# BIOL 5500: Research Design & Analysis for Ecologists

## I. General Information

Professor: Dr. Kenneth Schoenly
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Semester: Fall 2015
Credits: Lec/Activity 4
Meeting Times: MF 2-4:50
Room: N344

## II. Course Description

(Catalog Description): A practical, hands-on survey of experimental design and methods, and ecological statistics used by environmental scientists. Emphasis will be placed on published analyses of stressors on ecosystem structure and function. Corequisite: BIOL 5502. Prerequisites: Graduate standing in the Ecology and Sustainability program or consent of instructor. (Lecture, 3 hours; Activity 3 hours) (Fall).

## III. Student Learning Objectives:

1. The student will address ecological problems using established methods and models and answer questions related to experimental design, sampling, population and community estimation, ecosystem impacts, and other issues.

2. The student will interpret results that measure and interpret the magnitude of responses of populations, communities, and ecosystems to natural and anthropogenic stressors.

> ***"… if we want to test hypotheses, model data, and forecast future environmental conditions in the 21st century, we must move beyond basic statistical literacy and attain statistical fluency."***
> \- Ellison & Dennis 2010, p. 362

3. The student will have enhanced understanding of peer-reviewed literature in science, its cumulative, self-correcting, and hypothesis-testing features, and be able to critique the methodology used, thereby refining his/her communication and critical thinking skills.

4. The student will be guided in planning their own pilot studies and field experiments and in choosing the appropriate ecostatistical tools and models for analyzing his/her data.

5. This course addresses the University's graduate student learning goals numbered 1, 2, 5, and 7.

## IV. Required Readings/Software:

1. Textbooks (3): *Krebs. 2014. Ecological Methodology, 3rd edition (online at): http://www.zoology.ubc.ca/~krebs/books.html; van Emden. 2008. Statistics for Terrified Biologists*. *Mlodinow. 2008. The Drunkard's Walk: How Randomness Rules Our Lives*. Bring to every class period. Used copies available through on-line web sites.
2. Software: *Krebs 2009, v 7.2*. (free to students). Compatible with new Windows 7 and 8 platforms, 32-bit and 64-bit machines.
3. CD of papers from the ecological literature; web sites that offer free software (see "to do list" and below).

4. Handouts of spreadsheet exercises and accompanying questions to solve as in-class activities or take-home assignments. These will be given out in class or sent as attachments in future emails.

## V. Other Available Resources:

Below are some other texts, journals, and authoritative websites on quantitative ecology and related subjects (some are in our library):


Bolker, B.M. 2008. *Ecological Models and Data in R*. Princeton Univ. Press, Princeton, N.J.

Donovan & Welden. 2001. *Spreadsheet Exercises in Conservation Biology and Landscape Ecology*. Sinauer Associates, Inc., Sunderland, MA.

Gardener, M. 2012. *Statistics for Ecologists Using R and Excel. Data Collection, Exploration Analysis and Presentation*. Pelagic Publishing, Exeter, UK.

Gotelli & Ellison. 2013. *A Primer of Ecological Statistics, 2nd edition*. Sinauer, Sunderland, MA.

Gotelli & Graves. 1996. *Null Models in Ecology*. Smithsonian Institution Press, Washington, D.C.

Hairston. 1989. *Ecological Experiments: Purpose, Design and Execution*. Cambridge University Press, Cambridge.

Henderson, P.A. 2003. *Practical Methods in Ecology*. Blackwell Publishing.

Ludwig & Reynolds. 1988. *Statistical Ecology*. Wiley-Interscience, New York.

Magurran. 2004. *Measuring Biological Diversity*. Blackwell Publishing, Malden, MA.

Manly. 1991. *Randomization and Monte Carlo Methods in Biology*. Chapman & Hall.

*Methods in Ecology and Evolution*, a peer-reviewed open-access journal of the British Ecological Society, website: http://www.methodsinecologyandevolution.org/view/0/index.html.

Michener & Brunt. 2000. *Ecological Data: Design, Management and Processing*. Blackwell Science, Edinburgh.

Pielou. 1977. *Mathematical Ecology*. Wiley-Interscience, New York.

Quinn, & Keough. 2002. *Experimental Design and Data Analysis for Biologists*. Cambridge Univ. Press.

Resetarits & Bernardo. 1998. *Experimental Ecology: Issues and Perspectives*. Oxford Univ. Press, Oxford.

Rosner. *Fundamentals of Biostatistics, 7th edition.* Brooks/Cole.

