Estimating Spatial Distribution and Abundance of Florida Panthers Using Camera Traps and Telemetry

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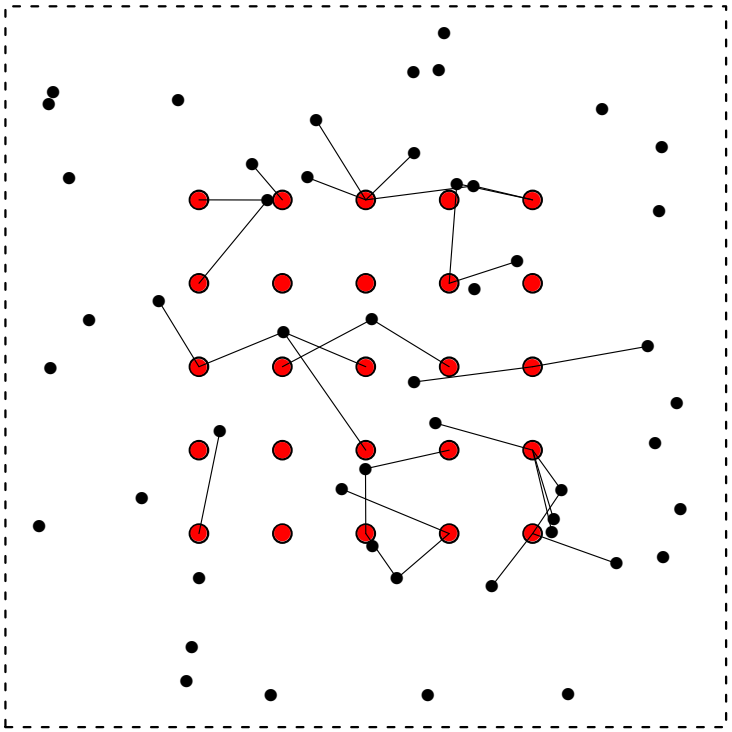
Camera Trap Surveys
(of elusive, low-density, or wide-ranging species)



Sampling design is crucial

- movement of individuals should ensure detection at multiple locations
- design should induce differential exposure of individuals to detection

Spatially Explicit Modeling of Camera-trap Survey Data

Marked

Partially marked

Unmarked

Components of Spatially Explicit Models

Ecological process - location of each individual's activity center

- Habitat and other spatial covariates
- Seasonality or time-dependence
  (dynamic models of directed movements, mortalities, births)

Observational process - detection of each individual at camera locations

- Distance between camera and individual activity center
- Sex-specific differences in extent of movement
- Selection/usage of locations by individuals (e.g., proximity of camera to roads/trails)
- Time-specific periods of an individual's movements
- Continuous period of camera's operation

Modeling Detections of Marked Individuals

Data

- T_k = period of operation of camera trap k $(k = 1, \ldots, K)$
- $\boldsymbol{x}_k$ = location of trap k
- y_{ik} = number of detections of individual i at trap k $(i = 1, \ldots, n)$
- $\boldsymbol{t}_{ik}$ = detection times of individual i at trap k

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- $\boldsymbol{v}(\boldsymbol{s})$ = spatial covariates of individual density at location $\boldsymbol{s} \in B$
- $\boldsymbol{w}_k$ = spatial covariates of encounter rate at trap k
- $\boldsymbol{z}(t_k)$ = temporal covariates of encounter rate at time $t_k \in (0, T_k]$

Modeling Detections of Marked Individuals

Ecological process

Spatial distribution and abundance of individual activity centers follows a Poisson process with intensity

$$\lambda(\boldsymbol{s}) = \exp(\boldsymbol{\beta}'\boldsymbol{v}(\boldsymbol{s}))$$

