Lecture 25: Community Ecology:
Species Richness
Community Dynamics

Note- Will begin occupancy work at the end of the lecture if time.

Population – Community Analogy

- Population
  - Comprised of individuals
  - Abundance changes via rates of birth, death, and movement
- Community
  - Comprised of species
  - Richness changes via rates of local colonization and extinction

Procedures for Estimating Species Richness

Adapt Capture-recapture Models

- Applied to counts from replicate points, times, observers.
- Species are analogous to individuals
- Sites, times or observers are analogous to capture occasions
- Estimate N, now the no. of species

$$\hat{N} = \frac{C}{\hat{p}}$$

Estimating Species Richness: Species Detection Probability

$$p_{ij} = 1 - (1 - p_{ij}^{*})^{n_{ij}}$$

p_{ij} is the probability of detecting species j at occasion i. It is the probability of detecting at least one individual.

p_{ij}^{*} is the probability of detecting one individual

Species detection probability is therefore a function of the number of individuals and also how hard each individual is to detect.

Key Point!!--This guarantees heterogeneous detection probabilities and the need for models which allow this!!

Table 3.1. Capture-recapture models for closed populations that allow for unequal capture probabilities. Monograph with minor changes.

Source	*of*	*variation*	*in*	*capture probability*
Model*	Heterogeneity	Trap response	Time	Estimator availability
M_o				yes
M_h	X[a]			yes
M_b		X		yes
M_{bh}	X	X		yes
M_t			X	yes
M_{th}	X		X	yes
M_{tb}		X	X	yes
M_{tbh}	X	X	X	no

*This set of 8 models comes from Otis et al. (1978).

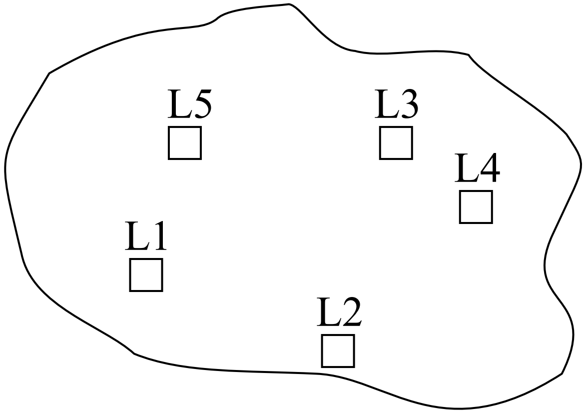
[a] Xs denote the sources of variation in capture probability incorporated in the models.

Sample Situations/Designs

- Have replicated counts
  - Over space
  - Over time
  - Over observers
- Don’t have replicate counts
  - Use empirical species abundance distribution in a modeified heterogeneity model.

Replicated counts (over space) at single time

Quadrat samples



Model issues:

M_h(detection probs vary by species)

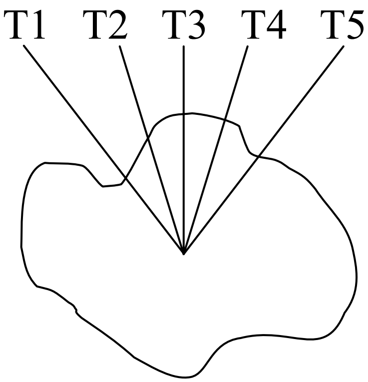
M_{th}(spatial variation in detection prob)

Short interval: Closed population model

-Estimate N

Replicated counts (over time) at single site

Multiple species lists



Short interval: Closed population models

-Estimate N

Useful Models

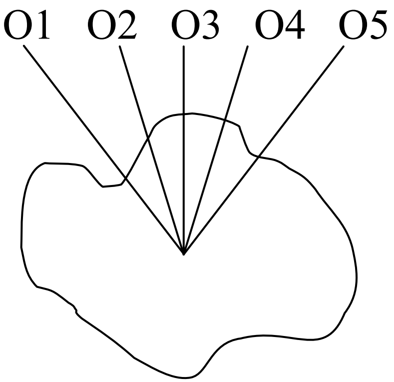
M_h (detection probs vary by species)

M_{bh} (Same observer more likely to redetect a species)

