Introduction to Course

ESS 575 Models for Ecological Data

N. Thompson Hobbs

January 16, 2017

Graduate Degree Program in Ecology
Department of Ecosystem Science and Sustainability
Colorado State University

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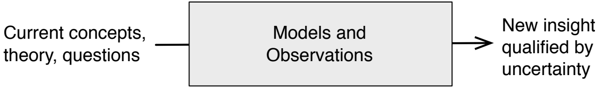
What is this course about?



What is this course about?

Probability model

Observations (data)

Deterministic model

Idea!

What is the probability that I would observe the data if my model is a faithful representation of the processes that gave rise to the data?

What is this course about?

Using models of ecological processes

$$[z_i|\boldsymbol{\theta}_p] \tag{1}$$

to gain insight from data

$$[y_i|z_i, \boldsymbol{\theta}_d] \tag{2}$$

using Bayesian methods.

What is this course about?

- Provide principles based understanding
- Foster collaboration
- Build a foundation for self-teaching
- Enhance intellectual satisfaction

What is this course about?

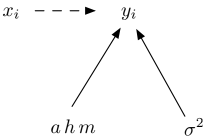
1. Understand basic principles of probability and distribution theory.
2. Explain maximum likelihood.
3. Explain key principles of Bayesian statistics.
4. Be able to diagram, write, and implement hierarchical models.
5. Explain the Markov chain Monte Carlo (MCMC) algorithm.
6. Use software for implementing MCMC methods (i.e., JAGS, R packages).
7. Understand procedures for model checking and model selection in the Bayesian framework
8. Be able to apply Bayesian methods to a broad array of analysis problems in ecological research.

What is this course about?

Sequence

- Basic principles (and learning R) (3 weeks)
- Models and data (2 weeks)
- Computation (1 week)
- Familiar models (2 weeks)
- Model evaluation (1 week)
- Special topics (4 weeks)

Cross cutting theme



$$\mu_i = \frac{m x_i^a}{h^a + x_i^a}$$

$$[a,h,m,\boldsymbol{\sigma}^2|\mathbf{y}] \propto \prod_{i=1}^{n}[y_i|\boldsymbol{\mu}_i,\boldsymbol{\sigma}^2][a,h,m,\boldsymbol{\sigma}^2]$$

```
model{

     for(i in 1:length(y)){

          mu[i] <- (m*x[i]^a)/(h^a+x[i]^a)
          y[i] ~ dgamma(mu[i]^2/sigma^2,mu[i]/sigma^2)

     }

a ~ dnorm(0,.0001)
m ~ dgamma(.01,.01)
h ~ dgamma(.01,.01)
sigma ~ dunif(0,5)
}
```

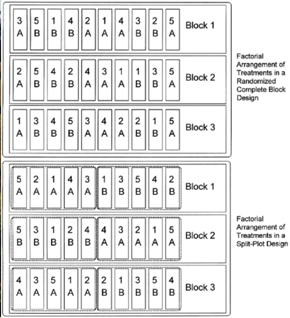
Why should you learn statistics from an ecologist?

Why this course?

