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

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

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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 and habitat selection in relation to human footprint and land cover data.

2 Introduction

Disturbance by humans has widespread impacts on the movements of animals, as confirmed by a large-scale meta study by Doherty, Hays, and Driscoll (2021). In this paper, two related research questions will be addressed:

1. Home Range Implications: Do animals exhibit smaller home ranges in high human impact areas? This will be analysed by comparing red fox (vulpes vulpes) home ranges in low and high human impact areas.
2. Habitat Selection in Human-Dominated Landscapes: How do animals select habitats (e.g., forests, agriculture) under varying levels of human influence? This will be analysed by TBD.

Different data sets are used for each research question. Relying on Movebank data, as described in Section 3.2.1, presents additional challenges stemming from the facts that (1) the data is used for purposes it was not originally collected for and (2) data from different studies that was collected in different manners is compared, and (3) TBD subsets from existing data sets are employed, i.e. only some of the animals from the existing studies are considered.

3 Material and Methods

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

3.1 Data sets

The Movebank database 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 is selected: Red fox data from Porteus et al. (2024) for the outskirt areas of villages in Wiltshire, UK and from Lai et al. (2022) for the remote uninhabited islands Bylot and Herschel in 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) is chosen. For land cover, the ESA WorldCover data described in Zanaga et al. (2022) is employed.

3.2 Data preparation and processing

This section describes data preparation and processing for all the datasets employed.

3.2.1 Movebank data

All Movebank data sets have the same schema. This simplifies data handling, enables code re-use, and requires the data contributors do perform preprocessing and data cleaning on their side to provide the data in an appropriate format. A library for data processing and trajectory handling in R is provided by Kranstauber, Safi, and Scharf (2024).

The R code for data download, preprocessing, and serialization of relevant data and charts can be found in: Red fox: UK wader nesting season home range, Red fox: montly home ranges, TBD Bobcat/coyote.

3.2.2 Human footprint data

The global 100 meter resolution terrestrial human footprint data (HFP-100) is a raster data set using Mollweide projection as described by Lapaine (2011). The 2020 version of the data was used. Only the relevant areas were downloaded using a 200 km buffer around the tracking points, and projected to the WGS84 coordinate system: HFP-100 download.

3.2.3 Land cover data

The relevant ESA WorldCover 2021 data at 10 m resolution was downloaded via the Microsoft Planetary Computer STAC API for simple programmatic access in R: ESA download.

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.

Figure 1: Interactive map of Bylot Island (11.067 km2) with high level view of GPS tracks (unfiltered).

Figure 2: Interactive map of Herschel Island (116 km2) with high level view of GPS tracks (unfiltered), some of them irregular.

The Bylot (see Figure 1) and Herschel (see Figure 2) 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 3 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.

Looking at the breakdowns by month as shown in Figure 4 reveals seasonal differences in the amount of data available.

3.3.2 Bobcat and coyote data

The bobcat (Lynx rufus) and coyote (Canis latrans) data from Prugh et al. (2023) contains data for 29 coyotes and 30 bobcats collected between June 2018 and June 2022. They reside in two separated geographical areas and have species-interspersed home ranges. Figure 5 shows a plot of the bobcat and coyote locations in the context of the extracted land cover data. Figure 6 reveals the human footprint in the area, which is generally low except for some settlements and country roads.

The mean (TBD?) data sampling intervals differ for the two species, as shown in Figure 7.