M_{th}(conditions vary across sample periods)

Replicated counts (over observers) at single site

Multiple species lists



Model issues:

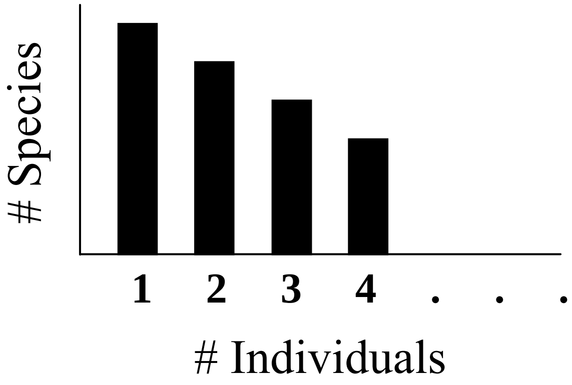
M_h(detection probs vary by species)

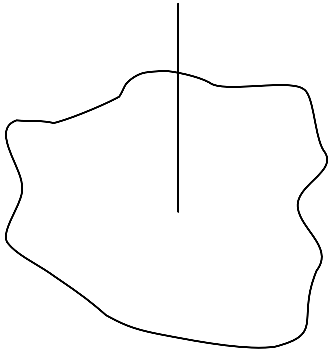
M_{th}(detection probs also vary across observers)

Short interval: Closed population models

-Estimate N

Summary of information used in SPECRICH





Empirical Species Abundance Distribution Approach (Burnham and Overton 1979)

Empirical Species Abundance Distribution Estimation Approach

- This uses the first 5 frequencies and the total number of detected species
- f_1 is the # of species where one individual was detected. f_2 is the # of species where two individuals were detected.
- It is a modification of the Mh model. Use SPECRICH to compute interactively on the Patuxent Software archive Web Site.

Programs for Species Richness

- SPECRICH (Patuxent)**
  - Capture frequency only (reduced from input)
- SPECRICH2 (Patuxent)
  - Summarized capture history input for M_h
  - Observed species, observed frequencies
- CAPTURE and MARK**
  - All M_h varieties (most general)
  - Unsummarized capture histories

Survey Route in MD, Data from 1966 and 1992
Estimating Species Richness

- Data: Capture history condensed from 50 stops (capture occasions)
- Use program CAPTURE (M_h)
- Results:
  - 1966: Count: 64 spp; Estimate=75 (5.62)
  - 1992: Count: 50 spp; Estimate=83 (11.61)
- Notes-Look at raw counts vs estimates. Also there is no evidence of a change in N between the two occassions. (Size of SEs)

Summary

- Capture-Recapture estimators that allow for heterogeneity are useful and are better than just using the counts.
- There are a variety of sampling protocols which give rise to various estimators.
- Not adjusting and using the species counts as indices would be dangerous due to possible changes in detection probability over space, time or observers.

Practical Issues

- Species pools need to have a “reasonable” number of species for these estimators to work (>10?)
- If a species has a detection probability of 0, it will not be part of the sampled species pool and no adjustment can account for this.
- Some taxa (mammals, fish, amphibians) often need many sampling methods to find all the species. Therefore one would need multiple sampling methods on each occasion or at each location to apply these methods.

