Cluster Spatial Capture-Recapture Models for Autonomous Recording Units

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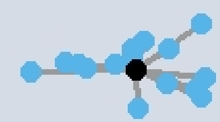
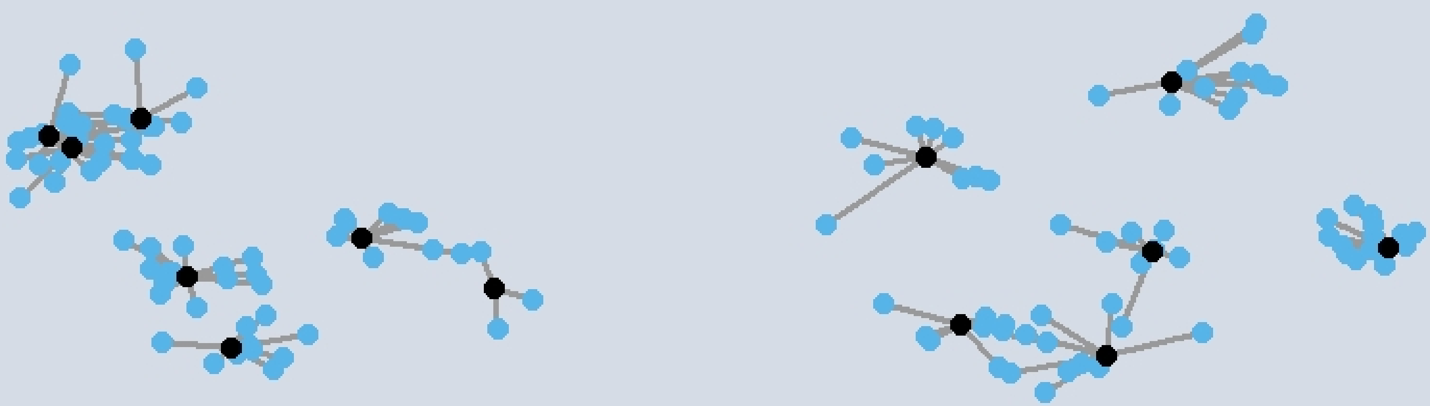




Autonomous Recording Units (ARUs)

- Many species difficult to monitor using cameras or DNA, but easy to hear

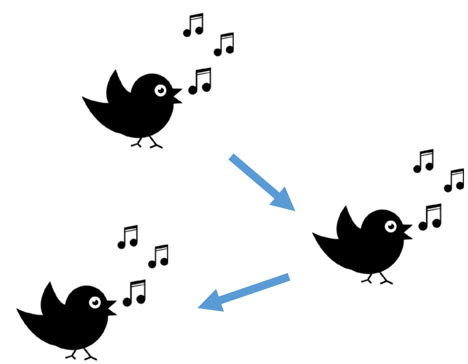
- ARU Data
  - Species-classified detections
  - Individual-classified detections
    - Limited by species/technology
- ARU Analyses
  - Occupancy
  - Density (limited)
    - Distance Sampling
    - Spatial capture-recapture (SCR)

SCR ARU Density Estimation – Challenges

- Variable Individual Identity
    - Known
    - Unknown
    - Partial

- Call spatial dependence
    - Individual calls clustered in space
    - Stationary and mobile calling
    - Informative of individual ID

- Unknown individual call rate



SCR ARU Density Estimation – Challenges

- Partial individual identity
    - Individual ID can be obtained from call spectrograms
    - Spectrogram features can be treated as partial identities
    - Can we exploit to inform individual ID?

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RESEARCH ARTICLE

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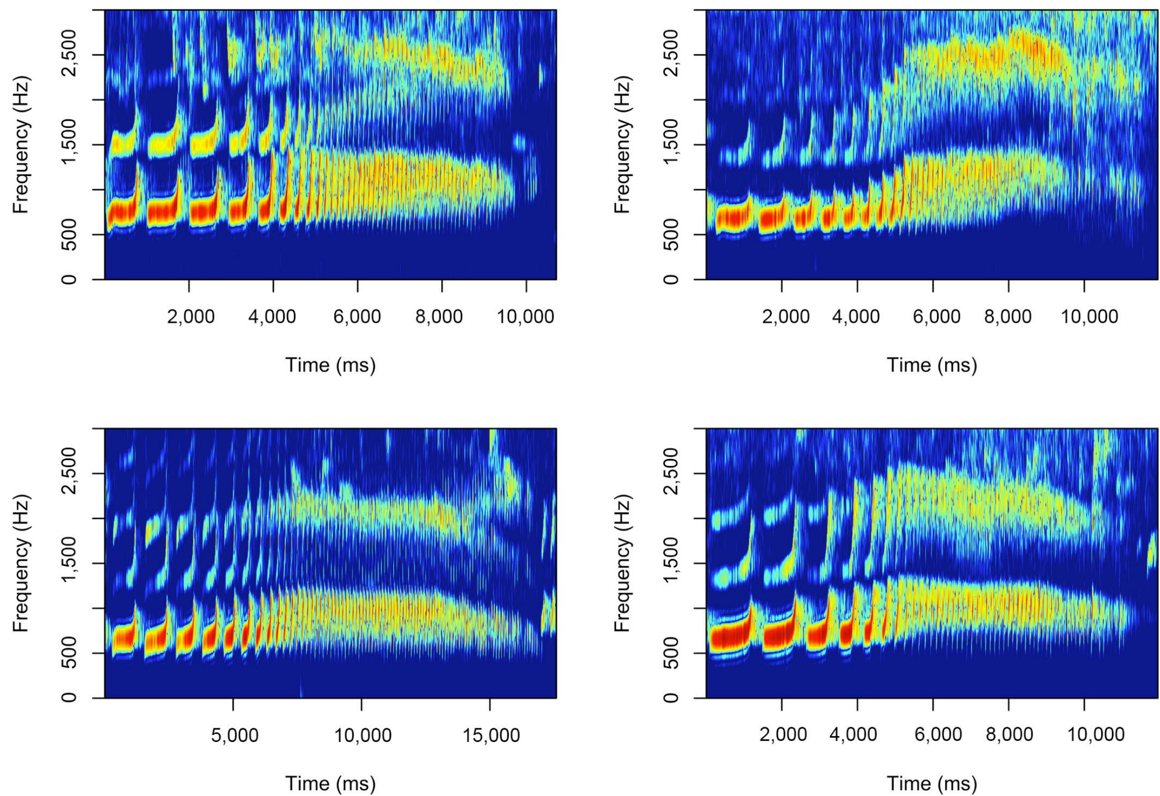
Unsupervised acoustic classification of individual gibbon females and the implications for passive acoustic monitoring

