Workshop on R and movement ecology:
Hong Kong University, Jan 2018

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Lecture 2
Home Ranges, Utilization Distributions, and Resource Selection

DEPARTMENT *of* ENVIRONMENTAL SCIENCE, POLICY, AND MANAGEMENT

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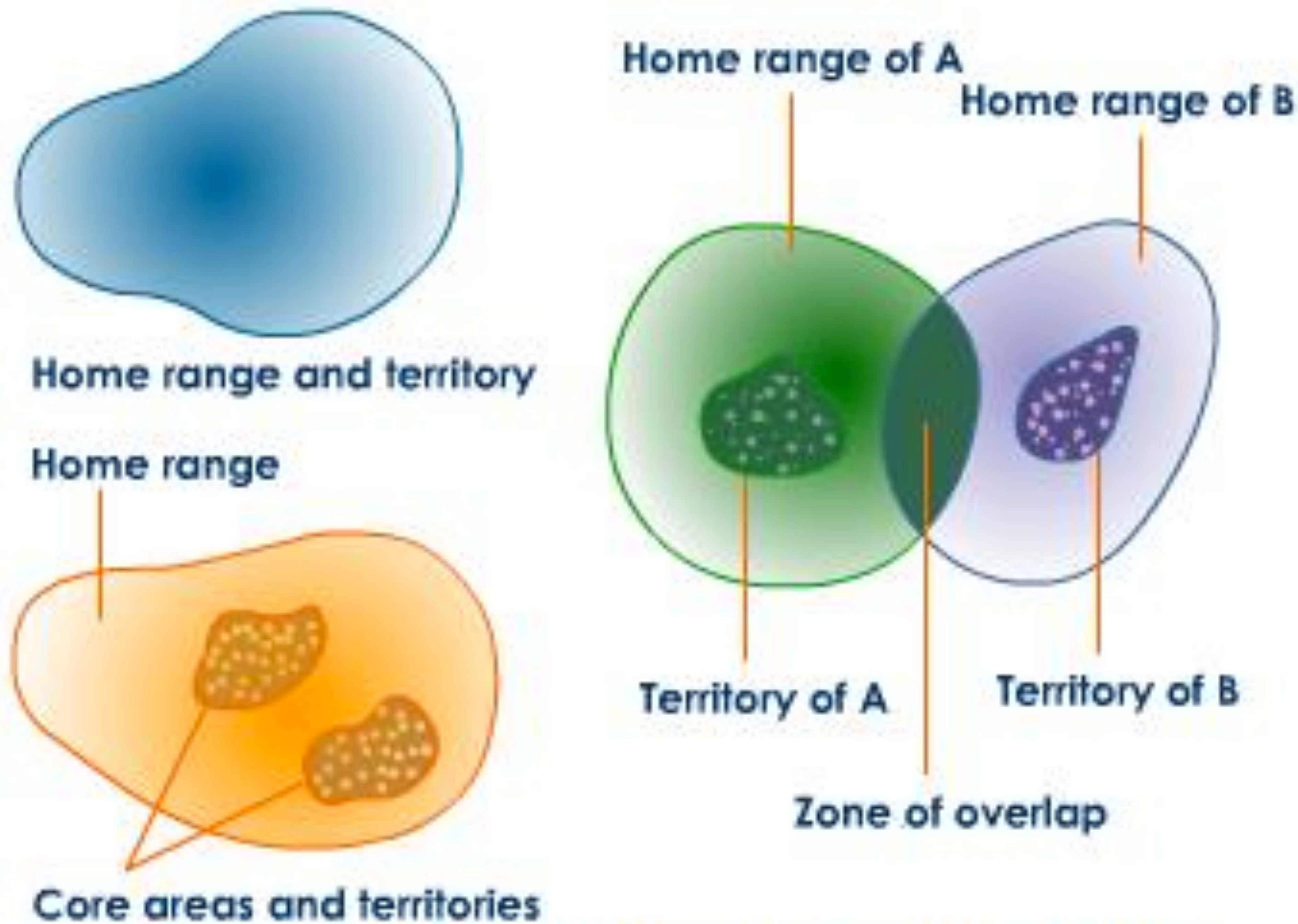
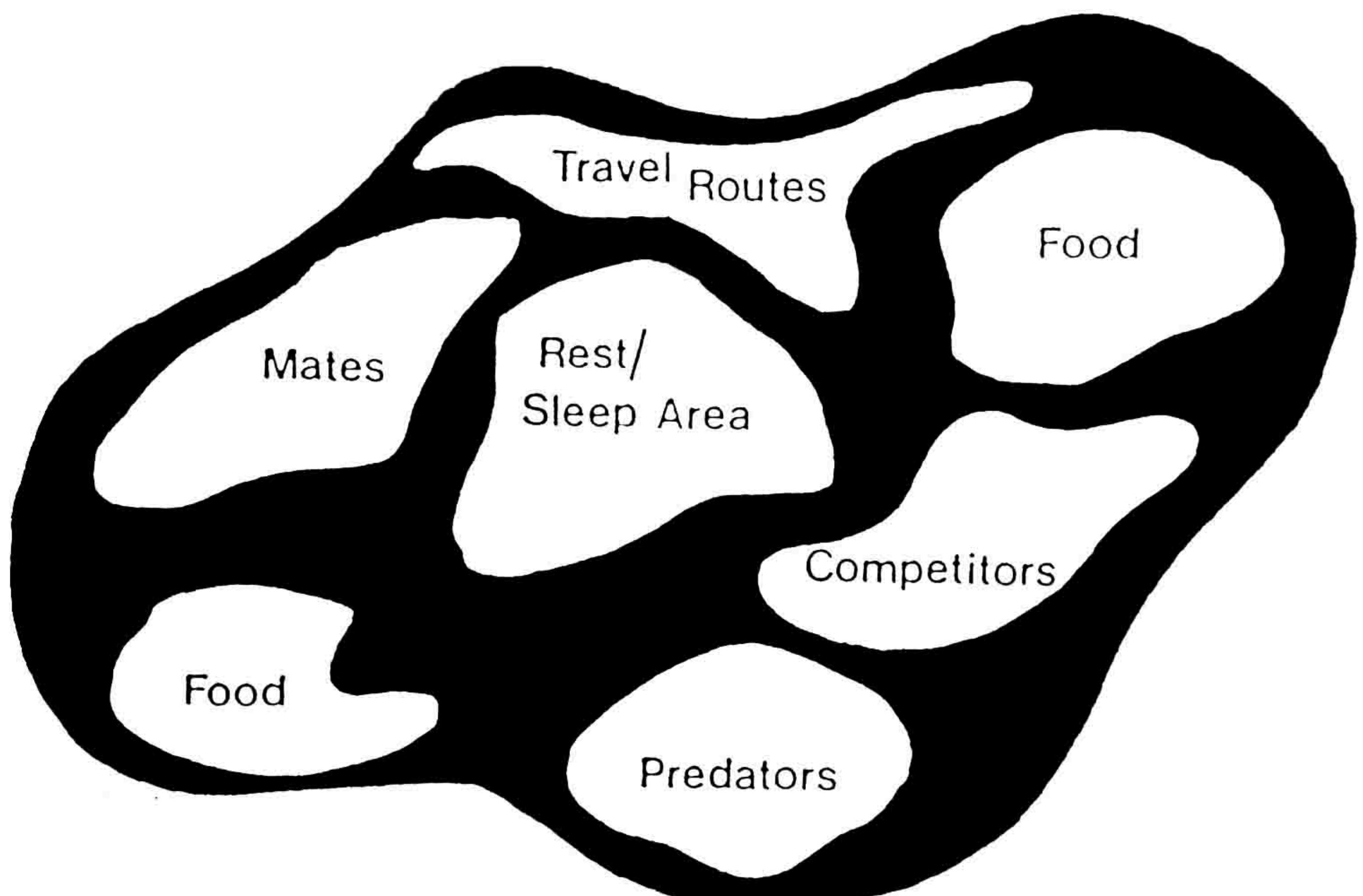
Home Range Primer



Diagrammatic Representation of Territories and Home Range of Two Species A and B

What is a Home Range?

- **The idea that animals restrict their movements has been established since the earliest ecological studies**
- **The most commonly cited definition of a home range (Burt, 1943):**
  “that area traversed by an individual in its normal activities of food gathering, mating and caring for young”
- **‘Occasional sallies’ should not be considered as part of the home range**



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  Space use patterns can arise from various behaviors, including the three mentioned by Burt. But these do not necessarily encapsulate all ‘normal’ activities. What about refuge use as a means of predator avoidance? Any others you can think of?

