Lower Colorado River
Multi-Species Conservation Program

Balancing Resource Use and Conservation

N-mixture models for estimating abundance from repeated counts

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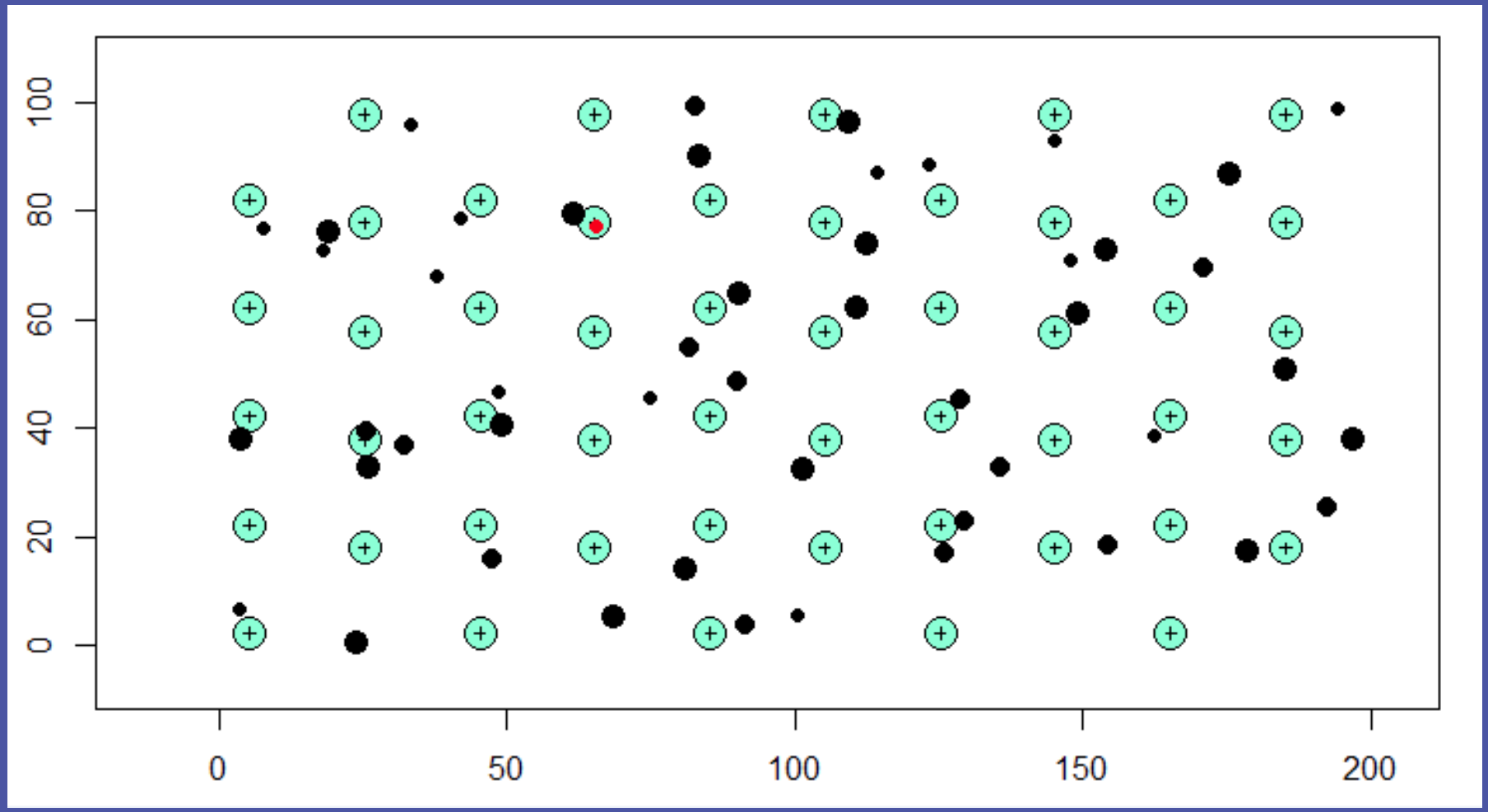
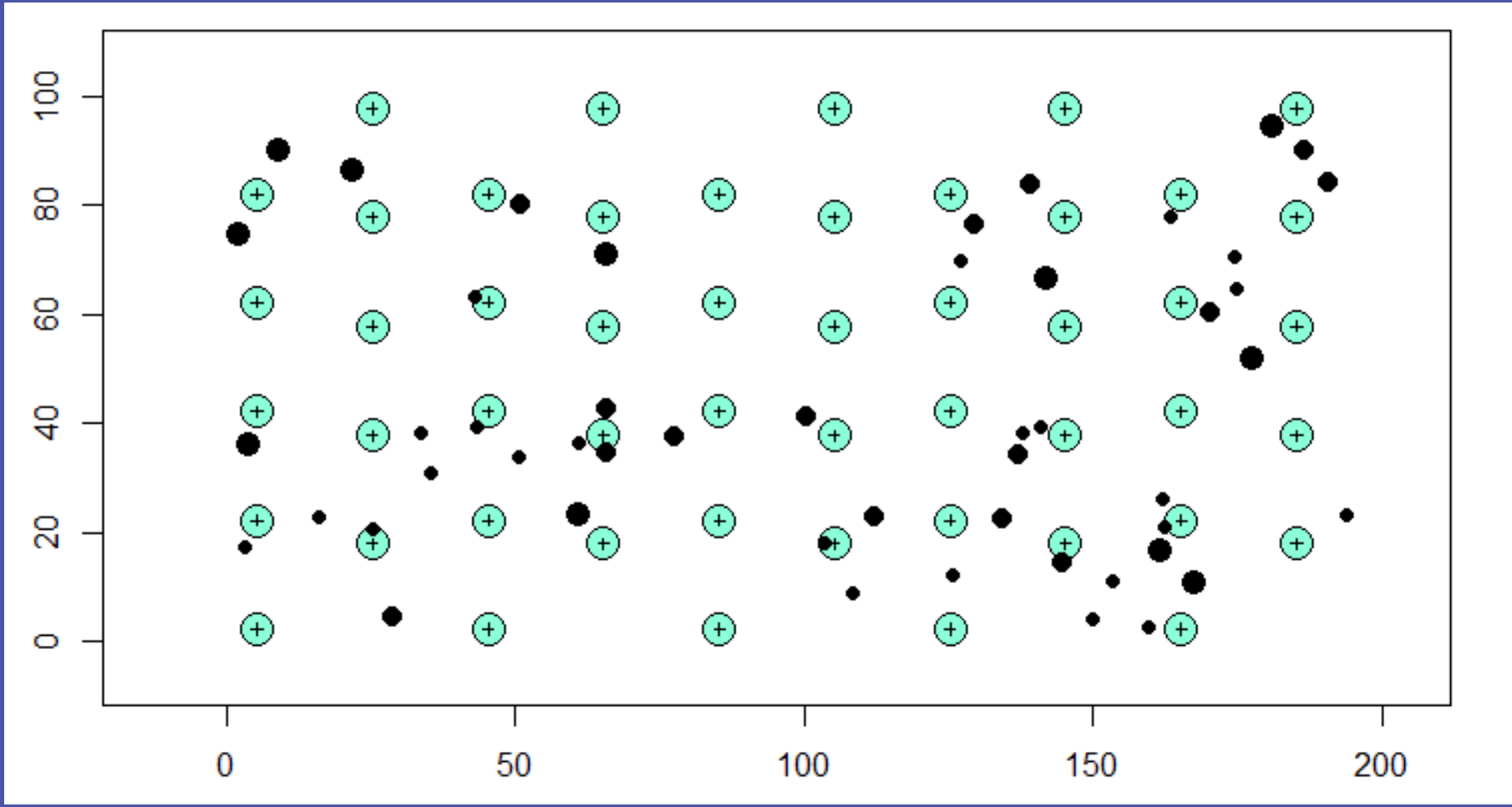
Objectives

