Integrating the Identification and Sightings databases with spatial capture-recapture models to estimate right whale density and movement

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Estimates of abundance and an understanding of processes that drive its variation across space and time are critical to assessments of population status and risks. Spatial capture-recapture models combine elements of distance sampling and conventional capture-recapture models to estimate abundance and its variation across space (i.e., density). These models utilize information on the identities of detected individuals (e.g., from the NARWC Identification database) and on the locations of these detections and survey effort (e.g., from the Sightings database). Spatial capture-recapture models overcome limitations of alternative approaches to estimating abundance by relaxing the assumption that all animals on the survey line are detected, by explicitly defining the spatial extent for which abundance is estimated, by permitting the movement of individuals into and out of the survey area, and by formally accounting for heterogeneity in detection probabilities due to differences in the location of individuals relative to the location of survey effort. In addition to estimating abundance, these models can be used to understand the distribution of animals across space, movement patterns, how density varies with environmental covariates, and how population processes (movement, recruitment, survival) drive changes in abundance over time. We will present an overview of this modelling framework and how it integrates sighting locations, survey effort, individual identifications, and environmental data using aerial surveys in the southeastern US as a case example.

Integrating Identification and Sightings data with spatial capture-recapture models

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- **Abundance** estimates critical for assessments of **population status** and **risk**

- Understanding processes that drive its variation across **space** and **time** needed to project consequences of management actions

- Can’t count all whales, need estimates

Capture-recapture models

- Recaptures of identifiable individuals to estimate abundance
- Extensions to model variation across time: recruitment/survival[1], arrival/residency[2]

- Ignore **locations** of sightings and survey effort
  - No inference on spatial distribution
  - Area for estimate not defined
  - Ignore capture heterogeneity due to location of individuals relative to survey effort

[1]Pace et al. 2017
[2]Krzystan et al. 2018

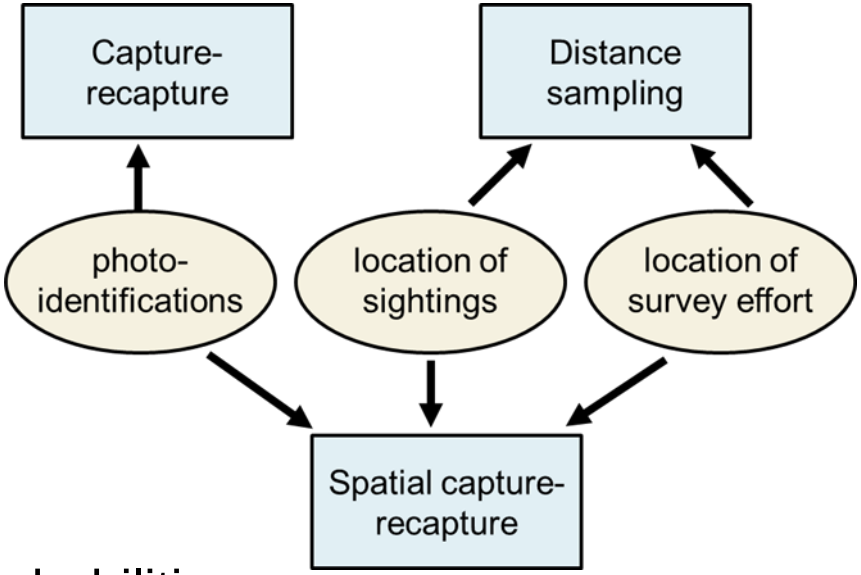
Distance sampling

- Considers location of animals relative to survey effort
- Extensions to model variation across space[3]

- Ignore **identifications** of individuals
  - Same individual may be sighted multiple times
  - Require detection on line to be 100%
    - Or ancillary data (tagging, double-observer surveys)
  - No inference on population dynamics (movement, survival)

