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# A DATA-INTENSIVE ASSESSMENT OF THE SPECIES-ABUNDANCE DISTRIBUTION.

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ECOLOGY CENTER



# OPEN SCIENCE

- Code:
  - [github.com/embaldridge](https://github.com/embaldridge)
  - [github.com/weecology](https://github.com/weecology)
- Data: [figshare.com](https://figshare.com)

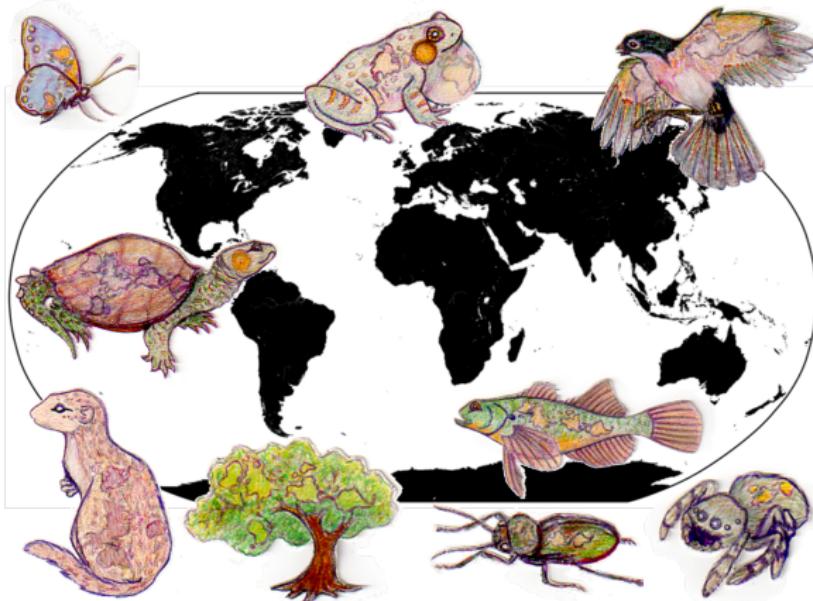


**figshare**  
credit for all your research



# MACROECOLOGY

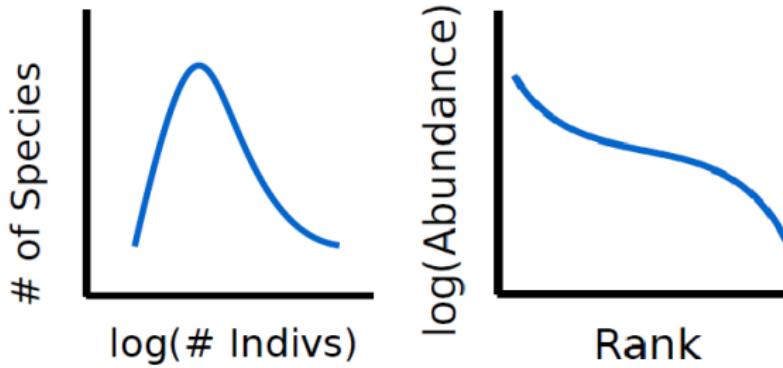
One approach for identifying general ecological patterns & processes.



## LET'S BEGIN WITH AN EXAMPLE...

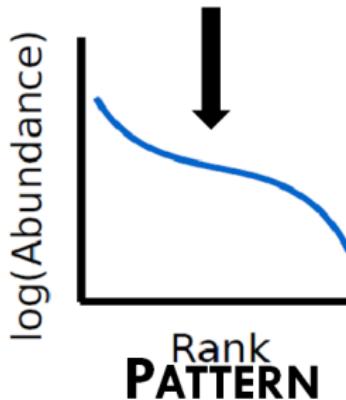
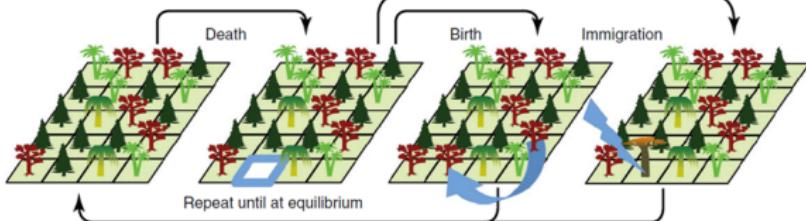
Species abundance distribution (SAD)

- Describes the distribution of commonness & rarity of species.



# LET'S BEGIN WITH AN EXAMPLE...

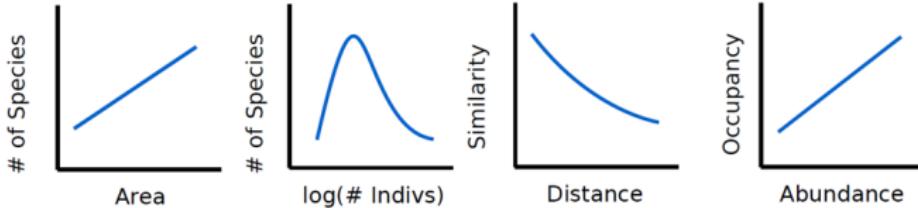
## PROCESS



# PATTERNS & PROCESS.

## Process

**COMPETITION    NICHES    DISPERSAL**  
**NUTRIENTS    NEUTRALITY    ETC.**



## Pattern

# PATTERN & PROCESS; SIGNAL & NOISE

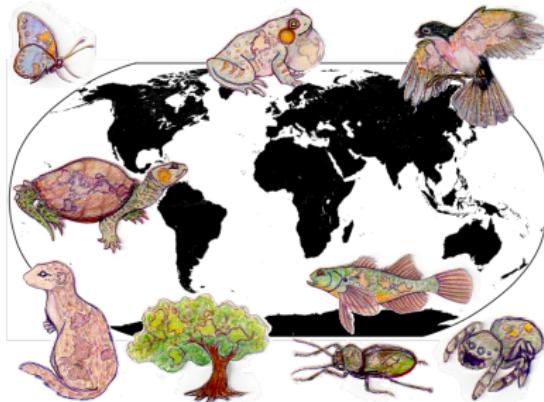


## CHALLENGES OF MACROECOLOGY

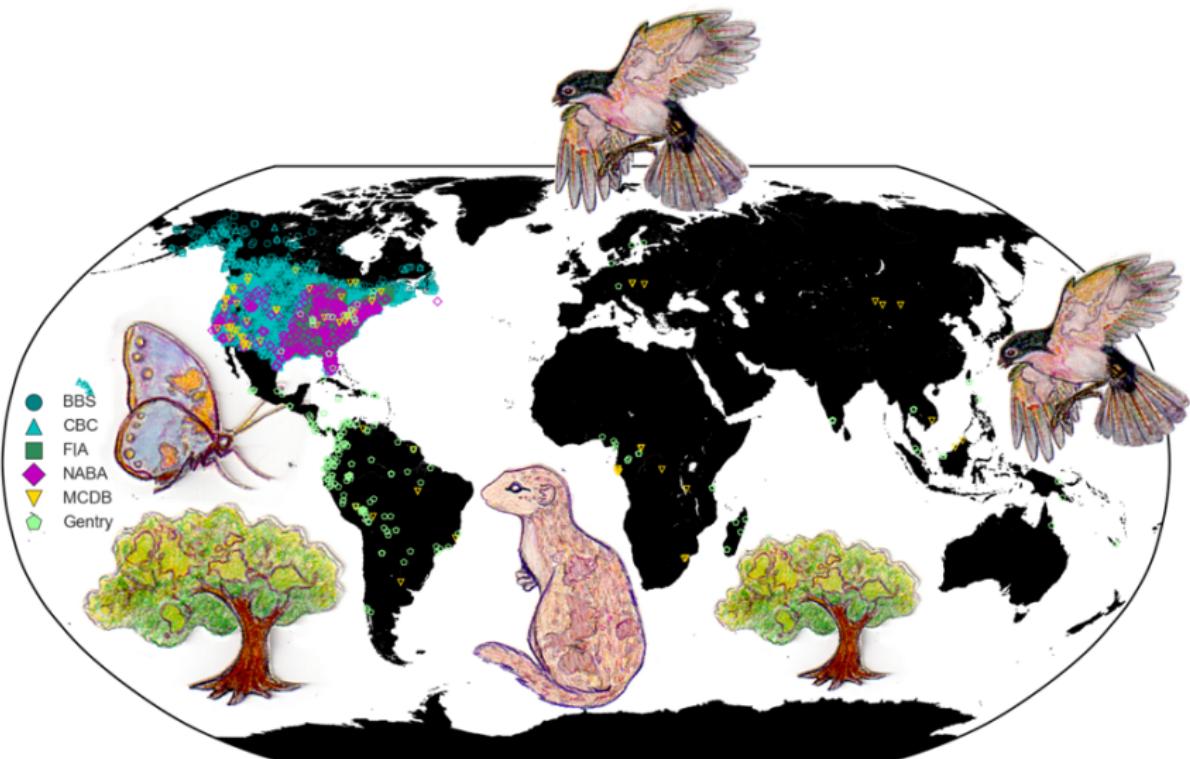
- Studies performed with a limited number of large datasets.
- Lack of identification of pattern generating mechanisms.