Dena J. Clink | Holger Klinck



SCR ARU Density Estimation – Current Solutions

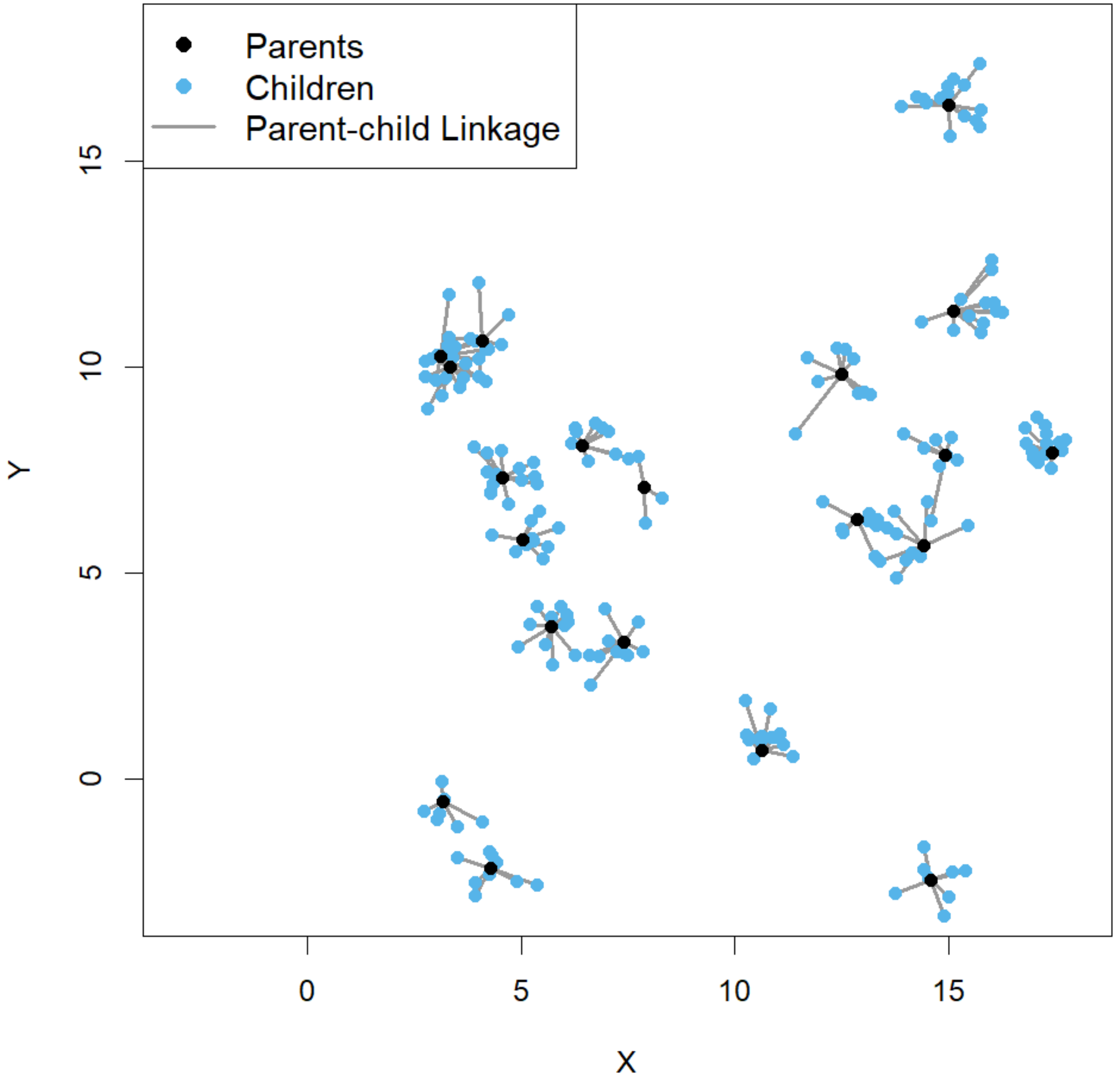
	Known ID	Unknown ID	Partial ID
Stationary Callers	Stevenson et al. (2021) Estimate call rate from detection data	Stevenson et al. (2015) Requires call rate estimate Does not use spatial info to inform ID	NA
Mobile Callers	NA	NA	NA