  Also, does normality shift over time? The home range of a young animal moving in conjunction with its mother will likely differ markedly from its movements as a sub-adult or adult.

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- **What qualifies as a ‘sally’?**

  In order to determine what qualifies as a ‘sally’, we need to have a clearly delimited home range, but to do that, we must first define which points should be removed because they are sallies! This circular reasoning means we need to lay down some a priori rules beforehand, but Burt gives no guidance on that front.

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- **How important is variation in the intensity of usage within this area?**

  Even at extremely fine scales, my movements reflect differential use of certain areas over others. I am in my bed for about 8 hours each day, but spend only about half an hour in my bathroom. According to Burt’s definition, we would not be able to differentiate between these magnitudes of intensity of use in my house.

What issues might arise from that definition?

- **What qualifies as ‘normal’ activity?**
- **What qualifies as a ‘sally’?**
- **How important is variation in the intensity of usage within this area?**
- **How should one delimit this region?**

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- **What qualifies as a ‘sally’?**
- **How important is variation in the intensity of usage within this area?**
- **How should one delimit this region?**

Here we come to one of the great challenges that researchers in wildlife ecology and, in particular, movement ecology, have faced over the past few decades. Various people have offered a number of alternative methods for delimiting a home range; we will discuss a few today and continue our discussion in the next lecture and activities.

Why do we care?

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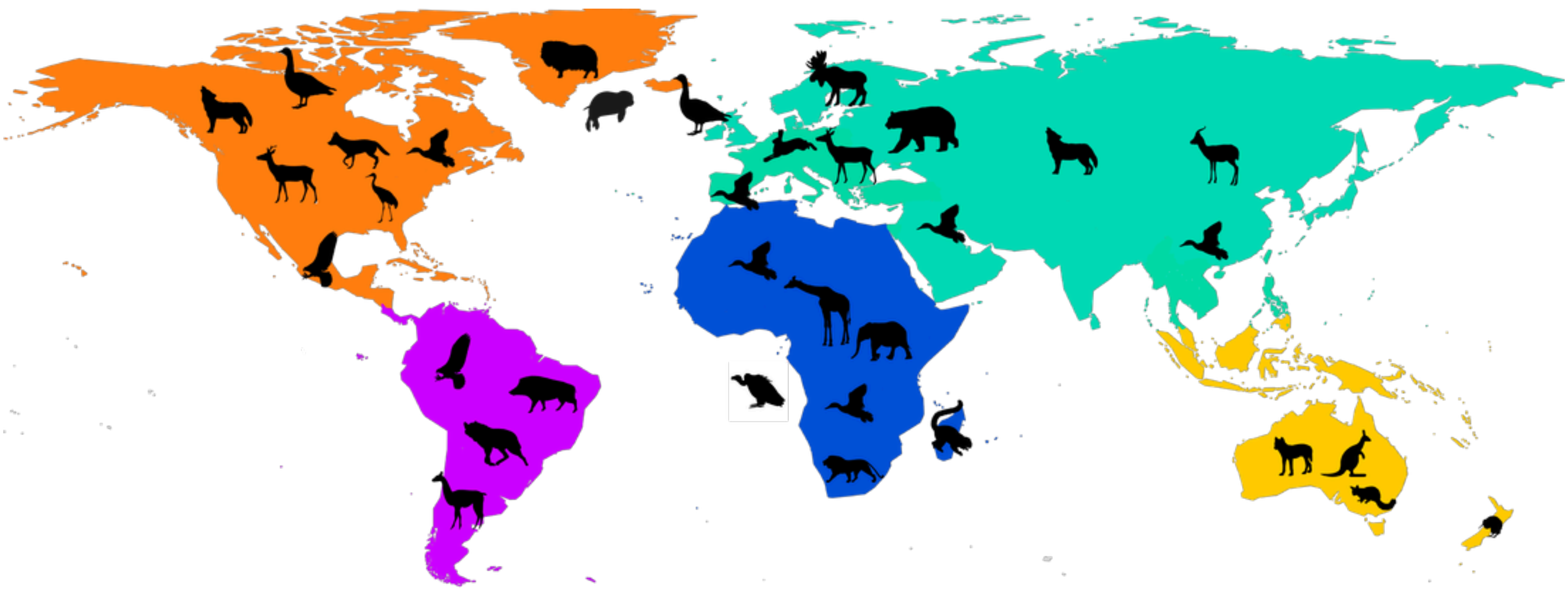
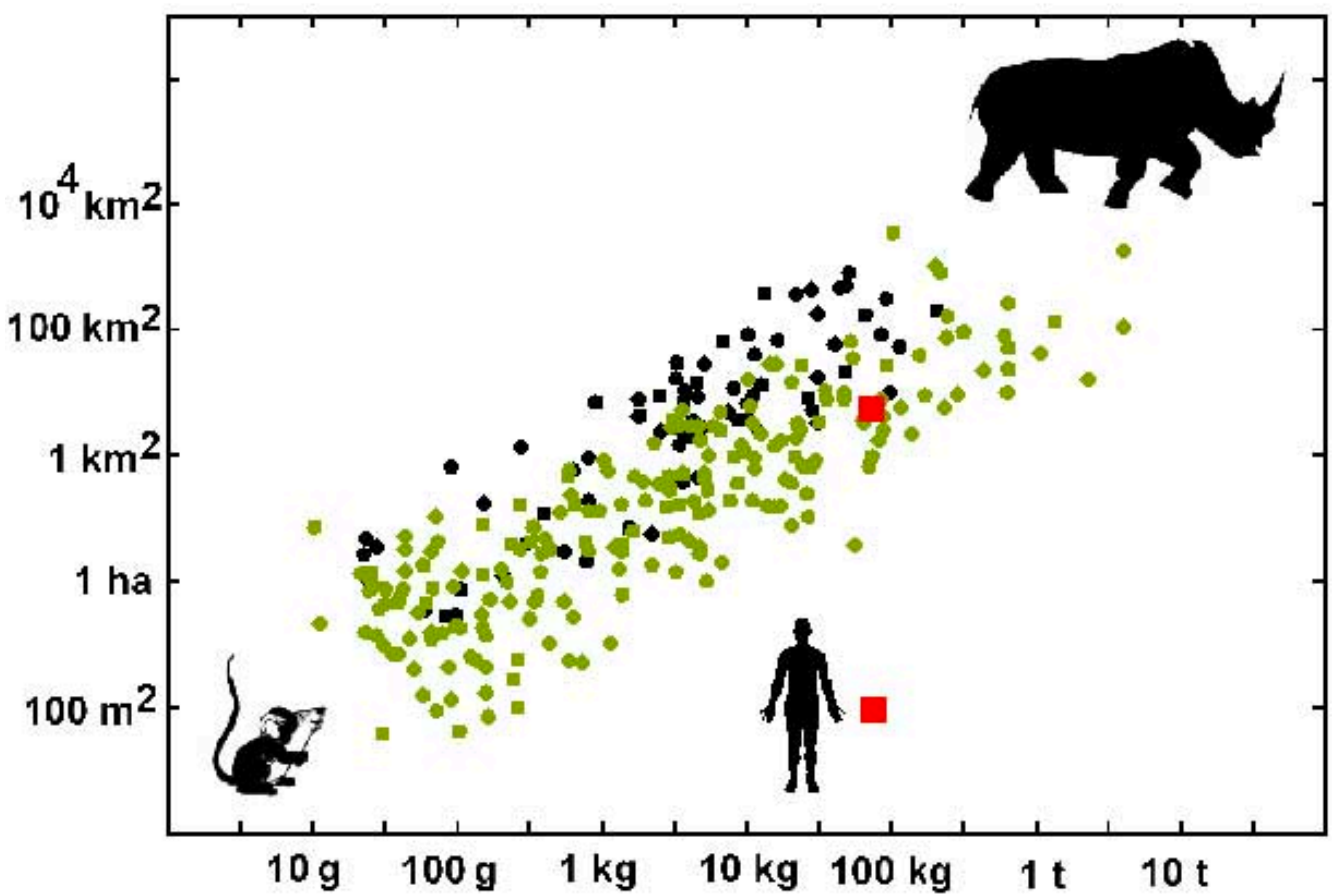
- **Any others you can think of?**

Home Range Size Predictors

- According to a recent meta-analysis based on available GPS data (Tucker et al. 2014), body size explains the majority of the differences in home range size (53-85% of the variance). Diet explained about 15% of the variance, but the environment seems to play a relatively small role in differences in home range size (1.7% of variance).



