Sarah Bray
Biology Program

Materials for Bingham Teaching Award Renewal

January 2017

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As I have been reviewing my teaching materials for renewal of the Bingham Award, I have actually been surprised with the amount of change I have undergone as a teacher. Due to a revision of our curriculum, I have developed three new courses, increased the quantitative aspect of my own courses and the biology curriculum in general, modified student learning outcomes in line with pedagogical research, and altered my daily classroom activities and assignments to emphasize the process of science. Thanks to continued interactions with my colleagues across the college, my perspective on how science should be taught to both majors and non-majors in a liberal arts perspective has changed and continues to evolve.

My Evolution as a Teacher

One of the biggest changes to my teaching came through a curriculum revision that I lead in 2013. The National Science Foundation and the American Association for the Advancement of Science have recommended that biology courses should introduce fewer core concepts while focusing on scientific process in the report Vision and Change in Undergraduate Biology: A Call to Action (AAAS 2011). Meanwhile, the most popular college-level text, which we used for our introductory biology course, weighed in at 1400+ pages. Cleary we needed to reassess what and how we would teach introductory biology. After seeing a presentation on a new textbook in-line with Vision and Change at a professional conference I attended, I convinced my program to invite Dr. Malcolm Campbell as an external reviewer for our program review. As a result of the program review, I spearheaded the development of a new three-course introductory sequence in our major. The two introductory courses, Integrated Concepts in Biology: Molecules and Cells (ICBM) and Organisms and Ecosystems (ICBO), use student-centered discussion of experiments that illustrate the core concepts in biology developed in Vision and Change. The third course, Biologist's Toolkit, develops core competencies with a focus on quantitative literacy and scientific communication. I was the primary architect of the global curriculum change and personally developed the ICBO and Toolkit courses.

For me, one of the challenges of ICBO was learning to give students the space and the time to process information themselves. Because the goal is to have a student-centered experience, I want to have the students do most of the talking. This was challenging for me because in my excitement about biology, I was prone to fill awkward pauses and explain the graph or concept. To encourage participation, I begin the semester talking about the goals of the course and explaining that because research shows students learn best by participating, I will make sure that everyone speaks each day. Another challenge has been that some experiments in our textbook do not give enough context for students to understand on their own. In these instances I often create worksheets that give additional information and/or breakdown the study into smaller parts that the students can handle. Finally, I often ask students, 'what's the next step,' and then introduce data from follow up studies. Thus in introductory biology, I have moved from being the expert imparting knowledge to more of a

coach, guiding students through the scientific process and bringing in my knowledge to help them make connections to the core concepts.

Although this new approach emphasizes process and depth over breadth, content is still central to the course and I continue to think about what content should be covered. James Wagner and I have been unsatisfied with how the authors addressed phylogeny (the reconstruction of evolutionary relationships among organisms), so we wrote a new chapter on this topic using the interesting biogeography and phylogeny of flightless birds (for example, emus in Australia, ostriches in Africa, and rheas in South America). After another semester of deployment and revision in the course, we hope to submit it to the authors of the text for incorporation into future editions of the text.

Quantitative reasoning has always been important learning goal of mine. I'm sure some of my focus on quantitative literacy is in part due to the fact that I am an ecologist, a field that is very dependent on statistics and modeling to be able to distinguish pattern from noise. As the Vision and Change report has noted, two of the six competencies that all biology graduates should have are quantitative. We now live in an era of Big Data with even molecular biologists (classically non-quantitative) analyzing large data sets and representing their data visually. I have worked diligently to increase the quantitative literacy throughout our major, increasing the use of graphs and statistical analysis in our new first-year curriculum and building on upon those skills in my upper-level courses. The biggest impact I have had on quantitative literacy of our majors is through the creation of the sophomore-level course in our new curriculum, Biologist's Toolkit.

My learning outcomes for Biologist's Toolkit are that student will: statistically analyze and visually present results; communicate results; and develop and test hypotheses. I decided to base a large portion of the course on making graphs and analyzing data with the free statistical programing platform, R, which I use in my own research and is becoming increasingly popular among scientists. I chose R because I thought it would not only give our students an edge in research opportunities and job prospects but also force them to more mindfully approach statistical analysis. My first time teaching the course, students were very resistant; most of them had no command-line programming experience and the learning curve for R is very steep. I found that I needed to incorporate more basic computer literacy into the first few weeks of the course and chose an upper-class student who previously had been successful in the class to be a TA to help with troubleshooting problems. I also required students to maintain a notebook of all their work in the course. In this notebook, students were encouraged to revise homework and respond to my comments to improve their grade and show that they had mastered the skill. The iterative nature of this notebook is very labor intensive for me, but has clearly improved student comprehension and retention of skills in this course. Students now refer back to these notebooks as they analyze data in their upper-

level courses. I have recently published a pedagogy paper about this course with James Wagner and Paul Duffin who have also taught the course (Bray et al. 2016).

Finally, I feel that I have matured as teacher due to my more nuanced understanding of a liberal arts education. Much of my development here has been a result of conversations and team-teaching with faculty within my program and across the college and my participation in the Liberal Arts Seminar in summer 2013. I think consciously about the role of biology and science play in a liberally educated individual's life when planning my courses and assignments. My central topic in non-majors courses is always the intersection of biology and society. For example, in my most recent non-majors course focusing on human evolution, we examined whether race has any biological meaning. A liberally educated individual must also be able to understand and evaluate graphical representation of data to be an informed citizen. I choose popular science books as a way for non-majors to begin exploring scientific issues, but often follow readings and discussions with examination and interpretation of figures from papers cited in the chapter. In my majors classes I also try to emphasize the interplay of science and society. Recently I have been exploring underrepresented groups in science—why and how do they continue to be underrepresented? How does the absence of these scientists affect the questions we ask and how we interpret the data?

The Interconnections of my Teaching and Scholarship

As mentioned above, many of my changes as a teacher have come through an engagement in the pedagogy literature. With the publication of my article on Biologist's Toolkit, I now am a participant in that pedagogy conversation. In the past five years I have been working hard to incorporate more students into my research in and out of the classroom. I have worked with nine Transy undergraduates and one high school student during this time resulting in five presentations at meetings and two publications with these students. One of these publications has an undergraduate as first author, Kali Mattingly. Undergraduates as first authors on biology manuscripts are relatively rare because of the increased effort required of faculty advisors on data analysis and multiple drafts of papers. Although it took a lot of effort and two years to get Kali's paper published (Mattingly et al. 2016), this experience encouraged Kali to enroll in graduate school. She has told me that the experience of working on this paper made her thesis much less intimidating and she is now enrolled in the ecology Ph.D. program at Ohio State University. My work with Kali has helped me in teaching writing; I now have better focus when giving feedback on writing assignments. My improvement in teaching writing has also improved the feedback I give to authors submitting manuscripts to The Journal of the Torrey Botanical Society, where I am a subject editor.

I also incorporate real research experiences into all of my courses. I feel that I have been particularly successful at this in my upper-level course, Ecology. In my most recent iterations of this class, we function as a research team investigating the impacts of invasive wintercreeper in a single field site. While I put some restrictions on projects to ensure their

success, students proposed their own hypotheses, study design, analysis, and presented their results in oral and written form. Particularly rewarding for me in this experience was to see students apply the skills that they learned in their Toolkit course to their own projects. Several groups actually worked independently to find and adapt new R code to analyze their data. The projects were so well done that the results of two projects were presented at a local meeting and I am currently collecting additional data on a third project with hopes of publishing it. It is difficult for me to imagine a better actualization of my goals of quantitative literacy, participation in the scientific community, and an understanding of the links between science and society.

Goals for Continued Development

While I am pleased with my progress I have made as a teacher in the last five years, as an evolutionary biologist, I subscribe to the Red Queen Hypothesis, "it takes all the running you can do to keep in the same place." I plan to stay engaged in the literature and my own scholarship and continue to bring them into my courses. I also try to stay current with responses to Vision and Change through list-serves and the literature. In the short term, I would like to continue to revise and write more chapters for our ICBO course. While we do have investigatory labs for ICBO, I would like to develop new lab modules as students are now anticipating particular sets of labs. I continue to modify Toolkit with a mind to students who have only known a world of apps. In the longer term I would like to create a course that utilizes the next-gen sequencing and computing tools, which I learned in my last sabbatical, into a new course. I hope to participate in workshop run by GCAT-SEEK supported by the Howard Hughes Medical Institute with one of my biology colleagues to help prepare that course. With the addition of a modeler in the mathematics program, I would like to increase the use of modeling and simulation in my courses as this is one of the core competencies where I feel our students are weakest. Finally, I have learned so much from teaching with faculty in the humanities; I hope I get more opportunities to team-teach.

Literature Cited

AAAS (2011) Vision and Change: A Call to Action, Final Report. http://visionandchange.org/finalreport/. Accessed 27 Jul 2016

Bray SR, Duffin PM, Wagner J (2016) Thinking deeply about quantitative analysis: Building a Biologist's Toolkit. CourseSource 3:1–8.

Mattingly KZ, McEwan RW, Paratley RD, Bray SR, Lempke JR, Arthur MA (2016) Recovery of forest floor diversity after removal of the nonnative, invasive plant Euonymus fortunei. J Torrey Bot Soc 143:103–116. doi: 10.3159/TORREY-D-14-00051

Curriculum Vitae

Sarah Bray

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EDUCATION

2005 **University of Florida, Gainesville, Florida**
Ph.D. Department of Botany. Dissertation: "Interactions between plants and soil microbes in Florida communities: implications to invasion and ecosystem ecology." Advisor: Kaoru Kitajima.

1999 **Tropical Biology: An Ecological Approach, Organization for Tropical Studies**

1998 **Coe College, Cedar Rapids, IA**
B.A. Biology and Environmental Science, *magna cum laude*, with honors

ACADEMIC POSITIONS

2012-present **Associate Professor of Biology, Transylvania University**
Courses taught:
BIO 1044 Biological Interactions
BIO 1164 Biology and Human Concerns
BIO 1206 Integrated Concepts of Biology: Organisms and Ecosystems
BIO 2024 Genetics
BIO 2042 Biologist's Toolkit
BIO 2144 Tropical Ecology (team-taught)
BIO 2424 Biology of Climate Change
BIO 2424 Walking the Isothermal Lines (team-taught, interdisciplinary)
BIO 3124 Field Botany
BIO 3314 Evolution
BIO 4144 Ecology
BIO 4444 Senior Seminar in Biology (Biology of Climate Change ('08), Why Pleasure? ('10), Sex and Consequences ('13))
IDS 2294 Darwin's Dangerous Idea (team-taught, interdisciplinary)
FLA 1004 Foundation of the Liberal Arts I
UNI 1111 Academic Career Skills

2007-2012 **Assistant Professor of Biology, Transylvania University**

2005-2007 **Curator, Midland Lutheran College, Nebraska Statewide Arboretum**

2005-2007 **Assistant Professor of Biology, Midland Lutheran College**
Courses taught: Principles of Biology, Ecology and Field Biology, Principles of Environmental Science, Evolution, Botany, Ecosystems of Florida

PUBLICATIONS

Bray, S.R., A.M. Hoyt^, Z. Yang, M.A. Arthur. 2017. *Euonymus fortunei* (purple wintercreeper) effects on alteration of decomposition environment and soil bacteria remains after its removal. Plant Ecology. DOI 10.1007/s11258-016-0689-3

Bray, S.R., P.M. Duffin, and J.D. Wagner. 2016. Thinking deeply about quantitative analysis: building a Biologist's Toolkit. CourseSource 3:1-8.

Mattingly, K.Z.*, R.W. McEwan, R.D. Paratley, **S.R. Bray**, J.R. Lempke, and M.A. Arthur. 2016. Recovery of forest floor diversity after removal of the non-native invasive plant *Euonymus fortunei*. The Journal of the Torrey Botanical Society 143(2): 103-116.

Arthur, M.A., **S.R. Bray,** K. Kuchle*, and R. McEwan. 2012. The influence of the invasive shrub, *Lonicera maackii*, on leaf decomposition and microbial community dynamics. Plant Ecology 213(10): 1571-1582.

Bray, S.R., K. Kitajima, M.C. Mack. 2012. Temporal dynamics of microbial communities on decomposing leaf litter of 10 plant species in relation to decomposition rate. Soil Biology and Biochemistry 49: 30-37.

Bray, S.R. 2009. Charles Wilkins Short: Immortalized through plants bearing his name. Transylvania Treasures 2(2): 6-7.

Bray, S.R. 2005. Interactions between plants and soil microbes in Florida communities: implications to invasion and ecosystem ecology. Ph.D. Dissertation, University of Florida, Department of Botany.

Bray, S.R., K. Kitajima, and D.M. Sylvia. 2003. Mycorrhizae differentially alter growth, physiology, and competitive ability of an invasive shrub. Ecological Applications 13: 565-574.

Bray, S.R. 1998. Demography of the epiphytic and hemiepiphytic community in the Rio Macho Forest Reserve and the effect of selective logging on that community. Undergraduate honors thesis. Coe College, Cedar Rapids, IA.

INVITED SEMINARS and PANELS

2017 Plant Pathology Department, University of Kentucky. 3 February 2017.

2016 "The vine that ate the mid-Atlantic? The new threat of wintercreeper to urban forest fragments." Urban Ecology: NSF-Sponsored Workshop. Ecological Research and Education Center, University of Kentucky. 12 November 2016.

2016 "Academic Careers at Primarily Undergraduate Institutions - Faculty Perspectives from Sciences and Liberal Arts." Society of Post-Doctoral Scholars, University of Kentucky. 5 April 2016.

2014 "From Charles Elton to H.G. Wells: a Life at a Liberal Arts College," Ecolunch, University of Kentucky Biology Graduate Program. 3 October 2014.

2012 "The living world and climate change: Lessons from the past, snapshots of the present, thoughts on the future," Science Pub, West 6th Brewery, Lexington, KY. 19 November 2012.

CONTRIBUTED PRESENTATIONS

Beatty, J.*, A. Wilburn*, L. Lietzenmayer*, J. McCullough*, R.D. Rowe*, **S.R. Bray**. 2016. Invasive plant *Euonymus fortunei* and *Lonicera maackii* reduce *Festuca arundiacea* germination and *Brassica rapa* growth. Urban Ecology Workshop, University of Kentucky Ecology Research and Education Center.

Beatty, J.*, N. Wisnoski, **S.R. Bray**, and J.T. Lennon. 2016. Residence time as a driver of abundance activity and resource-use in complex microbial communities. Kentucky Academy of Sciences Annual Meeting, University of Louisville.

Thomas, P.*, V. Kuo, **S.R. Bray**, B. Lehmkuhl, and J.T. Lennon. 2016. The effects of a resuscitation promoting factor (Rpf) on bacterial activity and plant biomass. Kentucky Academy of Sciences Annual Meeting, University of Louisville.

Hoyt, A.M.^, **S.R. Bray**, and M.A. Arthur. 2014. *Euonymus fortunei* (purple wintercreeper) increases decomposition via alterations of biotic and abiotic environment. Kentucky Academy of Science Annual Meeting, Lexington, KY.

Mattingly, K.Z.*, N. Truszczynski*, R.W. McEwan, R.D. Paratley, **S.R. Bray**, and M.A. Arthur. 2014. Recovery of forest diversity after removal of invasive *Euonymus fortunei.* Midwest Ecology and Evolution Conference, Dayton University.

Mattingly, K.Z*, **S.R. Bray**, and M.A. Arthur. 2014. Recovery of forest diversity after removal of invasive *Euonymus fortunei*. Oral Presentation. National Conference on Undergraduate Research, Lexington, KY.

Bray, S.R., and G.L. Bailey. 2012. Altering college students' misconceptions of evolution requires addressing views that evolution and religion are in conflict. Oral Presentation. Ecological Society of America Annual Meeting, Portland, OR.

Bussell, K.M.* and **S.R. Bray**. 2012. Timing disturbance alters gall-making arthropod abundance and goldenrod biomass and height. Poster Presentation. Mid-Atlantic Chapter of the Ecological Society of America, Blacksburg, VA.

Bray, S.R., and G.L. Bailey. 2012. Altering college students' misconceptions of evolution requires addressing views that evolution and religion are in conflict. Oral Presentation. Mid-Atlantic Chapter of the Ecological Society of America, Blacksburg, VA.

Bray, S.R. 2011. God-mediated locus of control and perceptions of evolution: a battle of hearts and minds. Academic Affairs, Transylvania University.

Bray, S.R., and G. L. Bailey. 2011. What do students really know about evolution? Measuring students' knowledge of and attitudes towards evolutionary science. Poster Presentation. Ecological Society of America Annual Meeting, Austin, TX.

Bray, **S.R.**, M.A. Arthur, R.W. McEwan, and C.R. Kuchle*. 2011. Accelerated leaf decomposition of an invasive shrub (*Lonicera maackii*) and its relationship to soil biota and leaf chemistry. Poster Presentation. Ecological Society of America Annual Meeting, Austin, TX.

Arthur, M.A., **S.R. Bray**, C.R. Kuchle*, and R.W. McEwan. 2011. Accelerated leaf decomposition of an invasive shrub, *Lonicera maackii*, and its relationship to soil biota, leaf chemistry, and decomposition environment. Poster Presentation. Joint Meeting of the 2nd Kentucky Invasive Species Conference and the 13th Annual Southeast EPPC Conference, Lexington, KY.

Kuchle, C.R.*, M.A. Arthur, and **S.R**. **Bray.** 2010. Effect of bush honeysuckle, an invasive plant species, on mycorrhizal growth in native tree species. National Conference on Undergraduate Research, University of Montana.

Bray, S.R. 2009. Invasion of *Lonerica maackii*: Science meets science fiction. Academic Affairs, Transylvania University.

Bray, S.R., K. Kitajima, and M.C. Mack. 2009. Succession of microbial communities on plant litter highly correlated with litter chemistry and decomposition rate. Oral presentation. Ecological Society of America Annual Meeting, Albuquerque, NM.

Kuchle, C.R.*, M.A. Arthur, R.W. McEwan, and **S. R. Bray**. 2009. Accelerated leaf decomposition in an invasive shrub (*Lonicera maackii*) is a function leaf chemistry, not the decomposition environment. Poster presentation. Annual Meeting of the Ecological Society of America, Albuquerque, New Mexico.

Bray, S.R. 2003. Alteration of microbial community function and composition over a range of geographical locations, plant communities and invasive plant species. Poster Presentation. Invasive Plants in Natural and Managed Systems Annual Meeting. Ft. Lauderdale, FL.

Bray, S.R. 2003. Alteration of microbial community function and composition over a range of

geographical locations, plant communities and invasive plant species. Oral paper. Ecological Society of America Annual Meeting, Savannah, GA.

Bray, S.R., K. Kitajima, and D. M. Sylvia. 2001. Effect of native fungi on growth, physiology and morphology of an invasive shrub, *Ardisia crenata.* Oral paper. Ecological Society of America Annual Meeting, Madison, WI.

Bray, S.R., K. Kitajima, and D.M. Sylvia. 2000. Effect of native mycorrhizal fungi on ecophysiology of an invasive shrub. Poster presentation. Ecological Society of America Annual Meeting, Snowbird, UT.

*Undergraduate student ^High school student

FUNDED GRANTS

External

Subcontractor on: NSF Dimensions of Biodiversity "Dimensions: Collaborative Research: Microbial seed banks: processes and patterns of dormancy-driven biodiversity," DEB 1442246**.** Awarded to JT Lennon, K Locey and S Jones. 2015-2020. **$50,000** to support Transylvania REU students.

2016-2017: Supplemental of **$13,660** to support year-long research of minority student, Jaylen Beatty.

NSF Department of Undergraduate Education, s-STEM. "STEM Scholars: Attracting and Retaining Students in Science and Mathematics Majors," DEB 1259026. Co-PI with E. Csuhai, M. LeVan and G. Kaufman. 2013-2018. **$616,377**.

Nebraska NSF EPSCOR. "Impacts of changing plant species composition on microbial community composition and function in a Nebraska pasture." $5000. 2006-2007

Florida Exotic Pest Plant Council. "Impact of *Ardisia crenata* on bacterial community composition of hardwood hammocks**."** $1000. 2002

Internal

Transylvania University Kenan Fund. "Restoration of Transylvania University's herbarium." Co-PI with Lindsey Duncil. $2926.25. 2015.

Transylvania University Kenan Fund. "Courting via symbionts: variation in house sparrow microbiome and its role in sexual ornaments." $4000. 2015

Transylvania University Kenan Sabbatical Fund. "Role of dormancy in maintaining microbial biodiversity." Sabbatical Grant, Kenan Fund for Faculty and Student Enrichment. $9810. 2013-2014.

Transylvania University Kenan Fund. "How does invasion and removal of an invasive species, *Euonymus fortunei*, alter microbial community composition?" $3500. 2014.

Transylvania University Kenan Fund. "What do students really know about evolution? $3300. 2012.

Transylvania University Kenan Fund. "Plant community composition and abundance of an old-field prior to the initiation of a new management regime." Co-PI with Kate Bussell. $4079.50. 2010.

Transylvania University Kenan Fund. "Links between microbial decomposer community and the alteration of ecosystem processes by an invasive shrub, *Lonicera maackii* (Amur honeysuckle)." $7000. 2008-2009.

Transylvania University Bingham Fund Start-up. $7000. 2007

FELLOWSHIPS AND AWARDS

2011-present	Bingham Teaching Fellow
2004	Nutter Dissertation Fellowship, University of Florida.
2004	University of Florida Graduate Assistant Teaching Award
1998-2001	NSF Pre-Doctoral Fellowship

RESEARCH SUPERVISION

Undergraduate independent projects

Nellie Heitzman. "Herbivory of a non-native liana *Euonymus fortunei*." 2017.

Jaylen Beatty (supported by D-BP-REU) and Julie Ward. "Microbial communities on decomposing invasive wintercreeper litter." 2016-2017.

Rachel Ferrill. "Do living and simulated wintercreeper vines increase decomposition rates?" 2016.

Lindsey Duncil. "Restoration and organization of the Transylvania University Herbarium." 2015.

Casey Coomes and Erin Snyder. "Development of techniques to assess house sparrow feather microbiome." 2014-2015.

Kali Mattingly. "Recovery of forest diversity after removal of invasive *Euonymus fortunei."* 2013

Kate Bussell. "Plant community composition and abundance of an old-field prior to the initiation of a new management regime." 2010-2012

Christina Kuchle (UK). "Effect of bush honeysuckle, an invasive plant species, on mycorrhizal growth in native tree species." 2009-2010.

Kelly Spratte-Lennington. “Impact of honeysuckle invasion on arthropod abundance and composition.” 2009

Rebecca Pasco and Colin Murphree. “Microbial communities on decomposing plant litter.” 2008-2009.

Craig Kreikemeier, Amanda Kuhr, Megan Lohmiller. “Impacts of changing plant species composition on microbial community composition and function in a Nebraska pasture” Midland Lutheran College. 2006-2007

Michelle Burch, “Impact of microinvertebrates on the colonization of *Acer rubrum* litter by culturable bacteria and fungi.” University of Florida. 2004.

Rebecca Gruby, “Characterization of microinvertebrates in a xeric hammock and those colonizing *Acer rubrum* litter.” University of Florida. 2004.

High school projects

Andy Hoyt. “Impacts of wintercreeeper invasion on decomposition and microbial community composition.” Henry Clay High School. 2014-2015.

Alex Reinstein. “Influence of fiber fractions on the composition of microbial communities on decomposing plant leaf litter. Won Best Student Research Paper Award and Best Student Presentation. University of Florida Student Science Training Program. 2004.

PROFESSIONAL SERVICE

2015-present	Urban Forestry Initiative Committee Member, Lexington, KY
2015	External Evaluator, Biology Program, Thomas More College
2015-present	Associate Editor, The Journal of the Torrey Botanical Society
2015-present	Discovering Darwin, podcast about the works of Charles Darwin with J. Adkins and J. Wagner
2007-present	Invasive Species Working Group of Kentucky
2006-2007	President, Midland Lutheran College AAUP chapter
2005-2007	Consulting member, Lower Platte Water Management Area
2001-2002	Plant invasion outreach project, Gainesville Nature Operations

Ad hoc reviewer for journals *Ecosystems*, *Soil Biology and Biochemistry, Texas Journal of Science, Functional Ecology, CourseSource, Plant Ecology, Plant Biology*

PROFESSIONAL DEVELOPMENT

2014	Sabbatical in lab of Jay Lennon at University of Indiana
2012	Microbial Metagenomics, Michigan State University
2008	Council of Undergraduate Education, Beginning a Research Program in the Natural Sciences at a Predominantly Undergraduate Institution. Davidson College, Davidson, NC.

2006	International Service-Learning Research Conference, Portland, OR.
2006	"New approaches and techniques for teaching science: addressing environmental problems to stimulate undergraduate learning," NSF-sponsored workshop.
2005	Tree maintenance workshop, Nebraska Forestry Service

SERVICE TO THE UNIVERSITY

2016-2018	Committee on Programs and Curriculum, chair (2016-2017)
2016-present	Yale Bioethics Seminar Selection Committee
2016-present	Faculty Budget and Finance Workgroup
2016-2017	Salary and Compensation Subcommittee
2015	Mathematics Faculty Search
2015	Computer Science Faculty Search
2014- present	NSF STEM Scholars Coordinator
2013	The Transylvania Seminar, Co-Coordinator
2012, 2013	Faculty Salary Report
2011, 2013	Academic Summer Camp Instructor
2010-2012	Subcommittee on tenure and promotion by-laws
2010-2012	Committee on Admissions and Academic Standards
2009-2011	Biology Club Advisor
2009-2010	Holleian Society President
2009-	Program Director, Biology (4 academic years)
2009-2010, 2011, 2012	Biology Faculty Searches (3 total)
2007-2008, 2011-2012	Chemistry Faculty Search (2 total)
2007-2009	Library Subcommittee

PROFESSIONAL SOCIETIES

Ecological Society of America
Soil Ecology Society
Southeastern Exotic Pest Plant Council

HONORARIES

Phi Beta Kappa
Phi Kappa Phi
Alpha Lambda Delta
Mortar Board

Supporting Materials

Below is a list of the materials I have included as illustration of my teaching and scholarship. For each entry I give a short synopsis about the goals of the course, assignment, or scholarly work. Links will take you directly to example.

I. Syllabi- I have taught nine different courses since I was awarded the Bingham Teaching Award, but present six of those courses here that represent both major and non-major courses from first-year to senior level.

   a. **Biology and Human Concerns (BHC, Winter 2016)**
   This is a course of open-ended focus for non-majors. In this particular semester, I chose to focus on human evolution. Some of the issues we explored included: how do we know evolution occurred? How does our evolutionary past interact with our current environment to affect our health? What can biology tell us about the concept of race?

   b. **Integrated Concepts of Biology: Organisms and Ecosystems (ICBO, Winter 2017)**
   As described in my essay, ICBO is one of the two new first-year courses for biology majors.

   c. **Biologist's Toolkit (Winter 2017)**
   As described in my essay, Biologist's Toolkit is a course intended for sophomore biology (all tracks) and neuroscience (biology track) majors. Both sections meet on Mondays and are generally introduced to a new statistical test. On Wednesday and Fridays, only one section attends for a studio day where students work on analyzing new data.

   d. **Walking Isothermal Lines (May 2015)**
   This was an interdisciplinary May term course taught by Spanish professor, Jeremy Paden, and me. While all the students in the course ended up being biology majors, approximately half of them were also Spanish majors or minors. We read a book, Tropical Nature, and discussed it in the winter semester and had approximately one week of class in Lexington before traveling to Peru. The primary biological emphasis of the class was to explore the adaptions of ecosystems to altitude and students explored this through reading of travel narratives including Humboldt, Darwin, and poet Sharon Doubiago.

   e. **Evolution (Winter 2015)**
   This is a required course for the EEB track and elective in the Biology track and is intended for juniors and seniors; this course does not have a lab. We often read a popular science book as entrance to the scientific literature as well as to discuss the how science is conveyed to a lay audience.

   f. **Ecology (Fall 2015)**
   Ecology is a course required for the Ecology, Evolution, and Behavior (EEB) track and an elective for the Biology track and is intended for juniors and seniors. The class is organized around large questions in ecology with an emphasis on the primary literature. Students complete a semester-long project investigating wintercreeper invasion.