- Objective: Develop models and estimation algorithms for these scenarios

Cluster SCR – Model Structure

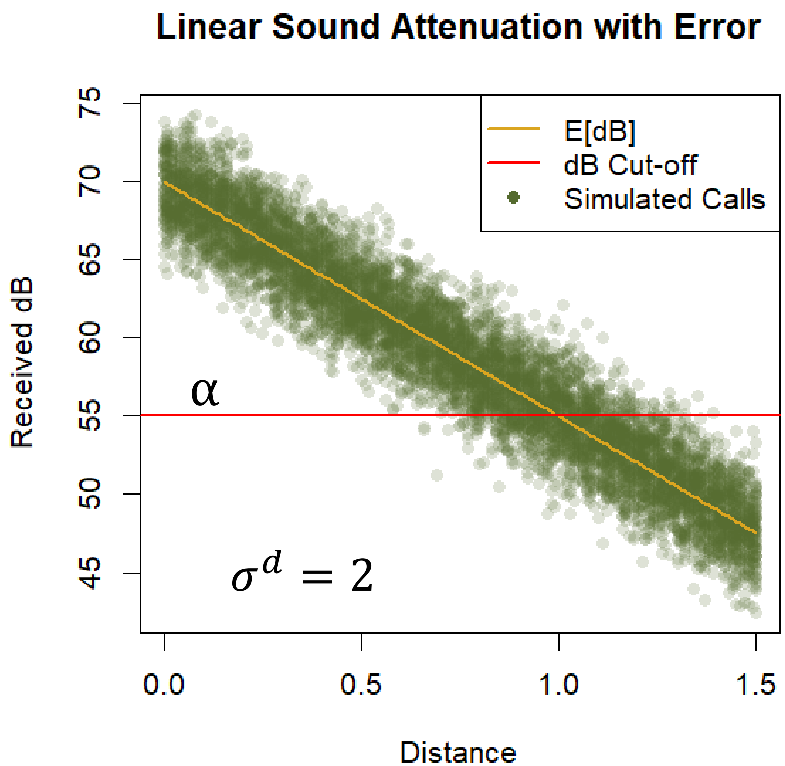
- Abundance
  - $N \sim \text{Binomial}(\psi, M)$
- Individual activity centers
  - $s_i \sim \text{Uniform}(\mathcal{S})$
- Cluster size
  - $c_i \sim \text{Poisson}(\lambda^C)$
- Cluster dispersion
  - u_l : location of call l
  - Movement: $u_l \sim BVN(s_i , \sigma^C)$
  - No movement: $u_l = s_i$ $(\sigma^C = 0)$

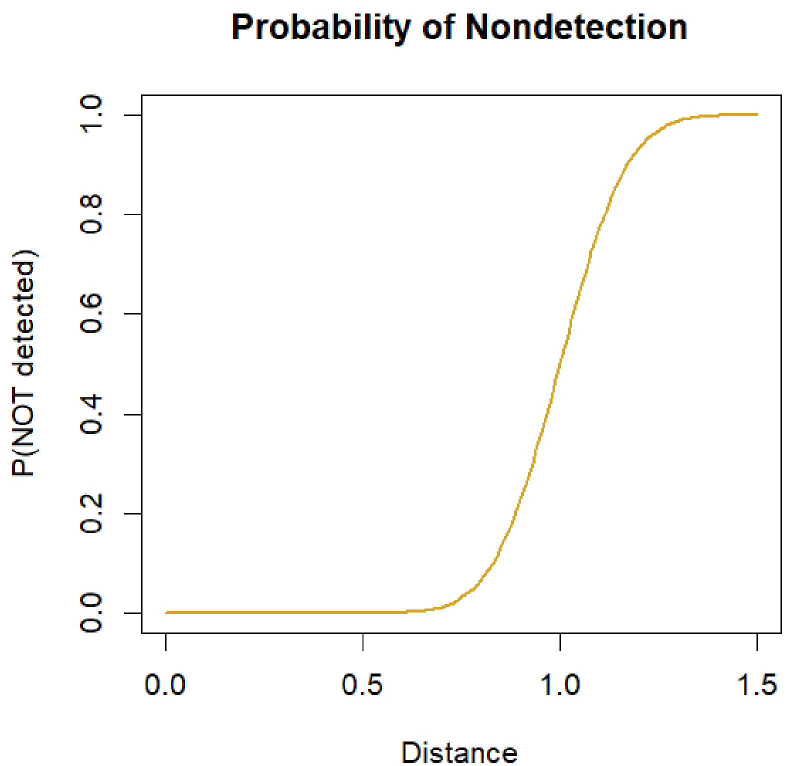
Thomas Point Process



Cluster SCR – Model Structure

- Observation model
- y_{lj}: the received sound level of call l at ARU j
- Expected sound level :
  - $\mu_{lj} = B_0 + B_1 \times d(u_l, x_j)$
- Minimum sound level, α
- Indicator for "exceeds α": δ_{lj}
- $y_{lj} \sim (\text{Normal}(\mu_{lj}, \sigma^d))^{\delta_{lj}} \times \left(\Phi\left(\frac{\alpha - \mu_{lj}}{\sigma^d}\right)\right)^{1-\delta_{lj}}$





