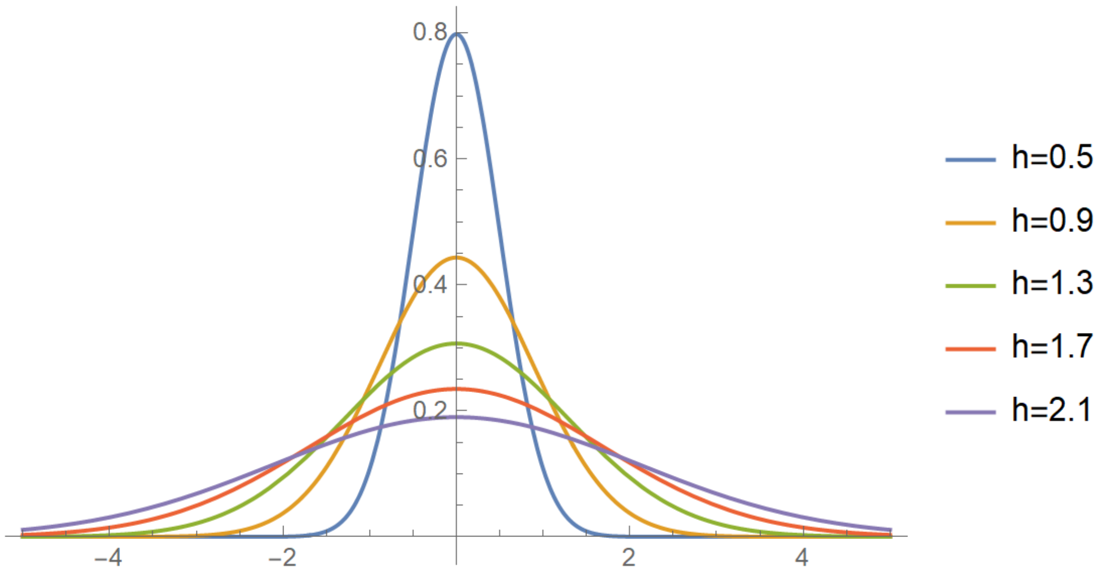
The total probability density over the entire area sums to 1

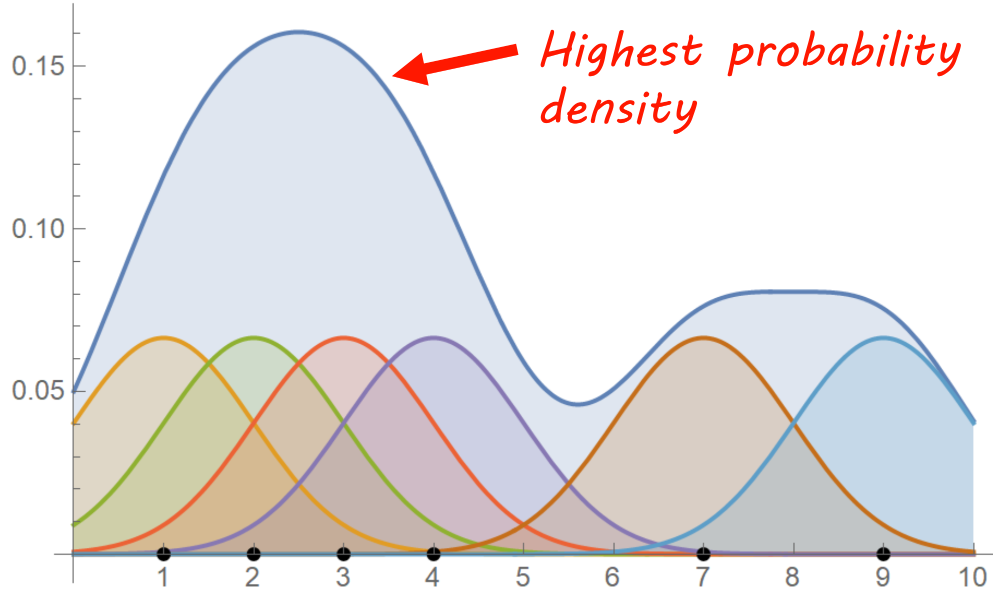
Wikipedia

Kernel density estimation (KDE)

