MBIO 740 Advanced Topics in Quantitative Biology: Bayesian Methods for Fisheries and Marine Biology

Spring 2026: Monday and Wednesday from 3:00-4:15
3-credits

Instructor: Mary Donovan
Contact Information: mdono@hawaii.edu
Office Hours: By appointment

Prerequisites: BIOL 220 or ECON 321 or MATH 372 or their equivalent, or instructor approval.

I. Course Description:
This course will provide an introduction to statistical modeling in a Bayesian framework. We will cover probability theory and probability distributions, Bayes theorem and model specification, linear and multivariate linear models, multi-level models, model fitting and model checking, and interpretation and reporting of modeling results. Throughout the course we will use computational tools to gain experience and apply concepts using R and Stan. Prior to enrolling in this course students should have some experience with statistical inference and computer coding.

II. Student Learning Objectives:
At the completion of this course, students will be able to:

a. articulate the differences between Bayesian and Frequentist approaches to inference,
b. interpret probability theory in the context of Bayes' theorem,
c. estimate and interpret Bayesian statistical models of different forms.

III. Course Format and Responsibilities:
Students will be expected to do weekly reading to prepare for the lectures, attend all classes, and participate in discussion and activities following the lectures. Class meetings will be twice weekly with approximately half of the class consisting of lecture and half consisting of discussion and activities.

The course will rely heavily on the following textbook:
Statistical Rethinking by Richard McElreath (2nd Edition)

IV. Course Assignments and Evaluation:
Students will be evaluated as follows:

- Weekly problem sets: 14 x 5 pts each = 70 pts
- Final project and presentation = 30 pts
- Total = 100 pts

Problem sets will be due weekly and consist of questions and exercises associated with each week's subject material. These problem sets will provide an opportunity to apply what is learned in each week's reading and lectures and practice the tools available for conducting Bayesian analyses. In these problem sets, students will utilize R and Stan coding languages to construct statistical models, test their assumptions, and visualize results.

The course will culminate in a final project and ~5 minute presentation. The goal is to apply what was learned to statistically address a fisheries relevant question. Students will use datasets they

identify, either from their own work or from other existing data, that will be described and analyzed using methods learned in the course. Students' presentations will include a statement of the fisheries or marine biology question, description of the data available to address it, description and justification for the statistical method they applied (SLO c), the results acquired and their interpretation in relation to the original question (SLO b), and how that interpretation would have varied with a frequentist approach (SLO a). The students will turn in their dataset, code and statistical results for evaluation and as a demonstration of their ability to create a reproducible workflow. In this way the student can be evaluated on all 3 of the major course SLOs in a manner that is relevant to their own research and the objectives of their degree. Presentations will be given in the last week of the course.

The grading structure will be as follows:

%	**Grade**
90-100	A
80-89	B
70-79	C
60-69	D
≤59	F

V. Course Calendar:

Module	**Topic**
1	**Introduction to the course:** Overview of the main topics covered in the course, as well as the structure, expectations, and intended outcomes of the course. **Installing software and introduction to tools used in the course.** **Introduction to a frame of thinking about statistical modeling:** *Statistical golems*. Bayesian versus Frequentist approaches to statistical inference. Reading: ***Statistical Rethinking*** **chapter 1**
2	**Designing, conditioning, and evaluating statistical models:** How to motivate a model through data stories, educating your model with data, and supervising and revising the model. **Introducing Bayes Theorem and model components:** Overview of the components of a model and how they fit together, how model parameters are estimated, and Bayes Theorem for tying it all together. Reading: ***Statistical Rethinking*** **chapter 2**