[3]Roberts et al. 2016

Spatial capture-recapture models

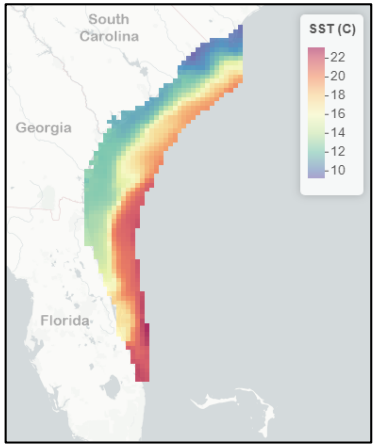


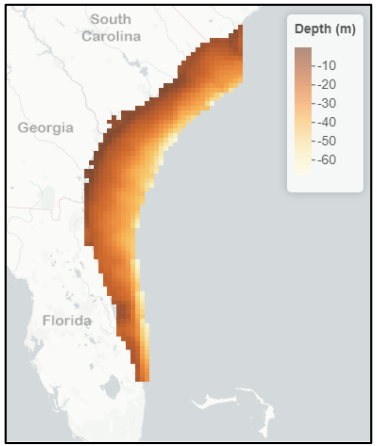
- Account for:
  - Spatial variation in density
  - Movement of individuals
  - Heterogeneity in capture probabilities

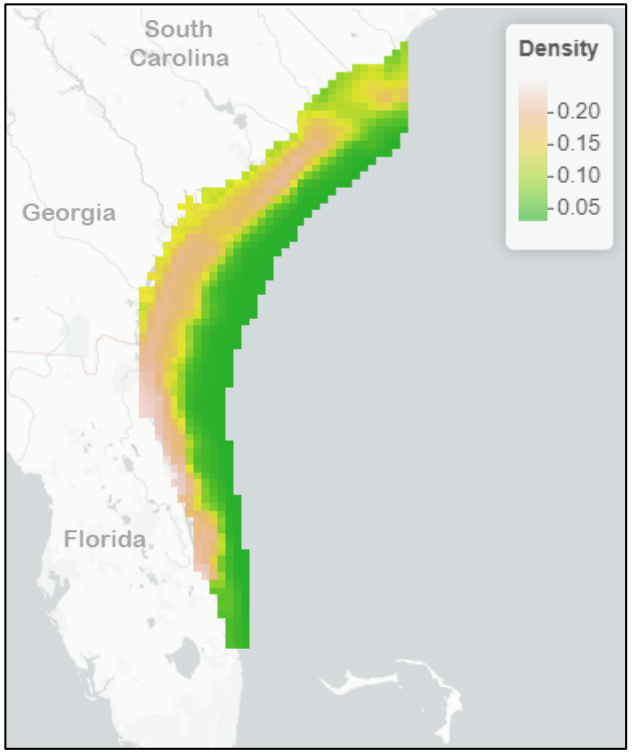
$$\text{Density}_g = e\text{^}(\boldsymbol{\beta_0} + \boldsymbol{\beta_1} sst_g + \boldsymbol{\beta_2} sst_g^2 + \boldsymbol{\beta_3} depth_g + \boldsymbol{\beta_4} depth_g^2)$$