Ruxton & Colegrave. 2003. *Experimental design for the life sciences, 2nd edition.* Oxford Univ. Press.

Scheiner & Gurevitch. 2001. *Design and Analysis of Ecological Experiments, 2nd edition*. Oxford Univ. Press, Oxford.

Southwood & Henderson. 2000. *Ecological Methods*, 3rd ed. Blackwell Science.

Sutherland, W.J. (ed.). 2006. *Ecological Census Techniques*, 2nd edition. Cambridge Univ. Press, Cambridge.

Tangren, J. 2000. A *Field Guide to Experimental Designs*, website: http://www.tfrec.wsu.edu/ANOVA/index.html.

Underwood. 1997. *Experiments in Ecology*. Cambridge Univ. Press, Cambridge.

## VI. Pre-Requisites:

Two math courses (undergraduate statistics and calculus) are necessary (and enforced) pre-requisites for this course. Additional mathematical courses that ecologists use as research tools include differential equations, matrix algebra, multivariate statistics, and graph theory, among others. With each new math course taken, your “comfort zone” with quantitative concepts increases. As a graduate student, we expect that you will perform at a higher level, take the initiative on class assignments, have excellent problem-solving skills, become a student member of one or more professional societies (e.g., *Ecological Society of America*, *Society for Conservation Biology*, *International Society of Ecological Economics*), and use ecostatistical methods in your thesis research (just to mention a few). It also affords you the opportunity to take an active role in shaping your future professional growth and for making contributions in your chosen field of study.

To maximize these benefits, both you and the university must make commitments. The university must make available the resources, both intellectual and physical, that are necessary for you to complete coursework, pursue your program of studies, and realize your potential. For your part, you must take advantage of the opportunities the program has to offer by being highly motivated and focused in the first place, and by directing that motivation in a productive manner. If you proceed appropriately, the lectures, homework, exams, presentations, and other course assignments will become exciting challenges and guidelines rather than hurdles and hindrances.

## VII. Course Requirements:

This course is a research design and methodology class for the Ecology and Sustainability graduate program. **Ecology is an experimental, observational, mathematical and correlative science.** This course will expose you to many quantitative methods and experimental designs that are used by ecologists to answer environmentally diverse questions. One semester is not enough time to cover all these methods and designs, so **we will explore some of the most common tools and case studies that use them.** Mastering these tools is critical to successful completion of your thesis and to future employment and career building as a professional ecologist.

The course’s subject matter will be introduced through formal lectures, assigned journal readings, student presentations, and self-paced lab and field activities that use ecostatistical software and EXCEL spreadsheets. Written exams will require you to know the proper uses, assumptions, limitations, interpretations (but not intimate mathematical steps) of all ecostatistical methods & models used. Successful completion of EXCEL activities will demonstrate mastery of the mechanical (individual calculation) steps leading to correct solutions.

**Presentations:** You will be required to deliver **two, 25-minute critiques of journal papers** (listed below) and **one spreadsheet/software exercise/demonstration** featured in the topics list below. I will supply all the papers (with few exceptions) to you as PDF’s on the CD that you will receive on the first class day. Each **presentation grade** will be based on your **verbal performance** and a **1-page synthesis** (i.e., study guide for your classmates) that summarizes the paper’s questions/hypotheses, methodology, results, and conclusions. Papers will be drawn at random during the 1st few weeks of the semester (i.e., sampling without replacement!); whereas, exercises will be assigned at random 1-2 class periods before their scheduled presentation. It will then be your job to ‘marry yourself’ to each paper or exercise and hand out your summary page (so we can follow) and spreadsheet/software output so you can 'teach' the topic to your classmates and instructor.

Assigned homework will be due at the next class meeting (no exceptions) and handed in (as hard copies); no homework will be accepted as email attachments. **Persons may be called upon at random to present homework and answer questions**. Presentations need to be practiced (several times, if necessary) so they finish under/on time (**no longer than 20/5 min for talk/questions**). Your instructor will evaluate your verbal performance and 1-page syntheses of your papers plus your spreadsheets/other outputs using a standardized grading sheet. **In the event you miss (or are unready to present) your scheduled talk, you will receive an automatic '0' for that assignment. HAVE YOUR PRESENTATIONS/SPREADSHEETS/FREEWARE WITH YOU AT THE START OF CLASS (ON COMPUTER, CD OR MEMORY CARD) AND BE READY TO TEACH THE CLASS WHEN YOUR TIME COMES!!**