Patterns in Home Ranges



Larger body masses are associated with larger home ranges. Black dots represent Carnivores, green dots represent herbivores. (Kelt & Van Vuren 2001, *American Naturalist*)

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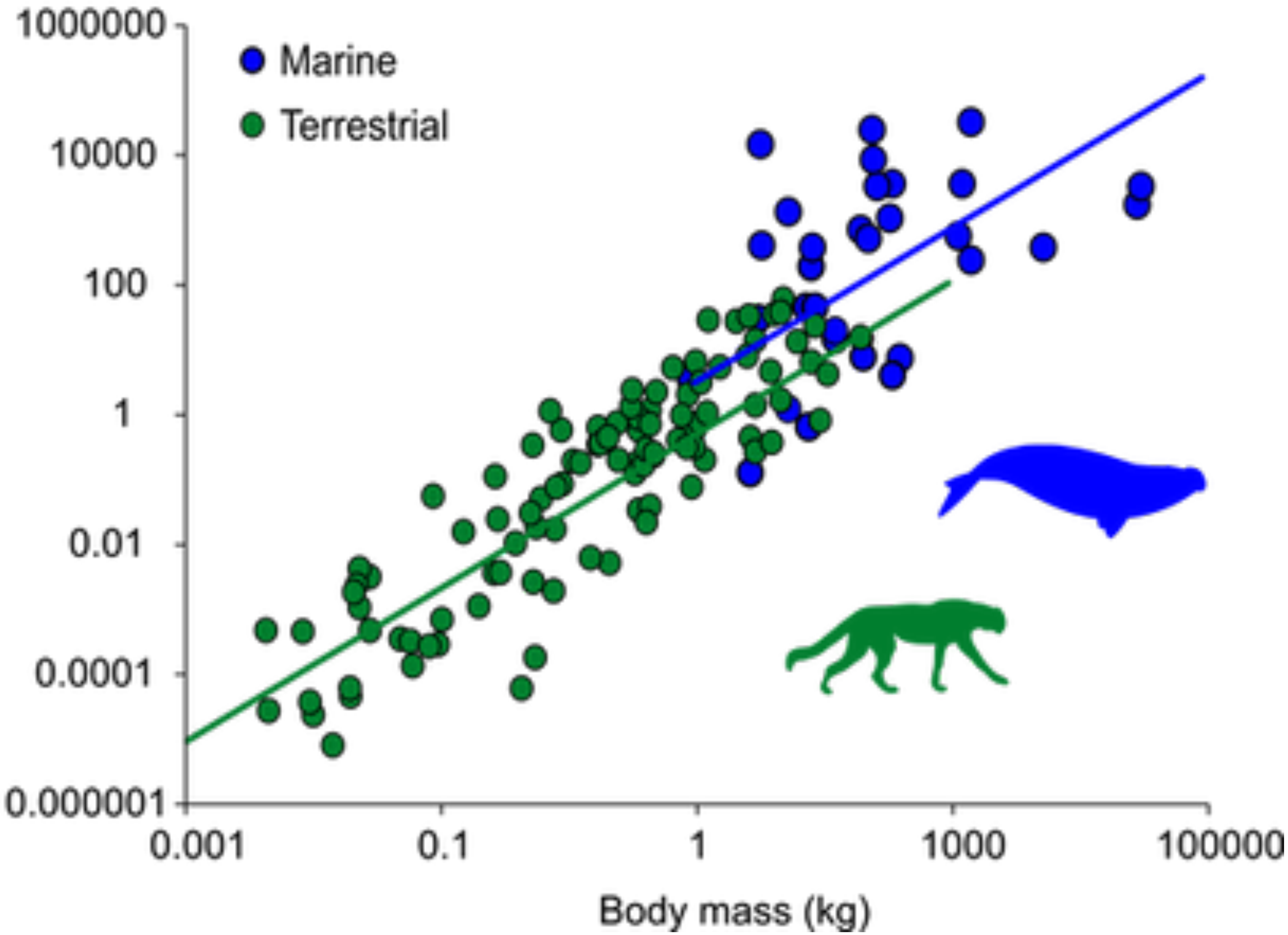
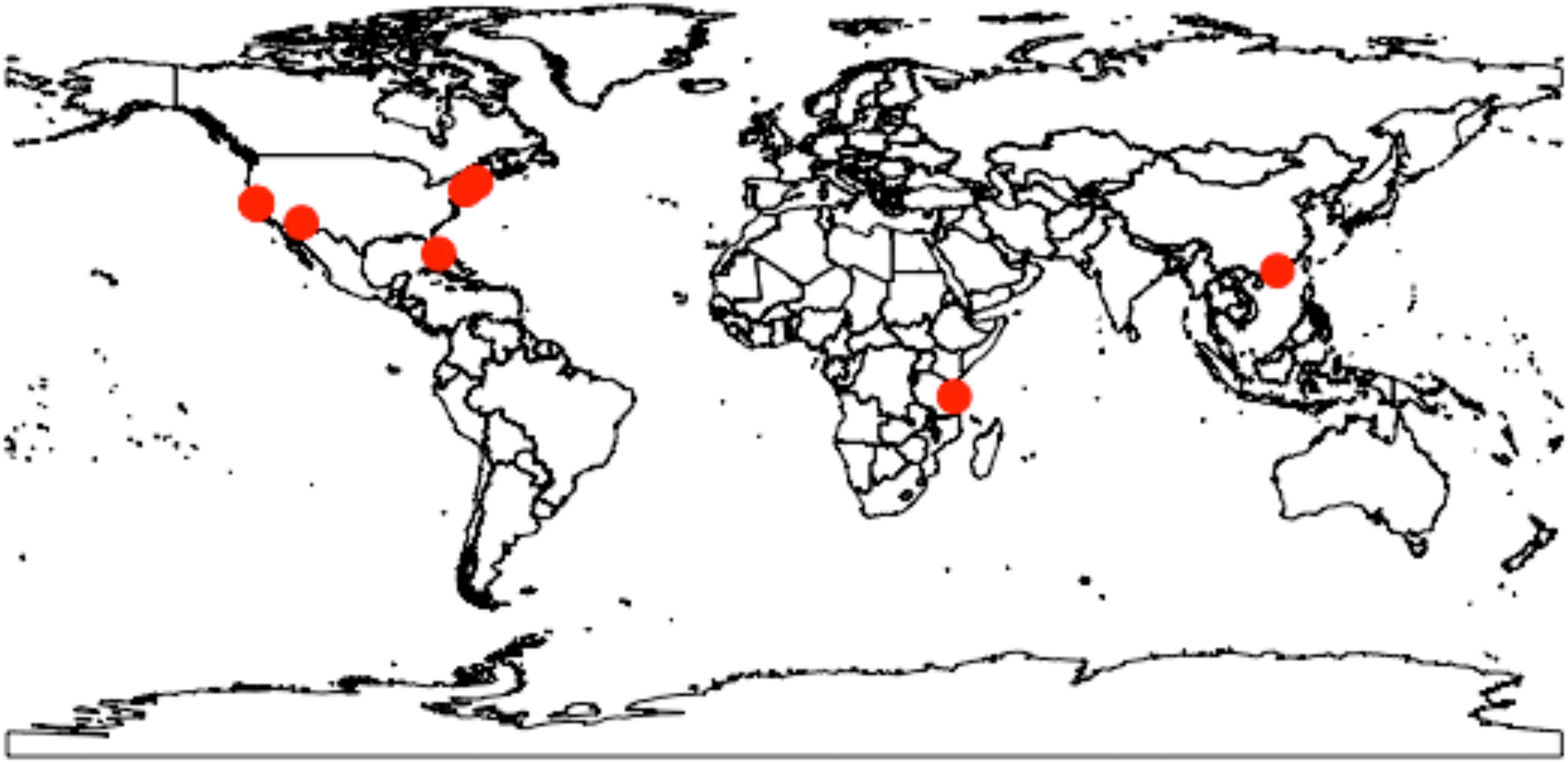