# BEST PRACTICE RECOMMENDATIONS

- Test multiple models with consistent statistical approach.
- Test with multiple taxonomic groups/ecosystems.



# CURRENT DATA



# MACROECOLOGICAL DATA

## Challenges of macroecology

- Limited number of large datasets.
- Lack of identification of process.

## Best practice recommendations

- Test with multiple taxonomic groups/ecosystems.

Plenty of data in the literature.

# THE RULES OF ECOINFORMATICS

Garbage in, garbage out.

- All data are good, not all data are appropriate.
- Fit the data to the question.

## BUILDING A DATABASE

- Decide on inclusion criteria.
- Decide what variables to collect.
- Decide on handling of missing data.
- Decide on database structure.
- Search for data.
- Sort papers into useable and not.
- Collect data.

Record decisions at all steps:

*Metadata are important.*

## ABUNDANCE DATABASE

Inclusion criteria:

- Quantitative abundances (counts).
- Complete sampling.
- Raw data (not heavily processed).
- High degree of taxonomic resolution.
- Observational.

# ABUNDANCE DATABASE

## Variables collected

Class  
Family  
Genus  
Species (Specific epithet)  
Abundance  
Collection Year, starting  
Collection Year, ending  
Site Name  
Biogeographic region  
Site notes  
Citation

TABLE : List of variables collected.

# DATA WRANGLING

- Fire and a Tallgrass Prairie Reptile Community: Effects on Relative Abundance and Seasonal Activity

^ v p. 14 (4 of 10) < >

14

JOHN F. CAVITT

TABLE 1. Number of individuals and relative abundance (#/100 Trap array days) by year and site for the 10 species of snakes and three species of lizards captured (\* indicates focal species).

Site	A			B		C		D		
	1994	1995	1996	1995	1996	1995	1996	1995	1996	Total
Number of Trap arrays	4	9	9	9	9	4	4	4	4	
<b>Snakes</b>										
* <i>Coluber constrictor</i>	33 9.37	44 5.82	52 6.64	58 7.67	20 2.55	4 1.82	31 7.75	15 7.81	28 7.00	
* <i>Thamnophis sirtalis</i>	5 1.42	12 1.59	9 1.15	15 1.98	10 1.28	21 9.55	10 2.50	26 13.54	7 1.75	115
<i>Elaphe emoryi</i>	2 0.57	13 1.72	3 0.38	3 0.40	7 0.89	5 2.27	3 0.75	8 4.17	4 1.0	48
<i>Lampropeltis getula</i>	5 1.42	5 0.66	6 0.77	7 0.93	7 0.89	1 0.45	1 0.25	1 0.52	5 1.25	38
<i>Lampropeltis triangulum</i>	3 0.85	1 0.13	3 0.38	7 0.93	4 0.51	— —	1 0.25	3 1.56	4 1.0	26
<i>Pituophis catenifer</i>	— —	— —	2 0.26	3 0.40	— —	2 0.91	2 0.5	5 2.60	12 3.0	26
<i>Elaphe obsoleta</i>	4 1.14	1 0.13	1 0.13	— —	2 0.26	— —	— —	— —	— —	8
<i>Tropidoclonion lineatum</i>	2 0.57	— —	— —	2						
<i>Lampropeltis calligaster</i>	— —	— —	1 0.13	— —	— —	— —	— —	— —	— —	1
<i>Storeria dekayi</i>	— —	1 0.52	— —	1						
<b>Lizards</b>										
* <i>Ophisaurus attenuatus</i>	17 4.83	22 2.91	10 1.28	30 3.97	10 1.28	2 0.91	— —	— —	— —	91
<i>Eumeces obsoletus</i>	1 0.28	2 0.26	— —	6 0.79	1 0.13	— —	1 0.25	— —	— —	11
<i>Eumeces septentrionalis</i>	— —	1 0.13	— —	5 0.66	— —	— —	— —	— —	— —	6

# DATA WRANGLING

Three LibreOffice Calc windows are displayed side-by-side, illustrating data wrangling steps:

- Species\_abundances.csv - LibreOffice Calc**: A data frame showing species abundance across sites. Row 20 has a highlighted cell in column E.
- Sites\_table\_abundances.csv - LibreOffice Calc**: A table mapping site IDs to names and locations. Site 10 is highlighted.
- Citations\_table\_abundance.csv - LibreOffice Calc**: A bibliography table with columns for citation ID, authors, year, and title. Citation 1 is highlighted.

**Species\_abundances.csv Data (approximate values):**

	A	B	C	D	E	F	G	H
1	Class	Family	Genus	Species	Relative_abundance	Abundance	Site_ID	Citation
2	Reptilia	Pitophis	catenifer		0	0	1	1
3	Reptilia	Lampropeltis	calligaster		0	0	1	1
4	Reptilia	Storena	dekayi		0	0	1	1
5	Reptilia	Eumeces	septentrionalis		0	0	1	1
6	Reptilia	Eumeces	obsoleteus	0.28	1	1	1	
7	Reptilia	Elaphe	emoryi	1.72	2	1	1	
8	Reptilia	Tropidoclonion	lineatum	0.57	2	1	1	
9	Reptilia	Lampropeltis	triangulum	0.85	3	1	1	
10	Reptilia	Elaphe	obsoleta	1.14	4	1	1	
11	Reptilia	Thamnophis	sirtalis	1.42	5	1	1	
12	Reptilia	Lampropeltis	getula	0.66	5	1	1	
13	Reptilia	Ophisaurus	attenuatus	4.83	17	1	1	
14	Reptilia	Coluber	constrictor	9.37	33	1	1	
15	Reptilia	Pitophis	catenifer	0	0	2	1	
16	Reptilia	Tropidoclonion	lineatum	0	0	2	1	
17	Reptilia	Lampropeltis	calligaster	0	0	2	1	
18	Reptilia	Storena	dekayi	0	0	2	1	
19	Reptilia	Lampropeltis	triangulum	0.13	1	2	1	
20	Reptilia	Elaphe	obsoleta	0.13	1	2	1	
21	Reptilia	Eumeces	septentrionalis	0.13	1	2	1	
22	Reptilia	Eumeces	obsoleteus	0.26	2	2	1	
23	Reptilia	Lampropeltis	getula	0.77	5	2	1	
24	Reptilia	Thamnophis	sirtalis	1.59	12	2	1	
25	Reptilia	Elaphe	emoryi	0.38	13	2	1	
26	Reptilia	Ophisaurus	attenuatus	2.91	22	2	1	
27	Reptilia	Coluber	constrictor	5.82	44	2	1	
28	Reptilia	Tropidoclonion	lineatum	0	0	3	1	
29	Reptilia	Storena	dekayi	0	0	3	1	
30	Reptilia	Eumeces	obsoleteus	0	0	3	1	

**Sites\_table\_abundances.csv Data (approximate values):**

A	B	C	D	E	F	G	H
3	1996	1	Konza A	Nearctic	20	hectares, burned 1980	1985
5	1996	1	Konza B	Nearctic	80	hectares, burned in 1980.	1986
7	1996	1	Konza D	Nearctic	36	hectares, annual burn 1972-197	1991
2	1995	1	Konza C	Nearctic	90	hectares, burned 1980.	1985, 1
4	1995	1	Konza B	Nearctic	80	hectares, burned in 1980.	1986
6	1995	1	Konza C	Nearctic	36	hectares, annual burn 1972-197	1991
8	1995	1	Konza D	Nearctic	36	hectares, burned 1980.	1991
1	1994	1	Konza A	Nearctic	90	hectares, burned 1980.	1985, 1
10	1980	2	Treatment A	Neotropical	Artificial fall	removals monthly for	

**Citations\_table\_abundance.csv Data (approximate values):**

A	B	C	D
Citation_ID	Authors	Yr	Title
1	Cavitt, John F.	2000	Fire and a tallgrass prairie reptile community: Effects on re
2	Bullman, T.L. and G.	1982	Abundance and community structure of forest floor spiders
3	Schlosser, I.J.	1985	Flow regime, juvenile abundance, and the assemblage stru
5	Jones, K. B.	1981	Effects of grazing on lizard abundance and diversity in We
6	Grossman, G.D.	1982	Dynamics and organization of a rocky intertidal fish assem
4	Brandt, A.	1997	Abundance, diversity and community patterns of epibenthic
8	Ortizchillo, W and En	1982	Responses in abundance and diversity of cornfield carabid
10	Petterson, R.B.	1996	Effects of forestry on the abundance and diversity of arbo
12	Menke, S.B.	2003	Lizard community structure across a grassland- creosote b

# DATA WRANGLING

The image shows four terminal windows side-by-side, each displaying a different CSV file or dataset.