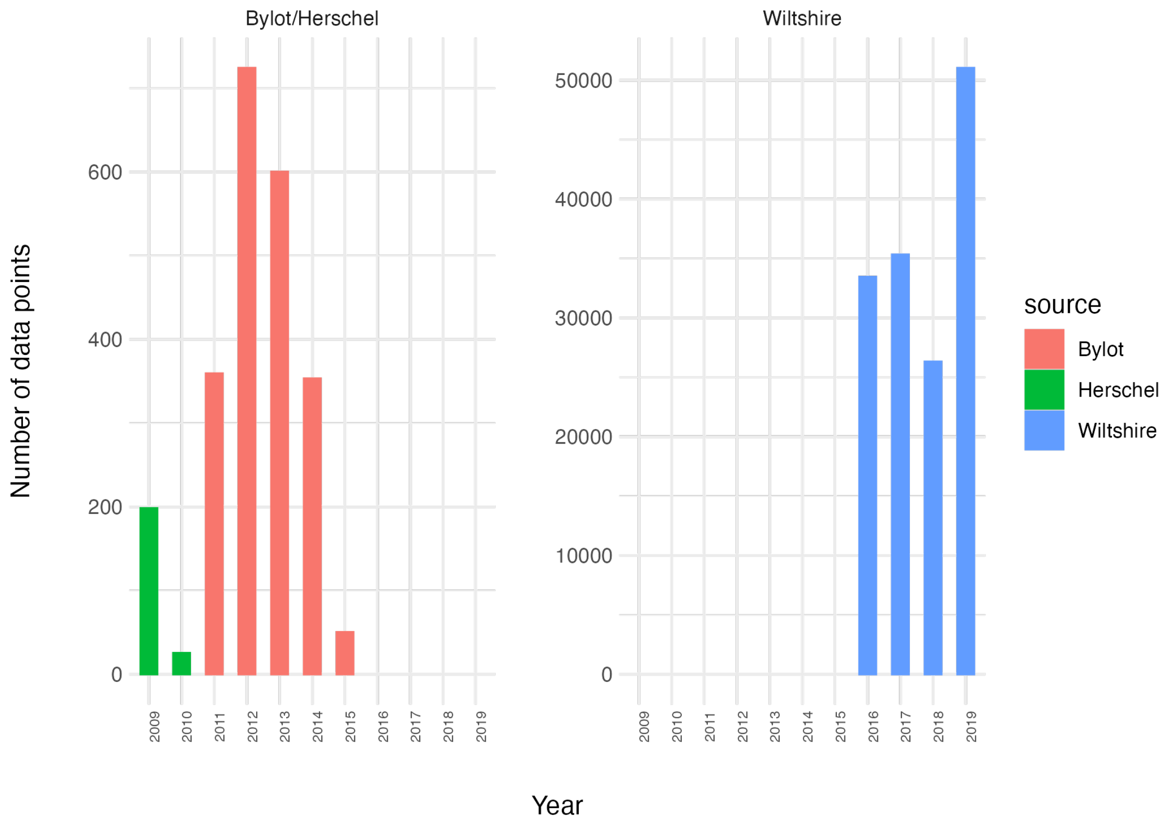

Figure 3: Data points per year

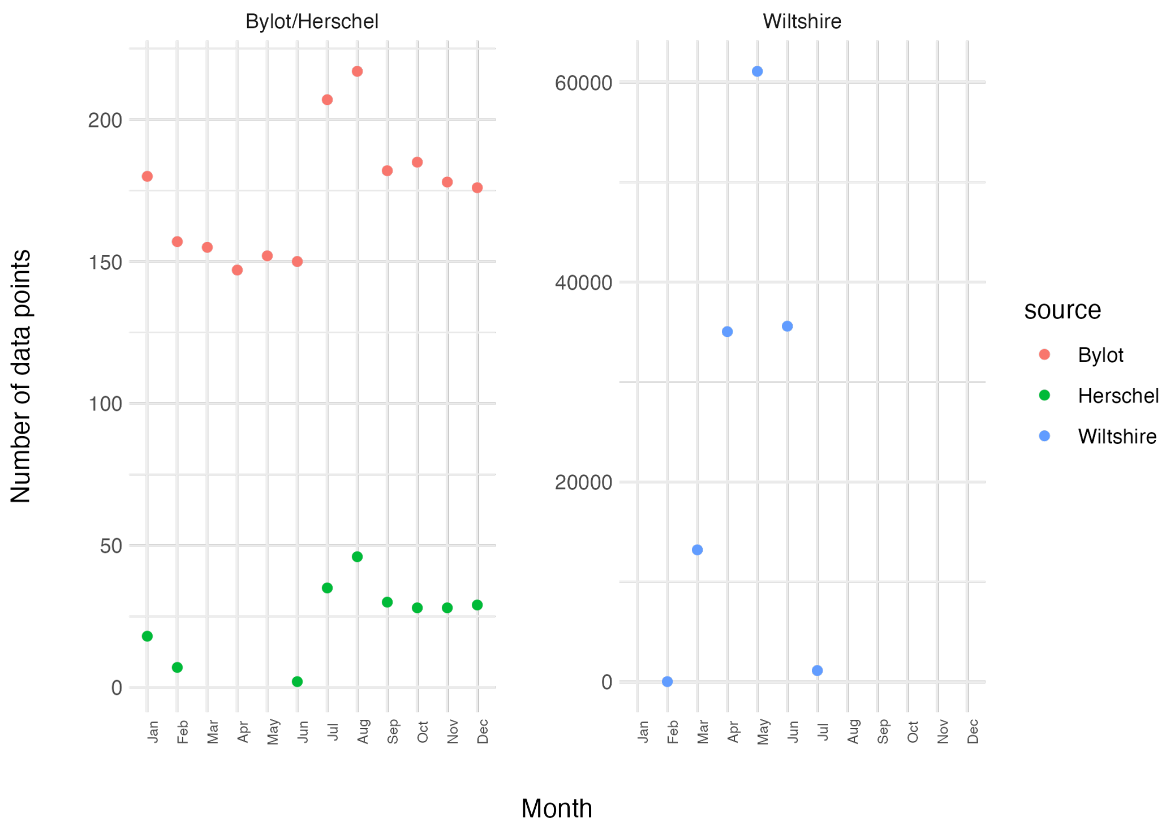

Figure 4: Data points per month

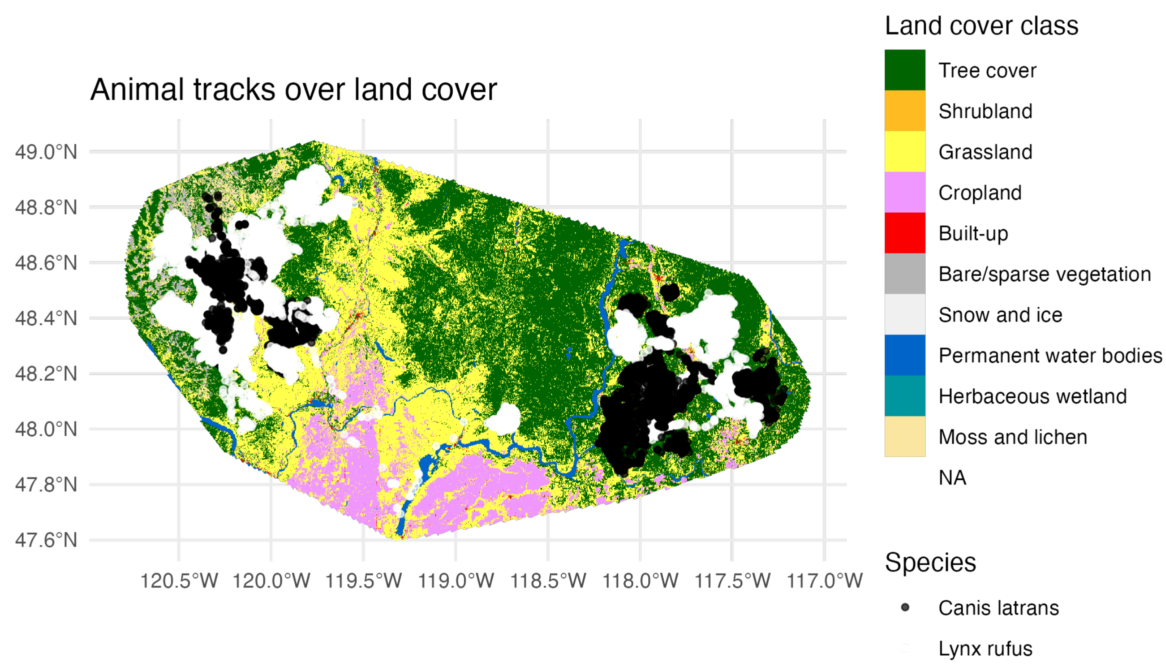