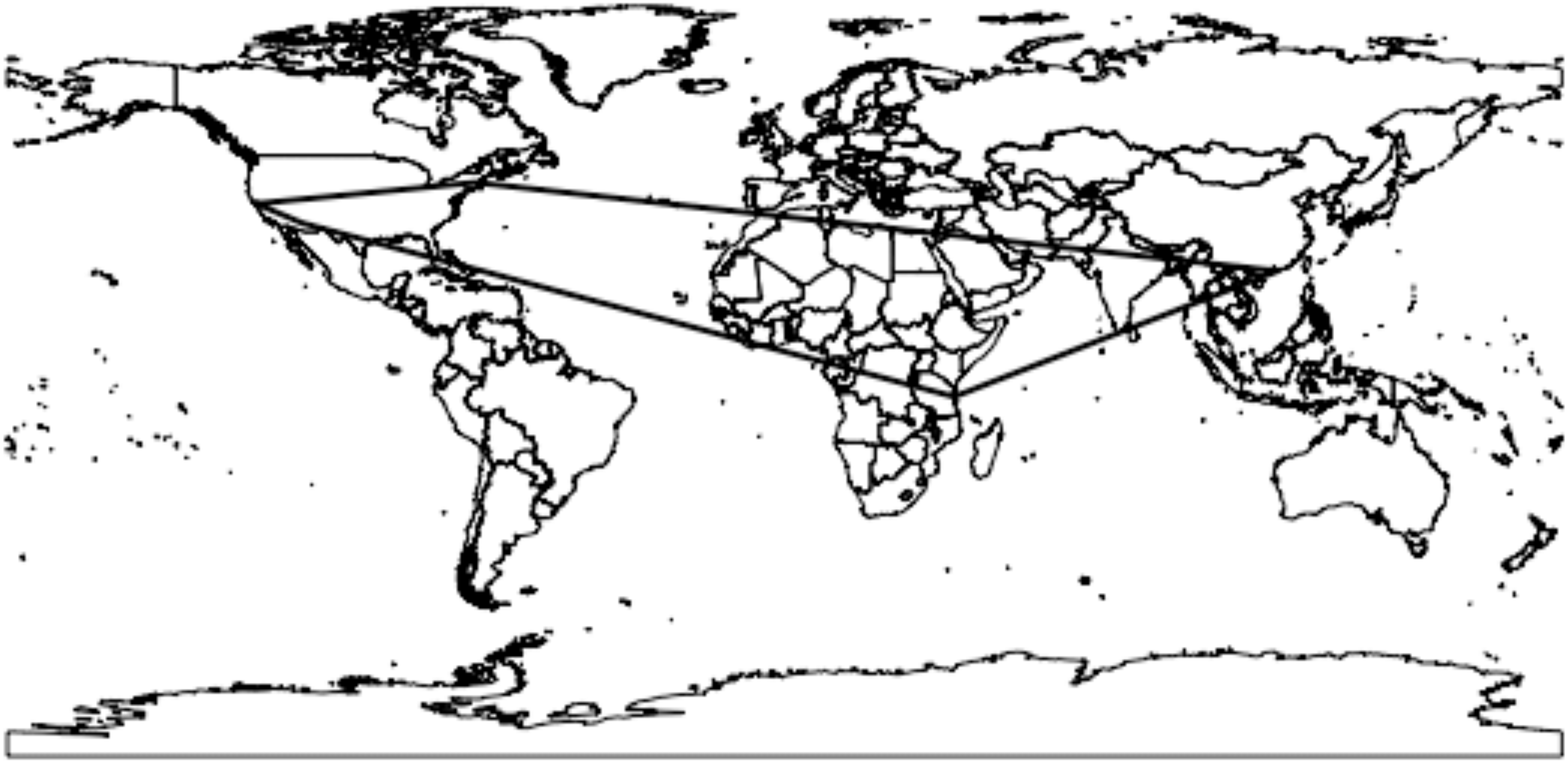
Marine species (blue dots) tend to have larger home ranges than terrestrial species (green dots), but mostly because they have larger bodies. (Tucker et al. 2014, *Global Ecology and Biogeography*)

Delimiting Home Ranges



Here, I have mapped some of my GPS locations over the past six months. I spent some time in California, Arizona, Florida, New Hampshire, and New York, not to mention Tanzania and now Hong Kong!

Delimiting Home Ranges



Let's take a look at the most basic method of delimiting a home range: the minimum convex polygon (MCP) method. This draws a polygon around the outermost points and calls everything within that polygon the home range

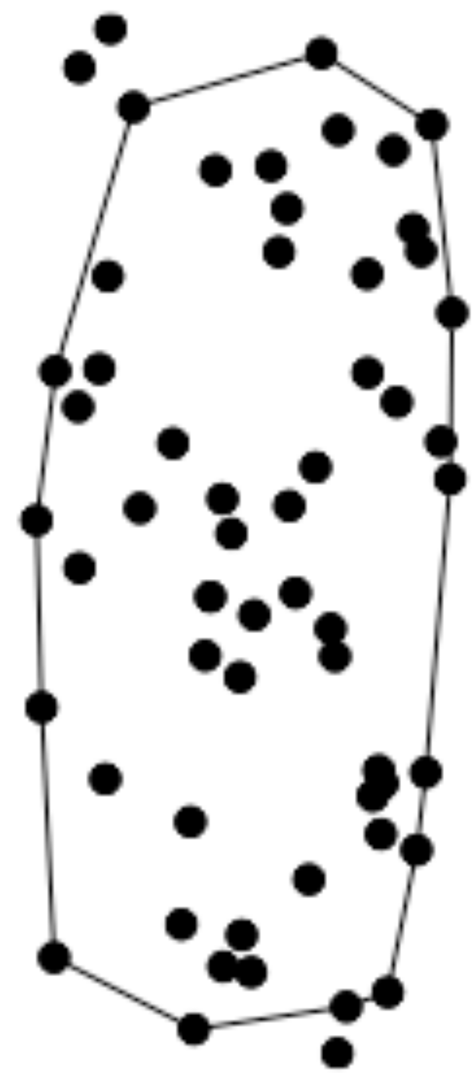
Delimiting Home Ranges

Let's zoom in a bit, and you'll see that we have included a ton of space in which I have never set foot: Much of the southeastern US, northern and central Africa, the Arabian Peninsula, India, several Southeast Asian countries. If we used the 100% MCP, we might expect that I have frequented all of those countries and the oceans separating them!

Delimiting Home Ranges

Now if we zoom in on my core area, we can see that my trips to Tanzania and Hong Kong are eliminated (they are treated as sallies), but so is Berkeley, because I spent a bit less time there this semester than usual. Still we have quite a lot of space in there that I've never occupied: Louisiana, Mississippi, Alabama, Kentucky, etc.

