Integrating spatial models and cetacean satellite telemetry: Some recent approaches

Kristin Laidre (with Mark Baumgartner and Hawthorne Beyer)

Satellite telemetry data in a nutshell:

- Longitudinal
- Spatially and temporally autocorrelated
- Collected from a sample of individuals and expected to represent population-level behavior

Added bonus with *cetacean* data:

- Very low sample sizes (# of individuals)
- Few locations per day (per individual)
- Large variation in tag attachment durations (usually short)
- Bad location qualities

Today's talk: Two approaches using Argos data

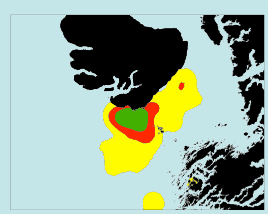
1. Estimation of functional space-use (Laidre and Beyer)
2. Estimation of habitat selection/avoidance (Baumgartner)

Understanding how animals make use of their environment and the consequences on fitness (survival and reproduction) is a central theme of ecology

- Identify core use areas → critical habitat
- Direct mitigation activities
- Improve population /PVA estimates
- Quantification of resource selection

Utilization distributions & home ranges

- widely used w/ data from telemetry studies
- estimate the true utilization distribution (i.e. relative space use) of an animal or group of animals



UD/HR estimators make implicit assumptions about animal distribution data.

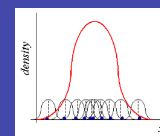
If those assumptions are invalid, what consequence does this have on our estimates?

Kernel Methods

Worton 1987, 1989

The probability density function, *f(x)*, can be estimated by:

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



Where:
K is a probability density function
n is the number of locations and
h is the smoothing factor

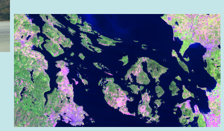
Kernels:
- uniform
- normal
- panechnikov
- biweight
- riweight
- quartic

Implicit assumption of all standard kernel methods is that straight-line distance between two points is an appropriate measure for weighting sampled locations.

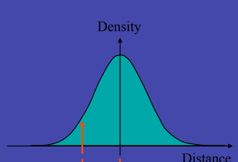
Validity?

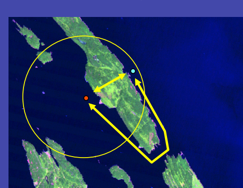
However, there are many circumstances in which this assumption is not valid!

- Absolute barriers to movement between two locations
- Render straight-line distance between locations meaningless from a biological perspective!



Functional distance instead?





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

Functional distance: the shortest distance between two locations given a set of barriers that cannot be crossed.

Algorithm in ArcGIS 9.0 calculates functional distance between two locations.

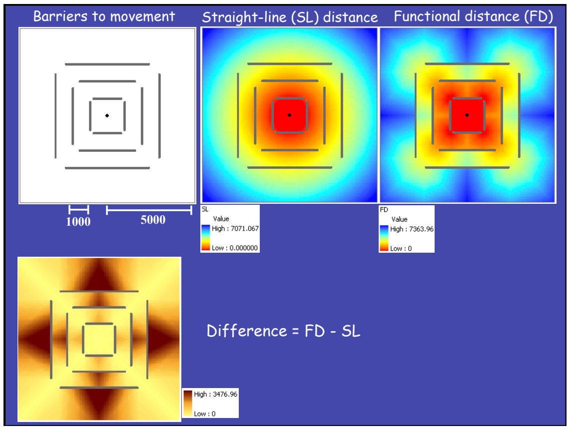
Barriers represented as a vector spatial dataset.

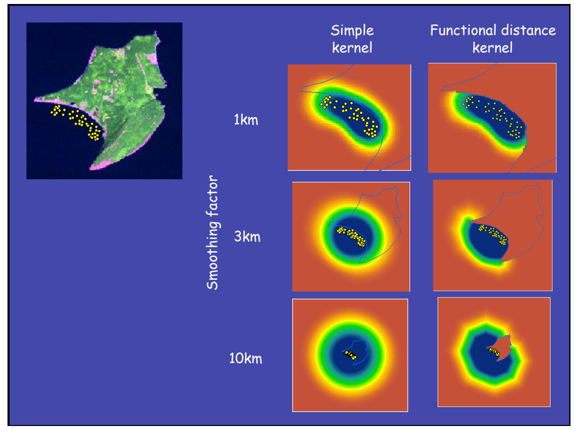
The result is a raster representing the functional distance from a given source location to the center of each grid cell.