Figure 5: Bobcat and coyote locations in the context of the land cover data

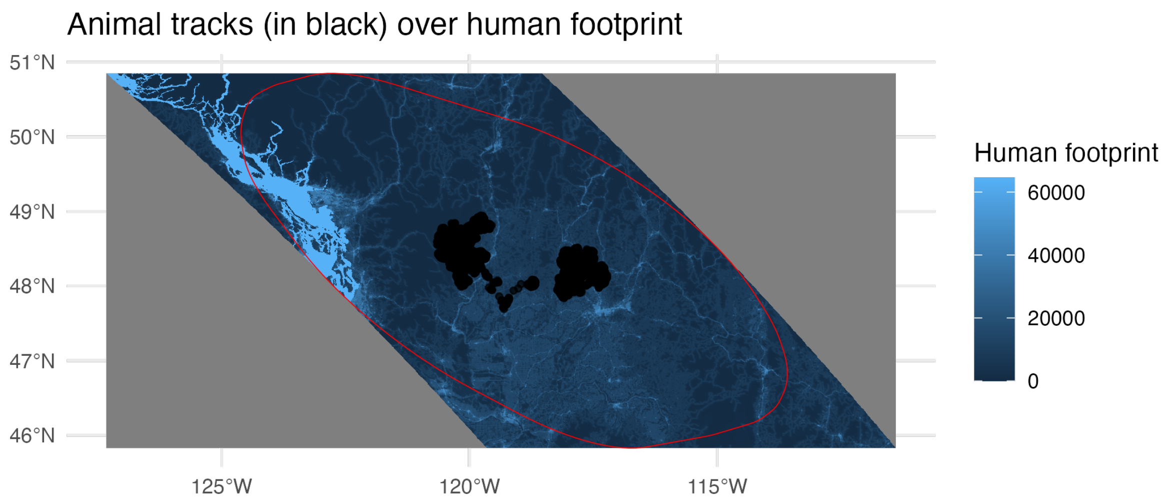

Figure 6: HFP-100 data with bobcat and coyote tracks shown in black and relevant area in red

