

How does human activity affect the movement patterns of wild animals?

An analysis of selected data sets from the Movebank animal tracking database

Jannis Bolzern and Elke Michlmayr

1 Abstract

We investigate how human activity influences the movement patterns of wild animals. Using tracking data from red foxes, bobcats, and coyotes across rural and remote areas in England, Canada, and the US, we analyze home range sizes, temporal activity shifts, and habitat selection in relation to human footprint and land use data.

2 Introduction

Research questions:

1. Home Range Implications: Do animals exhibit smaller home ranges in high human-impact areas?
2. Temporal Shifts in Activity Patterns: Do animals become more nocturnal in high human-impact areas to avoid direct human encounters?
3. Habitat Selection in Human-Dominated Landscapes: How do animals select habitats (e.g., forests, agriculture) under varying levels of human influence?

We will be using different data sets for each research question.

Additional challenges:

- We will be using data for purposes that it wasn't originally collected for.
- We will be using parts of data sets (missing animals in the bobcat/coyote study).
- We will be comparing between data from different studies for the same animals.
- We will be comparing data from different continents where weather conditions will differ for the same day of the year, leading to animal behavior likely also being different.
- We will be comparing data from different timezones.
- The data includes changes of timezone (winter to summer time).

3 Material and Methods

This section describes the data sets, the steps taken to prepare and process the different data set in use, and the methodological approach that was employed.

3.1 Data sets

Movebank by Kays et al. (2022) provides means for researchers to publish animal tracking data for public use, e.g. under Creative Commons licenses. The following data was selected:

- Red fox data from Porteus et al. (2024) for the outskirts areas of villages in Wiltshire, UK and from Lai et al. (2022) for the highly remote uninhabited islands Bylot and Herschel, Canada, and
- Bobcat and coyote data from Prugh et al. (2023) for remote areas with some rural structures in northern Washington, US.

For the human footprint data, the global 100 meter resolution terrestrial human footprint data (HFP-100) by Gassert et al. (2023) was chosen. For land use, the ESA WorldCover data Zanaga et al. (2022) is employed.

3.2 Data preparation and processing

3.2.1 Movebank

All Movebank data sets have the same schema. This simplifies data handling and enables code re-use. A library for data processing and trajectory handling in R is provided by Kranstauber, Safi, and Scharf (2024).

3.2.2 HRP-100

This raster data set uses the Mollweide projection Lapaine (2011). The 2020 version of the data was used. Since the data set is very big only the relevant areas were downloaded using a 200 km buffer around the tracking points.

3.2.3 ESA WorldCover

The ESA WorldCover 2021 data at 10m resolution was downloaded via the Microsoft Planetary Computer STAC API [\[link\]](#) for simple programmatic access in R.

3.3 Data exploration and analysis

3.3.1 Red fox data

The Wiltshire data was collected between 2016 to 2019 during the UK wader nesting season, which was defined to be March 15th to June 15th, for 35 foxes in total. It was sampled at 10 or 60 minute rates. The research team could set the sampling rate remotely to save battery at times the data was considered less interesting.

The Bylot/Herschel Canadian data was collected all year round, at a much lower sampling rate of once per day, at random afternoon times of the day. The collection period was June 2009 to Feb 2010 for Herschel and from 2011 to 2015 for Bylot, for two foxes per island. Figure 1 provides an overview of the amount of data points available per year. There is much more data from Wiltshire because of the higher number of foxes and the higher sampling rate.