II. Assignments

   a. **Worksheet on flocking behavior for ICBO**
   A series of experiments on the flocking behavior in birds were intended to illustrate the concept of emergent properties. Students had a hard time grasping what the two alternative hypotheses, topology and distance, were predicting and how we could test for them. This worksheet helps students to walk through the hypotheses and their predictions before we get to the results of the original study.

b. Phylogeny Chapter for ICBO

James Wagner and I felt that the presentation of phylogeny as well as the definition of species and the process of speciation did not work well, so we decided to write our own chapter. This chapter uses ratites (flightless birds) to illustrate these concepts. While I think it is safe to say this is still a work in progress, what I am most pleased about in this chapter is that we show that 1) studies are the beginning of knowledge, not the end, 2) we constantly refine our hypothesis with more data, and 3) our conclusions are limited by the techniques available to us.

c. Concept of Race BHC

This is also a worksheet to accompany a chapter in The Invisible History of the Human Race. Here my goal was to explicitly exam the "biology" of race from a liberal arts perspective. I wanted the student to try to evaluate the scientific evidence but to also think about how the questions asked and interpretation of results are influenced by our society.

d. British Genetic Structure for BHC

This was a worksheet that I developed to accompany a chapter we read in The Invisible History of the Human Race: How DNA and History Shaped our Identities and our Futures. I developed this from the primary literature articles on which the chapter is based. My goal was to delve more deeply in the science reported in the chapter and to make the students more familiar with how data is presented. After working on the worksheet in pairs in class, we discussed the worksheet in the following class.

e. Ecology lab project introduction

This is an introduction to the class and individual projects that would be completed in my Ecology class in fall 2015. I constrained projects to a particular field site and study species but allowed students to develop their own questions. I provided unpublished data from my research as a jumping off point for more questions. I tried to model the scientific process (and encourage them to participate) by showing how I myself was thinking through puzzling results and developing additional hypotheses.

III. Scholarly work- publications and presentation relating my teaching and scholarly work.

a. Bray, Sarah R, Paul M Duffin, and JD Wagner. "Thinking Deeply about Quantitative Analysis: Building a Biologist's Toolkit." *CourseSource* 3(2016): 1–8.

This article describes our Biologist's Toolkit course and encourages biologists to adopt a similar course. In the article we outline the course, student learning outcomes, short- and long-term outcomes, and potential pitfalls and how to avoid them.

b. Mattingly, Kali Z et al. "Recovery of Forest Floor Diversity after Removal of the Nonnative, Invasive Plant *Euonymus fortunei*." *Journal of the Torrey Botanical Society* 143.2 (2016): 103–116.

Kali completed an independent research semester with me and a summer research experience with my collaborator, Mary Arthur. I worked closely with Kali analyzing the data and writing the manuscript. Kali is now a Ph.D. student in ecology at the Ohio State University.

c. Beatty, Jaylen.*, Amanda Wilburn*, Laurel Lietzenmayer*, Jacob McCullough*, Robert D. Rowe*, Sarah R. Bray. (2016) Invasive plant *Euonymus fortunei* and *Lonicera maackii* reduce *Festuca arundiacea* germination and *Brassica rapa* growth. Urban Ecology Workshop, University of Kentucky Ecology Research and Education Center.

   I was so pleased with the projects developed by two of the groups in my 2015 Ecology class that I encouraged them to present their combined data at an Urban Ecology Workshop here in Lexington. I gather more data on these hypothesis in my ecology class next fall with the hopes of publishing their work.

IV. Podcasts

a. Campus Conversations. A podcast by student paper, The Rambler, discussing research with student Jaylen Beatty. Discusses some of my philosophy on undergraduate research. https://www.transyrambler.com/campus-conversation-sarah-bray-and-jaylen-beatty/
b. Discovering Darwin. A podcast about the works of Charles Darwin contextualized for our time. Host by Josh Adkins, Sarah Bray, and James Wagner. I believe this shows how I engage in the scientific body of knowledge from a liberal arts perspective. http://discoveringdarwin.blogspot.com/

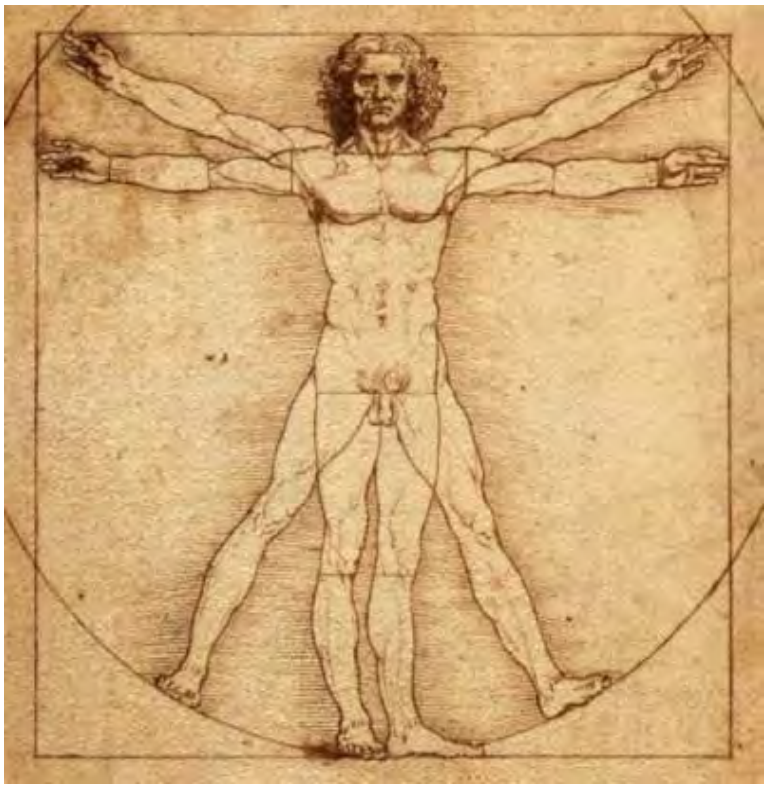
BIOLOGY AND HUMAN CONCERNS

BIO 1164

WINTER 2016

Lecture
MWF
11:30-12:20
BSC 320

Lab
Th
11-12:15
BSC310



Leonardo Da Vinci's ***Vitruvian Man, 1490***

How has evolution shaped what it means to be human?

The goal of this course is to introduce you to scientific inquiry in a liberal arts context. One of the major questions we seek to understand in the liberal arts is what does it mean to be human? To that end, we will be exploring how our history is reflected in our biology and how the ghost of evolution past influences our health today. We will accomplish this through reading and discussing original scholarship such as Darwin's Origin of Species, current literature, popular science texts, and by observation and experimentation in the laboratory.

WHERE IS IT?

Instructor Info	2
Course Requirements	2
Learning Objectives	2
Grading Scale	3
Policies	3 - 4
Schedule	3 - 4

Required Texts:

Darwin, C, J.T. Costa. 2011. The Annotated Origin: A Facsimile of the First Edition of *On the Origin of Species*. Belknap Press.

Kenneally, C. 2015. The Invisible History of the Human Race: How DNA and History Shaped our Identities and our Futures. Penguin Press.

Lieberman, D.E. 2013. The Study of the Human Body: Evolution, Health, and Disease. Vintage Press.

Course Objectives: In this course, we will explore science as a way of knowing, evolution as an example of science in practice, and how science and society interact. You will gain and demonstrate mastery of these concepts through reading, writing, and performing scientific experiments.

	Reading	Writing	Doing
Science as a Way of Knowing; evolution as science	Interpret data; apply evolutionary perspective to current human biology	Synthesize the results of multiple, possibly conflicting, studies	Design, implement, and analyze and interpret experiment
Science and Society	Explore how human history is reflected in our genes; Critique application of evolution	Communicate the results of scientific studies to a non-scientific audience.	Critique direct-to-consumer genetic analyses and uses.

Course Requirements

Participation and Daily Work (20%) Perhaps unlike science classes you took in high school, this course will primarily be based on shared discussion of our readings. It is imperative, therefore, that you read and attend class. Class will consist of discussion and your readings will be supplemented by additional information. Daily work will consist of participation and occasional in-class assignments. Daily work **CANNOT** be made up; however, your three lowest in-class assignments will be dropped from your final grade.

Lab Participation and Assignments (10%) Lab has been designed to introduce you to the real process of science and is required. The lab component is required to fulfill the general education credit; therefore attendance is required. Skipping lab will result in failing the course.

Exams (50%) Exams will be used to evaluate your understanding of the science of evolution and how culture influences science and vice versa. Two exams will take place during our laboratory session, the other exam will be a cumulative final. All exams will have equal weight.

Blogging (10%) You will be assigned to explore the primary literature relating to a chapter in our popular science texts. You will then write a blog for the class (and general public) on our course blog: wordpress.com/bhc2016. Blogs should be posted by class time for that chapter. Other students should comment on the blog (may include elements of class discussion) by the next class period.

Science in the News (10%) You will be asked to submit three 1-page essays on a science news item. Your essay should summarize the findings, state scientific confidence in the results, and critique the reporting of the science.

Homo naledi, was scientifically described in 2015 as perhaps the earliest example of *Homo*.

Instructor: Sarah Bray
Office: BSC 319
Email: sbray@transy.edu

Office hours
M, W: 9:30-11:30
Th: 1:30-3:00
F: 1:30-2:30
And by appointment

Grading

Source	#	Points Each	Total	Percentage
Daily Work (drop 3)	15	10	120	20%
Lab Participation	11	4	44	~7%
Lab Analysis	1	16	16	~2.5%
Exams	3	100	300	50%
Blog	1	40	40	~6.5%
Blog responses	1	20	20	~3%
Science in the news	3	20	60	10%
Total			600	100%

A: 90-100%	**B+: 87-89%**	**C+: 77-79%**	**D+: 67-69%**	**F < 60%**
A-: 88-89% if clear improvement	**B: 83-86%**	**C: 73-76%**	**D: 63-67%**	
	B-: 80-82%	**C-: 70-72%**	**D-: 60-62%**	

Date	Day	Topic	Reading	Lab (Thursday)
1/11	M	Introduction		
1/13	W	Genetic evidence of history	Kenneally Chp 8	Human Variation A-C #1SN
1/15	F	History of men and women	Kenneally Chp 9	
1/18	M	MLK		
1/20	W	Chromosomes and relatedness	Kenneally Chp 10	Mr. Potato Head D-J #1SN
1/22	F	Human migration	Kenneally Chp 12	
1/25	M	Is race in your face?	Kenneally Chp 13	
1/27	W	Populations and genetic disease	Kenneally Chp 14	Fast Plant set up K-O #1SN
1/29	F	Am I my genes?	Kenneally Chp 11	
2/1	M	Who was Darwin?	Darwin, Intro	
2/3	W	Variation under domestication	Darwin, Chp1	23andme P-Z #1SN
2/5	F	Variation in domestication/nature	Darwin, Chp2	
2/8	M	Finish variation		
2/10	W	Struggle for Existence	Darwin, Chp3	**Exam I** A-C #2SN
2/12	F	Struggle for Existence	Darwin, Chp3	

POLICIES

Absences

Please inform me in the first week of class for any absences due to university-related events or religious holidays. Be sure to get notes from a classmate after the missed class. If you will be missing a lab or exam due to a university-sponsored event, the activity must be made up before your absence. In-class assignments cannot be made up.

Respect and Classroom Climate

This a participatory class in which we are ALL responsible for each other's learning. Therefore it is imperative that everyone is treated with respect including, being focused on whomever is speaking (not your phone, computer, etc.) and allowing others to have a turn speaking.

Date	Day	Topic	Reading	Lab (Thursday)
2/15	M	Natural Selection	Darwin, pgs 80-87, 90-96, 101-109	Extract DNA D-J #2SN
2/17	W	Darwin's Finches		
2/19	F	Sexual Selection	Darwin, pgs 87-90	
2/22	M	Sexual Selection, continued	TBD	Harvest Plants K-O #2SN
2/25	W	Modern Synthesis	TBD	
2/27	F	Modern Synthesis, continued		
2/29	M	Speciation	Darwin, pgs 109-130	Candy Phylogeny P-Z #2SN
3/2	W	Speciation, continued		
3/4	F	Introduction to Tree Thinking	TBD	
3/7	M	Continue Tree thinking		Analyze Plant data A-C #3SN
3/9	W	Catch up day		
3/11	F	What are humans adapted for?	Lieberman, Chp 1	
3/14 – 3/18		**SPRING BREAK**		
3/21	M	Becoming bipedal	Lieberman, Chp 2	**Exam II** D-J #3SN
3/23	W	Eating the tough stuff	Lieberman, Chp 3	
3/25	F	In the hunt	Lieberman, Chp 4	
3/28	M	My, what a big brain you have	Lieberman, Chp 5	PCR K-O #3SN
3/30	W	Culture and evolution	Lieberman, Chp 6	
4/1	F	Modern life: an evolutionary mismatch	Lieberman, Chp 7	
4/4	M	Agriculture: windfall or downfall?	Lieberman, Chp 8	Gels P-Z #3SN
4/6	W	Industrial revolution	Lieberman, Chp 9	
4/8	F	Too much of a good thing	Lieberman, Chp 10	
4/11	M	Sloth and convenience	Lieberman, Chp 11-12	Discuss actinin3
4/13	W	Saving ourselves from ourselves	Lieberman, Chp 13	
4/15	F	Summary and Catch-up		
FINAL EXAM: Tuesday, April 19, noon – 2 pm				

POLICIES

Electronic devices:

I don't prohibit electronic devices because they can often enhance our experience, but I ask that you stay focused on the topic at hand. I also strongly encourage you to take notes by hand as research has indicated students taking longhand over computer notes performed better on quizzes.

ADA

If you have a documented disability seeking academic accommodations please contact Brenda Dennis (859-281-3682) with Disability Support Services to develop an official plan for accommodations. Contact me during the first two weeks of class to discuss your plan. All discussions will remain as confidential as possible.

Academic Honesty

Academic dishonesty will not be tolerated in this class. Academic dishonesty can be, but is not limited to bringing notes to an exam, copying off of another student's exam or assignment, or passing off another's work as your own (including plagiarism). Students caught cheating will at a minimum receive a zero on that assignment and will be reported to your advisor and the Dean's office.

BIO 1206-01: Integrated Concepts in Biology: Organisms and Ecosystems
Winter 2017

Instructor: Dr. Sarah Bray
Office: BSC 319
Phone: 233-8169
E-mail: sbray@transy.edu
Office hours: 1:30-3:30 MWF, and by appointment
Class time: MWF 9:30-10:20, BSC 320; LAB: Thursday, 9:30-12:15, BSC 310
Textbook: *Integrating Concepts in Biology,* by Malcolm Campbell, Laurie Heyer, and Christopher Paradise. http://www.trunity.net/BIO-1206-bray-fall-2016/

Your experience in biology to this point has probably been that of a linear progression from the cell to the organism and possibly to the level of the ecosystem. Although this a logical organization that fulfills our desires to categorize, it does a poor job of reflecting the core BIOLOGICAL PRINCIPLES at work. Our goal in our Intergrated Concepts of Biology sequence is to focus on these core concepts across all biological scales. This semester, we will focus on these principles at the level of the individual, population, and ecosystem. In addition to introducing you to the core concepts of biology that you will be exploring throughout your biology major, we are also introducing you to the 'habits of mind' of a working scientist.

Class Philosophy

Although you and I are most used to the lecture approach to teaching, it has been shown that the lecture approach is only a marginally effective method for teaching. The most effective manner to learn is for you to engage in the material in class with me acting more as a knowledgeable guide in your learning than the sole source of all knowledge. To that end you are going to be expected to come to class prepared to discuss the readings from the text and other materials I supply. Notice that the syllabus details the specific sections you are have expected to **read before the class** for that period. **You should have read the material and taken notes prior to class.** Class time will involve discussion and problem sessions aimed at clarifying and exploring the material covered in the text. The combination of text, lectures, and other sources, will expose you to a greater amount of material

Student Learning Outcomes

Students will:

- Integrate core biological concepts of cells, homeostasis, information, evolution, and emergent properties at individual, population, and ecosystem scales.
- Interpret graphs, charts, and tabular data to draw conclusions and make inferences about core biological concepts
- Differentiate between selective and nonselective evolutionary forces, natural and sexual selection, and apply these concepts to explain diversity of life
- Distinguish between abiotic and biotic, intraspecific and interspecific controls of population growth
- Examine the links between science and society

than any alone. Exams will draw on information from all sources as well as, lab material, assigned outside readings, and impromptu discussions from class and lab. **Consequently, attendance to both lab and lecture is required**.

GRADING

EXAMS

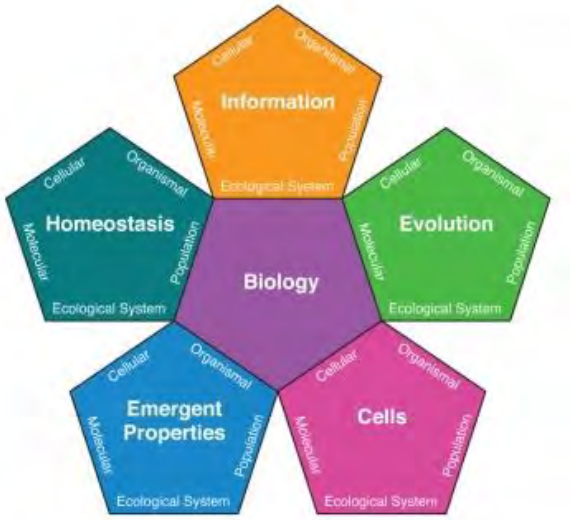
Exams will be a mixture of multiple choice, short answer and essay. You will often be asked to use graphs that we have discussed in class to support your answers. You will be provided with these figures for the exam. Knowledge is cumulative and so are my exams. This means that you may encounter a graph from earlier in the semester and be asked to use the graph to support a different biological concept. There will be three semester exams and a comprehensive final exam. All exams are worth approximately 67% of your final grade. Makeup exams will only be given for medical or emergency situations (proper documentation required).

ENGAGEMENT

Clearly you cannot earn points for engagement if you are not in class, but merely attending class is not enough to be successful. Before class you MUST READ the assigned section of the text. In class we will work our way through the problems in the text and I will make an effort to call upon EVERY STUDENT in EVERY CLASS PERIOD. **Having 3 or more unexcused absences from class will reduce your overall grade.** Because the best way to learn is to be actively engaged, 10% of your final grade will be based on your engagement in the classroom. Take every advantage of this. You will occasionally be assigned additional homework that will be a part of the classroom engagement grade.

ASSIGNMENTS

These may include pre-class assignments (additional readings and questions to answer), in-class quizzes, or summaries of class or lab materials. Two major assignments that you will complete during the semester are a write-up the data you collect and analyze about human variation and a worksheet on a computer model that examines how mechanisms of evolution alter allele frequencies in populations. You will receive additional information on these assignments when they are assigned.



LABS (SEE LAB SYLLABUS)

Source	#	Points	Total	Percentage
Exams	3	100	300	50%
Final	1	100	100	17%
Class Engagement			65	11%
Assignments			30	5%
Lab Notebook	3	15	30	5%
Lab Engagement			30	5%
Corn PowerPoint	1	20	15	2%
Final Presentation	1	50	30	5%
Total			600	100%

90-100% A to A+

80-82 B-	**83-86 B**	**87-89* B+**	*Students in the upper end of the B+ range who
70-72 C-	**73-76 C**	**77-79 C+**	have shown excellent engagement or
60-62 D-	**63-66 D**	**67-69 D+**	improvement over the term may be moved to an A-

Policies

Absences

Please inform me in the first week of class for any absences due to university-related events or religious holidays. Be sure to get notes from a classmate after the missed class. If you will be missing a lab or exam due to a university-sponsored event, the activity must be made up before your absence.

Submitting Assignments

Assignments are due at the BEGINNING of the class period in which they are due. Your grade will be reduced by 5% if not turned in at the end of class and will be reduced another 10% for each 24-hour period that elapses from the due date.

Academic Honesty

Academic dishonesty will not be tolerated in this class. Academic dishonesty can be, but is not limited to bringing notes to an exam, copying off of another student's exam or assignment, or passing off another's work as your own (including plagiarism). Students caught cheating will **at a minimum** receive a zero on that assignment and will be reported to your advisor and the Dean's office.

Respect and Classroom Climate

This a participatory class in which we are ALL responsible for each other's learning. Therefore it is imperative that everyone is treated with respect including, being focused on whomever is speaking (not your phone, computer, etc.), and allowing others to have a turn speaking. I support Transy's commitment to diversity, and welcome individuals of all ages, backgrounds, citizenships, disabilities, sex, education, ethnicities, family statuses, genders, gender identities, geographical locations, languages, military experience, political views, races, religions, sexual orientations, socioeconomic statuses, and work experiences. If you feel you feel threatened or discriminated against, I encourage you to speak with me and/or make a Hate/Bias Incident Report available on inside.transy.edu: https://publicdocs.maxient.com/reportingform.php?TransylvaniaUniv&layout_id=11

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, etc. If you or someone you know has been harassed or assaulted, you can find the appropriate resources here ...

- DPS (233-8118) or 911
- Bluegrass Rape Crisis Center: http://bluegrassrapecrisis.org/
- Title IX coordinator: Ashley Hinton-Monser (ahinton@transy.edu, 859-233-8854)
- Title IX incident report: https://publicdocs.maxient.com/reportingform.php?TransylvaniaUniv&layout_id=3

Americans with Disabilities Act

If you have a documented disability seeking academic adjustments or accommodations please contact Amber Morgan (233-8502, OM 211) with Disability Support Services to develop an official plan for accommodations. Contact me during the first two weeks of class to discuss your plan. All discussions will remain as confidential as possible.

WEEK	MONDAY	WEDNESDAY	FRIDAY
Jan 9-13	Introduction to class and textbook	18.1: Crickets, Bats and Opossums	18.2: Foraging by lizards and plants
16-20	NO CLASS: MLK	18.3: Chemical defense?	18.4: Predation and diversity
23-27	Darwinian Evolution	19.1: Mate choice in Guppies	Chapter 19.4: Non-adaptive evolution, review genetic drift
30- Feb 3	19.3 Gene flow and populations	19.2: Climate change and dispersal	20.5: Species and Trees (on Moodle)
Feb 6-10	20.6: Trees and tree reading (On Moodle)	20.4: Mosquitos and DDT	21.1: Yucca coevolution
13-17	21.1: snake – newt,	21.1: snake – newt, Supplemental Reading	Catch-up day
20-24	21.2: Endosymbiosis Coral reefs	21.3: Light and plant distribution	Population dynamics
27- Mar3	Chapter 24: 24.1 Unicellular growth	Chapter 24.2 Nitrogen cycle	25.1: Bee thermal
Mar 6-10	Chapter 25.3 Plants 'talk' to each other	25.3: Wasp 'cooperation'	26.2: population size and extinction
13-17	**SPRING BREAK**		
20-24	26.3: Flocks	27.1: Food web	27.2: Competition
27-31	27.3: Predation and stability	28.2 Tradeoffs & allocation	Catch-up
Apr 3-7	26.1: Age Structures in Populations; life history	29.1: Life History strategies	Chapter 29.2: Predation
10-14	29.2: Rabbits & cycles	30.1: Feedback cycles	30.3: ↑CO2 ecosystem response
Finals	**Final exam: Thursday, April 20 at noon**		

***Highlighted weeks are exam weeks; see laboratory syllabus schedule.**

Integrated Concepts in Biology:
Organism and Ecosystems Laboratory Syllabus

BIO1206-01 – Winter 2017

Course Information

Instructor: *Dr. Sarah Bray*
Office: *BSC 319*
Email: *sbray@transy.edu*
Office Hours:
MWF: 1:30 – 3:30 pm
and by apt.
Lab Time: *Th 9:30-12:15*
Lab Room: *BSC 310*

Student Learning Outcomes:

Students will:

- Learn and practice safe organismal lab technique
- Document observations, procedures, and conclusions in a lab notebook
- Apply process of science to design experiments to address testable hypotheses
- Analyze data from experiments using graphs and statistical inference to evaluate hypotheses.
- Communicate results through written and oral presentations

Lab Course Components – 17% of total class grade

Source	Number	Points	Total	Percent
Lab Notebook	2		30	5%
Lab Engagement	10	3	30	5%
Corn PowerPoint	1	20	20	2%
Final Presentation	1	30	30	5%

Participation – 5%

Attendance – Absence and tardiness pose problematic consequences in the lab. Labs require hands-on directions, modifications, safety concerns, materials, equipment and the presence of your professor. Make-up labs are not feasible.

Safety – Lab safety is imperative in any science lab. Please read the attached lab safety guidelines. You will be asked to sign a contract stating your compliance with these rules.

Ability to work with your peers – All labs require shared space, materials, and equipment with your peers. Furthermore, for some projects you will be working a partner or group. You will be expected to respect and work well with your peers, clean up your lab area, maintain experiments outside of class as necessary, and contribute equally to joint projects. Passing off your partner's work as your own will not only reduce your engagement grade, but is a violation of academic honesty. Don't be that guy/gal. You will also

Notebook – 5%

Recording objectives, hypotheses, experimental plans, protocols, observations, results, and conclusions in a lab notebook is one of the most important

components of scientific research. Please see the attached handout on guidelines for keeping a good lab notebook. These guidelines will be used in all of your lab courses at Transylvania.

Corn Presentation- 2%

You will create a PowerPoint or Google Slides presentation of your corn data with your partner(s). You will be evaluated only on the electronic file. The presentation should include motivation for your study that cites literature, hypothesis, methods, graphs with statistical analysis, conclusions on original hypothesis and evaluation of your hypothesis with reference to the literature. You will be given additional guidelines with the presentation is assigned.

Protist Presentation – 5%

At the conclusion of your final research protest project you and your partner will prepare a presentation reflecting the feedback you got on your corn presentation. You will give your oral presentation on the last day of lab. Presentations will be included on the final.

Lab Schedule*

Exams will be given during lab time.