- Definition: N-mixture models
- Development & Assumptions
- Example: Marsh Birds
- Advantages & Caveats
- References & Resources

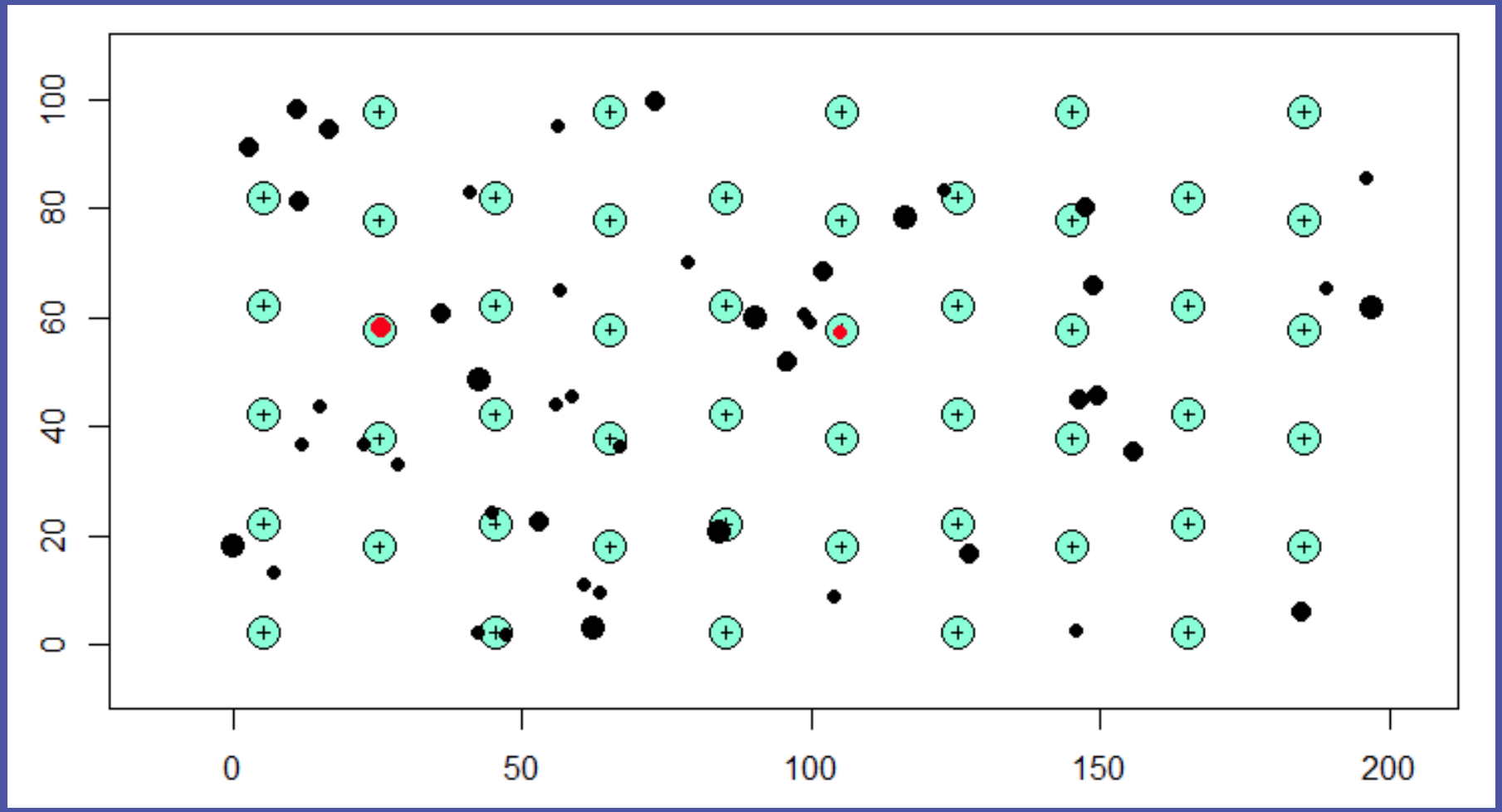
Context: Imperfect Detection, Hits = 1
50 groups, N ~ 80-95