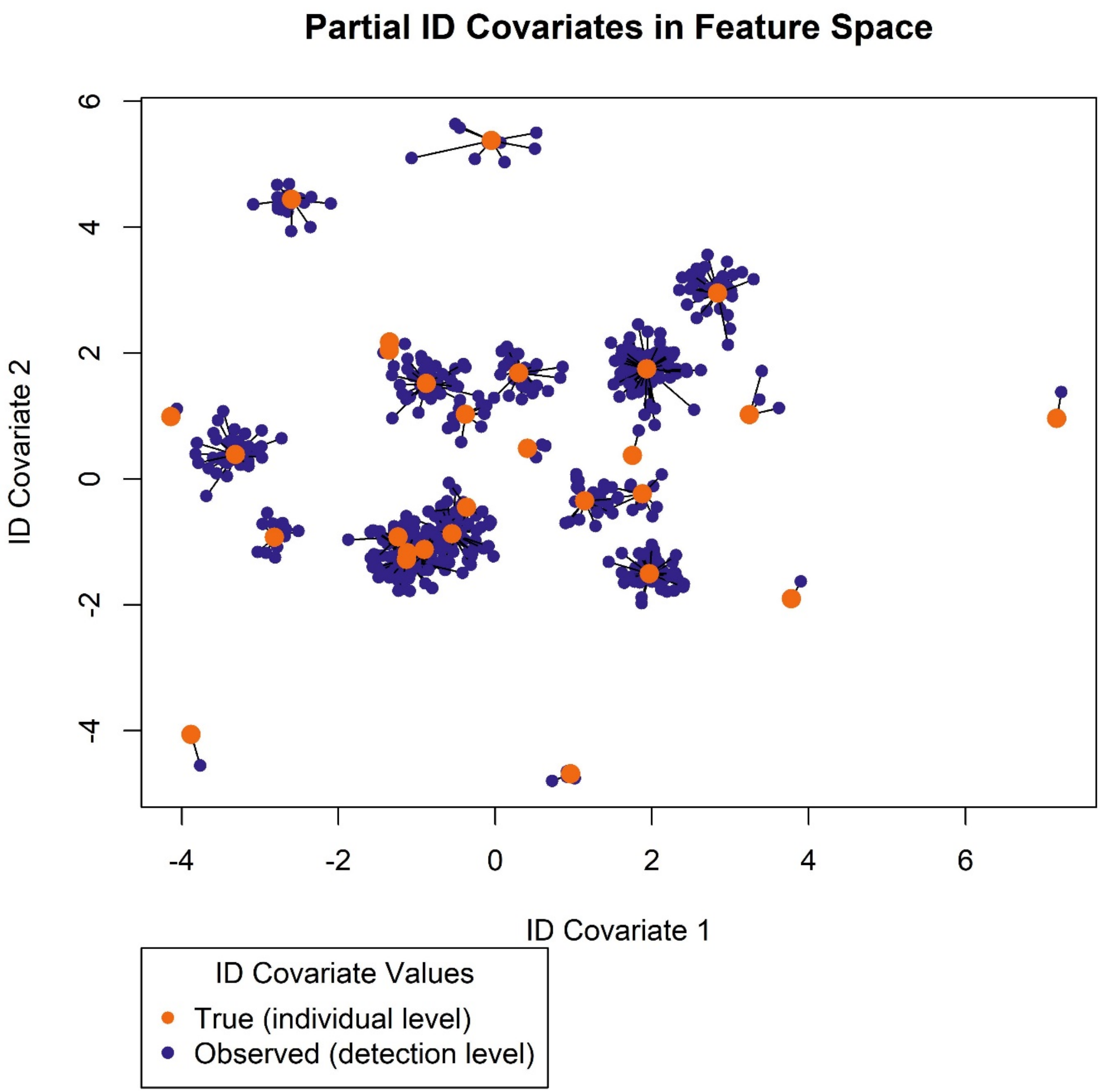
Cluster SCR – Model Structure

- Partial Identity Submodel

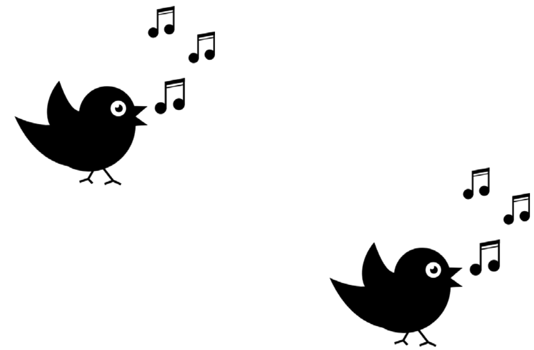
- "True features" measured at ARU with error

- $G^{true}_{im} \sim \text{Normal}(\mu^{G}_{m}, \sigma^{G}_{m})$
  - for i = 1,…, N individuals
  - m = 1, …, n^{cov} covariates

- $G^{obs}_{ljm} \sim \text{Normal}(G^{true}_{im}, \sigma^{obs})$
  - for call l belonging to individual i
  - j = 1,…, J ARUs

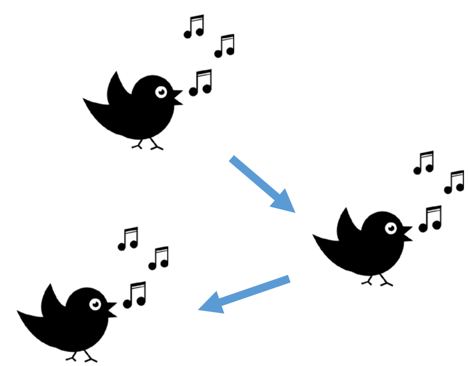


Simulation Study



- Scenarios
  - Stationary: known vs. unknown ID
  - Mobile: known vs. unknown ID
  - Mobile: known vs partial ID
- Can we estimate density precisely in these scenarios?
  - With a small number of ARUs?
  - Cluster designs
  - Coefficient of variation for abundance (N CV)