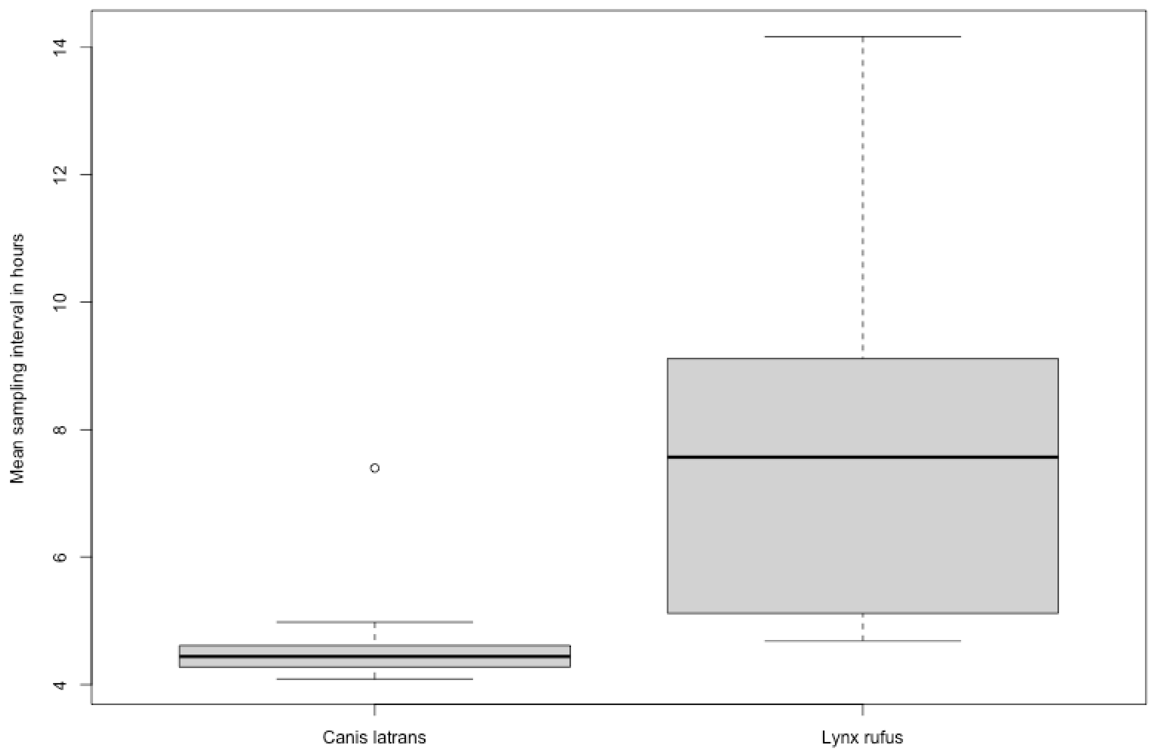

Figure 7: Mean sampling rates for bobcat and coyote data

3.4 Methodology

3.4.1 Home Range Assessment

The red fox data is used for home range assessment present for a rural and a remote location. Home range sizes are calculated using minimum convex polygons. This provides estimates of the area used by each individual animal that are easy to compare to each other.

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. But since 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.

For data exploration the simplest possible imperfect approach is employed, 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 even if animal behavior might be different, 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. Note that this approach has obvious limits. Among them is that the Herschel data is not applicable, since it has minimal overlaps with the Wiltshire data (see Figure 4).

To explore the impact of sampling intervals for problem #1, the home ranges for the Wiltshire data are additionally calculated on downsampled data, where a random data point from every 24 hour period is selected.

Finally, an analysis of monthly home ranges is conducted on all three data sets as an alternative solution to address problem #2.

3.4.2 Trajectory Analysis and Habitat Selection

Movement paths are analyzed to identify patterns in speed, direction, and habitat use. Step lengths and turning angles help infer behavioral states. Step-selection functions (SSFs) as described by Fortin et al. (2005) are employed as a statistical model for habitat preferences relative to movement patterns, allowing to quantify how animals respond to environmental covariates such as human footprint and land cover. Selection patterns across species and regions are compared to assess how habitat preferences vary with human influence.

Since SSFs requires a regular sampling rate, the animals tracks were re-sampled using the amt library's track_resample() function, which only keeps relocations that are approximately 4 hours apart with a specified tolerance window of 10 minutes. These tracks are translated into animals steps with certain step lengths and turning angles. The control group is comprised of randomly generated steps. Each animal location within its is joined with the relevant covariates, which are the accompanying land cover category, and the human footprint index value.

4 Results

The resulting home ranges for the UK wader nesting season time frame are shown in Figure 8 and Figure 9. The median home range size for the foxes in Bylot (75.3 km2) is more than 65 times bigger compared to the foxes in Wiltshire (1.1 km2). Note that there is one fox with an extraordinarily large home range in Figure 9. Kobryn et al. (2023) report similar patterns with a small number of foxes covering much larger areas than others. They conclude that potential for extensive movement patterns in urban foxes exists, and that in some studies such outlier data is either removed or not trackable, therefore underestimating home ranges.

