Spatial Data Analysis in R

Misc. Concepts 2: Space Use

Eco 697DR – University of Massachusetts, Amherst – Spring 2022
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For Today

- Chapter 8: definitions
  - We'll look at some examples on Wednesda
- In-class random walk activity
- Lab: work on lab 6 and individual final projects

Course Wiki

Only a few days left to add to the wiki

- Make sure you add an entry to the course Wiki!
- It's very easy and it's worth 7% of your course grade!

Chapter 8 Code

Updated and verified chapter 8 code is posted to Moodle.

A few warnings about the code:

- The book uses ggplot figures, but the code demos use base plotting.
  - Your plots won’t look nearly as pretty.
- I wasn’t able to re-create the exact focal type maps from section 8.3.3 for forest type
- There is no file called “landcover reclass.txt”
  - The filename is actually "resistance reclass.txt“, but… I’m not sure if this contains the exact text that the resistance reclass.txt file was meant to.

Habitats

Habitat Definitions

Species	Ecosystem
• Niche-like definition • Environmental attributes/resources required for a particular species	• Similar biotic community • Vegetation cover type • "Ecoregions are areas where ecosystems (and the type, quality, and quantity of environmental resources) are generally similar. This ecoregion framework is derived from Omernik (1987) …"

Habitat and Resources

- **Habitat** refers to biotic and abiotic environment
  - Doesn’t explicitly include mates, or items that are consumed.
- **Resource** also includes mates and food

Ideal Free Distribution

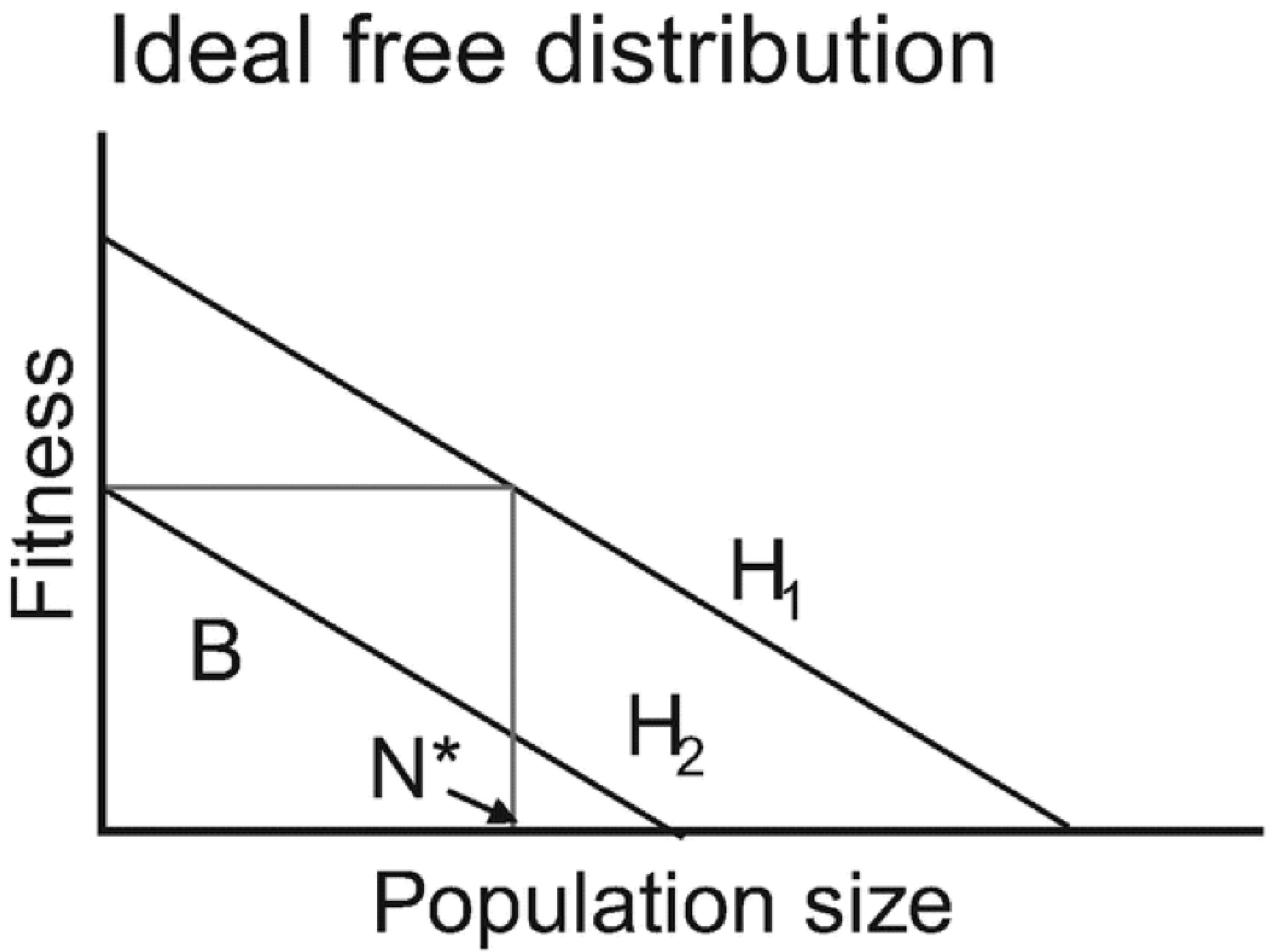
- Two (multi) patch model.
- Patches differ in their resource richness.
- Organisms attempt to maximize their resource utilization by selecting which patch to use.
- Organisms are free to select a patch
  - They prefer the richer sites
- Resource availability per organism depends on:
  1. Amount of resource in the patch
  2. Number of browser/scramble competitors in the patch