Observational process

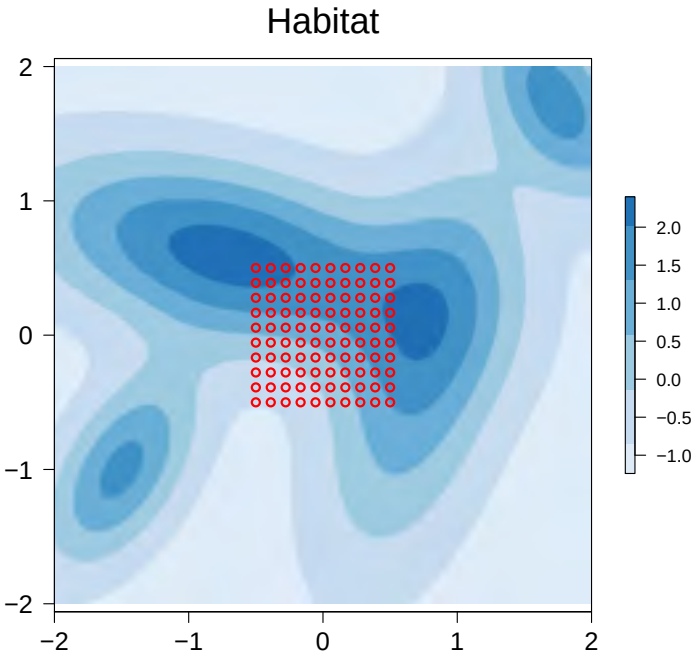
Temporal distribution and frequency of detections follows a Poisson process with intensity

$$\phi(t_k, \boldsymbol{s}, \boldsymbol{x}_k) = \psi_k \, \gamma(t_k) \, \exp(-||\boldsymbol{s} - \boldsymbol{x}_k||^2/(2\sigma^2))$$

where

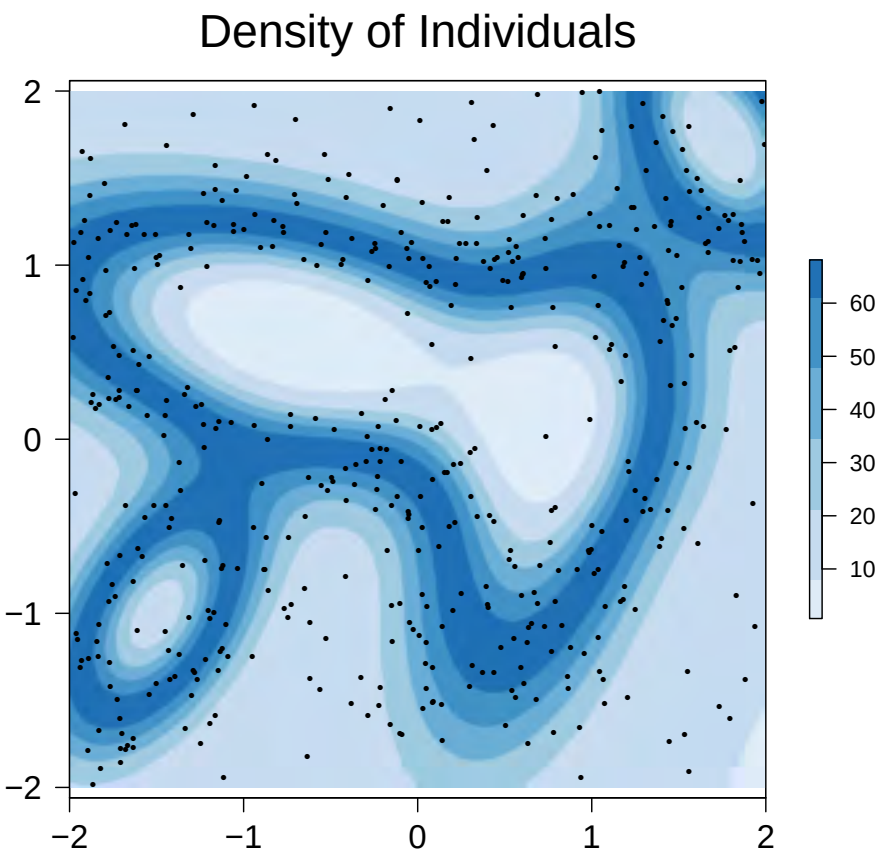
- $\psi_k = \exp(\boldsymbol{\alpha}'\boldsymbol{w}_k)$
- $\gamma(t_k) = \exp(\boldsymbol{\xi}'\boldsymbol{z}(t_k))$

