NRM 5302
Multivariate Methods in Ecology

Instructor: Justin French

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RAS 126
9:30 AM - 10:45 AM, Tuesday and Thursday
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Office Hours: Fridays, 1:00 PM to 4:00 PM, or by appointment.

1 Course Overview

This class introduces the concepts, mathematics, and applications of multivariate statistical methods in a variety of ecological domains. These methods are widely used in community ecology and remote sensing, but are applicable to a wide range of problems. Multivariate measurement is essentially the norm in ecology, however relatively few ecologists are versed in appropriate analysis techniques for such data. This course will change the way you (quite literally) see data and analysis.

Each week we will build progressively towards more and more general analysis frameworks. We will begin with the multivariate normal distribution and matrix algebra, and ultimately end up running statistics on data that cannot be reduced to numbers. By the end of this course you will be able to:

1. Identify the level of complexity in your data
2. Select appropriate analysis frameworks for that level of complexity
3. Fit multivariate models to your data
4. Interpret the results of your models

2 Required Texts

Legendre, P, and L. Legendre. 2012. Numerical Ecology. 3rd English Edition. Elsevier. Amsterdam, The Netherlands.

Bordard, D., F. Gillet, and P. Legendre. 2011. Numerical Ecology in R. Springer. New York, New York, USA.

These books are collectively the gold standard resource for multivariate methods in ecology. I cannot recommend getting a copy of each strongly enough. They will be essential reference material throughout your career.

3 General Assignments

I will assign exercises when appropriate throughout the semester. All work in this class will be done in R, which is a free statistical analysis package (and so much more, as you will see). It is best that you install both R and R Studio, which is a convenient interface. They are available for free download at:

- **R:** https://cloud.r-project.org/
- **R Studio:** https://rstudio.com/products/rstudio/download/

All assignments integrate written work and statistical results, so we will utilize a typesetting program called LaTeX within R Studio to do all assignments. There are many LaTeX distributions, but MiKTeX is likely the easiest to get started with. MiKTeX can be downloaded at:

- https://miktex.org/download

4 Semester Project

By the end of the semester you will complete a full-blown manuscript featuring an analysis of multivariate data. It will be done in R using LaTeXfollowing the British Ecological Society template. I will provide the template via Blackboard. Other templates can be considered if you have a particular journal in mind.

This assignment will be accomplished in stages. In general, you will follow the following progression:

1. Frame your research question, as well as it's motivations and potential implications
2. Select a framework for answering the question and design the data collection
3. Implement your analysis
4. Interpret results
5. Make inferences and discuss their implications

It is entirely possible for some of you to have a submission-worthy manuscript by the end of the semester, but this is not necessarily required. Because many of you are still collecting data, it may not be possible to produce final results within the semester. However, you will have laid the foundation of the manuscript from top to bottom in a way that only requires adding in new data once it is available and re-interpreting results.

Some of you may not have suitable data associated with your projects, but that should not deter you from taking the course. We have a tremendous amount of data on-hand and there are publicly available data sets you can use as well.

5 Grading Policy

Grades are based on weekly assignments, 1 exam, and the semester project. Each of these categories contribute contribute 33.3% of your final grade.

Letter grades follow: $100 > A \geq 90 > B \geq 80 > C \geq 70 > D \geq 60 > F$. There is no curve.

6 Attendance

Showing up is the only way to get the material you need. If you don't come to class, your grade will reflect it with no penalty needed from me. In the event of an excused absence, make arrangements with me to go over material ahead of time.

7 Academic Dishonesty

Academic dishonesty includes copying, sharing, or obtaining information from an unauthorized source, attempting to take credit for the intellectual work of another person, falsifying information, and giving or receiving information about a test, quiz, or assignment to other students. Any student involved in academic dishonesty will receive no credit (0) for work done and/or may be penalized in accordance with published University Rules.