Date	Topic/Experiment
1.12	Introduction and Lab Safety, Phenotypic plasticity; set up corn experiment
1.19	Introduction to Data Analysis with Google Sheets
1.26	Genetic Drift Populus lab
2.2	**Exam 1**
2.9	Introduction to literature search, phylogeny lab
2.16	Introduction to protists, design protist experiment
2.23	Break down corn lab, set up protist trial run
3.2	**Exam 2**
3.9	Analyze corn data, redesign protist experiment
3.16	NO LAB- SPRING BREAK
3.23	Set up 2nd protist experiment
3.30	Work on experiments
4.6	**Exam 3**
4.13	Protist Presentations

*Subject to Change. Some experiments will require time in addition to scheduled lab time

BIO 2042: BIOLOGIST'S TOOLKIT

WINTER 2017

Instructor: Dr. Sarah Bray
Email: sbray@transy.edu
Office: BSC 319
Phone: 233-8169
Office Hours: MWF: 1:30-3:30
Class meeting times: 8:30-9:30 MWF, BSC 320
Text: Gardner, Mark. 2012. Statistics for Ecologists Using R and Excel: Data Collection, Exploration, Analysis and Presentation. Pelagic Publishing.
Teaching Assistant: Devin Rowe (rdrowe17@transy.edu). **Office hours**: Jazzman's T/TH: 1:30-2:30, TH 9:30-10:30

Science is more than a body of knowledge; it's a way of thinking, a way of skeptically interrogating the universe. –Carl Sagan

APPROACH

Our goal for all of our students for them to ***be*** biologists rather than learn ***about*** biology. To that end, this course is meant to help you develop core competencies that you will use throughout your career at Transy and in your life as a biologist. In the Integrated Concepts of Biology sequence, you have learned how to interpret figures and make conclusions based on data. In this course you will begin to learn how to analyze and graph data and how to communicate your results to the scientific world. Much of this course will focus on using a free statistical programming language, R, to analyze and represent data.

LEARNING OUTCOMES

DATA INTERPRETATION, ANALYSIS, AND PRESENTATION

- Explain results conveyed by graphs, tables, and statistics
- Identify proper statistical test to evaluate a hypothesis
- Analyze data using Excel and R
- Create figures and tables that effectively communicate results

SCIENTIFIC COMMUNICATION

- Use search engines to locate scientific literature
- Write results and methods sections of scientific paper.

EVALUATION

COURSE NOTEBOOK

Please purchase a 1" binder that will ONLY CONTAIN MATERIAL FROM THIS COURSE. Your binder should contain your class notes, handouts, notes that you take on the textbook, notes on running code, scripts, and completed assignments. I can tell you from personal experience that taking excellent notes including file names, R codes, graphs, and notes on important statistical tests and conclusions are essential to NOT REPEATING all your work down the road. It will also be a useful reference for you in future classes when you analyze data. Your notebook should be organized chronologically, but you are welcome to use tags and/or dividers to help you quickly find material. When you receive graded homework assignments, place them in your notebook. Each graded homework assignment should have a response (possibly editing code, improving annotations, or revising a writing assignment).

PARTICIPATION

Attendance in class is required and you should be actively engaged. This means that you should have read before class, completed any homework assignments, and come prepared with your notebook and a charged laptop. Writing coding is likely new to many of you and it can be frustrating at times. Keeping a good attitude, trouble-

shooting on your own, and helping one another is critical to your participation grade. Before asking for help from Devin, a classmate, or me, annotate your code and google any error statements. After you have completed these steps, ask someone for advice. Often several people have the same issues and we can 'crowd-source' solutions. Remember, sharing is caring!

HOMEWORK

You will periodically be required to do homework that may include: skills assessments, exploring the literature, exploring publically available data sets, data exploration and presentation, analysis of scientific writing, and various writing assignments. You will usually have some time in class to work on these assignments, but will often need to complete them outside of class. Homework assignments are due on the following Wednesday or Friday at the beginning of class.

FINAL PROJECT

For the final project in this class you will be given a data set to analyze. You must first determine a hypothesis that can be tested using the data set and determine the statistical approach to testing this hypothesis. You will use the literature to generate your hypotheses and write a proposal and project plan (30% of final project grade). You will also be asked to write a project plan (10% of project grade). This will include an introduction based on the literature that motivates your study, two hypotheses, and the types of analyses you plan to use and how you plan to present your data (table, figure, what types of figures). You then need to write the code for the statistical analysis and figures or tables. This code should be well annotated. As you have been doing all semester, you should be making copious notes in your lab notebook as you analyze your data. As always, your notebook should contain your highly annotated script, location/names of your script and files, notes about problems you run into, any files created, and conclusions. The actual project will be written up as the statistical methods and results sections of a journal article. You will be required to use a template to put it in journal format.

STATISTICS QUIZ

We will have one quiz that will assess your knowledge of statistical approaches. This will include choosing the right statistical test for a given set of data/hypothesis, knowing the null hypothesis and assumptions of a statistical test, and correctly interpreting the output of a statistical test.

Component	Percentage
Course Notebook	25%
Participation	15%
Homework	30%
Final Project	20%
Statistics Quiz	10%

All grades will be based on the following scale:

A = 91 - 100	B+ = 87 - 88	B- = 80 - 82	C = 73 - 76	D+ = 67 - 69	D- = 60 - 62
A- = 89 - 90	B = 83 - 86	C+ = 77 - 79	C- = 70 - 72	D = 63 - 66	F = 0 – 59

The game of science is, in principle, without end. He who decides one day that scientific statements do not call for any further test, and that they can be regarded as finally verified, retires from the game. -- Karl Popper

Attendance Policy

If you are participating in a Transy event that conflicts with class, you must provide me with those dates in the first week of class. If your absence is approved, you must make up missed work BEFORE your absence. **You MUST attend the section to which you are registered (Wednesday or Friday) unless arrangements have been made in advance.**

Academic Integrity

You should abide by the Transylvania University academic integrity policy while conducting your work in this course. This policy is found in the student handbook, and all students are responsible for becoming familiar with this policy. Any infractions of academic integrity will result in a zero for the assignment and will be reported to the student's advisor and the academic dean.

Special needs and disability resources:

If you need course adaptations or accommodations because of a disability or chronic illness, please make an appointment with me as soon as possible, or see me during office hours. Please also contact Amber Morgan (x8502, OM 211) who will help you with coordinating reasonable accommodations.

Respect and Classroom Climate

This a participatory class in which we are ALL responsible for each other's learning. Therefore it is imperative that everyone is treated with respect including, being focused on whomever is speaking (not your phone, computer, etc.), and allowing others to have a turn speaking. I support Transy's commitment to diversity, and welcome individuals of all ages, backgrounds, citizenships, disabilities, sex, education, ethnicities, family statuses, genders, gender identities, geographical locations, languages, military experience, political views, races, religions, sexual orientations, socioeconomic statuses, and work experiences. If you feel you feel threatened or discriminated against, I encourage you to speak with me and/or make a Hate/Bias Incident Report available on inside.transy.edu:

https://publicdocs.maxient.com/reportingform.php?TransylvaniaUniv&layout_id=11

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, etc. If you or someone you know has been harassed or assaulted, you can find the appropriate resources here ...

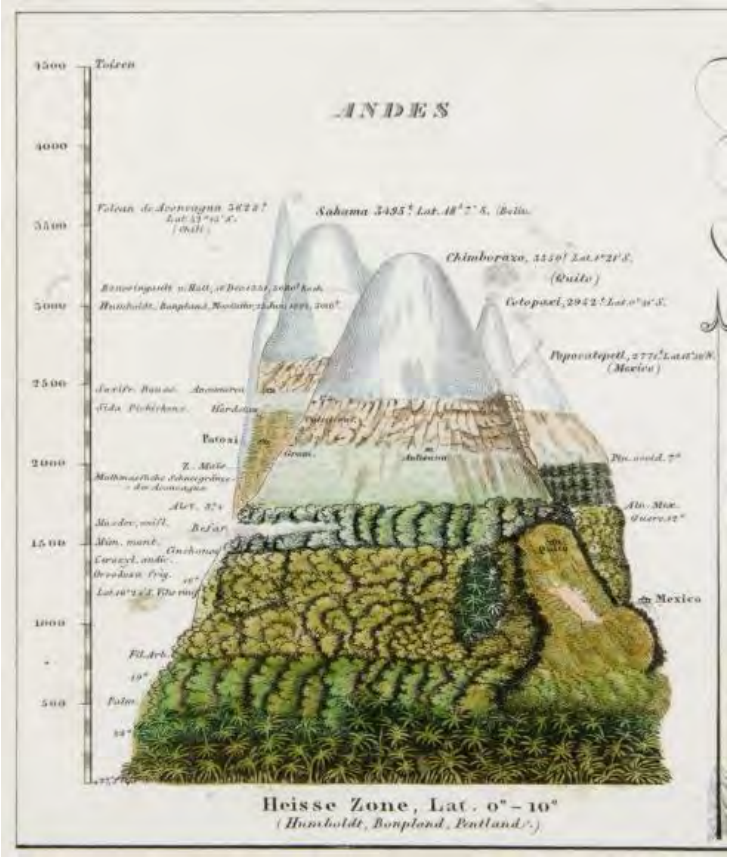
- DPS (233-8118) or 911
- Bluegrass Rape Crisis Center: http://bluegrassrapecrisis.org/
- Title IX coordinator: Ashley Hinton-Monser (ahinton@transy.edu, 859-233-8854)
- Title IX incident report: https://publicdocs.maxient.com/reportingform.php?TransylvaniaUniv&layout_id=3

TENTATIVE SCHEDULE

Date	Day	Topic	Reading/Assignment
Week 1 1/9	M	Getting R, R Studio, and Google Drive set up	
	W/F	The R environment, Key R syntax, importing files	1.8, 3.3
Week 2 1/16	M	NO CLASS MLK DAY	4.1-4.5
	W/F	Data Exploration, writing and annotating scripts	
Week 3 1/23	M	Normality and transformations	3.1
	W/F	Homework #1	
Week 4 1/30	M	Hypothesis testing	5.1-5.2
	W/F	What test when?	
Week 5 2/6	M	Correlation and Regressions	8.1-8.2, 8.4
	W/F	Correlation and graphing practice, Assign HW#2	
Week 6 2/13	M	T-tests and box plots	Chp 7
	W/F	Lizards; Assign HW#3	
Week 7 2/20	M	Intro to ANOVA, Assign HW #4	Chp 10
	W/F	ANOVA practice; Assign HW #5	
Week 2/27	M	Reading and Writing Statistical Methods, HW #6 assign	Reading TBA
	W/F	Writing exercises and peer review	
Week 9 3/6	M	Searching for literature- library	Project Proposal and Plan
	W/F	Installing and using Mendeley	
3/10	M-F	**SPRING BREAK**	
Week 10 3/20	M	Hunting for hypothesis	
	W/F	Choosing the right test	
Week 11 3/27	M	Reading and writing results sections, HW #7 Assign	Reading TBA
	W/F	Writing exercises and peer review	
Week 12 4/3	M	Advanced graphing: ggplot2	
	W/F	Refining graphs, Assign HW #6	
Week 13 4/10	M	Statistics Quiz	
	W/F	Individual meetings with Dr. Bray	
Week 14 12/5	M-F	Work on Projects- Dr. Bray additional office hours during normal class time.	
Finals	T	Final Papers and Notebooks due at noon on 4/18	

Walking the Isothermal Lines: Tropical Ecology and Travel Writing from Machu Picchu to Madre de Dios

Profs. Bray and Paden



Course Description

This course is an introduction to tropical ecology and to science/travel writing. It is designed as a comparative field course in biology and a workshop-based writing course that will introduce students to travel writing and popular science writing. We will read selections of classic Latin American travel and science writing. We will also study tropical and Andean ecology. When in Peru we will hike, explore, and study the flora of the high Andean desert and moorlands, the eastern cloud forests, and the low-tropical jungle of the Amazon. We will focus on the regions surrounding the Urubamba valley near Cuzco and Machu Picchu and the Amazon region near Madre de Dios. The Urubamba River starts high in the Peruvian Andes and is one of the headwaters of the Amazon River. Visiting Cuzco, Machu Picchu, and the Urubamba river valley will let us study the high Andean plains, grasslands, moors, and cloud forests in and around Cuzco and Machu Picchu. Visiting the Madre de Dios region will let us study the low-tropical jungle of the Amazon basin. This course brings together field research in biology, travel writing, and science writing.

COURSE DESIGN

Our readings before travelling, your presentations, and final blog posts will be centered around the following themes: ① natural history, ② climate change in the Andes, ③ climate change in the Amazon,④ ecotourism in the Andes, ⑤ecotourism in the Amazon,⑥ travelers and travel writing, and ⑦ climate as a driver of evolution and convergence. Pairs of students will choose a topic that will serve as a uniting theme for your pre-trip research, an inspiration for your journal writing on the trip, and for a blog and presentation upon returning to campus. The four class periods before we leave for the trip will be discussing readings in the morning. The afternoons will be available for you to do your research, read for the following class period, or meet with the instructors.

GRADES

Annotated Bibliography (10%): The annotated bibliography will be composed of at least 7 articles, 5 of which must be primary research articles, the remaining two may be reviews, book chapters, or popular articles. Remember that the difference between an abstract and an annotation is that an abstract is only a summary while an annotation is descriptive, but more importantly is meant to be an evaluation of the source and how the author (you) means to use it. Each student will prepare their own annotated bibliography on their own sources to be turned in by April 28. For more information on annotated bibliographies see: http://www.library.cornell.edu/olinuris/ref/research/skill28.htm

Travel Journal (30%): When traveling, you will need to carry a Journal. The point of the journal is to record your biological and cultural observations of the trip. Your journal should contain two major sections: daily entries and a running species list. We suggest that you leave the last several pages of your journal open for your species list. This may either be kept by day/site or as a cumulative species list where you record each time/location you site a particular species. This journal will serve as a basis for your final blog entry so invest time every day in it recording a daily entry. Daily entries should include drawings, maps and sketches of locales or organisms. While we encourage you to record your personal feelings about the trip, your reflections should also be motivated by the writing prompts you have been given and your research topic. The journal is NOT an outlet for travel angst or travel buddy tensions. See end of syllabus for suggested writing exercises. Two essays on keeping a field journal are available on Moodle. Your first journal entry should reflect these readings and a hike that you take BEFORE we leave on the trip.

Final Blog Entry (25%): Each of you will write a personal blog essay of about 1,000 words on your travel experience. Feel free to incorporate personal pictures and charts should your photographs and your topic demand this. The blog entry should be both a reflection on your experience and an analysis of your chosen topic. We are hoping that you will be able to find a way to balance the academic content of your readings with your personal experience.

Here are two examples to help you think about your own blog entry. The first example has a nice structure and is purely personal. The second example does a nice job of bringing in information about Bermuda that the reader might not know and merging it with personal experience:

http://www.nomadicmatt.com/travel-blogs/south-africa-farm-stay/
http://www.alexrobertsontextor.com/spendthrift_shoestring/2014/03/blast-from-the-past-bermuda.html

Presentation (10%): In contrast to your personal reflection of your experience in your blog, you and your partner will give a scholarly presentation on your topic. Your presentation should be centered on a research

question (thesis statement) that has arisen from readings on your topic. While the primarily focus of the presentation should be on your scholarly resources laid out in your annotated bibliography it may include pictures and experiences you have accumulated on the trip. The 15-minute presentation should include an introduction to the topic, thesis statement/research question, and scholarly evidence supporting your argument. Your conclusion may raise additional questions and lines of research.

Participation/Travel-ness (25%): Traveling as a group in a foreign country is difficult. Promptness and preparedness is not a luxury. We are a group and we must constantly think in terms of the group. Selfish behavior and traditional 'dorm lifestyles' will not be accepted. We will grade you on your mood, how altruistic you are, your promptness, safety, and maturity, plus your all around good citizenship. We need to look out for each other and keep a lookout for illness, stupidity, and danger. The tropics are full of perils and it is not for those who expect dangers to be removed by the local government. Before departing for Peru, we will develop a code of conduct that spells out our expectations for traveling. Any student that breaks the conditions of the contract will be sent home at their own expense.

SCHEDULE

Meeting Time: 9-11, Haupt 223

Date	***Topic***	***Reading***
4.22	*Natural History*	*Humboldt (Preface, 64-103, 120-135, 142-143); Darwin-Voyage of the Beagle (Ali-Halliday: Chp 15; Hieronymus-Stewart: Chp 16)*
4.23	*Ecotourism*	*Pro/Con*
4.24	*Climate Change*	*Climate Change: Andes and Amazon—Intro, Peru sections, Conclusions and Recommendations* ***Assignment: Hike + first journal entry.***
4.27	*Travel Writing*	*Dubiago and Turn Right at Macchu Picchu*
4.28	***Depart for Lima, 1:40pm***	***Turn in Annotated Bibliographies***
4.29	***Fly to Cuzco, explore***	
4.30	***Start Trek <camp>***	
5.1	***Trekking, <camp>***	
5.2	***Trekking, <camp>***	
5.3	***Trekking, <hostel>***	
5.4	***Machu Picchu***	
5.5	***Cuzco***	
5.6	***Travel to Puerto Maldonado, Amazon***	
5.7	***Amazon***	
5.8	***Amazon***	
5.9	***Fly to Lima***	
5.10	***Lomas de Lachay***	
5.11	***Day in Lima***	
5.12	***Arrive Lexington 1:33 pm***	
5.13	*Recover*	
5.14	*Class debriefing, guidance for writing*	
5.15	*Individual meetings with Bray and Paden*	
5.18	*Blog troubleshooting, etc.*	
5.19	*Final Presentations*	

WRITING EXERCISE

1. As you prepare for travel.
   a. Compile a list of quotes about Peru and about the Andes and about the Amazon. These can be historical in nature or scientific. They can come from poetry or from travel writing or from novels.
   b. Compile a wish list of species vegetable, mineral, animal, insect. Anticipating things to be seen will make you a better observer. Knowing something beforehand of the geography will also make you a better observer and help you understand where you are.
2. Write about the experience of travel. What is it like to spend the time on the airplane? What is it like to go through customs? Are there differences between the various airports? Are there differences between the large commercial airliners and the local Peruvian one? What are the roads and the buses like? What is the boat like? Be specific. Notice details. Focus more on the physical details rather than the feelings. If you do a good job noticing the physical aspects of the trip, the emotions will come back, but not the other way around.
3. Keep a species list. Keep two species list: one that is just a running list of biota, the other that notes where: What day. Where: altitude, shade/sun, riparian, stoney/sandy/clay, etc.
4. Notice smells and sounds. Keep a list of metaphors that try to translate these into images. Work over time trying to make more and more evocative images.
5. Write about a place. Sit in one place and write down as many specific and concrete details about the place as possible.
6. Write about a place through a quote from your quote book.
7. If you can draw, draw. If you are a photographer, take photographs.
8. Write about a place based on readings from the first part of class. What would Humboldt or Darwin have noticed?
9. Write about a place making references to your annotated bibliography. How does your topic and the class converge?

READINGS

Forsyth, A. and K. Miyata. 1987. Tropical Nature: Life and Death in the Rain Forests of Central and South America. Charles Scribner's Sons.

Pearson and Beletsky. 2005. Travellers' Wildlife Guides: Peru. Interlink Books

Additional Readings on Moodle.

BIO 3314: Evolution

Winter 2015
MWF, 9:30-10:20, BSC 320
Course website on Moodle

"Nothing in biology makes sense except in the light of evolution."
-Theodosius Dobzhansky

Professor: *Dr. Sarah Bray* ***E-mail:*** *sbray@transy.edu*
Office: *BSC 319* ***Phone:*** *233-8169*
Office hours*: MWF: 10:30-11:30, 1:30-3:00; and by appointment*
Texts*: Zimmer and Emlen. 2012. Evolution: Making Sense of Life. Roberts and Company. Possible additional text + papers.*

Course overview:

Evolution is the unifying theory of biology with applications to every field of biology including ecology, medicine, physiology, agriculture, and molecular biology, yet it remains an issue hotly disputed in society at large. In this course, we will discuss the evidence and scientific basis for evolution, mechanisms of evolution including genetic variation and natural selection, population genetics, and speciation. In addition, according to student interest we may also discuss applied topics such as Darwinian medicine, sexual selection, evolution of cooperation, and human evolution. We will also address the societal debates involving the teaching of evolution and/or intelligent design in schools. The format of the course will include participatory lectures and student-led discussions.

Attendance

Attendance is necessary to succeed in this class. Most class meetings will be a mix of lecture and group work and participation is worth 17% of the final grade. To earn full participation points you must not only attend, but contribute to discussion and group work. To contribute you ***MUST HAVE READ*** *the assigned reading* ***BEFORE*** *class. Missing more than 1 discussion may result in the reduction of the final grade.*

Participation in College-related Activities: Students are required to hand in a note signed by the activity sponsor (e.g., coach, director) indicating the days that the student is anticipated to miss class. This must be turned in by the second week of class. In the case of conflicts with exams, the student will take the exam the day prior to the rest of the class.

Evaluation

I do not "give" you a grade, you EARN a grade. There will be no extra credit. Your grade reflects the number of points you have accumulated in this course and you are wholly responsible for it. You will accumulate grades through the following assignments:

Exams*: There will be three exams (including the final) covering the material in your readings and discussed in class. Exams may include multiple choice questions, but will be primarily short answer*

and/or essay. Because I would like you to have more than 50 minutes to take the exam, we will discuss in the first week how to schedule exam times.

***Homework**: I will give you at least 4 homework assignments over the semester that will help you integrate and work through some of the important evolutionary ideas that we will cover. You will be given at least a week to complete the assignment. Specific instructions will be given for each assignment.*

***Discussions**: Much of this class will be discussion-oriented including the majority of labs. Your grade will be dependent upon the QUALITY not QUANITY of comments you make. If you do your reading and make at least 1 contribution to the discussion, you would receive an average grade (a C) for that class period. More insightful comments and participation in moving the discussion forward would result in a higher discussion grade. I will give you feedback on how you are doing on discussion several times throughout the semester so that you have an opportunity to improve your performance.*

Students (in pairs) will lead one discussion. In preparation for the discussion, the leaders should read the assigned material and meet with Dr. Bray one week before your discussion. The purpose of this meeting is to make sure that you 1) understand the material, 2) have a plan for the discussion, and 3) are making connections to topics in lecture and potentially external readings.

Guidelines for discussion:

1. Everyone should read "Let's give them something to talk about: choosing a discussion paper" which covers how to lead a good discussion.
2. Remember that everyone should have read the article/chapter(s) before class; you do not need to summarize or ask someone to summarize the reading.
3. Prepare a writing prompt for the class. This will help to get everyone on topic and help participants to organize their thoughts about the reading.
4. You need to guide the class members toward a good discussion of the following issues: Has the author(s) of the chapter or paper tried to make a particular argument? If so, what evidence has been given in support of that argument? Do you think the evidence presented is sufficient to support the author's claim? If not, what additional evidence would you seek and why?
5. After considering the argument and evidence presented within a paper, scientists critically consider how those arguments fit within the framework of the of biology field as a whole. You need to guide the class to a consideration of the major issues of evolution and science that we have discussed in class and how this argument fits with those paradigms.

***Tell me a story!** I think best way to teach something (and the most fun way to learn) is to tell a story. Many of you will probably be questioned by friends and family about why you "believe" in evolution. As an answer to that, I would like to all of you to have at least one great evolutionary story to tell. To that end, we will spend the last two weeks of the term hearing one another tell us about the great evolutionary stories. What are we looking for in a great evolutionary story? It should be something that was revolutionary and still has impacts on life today. I have a list of innovations that I think fit this bill, but we will also brainstorm as a class for other great stories. Students will select their topic in the first few weeks so that they can slowly gather information on their topic.* **The goal of your research will be to address the following questions: 1) how is this innovation hypothesized to have evolved? and 2)how has this innovation influenced evolution henceforth? There will be two final**

products to your story investigation: an annotated bibliography and a 10-12 minute presentation to the class during the last week of class.

	#	Points each	Total Points	% of grade
Exams	*3*	*100*	*300*	*50%*
Homework	*4*	*25*	*100*	*17%*
Discussion leader	*1*	*25*	*25*	*4%*
Presentation	*1*	*50*	*50*	*8%*
Annotated Bibliography	*1*	*25*	*25*	*4%*
Participation	*1*	*100*	*100*	*17%*

There is no curve in this class; your grade is simply determined by the sum of your points: ***90-100% = A(+/-); 80-89% = B(+/-); 70-79% = C(+/-), 60-69% = D(+/-); <59% = F***

Tentative Schedule

I tend to find that we get off track or that the class has different interests, so I have left the schedule after spring break relatively open. We will reassess where we stand every few weeks.

DATE	DAY	LECTURE TOPIC	READING
Jan 5-19	*M*	*Intro to course, interests*	*Chp 1*
Introduction^	*W*	*Overview, HIV as evolutionary Science*	
	F	*Contin.*	
Jan 12-16	*M*	*Review of Tree Thinking*	*Chp 4*
Phylogeny	*W*	*Building Trees* ***(Homework #1)***	
	F	***Discussion #1- Phylogenies***	
Jan 19-23	*M*	***MLK, Jr Day—NO CLASS***	
Evolutionary	*W*	*Molecular methods and gene trees*	*Chp 9.1-9.5*
Genetics	*F*	*Introduction to H-W, drift*	*Chp 6.1-6.5*
Jan 26-29	*M*	*Small populations, gene flow*	*Chp 6.7*
Evolutionary	*W*	*Selection, selection-mutation balance*	*Chp 6.6*
Genetics	*F*	*Computer Day* ***(Homework #2)***	
Feb 2-6	*M*	***Discussion #2- Population Genetics***	*<Exam Week>*
Quantitative	*W*	*Quantitative Traits and Selection*	*Chp 7.1-7.2*
Traits	*F*	*Phenotypic Plasticity*	*Chp 7.4*
Feb 9-13	*M*	***Discussion #3- Quantitative Genetics***	
Natural	*W*	*We will work through examples in Chapter 8 on Natural*	*Chp 8*
Selection	*F*	*Selection over these two class periods*	
Feb 16-20	*M*	***Discussion #4- Natural Selection***	
Adaptation	*W*	*Gene Duplication and Regulation*	*10.1-10.4*
	F	*Continued*	
Feb 23-28	*M*	***Discussion #5- Spandrels of San Marcos (Homework #3)***	*Spandrels*
Adaptation	*W*	*Constraints*	*10.5-10.8*
Limits	*F*	*Neutral evolution*	*9.6*
Mar 2-6	*M*	*Why sex? Variance in success.*	*Pgs 339-353*
Sexual	*W*	*Intra- or Intersexual selection?*	*Pgs 329-339*
Selection	*F*	*Other fun sexy things*	*Pgs 354-359*
			<Exam Week>
Mar 9-13		***Spring Break***	
Mar 16-20		*Book Discussion (Discussions 6-8)*	*TBA*
Mar 23-27			*TBA*
Student Choice			
Mar 30-Apr 3			*TBA*
Student Choice			
Apr 6-10		*Presentations*	

^ Because the material in chapters 2 and 5 has been covered in either Biological Interactions or Genetics, I will not cover this material in class, but you will be responsible for the material in these chapters. If you have questions about these chapters, be sure to meet with me.

Final Exam: Thursday, April 16 at noon.