- Metadata.txt:** A plain text file containing an introduction and metadata class descriptions.
- Species\_abundances.csv:** A CSV file with columns: Class, Family, Genus, Species, Relative\_abundance, Abundance, Site\_ID, Citation. The data includes various reptile species and their abundance across different sites.
- Sites\_table\_abundances.csv:** A CSV file with columns: Site\_ID, Collection\_Year, End\_Collection, Citation\_ID, Site\_Name, Biogeographic\_region.
- Citations\_table\_abundances.csv:** A CSV file with columns: Citation\_ID, Authors, Yr, Title, Journal, Issue, Pages. It lists scientific publications related to the study.

**INTRODUCTION**  
This dataset was developed to provide a source of abundance data for groups that do not have extensive compilations of abundance data.

There are several caveats to the use of this database. Abundance has been recorded as the raw abundance or the relative abundance, depending on what was available from the original source. Abundance is the total number of individuals captured, relative abundance is the total number of individuals captured for a single species/ total number of individuals of all species.

METADATA CLASS I. DATA SET DESCRIPTIONS

A. Data set identity:

- Title: MiscAbundance

B. Data set identification code:

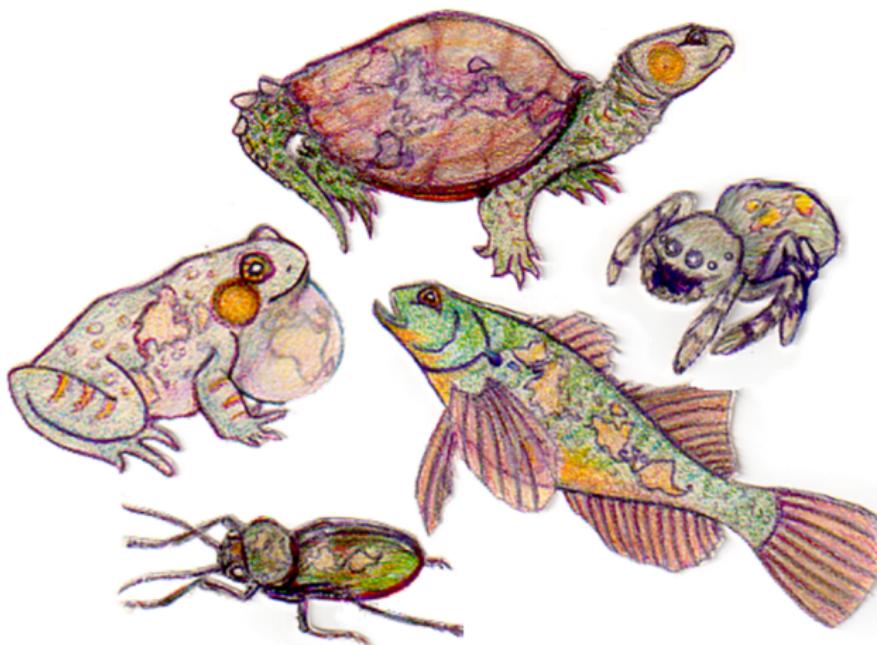
1. Abundance data: Species\_abundances.csv
2. Sites data file : Sites\_table\_abundances.csv
3. Reference file: Citations\_table\_abundances.csv

C. Data set description

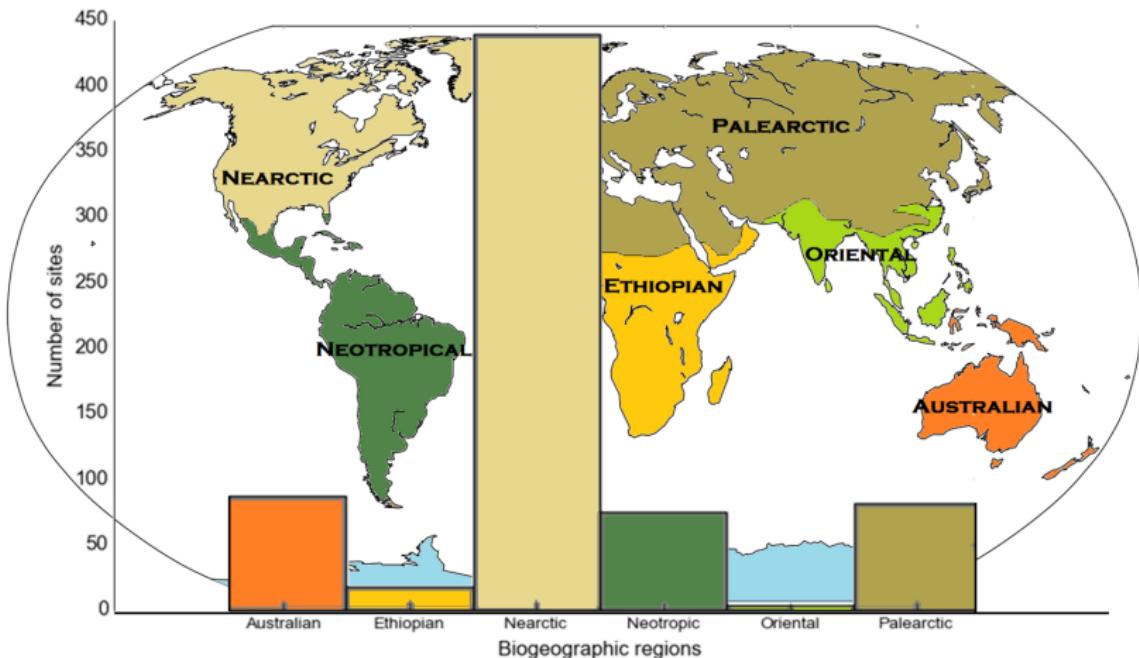
Principal Investigators:

Plain Text • Tab Width: 8 • Ln 6, Col 44

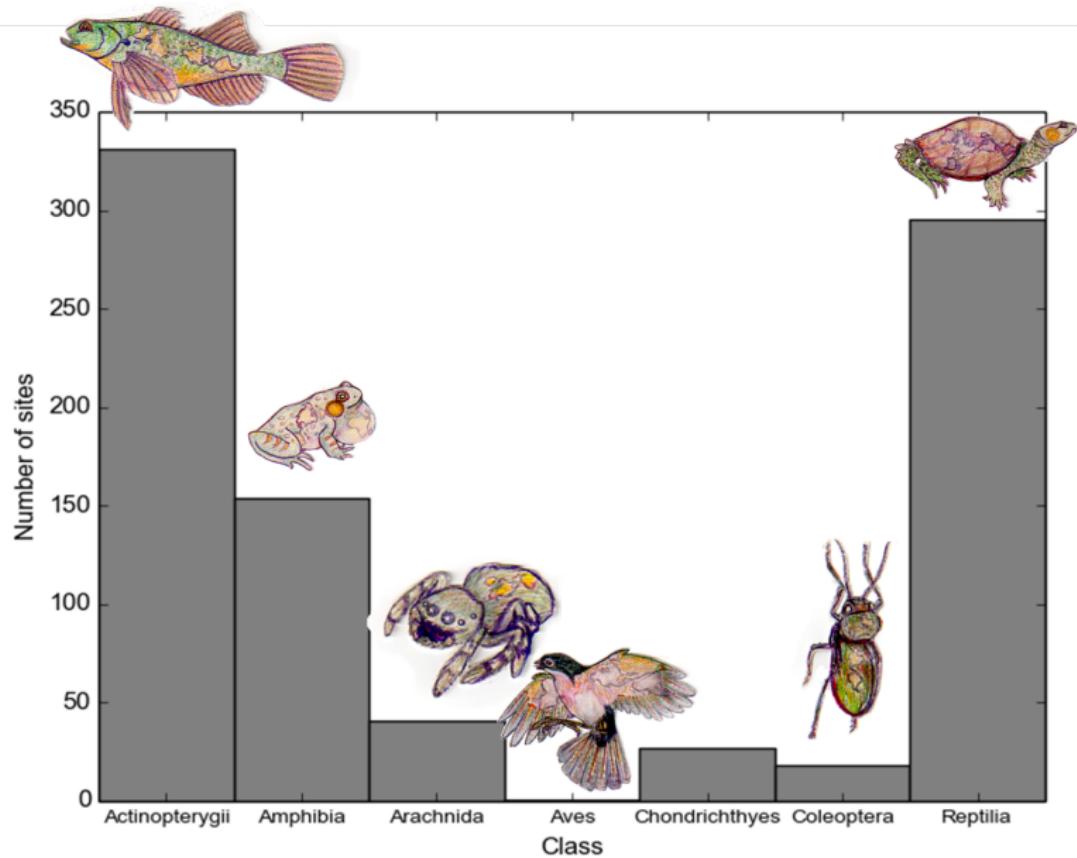
# ABUNDANCE DATABASE



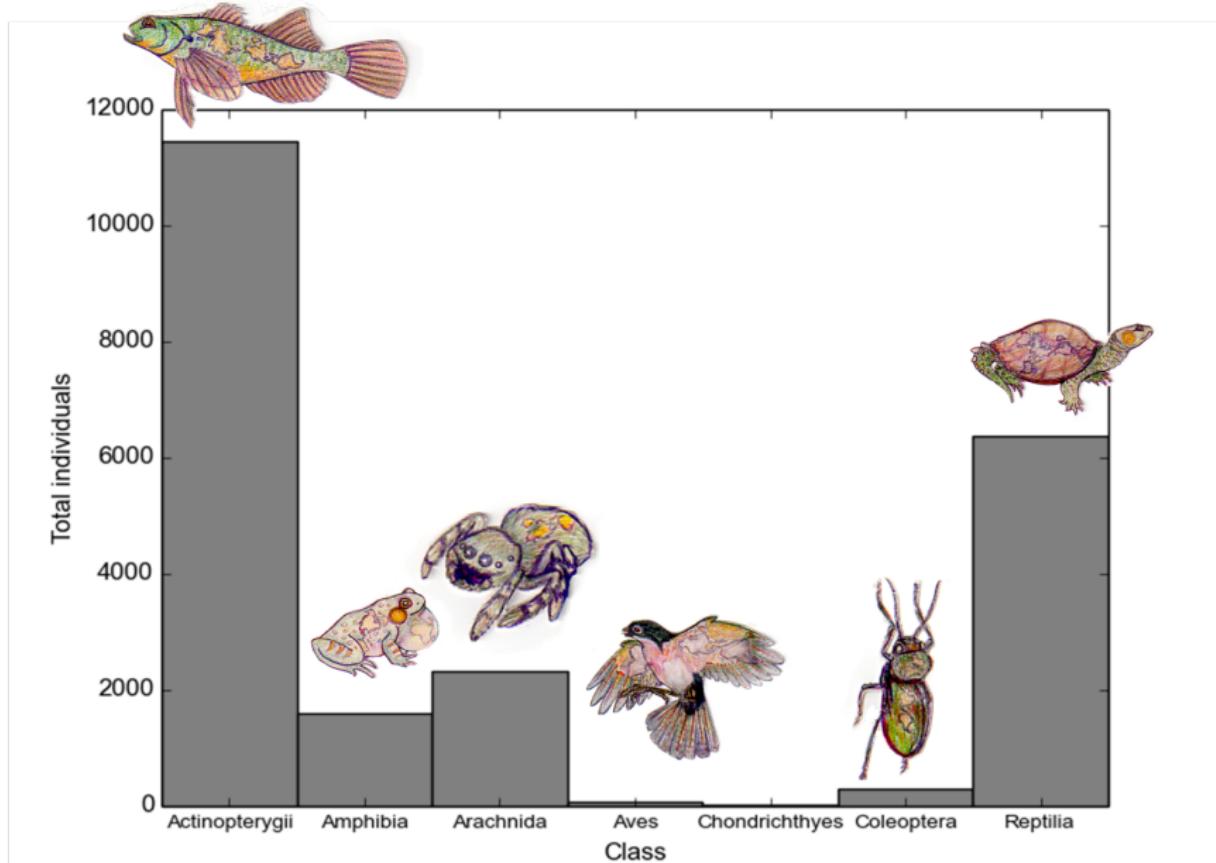
# ABUNDANCE DATABASE



# ABUNDANCE DATABASE



# ABUNDANCE DATABASE



## DATA AVAILABILITY

Public & open access through figshare.  
EcoData Retriever importable.

(<http://figshare.com>)

(<http://www.ecodataretriever.org>)

sad\_data =

ecoretriever::fetch('MiscAbundanceDB')



# DATA



# DATA



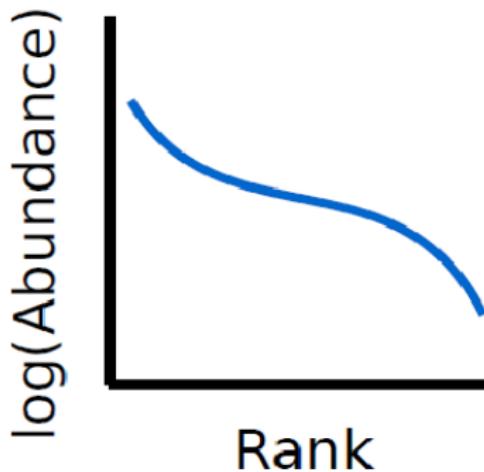
# SAD COMPARISONS

Dataset	Dataset code	Availability	Sites
Gentry's Forest Transects	Gentry	Public	10355
Breeding Bird Survey	BBS	Public	2769
Christmas Bird Count	CBC	Private	1999
Forest Inventory Analysis	FIA	Public	220
N. American Butterfly Count	NABA	Private	400
Actinopterygii, compiled	Actinopterygii	Public	161
Reptilia, compiled	Reptilia	Public	138
Mammal Community Database	MCDB	Public	103
Amphibia, compiled	Amphibia	Public	43
Arachnida, compiled	Arachnida	Public	25
Coleoptera, compiled	Coleoptera	Public	5

TABLE : Datasets used for species-abundance distribution comparisons.  
Datasets marked as Private obtained through data requests to the providers with  
Memorandums of Understanding.

## COMMONNESS & RARITY

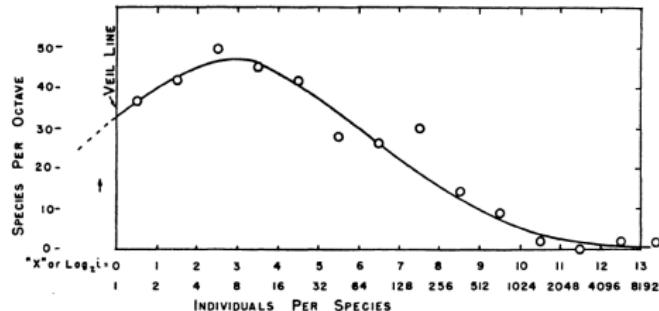
The species abundance distribution:



Many models of the species abundance distribution (SAD).

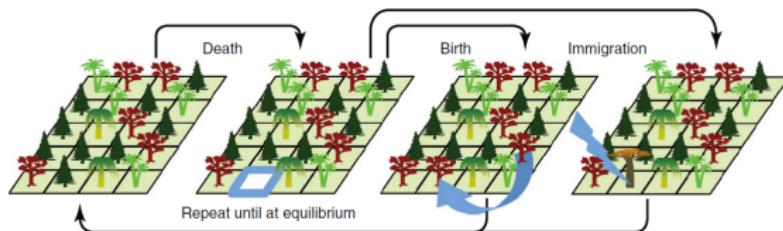
# SAD MODELS

## Statistical description



Preston 1962a.

## Process-based



Rosindell et al. 2011.

## SAD COMPARISONS

Most comparisons of the different models:

- Use only a small subset of available models (typically two).
- Focus on a single ecosystem or taxonomic group
- Fail to use the most appropriate statistical methods.

# SAD COMPARISONS

Selected five models from four classes for comparison.

Model class	Form of the distribution
Purely statistical	Logseries, Poisson lognormal
Branching process	Zipf
Population dynamics	Negative binomial
Niche partitioning	Geometric

TABLE : After B.J. McGill et al. 2007.