$$\text{Abundance}_g = \text{Density}_g * \text{Area}_g$$

$$\text{Abundance}_{total} = \sum_{g=1}^{G} \text{Abundance}_g$$

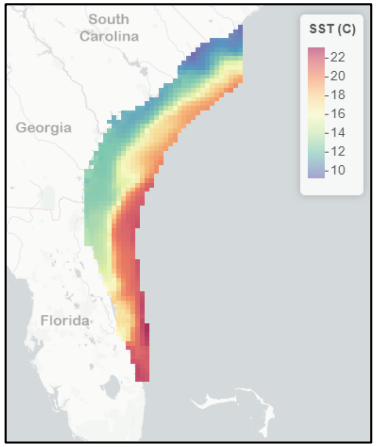


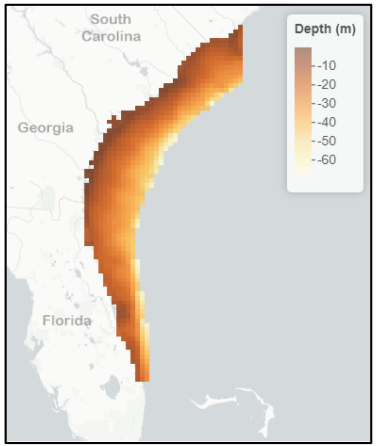


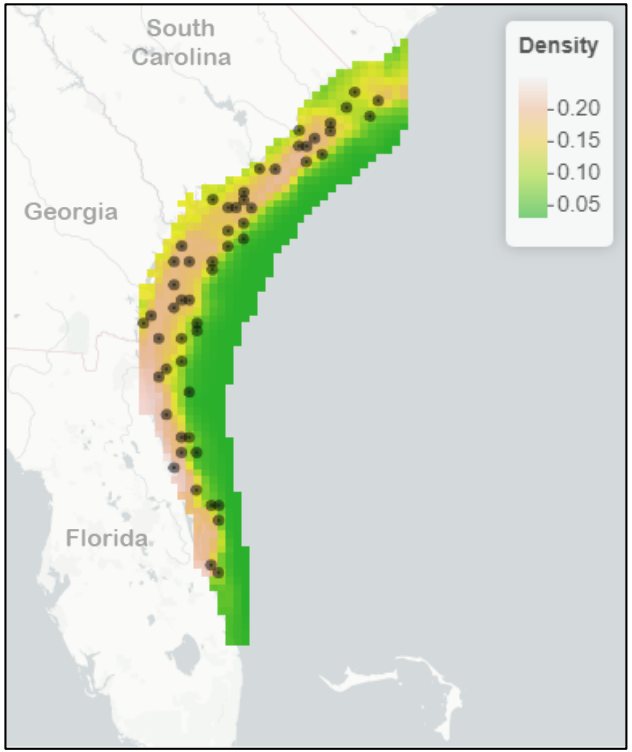


$$\pi_g = \frac{\text{Abundance}_g}{\text{Abundance}_{total}}$$

$$s \sim \text{Multinomial}(\text{Abundance}_{total}, \pi_1, \pi_2, \ldots, \pi_G)$$



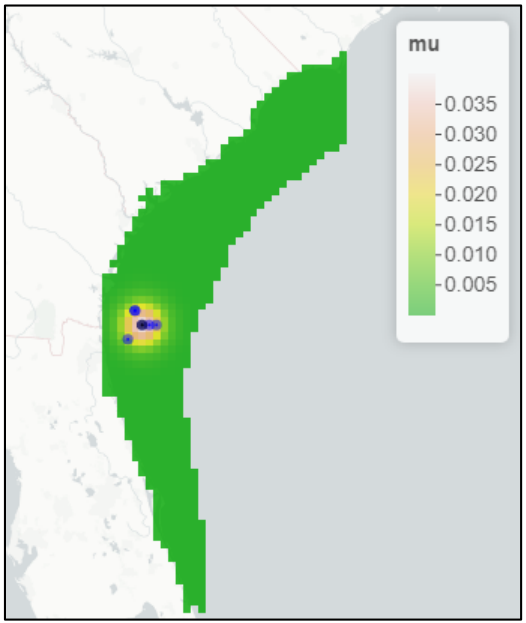




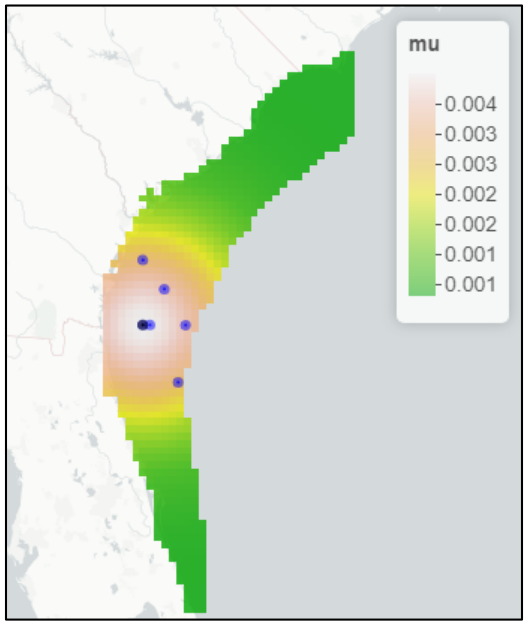
$$\mu_{i,g} = \frac{e\text{^}(-\boldsymbol{\alpha} dist_{g,s_i} + \boldsymbol{\beta_1} sst_g + \boldsymbol{\beta_2} sst_g^2 + \boldsymbol{\beta_3} depth_g + \boldsymbol{\beta_4} depth_g^2)}{\sum_{g=1}^{G} \mu_{i,g}}$$