Ideal Free Distribution

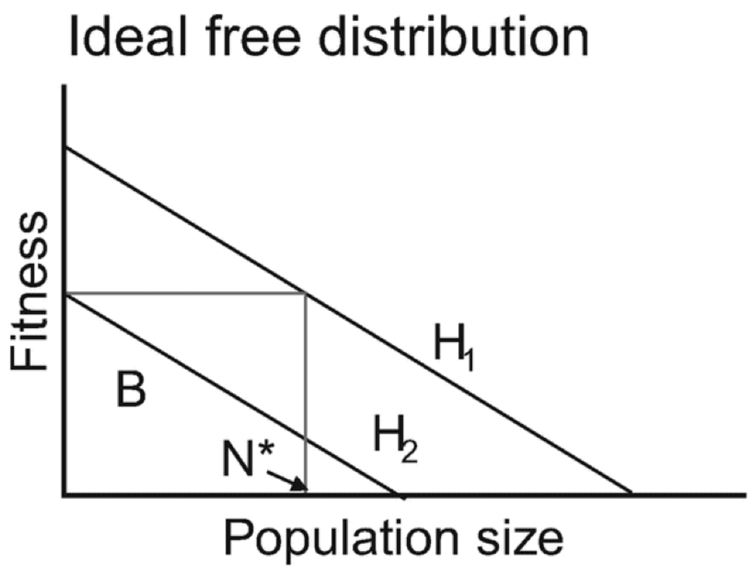
F+F Figure 8.1

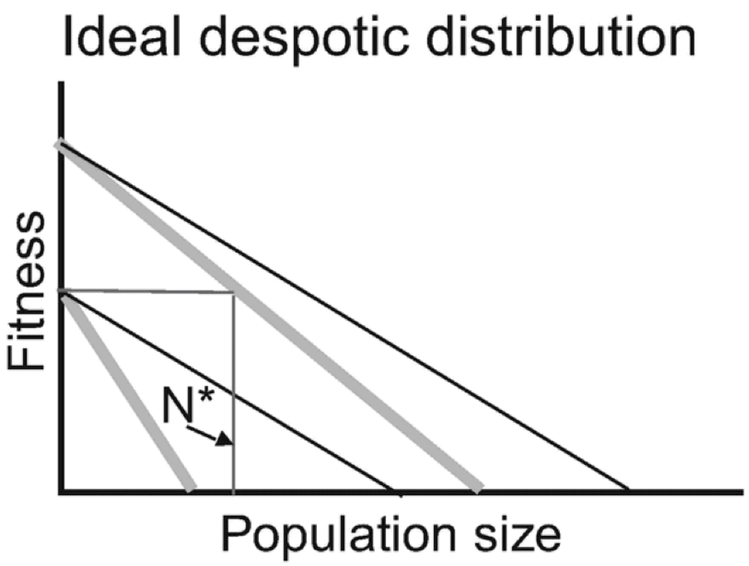
How to interpret these diagrams?

- Organisms move to H1 until per capita resource availability is equal to H2, then they start populating H2



Ideal Free Distribution





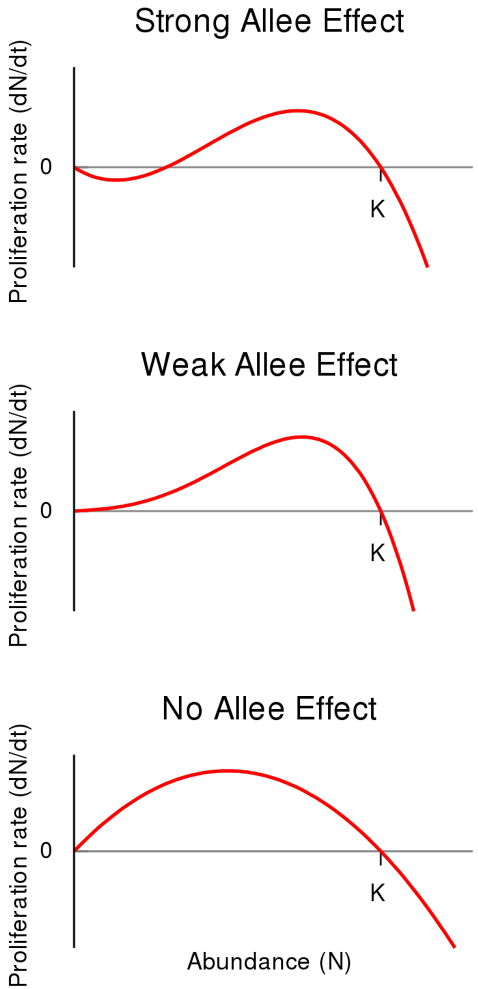
Assumptions
- Equal competitors
- Fitness of individuals declines with increasing density

Predictions
- At equilibrium, all individuals have similar fitness
- Underlying habitat quality correlates with number of individuals

Assumptions
- Unequal competitors
- Fitness of individuals declines with increasing density

Predictions
- At equilibrium, individuals have different fitness
- Densities in poor v rich will depend on competition intensity

Allee Effects



It's all about density-dependent fitness

- At high population densities, resources becomes limited and individual fitness decreases.
  - Populations may reach an equilibrium level (K)
- Individual fitness is often highest at moderate population densities.

What happens to individual fitness at low population density?

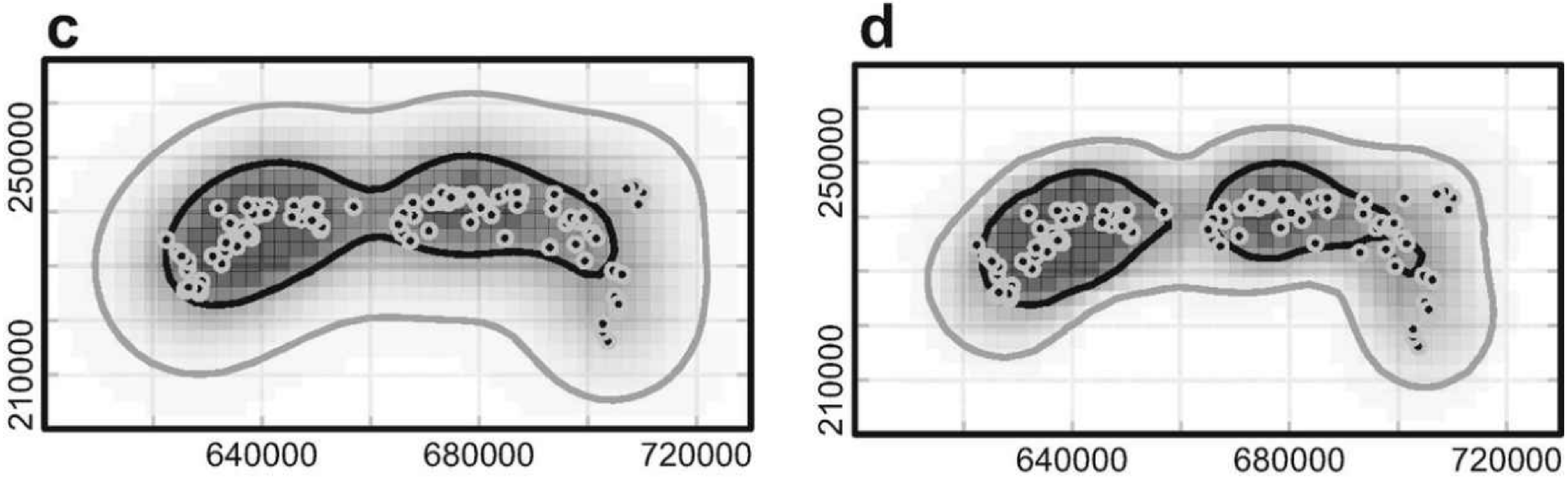
- Individual fitness may decrease. Possibly due to difficulty finding mates, need for cooperation, etc.