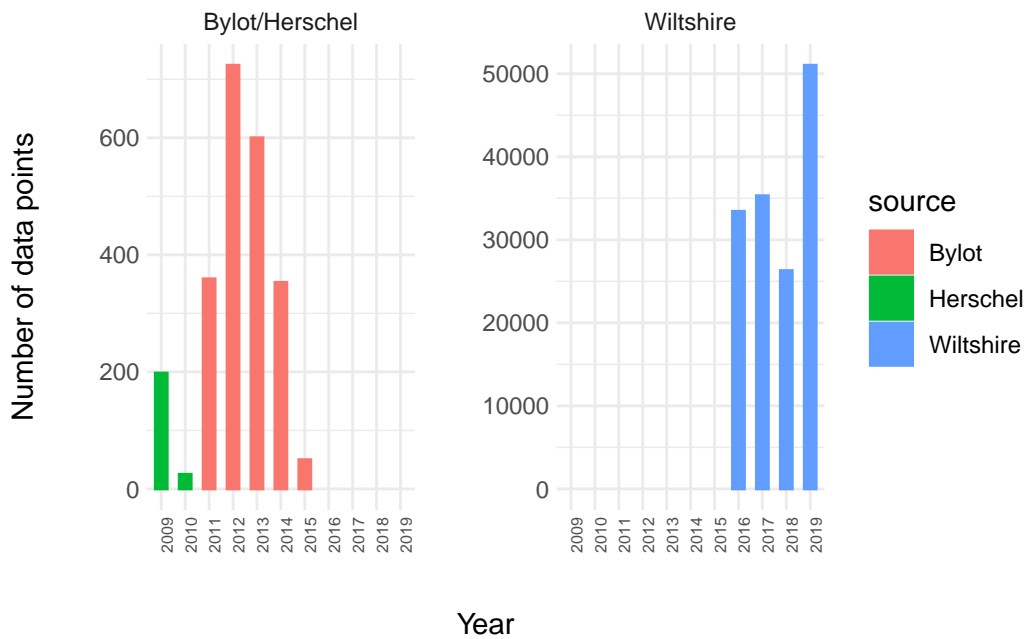


Figure 1: Data points per year

Looking at the breakdowns by month as shown in Figure 2 reveals seasonal differences in the amount of data available.

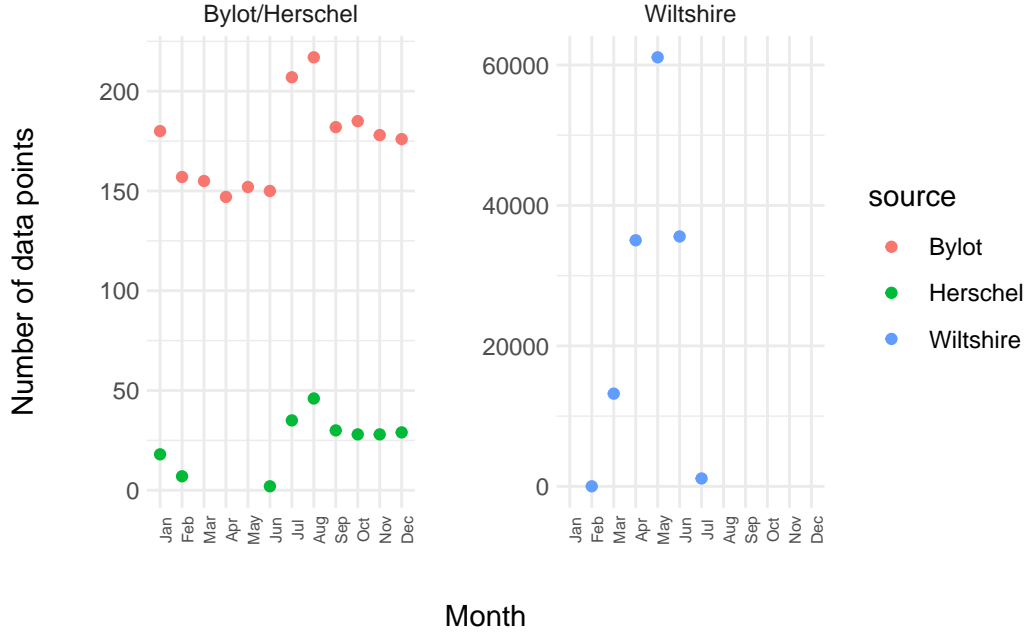


Figure 2: Data points per month

3.4 Methodology

3.4.1 Trajectory Analysis

Movement paths will be analyzed to identify patterns in speed, direction, and habitat use. Step lengths and turning angles will help infer behavioral states. Step-selection functions (SSFs, Fortin et al. (2005)) will be employed as a statistical model for habitat preferences relative to movement patterns, allowing us to quantify how animals respond to environmental covariates such as human footprint and land use.