$$U_i \sim \text{Multinomial}(\text{T}, \mu_{i,1}, \mu_{i,2}, \ldots, \mu_{i,G})$$

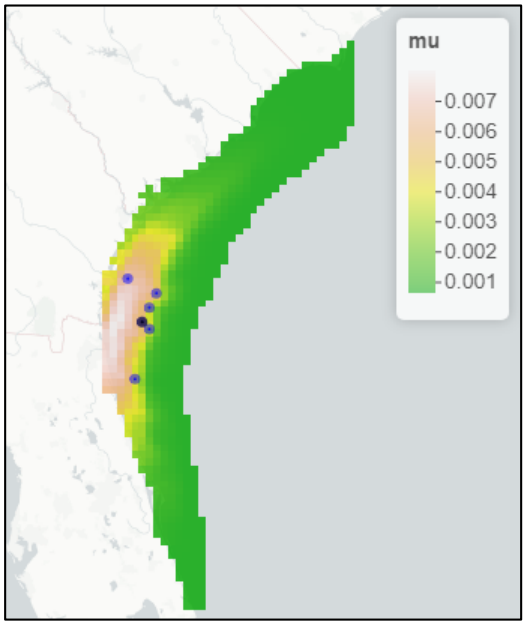
large $\boldsymbol{\alpha}$,
high fidelity