BIO 4144: ECOLOGY

Instructor: Dr. Sarah Bray
Email: sbray@transy.edu
Office Hours: MWF 12:30-1:30, 2:30-3:30; by appointment
Office: BSC 319
Class meeting times: 1:30-2:20 MWF (lecture)
1:30-4:15 (lab); BSC 320
Phone: 233-8169

Text: Smith and Smith. 2015. Elements of Ecology, 9th edition. (Required)
Gardner, Mark. 2012. Statistics for Ecologists Using R and Excel: Data Collection, Exploration, Analysis and Presentation. Pelagic Publishing. (Recommended)

APPROACH

Ecology encompasses the study of relationships—the interactions of organisms and their environment that determine their abundance and distribution. We will explore ecology in the same way ecologists do: by asking seemingly simple questions about our world. Why are invasive species so successful? Why are the tropics so diverse? Does diversity "matter?" To address these questions, we will consult the primary literature, design and implement our own experiments, and analyze data from our own and other studies. Ecology is a very quantitative field of biology and over the semester you will gain experience in basic statistics and ecological models. Because all of these skills are necessary for an understanding of ecology **you must be present for all lectures, discussions and field studies. Missing one or more class meetings may result in a grade deduction.**

LEARNING OUTCOMES

- Describe how interactions of organisms with their environment give rise to patterns of abundance and distribution
- Apply ecological principles to answer 'big questions': e.g., invasions, tropical species diversity
- Design effective experiments to test ecological hypotheses
- Analyze and interpret ecological data using Excel and R
- Effectively propose and present ecological experiments in written and oral form
- Critique ecological research questions, designs, and data interpretations

GRADING

Exams: There will be two exams and a final in this course which will be given during lab time. Exams will be short answer and essay often requiring interpretation of graphs and statistics.

Data Analyses: You will be given data that you will be asked to interpret in light of the material we are covering in class. These assignments will expand your understanding of statistical analysis from Biologists' Toolkit to experimental designs and analyses used in ecological studies. The goal of these assignments is not only to increase your technical know-how of statistics and R, but also to get you to apply and interpret these analyses in ecological context.

Discussions: Over the course of the semester will examine how the questions we are asking in class are being addressed in the ecological literature. In general, I will select two papers for our discussion that may be chosen to illustrate disagreements in the field, alternative methodologies that are being used to test similar hypotheses, and/or the historical development of a subfield. Both papers will be made available on Moodle and each student should print both articles and bring them to class. Sometimes I will ask one half of the class to focus on one of the articles, the other

half of the class the other article. **You should be prepared to be an "expert" on the article that you were asked to focus on; however, you should at least read the abstract of the other paper and examine the figures and tables of the other article.** You will be graded on the basis of evidence of close reading of the text, active (i.e. verbal) engagement in small group and whole class discussions, and the asking of thoughtful questions that help others to learn.

Lab Participation: Expect to be ready to head to the field at 1:30 pm on Thursdays. Labs will be the down-and-dirty (and most fun!) part of ecology. Wear long pants and sturdy shoes or boots and be prepared for dirty, wet, hot, and/or cold. Be sure to bring along some water and probably a snack. Come to lab, work hard, clean up, and have a good attitude and you'll get an "A" for lab participation. Not following directions, endangering yourself or your labmates, being lazy, or constant complaining will result in a deduction in your grade.

Field Notebook: You will be required to keep a field/lab notebook. Consult the "Transylvania University Lab Notebook Guidelines" document for what a scientific notebook should be like. Other than taking the notebook with you to the field, it should remain in the lab. EVERY visit to the field should contain an entry that includes: objective, protocols/methods (what you actually did in the field), data (sometime you may be using data sheets—reference these in your notebook), observations, and reflections/conclusions. You should transcribe your data into electronic form and note the name/location of that electronic file in your notebook. All entries in your notebook should happen on the day that you are in the field/lab. Field notebooks will be spot checked at random.

Independent Projects: We will be spending the majority of the laboratory time exploring hypotheses related to wintercreeper (*Euonymus fortunei*), an invasive vine. In the first lab, we will set up an experimental design to examine the impact of wintercreeper removal on decomposition (see handout). Additionally, in groups of 2, you will design sets of hypotheses related to the class project. Prior to the initiation of the projects, each group will write a **project proposal**. Partners will receive written **reviews** from the class and we will discuss the projects a final time before starting data collection. Although partners will be responsible for the design, analysis, and **presentation** of their projects, during field work we will often work as an entire class to collect data as efficiently as possible.

Metric	Number	Points Each	Points Total	Percentage of Grade
Exams	3	100	300	50%
Data Analyses	4	25	100	~17%
Discussion Participation	7	5	35	~6%
Project Discussion	1	20	20	~3%
Lab Participation	1	25	25	~4%
Field Notebook	1	25	25	~4%
Project Proposal	1	25	25	~4%
Project Review	1	20	20	~3%
Final Presentation	1	50	50	~8%
Total			600	

All grades will be based on the following scale:

A = 91 - 100	B+ = 87 - 88	B- = 80 - 82	C = 73 - 76	D+ = 67 - 69	D- = 60 - 62
A- = 89 - 90	B = 83 - 86	C+ = 77 - 79	C- = 70 - 72	D = 63 - 66	F = 0 – 59

Attendance Policy

Missing one or more class period or lab may result in the reduction of your grade. If you are participating in a Transy event that conflicts with a class or lab, you must provide me with those dates in the first week of class. If your absence is approved, you must make up missed work BEFORE your absence.

Electronic devices:

I don't prohibit electronic devices because they can often enhance our experience, but I ask that you stay focused on the topic at hand (no twitter, Instagram, Book of Faces, texting, tumblr etc.). I also strongly encourage you to take notes by hand as research has indicated students taking longhand over computer notes performed better on quizzes (http://pss.sagepub.com/content/25/6/1159).

Late Assignments

Assignments are due at 11:59 pm on the due date listed on the assignment prompt. Assignments not turned in by the due date will be docked 5% every 12 hours starting at 12:00 am. Assignments that are 4 days late will receive at 0.

Academic Integrity

You should abide by the Transylvania University academic integrity policy while conducting your work in this course. This policy is found in the student handbook, and all students are responsible for becoming familiar with this policy. Any infractions of academic integrity will result in a zero for the assignment and will be reported to the student's advisor and the academic dean.

Special needs and disability resources:

If you need course adaptations or accommodations because of a disability or chronic illness, please make an appointment with me as soon as possible, or see me during office hours. Please also contact Brenda Dennis (bdennis@transy.edu, X 3682) who will help you with coordinating reasonable accommodations.

Respect and Classroom Climate

This is a small class and I emphasize discussion and cooperation. Therefore, all members of this class are expected to treat one another with consideration and respect.

Why do we put up with it? Do we like to be criticized? No, no scientist enjoys it. Every scientist feels a proprietary affection for his or her ideas and findings. Even so, you don't reply to critiques, Wait a minute; this is a really good idea; I'm very fond of it; it's done you no harm; please leave it alone. Instead, the hard but just rule is that if the ideas don't work, you must throw them away.

–Carl Sagan, The Demon-Haunted World: Science as a Candle in the Dark

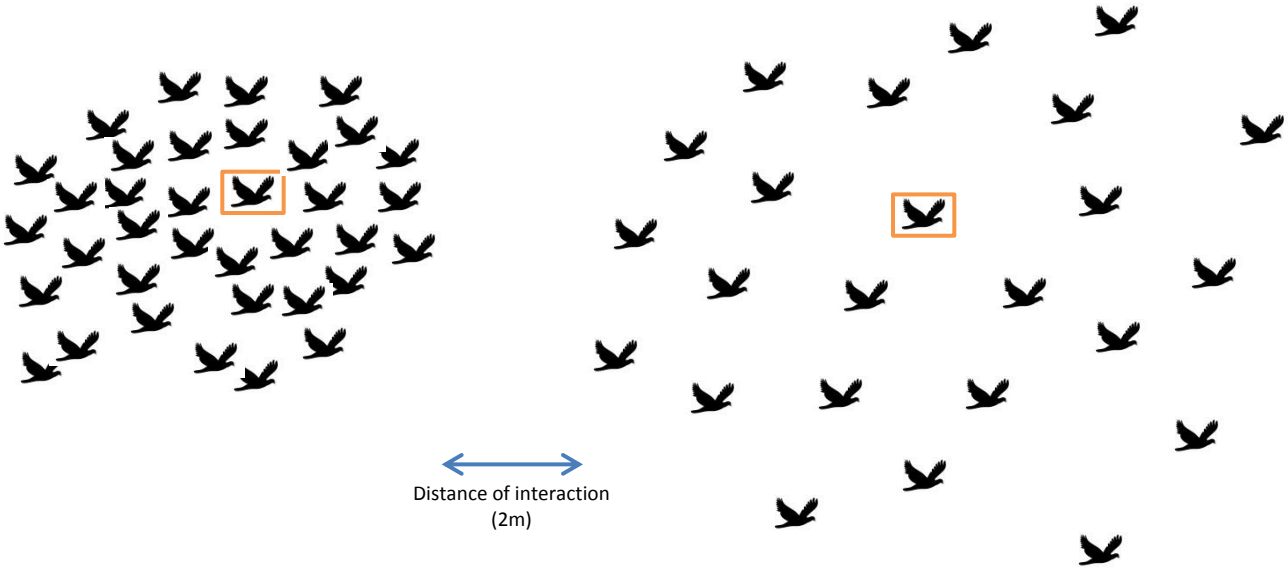
Tentative Schedule

Date	Day	Topic	Reading	Lab (Tuesday)
9/9	W	**Why aren't their penguins in the arctic?**	Chp 1	Set up Field Project
9/11	F	Climate	Chp 2	
9/14	M	Climate, Biomes	Chp 23	Finish in field Begin veg sampling
9/16	W	Continue Biomes		
9/18	F	**How will organisms respond to a changing environment?**	27.1-4	
9/21	M	Plant Adaptations	Chp 6	Deploy litterbags, Sample forest
9/23	W	Animal Adaptations	Chp 7	
9/25	F	**Discussion 1: Range, Physiology, and Climate Change**	**Proposals due (11:59 pm Sunday)**	
9/28	M	**Why are invasive species so successful?**		Project Critique, supply lists
9/30	W	Life history correlates of invasibility	10.1-7, 10.9, 10.13	
10/2	F	Life history to life tables	9.2-9.7	
10/5	M	Finish life tables		**EXAM 1**
10/7	W	How are populations normally held in check? Intraspecific competition	9.1, Chp 11	
10/9	F	**PRESIDENTIAL INAUGURATION- NO CLASS**		
10/12	M	Intraspecific competition, continued	Chp 11	Project Day
10/14	W	The niche: invasive species and competitive exclusion	12.6, 13.1-5	
10/16	F	How are populations normally held in check? Interspecific competition	13.1-5	
10/19	M	**Fall Break**		
10/21	W	**Discussion 2**: Competition- native vs. exotic	Moodle	No lab
10/23	F	Why doesn't competitive exclusion always occur?	13.6-13.12	
10/26	M	**How are populations normally held in check?- Predation**	14.1-6, 14.15	Project Day
10/28	W	Trophic interactions: Parasitism	15.1, 15.7-9	
10/30	F	Trophic interactions: Mutualisms	15.10-15.15	
11/2	M	**Discussion 3**: Biological control		Collect litter bags, dry
11/4	W	Summing up: invasive species and population biology		
11/6	F	What do we mean by 'community?'	16.1-3, 8-10	
11/9	M	Forces structuring communities	Chp 17	**EXAM 2**
11/11	W	Community Dynamics	Chp 18	
11/13	F	**Discussion 4**: Patterns of Species Diversity	26.3-7	
11/16	M	**Why are the tropics so diverse?** Paradox of tropical plant diversity		Weigh litter bags, Project Day
11/18	W	**Discussion 5:** Niches v. neutral model		
11/20	F	**Discussion 6:** Intermediate disturbance vs. Janzen-Connell		
11/23	M	Catch up		Optional Lab
11/25-27		**Thanksgiving**		
11/30	M	Putting it together: Ecosystem Energetics	20.1-4, 20.7	Open lab
12/1	W	Secondary productivity	20.8-12	
12/3	F	Decomposition	21.1-8	
12/7	M	Nutrient cycling	21.9-11, EIA	Final Presentations
12/9	W	Carbon and Nutrient Cycling	22.1-8	
12/11	F	Does diversity matter? **Final Discussion**		
Final: Thursday, December 17 at 9 a.m.				

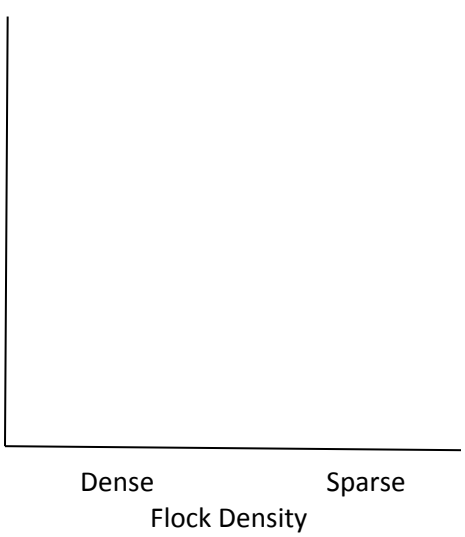
Flocking: An emergent property driven by topology or distance?

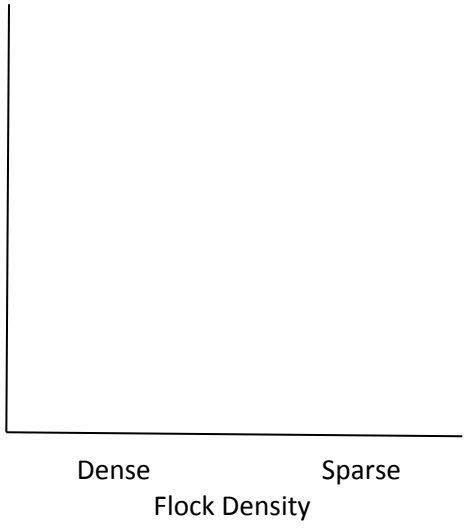
1. State in your own words what the topology and distance hypotheses are. For each hypothesis, which variable would best predict bird behavior?

2. Imagine you examine two flocks with differing densities (below). In each flock, indicate which birds the focal bird would be interacting with given the topology and distance hypothesis. Assume a γ = 1/3 (neighbors not interacting) when n = 2.5 birds



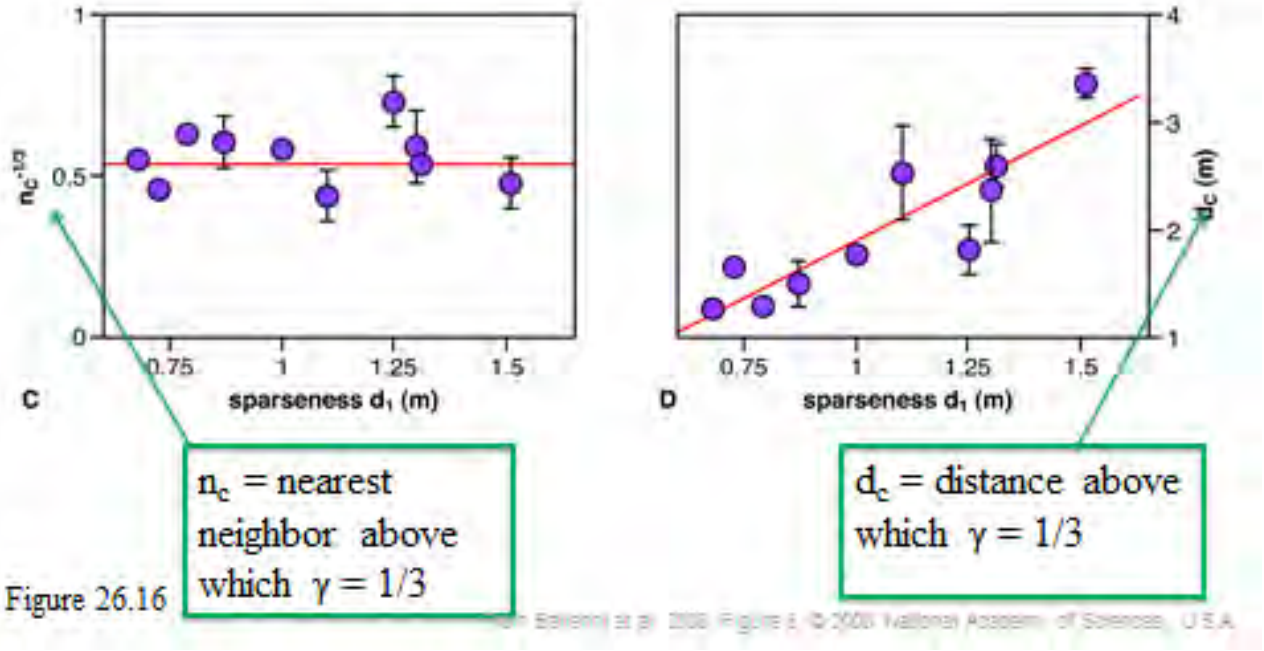
3. Based on your flocks above, graph:
A) The distance to the last neighbor the focal individual interacts with
B) # of individuals the focal bird is interacting with.
Your graphs should have 4 bars…. For each density, you should have one bar representing the distance hypothesis, another bar representing the topology hypothesis. What should the Y axis be? Llabel them





Based on these graphs, if the topology hypothesis is supported, what varies with flock density? What if the distance hypothesis is supported?

Assessing the topology and distance hypotheses for starling flocks



n_c = nearest neighbor above which $\gamma = 1/3$

d_c = distance above which $\gamma = 1/3$

Figure 26.16

Based on your predictions previously, what model is supported and why?

20.1 From Ladders to Trees

- Context: Evolution and Descent with Modification is the intellectual framework we use to understand how new species come about and how to organize the great diversity of life on earth.
- Major themes: Descent with modification results in closely related species sharing many characteristics but adaptations and selection can obscure relatedness.
- Bottom line: Defining a species is putting a static name on a dynamic, ever evolving entity.
-

Biology Learning Objectives
Contrast the Great Chain of Being view of life with Darwin's evolutionary tree. How do they influence our view of the value of a species?
Why is it difficult to define a species?
Explain how/why species are able to maintain their identity and how does a new species arise?

When Darwin was only 22 years old he took a five-year voyage on the Beagle during which he kept extensive notebooks on his travels where he documented his thoughts, observations and details about the wondrous locations and encounters he experienced. One of the most famous images from Darwin's journals can be found on page 36 of his notebook B (Transmutation 1837-1838) in which he crudely scratched in black India ink what looks to be a weird multi-legged dog but is actually meant to represent a family tree with its multi-bifurcated branches labeled at the tips with letters, labels for different species. This was the first time anyone had represented the relationship between species in a non-linear fashion. Up to this moment most philosophers and scientists organized life on the planet in a ladder-like fashion that reflected a divinely created hierarchical order where the lower rungs of the ladder represented plants and invertebrate animals, the intermediate rungs were dedicated to those animals that can fly or swim in the sea and the upper rungs were humans, of various degrees (slaves, women, nobles, etc.) depending upon the politics of the time, with the top rungs dedicated to angels and ultimately God. This linear organization is often referred to as the Great Chain of Being

In contrast to the Great Chain of Being, Darwin's hastily scrawled bush has no up, nor down, and it deliberately radiates in all directions eliminating the possibility of interpreting a position on the tree as having higher and lower status. Ultimately Darwin was trying to understand transmutation, the process in which new species arise from existing species and how this process results in groups of related species. In this chapter we will review the species concept and discuss ways in which species identity are maintained and how new species arise. We will then return to Darwin's sketch and see how his idea has given rise to the modern field of **phylogeny** and **systematics**.

The most recent version of the Tree of Life

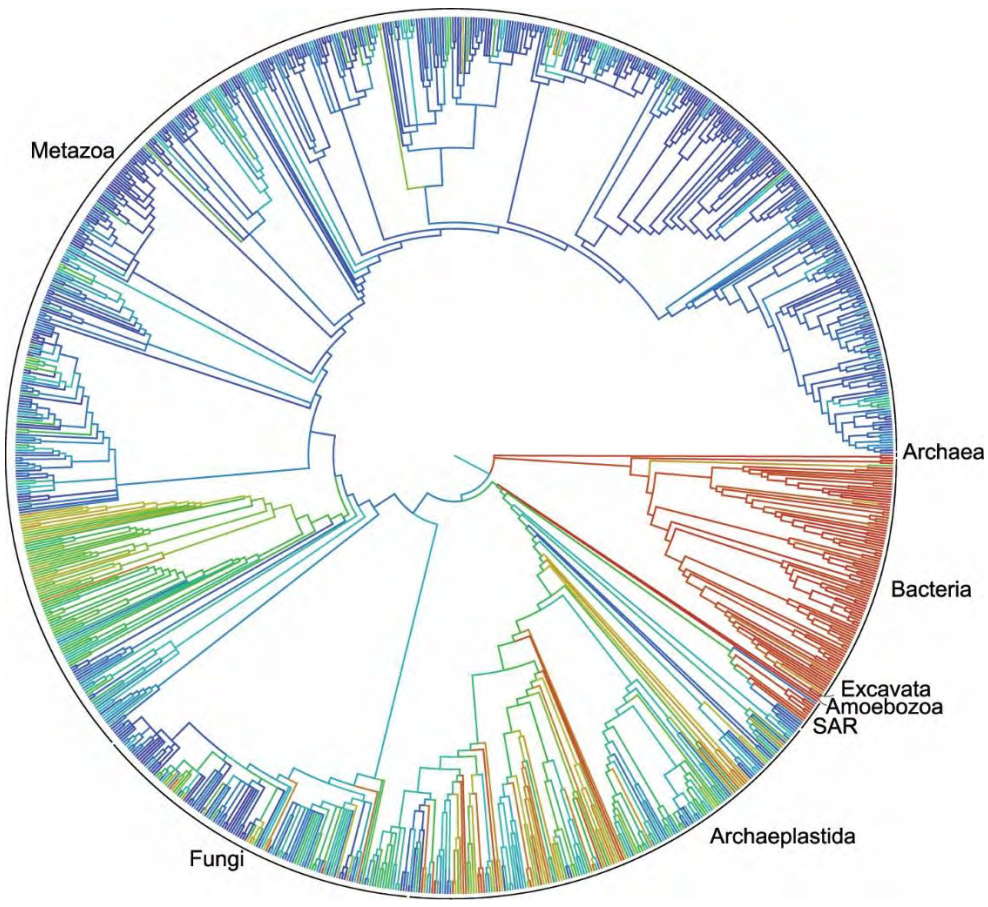


Figure 20.1 A first draft of the family tree of life for all of Earth's lifeforms. Impressive diversity in the 3.5-billion-year history of how life evolved and diverged. Credit: opentreeoflife.org
Read more at: http://phys.org/news/2015-09-tree-life-million-species.html#jCp, .

Species

Over a 130 years before Darwin published *Origin of Species* in 1859, Carolus Linnaeus (1707–1778) had proposed a formalized system for organizing and naming the diversity of life on earth. Linnaeus also employed a hierarchical order in his organization system although it was not formally based on the Great Chain of Being idea. Linnaeus' system grouped organisms within units of similarity that became more specific and restricted at each level. As you may recall the levels were:

Kingdom
Phylum
Class
Order
Family
Genus
Species

– with species being the final unit of distinct identity. There can be only one species, but there can be many species within their Genus and many Genus within their Family and many Families within their Order, etc. etc. up till Kingdom[1]. For example consider the ostrich, a large flightless [2] bird from Africa. The large black-plumed bird with an elongated neck and powerful legs stands up to 2.8 meters tall (9' 2") and can sprint up to 19 m/s (43 mph). It feeds mostly on vegetation and a few invertebrates, much like a free range domestic chicken.

Kingdom: Animalia
Phylum: Chordata
Class: Aves
Order: Struthioniformes
Family: Struthionidae
Genus: Struthio
Species: camelus

Within the genus *Struthio* there are 10 known species of ostriches, eight of which are **extinct** and two **extant** species – the Common and the Somali ostrich. These birds are similar but distinctly different from the flightless birds found in Australia and South America which Darwin himself noted in *Origin of Species* –

[1] Today we recognize a level above Kingdom which are known as Domains and there are only three – Archae, Bacteria, and Eukarya.
[2] Flightlessness is a specific morphological condition where the bird lacks the bony protrusion on the sternum known as a keel where the flight muscles are attached. Most people think penguins, chickens, turkeys and flamingos must also be flightless birds but they are not since they possess a keel and either rarely fly or fly underwater (penguin).

The plains near the Straits of Magellan are inhabited by one species of Rhea (American ostrich), and northward the plains of La Plata by another species of the same genus; and not by a true ostrich or emu, like those inhabiting Africa and Australia under the same latitude.

Ostrich

By Yathin S Krishnappa - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=38145796

Rhea

By Adrian Pingstone (Arpingstone) - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=5074712

Emu

By Benjamint444 - Own work, GFDL 1.2, https://commons.wikimedia.org/w/index.php?curid=13620753

Cassowary

http://www.wettropics.gov.au/cassowaries

Kiwi

https://www.thinglink.com/scene/791305313759264770

Figure 20.1 . Images of the distinct species of flightless birds found throughout the world. They range in size from Kiwi's at 25 cm (9.8 in) high and the females weighing 1.3 kg (2.9 lb) to ostriches 1.7 to 2.0 m (5 ft 7 in to 6 ft 7 in) tall and weighing up 63 to 145 kilograms (139–320 lb)

Darwin was the first to recognize that at a global scale, groups of similar species are often found near each other geographically. When Darwin traveled to a new continent he found clusters of new species which were similar to each other but quite different from those found on other continents. This is beautifully illustrated in the global distribution of the paleognathid (paleo=old, gnath=mouth) flightless birds which are represented by Ostriches (2 species) in Africa, Rheas (2 species) in South America, Emus (1 species) in Australia, Cassowaries (3 species) in New Guinea and northern Australia, and Kiwis (5 species) in New Zealand.

Notice how the clusters of different species correlate with their geographical distribution but what makes a specific group unique enough to be called a species? In Linnaeus's time he grouped species based upon a series of physical characteristics that were unique to the group – this type of species definition is called the *morphological species concept.* Of course what is unique to one person can be mundane to another which can create disagreement about what constitutes a true species. Darwin and others recognized that the morphological species concept created a species identity that could be arbitrary and only dependent upon the observer.

Originally only one species of extant ostriches was recognized, *Struthio camelus*, which originally ranged through Africa, some parts of Arabia and the Middle east but is now restricted only to regions in Africa. Within its current range two distinct populations have been recognized – the northern and southern populations. Within the northern and southern populations there were geographical and morphologically distinct populations of ostriches that were considered so unique they were indentified as *subspecies* of *S. camelus* and given an additional name subordinate to the species name to differentiate them, In the northern populations there were three subspecies identified– *S. camelus camelus, S. c. molybdophanes* and *S. c.* massaicus while the southern population only contained a single subspecies *S. c. australis*. Subspecies are varieties or populations that are so distinct that they may be, what Darwin called, incipient species, the early stages of a speciation event. The alternative hypothesis is the subspecies are actually distinctly different species but we cannot clearly distinguish them apart because we lack information on the trait(s) that unequivocally distinguishes the groups apart. Researchers in 1999 applied molecular analysis of mDNA to identify 11 maternal haplotypes (A-K) within the various subspecies of ostriches and measured the sequence difference between two short fragments of mDNA from the haplotypes. The table below was created by comparing the sequences obtained from different specimens of each subspecies. All of the *australis* subspecies were fairly similar to each other and *massacus* subspecies with divergences being low (ranging from 1.079%-1.738%). A high level of divergence was seen between subspecies *S. c. australis* and *S. c. molybdophanes* 7.278-7.773%).