3.4.2 Home Range Assessment

The red fox data will be used for home range assessment present for a rural and a remote location. Home range sizes will be calculated using minimum convex polygons (MCPs). This will provide estimates of the area used by each individual.

As discussed in Section 3.3.1, the data for the two locations have different temporal scale. Laube and Purves (2011) have found that the choice of temporal scale has considerable effects on movement parameter calculations, in turn affecting home range results.

How to make this data comparable? Problem #1 is that the sampling intervals are different. Problem #2 is that the data coverage varies by time of the year. Problem #3 is that there

are highly different amounts of data. Selecting the means and parameters for the comparison involves complex choices that will influence the results.

For #1, a possible approach to achieve similar sampling intervals would be to sample a random afternoon data point for each 24 hour window. However, this would include the implicit assumption that foxes will follow similar daily patterns in the different environments. For #2, a possible approach would be to compare the data for the same time of the year. However, the geographical locations are different. The seasonal weather conditions will differ for the same day of the year, likely leading to different animal behavior. For #3, aggregated comparisons can solve the issue assuming there is enough data for the smaller data source.

We employed the simplest possible imperfect approach, which is to ignore the different sampling intervals for problem #1, to compare the data for the same time of the year for problem #2, and to use exploratory data analysis to find out if a representative answer can be found given the amount of data present for problem #3.

The Herschel data is not applicable for this approach since it has minimal overlaps with the Wiltshire data (cf. Figure 2). To assess the impact of sampling intervals for problem #1, the Wiltshire data was downsampled. A random data point from every 24 hour period was selected.

3.4.3 Temporal Activity Patterns

Movement rates will be used to quantify diel activity shifts. We will test whether animals in high human-impact areas exhibit increased nocturnality, potentially as a strategy to avoid direct human encounters. This analysis will reveal how temporal behavior adapts to human presence.

3.4.4 Habitat Selection

SSFs will quantify selection for human-modified habitats (e.g., agricultural areas, urban edges) relative to natural habitats. By comparing selection patterns across species and regions, we will assess how habitat preferences vary with human influence.

4 Results

The resulting home ranges are shown in Figure 3 and Figure 4. The median home range size for the foxes in Herschel (75.3 km²) is more than 65 times bigger compared to the foxes in Wiltshire (1.1 km²).

The home range for the sampled Wiltshire data is shown in Figure 5. The median home range is 0.56 km² for the sampled data (and 1.1 km² for the full data).

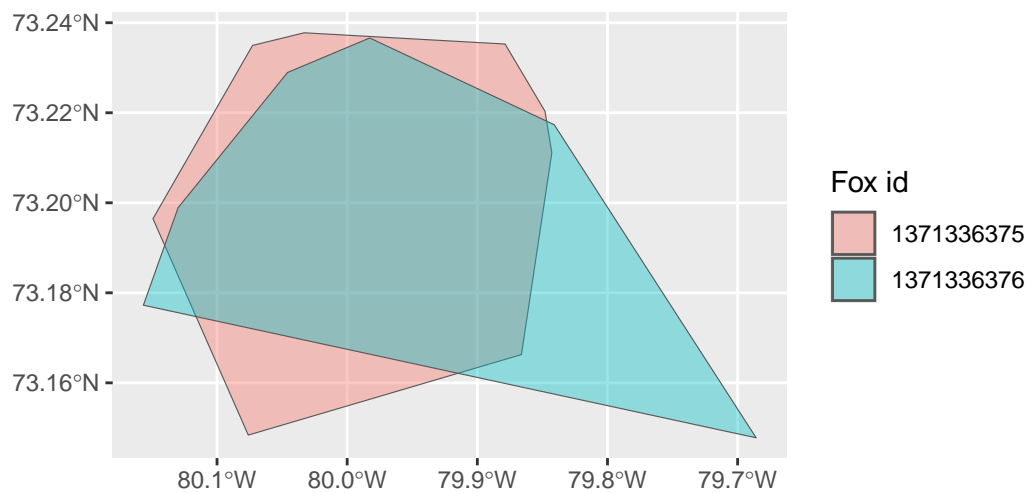


Figure 3: Home ranges for Bylot foxes (2012)