→ Different Kernel functions exist. Choice of Kernel function has little effect on the resulting Kernel density → most common Kernel function is the **bivariate normal**

→ The width of the Kernel function placed over each location is defined by the smoothing parameter **h**

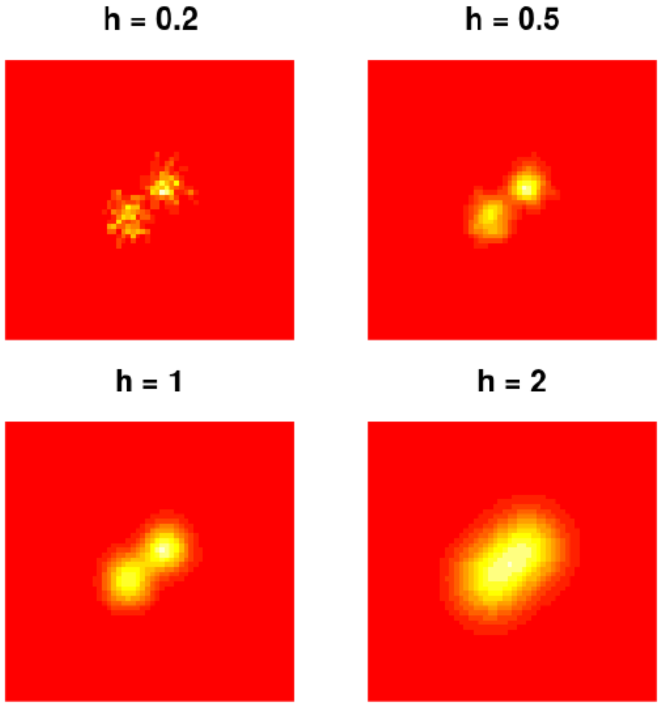




Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Smoothing parameter h

The choice of the smoothing parameter has considerable impact on the resulting Kernel density



Calenge 2015, adehabitatHR package

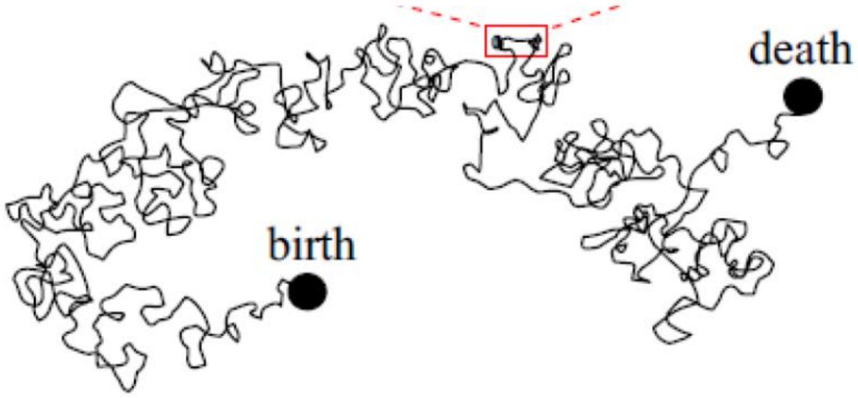
Kernel density estimation (KDE)