The home ranges for the sub-sampled Wiltshire data are shown in Figure 10. The median home range size is 0.56 km2 for the sampled data, which is roughly half as much as for the full data. This shows that the Wiltshire fox home ranges are overestimated in comparison to Bylot fox home ranges, because of the higher amount of data points available. It also demonstrates that the influence of sampling intervals is definitely present. However, it is secondary in comparison to the difference in fox behavior.

Similar differences in order of magnitude between remote and rural fox home ranges can also be observed for the monthly home range results shown as a boxplot in Figure 11. It is interesting to see that the fox home ranges for Bylot and Herschel are similar, even if the islands are different in size with Bylot being a hundred times larger. Note that outliers are removed, in particular the irregular data for Herschel (as seen in Figure 2). The accompanying monthly home range plots can be found in the Appendix in Figure 12, Figure 13, and Figure 14.

4.1 Model validation

According to Rykiel Jr (1996), model validation means demonstrating that a model is acceptable for its intended use. The purpose, criteria, and context of the model must be specified.

For the purpose of home range comparison, two models were defined comprised of data, home range calculation based on minimum convex hulls, and median selection. The validation

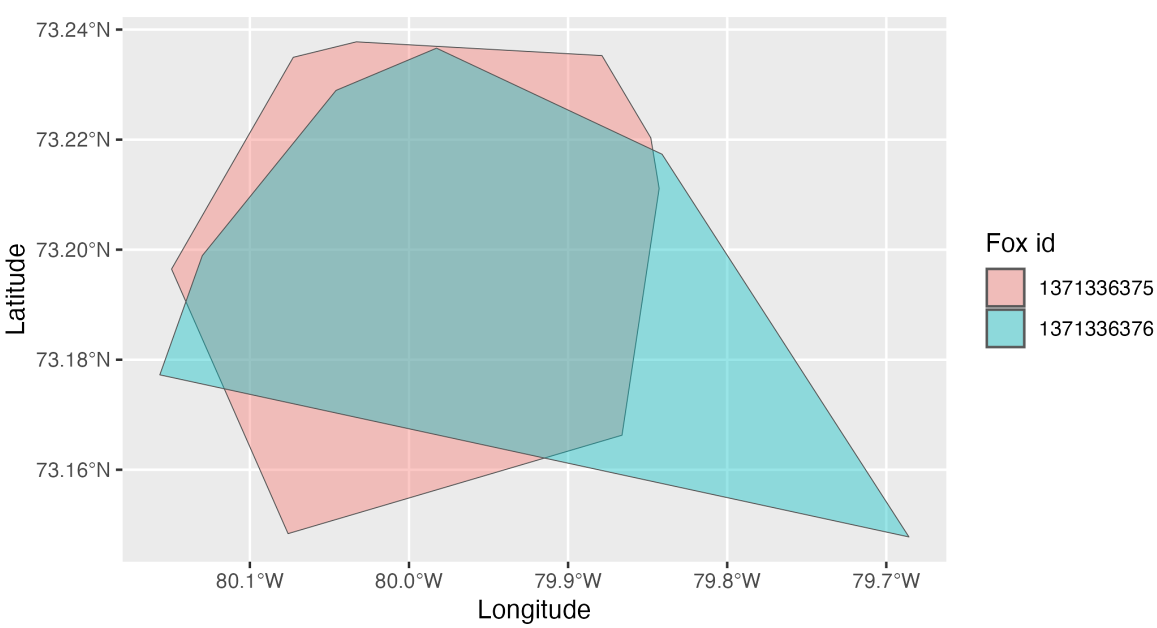

Figure 8: Home ranges for Bylot foxes (March 15th to June 15th, 2012)

