A Sampling Strategy Designed to Maximize the Efficiency of Data Collection of Food Web Relationships

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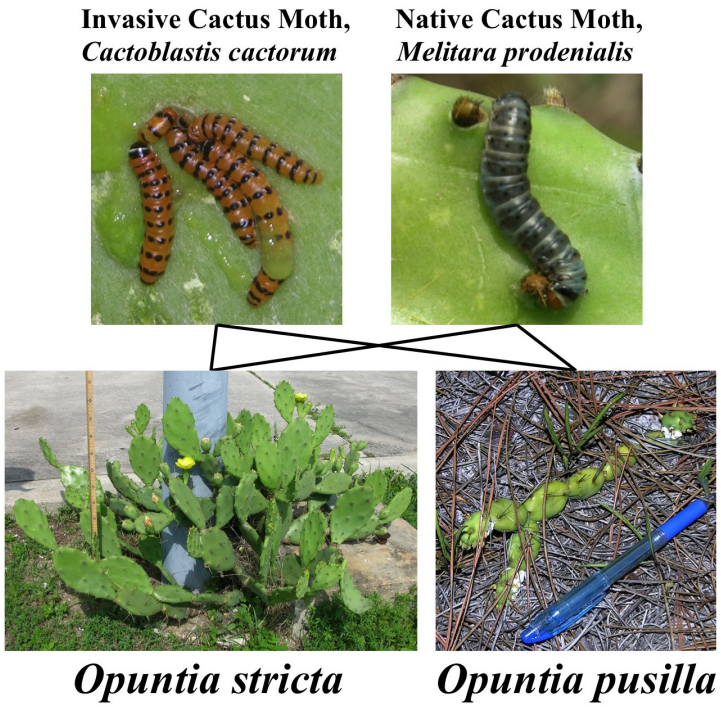
29 June 2016

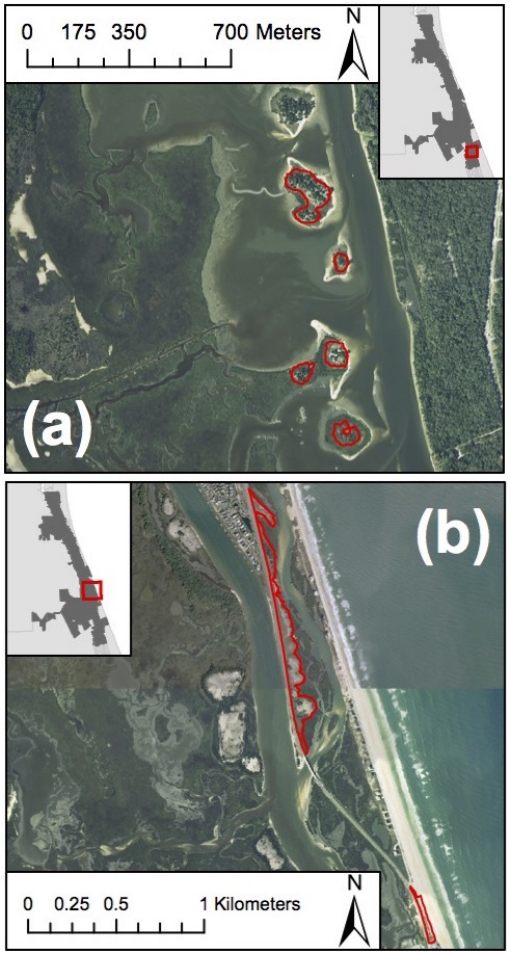
Introduction

- design efficient data collection methods
  - **minimize** costs of time/money
  - **maximize** information

Introduction

- **Variables:** occupancy, abundance
- Set up 1346 1-m^2 plots at 7 habitat patches from May-July 2012 in Northeastern Florida