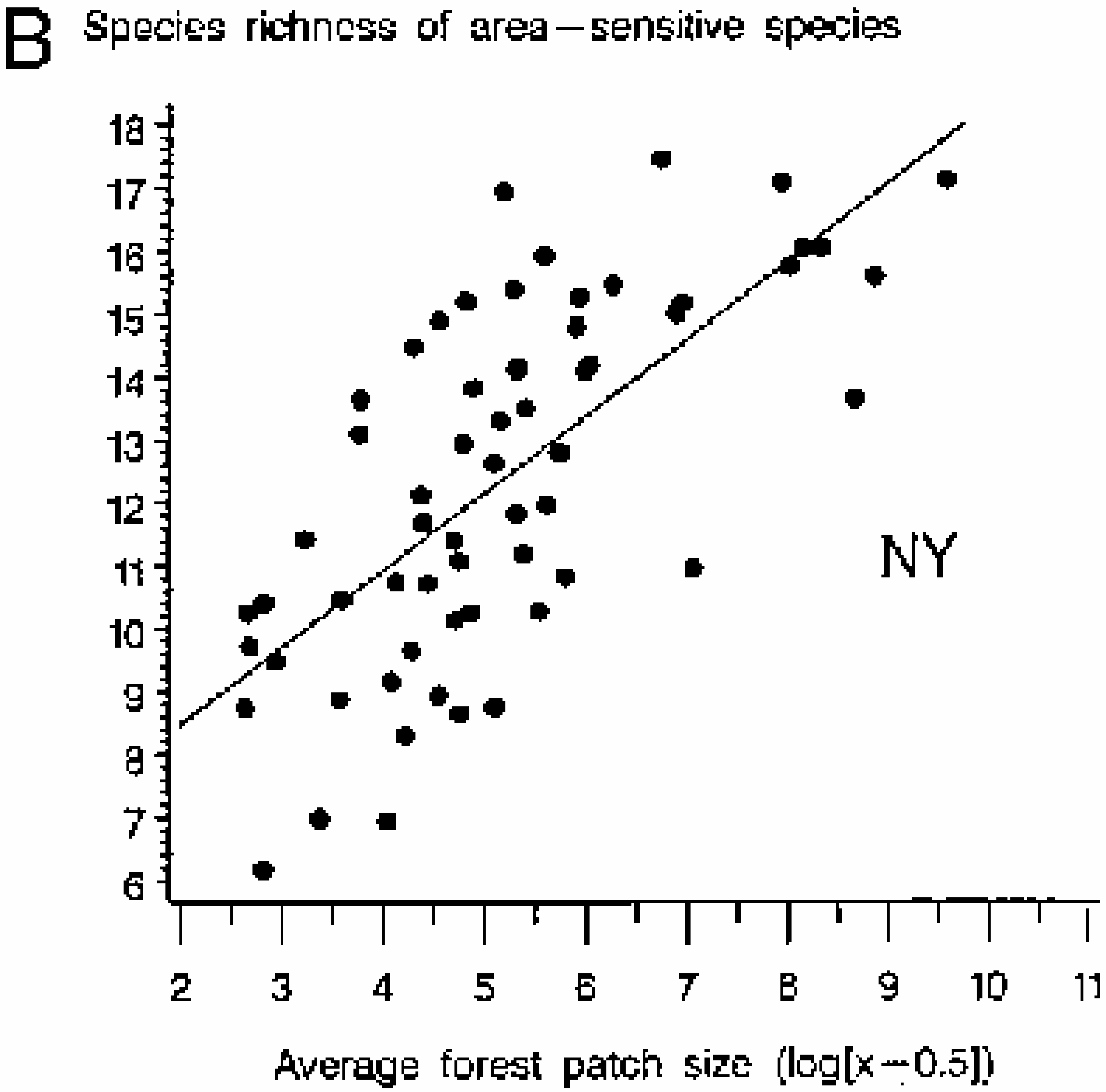
Nice Examples of Use of Species Richness