## VIII. Ecological Software:

We will be using software from commercial and "freeware" sources (see examples below). These programs run on your laptop (PC, Mac, or emulated versions). Commercial software is copyright protected and requires site licenses for individual student use. Unauthorized copying of commercial software is a serious crime, constituting copyright violation. See below for some examples:

*EstimateS* website: http://viceroy.eeb.uconn.edu/EstimateS (free)
*EcoSim* website: http://garyentsminger.com/ecosim/index.htm (free trial)
*Exeter* website: http://exetersoftware.com/cat/update_ecometh.shtml
*Ramas Software* website: http://www.ramas.com/indexEnv.htm
*Ecological Software Solutions* website: http://www.ecostats.com/software/software.htm
*SPADE (Species Prediction & Diversity Estimation) website:* http://chao.stat.nthu.edu.tw/blog/software-download/spade/ (free)
*PAST (Paleontological Statistics Software) website*: http://folk.uio.no/ohammer/past/ (free)

Other Helpful Websites for EXCEL Users (tools and YouTube videos):

PopTools (add-in): http://sunsite.univie.ac.at/Spreadsite/poptools/index.htm.
Alan Barasch's help site: http://xl.barasch.com/.
Mr. EXCEL: http://www.mrexcel.com/.
EXCEL Tutorial- Advanced Functions: https://www.youtube.com/watch?v=bpQ3KCVHLc4

## IX. Grading Procedure

As per university regulations, students with excessive absences will be dropped from the class. Two exams (**Fridays: October 9 and December 4**) will be 150 point mixed format. Exams will consist of long and short answer essays, graph/output interpretation, calculations, and ecostatistical questions that will come from the lecture notes, textbook, presentations, software, journal articles, and activities. All requests to take exams at other than scheduled times must be in writing to the instructor **at least 3 lecture days** prior to the scheduled exam date. It is your responsibility to contact me in the event you miss an exam or assignment. If you miss class on a test day, you are required to provide me with relevant written information (e.g., letter from a physician) documenting your absence. The final decision to offer a makeup exam rests with me.

**Cheating in any form is inappropriate conduct and will be dealt with swiftly and severely according to Sections 41301 through 41304 of Title 5 of the *California Code of Regulations*" which includes expulsion, suspension or probation.**

Correct spelling and grammar, and good penmanship are necessary for effective communication. Poor spelling, grammar and penmanship are signs of intellectual immaturity and carelessness. Therefore, such lapses will result in lost points on presentations, homework, and exams; illegible answers on exams and homework will receive no credit (i.e., If I can't read it, it's wrong).

### Grades and Weighting

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| Lecture Exams (2 @ 150 points each) | 300 |
| Journal Presentations (2 @ 150 points each) | 300 |
| Spreadsheet/Software Exercise | 150 |
| Homework | 200 |
| Miscellaneous (participation, initiative, attendance) | 50 |
| Total | 1000 points |

A = 900-1000, B = 800-899, C-F = 700 or fewer. No +/- grading will be applied to your final grade.

## X. Topics, Readings, In-Class/Homework Activities*

| TOPIC | CHAPTER READINGS** & EXERCISES | JOURNAL ARTICLE(S) |
|---|---|---|
| Introduction:<br>❑ spreadsheet hints/tips<br>❑ math functions/macros/add-ins pack<br>❑ freeware programs<br>❑ preparing data files | M1, V1<br>*DW2*<br><br><br>M1 | Ellison & Dennis 2010, Platt 1964, Gleick 1990<br><br>Curran-Everett 2008 |
| Properties/Challenges of Biological Data:<br>❑ introduction<br>❑ scales of measurement<br>❑ metadata, data archiving & sharing<br>❑ positional accuracy<br>❑ significant figures<br>❑ variability & uncertainty<br>❑ species detection & DNA barcoding<br>❑ measurement repeatability<br>❑ handling & visitation effects<br>❑ population growth (A, G, E, L) | K1,V2, M5<br><br>M7<br><br>V3<br><br>K11 (479-81)<br><br>K16 (717-21), M10<br><br>*DW7-8* | Michener 2006; Cook et al. 2001<br>Strier et al. '11<br>Dodd 2011<br><br>Longino & Colwell '97, Smith et al. 2008<br><br>Wolak et al. 2012; Hayes et al. 1998<br>Wallin & Van den Avyle '95, Klaring '99 |
| Statistical Foundations:<br>❑ three frameworks<br>❑ (pseudo)random numbers<br>❑ standards for statistical inference<br>❑ statistical significance and power<br>❑ parametric vs. non-parametric | M7<br><br>M5<br>K1 (13-15)<br>*PiFace* | Michaud et al. 2012<br>Curran-Everett '10; Thomas & Juanes '96 |