small $\boldsymbol{\alpha}$,
low fidelity

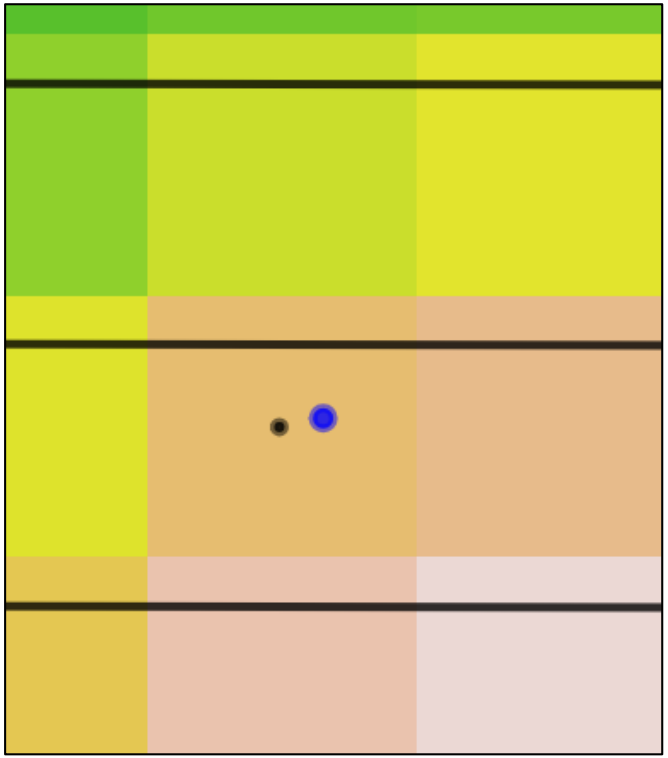


other covariates,
resource selection



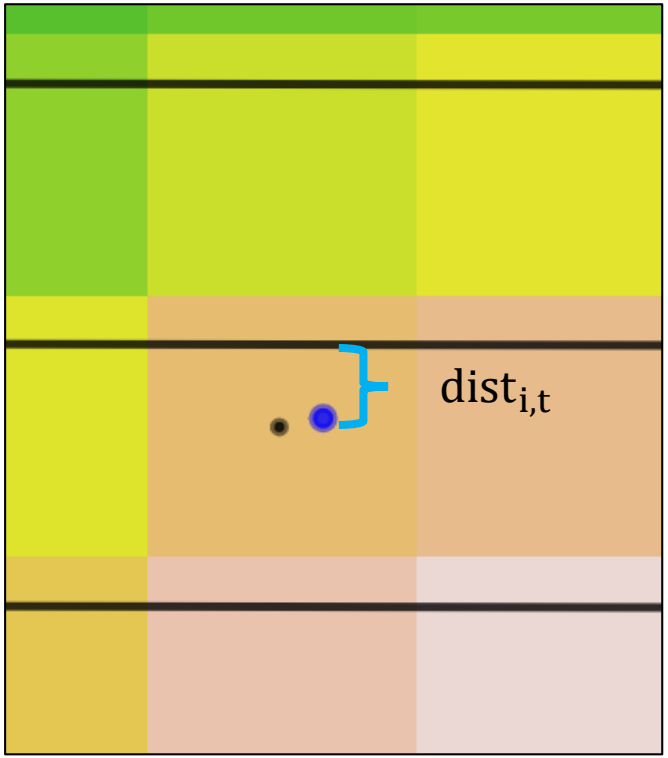
$$U_{i,t,x} \sim \text{Uniform}(-\frac{\text{side}}{2}, \frac{\text{side}}{2})$$

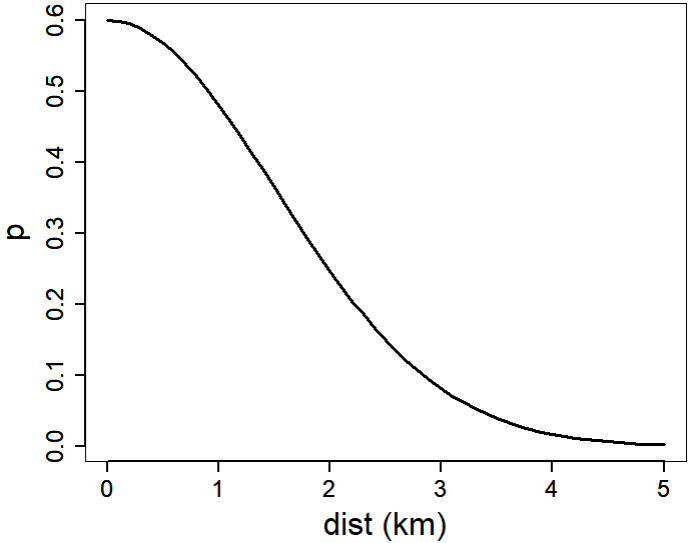
$$U_{i,t,y} \sim \text{Uniform}(-\frac{\text{side}}{2}, \frac{\text{side}}{2})$$



$$p_{i,t} = \boldsymbol{p_0}\, e\text{^}\left(-\frac{1}{2\boldsymbol{\sigma}^2}\, dist_{i,t}^2\right)$$

$$y_{i,t} \sim \text{Bernoulli}(p_{i,t})$$





Detected (yes/no)

CatalogID	16-Jan	18-Jan	19-Jan	20-Jan	22-Jan
3123	1	0	0	0	0
2614	1	0	1	1	0
3790	0	1	1	0	0
3260	0	1	0	1	0
…					