KEY TO STATISTICAL METHODS

	Design or Purpose	Measurement Variables	Ranked Variables	Attributes
1 variable 1 sample	Examination of a single sample	Procedure for grouping a frequency distribution, Box 2.1; stem-and-leaf display, Section 2.5; testing for outliers, Section 13.4 Computing median of frequency distribution, Box 4.1 Computing arithmetic mean: unordered sample, Box 4.2; frequency distribution, Box 4.3 Computing standard deviation: unordered sample, Box 4.2; frequency distribution, Box 4.3 Setting confidence limits: mean, Box 7.2; variance, Box 7.3 Computing g_1 and g_2, Box 6.2		Confidence limits for a percentage, Section 17.1 Runs test for randomness in dichotomized data, Box 18.3
	Comparison of a single sample with an expected frequency distribution	Normal expected frequencies, Box 6.1 Goodness of fit tests: parameters from an extrinsic hypothesis, Box 17.1; from an intrinsic hypothesis, Box 17.2 Kolmogorov–Smirnov test of goodness of fit, Box 17.3 Graphic "tests" for normality: large sample sizes, Box 6.3; small sample sizes (rankit test), Box 6.4 Test of sample statistic against expected value, Box 7.4		Binomial expected frequencies, Box 5.1 Poisson expected frequencies, Box 5.2 Goodness of fit tests: parameters from an extrinsic hypothesis, Box 17.1; from an intrinsic hypothesis, Box 17.2
1 variable ≥2 samples	Single classification	Single classification anova: unequal sample sizes, Box 9.1; equal sample sizes, Box 9.4 Planned comparison of means in anova, Box 9.8; single degree of freedom comparisons of means, Box 14.10 Unplanned comparison of means: T-method, equal sample sizes, Box 9.9; T′, GT2, and Tukey–Kramer, unequal sample sizes, Box 9.10; Welsch step-up, Box 9.11; STP test, Section 9.7; contrasts using Scheffé, T, and GT2, Box 9.12; multiple confidence limits, Section 14.10 Estimate variance components: unequal sample sizes, Box 9.2; equal sample sizes, Box 9.3 Setting confidence limits to a variance component, Box 9.3 Tests of homogeneity of variances, Box 13.1 Tests of equality of means when variances are heterogeneous, Box 13.2	Kruskal–Wallis test, Box 13.5 Unplanned comparison of means by a nonparametric STP, Box 17.5	*G*-test for homogeneity of percentages, Boxes 17.5 and 17.8 Comparison of several samples with an expected frequency distribution, Box 17.4; unplanned analysis of replicated tests of goodness of fit, Box 17.5
	Nested classification	Two-level nested anova: equal sample sizes, Box 10.1; unequal sample sizes, Box 10.4 Three-level nested anova: equal sample sizes, Box 10.3; unequal sample sizes, Box 10.5		
	Two-way or multi-way classification	Two-way anova: with replication, Box 11.1; without replication, Box 11.2; unequal but proportional subclass sizes, Box 11.4; with a single missing observation, Box 11.5 Three-way anova, Box 12.1 More-than-three-way classification, Section 12.3 and Box 12.2 Test for nonadditivity in a two-way anova, Box 13.4	Friedman's method for randomized blocks, Box 13.9	Three-way log-linear model, Box 17.9 Randomized blocks for frequency data (repeated testing of the same individuals), Box 17.11

Why this course?



Why this course?

Fleishman, E., et al., 2011. Top 40 Priorities for Science to Inform US Conservation and Management Policy. Bioscience 61:290-300.

Why this course?

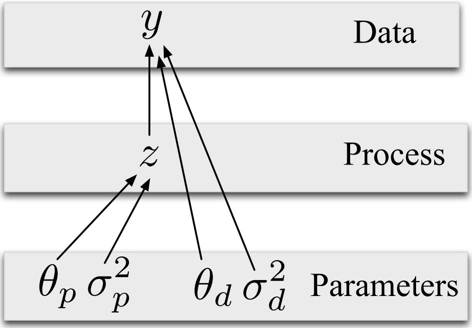
Problems poorly suited to traditional approaches

- Multiple sources of data
- Multiple sources of uncertainty
- Inference across spatial scales
- Unobservable quantities
- Derived quantities
- Forecasting

Why this course?

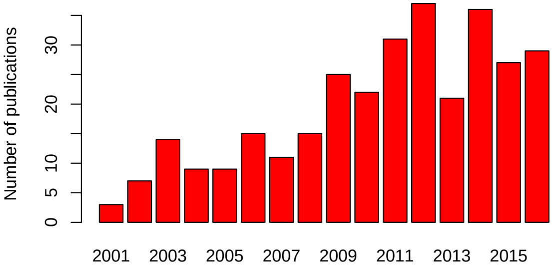
A single, principled approach applies to many problems.

- A model of an ecological process
- A model of the data
- Models of parameters



Why this course?

Papers using Bayesian analysis in *Ecological Monographs, Ecological Applications, and Ecology*



Why study modeling?
To get a job.