# SAD COMPARISONS

Analysis:

- Model fitting with maximum likelihood estimation.

$$l_x(\theta) = \log h(x) + \log f_\theta(x)$$

# SAD COMPARISONS

## Analysis:

- Likelihood based model selection to compare the fits of the different models.
  - Assess the fit of the model without corrections for parameter number or similarity to other models.
  - How well does the model describe the data?

# SAD COMPARISONS

## Analysis:

- Model comparison with corrected Aikaike Information Criterion (AICc) weights.
  - Assess the fit of the model correcting for parameter number and small sample size.
  - How well does the model describe the data relative to the number of parameters?
- The model with the greatest AICc weight was the "winner".

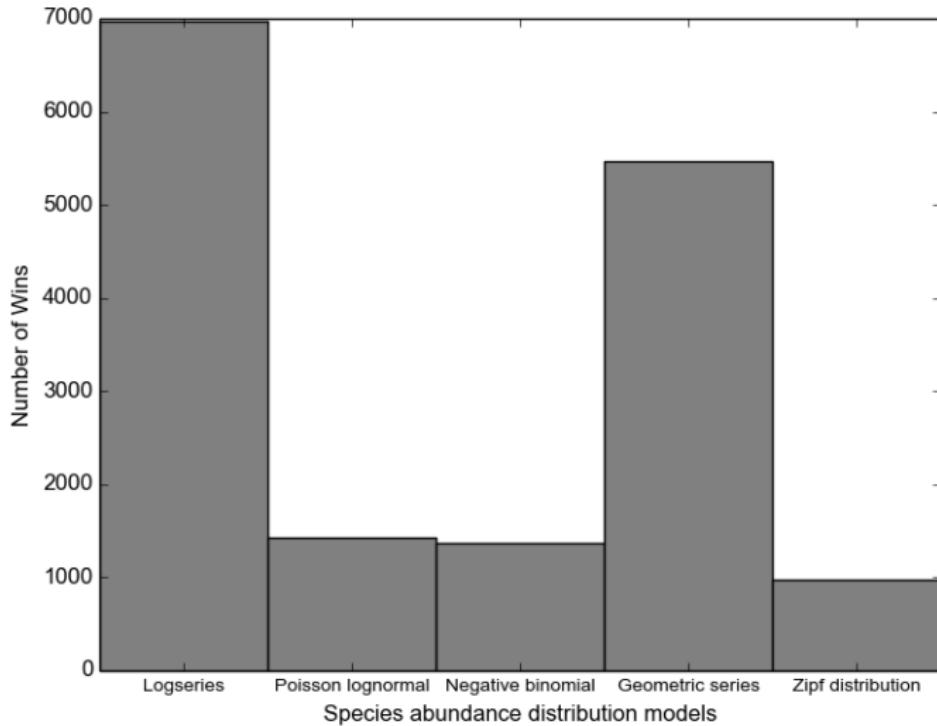
# SAD COMPARISONS

Computational tools:

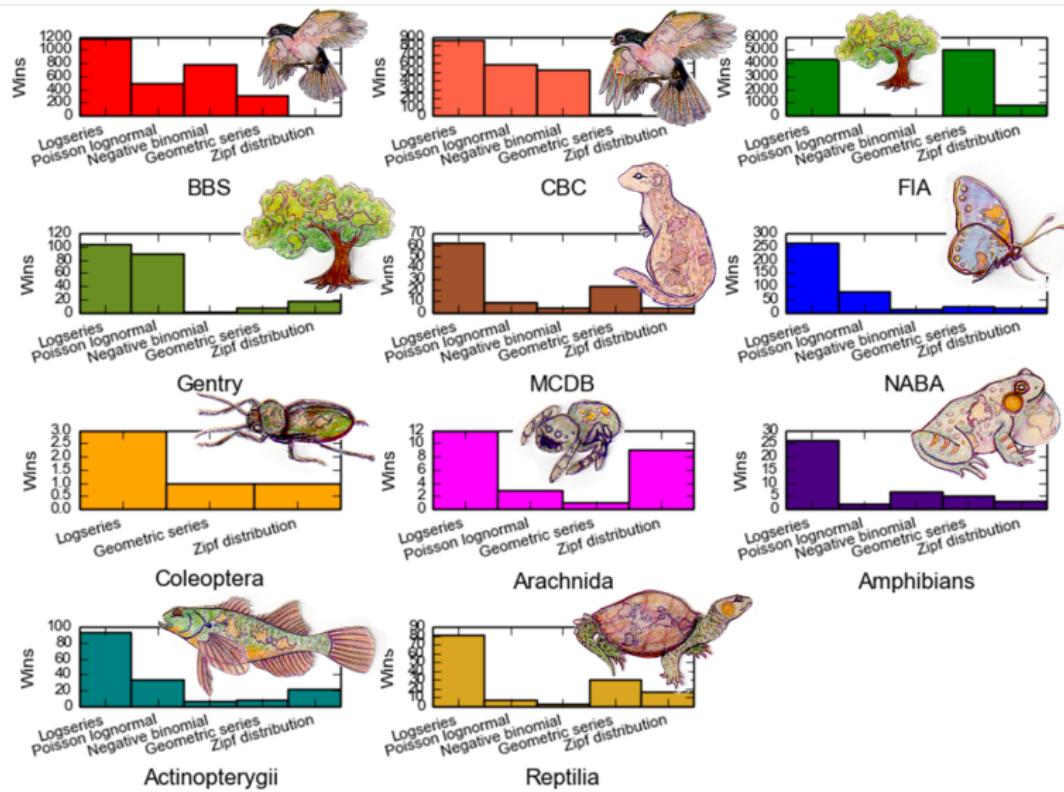
- Model fitting, log-likelihood, & AICc: macroecotools Python package.  
(<https://github.com/weecology/macroeccotools>)
- All code & majority of data are publicly available.  
(<https://github.com/weecology/sad-comparison>)