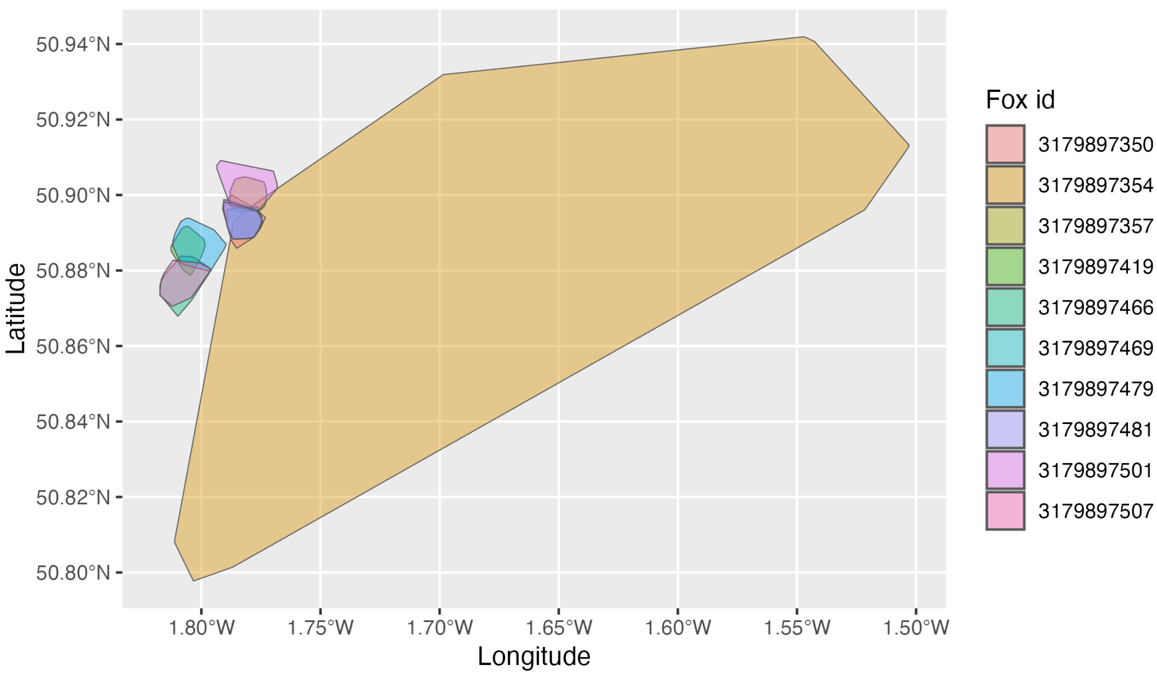

Figure 9: Home ranges for Wiltshire foxes (March 15th to June 15th, 2019)

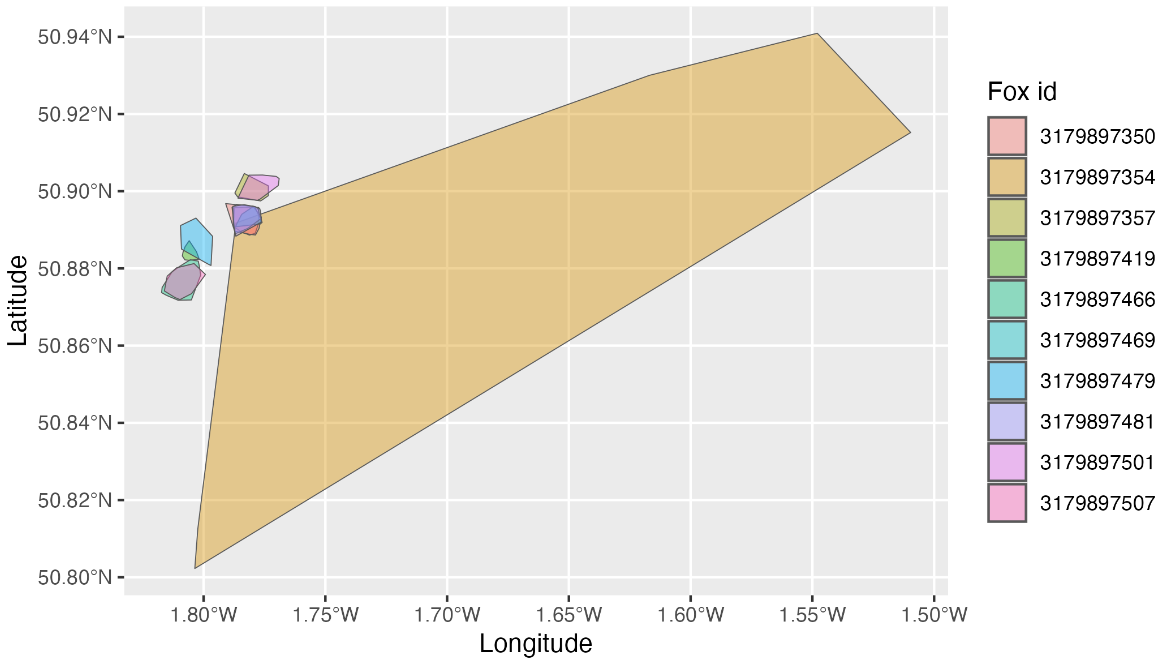

Figure 10: Home ranges for Wiltshire foxes (March 15th to June 15th, 2019, 24 hour sampling interval)