Simulated Habitat and Camera-trap Surveys



- $\log(\lambda) = \log(64) + 0.5v - 1.0v^2$
- $\sigma = 0.4$
- $\log(\psi) = \log(0.1) + 1.0w$
- $\xi = -1.0$
- $T_{nite} = T_{day} = 22$

Simulated Density, Activity Centers, and Detections



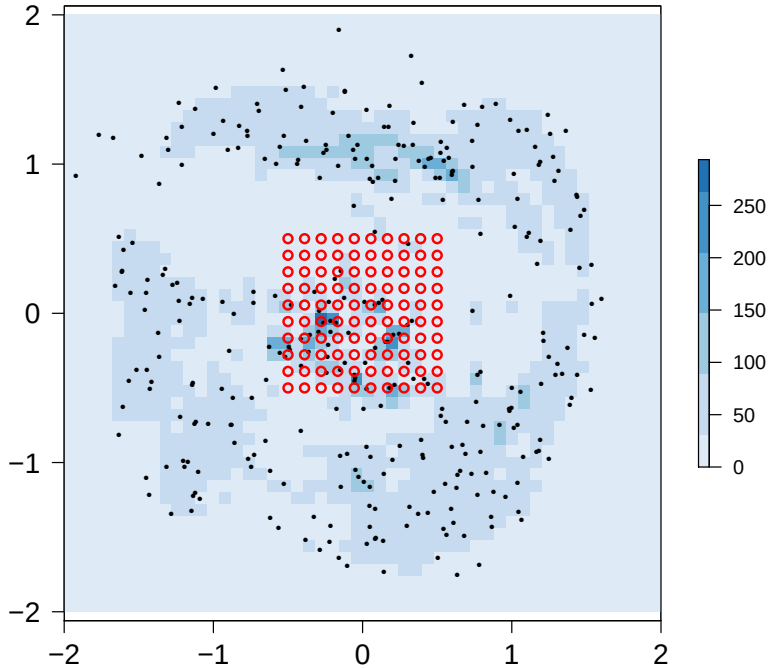
- $N = 504$
- $n = 336$
- $y_{\cdot\cdot} = 17,014$

Comparison of Parameter Values

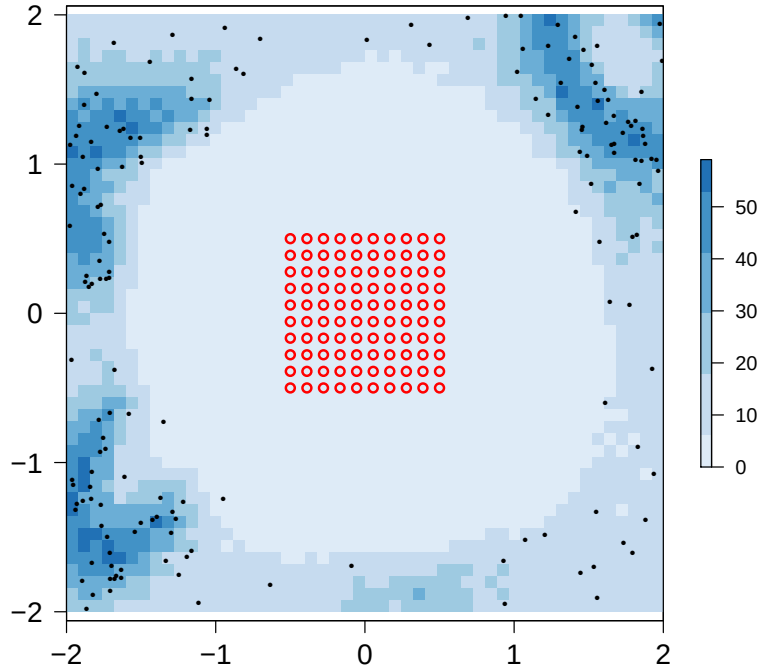
	True	Mean	2.5%	97.5%
σ	0.40	0.40	0.40	0.41
ξ	-1.00	-0.98	-1.02	-0.94
α_0	-2.30	-2.32	-2.35	-2.30
α_1	1.00	1.00	0.99	1.02
β_0	4.16	4.06	3.91	4.21
β_1	0.50	0.33	0.10	0.60
β_2	-1.00	-0.83	-1.06	-0.60