Table 3. Values above the diagonal correspond to the HKY 85 corrected percentage sequence divergence between the 11 *Struthio camelus* haplotypes observed in this study. Below the diagonal are the absolute number of changes between specimens. Clone numbers correspond to those given in Table 1.

		A	B	C	D	E	F	G	H	I	J	K
A	*S. c. australis*	*****	1.079	1.738	1.297	1.297	1.738	5.651	4.463	4.698	4.463	7.278
B	*S. c. australis*	5	*****	1.517	1.079	1.079	1.517	5.412	4.231	4.464	4.230	7.526
C	*S. c. australis*	8	7	*****	1.738	1.738	2.183	5.172	4.935	5.172	4.935	7.525
D	*S. c. australis*	6	5	8	*****	0.428	0.861	6.135	4.935	5.172	4.935	7.773
E	*S. c. massaicus*	6	5	8	2	*****	0.428	6.135	4.935	5.172	4.935	7.279
F	*S. c. massaicus*	8	7	10		2	*****	5.652	4.935	4.699	4.464	7.279
G	*S. c. camelus*	25	24	23	27	27	25	*****	1.960	1.738	1.960	7.792
H	*S. c. camelus*	20	19	22	22	22	22	9	*****	0.214	0.428	6.561
I	*S. c. camelus*	21	20	23	23	23	21	8	1	*****	0.214	6.805
J	*S. c. camelus*	20	19	22	22	2	20	9	2	1	*****	7.049
K	*S. c. molybdophanes*	32	33	33	34	32	32	34	29	30	31	*****

Table 20.1 mDNA Sequence similarity between specimens of different subspecies of ostriches. Differences arise from transitional changes where C↔T or G↔A substitutions occur.

Table 20.1 lists a range in the divergences observed in these small subsets of mDNA between the subspecies but there is no specified threshold of divergence that defines the species boundary. At the time of this study the Somali ostrich was considered a subspecies of ostrich but it differs from the common ostrich (*Struthio camelus*) in having the skin of its neck and legs a blue-grey color, with the male skin becoming blue during mating season, which is in sharp contrast to the pink neck and leg color of the common ostrich. Ultimately the documented differences in morphology, genetics and geographic distribution addition led to the decision in 2014 to make the Somali ostrich a separate species of ostrich.

In attempt to create a species concept that was independent of human judgement, a famous evolutionary biologist named Ernst Mayr in 1942 proposed the *biological species concept* (BSC) which defined a species as a population of organisms that can interbreed and create fertile and viable offspring. Barriers that prevent two species from interbreeding fall into one of two categories – *Prezygotic* isolating mechanisms and *Postzygotic* isolating mechanisms. The distinction between these two categories is at what point in reproduction does the barrier occur. Prezygotic ("before" the "zygote") mechanisms include geographical isolation, behavioral isolation, temporal isolation and gametic isolation. All of these processes prevent the fusion of gametes known as fertilization. Postzygotic isolating mechanisms occur after the sperm and egg have fused and a zygote is created. The zygote could be inviable and die at any stage in development or before adult stage. Some hybrids between species remain viable even until the adult stage but are infertile. The classic example of this is the interbreeding between a horse and a donkey that creates the infertile mule offspring.

Integrating Questions

1. What is the advantage and disadvantage of the morphological species concept?
2. How can convergent evolution complicate the morphological species concept {convergent evolution introduced in 12.3 How does a Venus flytrap catch its prey?}
3. Consider the number of organisms on the endangered species list {graph here} by taxonomic group. Does the idea of the Great Chain of Being influence this list?
4. Why would you not use the data alone from Table 20.1 to support making the Somali ostrich a unique species?
5. Are prezygotic and postzygotic isolating mechanisms adaptations for a species? Explain.
6. Lions (Africa) and Tigers (Asia) are considered separate species but in zoos they have been known to interbreed and produce hybrid ligers or tigons, depending upon who the father is. If the hybrids are fertile should lions and tigers be considered the same species?

How to build a Phylogenetic Tree

The morphological similarities among the flightless group of birds, called ratites, has long suggested to biologists a shared ancestry among this group of birds. It wasn't until the mid- to late-20th century that a method for using data to examine relationships among organisms arose. **Phylogenetics** is the examination of evolutionary relationships among taxa using morphological, biochemical, or genetic data. These data are then used to build tree-like diagrams (**cladograms**) that illustrate these evolutionary relationships. What made the phylogenetic approach different from previous approaches of understanding evolutionary relationships is its emphasis on using shared derived traits (**synapomorphies**) to build trees.

How do biologists determine these synapomorphies? First biologists choose characters to examine for the taxa of interest. For example, if we wanted to examine relationships among a number of plants, we might examine such traits as leaf venation (parallel or netlike) or number of floral parts (multiples of 3, 4, or 5). We try to choose traits that are **homologies**, traits that are the same due to shared ancestry, such as the forearm of quadrupeds (below), rather than **analogies**, traits that arise in two separate lineages, such as an insect's wing and a bat's wing. Once we choose and measure all of the characters for all of our taxa, we must determine which is the derived (most recently evolved) and which is the ancestral state of the character. We determine the polarity (ancestral or derived) of a character by looking at that trait in one or more taxa that are related to, but not a member of our taxa of interest, called the **outgroup**. If the character state is shared in common with the outgroup, it is deemed to be ancestral; if it is different from the outgroup, it is derived. When two or more taxa share a derived trait, it is called a synapomorphy. Additional Resource: http://evolution.berkeley.edu/evolibrary/article/phylogenetics_01

Joel Cracraft was one of the first biologists to apply phylogenetic techniques to understanding evolutionary relationships among the paloegnathid birds. Although most paleognathid birds are flightless, in South America there are 47 species of tinamou, small flying birds that have similar skull structure to paleognathid flightless birds. Tinamous are small chicken sized or smaller birds that spend their time foraging and nesting on the ground in a variety of habitats, forests, woodlands and open plains. Although tinamous do have a keel, they are very reluctant flyers preferring to freeze in place or scurry away into the deep vegetation to avoid predators. Cracraft measured 25 different morphological traits in the ratites and tinamus do develop a phylogenetic tree. To identify synapomorphies, the polarity of each trait was determined by comparing it with what was found in a jungle fowl (the wild ancestor of chickens) (see Table 20.2).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OG															
A	X	X	X								X				
B	X	X											X		X
C	X	X	X	X		X				X					
D	X	X											X	X	
E	X	X	X	X		X			X						
F	X	X	X	X	X		X								
G	X	X	X	X	X			X							
H	X											X			

Table 20.2: A portion of the character matrix created by Cracraft (1974). Characters are numbered 1-15 across the columns; taxa are labeled A-H in the rows. An "X" indicates that the taxa possesses the synapomorphy. A = Elephant bird, B = kiwi, C = Cassowary, D = Moa, E = Emu, F = Rhea, G = Ostrich, H = Tinamou, OG = outgroup (Gallus).

Integrating Questions

7. What character state seemed to evolve early in these taxa?
8. Which taxa seems to have the LEAST shared evolutionary history with the other taxa (i.e. the fewest number of synapomorphies shared with other taxa)?
9. Based on the matrix above, what two taxa would you predict are most closely related to one other?
10. Is there any evolutionary information in characters like #7? If so, what kind of information is it?

Cracraft used the character matrix above to make the phylogenetic tree below (Figure x.x). Note the synapomorphies are placed on the tree where they are hypothesized to have evolved. Any bird 'above' where a synapomorphy appears possesses that trait. This means you can read the tree from tip (taxa) to the base and determine all the traits that taxa possess. For example, if we trace the Rhea's lineage

backwards, we see that it possesses the following traits: 7, 5, 4, 3, 2, and 1. Notice that traits only appear once on the tree. Now, there are hundreds of thousands of ways we could arrange taxa and these characters on the tree, but generally when constructing phylogenies, we use the concept of **parsimony**. The most parsimonious explanation of something is the simplest (link to Occam's Razor). In an evolutionary tree, the most parsimonious explanation is one the requires the fewest evolutionary origins of traits.

We can also infer several things about relationships from this tree, but first, we need to learn a little bit more terminology to read trees. Where two branches of the tree meet is called a node; this node represents the most recent common ancestor shared by those two taxa. For example, the cassowary and emu share a common ancestor where their branches meet. Because they share the same most recent common ancestor, they are also called **sister groups**. Similarly, rheas and ostriches are sister species because they also share a most recent common ancestor. The more recently two taxa share a common ancestor, the more closely related they are. We often try to make our taxonomy reflect evolutionary history, thus we try to only name groups (**monophyletic clades**) which consist of a common ancestor and all its **descendants**. The group Rhea-Ostrich-Cassowary-Emu would be considered a monophyletic clade.

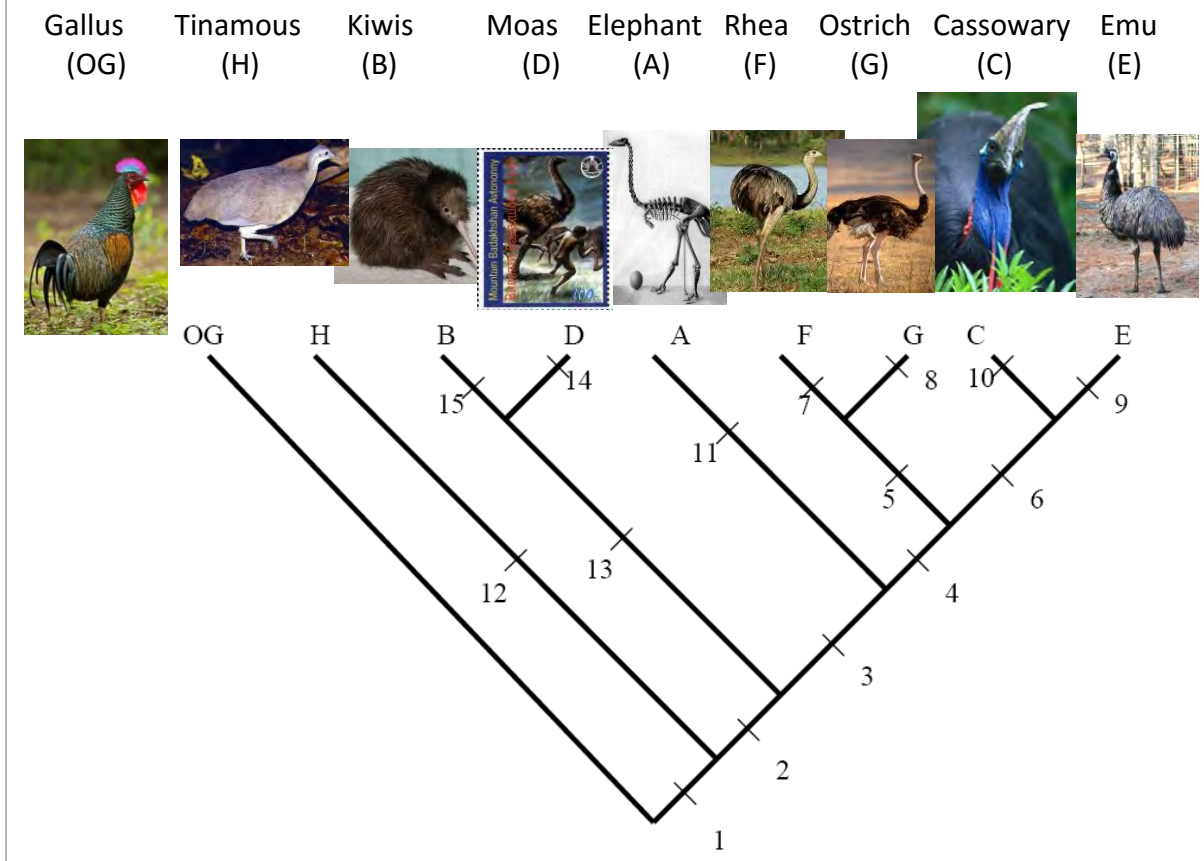


Figure 20.2 Phylogeny constructed by Cracraft (1974) from the character matrix in Table 20.2. Numbers represent synaopmorphies. Time can be inferred to be running from bottom (more ancient) to top (more recent).

Integrating Questions

11. What traits do kiwis possess?
12. Based on the phylogeny above, are the flightless birds monophyletic?
13. Are elephant birds more closely related to moas or emus?
14. Identify as many sister groups as you can in this tree.
15. How many times did flightlessness evolve in this phylogeny?

How to make a new species

As noted previously, the flightless ratites are distributed across the globe and extant species are currently found in South America, Africa, Australia, and New Zealand. How can we explain the **biogeography** of these species when they are flightless? One hypothesis is that an ancestral ratite was distributed across Gondwana (see Figure 20.3 below) and rafted away as the continents broke up. Once **gene flow** {*Connections 19.3 When are two isolated populations not isolated?*} was stopped, populations began to diverge from one another and **speciate**. When a physical barrier arises between populations that allow them to diverge and speciate, this form of speciation is called **allopatric speciation** via **vicariance**. Populations may also diverge toward allopatric speciation when a few individuals disperse to another location and become isolated from their parent population (for example finches flying to different islands in the Galapagos). As stated above, in the case of ratites, the vicariance hypothesis was favored since ratites are flightless. Sanmartin and Ronquist (2004) represented the breakup of Gondwana with a cladogram so that we can compare it directly to the ratite phylogeny (Figure 20.3).

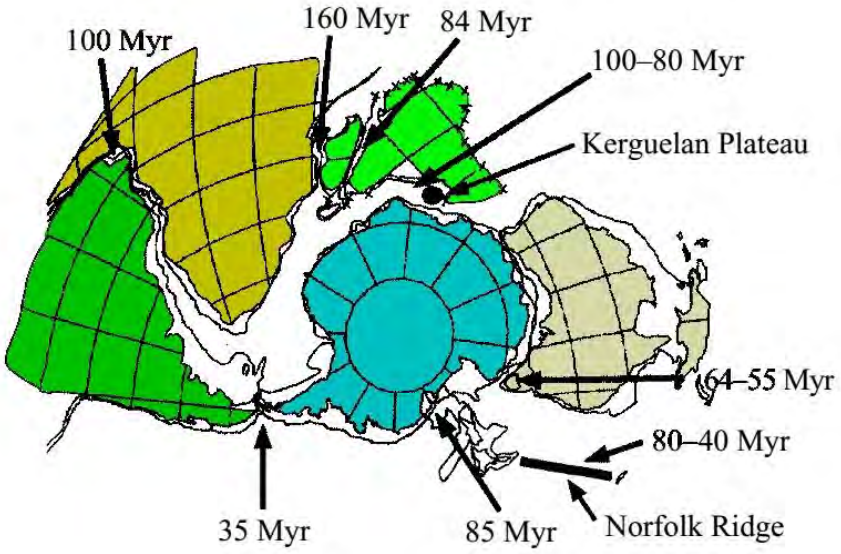


Figure 20.3 Map of the break up of Gondwana from Cracraft 2001. The dates indicate when the last land connection between two land masses existed in millions

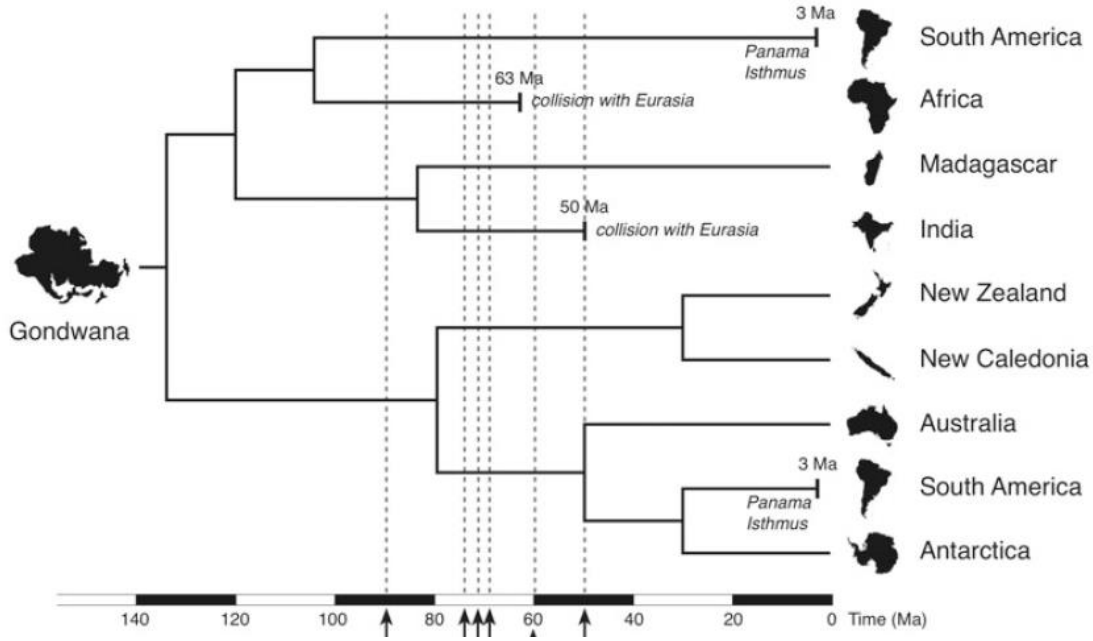


Figure 20.4: Geological area cladogram representing the breakup of Gondwana from Sanmartin and Ronquist (2004). Vertical lines represent collisions between landmasses.

Integrating Questions

11. Compare the ratite phylogeny and the geological area cladogram. Is the vicariance hypothesis of ratite speciation supported by this data? Explain.
12. We discussed allopatric speciation (above) as speciation that occurs when populations are physically or geographically isolated. Sympatric speciation occurs when populations are in the same physical location. What might prevent gene flow that would allow for sympatric speciation?

With the advent of affordable DNA sequencing, biologists started to use nucleotides of various segments of DNA as their source of data for building phylogenetic trees. Additional Resource: http://www.hhmi.org/biointeractive/creating-phylogenetic-trees-dna-sequences A consortium of researchers (Harshman et al. 2008) were looking to confirm or reject the hypotheses of A) monophylly of ratites and B) the singular evolution of flightlessness. They used 20 nuclear loci of with ~30% were protein-coding and ~70% were non-coding (see section 2.4) and examined them across 6 ratites, 4 tinamous, and 8 outgroup taxa.

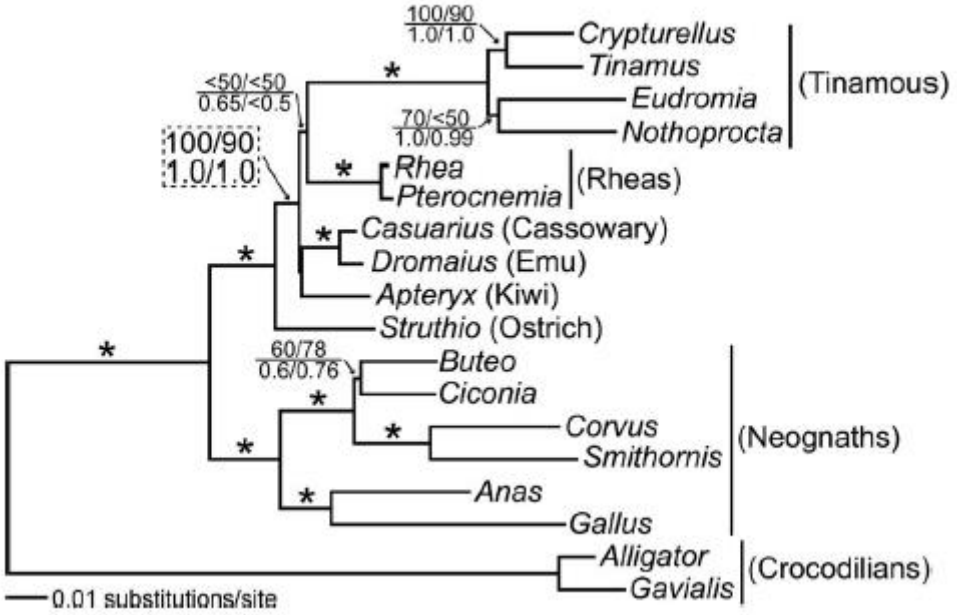


Figure 20.5: Phylogenetic analysis of 18 taxa from 4668 bp. Neognaths represent nearly all living species of birds that are not ratites. Support measures are unpartitioned maximum likelihood bootstrap (upper left), maximum parsimony bootstrap (upper right), and partitioned Bayesian posterior probability (lower right). Braches for which all support measures were 100% or 1.0 are indicated with an asterisk.

Integrating Questions

11. What seem to be the outgroup(s) in the Harshman phylogeny? Why do you think they were selected?
12. Compare the two ratite phylogenies. How are they different; how are they similar?
13. In this phylogeny are ratites (flightless birds) monophyletic?
14. What would be the most parsimonious way to describe the loss/gain of flight in the Harshman phylogeny?

So, if a group is not monophyletic, what is it? If the group is defined as having several different most recent common ancestors, the group is considered **polyphyletic**. If the group only contains some, but not all of the descendants of a common ancestor, the group is considered **paraphyletic**.

Harshman argue that this phylogeny does not support the monophylly of ratites or the single loss of flight. Instead, this phylogeny suggests flight was lost multiple times in at least three lineages. This also

removes the "need" of the vicariance model to explain the biogeography of flightless bird. They could have instead flown to their various locations and later lost the ability to fly. One of their lines of argument to support this hypothesis is that flight has been lost in at least 18 different bird families, and hundreds of times in the family Rallidae alone. Harshman references the rejections of the vicariance model to explain the biogeography of flightless birds with this line:

> *Perhaps the impact of our phylogeny should be viewed as yet another example of the phenomenon that Husley called "the great tragedy of science—the slaying of a beautiful theory by an ugly fact."*

So why did we get two different constructions of the evolutionary history of ratites? And which one is "right?" It's important to remember that like all biological research, a single study represents a test of one hypothesis. Thus, each tree is essentially one hypothesis of the evolutionary history of a group. Every time we construct a tree using a different data set, we are testing hypothesis of relationships again. Usually after testing a hypothesis several times, we start to find some branching patterns consistently supported by the data. <<talk here about differences in types of data used or not worth it?>> In fact, new phylogenies can be created using the data of previously published studies; Jordan Smith and colleagues (2013) did just this type of analysis. They combined their 40 nuclear loci with the 20 loci from the Harshman et al. (2008) study and mitochondrial DNA sequence data from Phillips et al. (2010). The phylogeny produced from this concatenated total molecular data set is Figure 20.6.

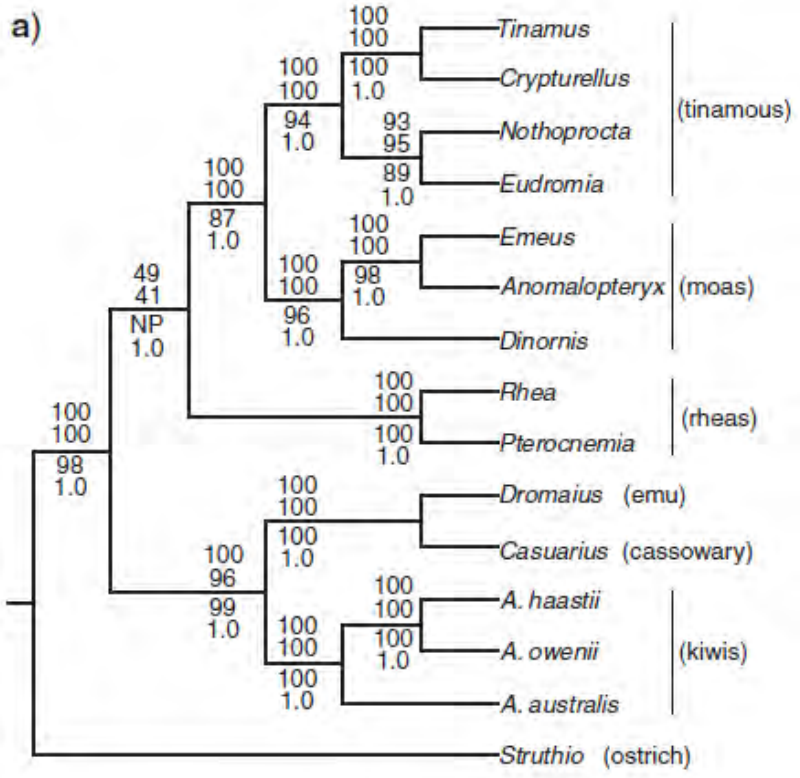


Figure 20.6: Total molecular evidence analysis using the taxa from Phillips et al. (2010). BS = % bootstrap support; PP = posterior probability values (Bayesian inference).

Review Questions

Bibliography

Glossary

Publishing Information

Discussion Questions
Kenneally, Chp 11
BHC Winter 2016

1. What evidence does this chapter provide for the *biological* existence of race? Against it?

2. How is the use of 'ancestry' different from the use of 'race?' What is the utility of using either term?

3. How should we interpret ancestry data? What are potential societal and personal repercussions?

4. How can scientists benefit from a liberal arts education? Think about specific examples discussed in this chapter that might have been handled differently if researchers had taken a bigger perspective.

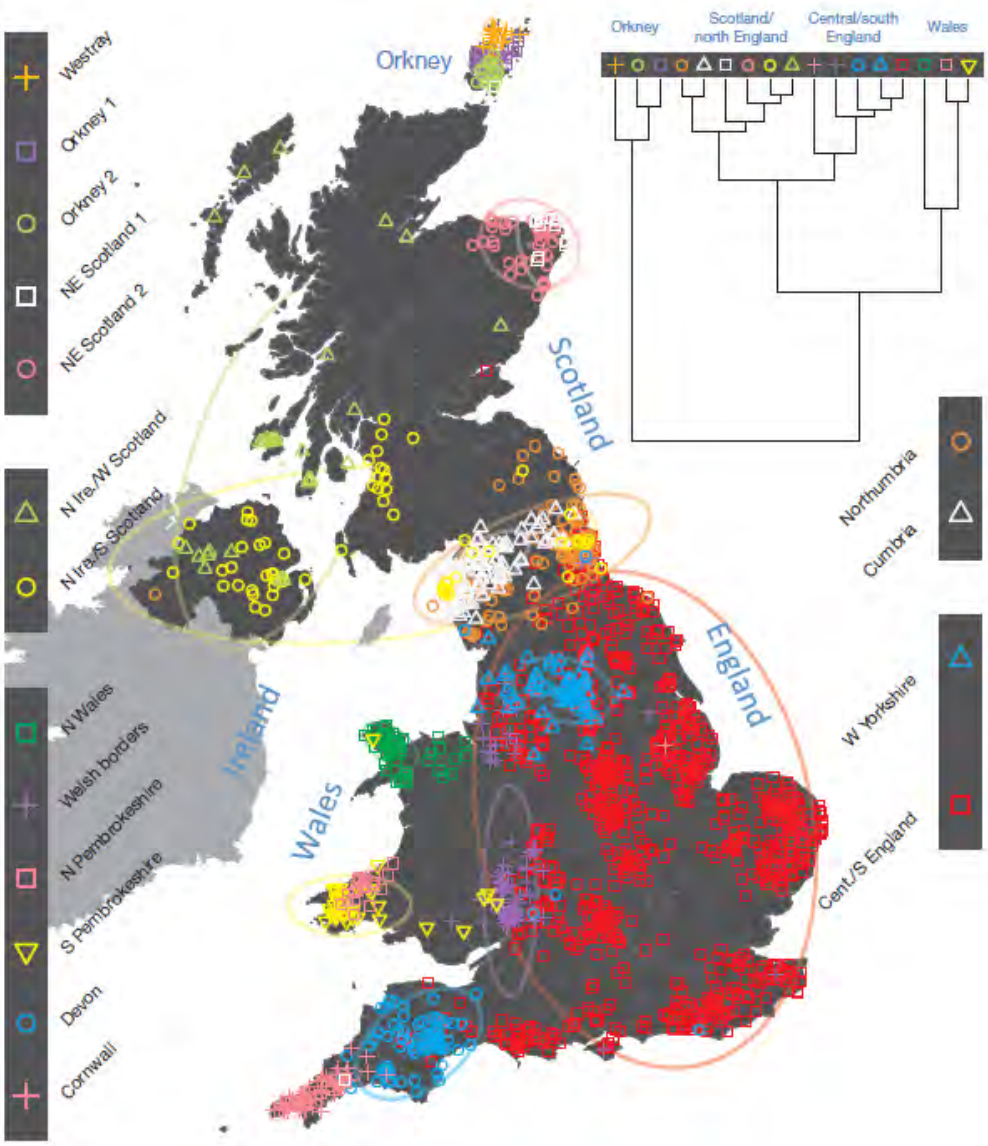


Figure 1 | Clustering of the 2,039 UK individuals into 17 clusters based only on genetic data. For each individual, the coloured symbol representing the genetic cluster to which the individual is assigned is plotted at the centroid of their grandparents' birthplaces. Cluster names are in side-bars and ellipses give an informal sense of the range of each cluster (see Methods). No relationship between clusters is implied by the colours/symbols. The tree (top right) depicts the order of the hierarchical merging of clusters (see Methods for the interpretation of branch lengths). Contains OS data © Crown copyright and database right 2012. © EuroGeographics for some administrative boundaries.