KDE assumes independence between locations

→ violated by definition of a movement path

Sample size & percentage of locations included may affect

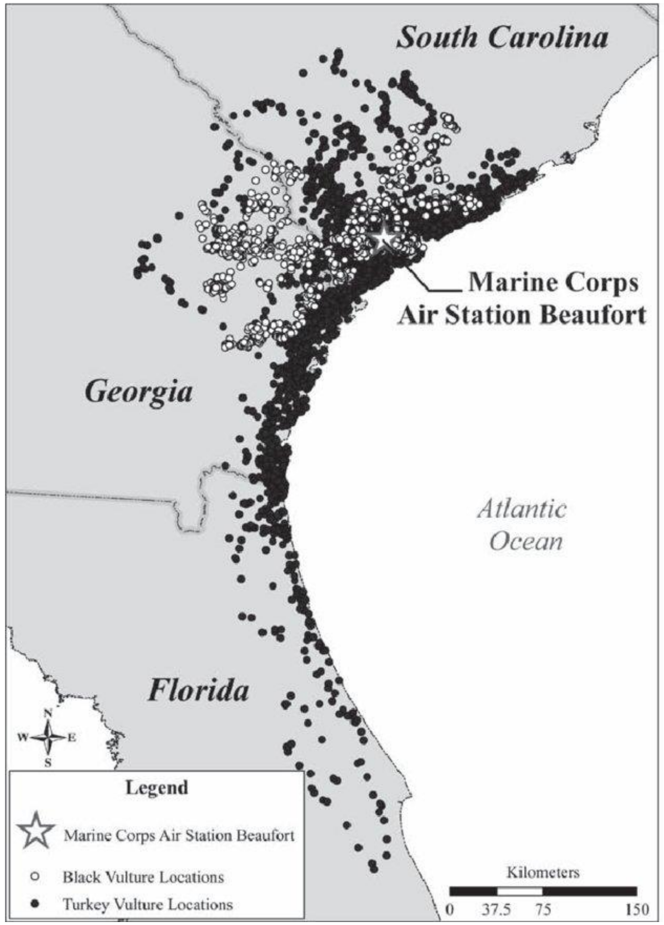
→ (**type I error**) excludes areas used by animal
→ (**type 2 error**) includes areas not used by animal



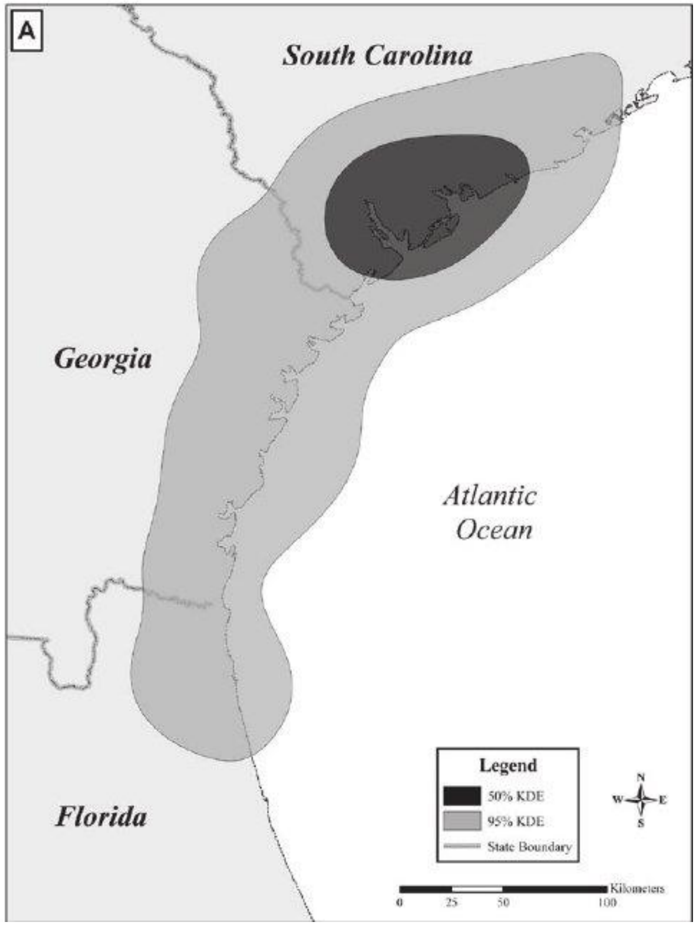
If sample of locations is representative for animal movement autocorrelation is of minor concern

Fieberg et al. 2012, BioOne

Kernel density estimation (KDE)