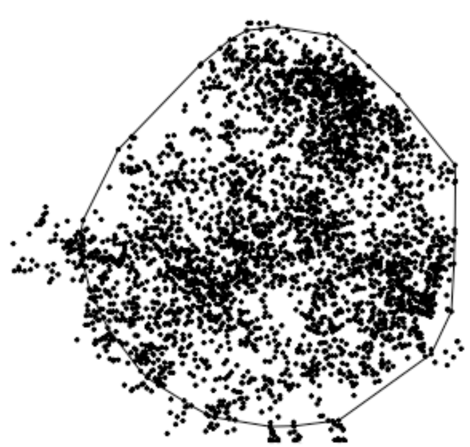
Delimiting Home Ranges



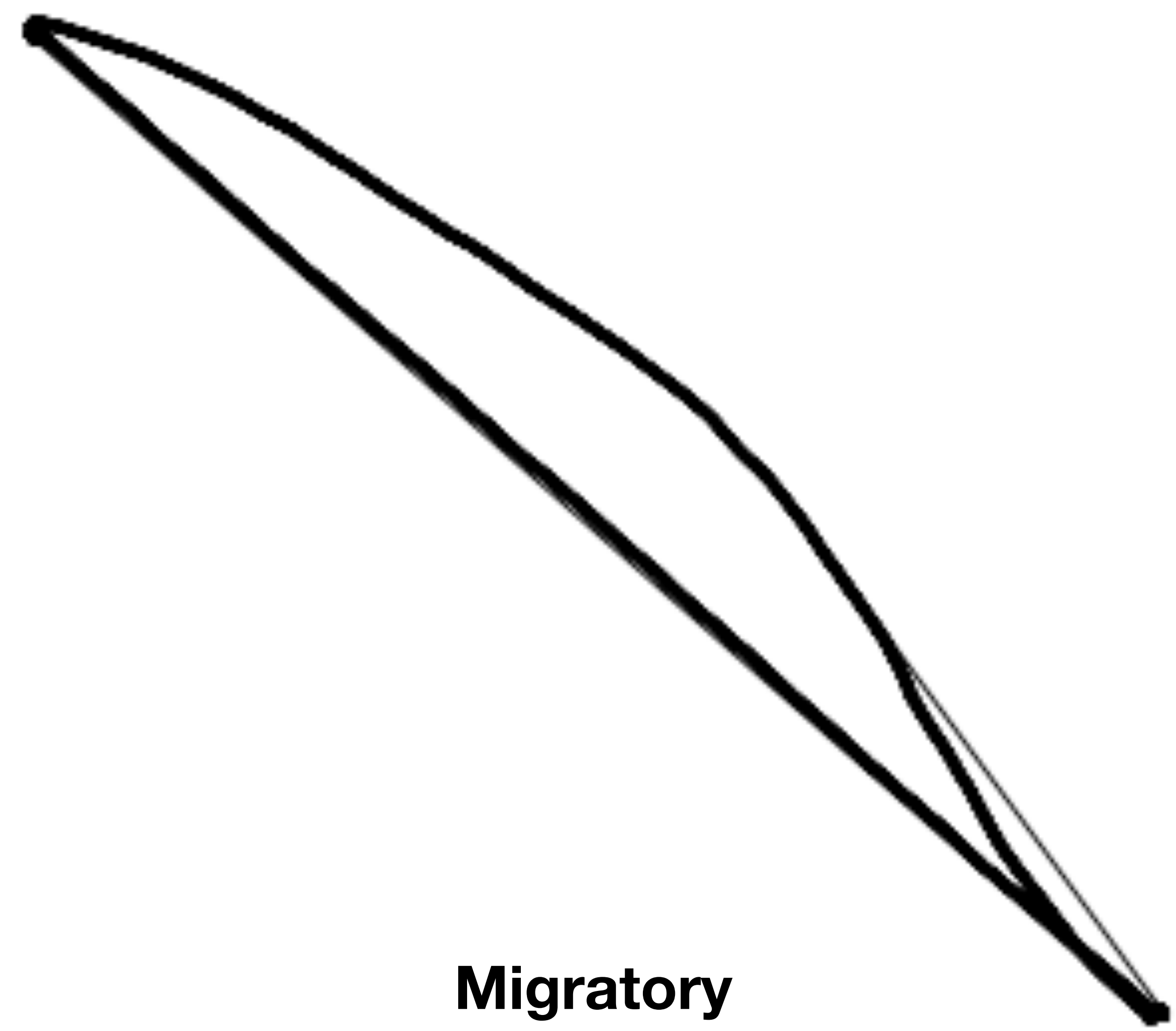
Perhaps if we zoomed into just one of these clusters of points, we could delineate a more reasonable home range using the MCP method. Here is the 95% MCP of the Arizona-based points. The MCP is really quite reflective of the space-use during the period of time during which this cluster of points was taken

Delimiting Home Ranges

- Clearly the MCP method is not an especially effective home range delimiter, particularly when an animal is relatively wide ranging (like me). For animal that stay within a relatively small home range throughout a season or year, treading over the same area quite regularly rather than migrating long distances, it may be somewhat more accurate.



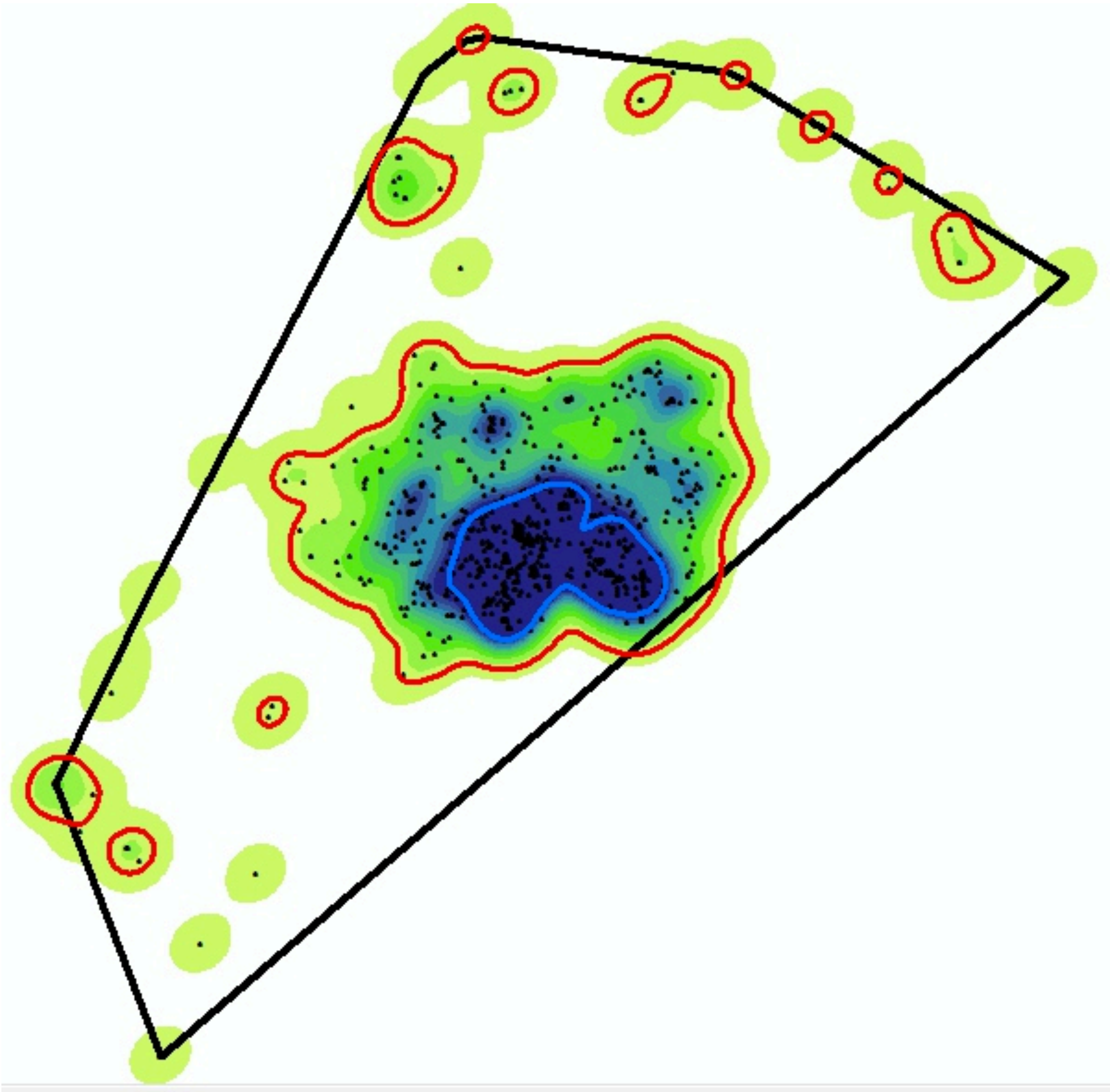
Territorial



Migratory

Delimiting Home Ranges

- In 1989, Bruce Worton introduced the concept of using kernel density estimator to define the utilization distribution, which goes beyond simply delimiting the borders of the home range to describing the probability of use throughout these areas



Delimiting Home Ranges

- The Utilization Distribution (UD) represents the distribution of an individual's position in the plane. To create this distribution, kernel density estimator (KDE) methods are used. We will not go over this in too much detail, but Worton set forth a fixed kernel method and an adaptive kernel method. The equations presented for both are below:

Fixed kernel method

Restricting ourselves to the bivariate case, suppose that $\boldsymbol{X}_1 = [X_1^{(1)}, X_1^{(2)}]'$; $\boldsymbol{X}_2 = [X_2^{(1)}, X_2^{(2)}]'$; . . . , $\boldsymbol{X}_n = [X_n^{(1)}, X_n^{(2)}]'$ is a random sample of n independent points from an unknown utilization distribution with probability density function $f(\boldsymbol{x})$, which is to be estimated, then the bivariate kernel estimator of $f(\boldsymbol{x})$ can be defined as

$$\hat{f}_h(\boldsymbol{x}) = \frac{1}{nh^2} \sum_{i=1}^{n} K\left[\frac{\boldsymbol{x} - \boldsymbol{X}_i}{h}\right],$$

where the kernel K is a unimodal symmetrical bivariate probability density function, and h is the smoothing parameter that can be varied by the user (Silverman 1986). As an example, if the bivariate normal density kernel is used, the kernel density estimator is

$$\hat{f}_h(\boldsymbol{x}) = \frac{1}{nh^2} \sum_{i=1}^{n} \frac{1}{2\pi} \cdot \exp\left(-\frac{(\boldsymbol{x} - \boldsymbol{X}_i)'(\boldsymbol{x} - \boldsymbol{X}_i)}{2h^2}\right).$$