1. Examine the distribution of symbols on the map. Which symbols are widely distributed and which are narrowly distributed? What does that mean, biologically? Is anything surprising to you?

2. Examine the tree diagram. The closer to the top that groups have a branching point (a node) in common, the more similar there genomes are. What additional information does this figure give you about the genetic history of the British Isles?

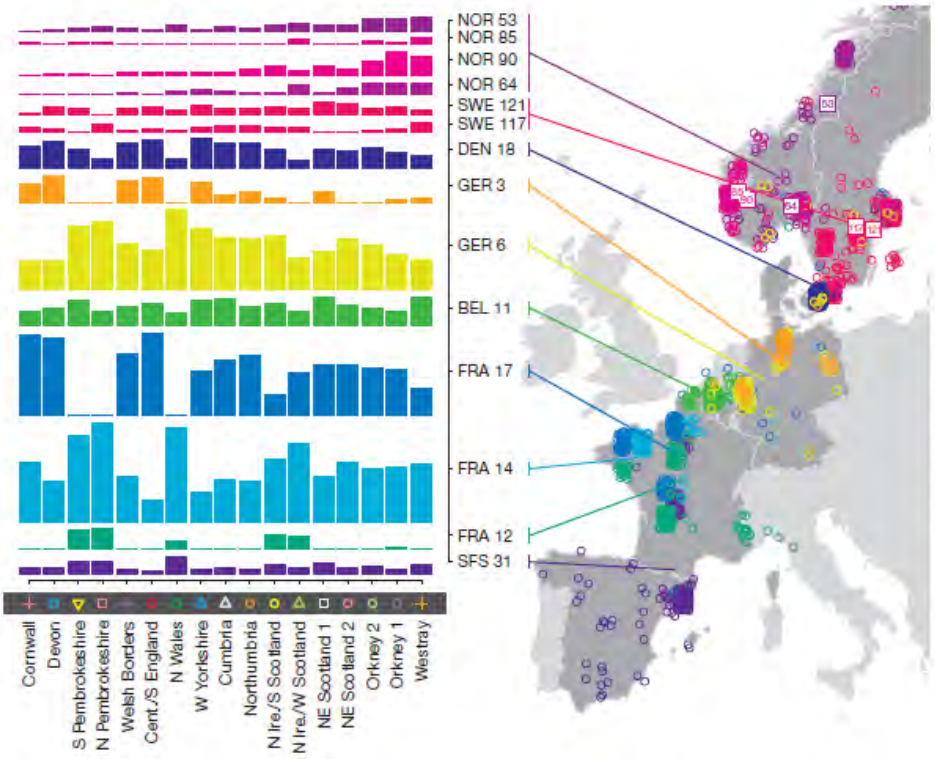


Figure 2 | European ancestry profiles for the 17 UK clusters. Each row represents one of the 51 European groups (labels at right) that were inferred by clustering the 6,029 European samples using fineSTRUCTURE. Only European groups that make at least 2.5% contribution to the ancestry profile of at least one UK cluster are shown. Each column represents a UK cluster. Coloured bars have heights representing the proportion of the UK cluster's ancestry best represented by that of the European group labelled with that colour. The map shows the location (when known at regional level) of the samples assigned to each European group (some sample locations are jittered and/or moved for clarity, see Methods). Lines join group labels to the centroid of the group, or collection of groups (Norway, Sweden, with individual group centroids marked by group number). © EuroGeographics for the administrative boundaries.

3. What European groups contributed most to the ancestry of people in the British Isles? Which genetic group seems to be most influenced by Vikings?

4. Compare Welsh genetic groups (Pembrokenshire (N and S), Welsh border, and N Wales). How are they similar to one another? Different? How to they compared to the most frequent Central/S England genetic group?

5. Any other interesting ancestry profile trends that you notice?

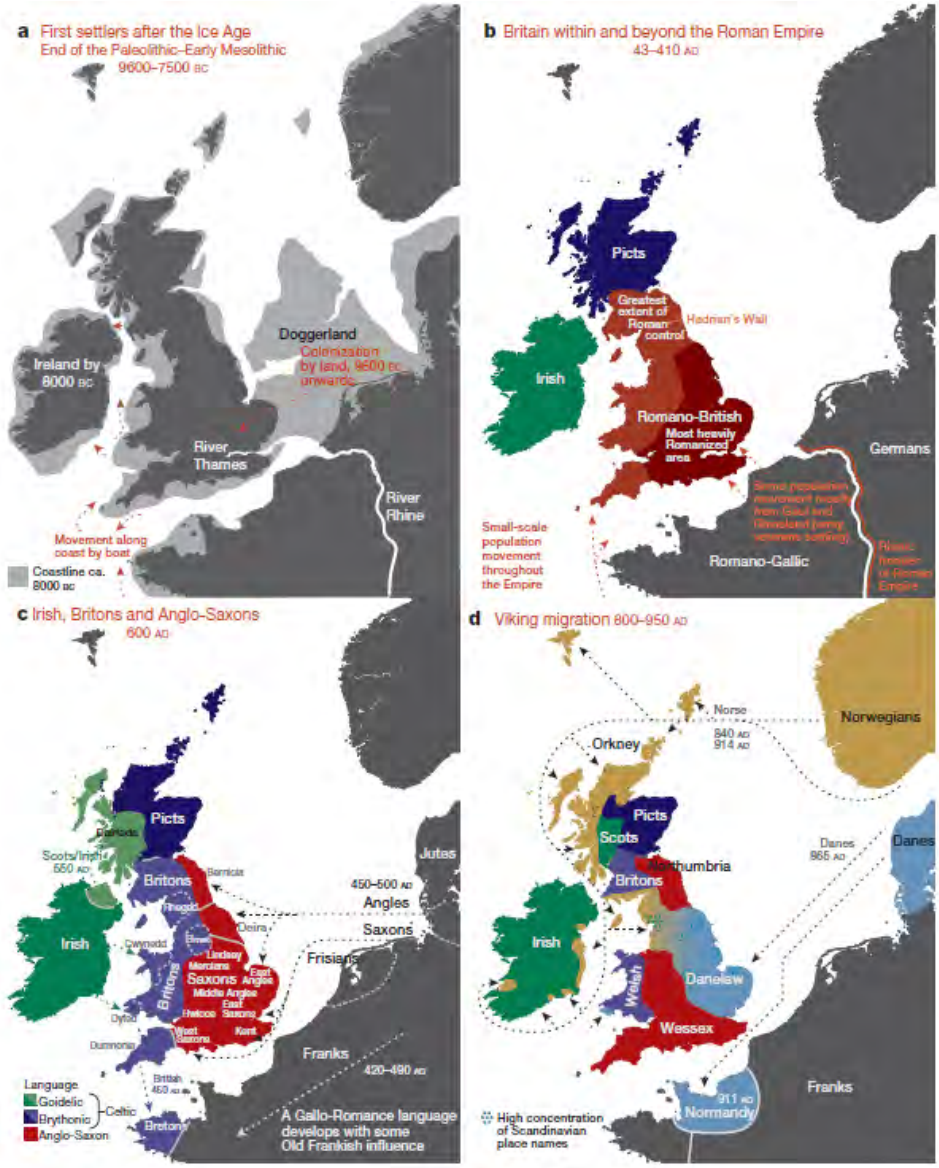


Figure 3 | Major events in the peopling of the British Isles. See Supplementary Note for further details. **a**, The routes taken by the first settlers after the last ice age. **b**, Britain during the period of Roman rule. **c**, The regions of ancient British, Irish and Saxon control. **d**, The migrations of Norse and Danish Vikings. The main regions of Norse Viking (light brown) and Danish Viking (light blue) settlement are shown. © EuroGeographics for the administrative boundaries (coastlines).

6. How are these maps reflected in the genetic groups in Figure 1?

7. Can you connect historical events to genetic ancestry of various genetic groups in figure 2?

Ecology Lab
Class and Partner Projects

As many of you may know, one of my main areas of research is on the impact of invasive plant species on ecosystem processes and microbial communities. Most recently, I have been working on wintercreeper (*Euonymus fortunei*), an exotic, evergreen vine that is invading central Kentucky forests (http://bit.ly/1Mk9nmD). My colleagues and I have been interested in how wintercreeper decomposition compares to a native vine and how wintercreeper cover itself may alter decomposition dynamics. We have found in some sites, that wintercreeper increases decomposition rates but in other sites has no effect (Bray et al. in prep, Figure 1). Puzzlingly, the site where there was no effect of wintercreeper on decomposition (Scotts Grove) had differences in bacterial community composition while the site where there was an effect of wintercreeper (Arboretum) on decomposition had no differences in bacterial communities (Figure 2). The differences in bacterial community response to wintercreeper presence/absence may be a function of the different histories of the site. At Scotts Grove, wintercreeper invasion is patchy and uninvaded plots have not experienced wintercreeper, thus differences between the plots may be a function of vegetation cover or preexisting differences between invaded/uninvaded plots. The Arboretum was completely invaded by wintercreeper where it was removed from some plots. The lack of difference in bacterial communities at the Arboretum, then, may represent a legacy effect of the prior wintercreeper cover. We also know that the wintercreeper mat at the Arboretum is much deeper than at Scotts Grove. I hypothesize the wintercreeper mat may modify the abiotic environment at the Arboretum leading to increased

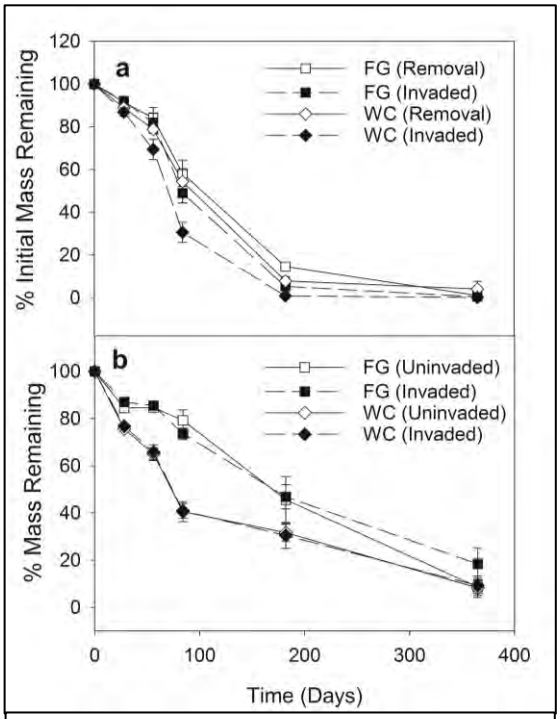


Figure 1: Initial litter mass remaining (%) as a function of time for a) Arboretum and b) Scotts Grove. Closed symbols = invaded plots; open symbols = removal/uninvaded plots.

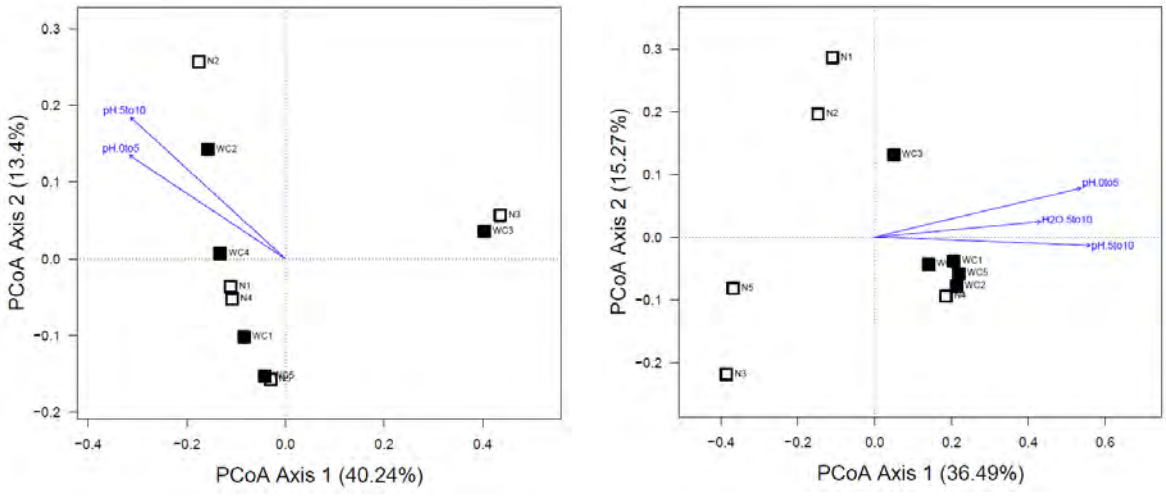


Figure 2: Bacterial Community composition at a) Arboretum and b) Scotts Grove. Filled symbols = invaded plots; open symbols = removal/uninvaded plots. The closer two symbols are, the more similar their bacterial communities are.

decomposition rates.

To test some of these hypotheses, we are going to generate data in a new site, UK's Ecological Research Facility (ERF: http://darwin.uky.edu/~erec/ERECFacilities.html). We will use already existing removal plots and add new removal plots. The already existing plots are in three blocks of four 8m x 8m plots and were initiated in three consecutive years from 2012-2014. In each block, there are four plots representing control, wintercreeper removal, honeysuckle removal, and honeysuckle + wintercreeper removal. We will establish one more block on the first day of lab. To create a non-living cover treatment, we will create a PVC frame with garland woven into it to function as a non-living abiotic insulator to test the microenvironment hypothesis. We will then examine differences in decomposition rates of two species, wintercreeper and some type of oak, in the three treatments. This decomposition project will be the class project, but I would like you all to develop (in pairs) additional questions that can utilize the same experimental design. Below are some questions that I have had about this system. I encourage you to develop projects from these questions and I will provide you with some papers to use as a source of methods. Feel free to talk with me about other ideas exploring responses to our field manipulations. I will also require you and your partner to meet with me in the second week of class to discuss your ideas before you write your proposal.

1. How does wintercreeper leachate (tea) alter microbial respiration?

2. How does wintercreeper removal and its abiotic replacement alter the abiotic environment?

3. What are the relative effects of wintercreeper roots and leaf litter on microbial respiration?

4. How does wintercreeper density alter:
    - soil moisture?
    - growth rate?
    - biomass allocation?

5. Does the microbial community found in wintercreeper invaded soils improve growth of wintercreeper?

6. How do our treatments alter arthropod use of the plots?

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CourseSource

Essay

Thinking deeply about quantitative analysis: Building a Biologist's Toolkit

Sarah R. Bray*, Paul M. Duffin, and James D. Wagner

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Abstract

Vision and Change in Undergraduate Biology Education encouraged faculty to focus on core concepts and competencies in undergraduate curriculum. We created a sophomore-level course, Biologists' Toolkit, to focus on the competencies of quantitative reasoning and scientific communication. We introduce students to the statistical analysis of data using the open-source statistical language and environment, R and R Studio, in the first two-thirds of the course. During this time the students learn to write basic computer commands to input data and conduct common statistical analyses. The students also learn to graphically represent their data using R. In a final project, we assign students unique data sets that require them to develop a hypothesis that can be explored with the data, analyze and graph the data, search literature related to their data set, and write a report that emulates a scientific paper. The final report includes publication quality graphs and proper reporting of data and statistical results. At the end of the course students reported greater confidence in their ability to read and make graphs, analyze data, and develop hypotheses. Although programming in R has a steep learning curve, we found that students who learned programming in R developed a robust strategy for data analyses and they retained and successfully applied those skills in other courses during their junior and senior years.

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Supporting Materials: S1. BiologistsToolkit-TU Curriculum, S2. BiologistsToolkit-Syllabus for Biologists Toolkit, S3. BiologistsToolkit-Homework Example, S4. BiologistsToolkit-Example of a script written and annotated by a student for a homework assignment, and S5. BiologistsToolkit-Final Project Description

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INTRODUCTION

In 2009, the American Association for the Advancement of Science and the National Science Foundation released their call to action report called *Vision and Change* (1) that recommended major changes in undergraduate biology education to reflect the changes in how advances in biology science occur in the 21(st) century. The authors of the report note *"To contribute effectively to this "New Biology" (NRC, 2009), scientists need to interact with information in new ways, including being able to manage large, complex data sets. Systems approaches and biological modeling rely on the application of mathematics and statistical analysis, while the explosive generation of larger and larger data sets demands increasingly sophisticated computational knowledge."* In response to this report, we reevaluated our own biology curriculum (S1: TU Curriculum) and dramatically changed the way we teach our introductory courses to emphasize the process and data of biology research more and the facts of biology less (2).

Like most biology major curricula across the country, however, we were outsourcing the quantitative competency training of our majors through a required course in calculus or statistics (3). Consequently, our students lacked the skills identified in the *Vision and Change* report: *"Students also should be competent in communication and collaboration, as well as have a certain level of quantitative competency, and a basic ability to understand and interpret data. These concepts and competencies should be woven into the curriculum and reinforced throughout all undergraduate biology coursework"*. In response to this realization, we created a course called Biologist's Toolkit to train our majors and minors in skills in data analysis, data interpretation, and data presentation. These skills not only help them to succeed in our upper-level courses, but also in their careers as biologists after graduation.

Our Biologist's Toolkit course is only a 2 credit-hour course, but it has been greatly effective in improving quantitative competency and confidence in our students. Toolkit was designed for sophomores who have completed at least 1 semester of a 2-semester introductory biology sequence (S1: TU Curriculum). The class meets twice a week; once for 50 minutes in a lecture setting with approximately 30 students. The class is then divided in half and meets separately in a workshop setting for an additional 50 minutes where they collaboratively work on new data analysis problems. We propose that biology programs consider the value of their own Biologist's Toolkit course to strengthen skills they find lacking in their graduating seniors.

Here, we describe our efforts and outcomes that demonstrate increased student confidence in production and understanding of graphs, statistical analysis, and developing hypotheses. Furthermore, we report that students use these skills, specifically the ability to write R Studio code, to analyze and graph data generated in laboratory exercises and projects, in upper-level courses. Our experiences show the benefits of integrating these skills across the curriculum and serve as a model for implementation of *Vision and Change's* goals of communication and quantitative literacy.

DESIGN OF THE BIOLOGIST'S TOOLKIT COURSE

Biologist's Toolkit seeks to inculcate skills that students will use throughout their collegiate and biological career, including analysis and presentation of data, searching and reading primary literature, and communication of science. Although students begin developing some basic spreadsheet and graphing skills in the first-year curriculum, we designed this course as an intensive immersion in quantitative literacy to prepare them for continued development and more independent work in their upper-level courses. To that end, we spend nine weeks of a fourteen-week term teaching basic statistics and graphing using the open-source statistical programing language, R. R offers many advantages for teaching quantitative skills: 1) it is freely available; 2) it runs on nearly all operating system platforms; 3) it is increasingly used by practicing natural and social scientists (4); and 4) we believe the process of coding analyses makes students think more deeply about how they are analyzing data than commercial statistical programs with graphical user interfaces (5,6). The majority of the semester is spent teaching quantitative and graphing skills in the R environment. We establish a course rhythm wherein the first day of the week is lecture-based with approximately 30 students and the second meeting is workshop-based with the class divided between two sections. We spend the first two weeks using RStudio Desktop to explore data and build a basic understanding of folder and directory structures, file and data management, and basics of script writing and annotating code. In the next six weeks, we introduce a new statistical approach at the first course meeting each week (S2: Syllabus for Biologist's Toolkit, see schedule at the end of the document). After providing background about the underlying theory and assumptions of a particular statistical approach, we hand out example code and go through the code as students annotate their copy (Figure 1, on page 3).

Students cited going through code examples as the most useful approach to learning R (Figure 2). For the second course meeting of the week, we divide the class into two workshop sessions during which students work on their own laptops, using RStudio to apply that week's statistical approach to analyze and graph a new data set. We have used a diversity of data sets such as those included in the R package *datasets* (7), provided by the author of the textbook we use (8), and data from our own projects or previous lab courses. In the workshop sessions, students are encouraged to help one another troubleshoot (e.g. using Help in RStudio, searching for error outputs, referencing their notebook or textbook, etc.) and we often encourage students using the same operating platform to sit together. The instructor and a teaching assistant (an undergraduate student who has previously excelled in the course) also float around the room to help guide students toward specific resources that will help them troubleshoot. Although students are encouraged to work together to solve coding problems, students are individually assessed via a one-page homework assignment. Homework assignments generally require a graph and a short paragraph describing the results and interpreting the statistical analysis (S3: Homework Example). Completing and receiving feedback on homework were cited as the second and third most helpful resources in learning R (Figure 2, on page 4).

One of the most important components of the course, we have found, is the notebook that we require each student to keep. In the notebook, students keep class notes, annotated handouts, homework, and printouts of the highly annotated scripts they create (S4: Student Script). This notebook serves as a reference during the course. Students can earn back points they lost on homework by responding to feedback in their notebooks and consult them heavily during the final project (see below). At the end of the semester, students cited their notebook as their most consulted resource (Figure 3, on page 4). We feel the greatest asset of notebooks, however, is that students refer back to their notebooks as they continue to analyze and present data in upper-level courses (see *Curricular Challenges*, below).

For the final assignment in the course (S5: Final Project Description), each student is presented with a unique data set and some basic information about how the data were collected. Students develop at least two hypotheses that can be explored with the data and then write the statistical methods and results sections of a scientific paper. This final assignment brings together many of the skills that they have learned in the course: finding and using literature to develop hypotheses, choosing appropriate statistical analyses, interpreting results, and using papers read in the course as examples for communicating science.

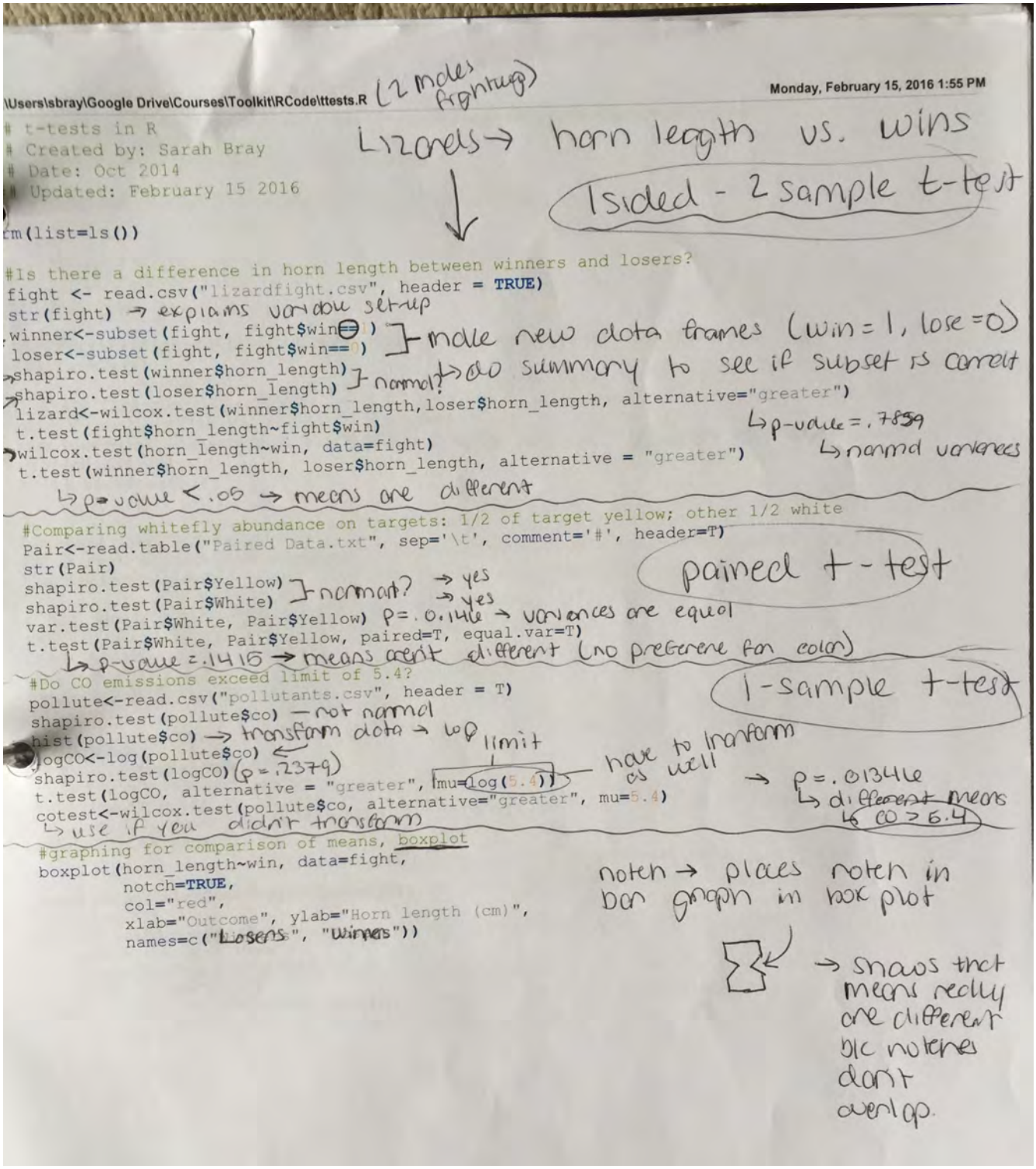

Figure 1. Example of R code annotated by a student.