Barriers and boundaries often not well represented
→ adaptations to the classical method exist
(e.g. Benhamou & Cornelis 2010, Fleming et al. 2015)

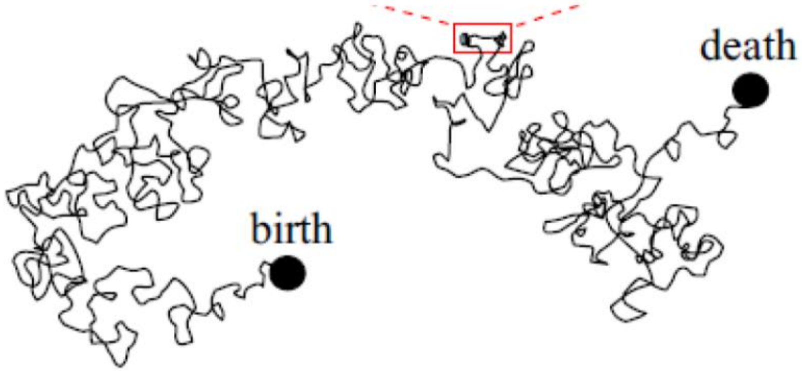


Taking into account time dependence

Sequential locations in a movement path are correlated

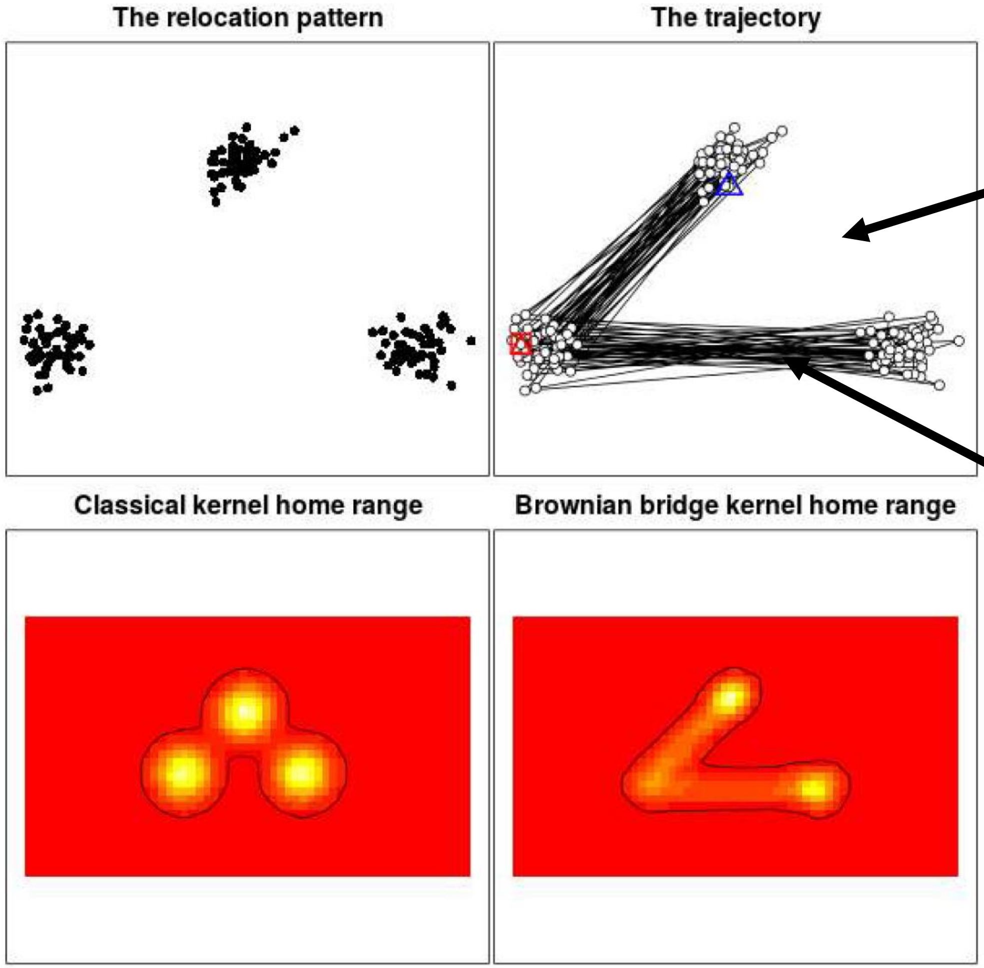
Brownian bridges take into account time dependence between relocations
→ place a **Kernel above each step** of a path