Functional distance calculations integrated with kernel density estimates using the quartic approximation to a Gaussian probability density function.

$$\hat{f}_h(x) = \frac{3}{\pi nh^2}\sum_{i=1}^{n}\left(1-\left(\frac{x - X_i}{h}\right)^2\right)^2$$

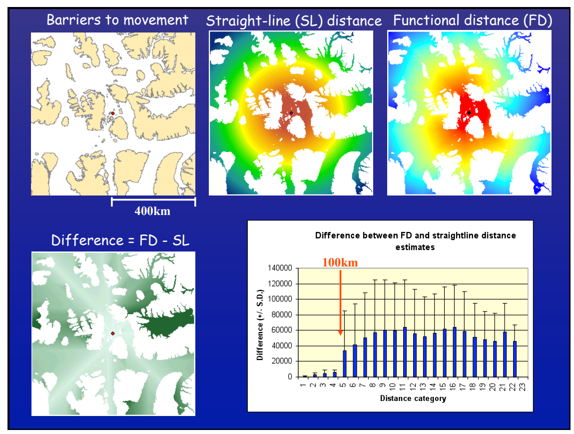
(Laidre and Beyer, unpubl.)





Short example: Narwhals on their summering grounds

- Need to estimate sub-population specific space-use
- Whales occupy coastal regions
- Highly complex fjord systems

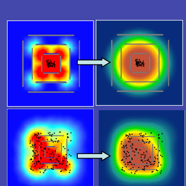


There can be a profound difference between straight-line distance and functional distance.

This difference is closely related to the scale and arrangement of barriers (and gaps).

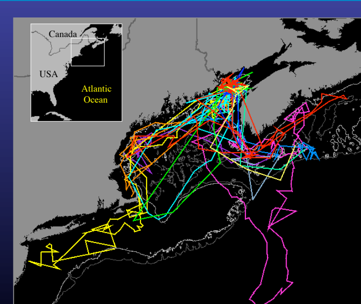
Functional distance appears to strongly affect kernel UD and HR estimates, especially if:

1. The smoothing factor is large relative to the scale of barriers (and gaps)
2. The points are not distributed evenly around the barriers



Point distribution	UD Estimate	95% HR Estimate
Even	Moderate	Good
Clumped	Poor	Poor

Satellite Tracking Right Whales



n = 18 right whales tagged for > 6 days during late summer

The Question

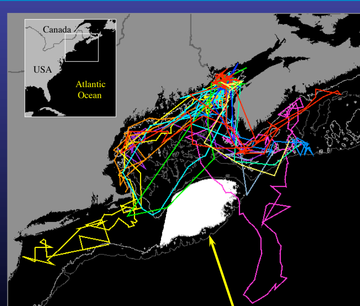
Given deployment durations, duty cycle and each whale's traveling speed, what are the chances that as many or more **locations** or **individuals** would have occurred in a particular region if the tagged animals had moved about at random?

Baumgartner, M.F. and B.R. Mate. 2005. Summer and fall habitat of North Atlantic right whales (*Eubalaena glacialis*) inferred from satellite telemetry. *Canadian Journal of Fisheries and Aquatic Sciences* 62:527-543.

Monte Carlo Test

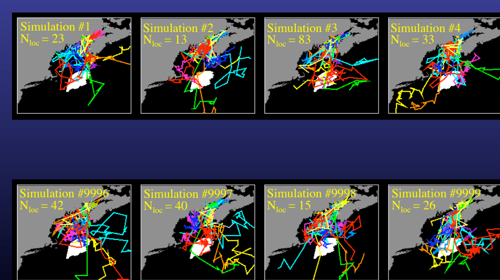
- Generate random tracks for whales
- Same **number of locations**, **start time**, **attachment duration** = ONLY **angle** changes
- Repeat 10,000 times to obtain a sampling distribution for each whale
- Compare observed number of locations and individuals to the sampling distributions
- Are 5% (or less) of values in sampling distribution as extreme as the observed value?