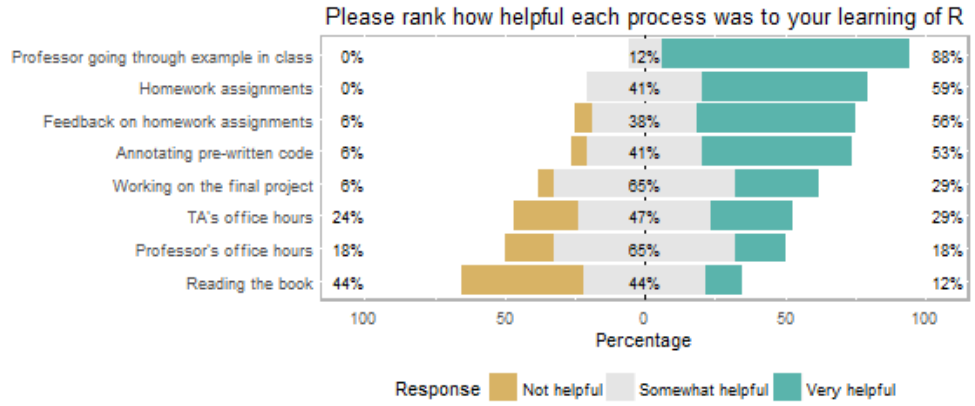

Figure 2. Winter 2016 post-term student responses to the prompt, "Please rank how helpful each process was to your learning of R."

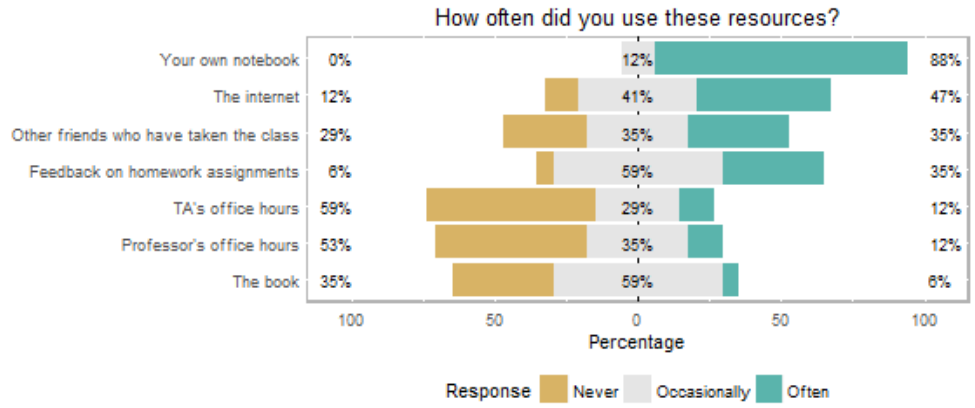

Figure 3. Winter 2016 post-term student responses to the question, "How often did you use these resources?"

SHORT- AND LONG-TERM OUTCOMES

Students self-reported increased confidence in developing hypotheses, understanding graphs, graphing data, and analyzing data (Figure 4) at the end of the course. It is interesting to note that the students taking the course in the Winter 2016 term had taken our new first-year introductory sequence (2), while the Fall 2014 students had taken our 'old' three-term introductory sequence. While both classes reported increased confidence in developing hypotheses, and graphing and analyzing data, the Winter 2016 class did not report an improvement in understanding graphs (Figure 4B). We think this result reflects a greater emphasis on interpreting results in our new intro sequence, as the Winter 2016 course had much greater confidence in their ability to interpret graphs as the **beginning** of the course than the Fall 2014 class did at the **end** of the course.

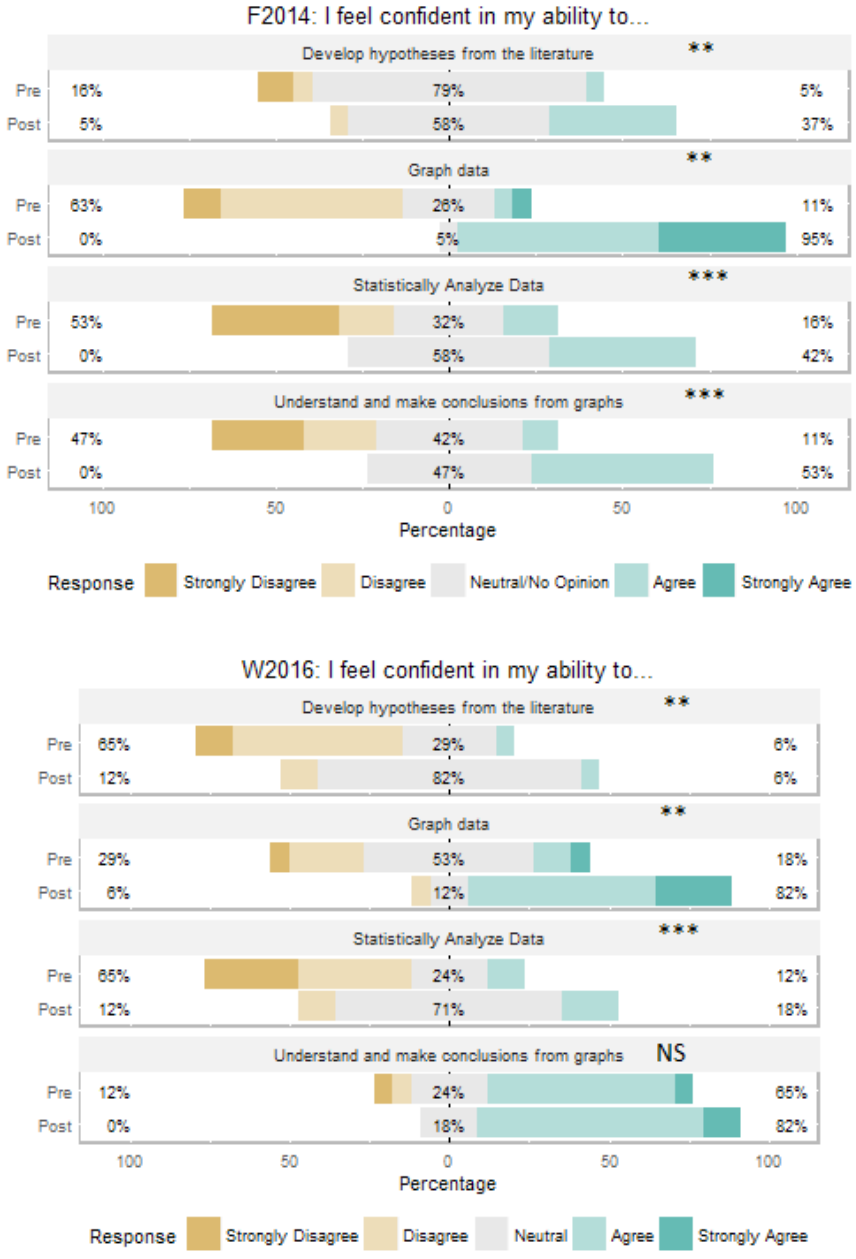

Figure 4. Pre- and post-term students' self-assessment of confidence in their ability in four competencies in **(A)** Fall 2014 and **(B)** Winter 2016. Pre- and post-term scores were compared using a Wilcoxon Sign Test; NS = not significant; ** = significance level at $p < 0.01$, *** = significance level at $p < 0.001$.

While students found R challenging, their comments at the end of the Fall 2014 (our first iteration of the course) suggested that they found R to be worth the challenge:

> "R is incredibly challenging, but very relevant for use in biology as a field. Being able to use this tool for a range of purposes will likely be the single most important take-away from the class and spending more time with more detail on that will help generalize our activities to classes beyond toolkit."

> "R studio and the skills I have developed in using it will be the most useful things I walk away from this class with; it is important in my mind to continue teaching them."

> ".....I definitely think that, through learning to use R, I've really improved my abilities to interpret data and understand what statistical tests and their results mean. I know that R can be frustrating, but I've found it to be the most interesting and rewarding part of this class."

We have seen the skills learned in Toolkit transferred and expanded upon in our upper-level courses and in student independent research (Table 1, on page 7). Two of the instructors of Toolkit extensively emphasize data analysis in upper-level courses, Ecology (SRB) and Animal Behavior (JDW). In Ecology, SRB expanded upon statistics learned in Toolkit by including data analysis assignments that explored some of the more common expansions of ANOVA and general linear models found in field experiments. Students also analyze the results of their lab projects using R. In Animal Behavior, students develop semester-long group projects. In the past, JDW performed all analyses for groups; in Fall 2015, all groups, except for one pair that had not completed Toolkit, performed their own analyses. The group who did not have knowledge of R worked with friends outside of class who had completed the Toolkit course and with assistance conducted their analysis and created publication-quality graphs along with the rest of the class. Some instructors have open-ended literature-based assignments that do not necessarily require quantitative analysis. Impressively, they have found that several students have intentionally chosen quantitative projects and analyze their data in R. We have been particularly pleased with our independent research students who have not only embraced R, but have the confidence and independence to learn new analyses on their own with limited guidance from their faculty mentors. Finally, although not one of our original goals for Toolkit, the *Vision and Change* competency of interdisciplinarity seems to have been unintentionally conveyed in this course. One of our students who is a double major in biology and political science, used R to analyze the speech of 2016 presidential candidates for his capstone project. We also have seen a rise the number of students interested in taking computer science courses. Toolkit seems to have also broadened students' view of career possibilities in the sciences. This year, we sent our first graduate in recent memory to a master's program in biostatistics.

CHALLENGES WITH THE COURSE

We recognized two levels of challenges in creating and operating the Biologist's Toolkit course within our program. One level of challenge was what we call *mechanistic challenges* and these are issues dealing with students and faculty learning the software, teaching students computer file structure and storage protocols, and understanding how to set up R and RStudio in a diversity of computers (PC and Mac) that often utilize a diversity of operating systems. The other level of challenges are *cultural and curriculum challenges* in that they extend beyond the faculty who specifically teach the Toolkit course, since it requires the entire biology faculty to integrate the skills learned by the students within the Toolkit course into their own upper-level course.

Mechanistic Challenges

The challenge in using R is also its strength as a teaching tool: one must plan carefully and be very mindful when doing data analysis or graphing, since you must type specific commands with specific syntax. This challenge is offset by the myriad of free and easily available resources on the internet that aid and assist in programming R. For example, you may not know specifically how to add error bars to your graph but asking "*how to make error bars in R*" in a Google search returned over 17 million results with detailed YouTube videos and online course materials that walk you through the process within the first two pages of the search (9,10). It has been our experience that it is more of a challenge to find a problem in R scripting that has not been resolved online, which reminds us of how unoriginal most of our problems are.

The first few times we taught the course, we did not appreciate the lack of understanding our students had concerning file formats, addresses, and file locations. As a result, the majority of student problems resulted from not having R looking in the correct location for the data file. We now approach the problem directly with a class dedicated to showing students how and where computer files are located and we standardize file locations within each student's computer by creating a master directory called Toolkit and then within that master directory two subdirectories, one called Data and the other called Scripts. By standardizing file location and directory structure, the faculty can quickly orient themselves within each student's computer and more quickly resolve operating problems the students may have. It is also important to develop a firm and secure foundation of understanding within the students as to the difference between a text (.txt) file and a comma separated value (.csv) file from a Word (.docx) and Excel (.xlsx) files. Rarely do students consider the format of a file, since computers typically open the file with the appropriate software without asking. However, using R requires the students always consider the format of their data and ensure it is the proper file format for R to use.

The last mechanistic challenge we have encountered is the diversity of students within the class, which is mirrored by the diversity of laptops, tablets, and portable computer systems and their subsequent unique operating system each student brings to the class. Luckily, R and the console RStudio are robust and operate well within Mac, Linux, and Microsoft operating systems. Prior to the first class, we require the students to download the most up-to-date basic R program (https://www.r-project.org/) and RStudio (https://www.rstudio.com/products/rstudio/download/) and have them saved on their computer. In class we walk them through the installation and file directory system mentioned above. We can accomplish these goals in a 50-minute class with up to 30 students and their menagerie of computers and computer systems.

Table 1. Upper-level courses offered by the Transylvania Biology program organized by lab approach and amount of quantitative analysis required by the course.

Courses with project-based lab and significant quantitative analysis	Courses with lab and some use of quantitative analysis	Courses without lab but some quantitative analysis	Courses without quantitative analysis
BIO 2124: Field Botany	BIO 2144: Tropical Ecology	BIO 2422: Genetics	BIO 3034: Molecular Genetics
BIO 2424: Field Biology	BIO 2164: Ornithology	BIO 3314: Evolution	BIO 2424: Innovations in Biology
BIO 3016: Comparative Vertebrate Anatomy	BIO 2504: Entomology		
BIO 3065: Animal Physiology	BIO 3026: Developmental Biology		
BIO 3204: Animal Behavior	BIO 3046: Microbiology		
BIO 4144: Ecology	BIO 3056: Bacterial Pathogenesis		

CULTURAL AND CURRICULAR CHALLENGES

One of the major challenges for a course like Biologist's Toolkit is to ensure that skills developed in the course are integrated across the curriculum. This challenge is exacerbated by the fact that different fields of biology rely on statistical data analysis to different degrees. For example, ecology and its derivations (e.g., behavioral ecology, community ecology, etc.) have a long history of relying on sophisticated statistical analysis to discern signal from noise. In contrast, fields like microbiology, developmental biology, and other molecular-scaled disciplines often rely on absolutes rather than on statistics. To accomplish integration of statistical skills, we agreed that all biology faculty should integrate into their courses student-driven data analysis, interpretation, and presentation to reinforce the skills the students learned in Toolkit. This approach enables students to understand how the various disciplines of biology utilize quantitative analysis to aid in their understanding of the world. In our program, most of the upper-level courses rely on student-designed research projects that generate data to test a hypothesis (Table 1). Therefore, data analysis, graphing and interpreting data became a natural extension of the upper-division lab experience.

Given the disparity in statistical and programming skill of faculty, students frequently ask those faculty members who are most adept in R for help on projects the students are doing with other faculty. In preparing for a Toolkit course that relies on R, it is valuable to have at least two faculty who are willing to teach the course and learn to code in R, as they can rely on each other for technical support and share the load of advising students in projects that use R. We have tried to minimize the demands on the R-savvy faculty by fostering a community-minded approach to use of R in the Toolkit course. Specifically, we teach students to search on the internet for solutions to R script problems, encourage them to discuss and share scripts with their peers, and most importantly, remind them to use their Toolkit notebooks and annotated scripts to guide them in their data analysis projects. Of course, it is easiest for students to simply ask for help before trying to resolve the problem themselves, so another challenge is to train the students to first try to resolve the problem on their own before meeting with a faculty for help. One of the faculty (PMD) required students who wanted to meet with him to first do an internet search on the specific error code since the diversity and activity of the R community means that almost every problem has already been identified and resolved online. Of course, it takes more initial time to train the students to resolve their own programming problems than it takes to write the code for them. Nevertheless, faculty must resist the urge to quickly supply the answer. Since the students learn R scripting skills as sophomores and then are asked to use these skills in their biology classes for the next two years, it pays great dividends to invest early in training the students to be independent in resolving their R script problems.

CONCLUSIONS

Based on our experience across three years and three faculty teaching the course, a required course dedicated to developing quantitative skills and scientific communication greatly improves students' abilities to be active scientists throughout their undergraduate experience. Although data analysis and quantitative thinking skills can be integrated into introductory biology courses (11), these efforts are often constrained by time and other goals of the courses. By devoting an entire course to foundational skills in analyzing, presenting, and communicating quantitative data, students enter upper-level courses with core skills and habits of mind of practicing biologists. As the biology faculty have adopted the use of RStudio in upper-level courses, we are integrating quantitative skills throughout the curriculum (12) and increasing students' quantitative sophistication. Although there are mechanistic and cultural/curricular challenges to our approach, we believe that sharing our missteps will allow others to avoid many of these challenges. The confidence we see in our students, their

increased independence, and their own acknowledgment of the importance of this course demonstrate the value of the Toolkit course to implement goals of *Vision and Change*.

SUPPORTING MATERIALS

- S1. BiologistsToolkit-TU Curriculum
- S2. BiologistsToolkit-Syllabus for Biologists Toolkit
- S3. BiologistsToolkit-Homework Example
- S4. BiologistsToolkit-Example of a script written and annotated by a student for a homework assignment
- S5. BiologistsToolkit-Final Project Description

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Recovery of forest floor diversity after removal of the nonnative, invasive plant *Euonymus fortunei*[1]

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Abstract. The vine *Euonymus fortunei* (Turcz.) Hand.-Mazz. is invading forests of the eastern United States; as a result, removal of *E. fortunei* has become a priority of resource managers. This study examined the effectiveness of five techniques for eliminating *E. fortunei*, restoring plant species richness, and enhancing recolonization by woody species. In 2003, the following five treatments were applied: burn with a propane torch, light exclusion by plastic tarp, burn and glyphosate application, cut (simulated grazing) and glyphosate application, mow and glyphosate application, plus an untreated control. Each treatment was replicated four times in a randomized block design located in a heavily *E. fortunei*–invaded forest remnant in Lexington, KY. Vegetation was surveyed in 2004, 2005, 2006, 2007, and 2013. Across years, most treatments were associated with reduced *E. fortunei* cover and increased total species richness. Over time, *E. fortunei* cover increased across treatments, such that by 2013, no difference in *E. fortunei* cover was detectible among treatments. Some differences in total and native species richness among treatments were still perceptible by 2013. Increased *E. fortunei* cover was correlated with decreased ground-layer species richness, native species richness, sapling richness, and sapling density. Light exclusion by plastic tarp, a method absent from many management recommendations, was unique in its long-term reduction of *E. fortunei* cover and its association with increased total species richness, but use of plastic tarps may have drawbacks. This study quantified the long-term community effects of removing an established invasive species from a mature, urban forest. Removal allowed native plants, notably woody species, to reestablish.

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Because richness continues to decline as *E. fortunei* reinhabits plots, land managers seeking to conserve biodiversity under conditions similar to those within our study site should maintain proactive *E. fortunei* removal plans.

Key words: *Euonymus fortunei*, invasive species, purple wintercreeper, restoration, species diversity

Nonnative, invasive species threaten the diversity and function of native ecosystems (Zavaleta 2002), and their removal poses an increasing and expensive challenge (Pimental *et al.* 2000). A need exists for refined restoration and adaptive management plans that control invasive plants and promote native plant recovery, and the study of these activities is an important scientific goal (Webster *et al.* 2006). Invasive plants possess a suite of traits that may facilitate their invasion and may negatively affect native species (McNeish *et al.* 2012, Luken 2014), but these traits and their effects vary across spatiotemporal scales (Theoharides and Dukes 2007). Studies at various scales, over time, and of different species provide insights that contribute to our understanding of invasion ecology.

Wintercreeper (*Euonymus fortunei* (Turcz.) Hand.-Mazz.) (winter creeper) is an invasive woody vine that was first introduced to the United States from Asia in 1907 (Remaley 2009). This species has been described as invasive in 11 states (Invasive Plant Atlas of the United States 2013), and currently, the invasion is most severe in central Kentucky, the site of the present study, where *E. fortunei* affected an estimated 2,593 ha (6,644 ac) of forest in 2008 (Miller et al. 2008). The current extent of invasion by *E. fortunei* is patchily distributed, confined to disturbed sites, such as roadsides, parks, and urban woodlands (Zouhar 2009). *Euonymus fortunei* is still available from many nurseries and may continue to colonize urban and suburban forests. Ongoing urbanization fragments forests, and fragments may conserve biodiversity by providing refugia for plants and wildlife (Campbell 1981, Miller and Hobbs 2002). Proximity of urban forests to cultivated landscapes and further anthropogenic disturbance may allow nonnative, invasive plants to displace native plants in these ecosystems (McKinney 2002), increasingly so, toward urban centers (Kowarik 1990). *Euonymus fortunei* seriously threatens the forests it currently inhabits, and increased penetration into forests of the eastern United States could have devastating effects on biodiversity. Others have recognized the threat of *E. fortunei* to native species ecology; a collaboration of Chinese and American researchers (Ding *et al.* 2006) recognized *E. fortunei* as a "top 10 concern" among invasive plants of Asian origin.

Relatively little research has explored the ecology of *E. fortunei*, and most knowledge of the life history of *E. fortunei* comes from horticultural literature and anecdotal observations. The plant is a popular ground cover in the United States. Its features include a fast growth rate and rapid spread enabling it to achieve nearly 100% ground cover quickly, and it is available in many ornamental cultivars, including 'Emerald and Gold,' 'Coloratus,' and 'Variegata' (Dirr 1998, Zouhar 2009). *Euonymus fortunei* is shade tolerant and has thick-cuticled leaves that resist drought (Zouhar 2009). These traits make *E. fortunei* not only a hardy ornamental but also a competitive understory plant, which may suppress less-competitive native understory species (Randall and Marinelli 1996, Swearingen *et al.* 2002). *Euonymus fortunei* propagates either through seed or vegetatively (Zouhar 2009). Its vegetative spread along the forest floor is thought to contribute to its invasion; it forms a thick mat of vegetation that may suppress other plants (Randall and Marinelli 1996, Swearingen *et al.* 2002, T. J. Rounsaville, University of Kentucky Arboretum, pers. comm.).

To our knowledge, no published study has examined the community ecology of recovering forests that have undergone removal of *E. fortunei*, although many have investigated responses to removal of other invasive plants. A meta-analysis by Kettenring *et al.* (2011) suggested that different invasive species control methods produced different native and invasive revegetation outcomes based on a review of 355 invasive species control studies. They found that herbicide reduced invasive species most effectively overall, whereas removal by cutting decreased invasive species biomass and cover less effectively, and burning increased invasive species biomass and density. For native species across studies, no treatments were associated with strongly positive gains, and burning actually reduced native biomass (Kettenring *et al.* 2011). The authors also highlight

differences in methodology among studies, especially concerning duration and scale. Interestingly, only 6% of the 355 studies included in this meta-analysis monitored treatment plots for longer than 5 yr (Kettenring *et al.* 2011).

The structure of a community, consisting of both biotic and abiotic factors, may predict its vulnerability to invasion or reinvasion after treatment (Souza *et al.* 2011, Wilson *et al.* 2013), and invasive species can create permanent changes in affected ecosystems (Bakker and Wilson 2004, Bradford *et al.* 2012). The success of many invasive plants is associated with tolerance of disturbance, and some invasive plants have been shown to promote additional disturbance in sites they invade (Buckley *et al.* 2007). Smith and Reynolds (2011) found evidence that *E. fortunei* conditions the soil in which it grows, likely by affecting microbial communities. *Euonymus fortunei* is known to produce compounds that repel insects (Jinbo *et al.* 2002), but the allelopathic effects on other plants have not been examined. It remains to be determined whether, after *E. fortunei* removal, native plant communities can recover and maintain plant species diversity. In general, reinvasion, whether by the originally treated species or novel invaders, is common in treated sites even after effective initial control (Kettenring *et al.* 2011, Webster *et al.* 2006).

It is crucial that land managers create effective plans for *E. fortunei* removal, given the plant's potential threat to forests of the eastern United States. The US Department of Agriculture, Forest Service, currently recommends several *E. fortunei* removal strategies. The most-effective method for eliminating *E. fortunei* is manually removing the whole plant, including roots (Zouhar 2009). Unfortunately, this technique is labor intensive and often impractical, so systemic herbicides, such as glyphosate, are commonly employed. Cutting or mowing without additional application of systemic herbicide has been shown to increase growth of *E. fortunei* and other invasive plants (Sink *et al.* 2005), so the supplementation of systemic herbicide after disturbance is essential. Some land managers have used plastic tarps to suppress *E. fortunei* by light exclusion, with anecdotal success (Zouhar 2009). Other removal techniques tested in the past have been shown to be ineffective. For example, burning cannot remove belowground biomass, whereas the thick cuticle of *E. fortunei* resists damage aboveground (Zouhar 2009). Often, a variety of removal techniques are used in combination.

The present study evaluated the effectiveness of five removal techniques for eliminating *E. fortunei* and examined the plant community responses to removal over 10 yr. The specific research questions addressed in this study were (a) which removal treatments provide the greatest long-term control of *E. fortunei*, (b) which treatments most effectively increased native plant species cover and richness, and (c) how does removal of *E. fortunei* affect sapling density. Based on the results of this study, recommendations can be made for *E. fortunei* control, pertaining to the restoration of plant species diversity and forest community structure.

Materials and Methods. STUDY SITE AND BACKGROUND. This study was conducted in the University of Kentucky's Arboretum Woods, located in Lexington, KY (38°0′54.87″N, 84°30′38.37″W). Measuring 5.8 ha, the Arboretum Woods is one of the largest fragments of eastern deciduous forest located in the Inner Bluegrass physiographic region of central Kentucky (Campbell 1981). At the time of this study, the most important species in the overstory of the woodland included *Celtis occidentalis* L. (common hackberry), *Juglans nigra* L. (black walnut), *Fraxinus americana* L. (white ash), *Acer negundo* L. (boxelder), *Prunus serotina* Ehrh. (black cherry), and *Quercus macrocarpa* Michx. (bur oak). Shrubs and saplings near the treatment plots included *Euonymus atropurpureus* Jacq. (eastern wahoo), *Carya laciniosa* (Michx. f.) G. Don (shellbark hickory), *Gymnocladus dioicus* (L.) K. Koch (Kentucky coffeetree), *Fraxinus quadrangulata* Michx. (blue ash), and *Ulmus americana* L. (American elm). The soils of treatment plots were phosphate-rich silt loams that were deep and well-drained (Wharton and Barbour 1991). Regional climate was continental, and mean annual temperature and precipitation were 12.8 °C and 111.8 cm, respectively (Wharton and Barbour 1991). The location of the study site in an urban/suburban area has made it particularly vulnerable to disturbance and to the encroachment of invasive plants. *Euonymus fortunei* cover approaches 100% in most areas of this woods and has been established for many years (Campbell 1981). The site for this study was chosen based on its uniform 100% *E. fortunei* cover, level

Table 1. Treatment abbreviations and details of *E. fortunei* removal treatments in an urban forest, Lexington, KY.

Abbreviation	Treatment	Description
CONT	Control	Retained ~100% *E. fortunei* cover with no additional disturbance, approximating pretreatment condition.
TARP	Plastic tarp and herbicide	Covered April 2003 to October 2003 with a plastic tarp typically used to protect athletic turf. Covered from October 2003 to fall 2004 with 6-mil black plastic sheeting. In fall 2004, remaining green stems near the perimeter of the black tarp were sprayed with herbicide.
MHRB	Mow and herbicide	Plots mowed in April 2003, then cut stems were sprayed on the same day with herbicide. After 7 mo, in November 2003, this process was repeated.
XHRB	Cut and herbicide	For cuttings meant to approximate the effects of goat grazing, vegetation was mowed in two plots and cut with hedge trimmers in the two other plots in April 2003. After 1 mo, this treatment was intended to experience a controlled burn, but weather prevented a burn, and herbicide was used to treat each plot instead.
XBRN	Cut and burn and herbicide	In April 2003, vegetation was cut with hedge trimmers. In June 2003, plots were lightly burned with a propane torch enough to penetrate cuticle and were covered with herbicide on the same day.
BURN	Burn	Burned with a propane torch in April 2003 until stems and leaves were no longer green, then new growth was burned again in June 2003 and once again burned in July 2003. In February 2004, three of the four plots were burned again.

topography, and adequate drainage after abundant rainfall.