Maps of Estimated Densities

Estimated Density of Detected Individuals

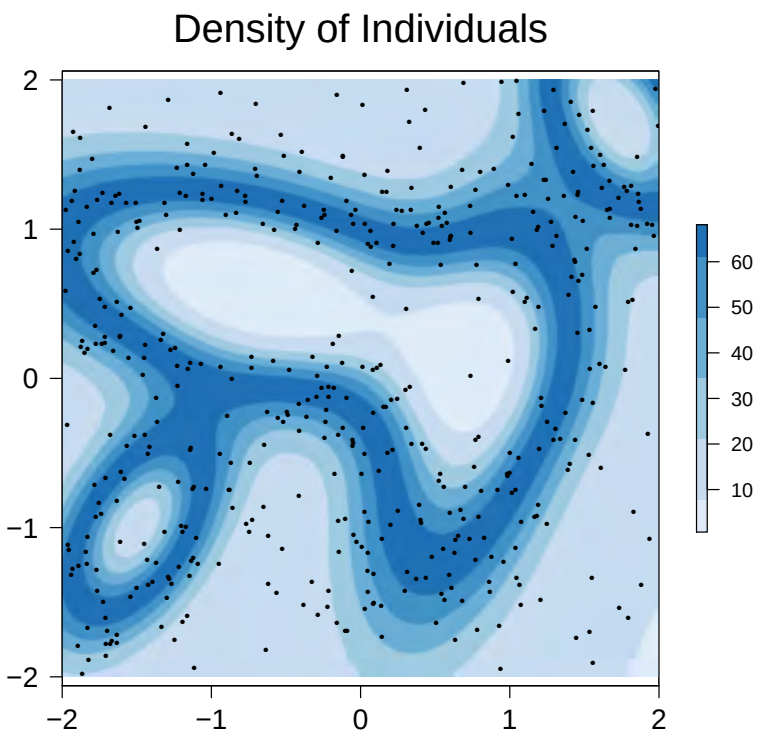


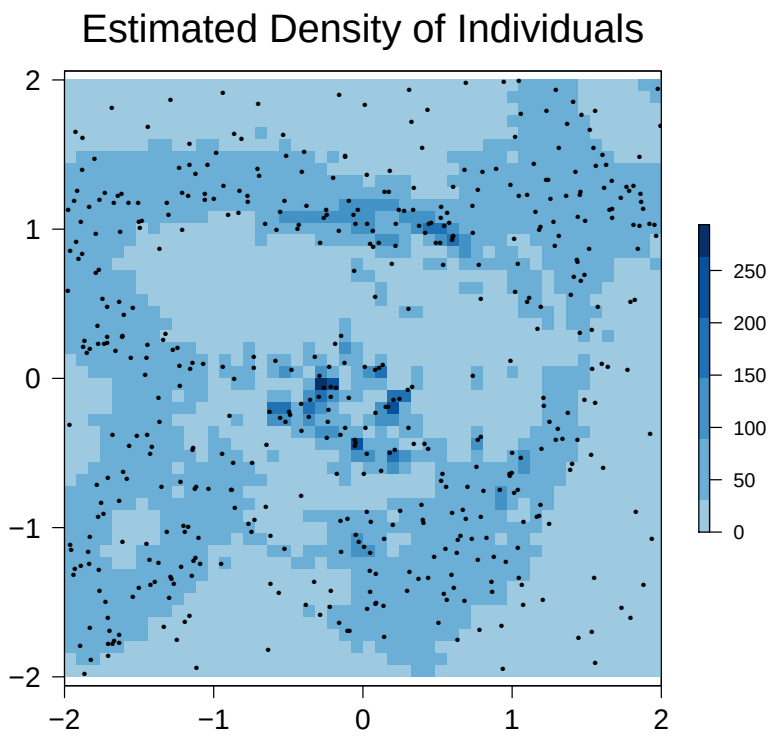
Estimated Density of Undetected Individuals