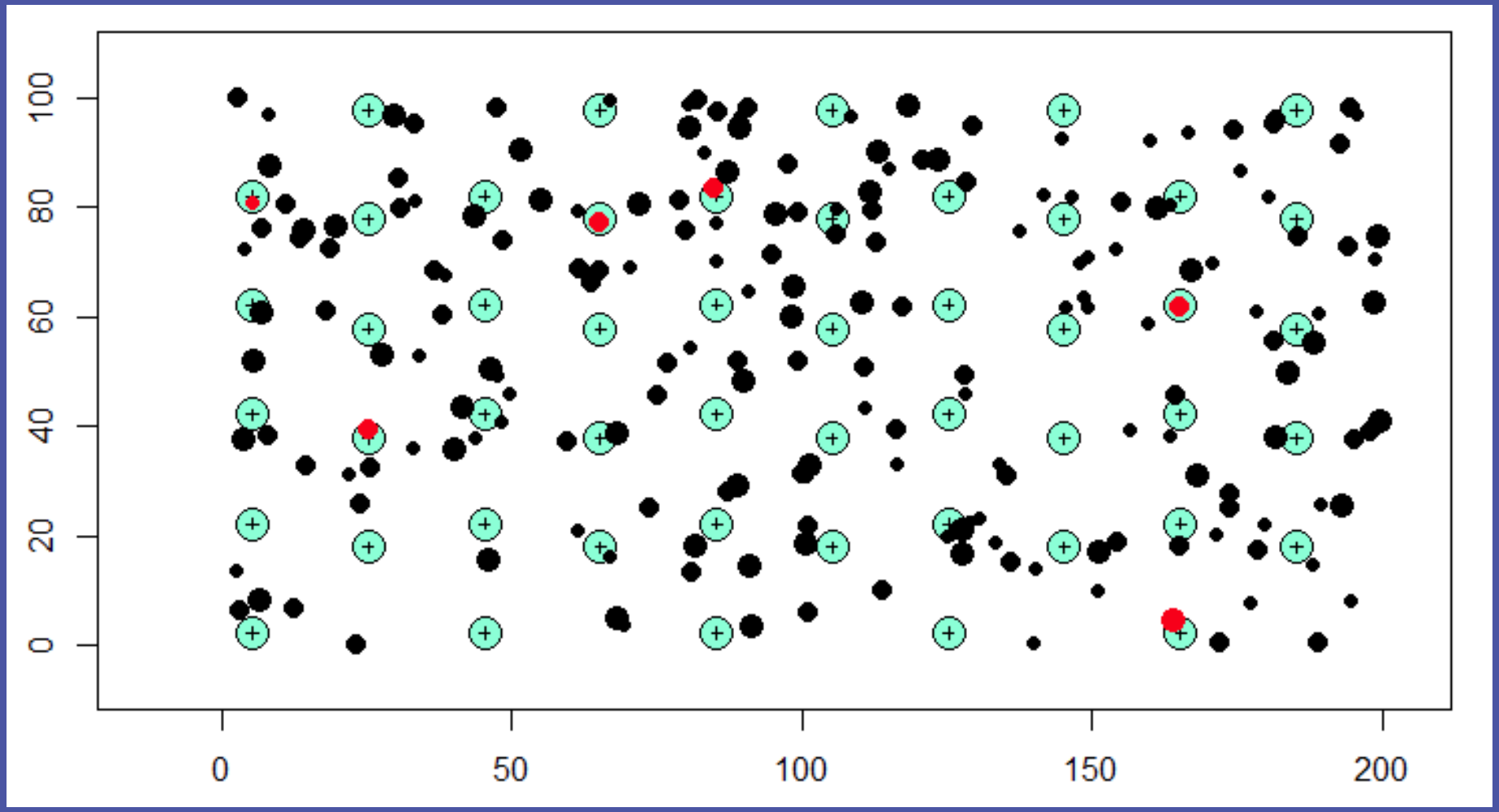
Context: Imperfect Detection, Hits = 0, 50 groups, N ~ 80-95



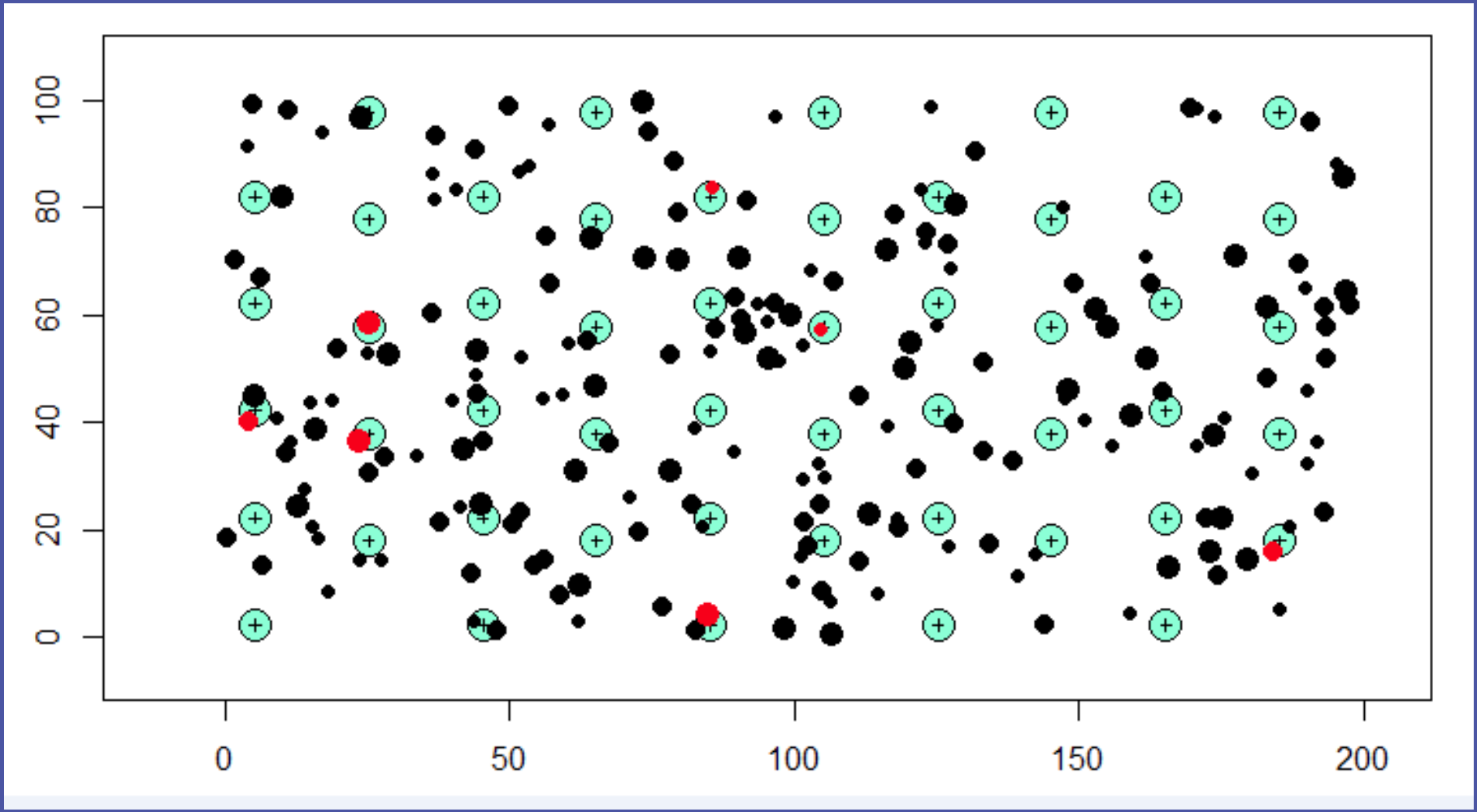
Context: Imperfect Detection, Hits = 2,
50 groups, N ~ 80-95