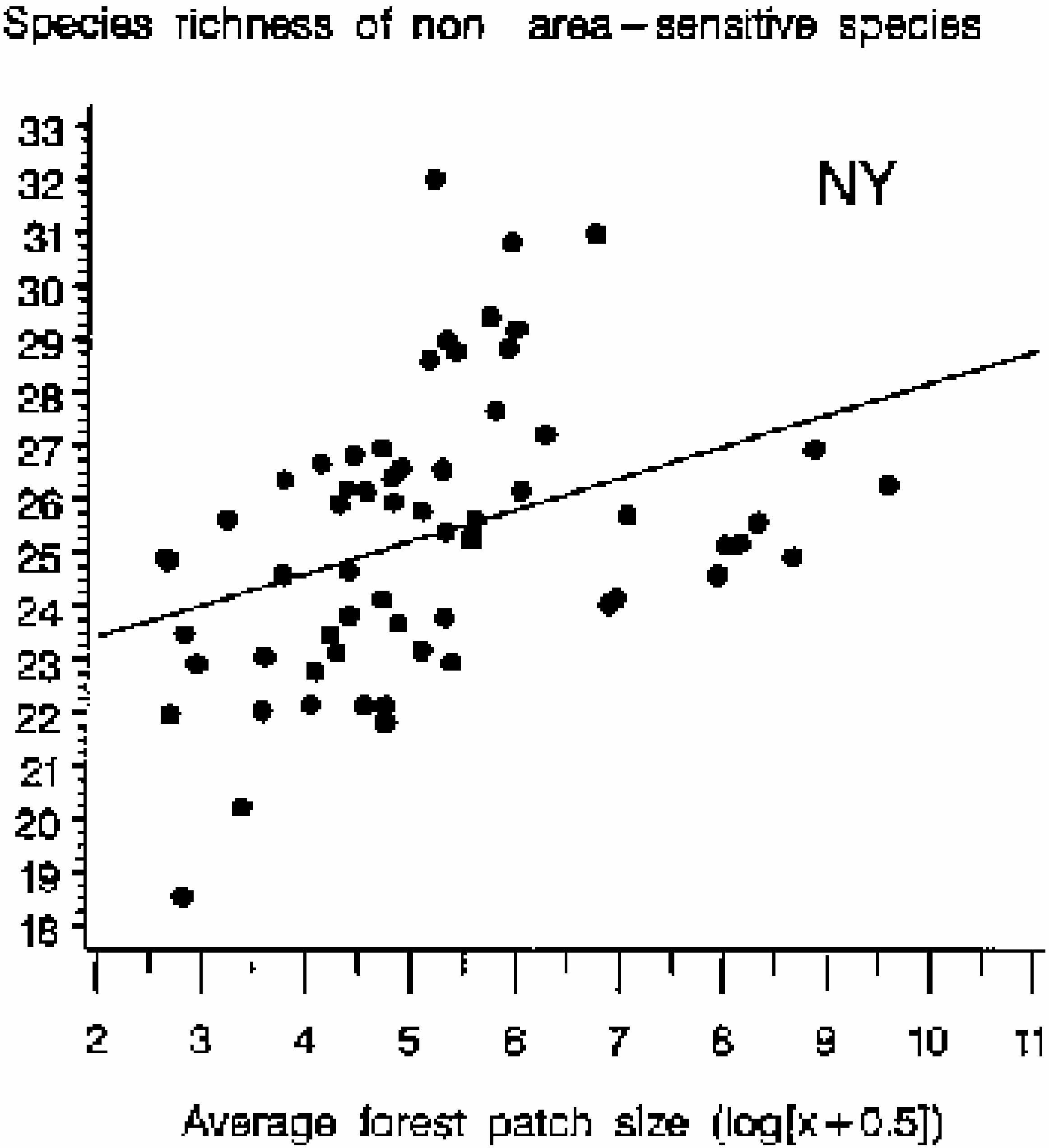
Boulinier et al. (1998). Estimating Species Richness: The Importance of heterogeneity in Species Detectability. Ecology. They used BBS data to illustrate the methodology

- Detection rates were heterogeneous by species
- Detection rates varied by state, observers. Therefore naïve species richness comparisons would have been dangerous.

Nice Examples of Use of Species Richness

- Boulinier et al. (1998). Higher temporal variability of forest breeding bird community in fragmented landscapes. Proc N Acad Sc.
- One figure in paper showed Species Richness of area sensitive birds to be strongly related to forest patch size whereas non area sensitive species richness less related to patch size. Used BBS data in NY State.

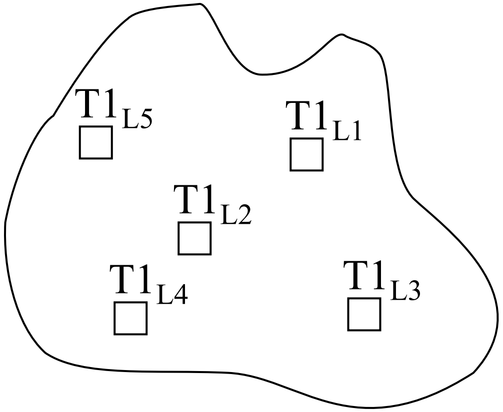

B
Species richness of area-sensitive species
18
17
16
15
14
13
12
11
10
9
8
7
6
NY
2
3
4
5
6
7
8
9
10
11
Average forest patch size (log[x+0.5])