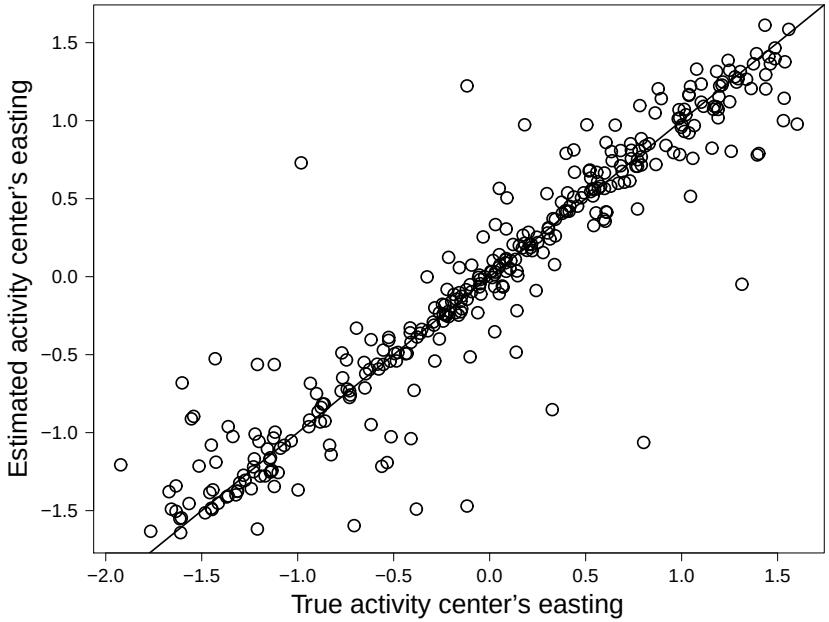
Comparison of True and Estimated Densities

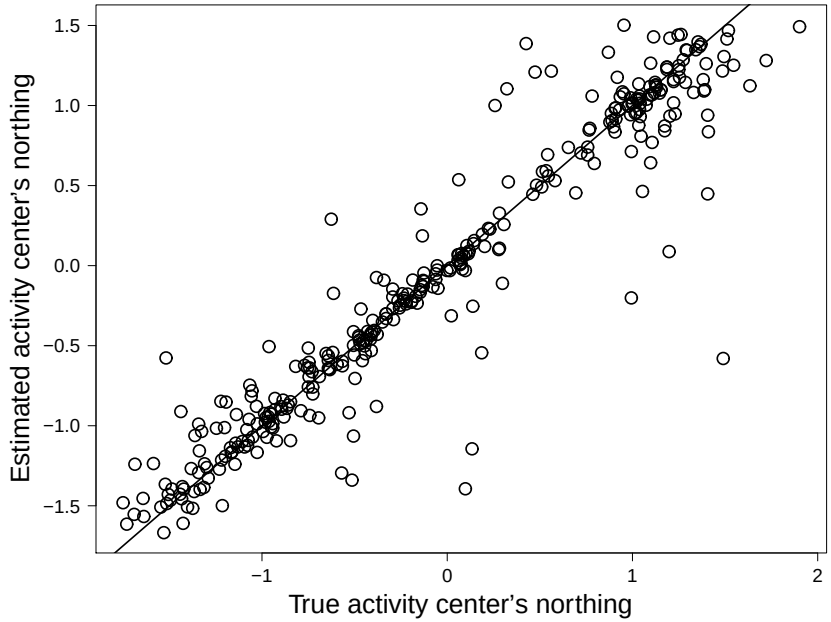
$N = 504, \quad \hat{N} = 516$ (95% CI: 479–556)