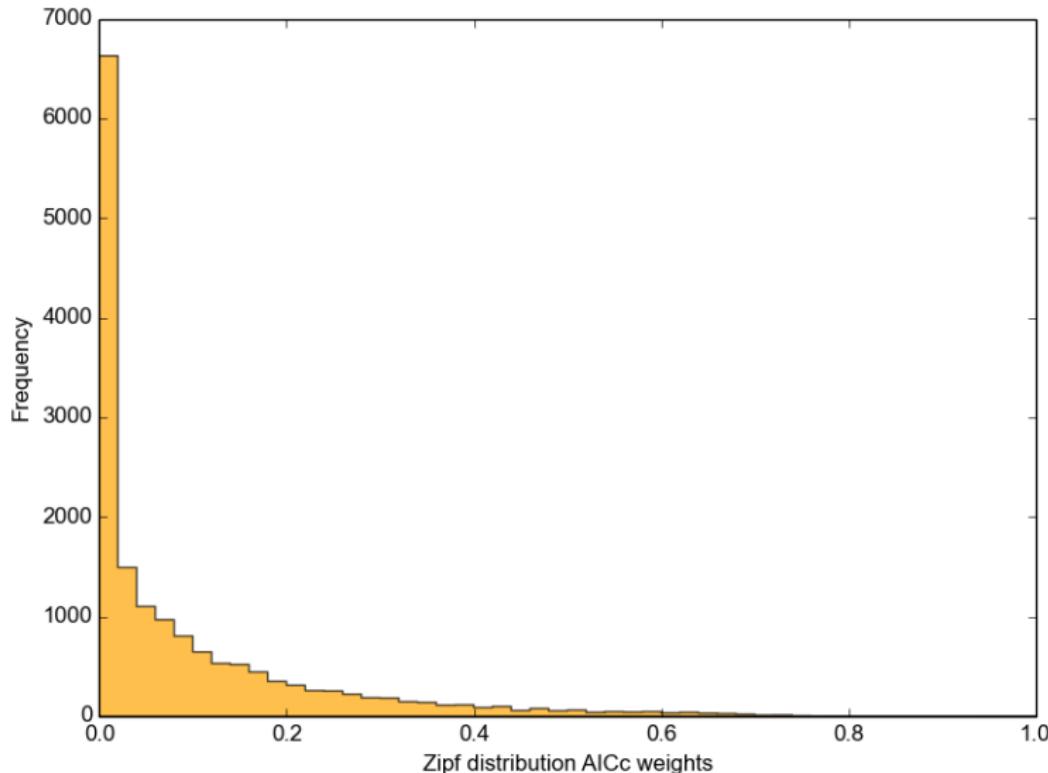
# SAD COMPARISONS



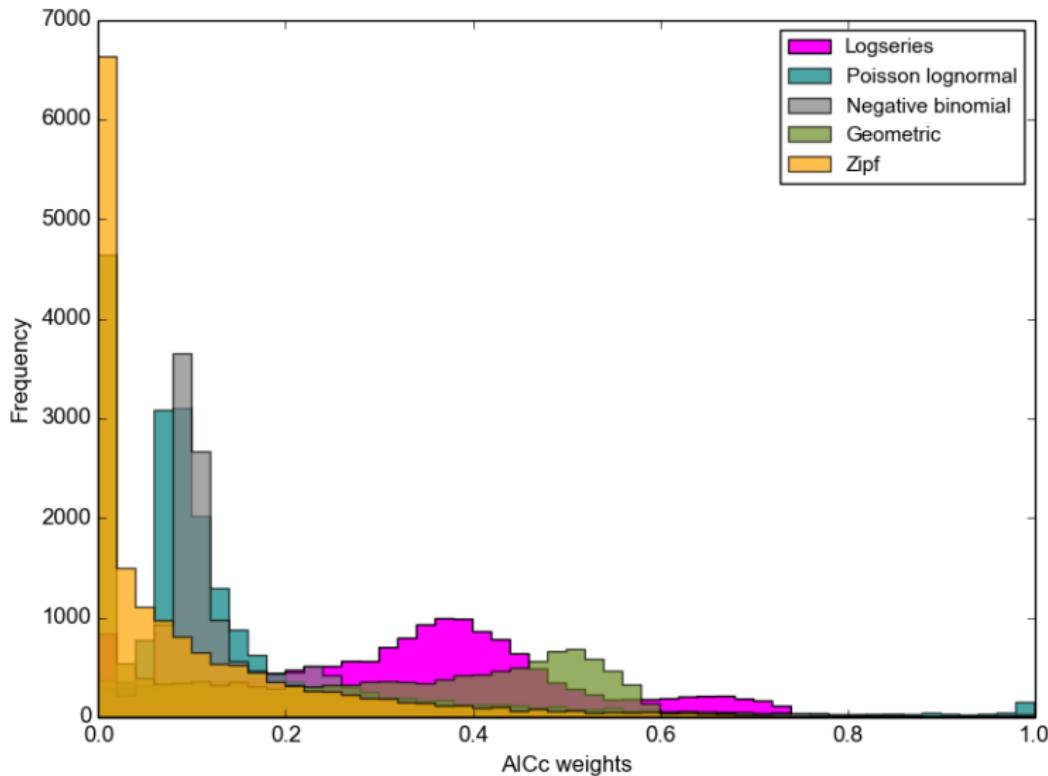
# SAD COMPARISONS



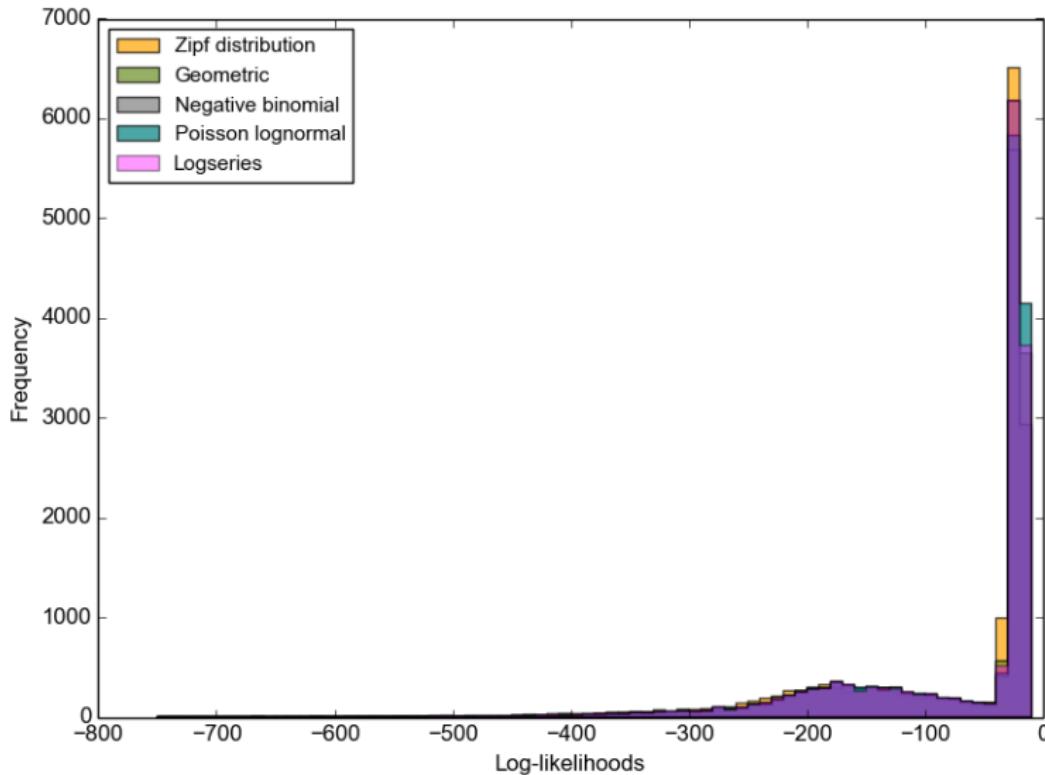
# SAD COMPARISONS



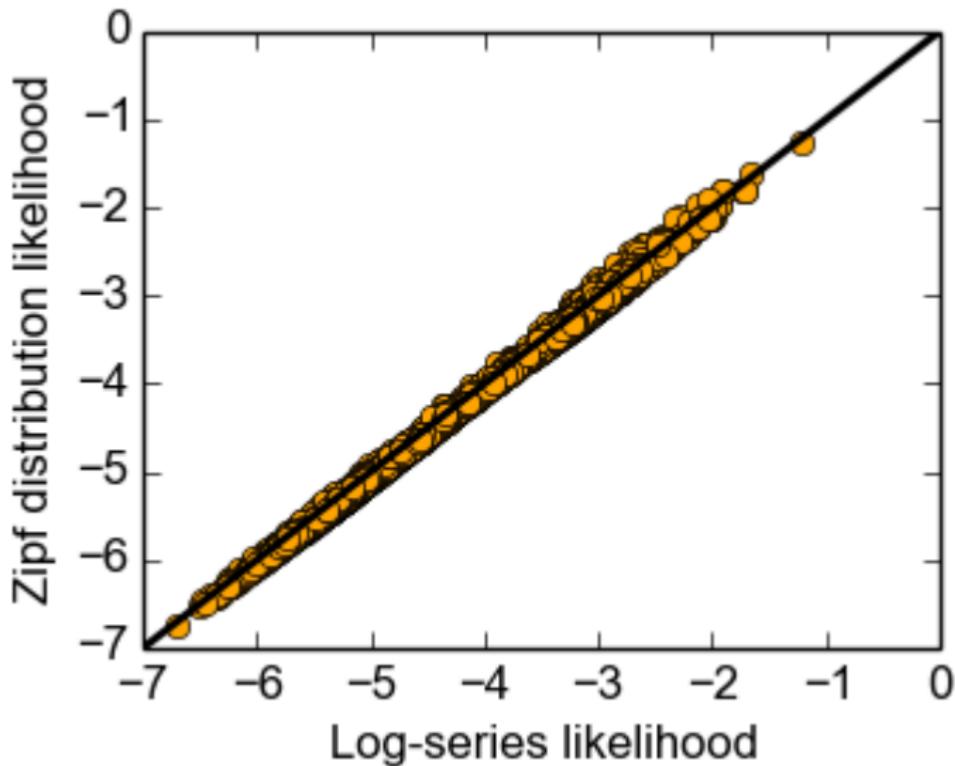
# SAD COMPARISONS



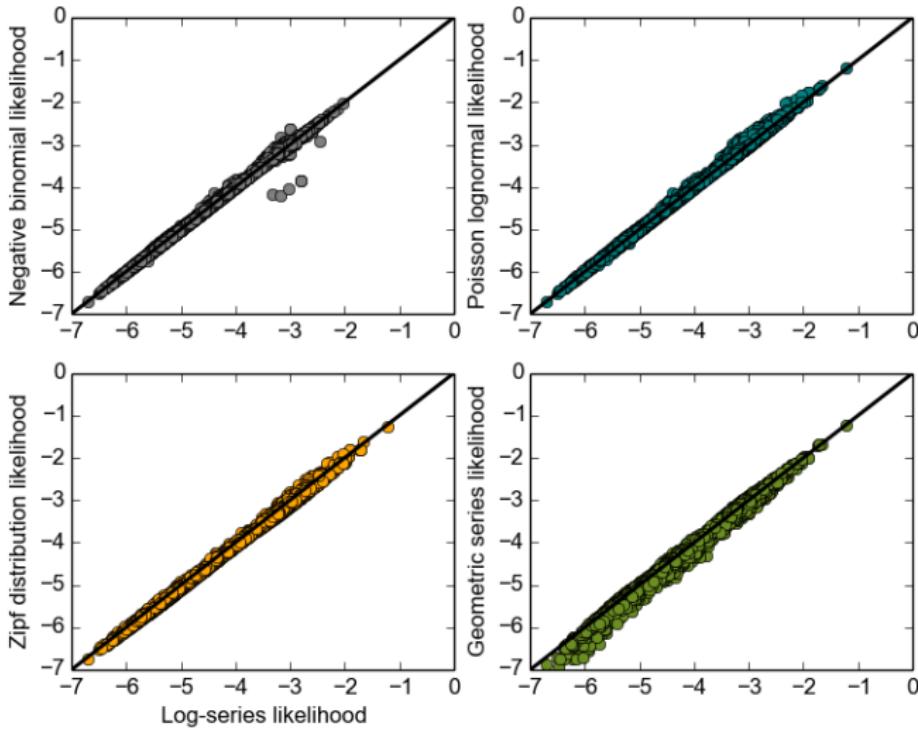
# SAD COMPARISONS



## SAD COMPARISONS



# SAD COMPARISONS



## SAD COMPARISONS

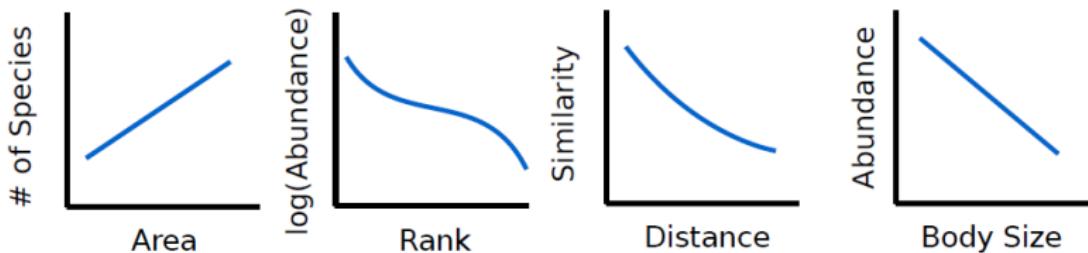
Existing models provide equivalently good absolute fits to empirical data.

- Models with fewer parameters perform better in AIC-based model selection.
- Logseries provides a good naive model for fitting SADs.
  - Produces equivalent likelihoods.
  - Has a single fitted parameter.
  - Easy to fit to empirical data.
  - Best overall model.

# SAD COMPARISONS

Identifying pattern generating mechanisms:

- Compare predictions of different models using multiple macroecological patterns simultaneously.



## SAD COMPARISONS

Identifying pattern generating mechanisms:

- Examine scale dependence of pattern.
- More general approach to process.

## NEUTRAL ANALYSIS

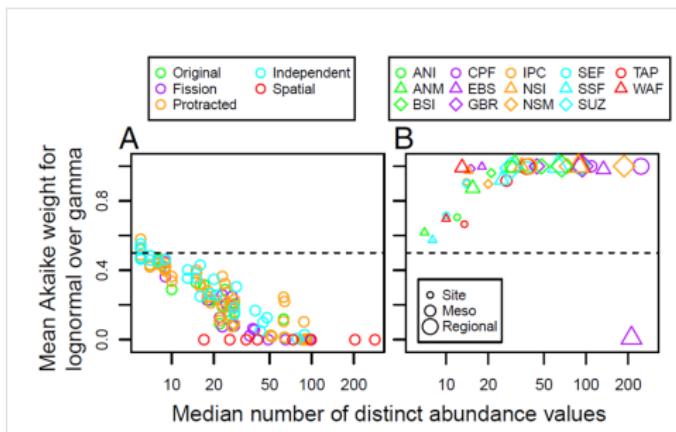