Allows to discern areas used and not used by taking **order of relocations** into account



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

Brownian bridge method



Unused area

Travel corridor

Brownian bridge method takes order of locations into consideration

Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

General considerations

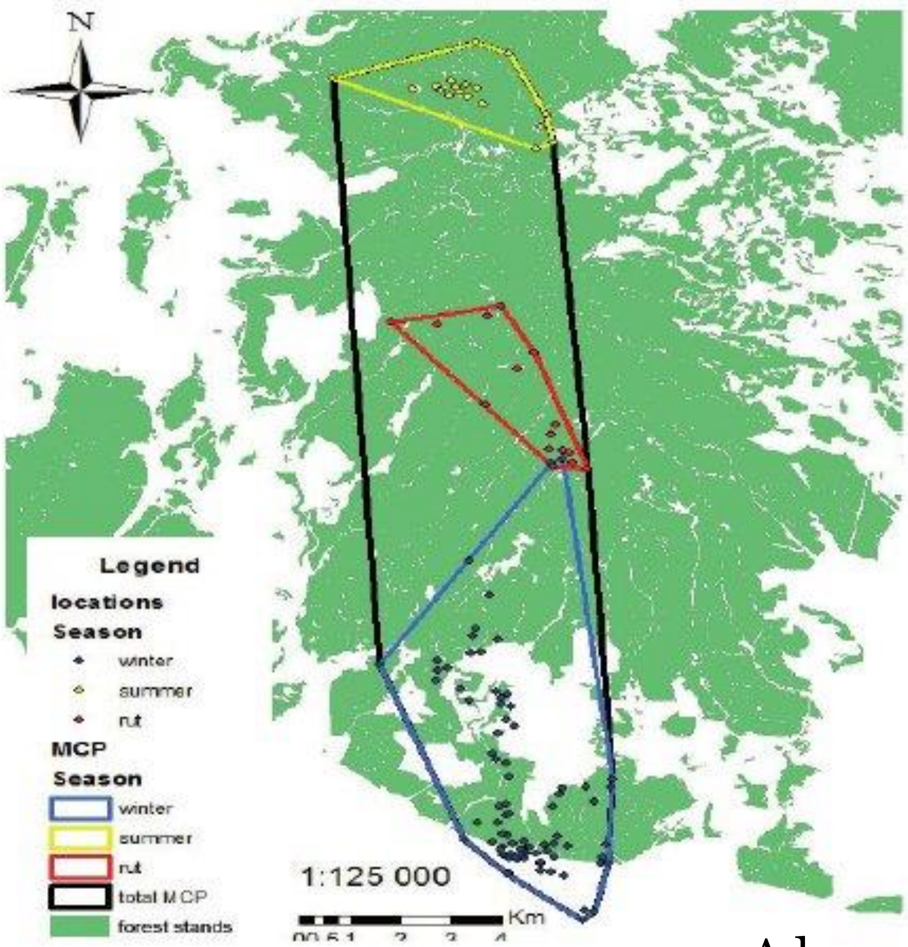
It's important for the data to be representative of animal movement

→ Missing data may bias home range estimate
e.g. time of day or weather affects data collection (VHF) or probability of a successful fix location is habitat dependent (GPS)

→ Home ranges will vary over time – seasonal home ranges, day vs night, old vs young, etc.