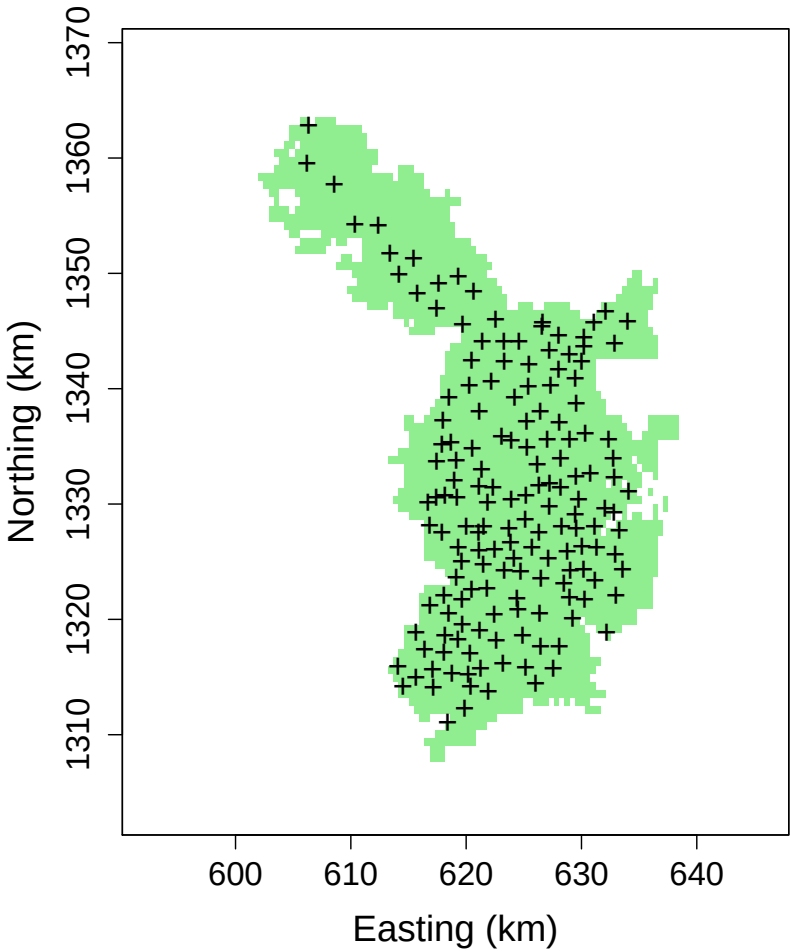


Comparison of True and Estimated Activity Centers of Detected Individuals



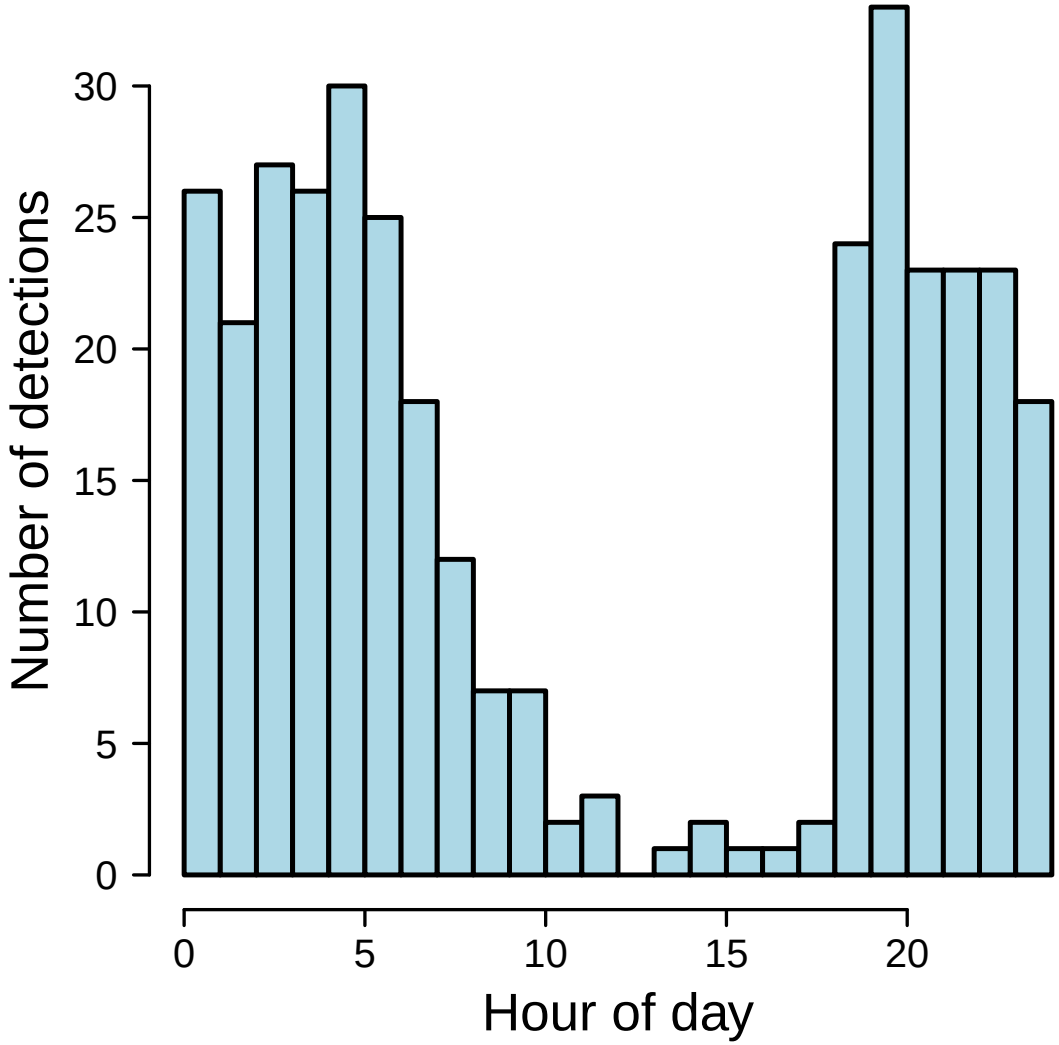


Camera-trap Survey of Tigers in Nagarahole National Park, India (Nov 2014 – Jan 2015)



- Area $= 862$ km^2
- $K = 162$ cameras
- $\bar{T}_{nite} = 23.4$ days
- $\bar{T}_{day} = 21.2$ days
- $n = 86$ tigers
- $y_{\cdot\cdot} = 355$ detections