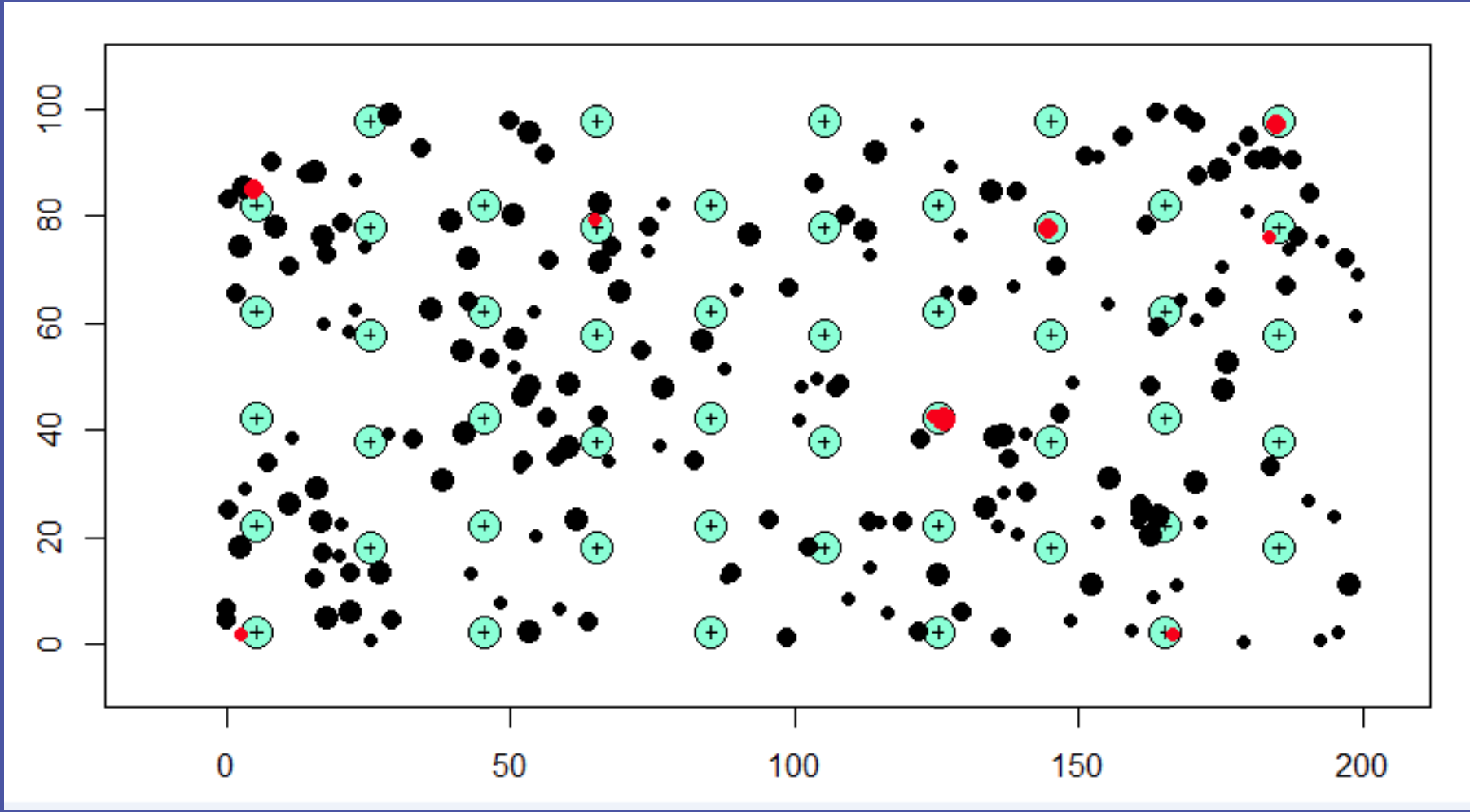
Context: Imperfect Detection, Hits = 6, 200 groups, N ~ 365-380