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| ❑ central limit theorem<br>❑ norm. distr. & tests for normality<br>❑ accuracy, precision, bias<br>❑ hypothesis tests & confidence intervals<br>❑ data transformation<br>❑ one-tailed vs. two-tailed tests<br>❑ confidence intervals<br>❑ exploratory data analysis<br>❑ statistical modeling<br>-- bootstrap (introduction)<br>-- jackknife (introduction) | *DW4*<br>V5-7, M7-8<br>K1 (9-10)<br>*DW5*<br>K16 (701-16)<br>K16 (734-740) | Wang & Riffel 2011<br>Walther & Moore 2005<br>Curran-Everett 2009a<br>Ruxton & Neuhauser 2010<br>Curran-Everett 2009b<br>Meyer et al. 1986 |
| Experimental Designs:<br>❑ definitions, types<br>❑ true replication, pseudoreplication<br>❑ field designs for ANOVA<br>❑ field designs for env. impacts (BACI)<br>❑ repeated measures designs<br>❑ meta-analysis (theory, computation)<br>❑ meta-analysis (applications) | K10-11, V11-15 | Hurlbert. 1984; Heffner et al. 1996<br>Steinbeck et al. 2005<br>Gill and Haps 1971<br>Arnq. & Woost.'95; Kotaiho & Tomk. '02;<br>Letourn. et al. '11; Vance-Chalc. et al. '07 |
| Statistical Distributions & Dispersion Tests:<br>❑ introduction to probability theory<br>❑ Poisson<br>❑ negative binomial<br>❑ goodness of fit tests<br>❑ indices of dispersion<br>❑ spatial distribution tests | *DW3*<br>M4<br>K4<br>K4<br>K4<br>K6<br>*SpatDist* | Myers 1978<br>Syrjala 1996 |
| Min. Samp. Sizes for Populations, Communities<br>❑ 1- & 2-sample tests, statistical power<br>❑ quadrats & sequential sampling<br>❑ collectors' curves, asymptotic sampling<br>❑ stopping rules & sampling optimization<br>❑ optimal quadrat shape & size | K7, V (App 1)<br>*RVSP*<br>*EstimateS, Chao*<br>*Cobra* | Marvier 2002<br>Naranjo & Hutchison 1997<br>Colwell & Coddington '94; Chao et al. '09<br>Cardoso 2009<br>Pringle. 1984. |
| Mark-Recapture Methods:<br>❑ Lincoln-Peterson<br>❑ Schnabel<br>❑ Bailey's Triple Catch<br>❑ Jolly-Seber<br>❑ Camera traps | K2<br>*DW23* | Thorne et al. 1996<br>Hamel et al. 2013 |
| Estimating Community Diversity:<br>❑ theory & models<br>❑ undersampling bias<br>❑ alpha, beta & gamma diversity<br>❑ diversity indices<br>❑ rarefaction (interpolation)<br>❑ richness estimators (extrapolation) | K13<br>*DW6*<br>*EstimateS, R&R*<br>*EstimateS* | Longino et al. 2002<br>Coddington et al. 2009<br>McCabe and Gotelli 2000<br>James & Rathbun '81; Buddle et al. '05,<br>Richardson & Richards 2008<br>Chiarcucci et al. 2001 |
| Null Models and Community Assembly<br>❑ theory and models | M9 | Conner and Simberloff 1986 |

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| ❑ species co-occurrences<br>❑ assembly rules<br>❑ spp. importance to ecosystem function | *EcoSim*<br>*EcoSim* | Adams 2007<br>Feeley 2003<br>Gotelli et al. 2011 |
| Analysis of Multivariate Data:<br>❑ theory and examples<br>❑ binary vs. quantitative similarity<br>❑ multivariate distance<br>❑ SMRA, ordination, classification<br>❑ CA, PCA, DFA<br>❑ CCA | K12<br><br><br><br>*PAST*<br>*PAST*<br>*PAST* | Wolda 1981<br><br>Townsend et al. 1983<br>Stancampiano & Schnell 2004<br>Wiens et al. 2001 |
| Review of Student Thesis Projects (Experimental & Statistical Methods) | | |

* Topic content may be changed due to extenuating circumstances.
**Readings: K = Krebs, V = van Emden, M = Mlodinow, DW = Donovan & Weldon.