→ Sample size is the number of animals or time intervals!
More locations results in more precise home range estimators – more animals results in better population level inference

Seasonal home ranges



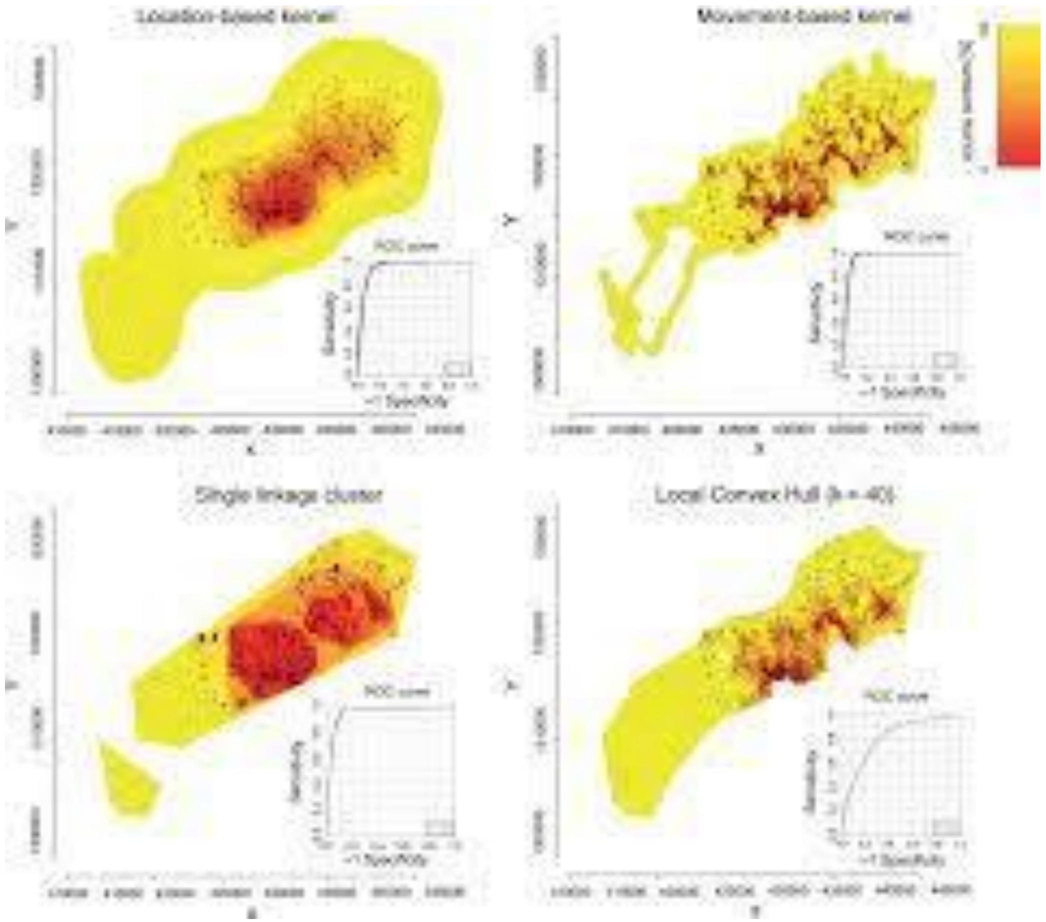
Adam et al. 2015, Forestry Journal

Comparing different methods

Most appropriate home range estimation method depends on study question → e.g. total area used, area used, intensity of use, etc.

Not all methods deal equally well with missing data or small datasets

Good practice: test sensitivity of method used by comparing results of different methods applied to the same data set



Benedikt Gehr, Beatrice Nussberger, benedikt.gehr@wildtier.ch, beatrice.nussberger@wildtier.ch
Wildtier Schweiz, Winterthurerstrasse 92, CH-8006 Zürich, www.wildtier.ch