Context: Imperfect Detection, Hits = 7, 200 groups, N ~ 365-380



Context: Imperfect Detection, Hits = 9, 200 groups, N ~ 365-380



N-mixture models

Combines probability models for:

- True *abundance* (unknown)
  e.g., Poisson, Negative Binomial
  $N_i|\lambda_i \sim Poi(\lambda_i)$

- Observation > Detection (p)
  $c_{ij}|N_i \sim \text{Bin}(N_i, p_{ij})$
  Binomial or Multinomial

Estimating Abundance, Unmarked Animals

Royle & Nichols (2003)
Presence/absence data, closed population

Repeated counts

Royle (2004)
Closed population

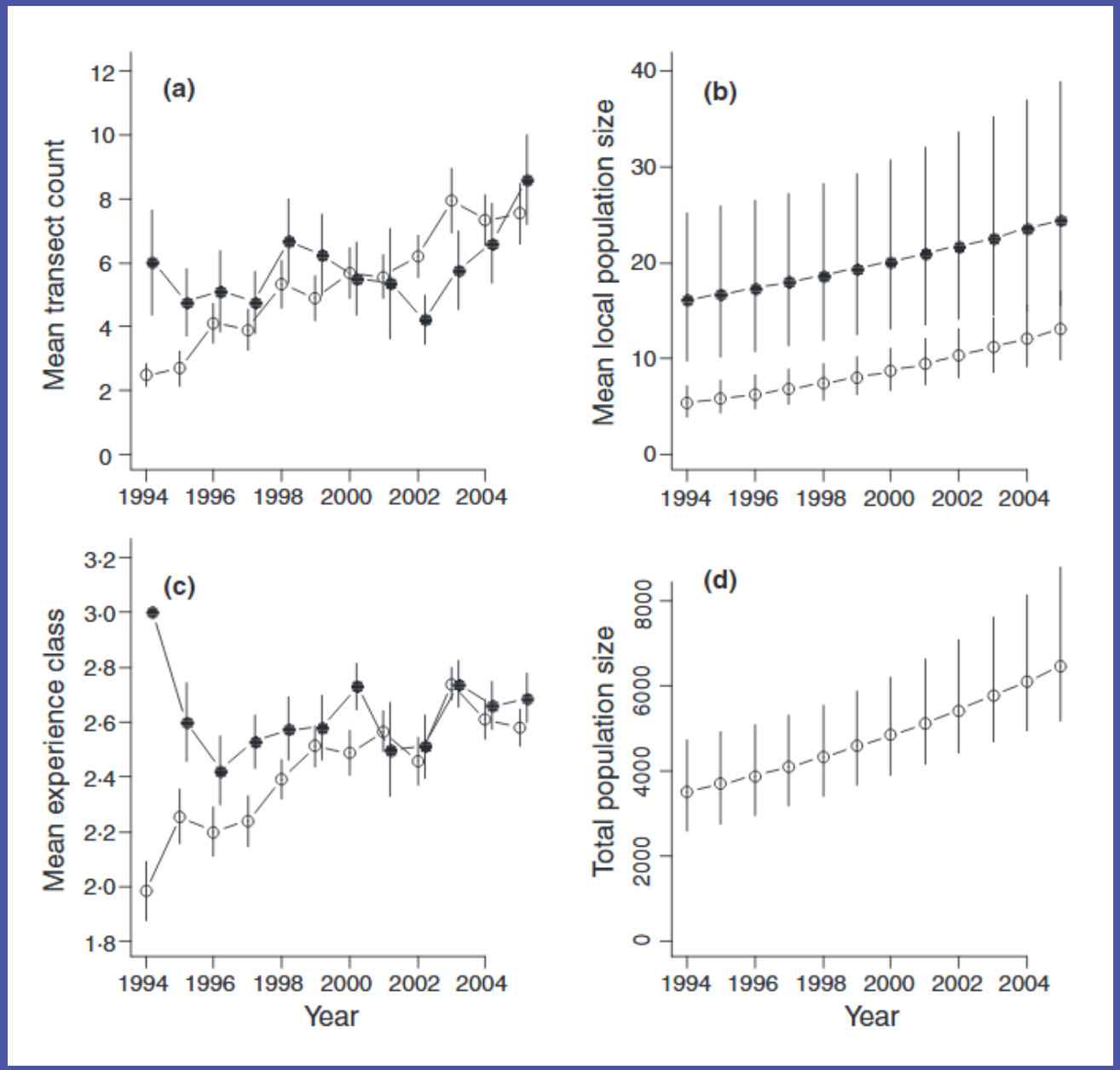
Chandler et al (2011)
Closed, Temporary emigration