Species richness of non area-sensitive species
NY
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
2
3
4
5
6
7
8
9
10
11
Average forest patch size (log[x+0.5])

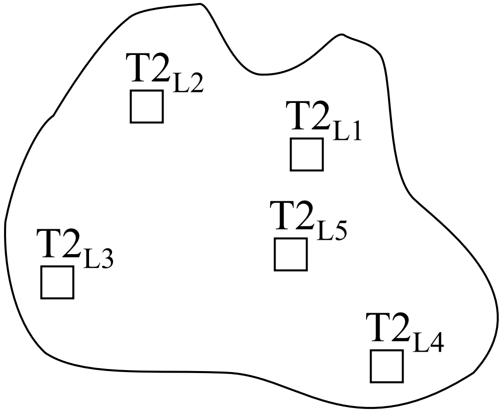
This Class: Community Temporal and Spatial Dynamics

- Read ahead in Ch 20 if you are interested.
- Many quantities of interest.
  - Change in N over time or space
  - Local Extinction
  - Local Colonization by new species
  - Number of New Species
- Will Use Robust Capture-Recapture Design
  - Estimate richness with closed models in a year
  - Estimate local colonization and extinction between years.

Robust Designs:



Time 1



Time 2

Robust design: Temporal Change Using Spatial Subsampling in primary periods

Estimation: Rate of Change

- Rate of change in species richness over time is defined similarly to the rate of change in population size. Here j refers to the most recent year and i to the earlier year.

$$\hat{\lambda}_{ij} = \hat{N}_j / \hat{N}_i$$

BBS Example: Rate of Change: Tables 20.4 & 5

MD

$$\hat{\lambda}_{70,90} = \hat{N}_{90} / \hat{N}_{70} = 69.4/78.5 = 0.88 (SE = 0.18)$$

WI

$$\hat{\lambda}_{70,90} = \hat{N}_{90} / \hat{N}_{70} = 99.9/77.2 = 1.29 (SE = 0.17)*$$

Estimation: Local Extinction Probability (1-φ_{ij})

- Probability that species present at *i* not present at *j*
- R_i = number of species present in year *i*
- $\hat{M}_j^{R_i}$ = estimated number of these species still present in year *j*

$$\hat{\phi}_{ij} = \frac{\hat{M}_j^{R_i}}{R_i}$$

- Estimate obtained using model M_h on the subset of species that were present at time i.
- Local extinction rate is then 1-this "survival" estimate.

BBS Example: Local Persistence and Extinction Probabilities (1-φ_{ij})

MD

$$\hat{\phi}_{70,90} = \frac{\hat{M}_j^{R_i}}{R_i} = \frac{54.7}{65.0} = 0.84(SE = 0.15)$$

WI

$$\hat{\phi}_{70,90} = \frac{\hat{M}_j^{R_i}}{R_i} = \frac{61.6}{66.0} = 0.93(SE = 0.09)$$

Estimation: Local NonTurnover (φ_{ji}) and Turnover Probabilities ($1-\varphi_{ji}$)

- Probability that species selected at random in year *j* is a “new” species (not present in year *i*)
- Estimation
  - Using the extinction probability estimator with data placed in reverse time order (see text)
- R_j = number of species present in year *j*
- $\hat{M}_i^{R_j}$ = estimated number of species observed in *j* that were also present in *i*

$$\hat{\phi}_{ji} = \frac{\hat{M}_i^{R_j}}{R_j}$$

BBS Example: Local Turnover Probability (1-φ_{ji})

MD

$$\hat{\phi}_{90,70} = \frac{\hat{M}_i^{R_j}}{R_j} = \frac{51.1}{55.0} = 0.93(SE = 0.09)$$

WI

$$\hat{\phi}_{90,70} = \frac{\hat{M}_i^{R_j}}{R_j} = \frac{62.5}{80.0} = 0.78(SE = 0.16)$$

1-Value gives you turnover!!