Early tests of neutral theory compared the fit of empirical species abundance distributions to the neutral prediction.

Later tests suggested species abundance comparisons were insufficient for a rigorous test of neutrality.

*However...*

# NEUTRAL ANALYSIS

Connolly et al. 2014 identified non-neutral species abundance distributions in marine communities.

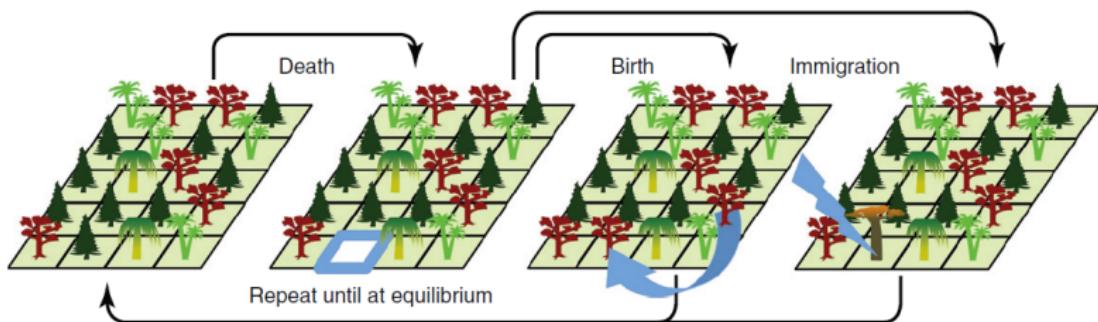


May be a robust method for identifying communities that exhibit non-neutrality.

# NEUTRAL THEORY

Many formulations, but:

- Species & individuals ecologically & demographically equivalent.



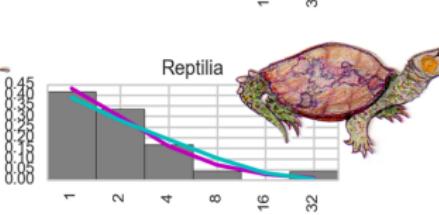
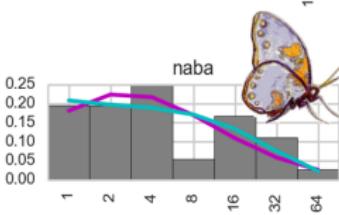
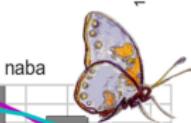
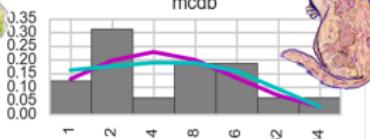
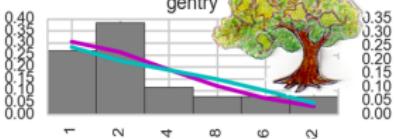
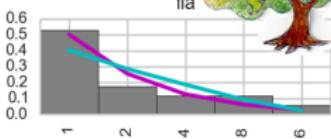
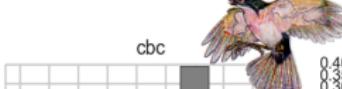
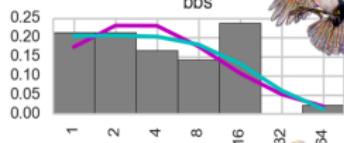
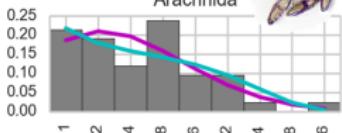
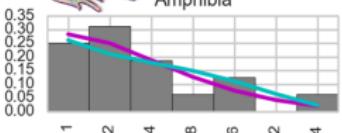
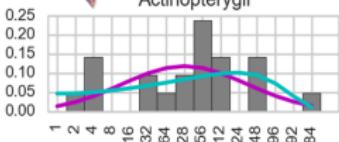
Rosindell et al. 2011.

## NEUTRAL ANALYSIS

Used the same data and model fitting approach.