Dail & Madsen (2011)
Open population
Recruitment, Survivorship

Others ref'd in Dénes et al. 2015

Assumptions, Royle 2004

- Closed Population
- No double counts
- Independent detections
- Equal *p* for all individuals within sample
- Parametric model (binomial, Poisson)



Kéry et al. (2009) Journal of Applied Ecology 46:1163–1172

Performance? Simulation Studies

- Varying sample size (*R*), # of visits (*T*) and detection probability (*p*).
- Royle (2004) unbiased even at low *R* (20) except for low *p* (e.g., small + bias, *R* (*p*) = 20 (0.25))
- Larger *T* and *p* counter small *R*
- Most other models tested with $R \geq 100$, $T \geq 3$, $p \geq 0.25$
- Dail & Madsen Open model, *R* = 20, 100. Less biased than Royle binomial (closed) model at low *R*.
- General problem with Negative Binomial, esp. at low *p*.

Performance? Field Data

- Higher abundance relative to territory maps of birds, distance sampling estimates of desert tortoises (Kéry *et al*. 2005, Zylstra *et al*. 2010)
- But not compared to direct observations of lizards (Doré *et al*. 2011).
- Temporary emigration less biased than Royle closed and multinomial (removal sampling) models when compared with spot mapping data on Chestnut sided Warbler.
- Capture-recapture estimates ~ 2x higher than distance and N-mixture models. In simulations, N-mixture biased high when $p < 0.5$ (Courturier *et al.* 2013).

Model Fitting

Maximum Likelihood

Presence (limited), **R package *unmarked***

Requires *K*, upper integration boundary (> max count/point) – problem with Neg. Binomial

Bayesian

WinBugs, JAGS

Priors, Markov Chain Monte Carlo

Kéry et al. (2009) – extends basic Royle model for varying N over years.

unmarked

- Range of model types
  Occupancy, N-mixture, Distance
- Utilities for correct file format
- Goodness of fit (bootstrap w/ *parboot*)
  but also *Nmix.gof.test* {*AICcmodavg*}
- Open models and GOF **<u>VERY SLOW</u>**

Example code
Royle (2004) model

```
library(unmarked)
library(AICcmodavg)
clra2013 <- read.csv("clra2013_np.csv")
umf13 <- unmarkedFramePCount(y=clra2013)
(fm13 <- pcount(~1 ~1, umf13, mixture="P"))
(bts <- backTransform(fm13, type="state"))
confint(bts)
(btd <- backTransform(fm13, type=“det"))
confint(btd)
```

Interpreting Results

λ = average abundance at site

Area expansion to get population total or simple multiplication by # of sampling sites, $R\lambda$

Difficult to interpret without fixed radius plot.