Estimation: Number of Colonizing Species

- The number of species not present at time *i* that colonize and are present at time *j*. New colonisers

$$\hat{B}_{ij} = \hat{N}_j - \hat{\varphi}_{ij}\hat{N}_i$$

- Number of surviving species is subtracted from species richness at j.

Example: Number of Colonizing Species

$$MD$$

$$\hat{B}_{70,90} = \hat{N}_{90} - \hat{\varphi}_{70,90}\hat{N}_{70} = 69.4 - 0.84x78.5$$

$$= 3.4?(3.3\text{Table})$$

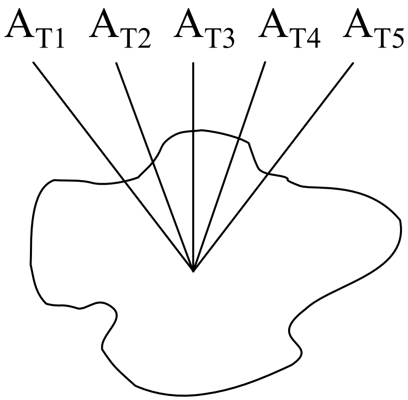
$$WI$$

$$\hat{B}_{70,90} = \hat{N}_{90} - \hat{\varphi}_{70,90}\hat{N}_{70} = 99.9 - 0.93x77.2$$

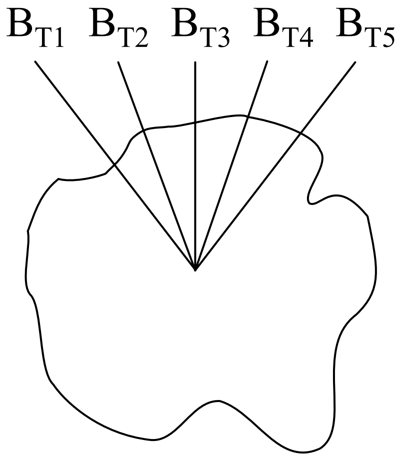
$$= 28.1?(27.9\text{Table})$$

There are Spatial Versions of the Robust Design

- This can be used to estimate species co-occurences at different places.