- Is estimation computationally feasible?
  - Run time
  - Abundance effective sample size (N ESS)

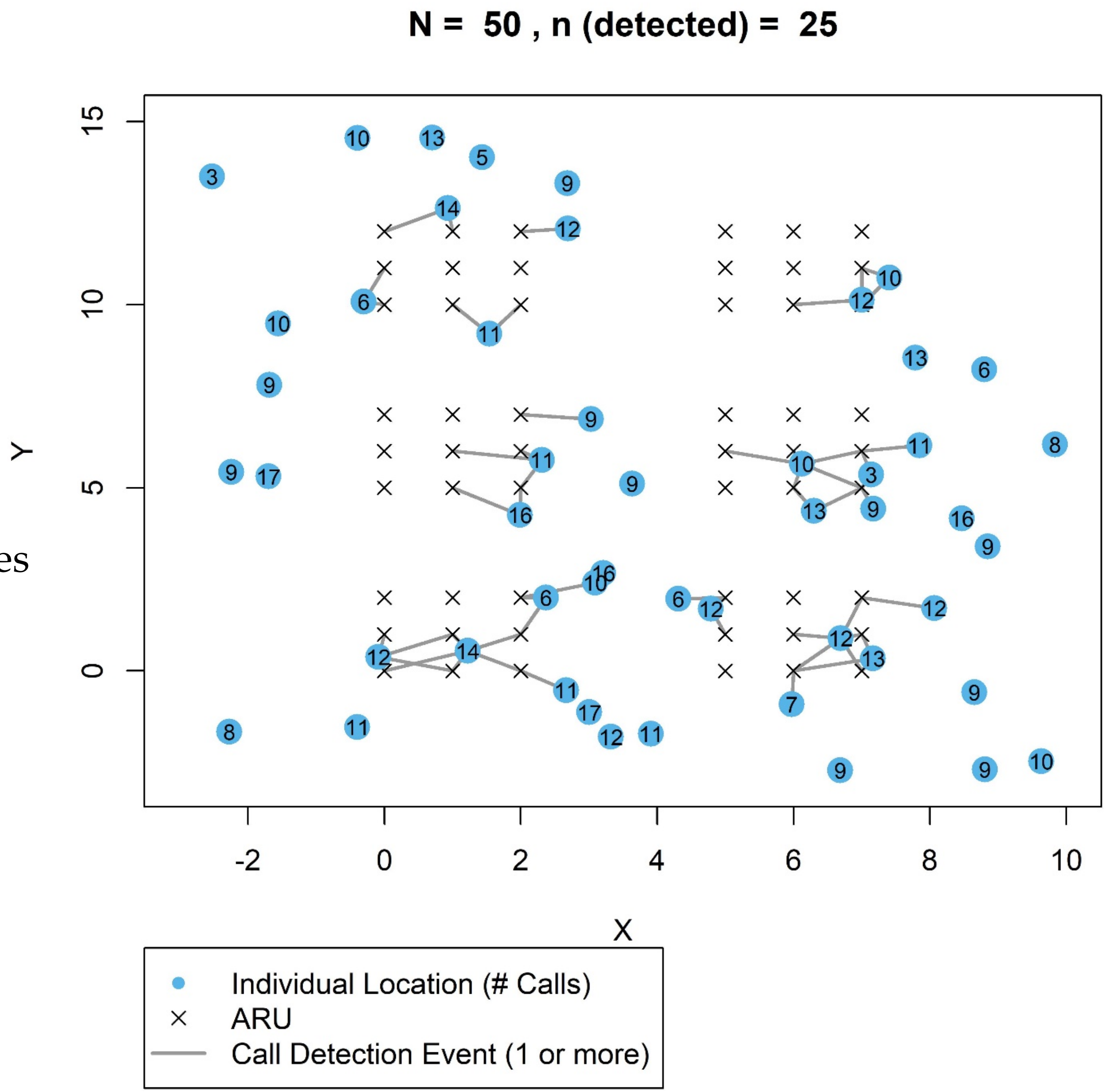


Simulation Scenarios - Stationary

- N = 50
- $\lambda^C = 10$
- 6 clusters of 9 ARUs

- Known ID
  - N CV: 16.2%
  - Mean chain runtime: 39 minutes
  - N ESS: 27,900

- Unknown ID