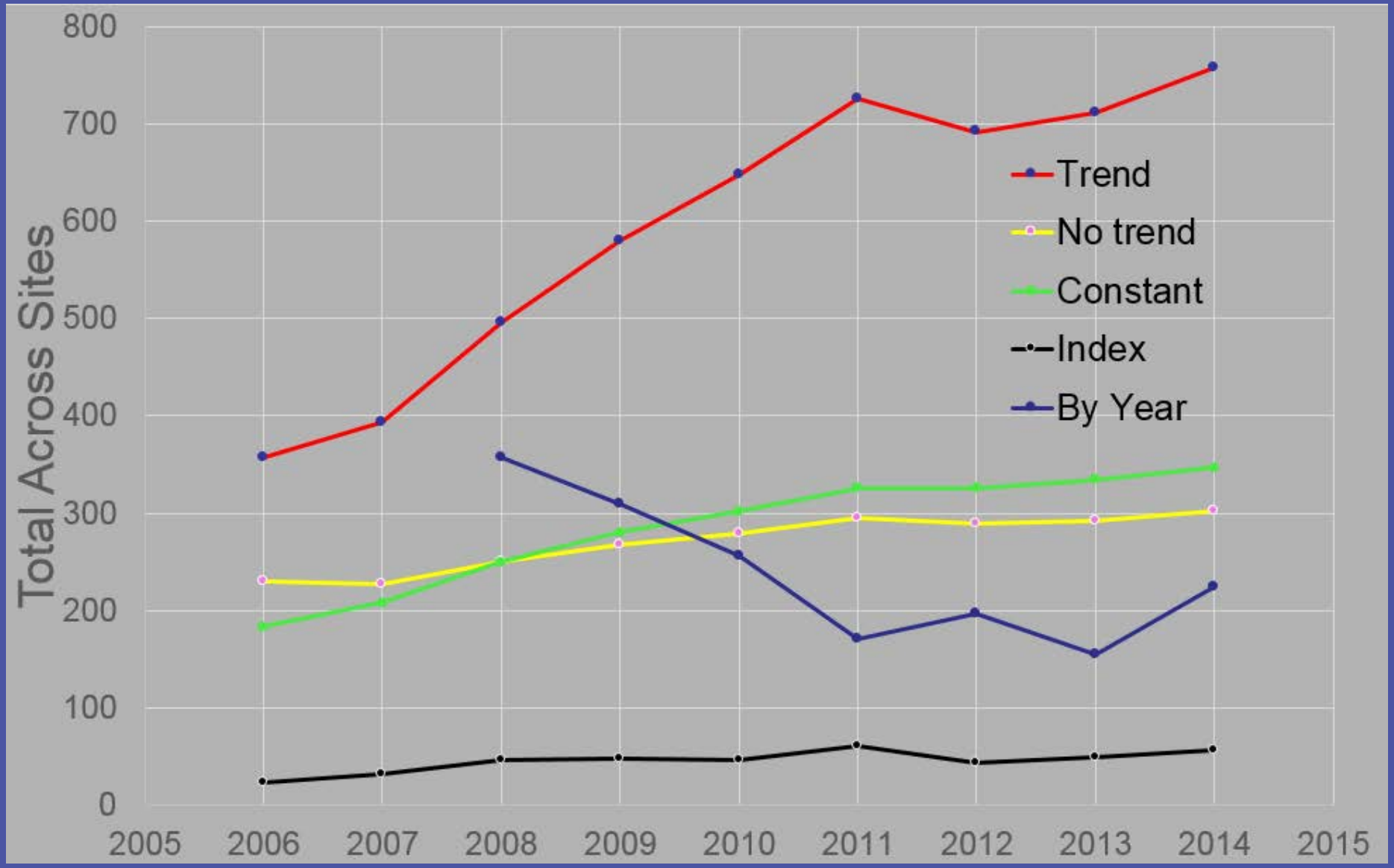
Clapper Rail Example

N = 52, 3 surveys per year

Model & Year	AIC	Est. N	Est. Total	95% LCL	95% UCL	*p*
Royle & Nichols, P/A, 2013	184.5	1.4	73.8	45.0	120.9	0.42
2014	187.8	1.3	66.4	39.2	112.6	0.39
Royle 2004, Poisson, 2013 data	434.9	3.0	155.2	110.8	217.3	0.35
Zero-inflated Poisson	409.6	6.1	316.2	181.8	549.5	0.25
Negative Binomial	380.8*	32.5*	1518.4	574.7	3296.1	0.04
2014, Poisson	530.0	4.3	223.9	153.7	326.2	0.27
Zero-inflated Poisson	465.4	14.4	751.0	310.5	1816.5	0.13
Chandler Poisson, 2013-14	866.7	3.5	181.5	146.0	225.7	0.31
Dail & Madsen Open Pop, Poisson, 2013-14	868.5	3.4	176.3 (182.6)	136.4	227.7	0.31
Dail & Madsen, ZIP	823.0	6.4	331.8 (337.5)	244.1	450.8	0.23

Clapper Rail Example

N = 52, 3 surveys per year, 2006-2014



Advantages

- Simple models
- Relatively inexpensive data
- Missing values OK
- Covariates for both N and *p*
- For a few species, Open Population (Dail & Madsen) model fits BBS data OK, ‘reasonable’ results based on other information.

Caveats

- New models, simulations of limited scenarios
- Need working knowledge of R and unmarked for getting CI's
- Limited field testing
- Problems with Negative Binomial (sparse data)
- Poor fit on BBS data for many species. Extend to use distance sampling data?

Resources

Dénes, F.V., L.F. Silveira, and S.R. Beissinger. 2015. Estimating abundance of unmarked animal populations: accounting for imperfect detection and other sources of zero inflation. Methods in Ecology and Evolution 6:543-556.

Kéry, M. and J.A. Royle. 2016. Applied hierarchical modeling in ecology: Analysis of distribution, abundance and species richness in R and BUGS. Volume 1:Prelude and Static Models. Academic Press.

R package *AHMbook* – complements *unmarked*

Google Groups: “unmarked”

Workshops – Training postings at Google group or phidot.org

Questions, Comments?

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