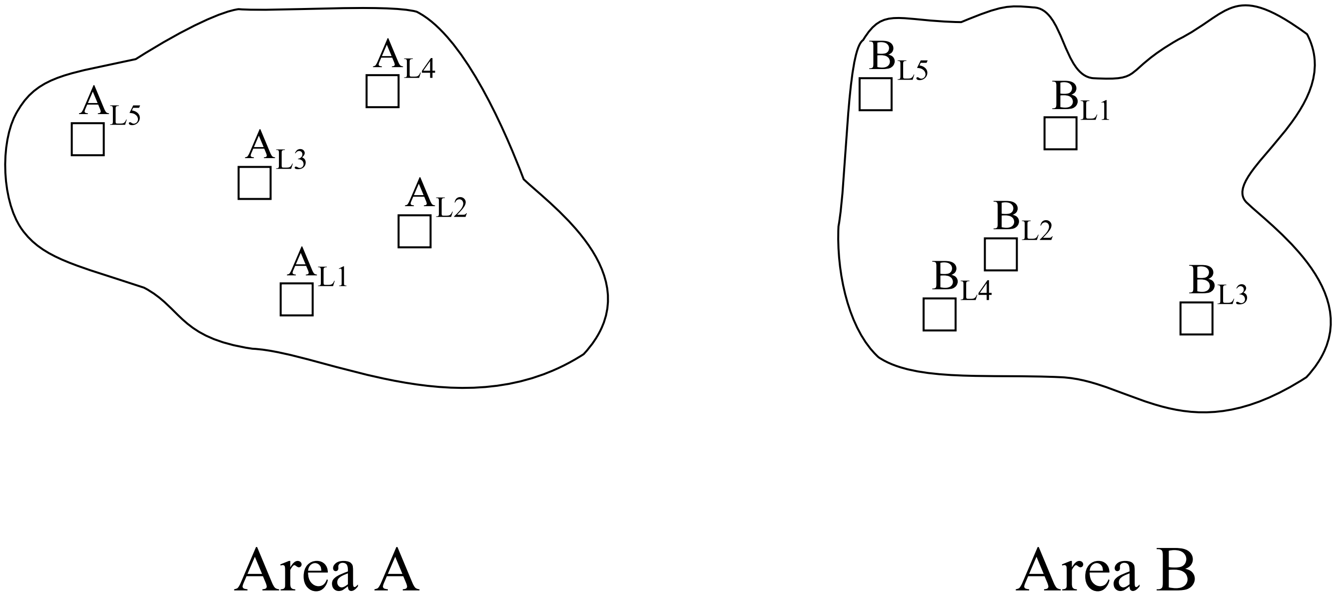


Area A

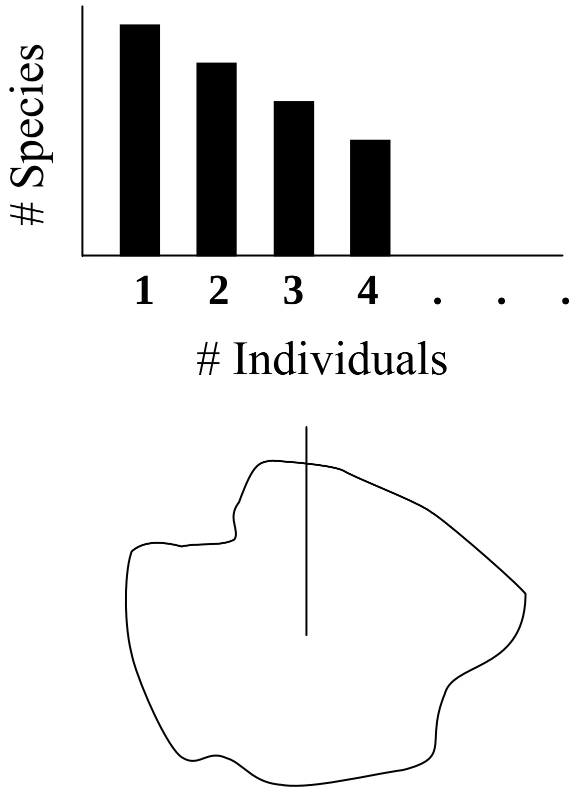


Area B

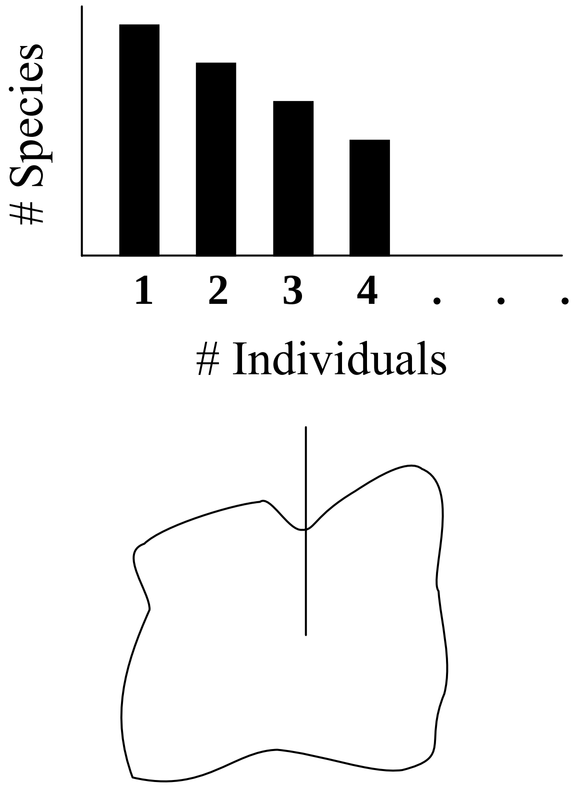
Spatial robust design: temporal subsampling within primary periods



Spatial robust design: Spatial subsampling within units



Area A



Area B

Spatial robust design: Spatial subsampling with capture frequences

Interesting Example

Boulinier et al.(2001). Forest Fragmentation and Bird Community Dynamics: Inference at Regional scales. Ecology.

- Sp Richness lower in smaller patches as in their earlier papers
- Also local extinction and turnover rates were higher in smaller patches for area sensitive species.