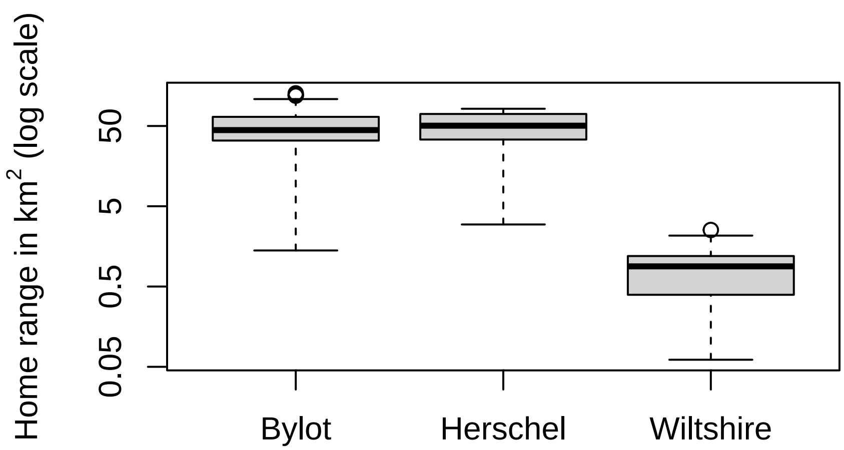

Figure 11: Box plot comparing monthly home ranges (outliers removed)

criteria required the amount of difference between the results to be significantly larger (i.e., by a factor of more than 10 times) than the effects on the results introduced by data properties.

Since the geographic location context was diverse, to exclude distortions in the coordinate system as a potential unwanted influence, the results for Bylot island were spot checked for three applicable coordinate systems: WGS84 geographic coordinate system (EPSG:4326), NAD 83 / Statistics Canada Lambert projection (EPSG:3347), and Universal Transverse Mercator (UTM) zone 17N (EPSG:2958). These were identified using the CRS Explorer. The differences in the median home rage size results (UK wader season) for the foxes in Bylot were minor: 75.3 km2 for WGS84, 73.3 km2 for EPSG:3347, and 75.8 km2 for EPSG:2958.

For the habitat selection TBD

5 Discussion

The fox home range results differ enormously between rural and remote areas. We conclude that human presence impacts fox movement behavior significantly, with availability of anthropogenic food sources likely being relevant. The influence of technical aspects, like sampling intervals, on home range calculation results is significant. However, it plays a secondary role in comparison to the difference in fox behavior, which enables the chosen approach of comparing data from heterogeneous sources.

6 Appendix

6.1 Additional charts

6.2 Use of Large Language Models and Generative AI

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

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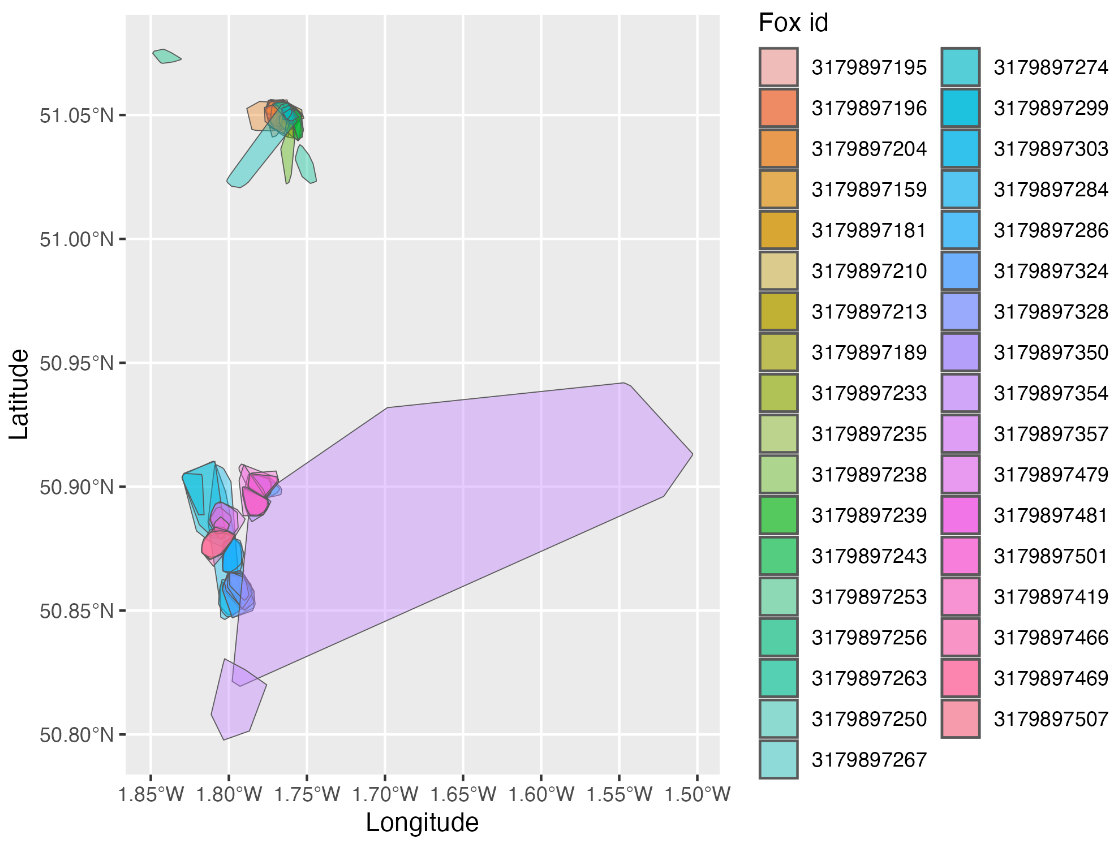