Adaptive kernel method

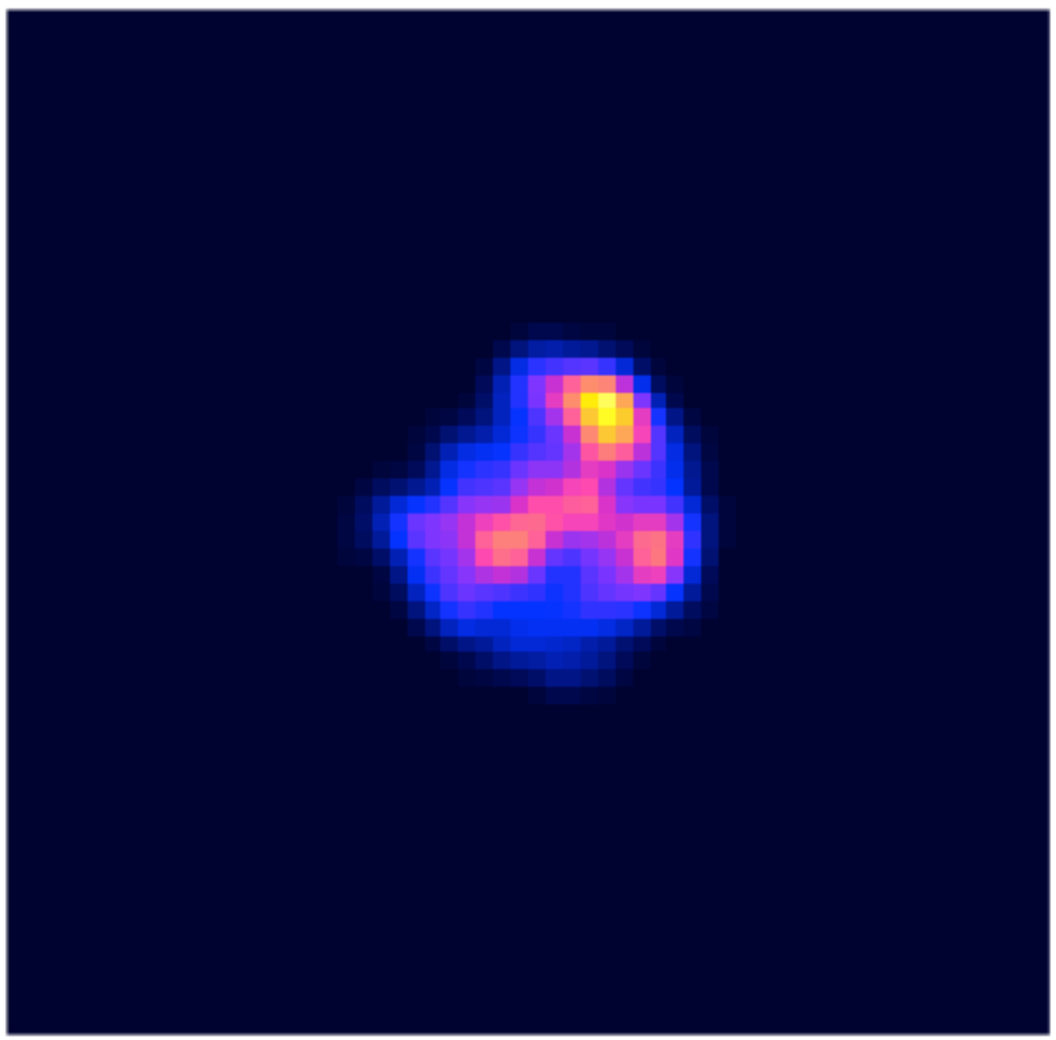
Sometimes a more sophisticated kernel approach called the adaptive kernel method is needed. This method varies the smoothing parameter so that areas with a low concentration of points have higher h values than areas with a high concentration of points, and are thus smoothed more. Therefore, the adaptive method is an improvement on the fixed kernel method, particularly in the tails of the density. The UD density estimator is

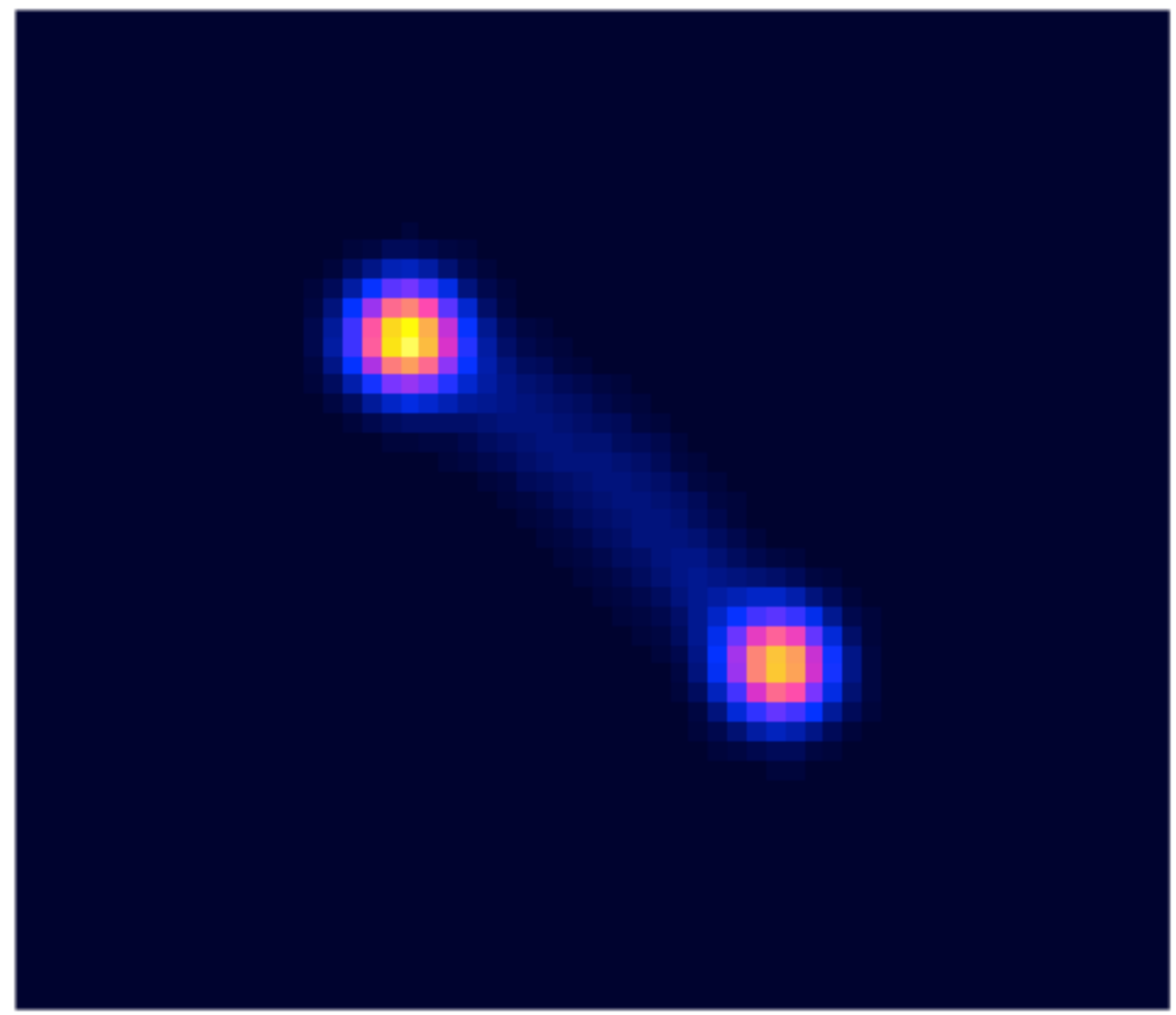
$$\hat{f}_h(\boldsymbol{x}) = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{h_i^2} K\left(\frac{\boldsymbol{x} - \boldsymbol{X}_i}{h_i}\right),$$

where the smoothing parameters h_i are based on some "pilot" estimate of the density. Silverman (1986:101)

Delimiting Home Ranges

- Fortunately, we need not worry too much about the mathematics behind the kernel density estimation methods, though it should be noted that the process does involve some user-defined parameters (namely, the smoothing method and the bandwidth value) that may result in different implementations and resulting home ranges.

