Course Description: Ecological data pose many challenges to statistical inference. Most data come from observational studies rather than designed experiments; observational units are frequently followed over time, resulting in multiple, non-independent measurements; response data are often binary (e.g., presence-absence data) or non-negative integers (e.g., counts), and therefore, the data do not fit the standard assumptions of linear regression (Normality, constant variance); lastly, measurement error, resulting from difficulties in observing or detecting individuals, is common in ecological studies, and typically requires specialized data collection protocols and associated models to obtain unbiased estimates of ecological parameters. This course will familiarize students with modern statistical methods that address these complexities, with an emphasis on Bayesian implementations of commonly used regression models. We will begin with a review of linear regression, emphasizing the role of design matrices in model construction. We will learn how to create explanatory variables (e.g., when fitting models with categorical predictors) and also generate model-based estimates of predicted values along with associated measures of uncertainty. With this foundation in place, we will then consider extensions to non-Normal data (e.g., generalized linear models) and correlated data (mixed models, generalized estimating equations). Lastly, we will explore models for repeated survey and capture-mark-recapture data that allow estimation of detection probabilities. Exercises will utilize program R and general Bayesian modeling software WinBugs/JAGS and will make extensive use of both real and simulated data sets.

Prerequisites:
A graduate-level statistics class (e.g., ST 5021), and an understanding of key statistical concepts, including hypothesis tests, the Normal distribution, and linear regression. In addition, you should have a working knowledge of the R programming language (e.g., be able to read in data, work with common object types [lists, matrices, data frames], install and load packages, access help functions, and construct simple plots) . Students without any R experience should seek to obtain a basic level of understanding prior to the course through self-study. One possibility is the online course located here: http://tryr.codeschool.com.

Learning Objectives:
The overarching goal of the course is to train students to effectively analyze the data they collect as part of their research. By the end of this course, you should be able to:
- Construct models that address specific biological objectives.
- Understand the role of random variables and common statistical distributions in formulating modern statistical regression models.
• Identify key model assumptions, utilize diagnostic tools to assess validity of these
assumptions, and conduct sensitivity analyses to evaluate model robustness to assumption
violations.
• Gain an appreciation for challenges associated with selecting among competing models
and performing multi-model inference.
• Critique statistical methods used in the applied literature; identify strengths and
weaknesses of different modeling approaches and select appropriate analyses in your
work
• Conduct research using a workflow that maximizes ‘reproducibility’ of your work.

To achieve the above learning objectives, you will be expected to develop new statistical
modeling and computing skills (see Skills Objectives).

Skills Objectives:
Participants should be able to:
• Construct covariates that allow fitting of models with categorical predictors and that
allow for non-linear relationships between explanatory and response variables.
• Fit and evaluate a variety of regression models in both Frequentist (using R) and
Bayesian frameworks (using WinBugs/JAGs).
• Use simulation methods to test their understanding and evaluate power and robustness of
different regression models.
• Obtain model-based estimates of predicted responses along with confidence and
prediction intervals for a variety of commonly used regression models.
• Model non-Normal data using generalized linear models.
• Fit models to correlated data using mixed models and generalized estimating equations;
estimate robust standard errors by performing a cluster-level bootstrap (resampling
independent observational units).

Textbooks and Assigned Reading:
The course will largely follow the book by Marc Kéry, below (the only required text for the
course):


Students interested in exploring population abundance or trend estimation (or estimation and
modeling of demographic rates of survival, recruitment and movement) for their course project
or in their research are also strongly recommended to purchase:


In addition, the course will make heavy use of Zuur et al.’s book, below, for data examples and
applications using Frequentist methods:

York.
Lastly, these texts will be supplemented with readings from online e-books and journal articles as needed.