Conclusions

- Species Richness estimates should take account of uncertain detection.
- Can extend ideas to study community dynamics. Important implications for conservation biologists.
- Local extinction, turnover and colonisation rates can all be estimated in a logical way with appropriate standard errors.

Reminder: Metrics Ecologists Use

Population of a Species
Abundance and Relative Abundance
Population Dynamics
(Earlier Lectures in Class)

Metapopulations of a Species
Abundance and Dynamics by Patch
(Multi-State Models Lectures)
*Patch Occupancy and Dynamics
(Begin Now, Final Topic)

Communities
Species Richness and Community Dynamics
(Lecture 24-25)

Ecological Metrics: Different Choices for Different Situations

One Common Theme in the Recent Research on all Metrics is the Need To Account For Detection Probability

Reminder: Individual Species Metrics

- Population Metrics
  - Abundance
    - Relative Abundance Indices
    - Absolute (Popn Size or Popn Density)
  - Demographic Parameters
    - Survival Rates
    - Recruitment Rates
    - Movement (Emigration and Immigration)

Sometimes We Want Individual Species Metrics that Cover Larger Spatial Scales and also One that May Be Easier to Measure than these Common Popn Metrics

Brief Introduction to Occupancy

Costs and larger Scale lead to the use of occupancy metrics.

Patch Occupancy Rate Metric: The Problem

- Conduct “presence-absence” (detection-non detection) surveys for a particular species of interest
- Estimate what fraction of sites (or area) is occupied by a species (ψ) when the species is not always detected with certainty, even when present (i.e. $p < 1$)
- Naïve Occupancy rate estimates are biased low because some sites where the species was not detected are occupied.
- In other words apparent absence of a species from a site may just be a failure to detect the species. This could be be because individuals are hard to detect or because the species is very rare or both!!
- Also can we detect changes in the occupancy rate temporally or spatially.

Patch Occupancy Metric: Motivation

Some Reasons why the Information may be Needed

- Extensive Monitoring Programs
- Geographic Range Changes (climate change, habitat fragmentation, pollution)
- Meta Population Processes
- Habitat Selection
- Invasive Species Spread

Occupancy Estimation: Reference

MacKenzie, D. I., Nichols, J. D., Royle, J. A., Pollock, K. H., Bailey, L. L., and Hines, J. E. (2005).

Occupancy Estimation and Modeling : Inferring Patterns and Dynamics of Species Occurrence.

Elsevier, San Diego, USA.

Make Sure You all Run Out and Buy It as I need the Royalties!

Model Parameters

ψ_i -probability site *i* is occupied

p_{ij} -probability of detecting the species in site *i* at time *j*, given species is present

Patch Occupancy Metric: Key Design Issue is "Replication" to Estimate Detection Probability

- Replication is crucial if we are to separate occupancy from detection probability. There are several types of replication possible.
- Usual method is **temporal replication**: several repeat visits to sample units within a relatively short period of time (e.g., a breeding season)
- **Spatial replication**: randomly select a subsample of sites within each sample unit
- **Observer replication**: have several observers go to each site independently

Typical Occupancy Data

100 Sites visited 5 times 1 species detected 0 species not detected

Site	Detection History
1	10011
2	11011
3	00011
4	00000- site never detected as occupied
5	00001
100	11110

A Probabilistic Model: Very Similar to Capture-Recapture Models in Concepts Used

Sites that are occupied, For example

Pr(detection history 1001) = Pr (h_i = 1001) =

$$\psi_i\left[p_{i1}\left(1-p_{i2}\right)\left(1-p_{i3}\right)p_{i4}\right]$$

Model: Key Issue, Apparent vs. True Absence

Sites where the species was not detected at all. These sites may or may not be occupied

Pr(detection history 0000) = Pr (h_k = 0000) =

$$\psi_k \prod_{j=1}^{4} \left(1 - p_{kj}\right) + \left(1 - \psi_k\right)$$

First Term- Site is Occupied but Species Escapes Detection

Second Term- Site is Unoccupied

Likelihood Inference

- In the next lecture We will talk about how to estimate the occupancy parameter and the detection probabilities, possibly as functions of covariates