Figure 12: Monthly home ranges for Wiltshire foxes

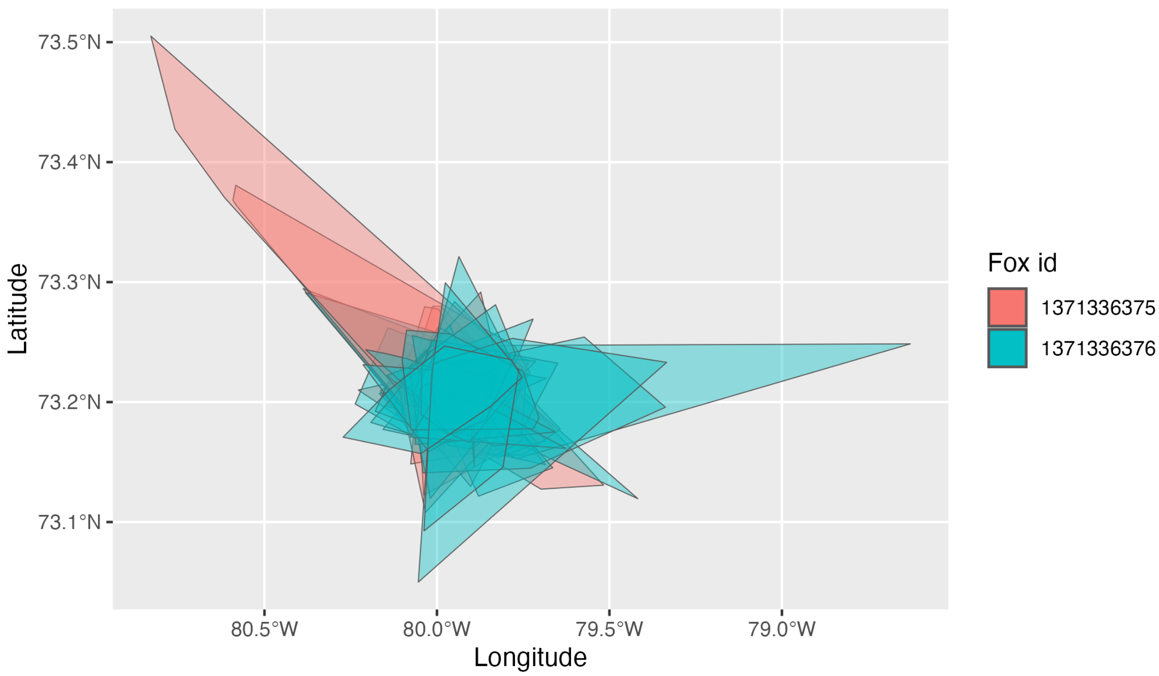

Figure 13: Monthly home ranges for Bylot foxes

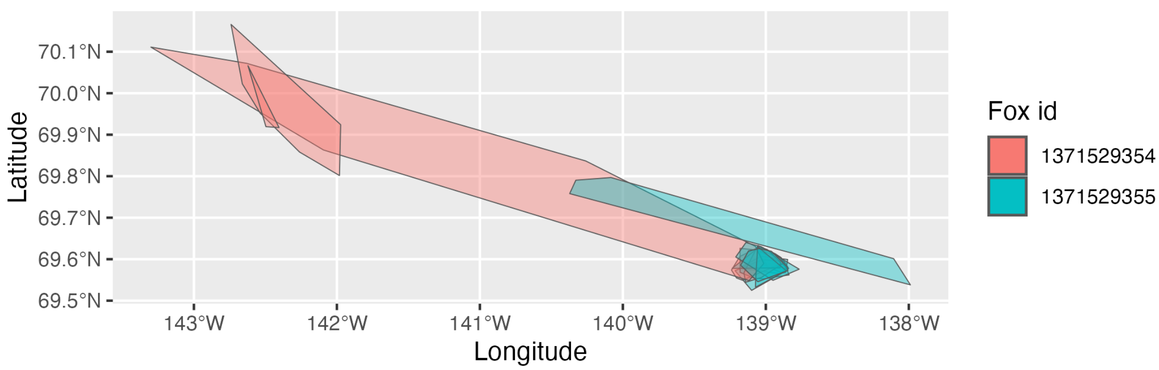

Figure 14: Monthly home ranges for Herschel foxes

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