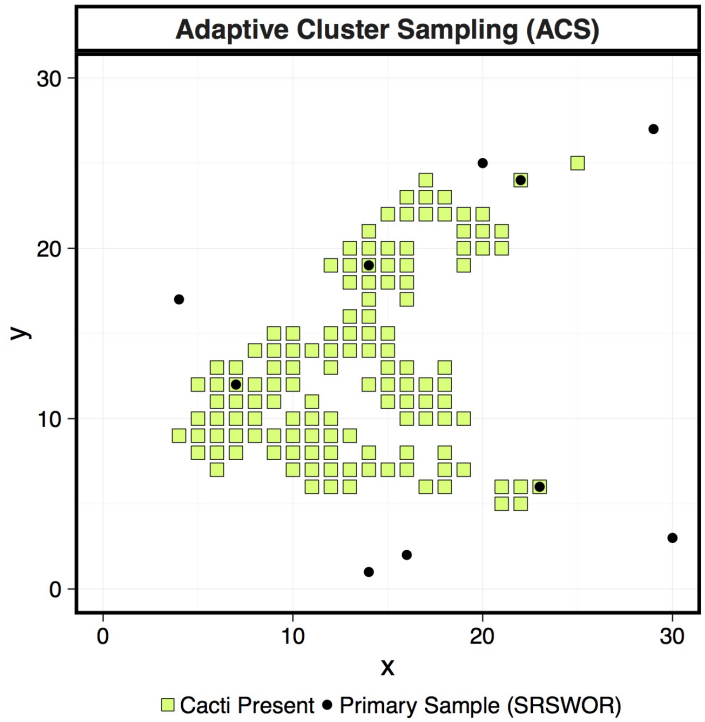


Adaptive Cluster Sampling (ACS)

Proposed in Thompson, S. (1990). Adaptive cluster sampling. Journal of the American Statistical Association, 85(412), 1050–1059.

Design:

- A primary sample of n_1 units is selected from N units, based on some probability sampling scheme

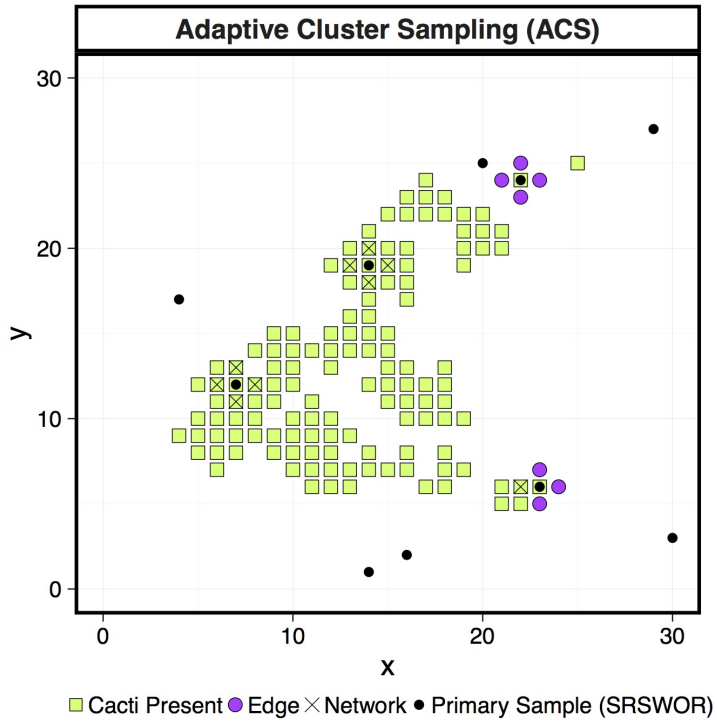


Adaptive Cluster Sampling (ACS)

Design:

- **Adaptive**: A secondary sample is selected if primary units satisfy a condition (e.g., cacti are present)

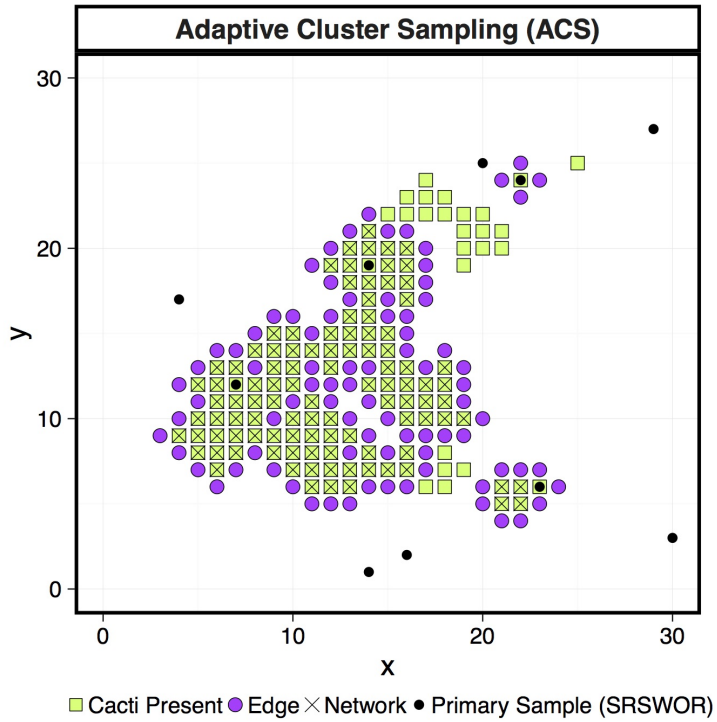
1. Adjacent units sampled in the four cardinal directions