Home Ranges and Territories

Home Range	Territory
• Area used by individuals, not necessarily actively defended. • Usually larger than a territory • May change seasonally or over the course of an organism's life.	• Area actively defended by an organism. • May include prime feeding resources, mating area, etc. • Usually smaller than the home range. • May be defended from individuals of same or different species • Usually smaller than a home range

Utilization Distribution

- Frequency distribution of space used by an animal.
- From F+F Figure 8.9:



Movement

Movement Null Models

Diffusion	Random Walks

• Continuous time
• Continuous space
• Focus is on population: Eulerian
  • Describes the probability of finding an organism at position (x, y).
• Differential Equations
	• Discrete time: time steps
	• Space may be continuous or discrete
	• Focus on individuals: Lagrangian
	  • Describes rules for how an animal may move, possibly influenced by previous states or positions.
	• Simulations
	• Brownian Motion: occurs when time steps are decreased to zero, i.e. the random walk becomes continuous

A Framework for Movement

4-component framework from Nathan et al. 2008:

- Intrinsic state of individual
- Motion capacity
- Navigation capacity
- External environment

Random Walks

Doing the Mersenne Twist!

What's a Random Walk?

It's a rule-based movement model, usually with discrete time steps, that describes what happens when an object chooses movement distances and/or directions randomly.

- A random walk is a realization of a stochastic process
- A random walk is usually memoryless, but can be modified to remember previous steps, for example direction of the previous time step.
- Various constraints and modifications are possible:
  - Direction: grid or continuous angles
  - Step length: constant, uniform or normally distributed, exponentially distributed

What's a Random Walk?

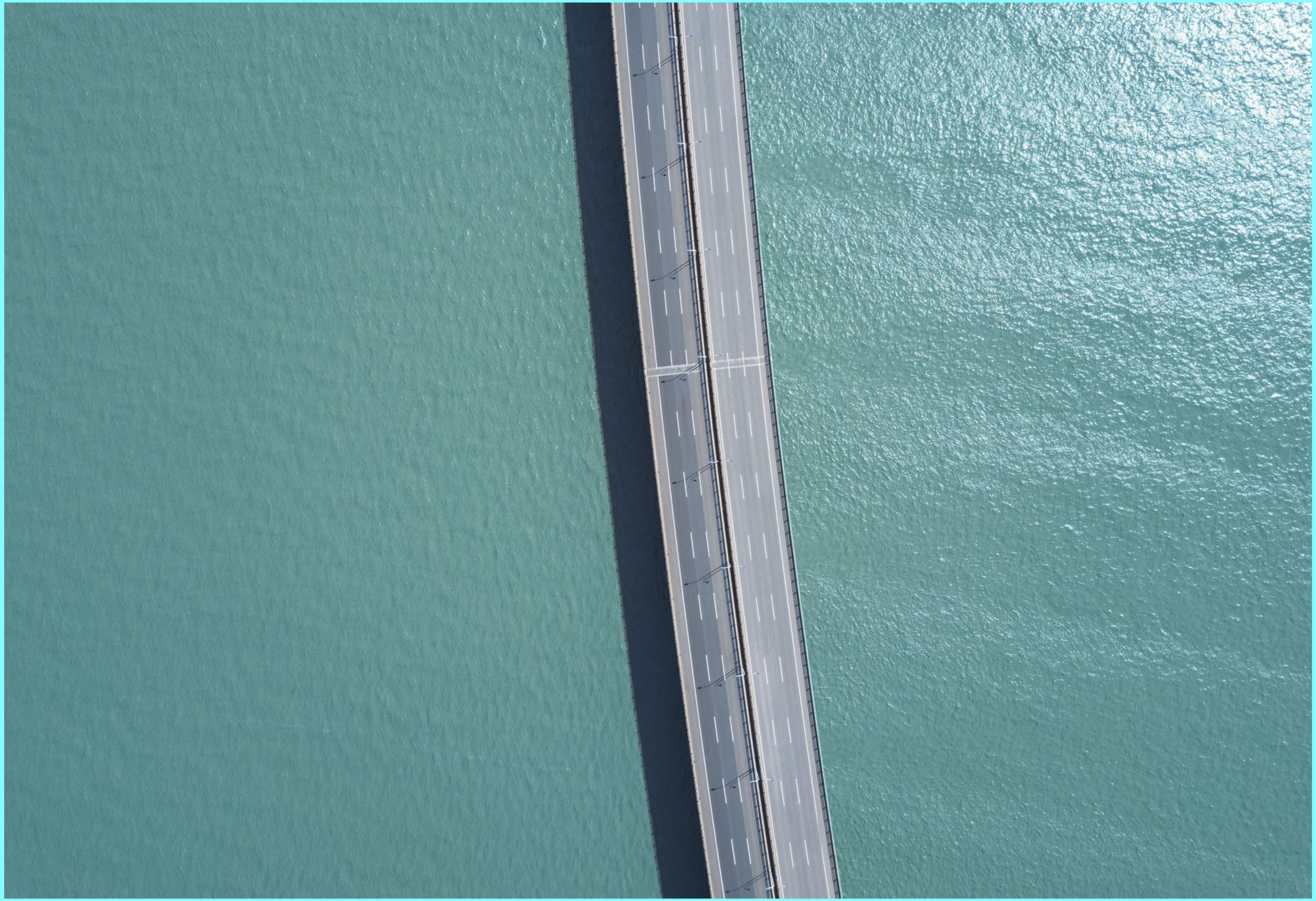
A random walk can be considered a basic type of **agent-based model**

- A random walk embodies the 4-component framework from Nathan et al. 2008:

1. Intrinsic State: current position, direction
2. Motion capacity: possible step lengths
3. Navigation capacity: range of possible direction changes
4. External environment: usually not considered in basic random walks, but preferences for movement toward resources or favorable habitat can be incorporated.

Describing Home Ranges

- Convex Hulls: minimum convex polygons
- Kernel density
- Brownian bridge
- Local convex hulls



Convex Hulls

The smallest convex polygon that completely encloses a set of points.

What does convex mean?