## Readings


Ellison, A.E. and B. Dennis. 2010. Paths to statistical fluency for ecologists. Frontiers in *Ecology and the Environment*. 8: 362-370.

Platt, J.R. 1964. Strong inference. *Science* 146: 347-353.

Gleick, J. 1990. The census: why we can't count. *NY Times Magazine (July 13):* 22-26.

Curran-Everett, D. 2008. Explorations in statistics: standard deviations and standard errors. *Advances in Physiol. Educ*. 32: 203-208.

Michener, W.K. 2006. Meta-information concepts for ecological data management. *Ecological Informatics* 1: 3-7.

Cook, R.B. et al. 2001. Best practices for preparing ecological data sets to share and archive. *Bulletin of the Ecological Society of America*. 82: 138-141.

Strier et al. 2011. The Primate Life History Database: a unique shared ecological data resource. *Methods in Ecology and Evolution* 1: 199-211.

Dodd, M. 2011. Where are my quadrats? Positional accuracy in fieldwork. *Methods in Ecology and Evolution* 2: 576-784.

*Longino, J.T. and R.K. Colwell. 1997. Biodiversity assessment using structured inventory: capturing the ant fauna of a tropical rainforest. *Ecological Applications* 7: 1263-1277.

*Smith, M.A. et al. 2008. Extreme diversity of tropical parasitoid wasps exposed by iterative integration of natural history, DNA barcoding, morphology, and collections. *Proceedings of the National Academy of Sciences of USA* 105: 12359-12364.

Wolak, M.E. et al. 2012. Guidelines for estimating repeatability. *Methods in Ecology & Evolution* 3: 129-137.

*Hayes, J.P. et al. 1998. Repeatability of mammalian physiology: evaporative water loss and oxygen consumption of *Dipodomys merriami*. *Journal of Mammalogy* 79: 475-485.

*Wallin, J.E., and M.J. Van den Avyle. 1995. Interactive effects of stocking site salinity and handling stress on survival of striped bass fingerlings. *American Fisheries Society* 104: 736-745.

*Klaring, H-P. 1999. Effects of non-destructive mechanical measurements on plant growth: a study with sweet pepper (*Capsicum annuum* L.). *Scientia Horticulturae* 81: 369-375.

Michaud, J-P, K. Schoenly, and G. Moreau. 2012. Sampling flies or sampling flaws? Experimental design and inference in forensic entomology. *Journal of Medical Entomology* 49: 1-10.

Curran-Everett, D. 2010. Explorations in statistics: power. *Advances in Physiol. Educ.* 34: 41-43.

Thomas, L. and F. Juanes. 1996. The importance of statistical power analysis: an example from animal behavior. *Animal Behavior* 52: 856-859.

Wang, M. & M. Riffle. 2011. Making the right conclusions based on wrong results and small sample sizes: interpretation of statistical tests in ecotoxicology. *Ecotoxicology and Environmental Safety* 74: 684-692.

Walther, B.A. & J.L. Moore 2005. The concepts of bias, precision, and accuracy, and their use in testing the performance of species richness estimators, with a literature review of estimator performance. *Ecography* 28: 815-829.

Curran-Everett, D. 2009a. Explorations in statistics: hypothesis tests and P values. *Advances in Physiol. Educ.* 33: 81-86.

Ruxton, G.D. & M. Neuhauser. 2010. When should we use one-tailed hypothesis testing? *Methods in Ecology and Evolution.* 1: 114-117.

Curran-Everett, D. 2009b. Explorations in statistics: confidence intervals. *Advances in Physiol. Educ.* 33: 87-90.

*Meyer, J.S. et al. 1986. Estimating uncertainty in population growth rates: jackknife vs. bootstrap techniques. *Ecology* 67: 1156-1166.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs* 54: 187-211.

Heffner, R.A. et al. 1996. Pseudoreplication revisited. *Ecology* 77: 2558-2562.

*Steinbeck, J.R. et al. 2005. Detecting long-term change in complex communities: a case study from the rocky intertidal zone. *Ecological Applications* 15: 1813-1832.

Gill, J.L. and H.D. Haps. 1971. Analysis of repeated measurements of animals. *Journal of Animal Science* 33: 331-336.

Arnqvist, G. and D. Wooster 1995. Meta-analysis: synthesizing research findings in ecology and evolution. *Trends in Ecology and Evolution* 10: 236-240.