  - N CV: 17.2%
  - Mean chain runtime: 6.1 hours
  - N ESS: 16,550

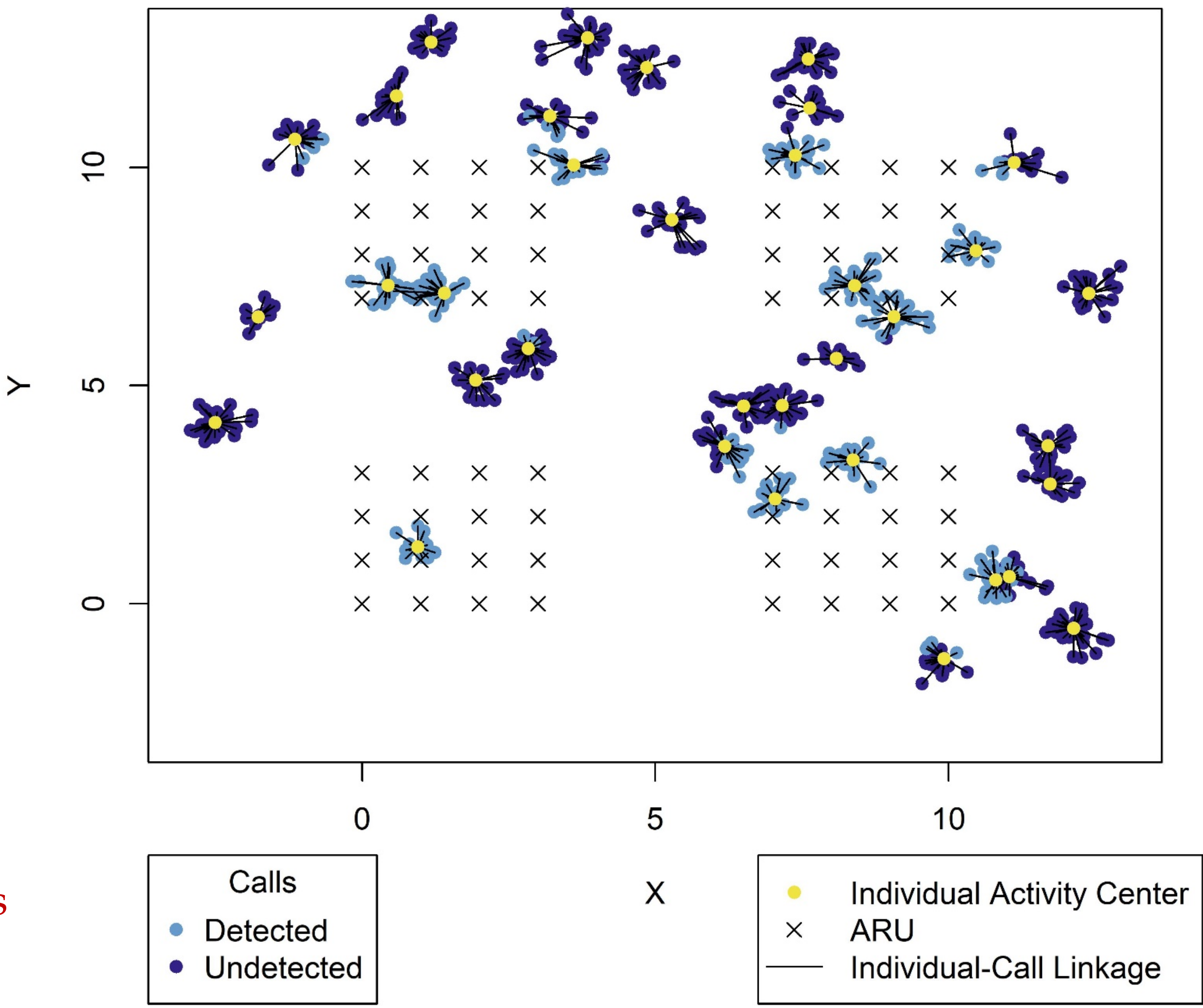


Simulation Scenarios - Mobile

- N = 35
- $\lambda^C = 20$
- $\sigma^c = 0.25$
- 4 clusters of 16 ARUs

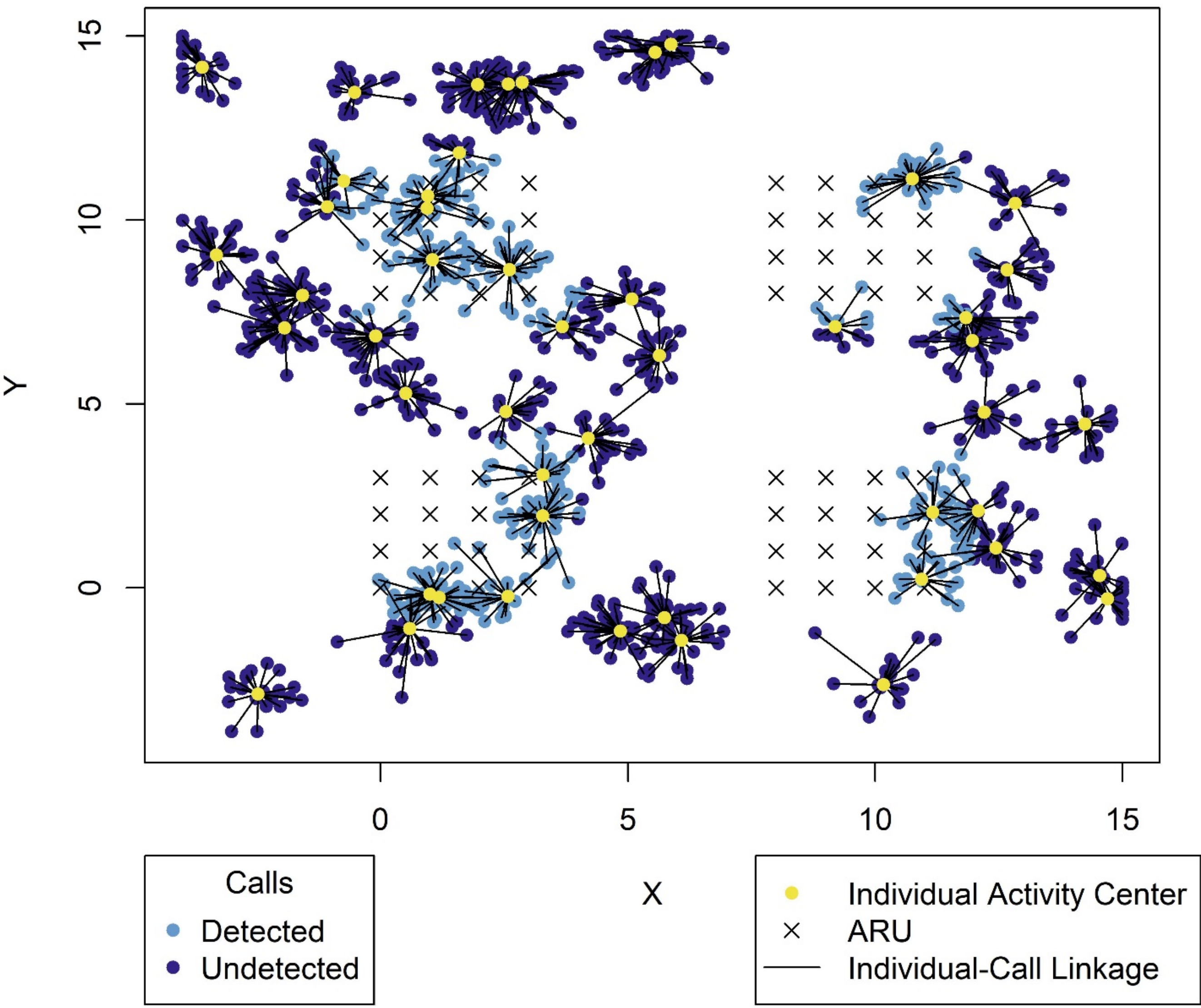
- Known ID
  - N CV: 16.8%
  - Mean chain runtime: 5.9 hours
  - N ESS: 1,099