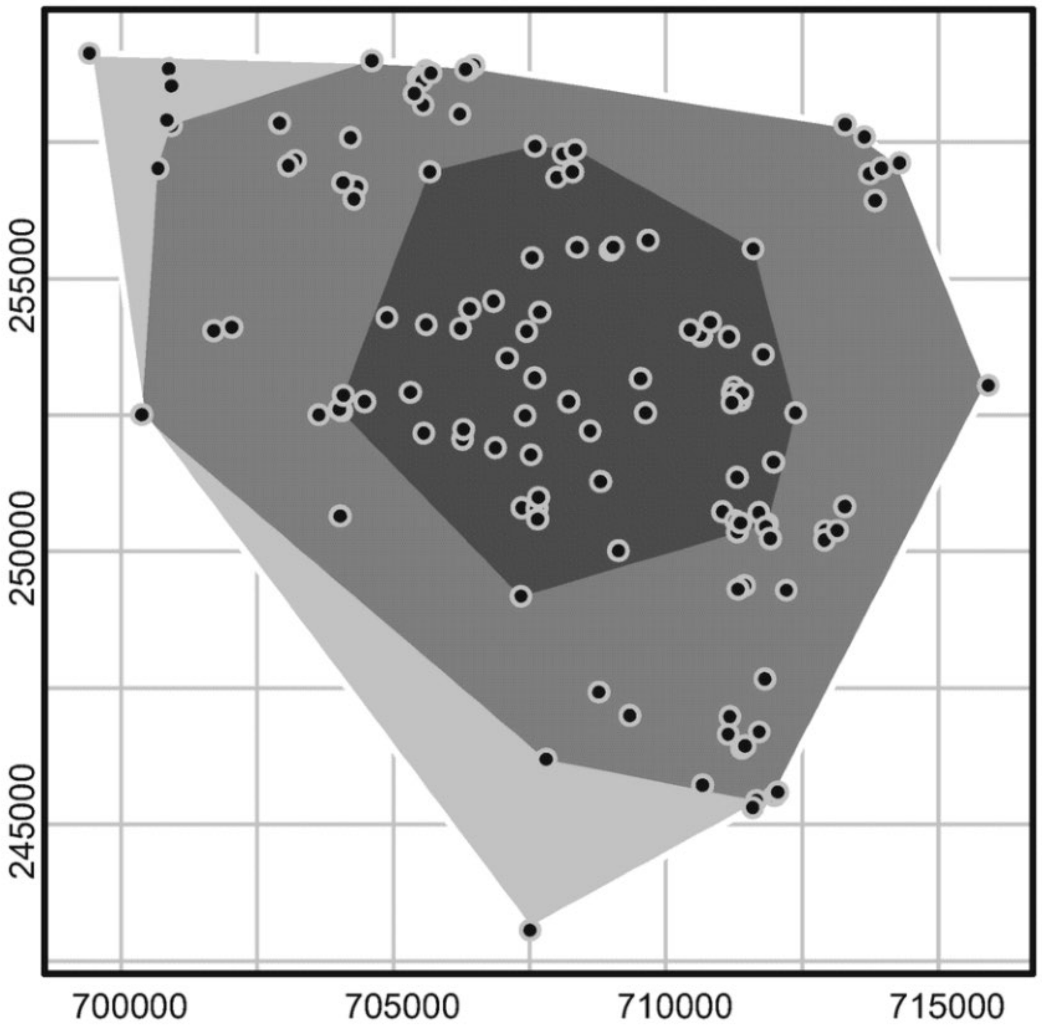
- Every angle in the polygon is less than 180 degrees, i.e. no concave angles.

Percentile minimum convex polygons:

- Hull contains n% of points in collection
- Implemented in adhabitatHR::mcp()

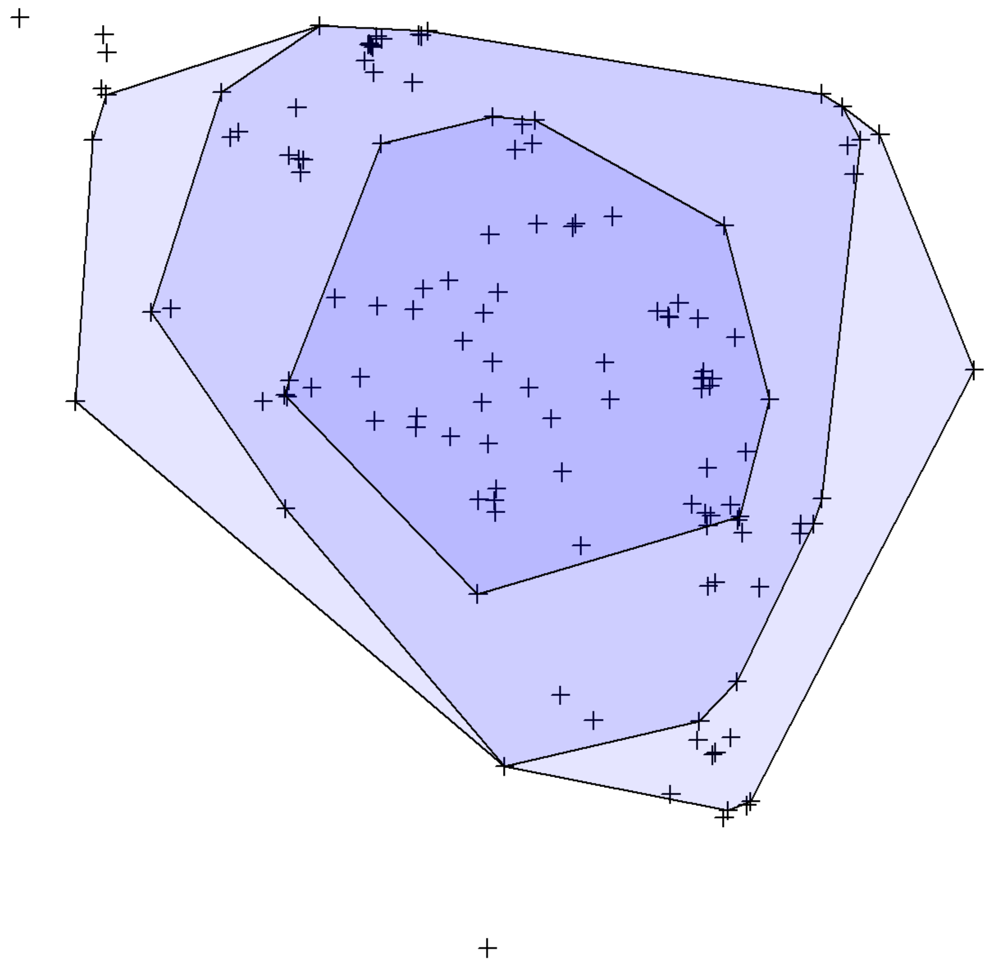
Binary utilization distribution

From F + F figure 8.8:



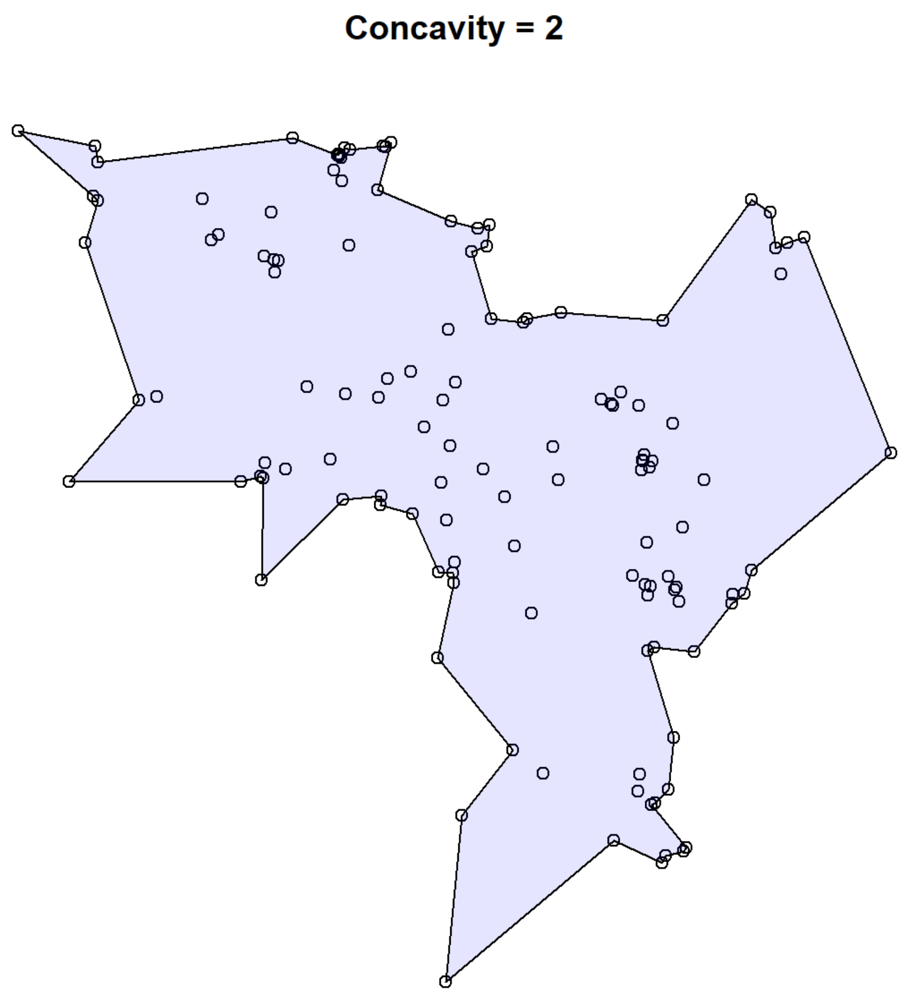
Minimum Convex Hulls: Panther # 100

```
pan_100 = subset(panthers, CatID == 100)
plot(pan_100)
plot(
  mcp(pan_100, percent = 95),
  add = T,
  col = adjustcolor("blue", 0.1))
plot(
  mcp(pan_100, percent = 85),
  add = T,
  col = adjustcolor("blue", 0.1))
plot(
  mcp(pan_100, percent = 50),
  add = T,
  col = adjustcolor("blue", 0.1))
```

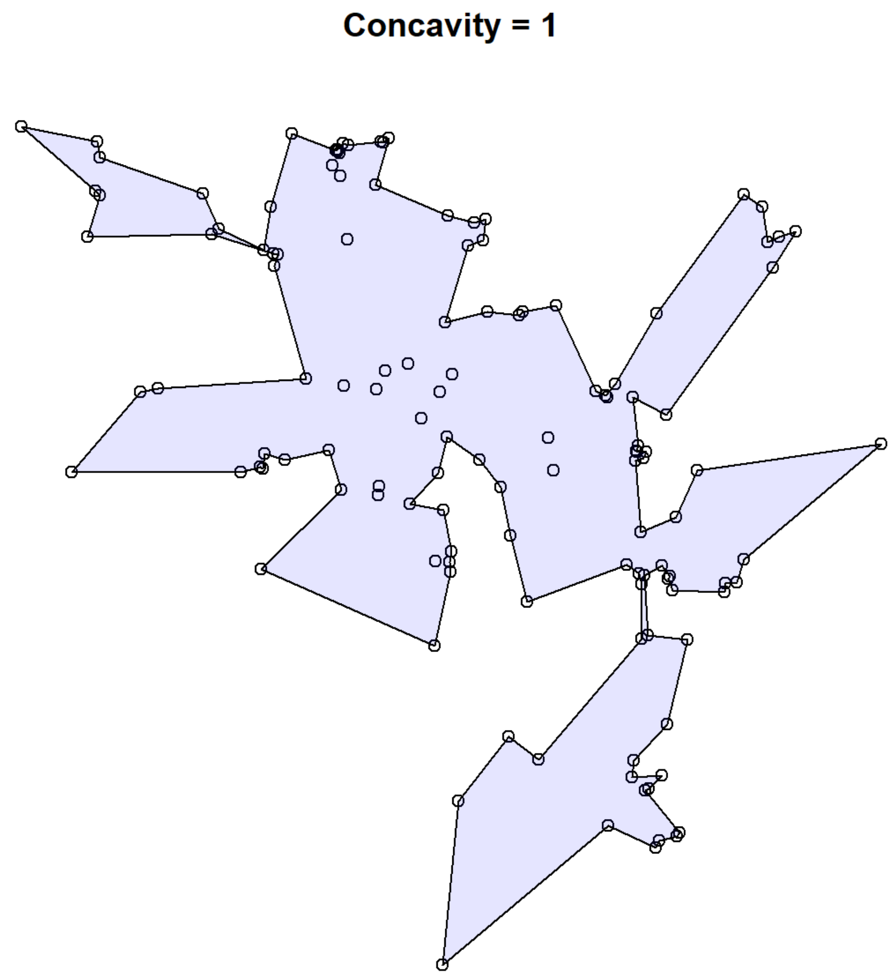


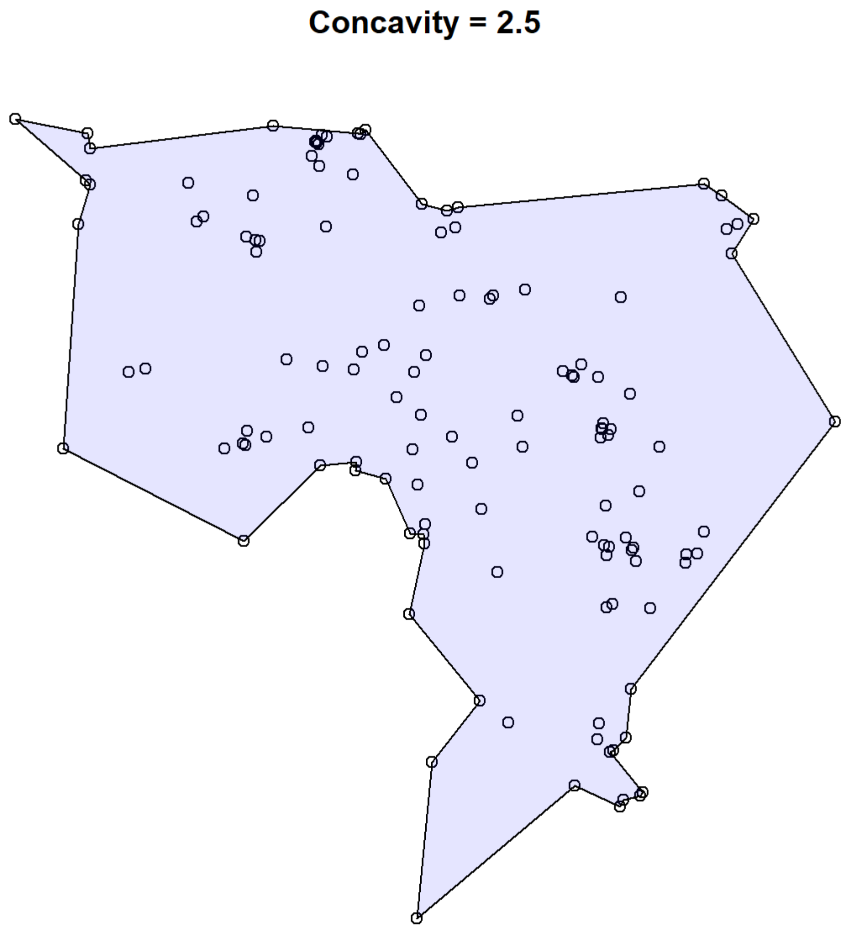
Concave Hull

- Related to convex hulls, but allows for concavity.
- Concavity controlled by a parameter.
- Implemented in package `concaveman` in R.
- Binary utilization distribution
  - Area is either home range or not, no probability/uncertainty