Kotiaho, J.S. and J.L. Tomkins. 2002. Meta-analysis, can it ever fail? *Oikos* 96: 551-553.

*Letourneau, D.K. et al. 2011. Does plant diversity benefit agroecosystems? A synthetic review. *Ecological Applications* 21: 9-21.

*Vance-Chalcraft, H.D. 2007. Influence of intraguild predation on prey suppression and prey release: a meta-analysis. *Ecology* 88: 2689-2696.

Myers, J.H. 1978. Selecting a measure of dispersion. *Environmental Entomology* 7: 619-621.

Syrjala, S.E. 1996. A statistical test for a difference between the spatial distributions of two populations. *Ecology* 77: 75-80.

*Marvier, M. 2002. Improving risk assessment for nontarget safety of transgenic crops. *Ecological Applications* 12: 1119-1124.

Naranjo, S.E. & W.D. Hutchison. 1997. Validation of arthropod sampling plans using a resampling approach: software and analysis. *American Entomologist* (Spring): 48-57.

Colwell, R. and J. A. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society of London B* 345:101-118.

Chao, A. et al. 2009. Sufficient sampling for asymptotic minimum species richness estimators. *Ecology* 90: 1125-1133.

Cardoso, P. 2009. Standardization and optimization of arthropod inventories – the case of Iberian spiders. *Biodiversity and Conservation* 18: 3949-3962.

*Pringle, J.D. 1984. Efficiency estimates for various quadrat sizes used in benthic sampling. *Canadian Journal of Fisheries and Aquatic Science* 41: 1485-1489.

*Thorne, B.L. et al. 1996. Evaluation of mark-release-recapture methods for estimating forager population size of subterranean termit (Isoptera: Rhinotermitidae) colonies. *Environmental Entomology* 25: 938-951.

*Hamel, S. et al. 2013. Towards good practice guidance in using camera-traps in ecology: influence of sampling design on validity of ecological inferences. *Methods in Ecology and Evolution* 4: 105-113.

*Longino, J.T. et al. 2002. The ant fauna of a tropical rain forest: estimating species richness three different ways. *Ecology* 83: 689-702.

Coddington, J.A. et al. 2009. Undersampling bias: the null hypothesis for singleton species in tropical arthropod surveys. *Journal of Animal Ecology* 78: 573-584.

*McCabe, D.J. and N.J. Gotelli. 2000. Effects of disturbance frequency, intensity, and area on assemblages of stream macroinvertebrates. *Oecologia* 124: 270-279.

James, F.C. & S. Rathbun. 1981. Rarefaction, relative abundance, and diversity of avian communities. *Auk* 98: 785-800.

Buddle, C. et al. 2005. The importance and use of taxon sampling curves for comparative biodiversity research with forest arthropod assemblages. *Can. Entomol*. 137: 120-127.

Richardson, J.M.L. and M.H. Richards. 2008. A randomisation program to compare species-richness values. *Insect Conservation and Diversity* 1: 135-141.

*Chiarucci, A. et al. 2001. Evaluation and monitoring of the flora of in a nature reserve by estimation methods. *Biological Conservation* 101: 305-314.

Conner, E.F. and D. Simberloff. 1986. Competition, scientific method, and null models in ecology. *American Scientist* 74: 155-162.

*Adams, D.C. 2007. Organization of *Plethodon* salamander communities: guild-based community assembly. *Ecology* 88: 1292-1299.

*Feeley, K. 2003. Analysis of avian communities in Lake Guri, Venezuela, using multiple assembly rule models. *Oecologia* 137: 104-113.

*Gotelli, N., W. Ulrich, and F.T. Maestre. 2011. Randomization tests for quantifying species importance to ecosystem function. *Methods in Ecology and Evolution* 2: 634-642.

Wolda, H. 1981. Similarity indices, sample size and diversity. *Oecologia* 50: 296-302.

*Townsend, C.R. et al. 1983. Community structure in some southern English streams: the influence of physicochemical factors. *Freshwater Biology* 13: 521-544.

*Stancampiano, A.J. and G.D. Schnell. 2004. Microhabitat affinities of small mammals in southwestern Oklahoma. *Journal of Mammalogy* 85: 948-958.

*Wiens, J.A. et al. 2001. A canonical correspondence analysis of the effects of the Exxon Valdez oil spill on marine birds. *Ecological Applications* 11: 828-839.

*student presentations