University of California Berkeley	"We are seeking a candidate with strong analytical and modeling skills…"
San Francisco State University	"We seek candidates with leadership in developing computational or quantitative methods to study biological questions…,"
Oregon State University	"We particularly seek those whose research integrate empirical and theoretical approaches…",
University of Maryland	"We seek an outstanding candidate taking informatic, experimental, statistical, and/or theoretical approaches..
University of Vermont	"We seek a creative individual with an interdisciplinary background in areas such as landscape or systems ecology..."
Oregon State University	"…expected to establish a vigorous and innovative research program addressing fundamental questions in plant population, community, ecosystem, or evolutionary ecology using…computational approaches…Candidates whose research programs integrate multiple methodologies (e.g., genomics, experimental, modeling, and field studies) are especially encouraged to apply."

Why this course?

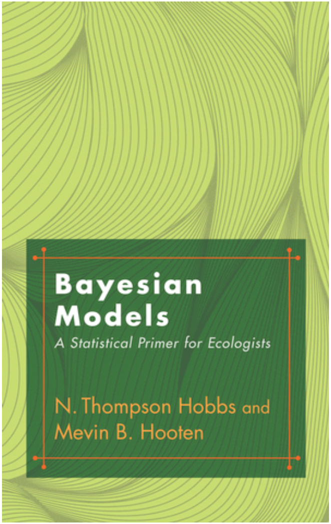
Recent modeling hires from GDPE

Student	Position
Ann Raiho	Ph.D., Notre Dame
Megan Vahsen	Ph.D., Notre Dame
Nathan Galloway	Biologist, National Park Service
Nell Campbell	Post-doc, Univ. New Hampshire
Katie Renwick	Post-doc, Univ. Montana
Alison Ketz	Post-doc, USGS
Zhongqi Miao	Ph.D., Berkeley
Greg Wann	Post-doc, USGS

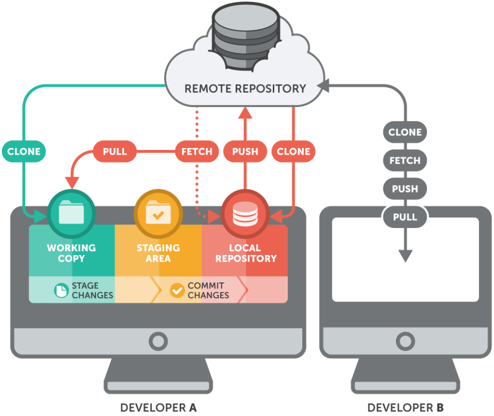
Teaching philosophy

- Everyone learns, everyone teaches.
- Teaching trumps evaluation.
- The best learning comes from solving problems.
- I will review basic math needed to understand lectures.
- Whenever possible, I teach in the first person voice.

Text


Bayesian Models
A Statistical Primer for Ecologists
N. Thompson Hobbs and
Mevin B. Hooten

Accessing course materials on GitHub



Learn Version Control with Git: A step-by-step course for the complete beginner

Accessing course materials on GitHub

Show possible file structure for course materials on board.

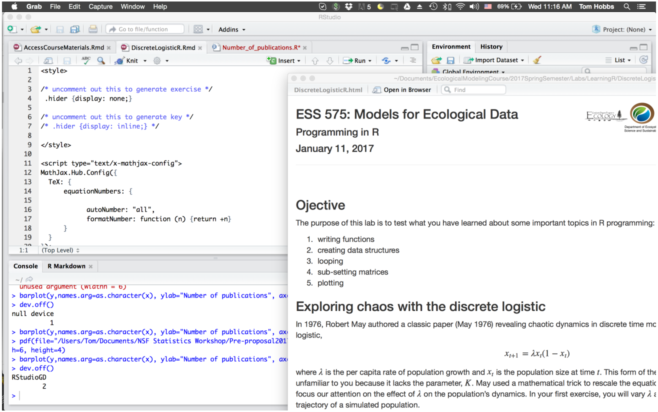
Housekeeping

- Lab in NESB B302
  - Most students use their own laptops, but there are Windows desktops available.
  - If you don't use your own laptop, you will certainly need a memory stick.
- Lecture in NESB A302 starting promptly at 9:30

Housekeeping

- R primer for first laboratory available on GitHub
- Lecture notes: download morning of class (after 8:30)
- Some board work (not boring work), so be prepared to take notes.