Concave Hull

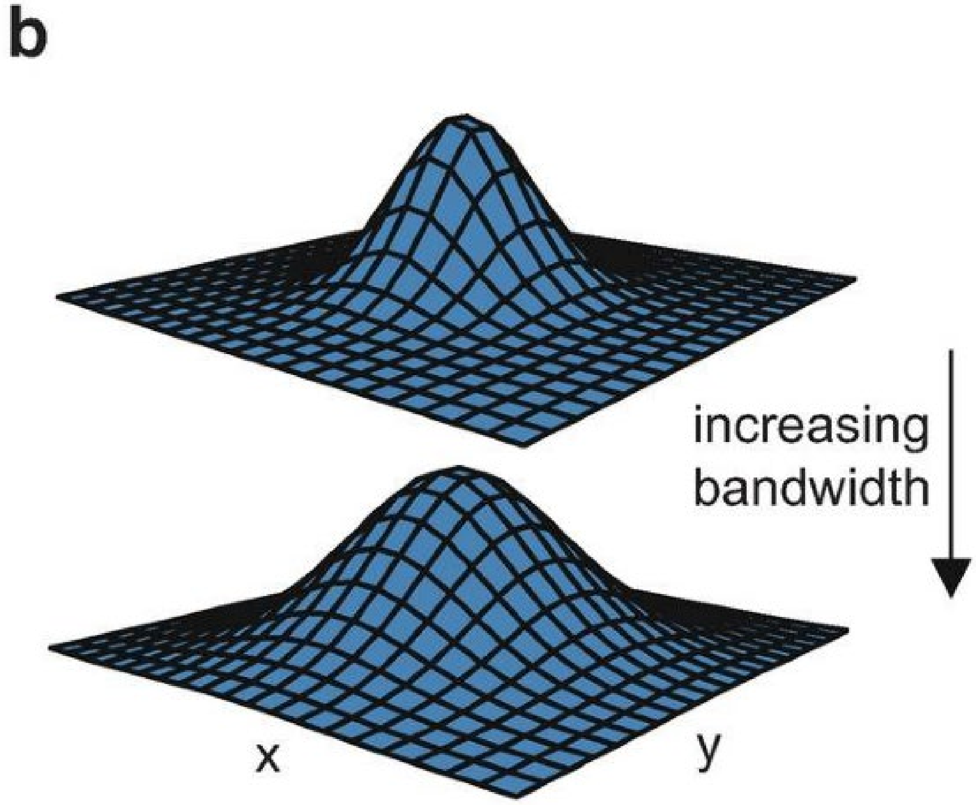




Kernel Density

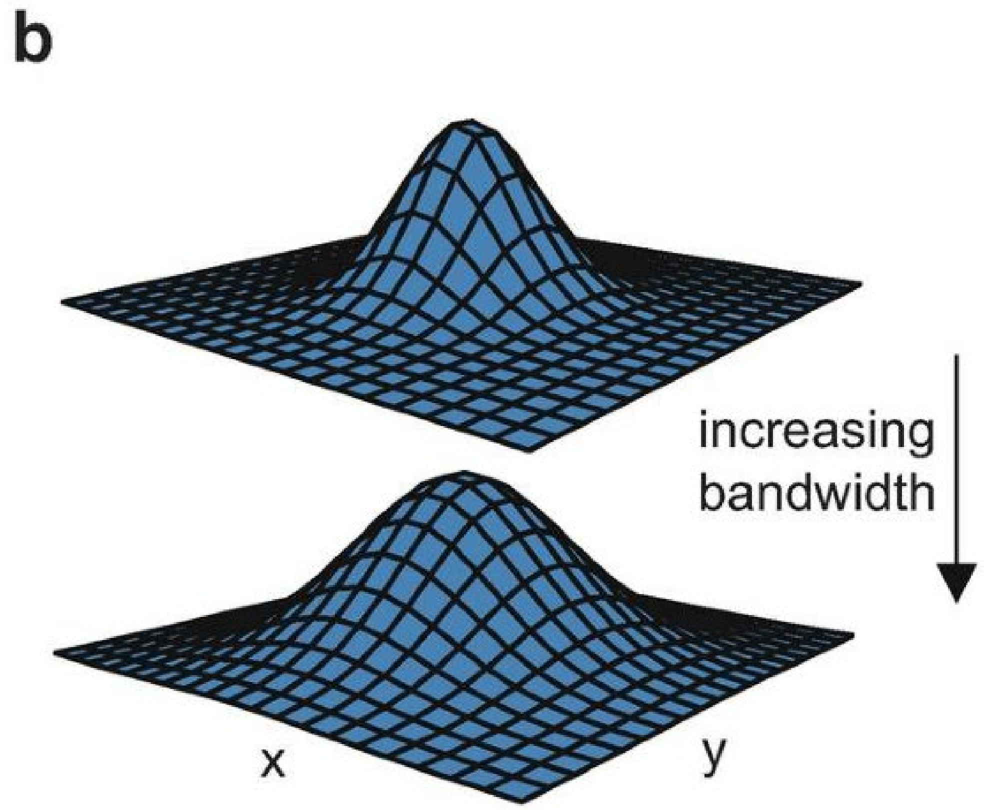
- Assumes that there is some probability of utilization in area surrounding known points.
- Kernel refers to the smoothed probability of occurrence surrounding point.
  - Often uses a bivariate normal, others are possible
  - High probability at point, decreases with distance.
- Overlays the kernel over all the known points and applies a smoothing altorithm