Adaptive Cluster Sampling (ACS)

Design:

1. For neighboring units whose values satisfy the condition, their neighbors are also surveyed
2. **Cluster Sampling**: Sampling of neighboring units continues until no additional units satisfy the condition



Adaptive Cluster Sampling (ACS)

Advantages

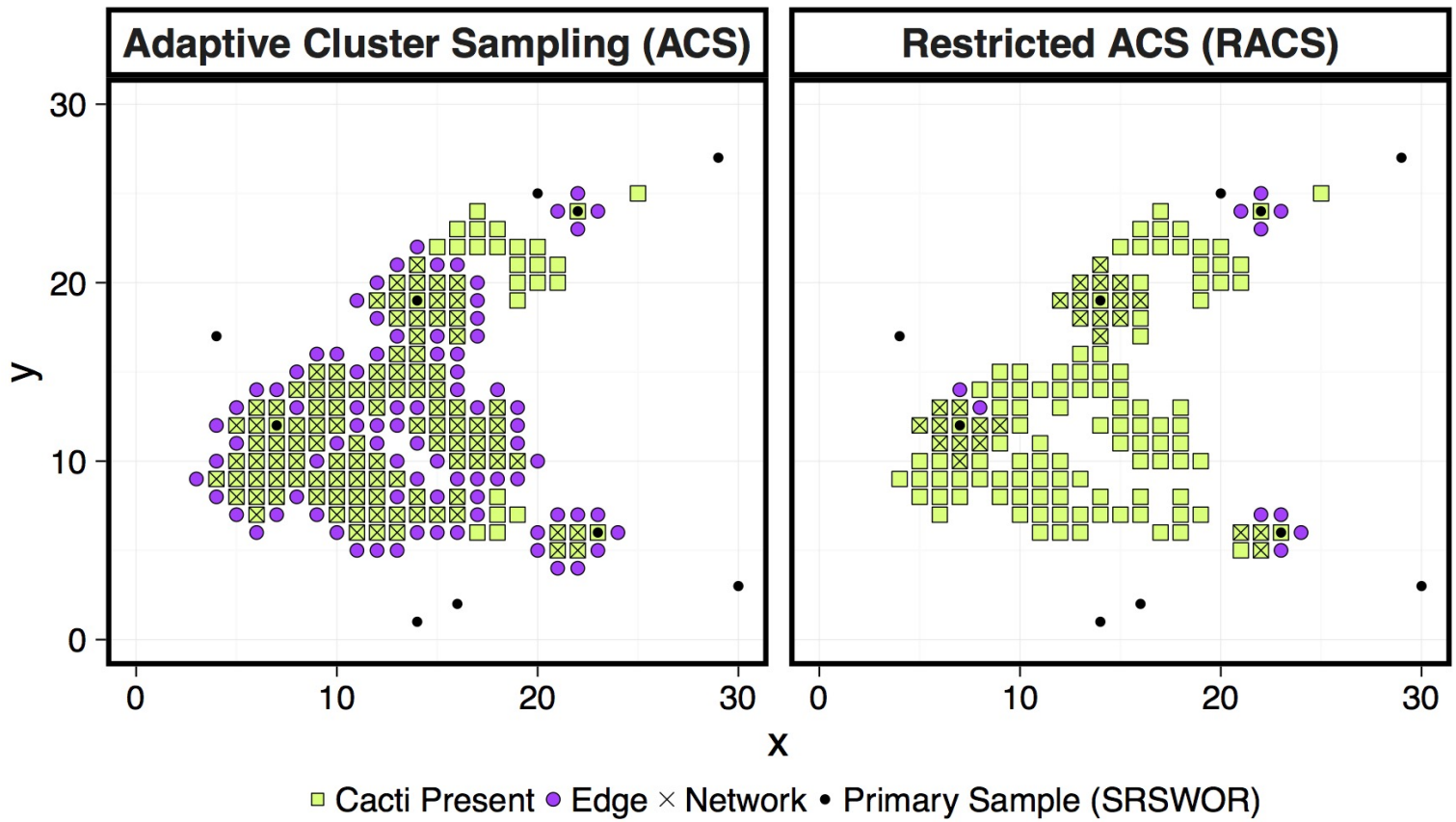
- Best for studies involving populations of rare and clustered individuals
- Compared to designs such as simple random sampling:
  - Increased sampling efficiency
  - Reduced variance