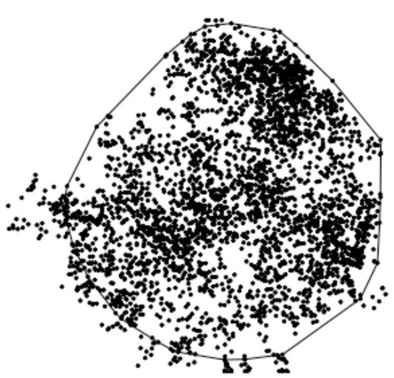


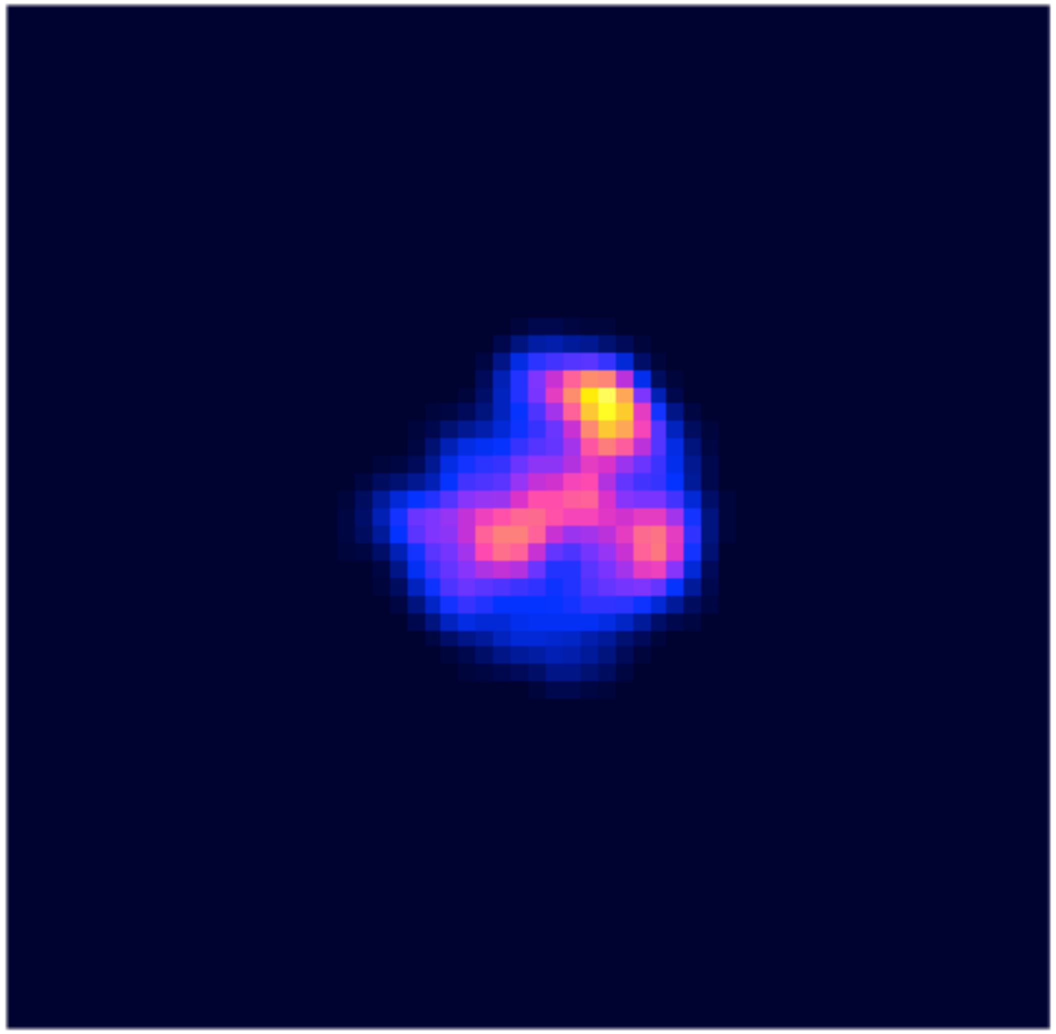


Here are the same territorial and migratory individual as for the MCPs we developed before. Clearly there is some variation in the intensity of use of the home ranges that we cannot see using the 95% MCP home range

Delimiting Home Ranges

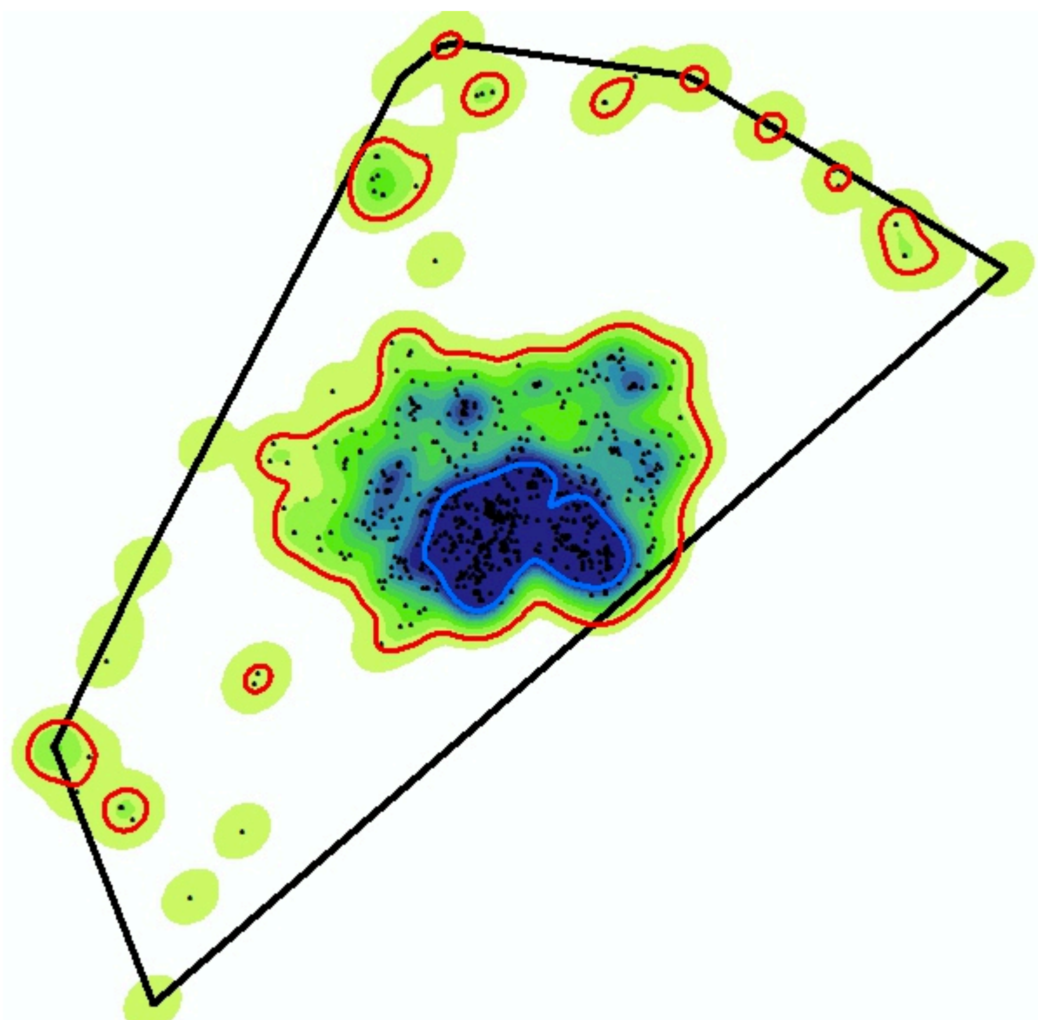
- MCP and UD represent two of the many possible methods one can apply to movement data to delimit a home range. If one is interested in finer-scale details of where within a home range an animal is likely to occur, the UD method may be most useful. For broader-scale processes like potential disease transmission based on home range overlap, the MCP may be sufficient.