From Fig. 8.4 in F+F



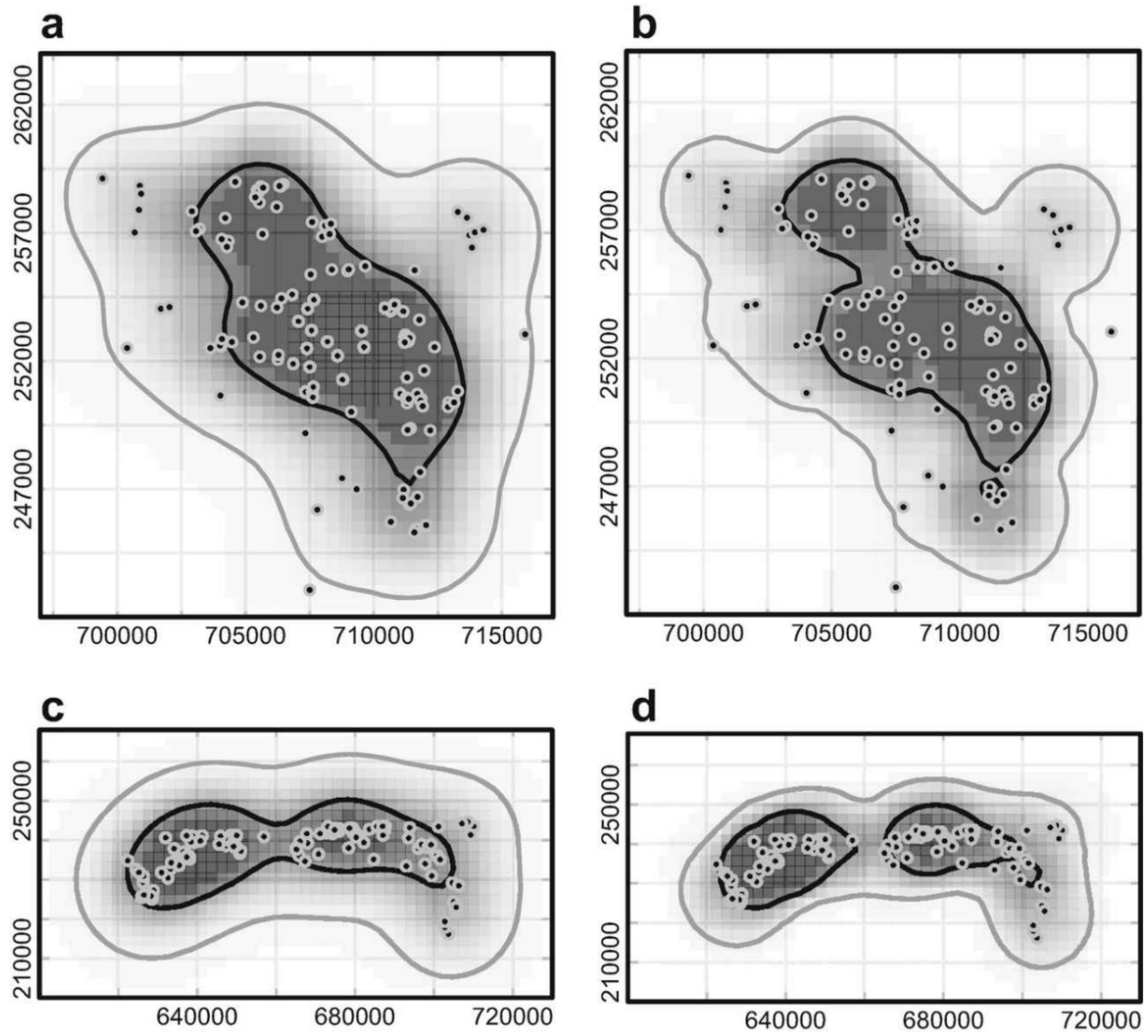
Kernel Density

- Like a 2-D smoothing of a histogram:
  - Height of density comes out of the page along the z-axis.
  - Regions with lots of points have high z-value
  - Sparse regions have low z-values
- Amount of smoothing: Bandwidth
  - You can use a default smoothing bandwidth.
  - You may use an ‘adaptive’ bandwidth which takes into account the number of points in the neighborhood.

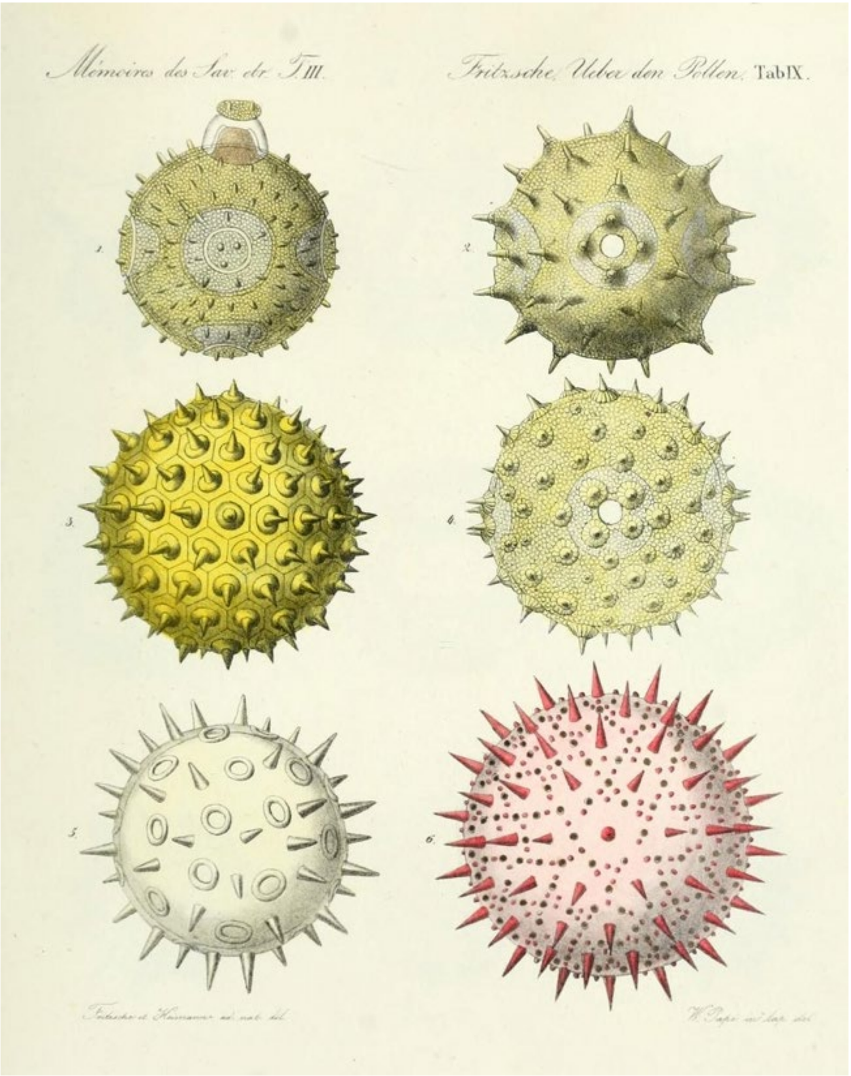


Kernel Density

- Unlike a hull-based approach, KDE gives a continuous estimate of the resource utilization distribution.
- From figure 8.9 in F+F



Brownian Motion



https://publicdomainreview.org/collection/pollen-up-close-1837

- Describes the random motion of a particle suspended in a fluid.
- Motion is a result of random collisions with other particles in the fluid
- Observed by botanist Robert Brown in 1827, contributed his name to the phenomenon. More fully described in a paper by Einstein in 1905.