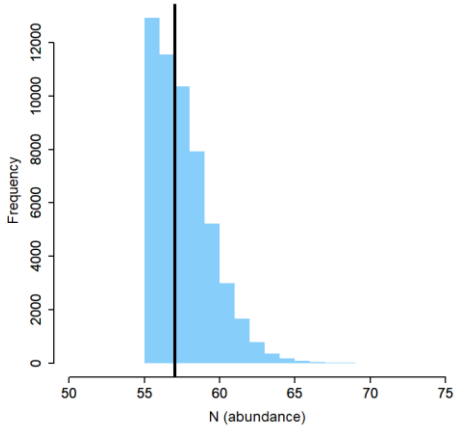
Longitude

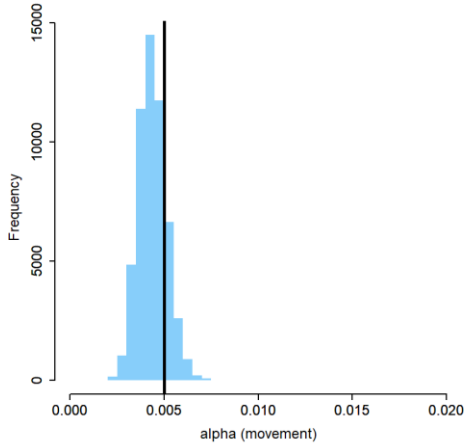
CatalogID	16-Jan	18-Jan	19-Jan	20-Jan	22-Jan
3123	-81.321	NA	NA	NA	NA
2614	-81.302	NA	-81.306	-81.200	NA
3790	NA	-81.133	-80.970	NA	NA
3260	NA	-80.926	NA	-81.200	NA
…					

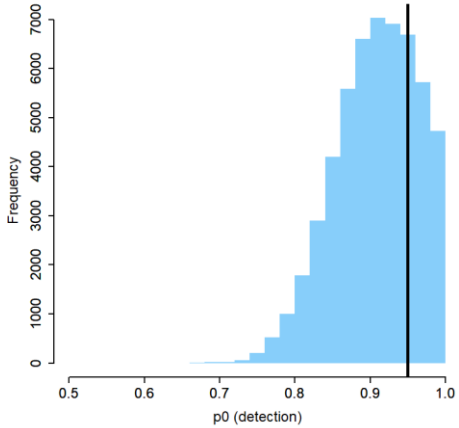
Latitude

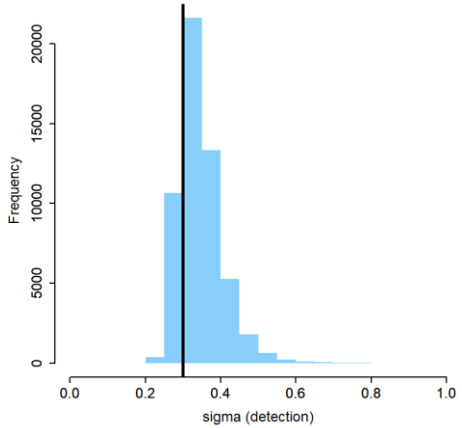
CatalogID	16-Jan	18-Jan	19-Jan	20-Jan	22-Jan
3123	30.573	NA	NA	NA	NA
2614	30.618	NA	30.638	30.534	NA
3790	NA	30.675	30.970	NA	NA
3260	NA	31.176	NA	30.534	NA
…					

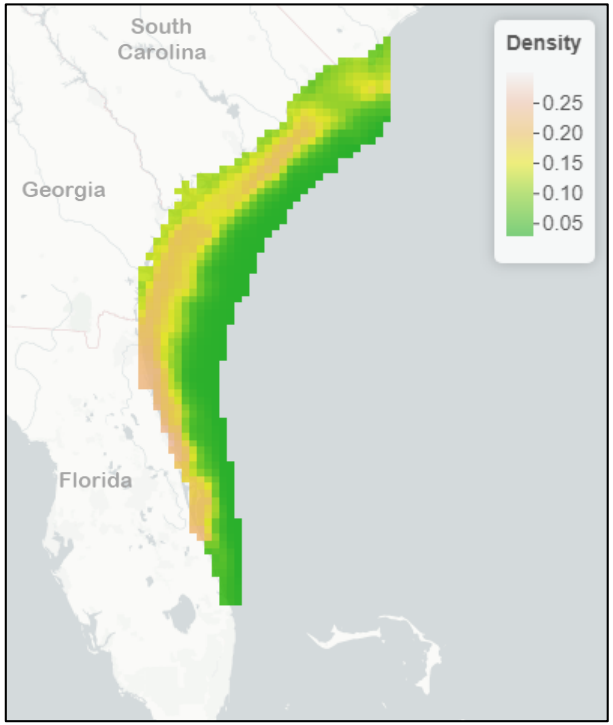
true, simulating value
vs.
model posterior estimate