8 Counseling and Accessibility Services

Sul Ross State University is committed to equal access in compliance with the Americans with Disabilities Act of 1973. It is the student's responsibility to initiate a request for accessibility services. Students seeking accessibility services must contact Mary Schwartze, M. Ed., L.P.C., in Counseling and Accessibility Services, Ferguson Hall, Room 112. The mailing address is P.O. Box C-122, Sul Ross State University, Alpine, Texas 79832. Telephone: 432-837-8691. E-mail: mschwartze@sulross.edu.

9 Course Schedule (Tentative)

- Module 1: Matching Methods to Data Complexity
  - **Week 1 (1/13-1/17):** Course Intro and Fundamentals
    - Lecture 1: None because semester starts on Wednesday.
    - Lecture 2: What does "multivariate" mean? Meet the multivariate normal distribution.
    - Reading: L&L Ch. 2
    - Exercise: A brief refresher in linear algebra
  - **Week 2 (1/20-1/24):** Eigenvalues, Eigenvectors, and PCA
    - Lecture 1: Exploring linear algebra: What's an eigenvector?
    - Lecture 2: Principal Components Analysis
    - Reading: L&L Ch.9 (pp.387–424)
    - Exercise: Rolling your own PCA
  - **Week 3 (1/27-1/31):** Applications of PCA
    - Lecture 1: Dissecting community structure
    - Lecture 2: Processing hyperspectral imagery
    - Reading: L&L Ch.9 (pp.387–424)
    - Exercise: PCA in community ecology and remote sensing
  - **Week 4 (2/3-2/7):** Limitations of linear models 1
    - Lecture 1: The double-zero problem, distance, and Euclidean space
    - Lecture 2: Decisions with diverse distances
    - Reading: L&L Ch.7
    - Exercise: What to do with a horseshoe
  - **Week 5 (2/10/2/14):** Limitations of linear models 2
    - Lecture 1: Correspondence Analysis and Principal Coordinate Analysis
    - Lecture 2: Interpreting CA and PCoA
    - Reading: L&L Ch.9 (pp.424–480)
    - Exercise: Exploring community structure in non-Euclidean space
  - **Week 6 (2/17-2/21):** Constrained ordination
    - Lecture 1: Extending PCA with Redundancy Analysis
    - Lecture 2: Constrained ordination in non-Euclidean space
    - Reading: L&L Ch.11
    - Exercise: What's driving community structure?

- **Week 7 (2/24-2/28)**: Distance-based analyses
  - Lecture 1: Clustering and Mantel correlation
  - Lecture 2: A better MANOVA
  - Reading: L&L Ch.8
  - Exercise: Compare *all* the things

- **Week 8 (3/3-3/7):** Functional data: beyond numbers
  - Lecture 1: What are functional data?
  - Lecture 2: Functional PCA
  - Exercise: Dissecting landscape dynamics

- **Week 9 (3/10-3/14):** Exam Week
  - Lecture 1: Review of methods decision process
  - Lecture 2: Exam
  - Exercise: None

- **Week 10 (3/17-3/21):** Spring Break
  - Lecture 1: None
  - Lecture 2: None
  - Exercise: None

- Module 2: Applying What You've Seen
  - **Week 11 (3/24-3/28):** Specifying your project
    - **Reading:** TBD
    - Lecture 1: Discuss project ideas
    - Lecture 2: Discuss reading

  - **Week 12 (3/31-4/4):** Choose and implement analysis
    - **Reading:** TBD
    - Lecture 1: Discuss project analysis choices
    - Lecture 2: Discuss reading

  - **Week 13 (4/7-4/11):** Discuss results 1
    - **Reading:** TBD
    - Lecture 1: Discuss results and interpretation
    - Lecture 2: Discuss results and interpretation

– **Week 14 (4/14-4/18):** Discuss results 2
  * **Reading:** V&G: Chapter 4; p.81–91, 122–125
  * Lecture 1: Discuss results and interpretation
  * Lecture 2: Discuss results and interpretation

– **Week 15 (4/21-4/25):** Present!
  * Presentation schedule TBD

– **Week 16 (4/28-5/2):** Wrapping up
  * Submit publication draft by `2024-05-05 17:00:00 CST`.