Disadvantage

- Final sample size is unknown at the start of sampling

Restricted ACS (RACS)

- same procedure as ACS, **except** that we restrict the number of neighboring units to q (in our example, $q = 12$)

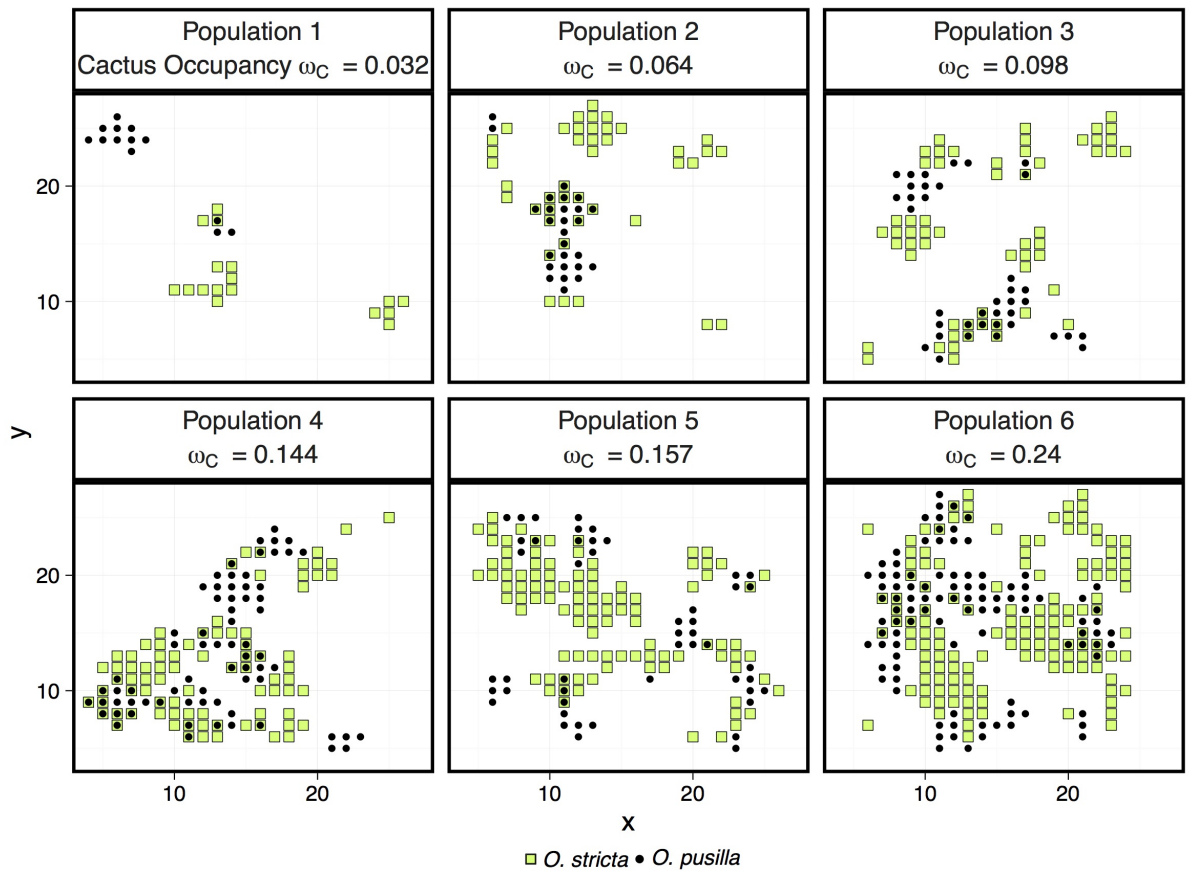


Estimators

- The unbiased (for ACS) Horvitz-Thompson estimator of the population mean of variable x is $\bar{x}_{HT} = \frac{1}{N}\sum_{i=1}^{v}(x_i J_i)/\pi_i$
  - N = population size, n_1 = primary sample size
  - v = the number of unique units in the sample
  - J_i is an indicator variable, equalling 1 if the ith unit in the sample satisfies the condition or was included in the primary sample and 0 otherwise
  - **inclusion probability:** $\pi_i = 1 - \binom{N-m_i}{n_1} \Big/ \binom{N}{n_1}$**, where** m_i **is the number of units in the network** ψ_i

Simulations

- **Objective**: Explore properties of the RACS design by bootstrapping populations created with a dataset of two cactus species and their associated insects.
- randomly sampled the survey data to generate 6 populations