- Unknown ID
  - N CV: 18.8%
  - Mean chain runtime: 23.0 hours
  - N ESS: 10,260



Simulation Scenarios – Mobile, Partial ID

- N = 49
- $\lambda^{C} = 20$
- $\sigma^{c} = 0.50$
- 4 clusters of 16 ARUs
- 3 partial ID covariates
- Clink and Klinck (2021)
  - 177 Mel-frequency cepstral coefficients (MFCCs) provided 71% classification accuracy

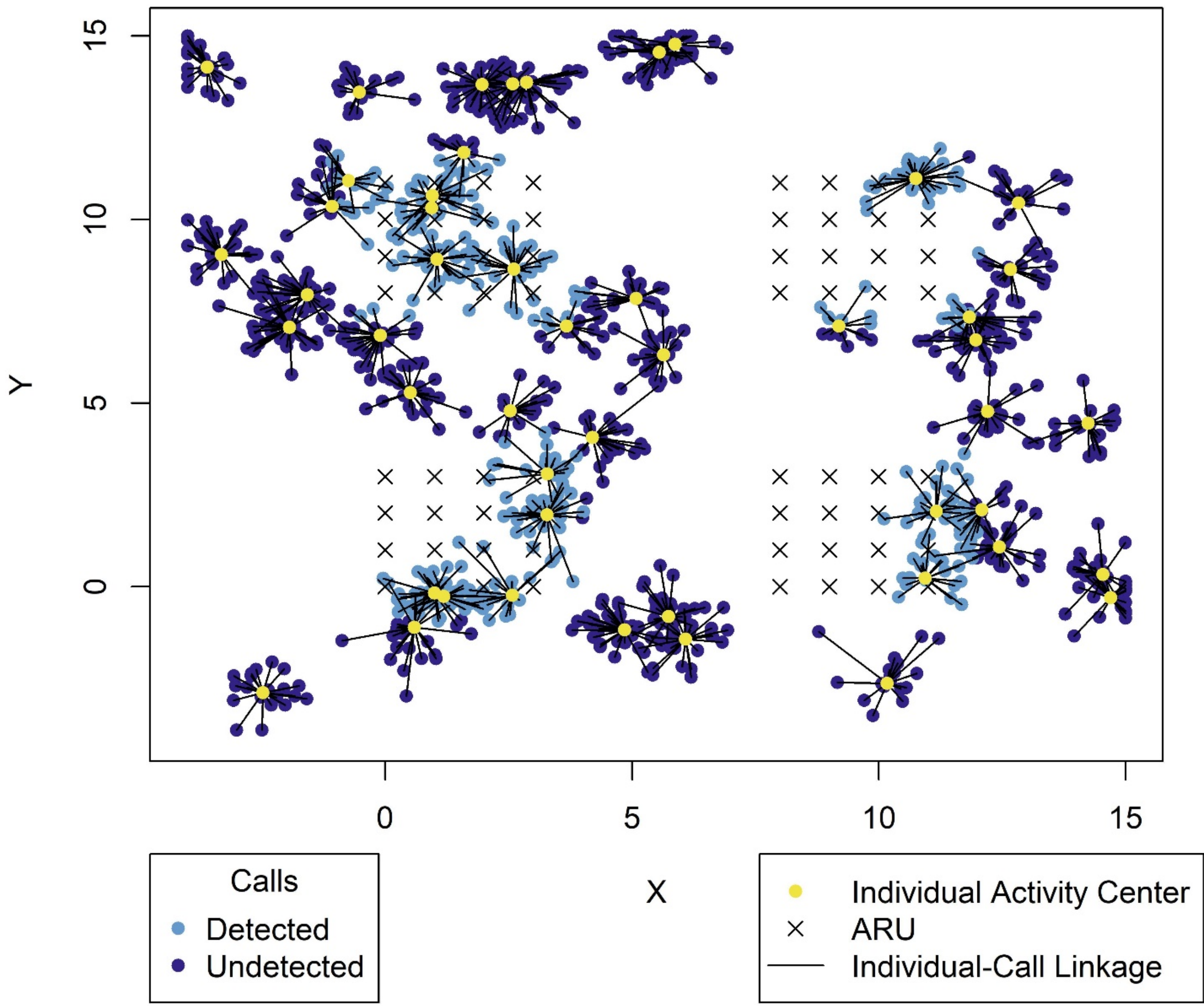


Simulation Scenarios – Mobile, Partial ID

- N = 49
- $\lambda^C = 20$
- $\sigma^c = 0.50$

- Known ID
  - N CV: 15.6%
  - Mean chain runtime: 5.6 hours
  - N ESS: 2,536

- Partial ID
  - N CV: 16.8%
  - Mean chain runtime: 2.6 days
  - N ESS: 19,166

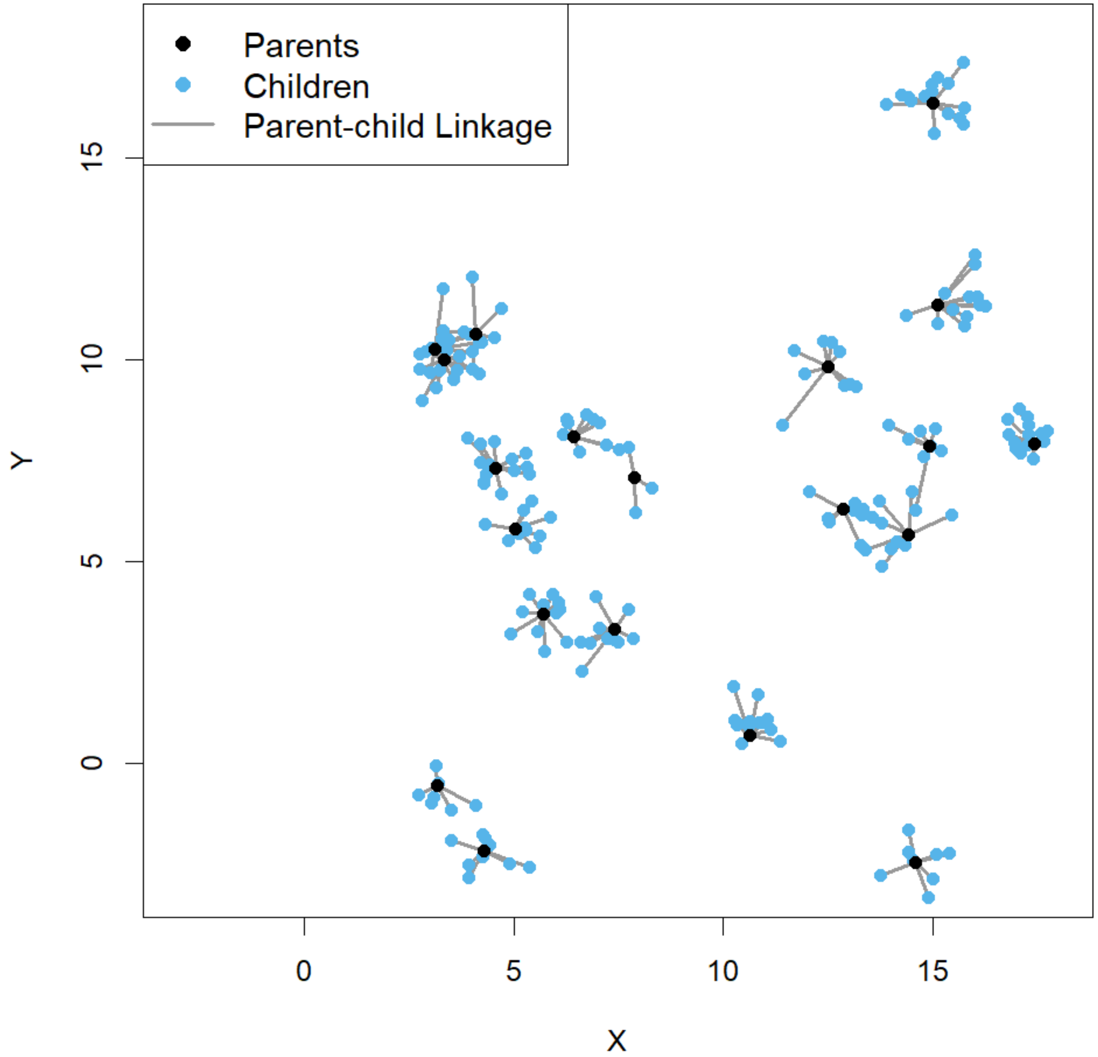


Summary

- Can estimate density estimation with:
  - Known, unknown and partially-known individual ID
  - Stationary or mobile callers
  - No independent call rate or movement data
- Parameter estimates precise with not many individuals/calls
  - Fewer required calls, less potential for movement
- Not much precision lost without known individual ID
  - In scenarios considered
- Long runtimes
  - Limits the number of individuals and calls
  - Parallel processing

Future Directions

- Apply cluster SCR methods to real acoustic data set
- Evaluate study designs
  - Observation models
  - ID requirements
  - ARU placement
- More complex movement models
- Other cluster applications
  - Group or pack living species
  - Others?



Acknowledgements

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