Monte Carlo Test Example

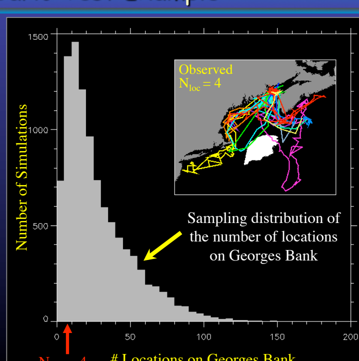


H_0: Right whales avoid Georges Bank.
Observed n=4 locations on Georges Bank. Is this evidence of avoidance?

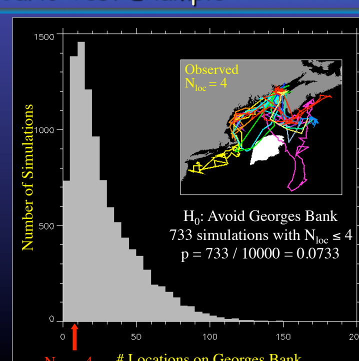
Monte Carlo Test Example



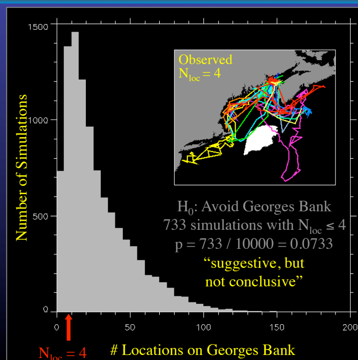
Monte Carlo Test Example



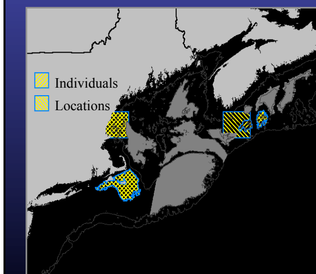
Monte Carlo Test Example



Monte Carlo Test Example



Monte Carlo Results: What to test for?

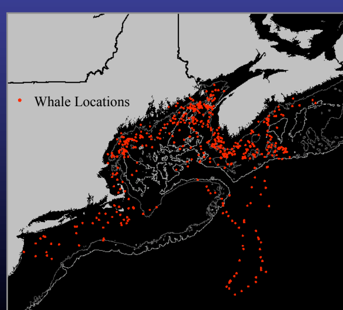


Are areas important to individuals? (i.e. a few individuals spent a lot of time in one region)

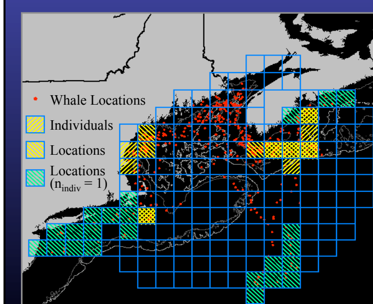
OR

Are areas important to the population? (i.e. most or many animals visited region regardless of how much time they spent there)

Monte Carlo Results



Monte Carlo Results

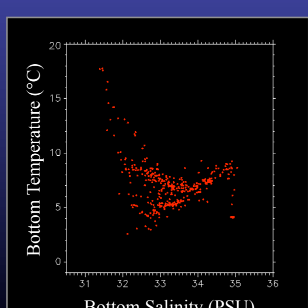


Instead of testing for a particular region, test in standardized 'boxes'.

Yellow – Significant

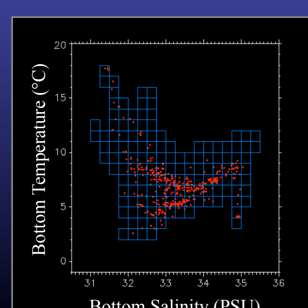
Blue- Significant but only due to behavior of one animal.

Monte Carlo Results



Each red dot – Argos location from a whale linked to salinity and bottom temperature

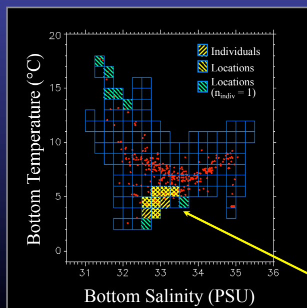
Monte Carlo Results



Same grid on top of the locations.

Create a sampling distribution from the number of dots in each box bound by min/max temperature and salinity values.

Monte Carlo Results



Right whales found in areas with cold bottom temperatures

In summary, two approaches presented

Functional distance kernels and Monte-Carlo simulations

Address assumptions 'imported' from the terrestrial world or inherent complexities with Argos data

Work well for cetaceans - but also other marine spp.!