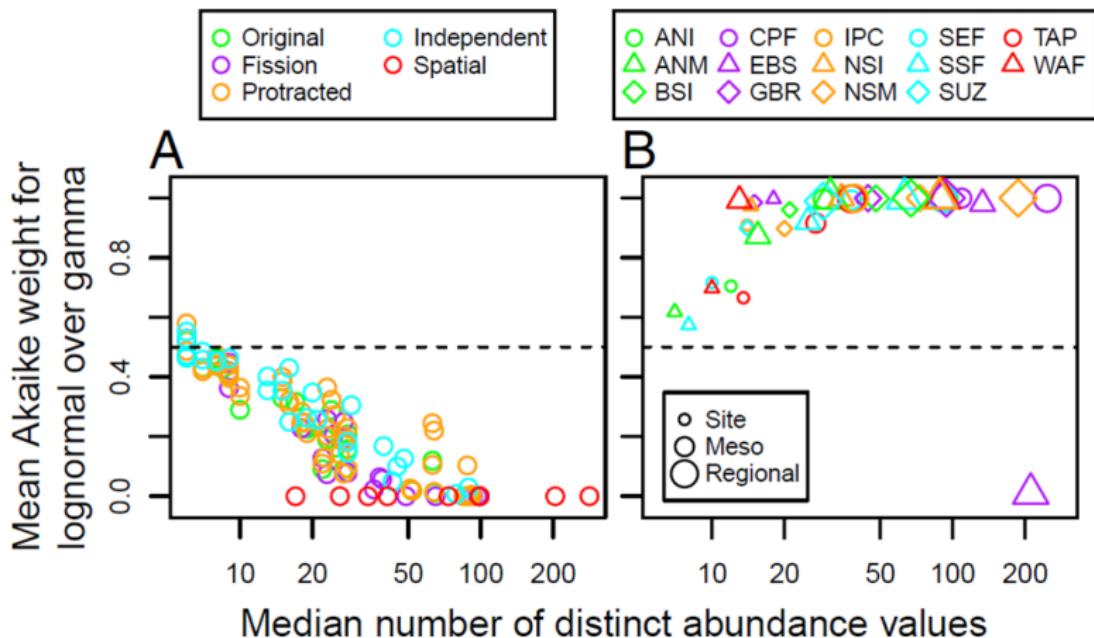
Compared a non-neutral model (Poisson lognormal) to a neutral model (negative binomial).

# NEUTRAL ANALYSIS

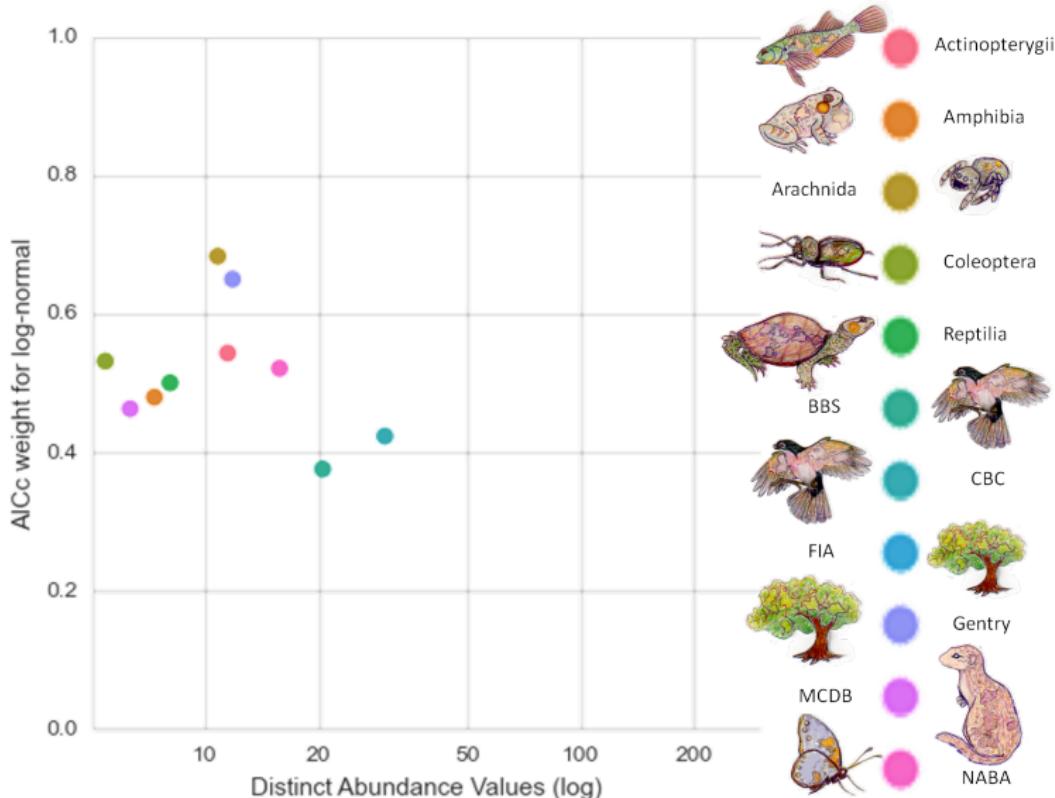


Poisson lognormal  
Negative binomial

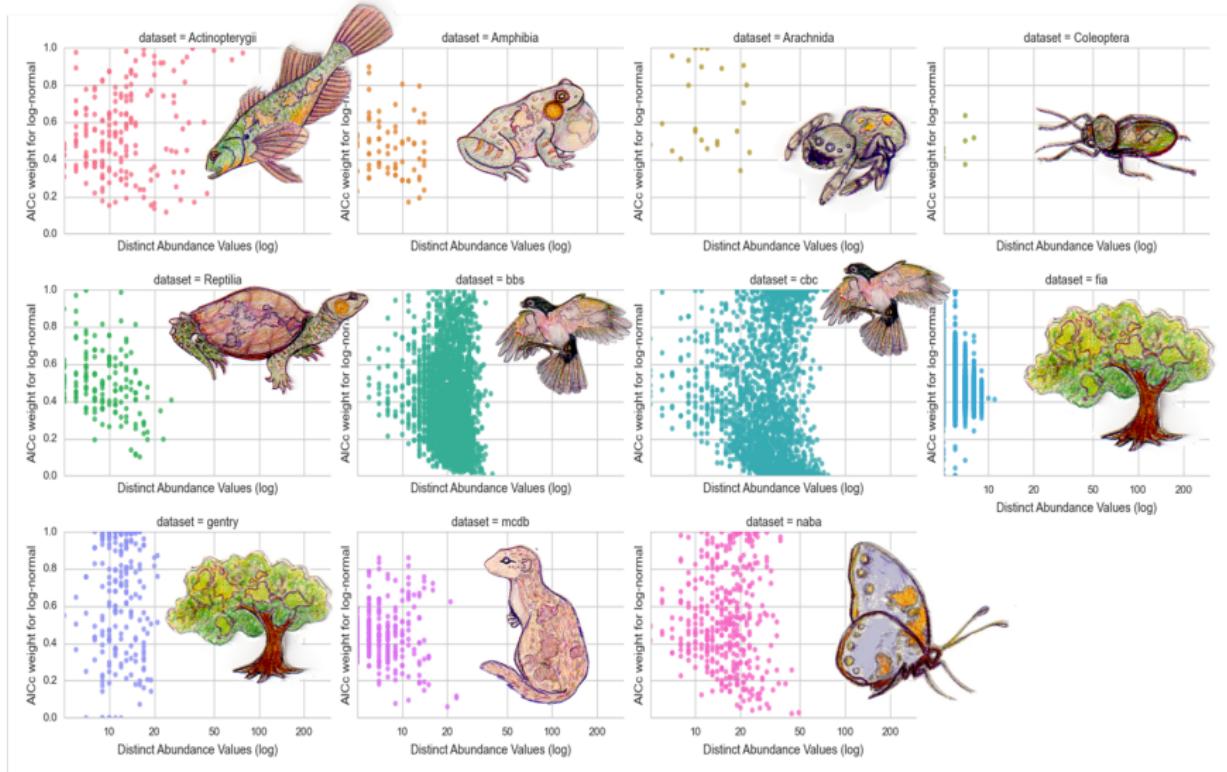
# NEUTRAL ANALYSIS



# NEUTRAL ANALYSIS



# NEUTRAL ANALYSIS



## NEUTRAL ANALYSIS

Difficult to identify a clear winning model.

- Results consistent with our species abundance distribution model comparisons.
- Results different from Connolly et al. 2014.
  - May be biological mechanisms responsible for differences between marine and terrestrial communities.

# CONCLUSIONS

Challenging to infer process from species abundance distributions alone.

- Multiple mechanisms proposed for each SAD formulation.
- Broad model categorization (i.e. neutral or non-neutral) may be more productive.
- May not be one single suite of processes that dominates.

# CONCLUSIONS

Challenges in identifying mechanism among datasets.

- Biological vs. non-biological differences (spatial structuring, sampling intensity).
- Diverse data removes uncertainty about non-biological pattern generating mechanisms.
- Even with a great deal of data, identifying mechanism is still challenging.

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# ACCESSIBILITY

This dissertation brought to you by:

## Disability accommodations

- Remote access & participation.
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# QUESTIONS?