Hypotheses

Horvitz-Thompson estimators will be

1. **biased** for the variable on which the RACS criterion is based
   - *i.e.*, cactus presence
2. **unbiased** for variables that
   - are not used to generate the RACS criterion
   - are uncorrelated with the variable on which the RACS criterion is based
   - *i.e.*, insect presence, evidence of insect damage

Simulations

- We used cactus presence as our criterion to initiate cluster sampling
- We ran 5000 simulations of the RACS and ACS designs per
  - population
  - primary sample size (20, 30, 40, 75, and 100)
- For each simulation we estimated:
  - *O. stricta*, *O. pusilla*, and cactus occupancy
  - insect occupancy given cactus presence

Simulations

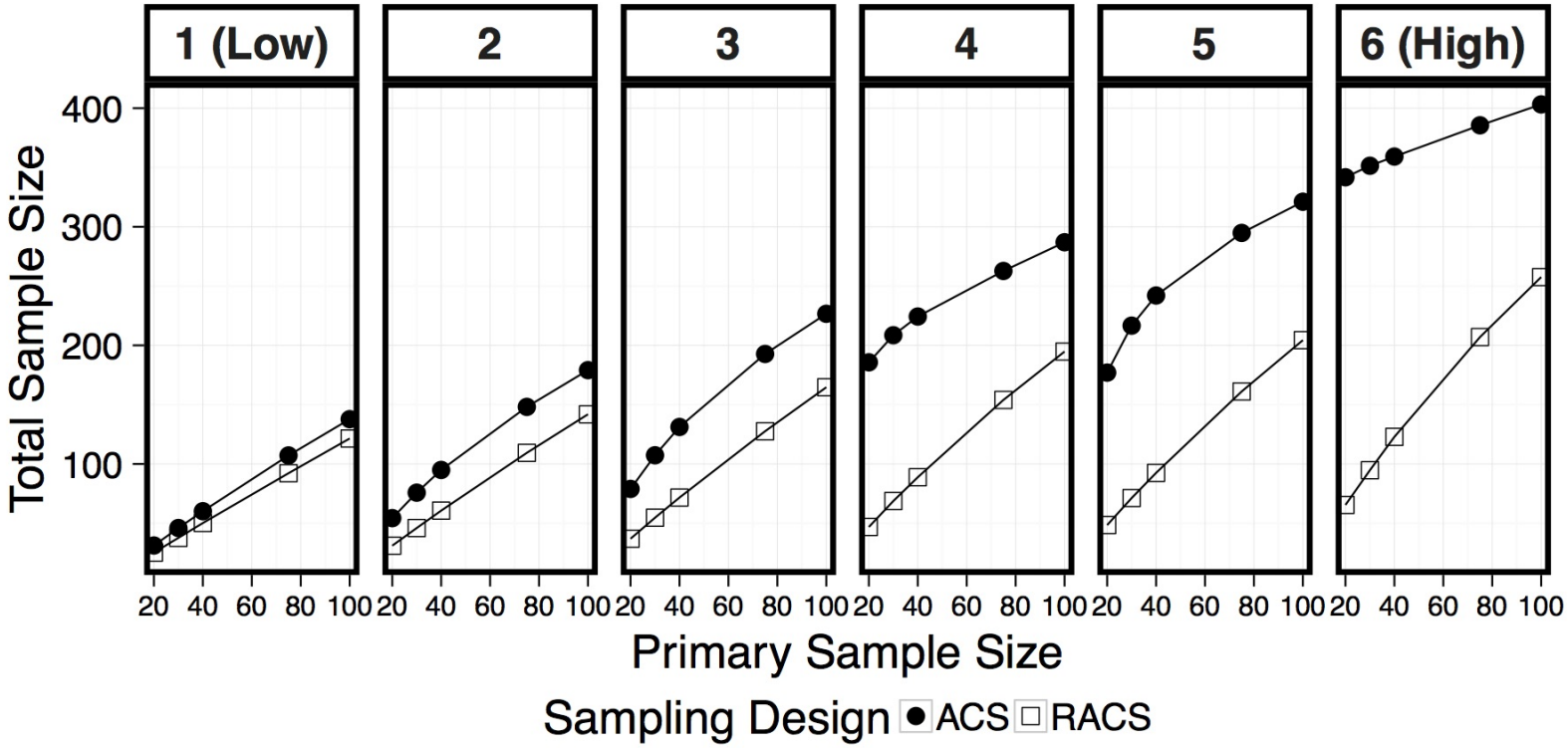
- relative bias of the mean:

$B_{\bar{x}_{HT,i}} = (\bar{x}_{HT,i} - \mu)/\mu$

- μ is the true population mean
- $\bar{x}_{HT,i}$ Horvitz-Thompson mean of variable x from the ith simulation
- mean percent relative bias for the S simulations

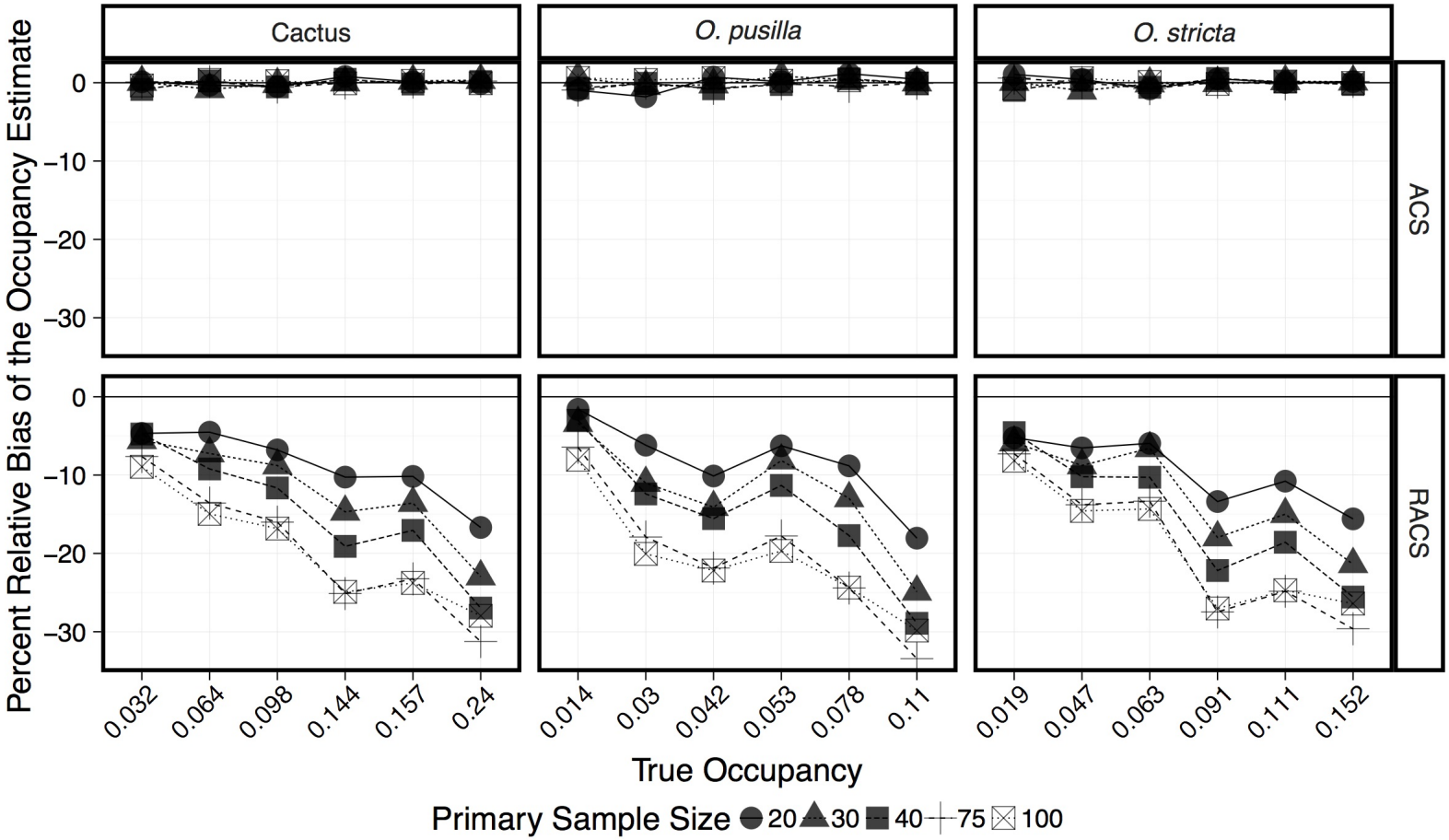
$\text{mean}(B_{\bar{x}_{HT}}) = 100 \times S^{-1} \sum_{i=1}^{S} B_{\bar{x}_{HT,i}}$