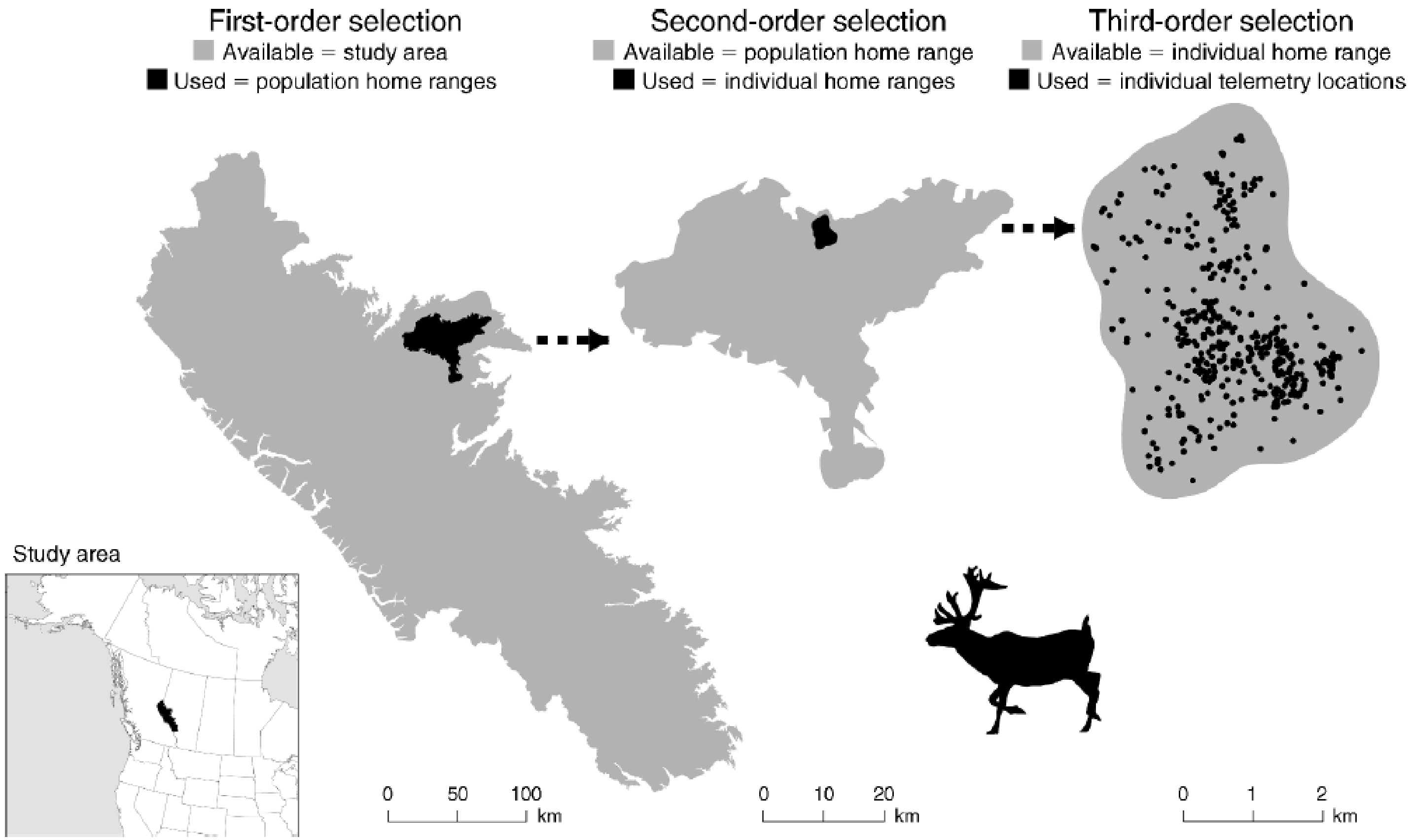
Next steps for another lecture…

The study of habitat selection

- Animals interact and respond to their environment
- Record animal space use/locations and intersect with environmental variables
- Make inference about why habitat is selected – most commonly by comparing used to available habitat

WildCRU website; Ocelot habitat selection

Next steps for another lecture…



Johnson, D., 1980, Ecology DeCesare, 2012, Ecological applications