Some Important notes on the books:
- You can download an electronic version of Zuur et al. or purchase a softcover version for $25 through the UMN library via this link: http://link.springer.com.ezp2.lib.umn.edu/book/10.1007/978-0-387-87458-6

Software:
We will make extensive use of R and JAGS during the course. R is a modern statistical computing package supported by a large network of scientists worldwide. JAGS is a popular software platform that makes Bayesian modeling ‘easy’ (or at least more accessible to a wider audience). Although the learning curve associated with these programs can be steep, invest the time to become comfortable now and you will see huge dividends in the future. Importantly, these programs are free so you can take the skills you learn anywhere you go.

If you have a personal computer, you should download current versions of these programs. In addition, I strongly recommend using RStudio along with the knitr package to produce reproducible html documents that summarize your work. You can download necessary software here:
1. R: http://streaming.stat.iastate.edu/CRAN/
2. JAGS (works with Windows, Macintosh, and Linux operating systems): http://www-ice.iarc.fr/~martyn/software/jags/
3. RStudio: http://www.rstudio.com/

Lastly, you should install the following packages in R: nlme, lme4, knitr, R2WinBugs, R2jags, rjags, gplots, lattice, latticeExtra, rms, ggplot2. These packages can be installed from within R or RStudio by typing:


Course Notes and Website: Students will often be expected to read or work through lecture material before class. Any assigned readings, as well as all lectures and homework assignments will be posted on a classroom website within Moodle.

Assessments: learning objectives will be evaluated using a series of in-class and take home assignments and a project. I encourage you to work together on all assignments, but each student will be responsible for writing their own computer code and producing their own written report (see Scholastic Dishonesty). This report should include: a) the code used for analyzing the data; b) the rationale for choosing the particular analysis approach; c) and a short paragraph or
two that describes key findings. These reports should be completed using the knitr package in Program R.

**Project:** as part of the class, each student will complete a project that involves either an analysis of real data or a simulation study to assess the properties of one of the methods described in the class (e.g., robustness to assumption violations). Each student will then produce a short paper that describes their project. The format of this paper should be similar to that of a research journal, with the following sections: *Introduction* (outlining the biological questions of interest, or alternatively, the reason for conducting a simulation study), *Methods*, *Results*, and *Discussion* sections. These will be peer-reviewed (and graded) by students as part of the class.

**Grading/Evaluation:** In-class and take-home assignments: 60%; Project: 35%; Participation: 5%

Class participation and feedback are critical for mastering the material and also for improving the course. Students will be asked to either submit questions related to the assigned readings or provide feedback on the material presented in a previous lecture. These submissions will be used to score class participation.

**Grades:** Grades will be assigned in a manner consistent with the University’s Grading Standards listed here:

http://policy.umn.edu/Policies/Education/Education/GRADINGTRANSCRIPTS.html

**Workload, Deadlines and Late Assignments:** University guidelines suggest that the average student should expect to spend approximately 8 hours of additional out-of-classroom work per week for a 4-credit class. Most of this time will be spent reading, working through assignments, or working on your project.

Assignments will be submitted electronically through Moodle. Each homework assignment will have associated with it a specific due date. As in the real world, there will be significant penalties for not meeting deadlines. I will accept late homework assignments for up to 3 days after the original due date, but will subtract 10% of the total point value for each day the assignment is late. Assignments will often take considerable time – you should plan on starting them early; it will be difficult to complete them in a single sitting. Penalty-free extensions may be granted in rare cases (e.g., documented illness or emergencies), but in general, I expect you to plan ahead for sanction events (e.g., intercollegiate athletic events, University activities, religious observances, etc.) so that you can turn in assignments on time.

**Preliminary Course Outline:**

**Week/Topic**
1. Linear regression; sampling distributions, bootstrap distribution
2. Linear regression and design matrices; ANOVA, ANCOVA, interactions.
3. Model comparisons, model-averaging, bootstrap validation
4. Causal networks
5. Probability, random variables
6. Probability distributions: normal, binomial, negative binomial, Poisson
7. Maximum Likelihood and Introduction to Bayesian Statistics
8. Fitting models in JAGS
9. Generalized linear models
10. Generalized linear models (continued)
11. Linear mixed models
12. Linear mixed models (continued)
13. Generalized estimating equations and cluster-level bootstrap
14. Generalized linear mixed effects models
15. Modeling data with lots of zeros
16. Estimating detection probabilities: Models applied to repeated presence-absence data
17. Estimating detection probabilities: Models applied to mark-recapture data