Results - Final Sample Sizes



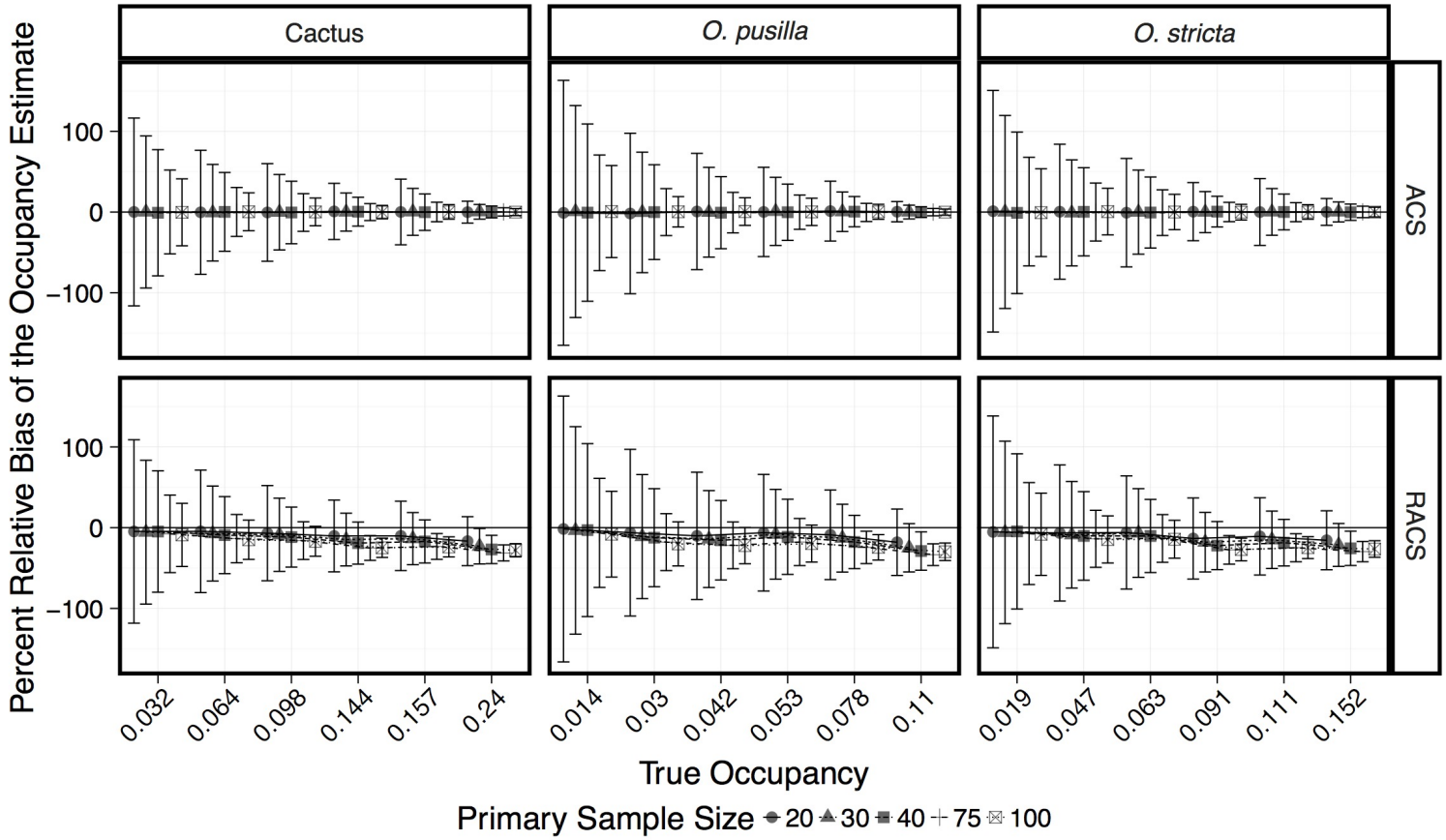
Results - Cactus Occupancy

- with RACS, we underestimate occupancy (negative percent relative bias)
- this underestimate increases with cactus occupancy