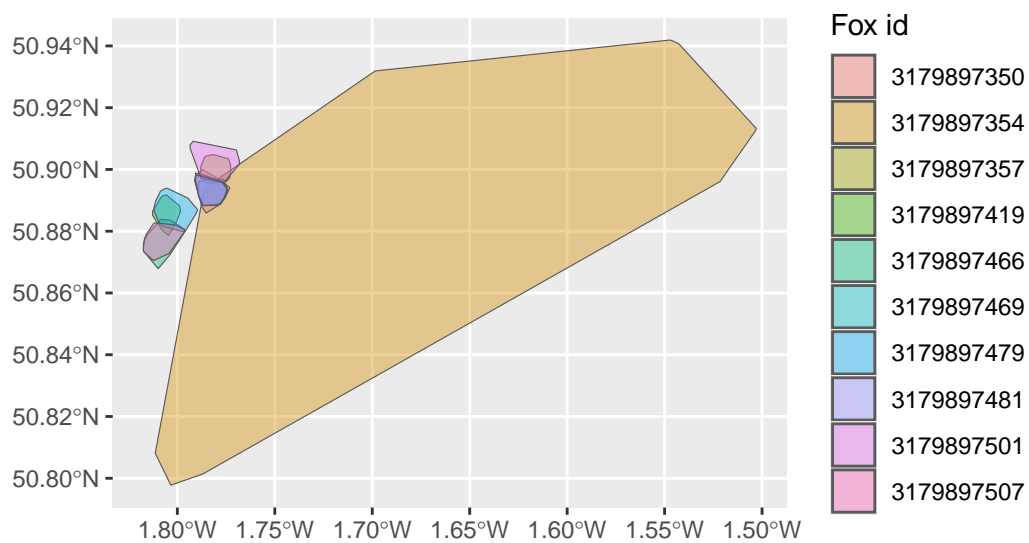


Figure 4: Home ranges for Wiltshire foxes (2019)

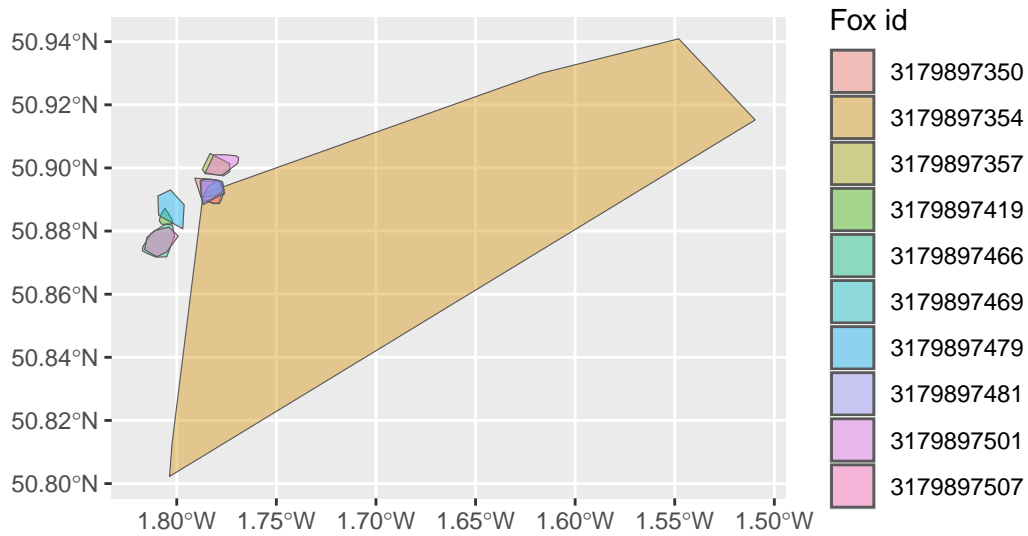


Figure 5: Home ranges for Wiltshire foxes (2019, 24 hour sampling interval)

5 Discussion

The fox home range results differ enormously between rural and remote areas. We can conclude that human presence massively impacts fox movement behavior, with availability of food likely being relevant.