Student Conduct Code:
As a student at the University you are expected adhere to Board of Regents Policy: Student Conduct Code. To review the Student Conduct Code, please see:


Scholastic Dishonesty:
You are expected to do your own academic work and cite sources as necessary. Failing to do so is scholastic dishonesty. Scholastic dishonesty means plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using test materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; altering, forging, or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis. See - Student Conduct Code:

http://regents.umn.edu/sites/default/files/policies/Student_Conduct_Code.pdf)

What does this mean for you and this course?
1. Although you are encouraged to collaborate on homework assignments, each individual will be responsible for writing their own analysis code and also description of their work and main findings.
2. Your final paper should accurately cite sources relevant to your paper. You need to be able to understand how to cite relevant sources and also the difference between plagiarism and paraphrasing. U of M libraries has tutorials that can help you to cite your sources and to learn more about plagiarism: http://tutorial.lib.umn.edu/. Also, the Center for Writing can help you with the writing process: www.writing.umn.edu.

Obvious forms of plagiarism on homework assignments and final papers will result in a 0 for the assignment. In addition, I will be forced to file a formal report to the Office for Student Conduct and Academic Integrity. If you ever have any questions about what might or might not be permissible, ask!
**Sexual Harassment:**
"Sexual harassment" means unwelcome sexual advances, requests for sexual favors, and/or other verbal or physical conduct of a sexual nature. Such conduct has the purpose or effect of unreasonably interfering with an individual's work or academic performance or creating an intimidating, hostile, or offensive working or academic environment in any University activity or program. Such behavior is not acceptable in the University setting. For additional information, please consult Board of Regents Policy:

http://regents.umn.edu/sites/default/files/policies/SexHarassment.pdf

**Equity, Diversity, Equal Opportunity, and Affirmative Action:**
The University provides equal access to and opportunity in its programs and facilities, without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, veteran status, sexual orientation, gender identity, or gender expression. For more information, please consult Board of Regents Policy:


**Disability Accommodations:**
The University of Minnesota is committed to providing equitable access to learning opportunities for all students. Disability Services (DS) is the campus office that collaborates with students who have disabilities to provide and/or arrange reasonable accommodations.

If you have, or think you may have, a disability (e.g., mental health, attentional, learning, chronic health, sensory, or physical), please contact DS at 612-626-1333 to arrange a confidential discussion regarding equitable access and reasonable accommodations.

If you are registered with DS and have a current letter requesting reasonable accommodations, please contact your instructor as early in the semester as possible to discuss how the accommodations will be applied in the course.

For more information, please see the DS website, https://diversity.umn.edu/disability/.

**Mental Health and Stress Management:**
As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance and may reduce your ability to participate in daily activities. University of Minnesota services are available to assist you. You can learn more about the broad range of confidential mental health services available on campus via the Student Mental Health Website: http://www.mentalhealth.umn.edu.

**Academic Freedom and Responsibility:**
Academic freedom is a cornerstone of the University. Within the scope and content of the course as defined by the instructor, it includes the freedom to discuss relevant matters in the classroom
and conduct relevant research. Along with this freedom comes responsibility. Students are encouraged to develop the capacity for critical judgment and to engage in a sustained and independent search for truth. Students are free to take reasoned exception to the views offered in any course of study and to reserve judgment about matters of opinion, but they are responsible for learning the content of any course of study for which they are enrolled.* When conducting research, pertinent institutional approvals must be obtained and the research must be consistent with University policies.

Reports of concerns about academic freedom are taken seriously, and there are individuals and offices available for help. Contact the instructor, the Department Chair, your adviser, the associate dean of the college, or the Vice Provost for Faculty and Academic Affairs in the Office of the Provost.

* Language adapted from the American Association of University Professors "Joint Statement on Rights and Freedoms of Students".