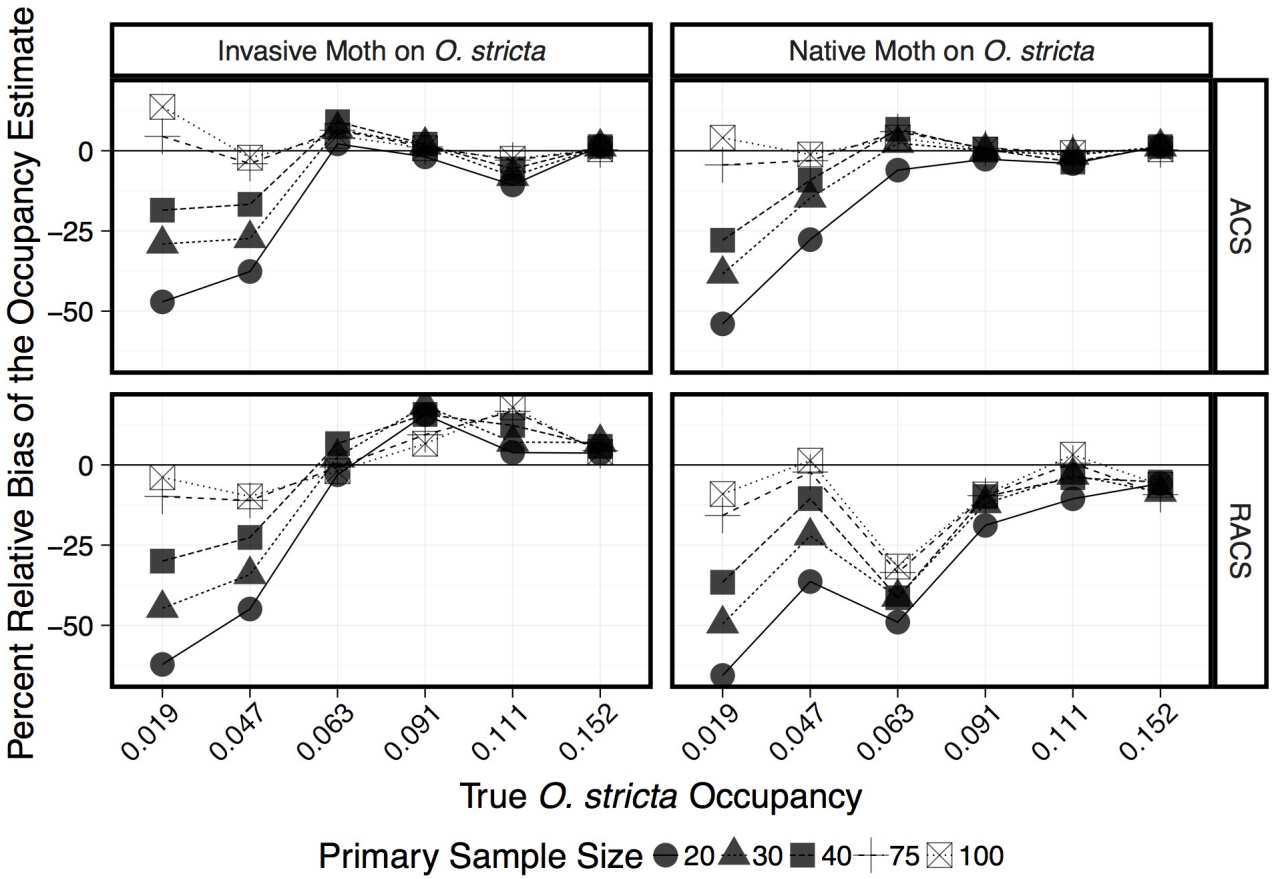
Results - Cactus Occupancy

- Variability decreases with increased primary sample size and occupancy



Moth Occupancy on *O. stricta*

- bias decreases with increasing primary sample size
- noise suggests that something other than just occupancy (e.g., spatial structure) is influencing the bias



Conclusions (So Far)

- Compared to ACS, RACS generates smaller final sample sizes, particularly for populations with relatively high occupancy
- confirmed that estimate of cactus occupancy is biased
  - may need to fix calculation so that bias does not increase with n_1
- with larger sample sizes, our estimates of moth occupancy is less biased

Bias Correction Techniques

- correct bias by correcting inclusion/intersection probabilities
- ways to do this:
  - analytical - come up with a formula based on average behavior
  - use nonparametric technique such as bootstrapping
    - keep track of how many times a unit is sampled we can estimate the probabilities

Additional Work

- we have also looked at bias for:
  - variance
  - insect damage occupancy
  - max. plant height
  - percentage of plot covered by cacti
- we have created a R package, "ACSampling," that we will release as a public Github repository

Future Work

- Estimate bias of the variance
- Run more simulations
- Test bias reduction techniques
- compare efficiency of RACS, ACS, and SRSWOR
  - primary sample size = 40 + RACS = 40 vs. SRSWOR = 80?

Acknowledgements

- R.D. Holt

Data Collection

- Guana Tolomato Matanzas National Estuarine Research Reserve
- Katie Petrinec
- Matt Welsh
- Polly Harding, undergrad. volunteer

Funding

- QSE3 IGERT (NSF Award # 0801544)
- Cactus and Succulent Society of America
- Garden Club of America/Center for Plant Conservation
- University of Florida Graduate Student Council