R markdown


RStudio
AccessCourseMaterials.Rmd
DiscreteLogisticR.Rmd
Number_of_publications.R*
Knit
Insert
Run
Environment
History
Import Dataset
Global Environment
Addins
Project: (None)
<style>
/* uncomment out this to generate exercise */
.hider {display: none;}
/* uncomment out this to generate key */
/* .hider {display: inline;} */
</style>
<script type="text/x-mathjax-config">
MathJax.Hub.Config({
TeX: {
equationNumbers: {
autoNumber: "all",
formatNumber: function (n) {return +n}
}
}
(Top Level)
Console
R Markdown
> barplot(y,names.arg=as.character(x), ylab="Number of publications", ax
> dev.off()
null device
1
> barplot(y,names.arg=as.character(x), ylab="Number of publications", ax
> pdf(file="/Users/Tom/Documents/NSF Statistics Workshop/Pre-proposal201
h=6, height=4)
> barplot(y,names.arg=as.character(x), ylab="Number of publications", ax
> dev.off()
RStudioGD
2
DiscreteLogisticR.html
Open in Browser
Find
ESS 575: Models for Ecological Data
Programming in R
January 11, 2017
Ojective
The purpose of this lab is to test what you have learned about some important topics in R programming:
1. writing functions
2. creating data structures
3. looping
4. sub-setting matrices
5. plotting
Exploring chaos with the discrete logistic
In 1976, Robert May authored a classic paper (May 1976) revealing chaotic dynamics in discrete time mc
logistic,
$x_{t+1} = \lambda x_t(1 - x_t)$
where λ is the per capita rate of population growth and x_t is the population size at time t. This form of the
unfamiliar to you because it lacks the parameter, K. May used a mathematical trick to rescale the equatic
focus our attention on the effect of λ on the population's dynamics. In your first exercise, you will vary λ a
trajectory of a simulated population.

Evaluation

- Ten laboratory exercises worth 50 - 100 points each. (75% of grade)
- A capstone problem done individually (25% of grade)
- You are graded relative to material, not relative to each other.
- Relax. You will get an A if you do the assignments carefully and thoughtfully.
- See syllabus for details.

Individual projects

- Purpose
- Process
- Product

Getting help

- From me: Tuesday-Thursday 11:00 - 12:00 or by appointment, NESB B227 or by email (tom.hobbs@colostate.edu). Please put ESS 575 in subject line.
- From TA, Megan Vahsen: Thursday 2:00-4:00 or by appointment, Plant Sciences C-033, mlvahsen@gmail.com.

Chores

- Fill out spreadsheet in class Dropbox (ESS575) *today*.
- Get account on GitHub and pull repository ESS_575_2017 to your local machine. See instructions in `Accessing course material.html`.
- Install R and R studio before lab tomorrow. See instructions in R primer.
- Install the R package `ESS575` containing course data library. See instructions in `Accessing course material.html`.
- Print R primer for first laboratory.
- Read materials in `Admin` folder of ESS_575_2017.

First assignment

- Read the syllabus.
- Prepare ≤ 2 minute presentation about yourself: background, what are you studying, who is your major professor, why you are taking this class.
- Prepare a 1-2 paragraph description of an important non-linear, static, deterministic model in your field of ecology. See `FirstAssignment.pdf` in Admin folder of ESS_575_2017. Due Friday.
- Dust off your calculus book. Review the definite integral and how it is derived .

Discussion topic (if time)

What do you think of when someone is described as an “ecological modeler?” Mevin and I say in our book that all ecological researchers are modelers. Why do you suppose we say that? Describe your ideas about the relationships among observations, mathematical models, and statistical models in ecology.