The influence of technical aspects like sampling intervals is significant. However, in this case it plays a secondary role in comparison to the fox behavior. This is the enabling factor for the chosen approach of comparing data from heterogeneous sources.

6 Appendix

6.1 Don't do

- Home ranges: Compare median monthly home range per animal and location
- There are several ways to calculate home range, we could compare (and could focus on only that)
- Do home range for foxes first, for bobcat and coyote data later, potentially even cross-species analysis
- Use kernel density estimation (KDE)

6.2 Wordcount

Method	koRpus	stringi
Word count	1311	1301
Character count	8405	8432
Sentence count	86	Not available
Reading time	6.6 minutes	6.5 minutes

6.3 Use of Large Language Models and Generative AI

Elke used NotebookLM (2025) for querying the papers cited in the references.

References

- Fortin, Daniel, Hawthorne L Beyer, Mark S Boyce, Douglas W Smith, Thierry Duchesne, and Julie S Mao. 2005. “Wolves Influence Elk Movements: Behavior Shapes a Trophic Cascade in Yellowstone National Park.” *Ecology* 86 (5): 1320–30.
- Gassert, Francis, Oscar Venter, James EM Watson, Steven P Brumby, Joseph C Mazzariello, Scott C Atkinson, and Samantha Hyde. 2023. “An Operational Approach to Near Real Time Global High Resolution Mapping of the Terrestrial Human Footprint.” *Frontiers in Remote Sensing* 4: 1130896.
- Kays, Roland, Sarah C Davidson, Matthias Berger, Gil Bohrer, Wolfgang Fiedler, Andrea Flack, Julian Hirt, et al. 2022. “The Movebank System for Studying Global Animal Movement and Demography.” *Methods in Ecology and Evolution* 13 (2): 419–31.
- Kranstauber, Bart, Kamran Safi, and Anne K Scharf. 2024. “Move2: R Package for Processing Movement Data.” *Methods in Ecology and Evolution* 15 (9): 1561–67.
- Lai, Sandra, Chloé Warret Rodrigues, Daniel Gallant, James D Roth, and Dominique Berteaux. 2022. “Red Foxes at Their Northern Edge: Competition with the Arctic Fox and Winter Movements.” *Journal of Mammalogy* 103 (3): 586–97.
- Lapaine, Miljenko. 2011. “Mollweide Map Projection.” *KoG* 15 (15.): 7–16.
- Laube, Patrick, and Ross S Purves. 2011. “How Fast Is a Cow? Cross-Scale Analysis of Movement Data.” *Transactions in GIS* 15 (3): 401–18.
- NotebookLM. 2025. “NotebookLM.” <https://notebooklm.google/>.
- Porteus, Tom A, Mike J Short, Andrew N Hoodless, and Jonathan C Reynolds. 2024. “Movement Ecology and Minimum Density Estimates of Red Foxes in Wet Grassland Habitats Used by Breeding Wading Birds.” *European Journal of Wildlife Research* 70 (1): 8.
- Prugh, Laura R, Calum X Cunningham, Rebecca M Windell, Brian N Kertson, Taylor R Ganz, Savanah L Walker, and Aaron J Wirsing. 2023. “Fear of Large Carnivores Amplifies Human-Caused Mortality for Mesopredators.” *Science* 380 (6646): 754–58.
- Zanaga, Daniele, Ruben Van De Kerchove, Dirk Daems, Wanda De Keersmaecker, Carsten Brockmann, Grit Kirches, Jan Wevers, et al. 2022. “ESA WorldCover 10 m 2021 V200.”