Hourly Variation in Detections of Tigers

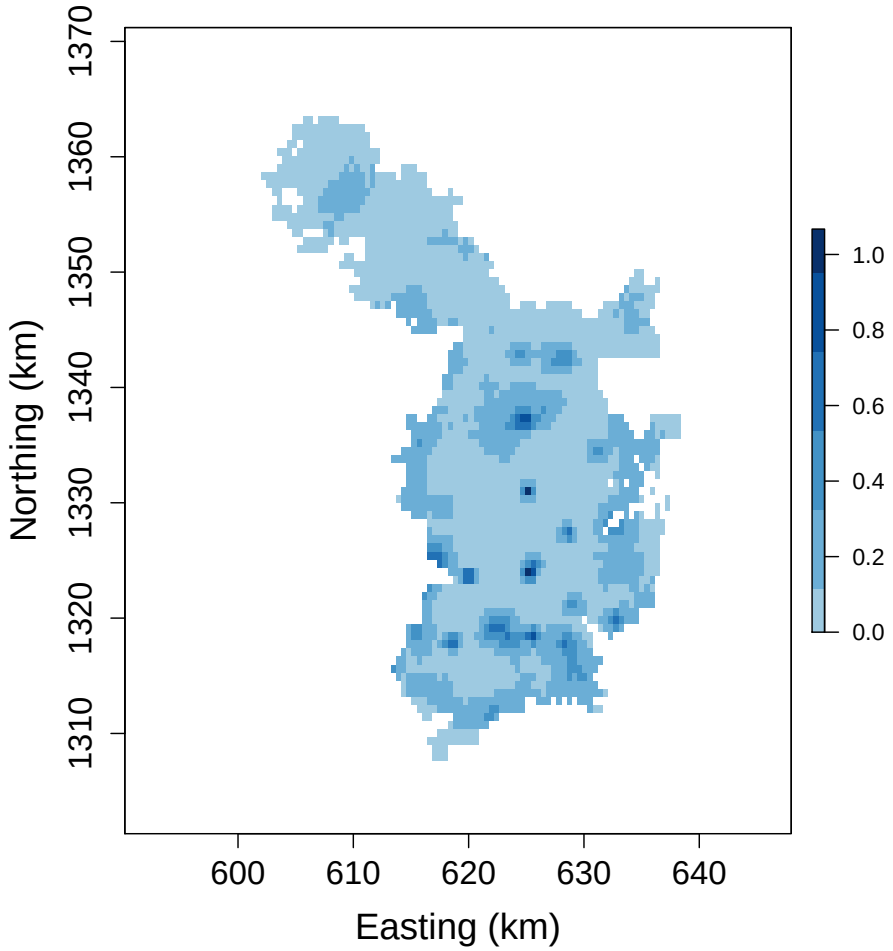


Estimates of Model Parameters

	Mean	2.5%	97.5%
σ	1.71	1.60	1.83
ξ	-1.67	-1.96	-1.38
α_0	-3.09	-3.27	-2.92
β_0	-2.20	-2.43	-1.99

- Baseline encounter rate during night time = 0.046 detections / day
- Baseline encounter rate during day time = 0.009 detections / day
- Density of individuals = 0.11 tigers / km^2

Estimated Density of Tigers in Nagarahole National Park, India ($\hat{\lambda} = 0.11$ tigers km^{-2}, $\hat{N} = 88.6$ tigers)



Modeling Detections of Unmarked Individuals

Data

- T_k = period of operation of camera trap k $(k = 1, \ldots, K)$
- $\boldsymbol{x}_k$ = location of trap k
- $y_{\bullet k}$ = number of detections at trap k

	Camera trap				
indiv i	1	2	3	$\cdots$	K
1	y_{11}	y_{12}	y_{13}	$\cdots$	y_{1K}
2	y_{21}	y_{22}	y_{23}	$\cdots$	y_{2K}
3	y_{31}	y_{32}	y_{33}	$\cdots$	y_{3K}
4	y_{41}	y_{42}	y_{43}	$\cdots$	y_{4K}
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
n	y_{n1}	y_{n2}	y_{n3}	$\cdots$	y_{nK}
$n+1$	0	0	0	0	0
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
N	0	0	0	0	0

Modeling Detections of Unmarked Florida Panthers

Data needs

- Spatial shape files of region occupied by panthers
- Camera trap location and period of operation
- Date and time of each detection of unmarked panthers
- Date, time and identity of each detection of panthers bearing a collar
- Spatial shape files of panther habitat covariates
- Trap-specific covariates of encounter rate
- Temporal covariates of encounter rate

Acknowledgments

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