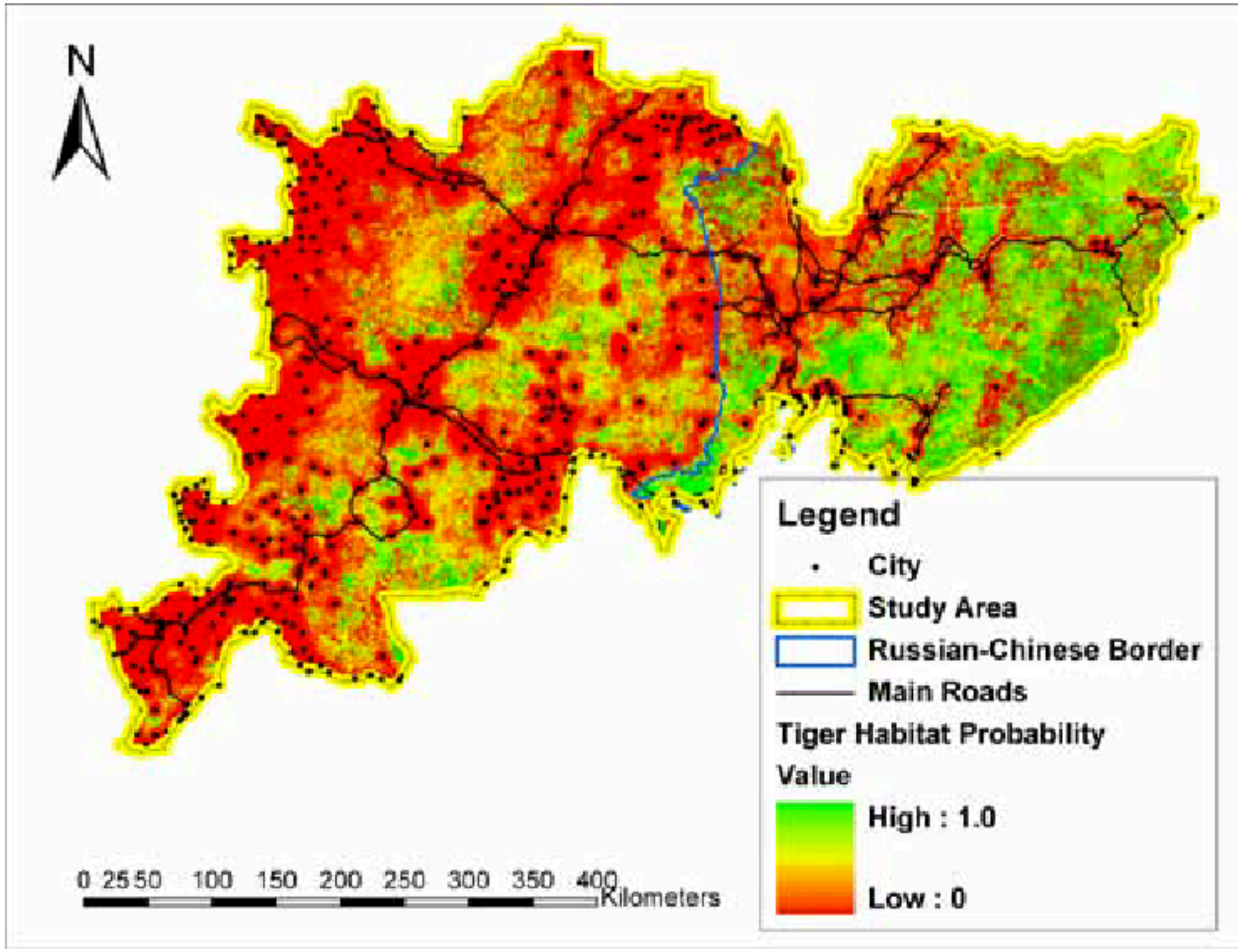




From Description to Prediction

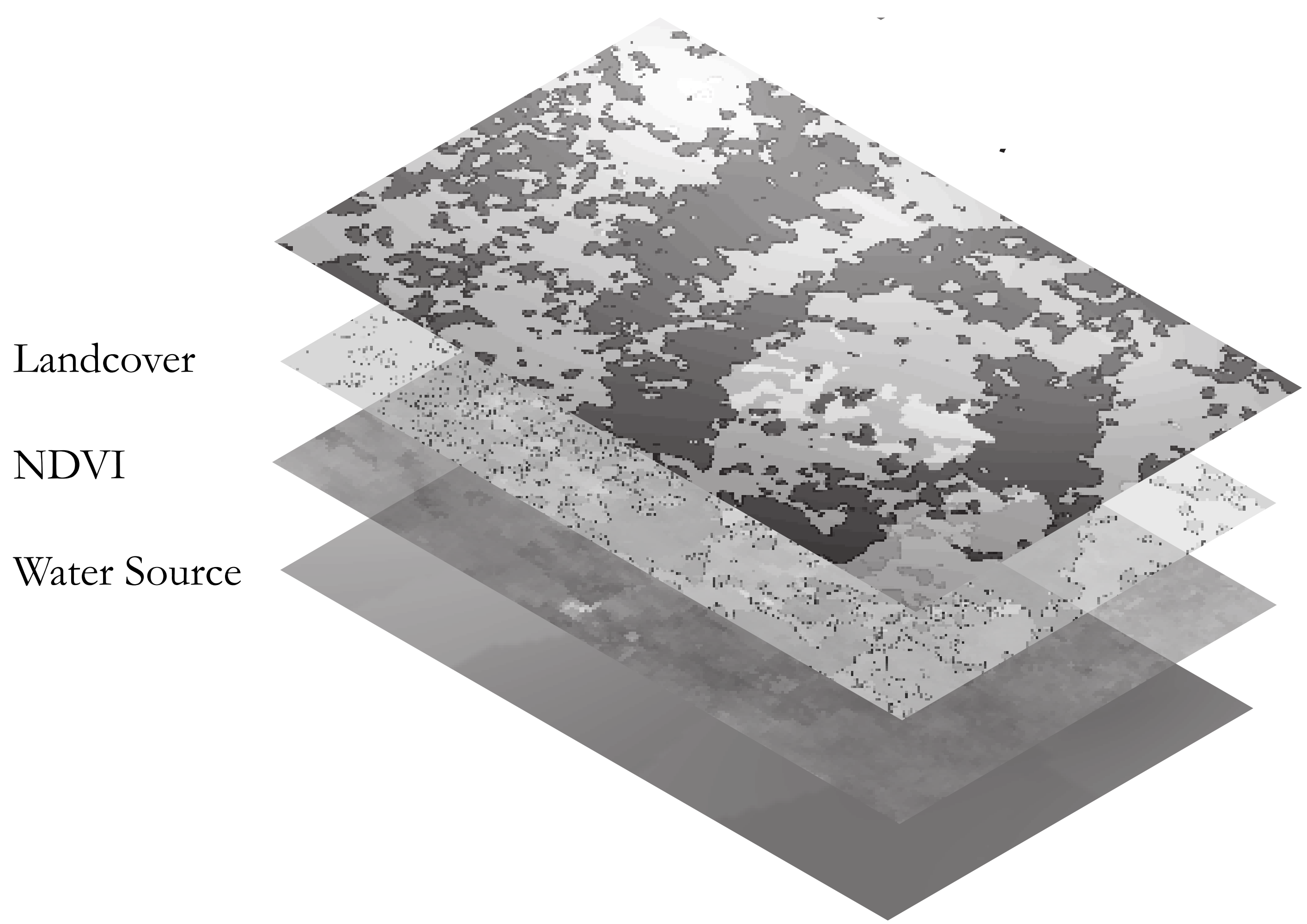
- The home range methods that we have discussed are meant to **describe** the movement patterns of individuals across landscapes based on recorded positional data. But what if we want to **predict** where an animal might be based on previous knowledge of their whereabouts?





Resource Selection Functions

- At a relatively broad-scale (landscape-level), one can consider all of the potential (or at least measurable) contributors to an animal's movement patterns. The resource selection function (RSF) framework was developed to create predictive maps or where we should expect animals to be based on their previous locations.



Resource Selection Functions

- An RSF is a model that yields values proportional to the probability of use of a resource unit. These are often fit using generalized linear models (GLMs), and model selection (i.e., selecting the right predictor variables to consider) is normally done through AIC or BIC approaches.

$$w(x) = \exp(\beta_0 + \beta_1 X_1 + \ldots + \beta_i X_i)$$

Where w(x) is the relative probability of a pixel being selected, β_0 is the intercept, and β_1 is the estimated coefficient for variable χ_1.

If $\beta > 1$, a preference for that resource is indicated, whereas $\beta < 1$ indicated avoidance of that resource relative to its availability on the landscape