3	**Sampling from the posterior:** Manipulating posterior distributions to produce intervals, point estimates, and predictive checks for summarizing results and checking models. Reading: ***Statistical Rethinking*** **chapter 3**
4	**Introduction to Rstan:** Overview of Rstan as a tool for estimating Bayesian models. **Markov Chain Monte Carlo:** Purpose and approach of MCMC algorithms, and introduction to apply Hamiltonian Monte Carlo engine. Reading: ***Statistical Rethinking*** **chapter 9**.
5	**Gaussian distribution and linear regression:** Using models as a language for expressing hypotheses, designing, educating, and supervising linear regression models. Reading: ***Statistical Rethinking*** **chapter 4**
6	**Multiple regression:** Expanding linear regression to include multiple predictors. Challenges with confounding, causation, and interactions. Treatment of categorical predictors. Reading: ***Statistical Rethinking*** **chapter 5**
7	**Multicollinearity and simulating data:** Considerations for correlated predictors and exercises in data simulation to uncover hidden consequences of model design choices. Reading: ***Statistical Rethinking*** **chapter 6**
8	**Over (and under) fitting and comparing models:** Introduction to the problem of overfitting and tools for evaluating and comparing models. Reading: ***Statistical Rethinking*** **chapter 7** ***Introduction to Final Projects***
9	**Confounding and interactions:** Including associations between a predictor and an outcome to be influenced by another predictor, with an emphasis on the difficulty in visualizing and interpreting interactions. Reading: ***Statistical Rethinking*** **chapter 8**.
10	**Generalized Linear Models:** Introduction to probability distributions and maximum entropy as building blocks for GLMs, with applications for General Linear Models for count data. Reading: ***Statistical Rethinking*** **chapters 10-11**.

11	**GLMs for count data:** Practice applying concepts and tools from Weeks 5-10 using Binomial and Poisson regression. Reading: ***Statistical Rethinking* chapter 11** (review).
12	**More types of GLMs:** General Linear Models for overdispersed counts and ordered categorical outcomes. Reading: ***Statistical Rethinking* chapter 12**.
13	**Multilevel Models - varying intercepts:** Motivation, implementation, and interpretation of basic multilevel models involving varying intercepts. Reading: ***Statistical Rethinking* chapter 13**.
14	**Multilevel Models - varying slopes:** Motivation, implementation, and interpretation of multilevel models involving varying intercepts and slopes. Reading: ***Statistical Rethinking* chapter 14**.
15	**Multilevel Models - considerations for model fit and interpretation:** Review of multilevel models and exploration of considerations necessary for properly fitting and checking models **Reporting Bayesian Models:** Overview of how Bayesian models are reported in the literature and considerations for reproducibility. Reading: ***Gabry et al. (2019). Visualization in Bayesian workflow. J. R. Stat. Soc. A, 182: 389-402***. https://doi.org/10.1111/rssa.12378
16	*Final presentations*

VI. Course Information, Policies, and Resources:

a. **Attendance Policy:** Attendance is mandatory for all classes, and unexcused absences will not be permitted. Students with extenuating circumstances must speak with the instructor to ensure that their absence is excused to avoid impacting their success in the course.

a. **Statement on Disability (KOKUA Program):** If students have a disability and related access needs, they are encouraged to discuss those needs with the course instructor as early as possible to ensure that we are able to meet access needs and enable complete participation in the course. Students should also contact the KOKUA Program in the Office for Students with Disabilities at 808-956-7511 (KOKUA@hawaii.edu) or go to Room 013 in the Queen Lili'uokalani Center for Student Services. The services offered here are confidential and free of charge.

b. **Academic Integrity and Ethical Behavior (Office of Student Conduct):** Academic dishonesty will not be tolerated in this course, and suspected incidents will be reported to the Office of Student Conduct.

c. **Office of Title IX:** (808) 956-2299; t9uhm@hawaii.edu; https://manoa.hawaii.edu/titleix/

d. **Department of Public Safety:** 808-956-6911 (for emergencies); 808-956-8211 (for non-emergencies); http://manoa.hawaii.edu/dps/

e. **UH System Basic Needs:** Lacking access to basic needs (e.g., housing, childcare, food, health care, mental health support resources) can affect every aspect of your life, including your education. If you or other students you know are experiencing challenges related to basic needs, please look into these resources: https://www.hawaii.edu/student-basic-needs/resources/manoa/

f. **Student Success Resources:** The Division of Student Success (DSS) houses student support services to build success, including academic advising, learning assistance, career counseling, family and relationship support, identity-based services, health and wellness, and more. Please contact 808-956-3290 or go to https://manoa.hawaii.edu/studentsuccess/departments/ for more information.

g. **Additional Student Resources:** https://manoa.hawaii.edu/ovpae/course-actions-2/sample-syllabus/selected-campus-resources-optional/