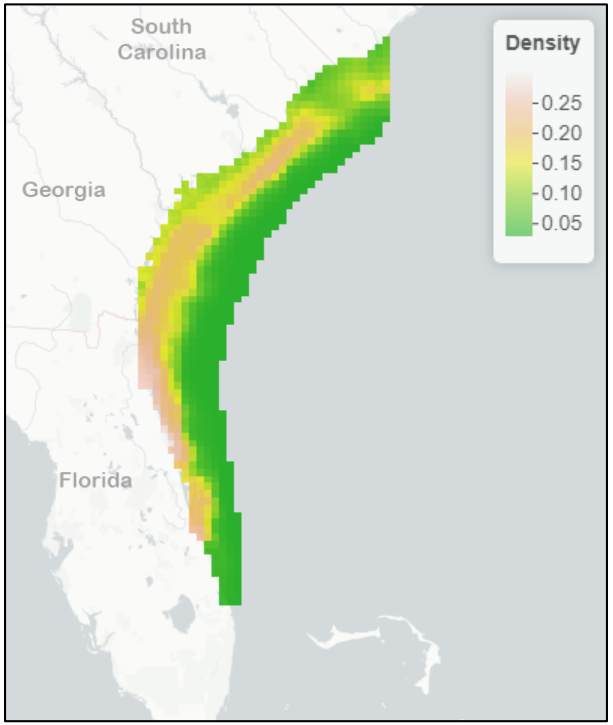




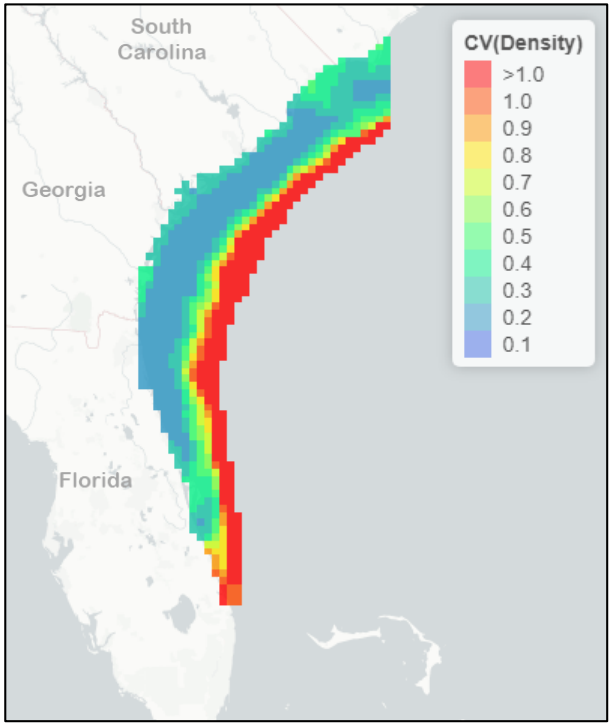




simulated density



estimated density



CV(density)

Future Work

- Different detection functions for different platforms
- Different detection/movement for calving females
- Effect of group size on detection
  - What influences group size?
- Extend to open model
  - Number/location of activity centers in area varies over time
  - Tradeoff between number of recaptures and closure assumption
- Coast-wide analysis
  - Spatial/temporal resolution vs. computation time
  - Movement processes within region vs. between regions
  - Different habitat covariates in different regions
    - Extrapolation depends on habitat covariates

Acknowledgements

- Royle JA, Chandler RB, Sollmann R, Gardner B (2013) *Spatial capture-recapture*. Academic Press.

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