The Brownian Bridge Model

- Describes the probabilistic path of an animal given a set of ordered, known locations in space.
- Between two known points, builds a probability surface of the possible Brownian motion paths the animal may have taken.
- Points are considered certain, intermediate paths incorporate uncertainty.
- Brownian motion (random walk) paths that begin and end at the known points.
  - Uncertainty is maximized at midpoints

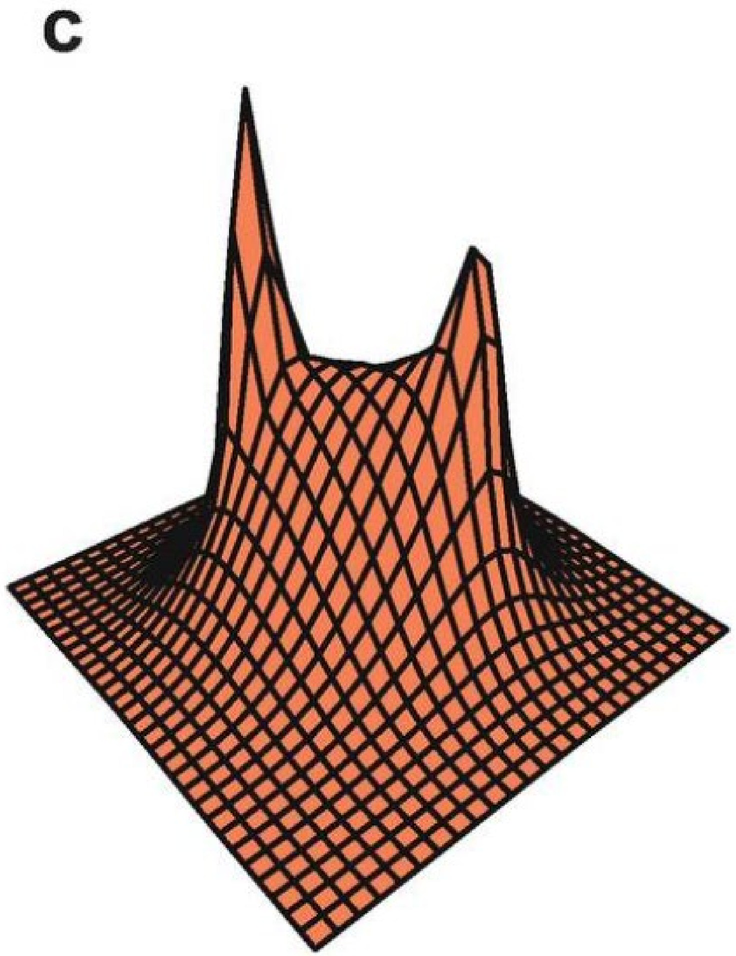
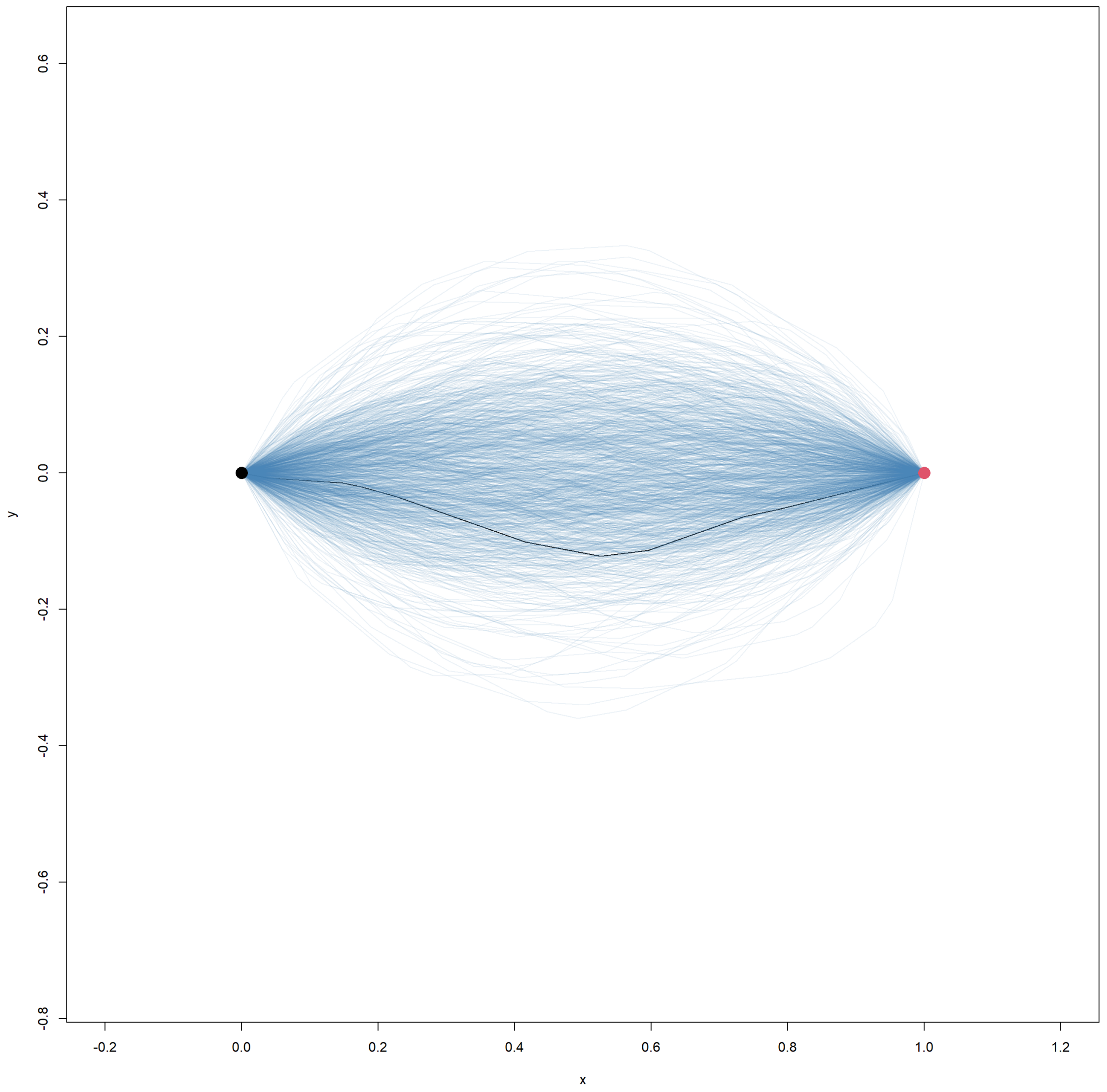


Figure 8.4 in F+F

Brownian Bridge

Brownian Bridge and Random Walks

- Based on properties of random walks, but not actually a simulation method.
- Random walks are simulations, but there's well-developed theory about their average (statistical) properties.
- B.B. uses theory of random walks to populate a probability surface.



Local Convex Hulls

- Related to minimum convex hulls.
- Creates a series of 'local' convex hulls using each point as a focus.
  - You decide the number of nearest neighbors to include in the hull
  - Radius-based methods also available
- Overall hull is the union of all the local hulls
- Larger number of nearest neighbors: more like the global convex hull.
- Fewer neighbors: greater concavity

Figure 8.10 in F+F