Understanding the plant community's response to *E. fortunei* removal, the focus of this study, requires understanding the history of invasion and recovery in the study area. In the past, the area existed as woodland underlain by mowed understory. Mowing ceased in 1980 (Campbell 1981). Since then, the area has been in succession to forest understory, but invasive species, such as *Lonicera maackii* (Rupr.) Herder (Amur honeysuckle), *Lonicera japonica* Thunb. (Japanese honeysuckle), *Alliaria petiolata* (M. Bieb.) Cavara & Grande (garlic mustard), *Euonymus alatus* (Thunb.) Siebold (burningbush), and *E. fortunei* have impeded reestablishment of native herbs and shrubs. This study began in 2003 as part of an adaptive management plan to determine an effective means for *E. fortunei* removal.

EXPERIMENTAL DESIGN AND RESTORATION TREATMENTS. Beginning in April 2003, Arboretum staff established an experiment to examine the effectiveness of five different *E. fortunei*–removal treatments (Table 1). All herbicide treatments were foliar applications of Roundup Concentrate Plus (Monsanto Company, St. Louis, MO; 18% glyphosate and 0.73% diquat) diluted to a final concentration of 1.6% glyphosate. A sponge-like nozzle minimized herbicide contamination of other plots. All burn treatments were performed with a "Go Devil" propane torch (500,000 BTU rating) until the leaf cuticles visibly cracked. Each plot measured 6.096 m × 6.096 m (20 ft × 20 ft), and each treatment was replicated four times in a randomized block design (Fig. 1). Treatment plots directly bordered each other, and the total treatment area was surrounded by untreated vegetation. Control (CONT) plots were not included in the design in 2003 but were added in 2004 within the untreated vegetation directly bordering the treatment area.

VEGETATION SURVEY. Vegetation surveys were performed in 2004, 2005, 2006, and 2013 using the following sampling technique. Percentage of cover by *E. fortunei* and other species was estimated within 1-m^2 subplots within each larger treatment plot. In 2004, 2005, 2006, and 2007 we used two 1-m^2 subplots in fixed locations in each plot, and in 2013, we used four evenly spaced 1-m^2 subplots. Within-plot samples were averaged for analysis. To supplement the 1-m^2 samples and compile more exhaustive species lists that could better characterize species communities, in summer 2005 and summer 2007, all plant species present in the whole block were inventoried (Table 2).

Percentage of cover for each ground-layer species was estimated according to the guidelines of Kent and Coker (1995). Class A (almost absent) was defined as a percentage of cover of <1%, and class B (barely present) was defined as 1%–5% cover. These two classes were estimated using cardboard squares measuring 10 cm × 10 cm for class A and 22.36

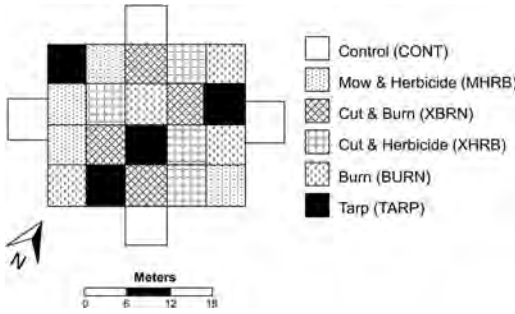

FIG. 1. Spatial layout of treatment plots created in 2003 in a randomized block design; each row is a block. Controls were added to treatment area perimeter in 2004.

cm × 22.36 cm for class B. The remaining classes were visually estimated, and include class R (rare) of 6%–25%, class P (patches) of 25%–49%, class I (interrupted) of 50%–74%, and class C (continuous) of ≥75%. This scheme was used for all herbaceous species and woody species <50 cm tall, with the exception of *E. fortunei*, which was not estimated categorically. Because *E. fortunei* was our focus species, we estimated cover for this species to 1% cover. Botanical nomenclature follows Jones (2005).

Data from 2004, 2005, 2006, and 2007 were collected in late summer or early fall. In 2013, data were collected twice, in summer (between June 10 and July 2) and early fall (September 21–23). For 2013, summer data were used in statistical analyses and all graphs depicted here because there were no statistical differences in *E. fortunei* cover ($F = 0.327$, $P = 0.569$) between midsummer and early fall data.

By 2013, a sapling layer had developed where previously it was absent, so woody plants were quantified for the first time in the 2013 survey. All woody species >50 cm tall but <10 cm diameter at breast height (DBH; 1.37 m) were inventoried within each 6-m × 6-m plot and are henceforth called *saplings*. Woody species with DBH > 10 cm were not recorded but were assumed to have predated the treatments.

STATISTICAL ANALYSIS. Analyses were conducted using JMP 10 Statistical Discovery Software (SAS Institute Inc. 2013), IBM SPSS Statistics version 19 (SPSS Inc. 2010), and R version 3.1.3 (R Core Team 2015). Figures were made using SigmaPlot (Systat Software 2011). None of the data were normally distributed after log or square-root transformation, so nonparametric analyses were used to test for trends in response variables.

Kruskal-Wallis tests were employed to examine effects of treatment on vegetative characteristics (*E. fortunei* cover, species richness, native species richness, sapling density, seedling cover) in 2013. Mann-Whitney U-test pairwise comparisons were performed if Kruskal-Wallis tests indicated significance. Only treatment-control pairwise comparisons were performed (*e.g.*, cut, burn, and herbicide [XBRN]-CONT, not XBRN-plastic tarp and herbicide [TARP]) to minimize type I error. A Bonferroni-corrected alpha was computed ($\alpha = 0.05$/number comparisons = 0.01). *P*-values reported were exact 2-tailed significance values, except in cases in which exact significance could not be computed. In such cases, asymptotic significance was reported.

Friedman tests were used to compare effects of treatment and year on vegetative characteristics measured in 2004, 2005, 2006, 2007, and 2013. If Friedman tests indicated significance, Wilcoxon pairwise comparisons were performed. For treatments, only treatment-control pairwise comparisons were performed, and each year was compared with 2004, the first year after treatment, at which time *E. fortunei* cover was presumably lowest. Bonferroni corrected alpha was computed for treatments ($\alpha = 0.01$) and years ($\alpha = 0.0125$), and *P*-values reported were exact 2-tailed significance values.

We calculated Spearman's rank correlations to examine relationships between *E. fortunei* cover and 2013 vegetative characteristics (average herbaceous richness, average native herbaceous richness, sapling richness, and saplings density).

To test for effect of plot location, we performed a series of Kruskal-Wallis tests comparing vegetative characteristics measured in 2013 to block number. The CONT plots were excluded from this analysis because they were not located within the blocks but on the exterior (Fig. 1).

To characterize differences in plant communities developing in response to different treatments, nonmetric multidimensional scaling (NMS) ordinations were conducted. For species community data compiled in 2013, PC-ORD version 6 software was used to create NMS ordinations describing the plant communities associated with each treatment type (McCune and Mettford 2011). The main matrix was composed of the 37 species found in

Table 2. Species present in years 2005, 2007, and 2013; NMS ordination *r*-values. Species lists from 2005 and 2007 were compiled by surveying every plant in each 6-m × 6-m plot. In 2013, four 1-m^2 subplots were inventoried within each larger 6-m × 6-m plot. Nomenclature follows Jones (2005). Nonnative status indicated with an asterisk (*). If only identified to genus, native/nonnative status could sometimes not be ascertained. For ground layer species present in summer 2013, Pearson correlation *r*-values for NMS axes are included (for ordination graph of axes, Fig. 4); *r*-values > 0.4 are shown in bold.

Species	Years observed			r-values		
	2005	2007	2013	Axis 1	Axis 2	Axis 3
Acer negundo L.			x			
Ageratina altissima (L.) R.M. King and H. Rob		x				
Alliaria petiolata (M. Bieb.) Cavara and Grande*	x					
Ambrosia trifida L.	x	x	x	−0.074	−0.003	−0.011
Asclepias L.	x					
Barbarea R. Br.	x					
Bidens L.	x					
Bryophyta	x		x			
Calystegia (L.) R. Br.	x					
Cardamine hirsuta L.*	x					
Carduus nutans L. subsp. *nutans**	x					
Carex blanda Dewey			x	0.089	−0.067	0.060
Carex granularis Muhl. ex Willd.			x	0.154	0.130	0.069
Carex grisea Wahlenb.			x	−0.035	0.027	0.086
Carex spp. L.	x	x	x	0.048	−0.023	−0.002
Carya cordiformis (Wangenh.) K. Koch	x	x	x			
Carya laciniosa (F. Michx.) Loudon		x	x			
Celtis occidentalis L.	x		x	0.101	−0.149	0.069
Cercis canadensis L.			x			
Cirsium arvense (L.) Scop. var. *arvense**	x					
Cirsium vulgare (Savi) Ten.*	x					
Conyza canadensis (L.) Cronquist	x					
Cornus drummondii C.A. Mey.	x	x	x	0.094	−0.057	0.014
Cornus foemina Mill.			x			
Crataegus L.		x				
Dichanthelium clandestinum (L.) Gould		x				
Digitaria Haller	x					
Duchesnea indica (Andr.) Focke*	x	x	x	0.212	−0.013	−0.060
Elephantopus carolinianus Raeusch.	x	x				
Elymus canadensis L.	x					
Elymus virginicus L.	x					
Elymus villosus Muhl.			x	−0.006	−0.101	0.132
Erechtites hieraciifolia (L.) Raf.	x					
Erigeron annuus (L.) Pers.	x	x	x			
Euonymus alatus (Thunb.) Siebold*			x			
Euonymus atropurpureus Jacq.	x	x				
Euonymus fortunei (Turcz.) Hand.-Mazz.*	x	x	x			
Fraxinus americana L.	x	x	x	0.003	−0.235	**−0.476**
Fraxinus quadrangulata Michx.	x					
Geranium carolinianum L.	x					
Geum canadense Jacq.	x	x	x	**0.422**	0.137	**−0.436**
Geum vernum (Raf.) Torr. and A. Gray	x	x	x	**0.603**	0.156	**−0.466**
Glechoma hederacea L.*	x		x	0.016	−0.234	−0.049
Glyceria R. Br.	x	x				
Gymnocladus dioicus (L.) K. Koch	x	x	x			
Hackelia virginiana (L.) I.M. Johnst.	x					
Hypericum perforatum L.*	x					
Ilex L.		x				
Impatiens capensis Meerb.			x	0.104	0.159	0.178
Juglans nigra L.		x	x			
Juncus L.	x	x	x	−0.006	−0.106	−0.092
Juniperus virginiana L.			x	−0.050	−0.162	0.097
Lactuca canadensis L.	x					
Lactuca serriola L.*	x					
Lamium L.*		x				

Table 2. Continued.

Species	Years observed			r-values		
	2005	2007	2013	Axis 1	Axis 2	Axis 3
Leersia virginica Willd.	x					
Ligustrum sp. L.*		x	x	0.203	0.019	0.053
Liriodendron tulipifera L.	x					
Lobelia inflata L.	x	x				
Lobelia siphilitica L.	x	x				
Lonicera japonica Thunb.*	x		x	0.263	**0.539**	0.065
Lonicera maackii (Rupr.) Maxim.*	x	x	x	0.050	0.110	−0.010
Morus alba L.*	x	x	x	−0.058	0.115	0.023
Morus rubra L.		x	x	−0.083	−0.049	−0.127
Muhlenbergia schreberi J.F. Gmel.	x	x	x	0.131	0.122	−0.160
Nyssa sylvatica Marshall	x					
Oxalis L.	x	x	x	0.028	−0.087	0.078
Packera Á. Löve and D. Löve	x					
Parthenocissus quinquefolia (L.) Planch.	x	x	x	−0.265	−0.282	0.537
Phacelia purshii Buckley	x					
Phytolacca americana L.	x	x				
Plantago major L.*	x					
Polygonum caespitosum Blume var. *longisetum* (Bruijn) A.N. Steward*	x		x			
Polygonum punctatum Elliot		x				
Polygonum pensylvanicum (L.) Small	x					
Polygonum virginianum L.	x	x	x	0.367	−0.091	−0.248
Prunella vulgaris L.			x	0.003	−0.106	0.007
Prunus serotina Ehrh.	x	x	x	0.069	−0.073	0.241
Quercus L.		x				
Quercus macrocarpa Michx.	x		x			
Quercus palustris Münchh.		x				
Rosa multiflora Thunb.*		x	x	−0.036	0.122	−0.064
Rubus occidentalis L.	x	x	x	**0.445**	**0.430**	−0.127
Sambucus canadensis L.	x	x	x	0.177	−0.135	0.092
Sanicula L.	x					
Sanicula canadensis L.	x					
Setaria P. Beauv.*		x				
Sisyrinchium atlanticum E.P. Bicknell	x					
Smilax glauca Walter			x	0.022	0.094	−0.113
Solanum L.	x					
Solidago L.	x	x	x	0.024	0.234	−0.147
Sonchus arvensis L. subsp. *arvensis**	x					
Stellaria media (L.) Vill.*	x					
Stylophorum diphyllum (Michx.) Nutt.			x	0.004	0.096	−0.002
Symphoricarpos orbiculatus Moench.	x	x	x	0.142	−0.076	−0.144
Symphyotrichum Nees.	x					
Taraxacum officinale (L.) Weber*	x					
Toxicodendron radicans (L.) Kuntze	x	x	x	−0.362	**0.414**	−0.100
Trifolium repens L.*	x	x				
Ulmus americana L.		x				
Ulmus rubra Muhl.			x	0.185	0.057	−0.007
Vernonia gigantea (Walter) Trel.	x					
Veronica agrestis L.*	x					
Veronica hederifolia L.*	x					
Vitis vulpina L.	x	x	x	−0.130	**0.491**	−0.365

the plots in 2013, but did not include *E. fortunei*, the most obvious driver of difference among treatments. The final NMS configuration was reached by analyzing a relativized Sorenson's distance, stepping down in dimensionality, from six-axis to one-axis solution using 25 runs each of real and Monte Carlo randomized data, with a maximum of 300 iterations and a final instability of 0.0005. The best solution was a three-axis solution. Coefficients of determination for the correlations between ordination distances and distances in the original *n*-dimensional space were examined to determine the amount of variation described by

each axis. Differences in species composition among treatments were examined with multiresponse permutation procedures (MRPPs) using the relative Sorenson distance measure of the species-composition matrix. The MRPP is a nonparametric procedure in which the A-value describes within-group homogeneity and the *P*-value ($P \leq 0.01$ to reject null) evaluates how likely an observed difference is due to chance (McCune and Grace 2002).

Results. TREATMENT EFFECTIVENESS. Changes in *E. fortunei* were considered by treatment and over time (Fig. 2A). We found a significant treatment-by-year interaction effect ($\chi^2 = 0.842$, 20 d.f., $P < 0.001$), indicating that *E. fortunei* cover changed over time and varied by treatment. All treatments had significantly lower mean ranks for *E. fortunei* cover compared with CONT ($P < 0.001$, all comparisons). For year, a significantly higher richness for *E. fortunei* cover was detected for 2004 compared with 2013 ($P < 0.001$), indicating that *E. fortunei* had increased across treatments by 2013. By 2013, difference among treatments was not statistically significant ($\chi^2 = 10.250$, 5 d.f., $P = 0.068$), but *E. fortunei* cover in TARP averaged 45.625%, whereas the CONT and burning (BURN) approached 100% cover (Fig. 2A). For 2013, plot location was not associated with *E. fortunei* cover ($\chi^2 = 4.055$, 20 d.f., $P = 0.256$).

GROUND LAYER SPECIES RICHNESS AND SAPLINGS. Total species richness in the ground layer (including herbaceous plants and woody plants <50 cm tall) showed a significant treatment-by-year interaction ($\chi^2 = 0.738$, 20 d.f., $P < 0.001$) (Fig. 2B), as did ground layer total native richness ($\chi^2 = 0.726$, 20 d.f., $P < 0.001$). These results indicated that species richness changed over time and that these changes varied among treatments. For total species richness across years, all treatments, with the exception of TARP ($P = 0.153$), had significantly higher mean ranks compared with the CONT ($P < 0.001$, all other comparisons). Although TARP had high total species richness in later years, TARP was associated with a longer lag in posttreatment response, whereas other treatments supported faster but less sustained increases in total species richness (Fig. 2B). For year, a significantly higher richness was detected for 2006 and 2013 ($P < 0.001$, both comparisons), as compared with 2004. Using a noncorrected $\alpha = 0.05$, the other two years in which data were collected also had higher richness, compared with 2004 ($P = 0.024$ for 2005, $P = 0.040$ for 2007), indicating a trend of increased richness in later years compared with the first year posttreatment. Differences in richness were dynamic over time with the highest values for total species richness recorded in the intermediate years of the study (2005, 2006), whereas richness decreased and stabilized in later years (2007, 2013).

By 2013, there were significant differences in total species richness among all treatments ($\chi^2 = 11.438$, 5 d.f., $P = 0.043$) (Fig. 2B). Mean total species richness in 2013 ranged from <4 for CONT to >10 for TARP. Using a Bonferroni correction ($\alpha = 0.01$), no treatment had significantly different total species richness compared with the CONT. Using a noncorrected $\alpha = 0.05$, TARP had significantly higher total species richness compared with the CONT ($P = 0.029$), indicating marginally greater 2013 species richness in TARP *vs.* CONT.

For sapling density recorded in 2013, there were significant differences among treatments ($\chi^2 = 16.167$, 5 d.f., $P = 0.006$). Using a Bonferroni-corrected $\alpha = 0.01$, none of the treatments had significantly different sapling densities compared with the CONT. A noncorrected $\alpha = 0.05$ indicated marginally higher sapling densities than the CONT for the treatments cut and herbicide plots (XHRB) ($P = 0.029$), XBRN ($P = 0.029$), and TARP ($P = 0.029$). For 2013 seedling cover, there were no significant differences among treatments ($\chi^2 = 5.699$, 5 d.f., $P = 0.337$).

Species richness and density were negatively correlated with *E. fortunei* cover (Fig. 3). A scatter plot (Fig. 3A) indicated greater ground layer species richness in treatments with low *E. fortunei* cover in 2013 ($\rho = -0.797$, $n = 24$, $P < 0.001$), and the four CONT plots were clustered at high *E. fortunei* cover and low herbaceous richness. Most mow and herbicide (MHRB) plots and XBRN plots were clustered nearer to the CONT, whereas most TARP and XHRB plots diverged from the CONT, reflecting greater richness and lower *E. fortunei* cover (Fig. 3A). Similarly, increasing *E. fortunei* cover was negatively correlated with total native species richness in the ground layer ($\rho = -0.770$, $n = 24$, $P < 0.001$) (Fig. 3B), sapling richness ($\rho = -0.620$, $n = 24$, $P = 0.001$) (Fig. 3C), and sapling density ($\rho = -0.621$, $n = 24$, $P = 0.001$) (Fig. 3D).

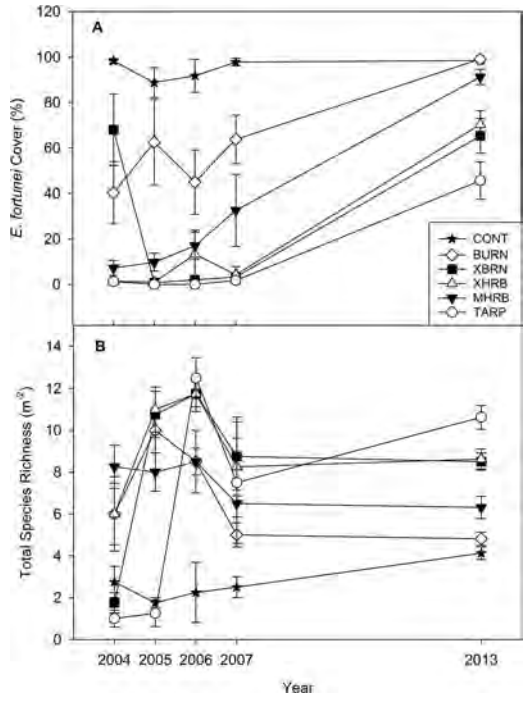

FIG. 2. (A) Mean percentage of cover of *E. fortunei* (± SE) by treatment and year. For descriptions of abbreviated treatments, see Table 1. Friedman's test, $\chi^2 = 0.842$, 20 d.f., $P < 0.001$. (B) Mean total species richness per square meter (± SE) by treatment and year. For descriptions of abbreviated treatments, see Table 1. Friedman's test, $\chi^2 = 0.738$, 20 d.f., $P < 0.001$.

In 2013, plot location within the study site was not a predictor of ground layer total species richness ($\chi^2 = 1.321$, 20 d.f., $P = 0.748$), ground layer native species richness ($\chi^2 = 1.244$, 20 d.f., $P = 0.766$), sapling richness ($\chi^2 = 1.988$, 20 d.f., $P = 0.603$), or sapling density ($\chi^2 = 0.670$, 20 d. f., $P = 0.880$). These findings indicated that experimental design did not significantly affect any of these vegetative characteristics.

NMS ORDINATION OF GROUND LAYER COMMUNITY. The NMS ordination revealed variation among the treatment plots in overall community composition in the 2013 survey (Fig. 4). The NMS ordination yielded a three-axis solution that explained a large amount of variation in the overall plant community ($R^2_{total} = 0.777$), and the final stress (16.322) and final instability (<0.001) were within acceptable ranges (McCune and Grace 2002). The CONT was distinct from all other treatments, which were spread mostly along axis 1 with TARP on the far right (Fig. 4A, B). The MRPP analysis indicated that plant community composition varied among treatments ($A = 0.106$, $P < 0.001$). The MRPPs revealed that three of the treatments varied significantly from the CONT: TARP ($P < 0.001$), XBRN ($P < 0.001$), and XHRB ($P = 0.002$). The MHRB was almost significantly different from the control ($P = 0.014$), but $P \leq 0.01$ was required to reject the null based on a Bonferroni correction for multiple comparisons. The other treatment, BURN, had plant communities that were not significantly different from the CONT ($P = 0.320$).

We explored the source of these differences by considering the correlation between individual species abundances and the NMS axes (Table 2). *Euonymus fortunei* was an obvious source of variation among communities and was not included in the ordination matrix, allowing for consideration of other species associated with divergence among treatments. Some species showed strong correlations with axes, and this correlation information allowed for further interpretation of the NMS ordination (Fig. 4). Native species more commonly found in TARP plots as compared with CONT plots (positively correlated with axis 1) included *Geum vernum* (Raf.) Torr. & A. Gray (spring avens) ($r_1 = 0.603$, $r_3 = -0.466$) and *Geum canadense* Jacq. (white avens) ($r_1 = 0.422$, $r_3 = -0.436$), and the woody understory species *Rubus occidentalis* L. (black raspberry) ($r_1 = 0.445$). Several vines were more frequent in TARP (positively correlated with axis 2) as compared with other treatments, including *Vitis vulpina* L. (frost grape) ($r_2 = 0.491$), *Toxicodendron radicans* (L.) Kuntze (eastern poison ivy) ($r_2 = 0.414$), and nonnative *L. japonica* ($r_2 = 0.539$). The TARP treatment was also more likely (negatively correlated with axis 3) to contain *F. americana* seedlings ($r_3 = -0.476$) as compared with the CONT and the BURN treatment. Species more frequent in the CONT and the BURN treatment (positively correlated with axis 3) included *Parthenocissus quinquefolia* (L.) Planch. (Virginia creeper) ($r_3 = 0.537$) and *R. occidentalis* ($r_3 = 0.430$). Other species in the matrix contributed relatively less to the spatial configuration.

Discussion. TREATMENT AND REINVASION. Across years, treatments reduced *E. fortunei* cover and increased total and native species richness in the ground layer. However, 10 yr

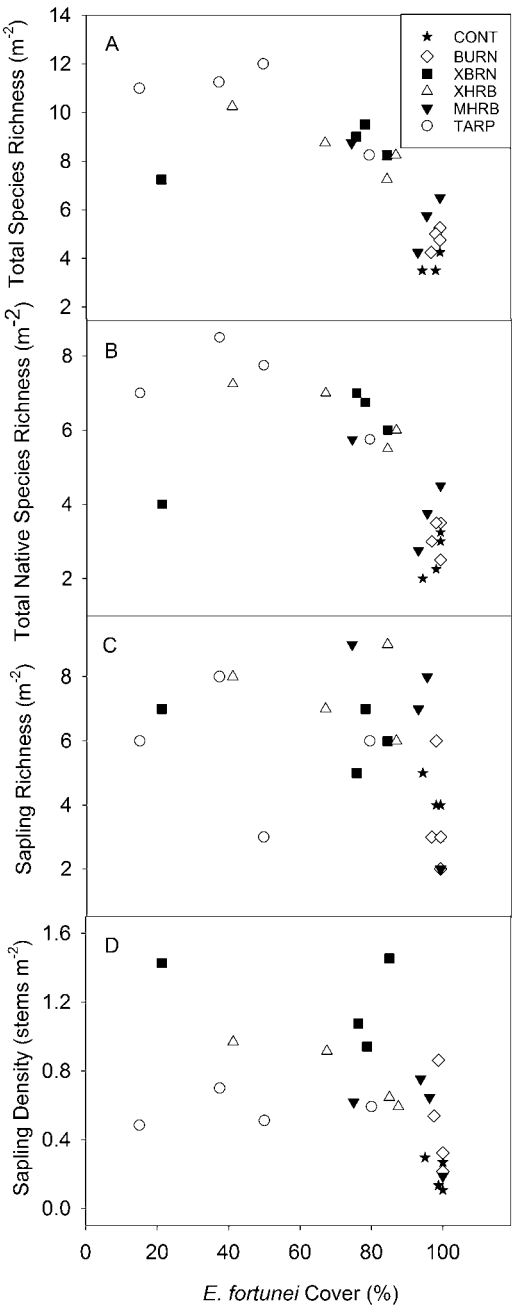

FIG. 3. Scatter plots of vegetative characteristics *vs.* mean *E. fortunei* percentage of cover in 2013. For descriptions of abbreviated treatments, see Table 1. (A) Total species richness m^{-2} in 2013 *vs.* mean *E. fortunei* percentage of cover; $\rho = -0.797$, $n = 24$, $P < 0.001$. (B) Total native species richness per square meter in 2013 *vs.* mean *E. fortunei* percentage of cover; $\rho = -0.770$, $n = 24$, $P < 0.001$. (C) Total sapling richness per square meter in 2013, adjusted from 6-m × 6-m plot surveys *vs.* mean *E. fortunei* percentage of cover; $\rho = -0.620$, $n = 24$, $P = 0.001$. (D) Total density of sapling stems per square meter in 2013, adjusted from 6-m × 6-m plot surveys *vs.* mean *E. fortunei* percentage of cover; $\rho = -0.621$, $n = 24$, $P = 0.001$.

after *E. fortunei* removal, *E. fortunei* cover and ground layer species richness had mostly converged among treatments, and a similar trend appeared for woody species. Still, in 2013, treated plots contained herbaceous and woody species not present in the CONT plots, which typically had nearly 100% *E. fortunei* cover. A few of the most common herbaceous species included *P. quinquefolia*, *V. vulpina*, *R. occidentalis*, *G. canadense*, and *G. vernum*, whereas common woody species included *Symphoricarpos orbiculatus* Moench (coralberry), *F. americana*, *P. serotina*, and *Cornus drummondii* C.A. Mey. (roughleaf dogwood). Different communities emerged in response to different treatments, and NMS ordination and MRPP distinguished TARP as a unique treatment in terms of community composition. Considering plots and sampling units were small, the fact that these results showed treatment communities that differed significantly from the CONT, as well as each other, strengthened our findings. Overall, these results suggest that, although treatment only suppressed *E. fortunei* in the short term, in the long term, treatments facilitated establishment of several woody and herbaceous species not found in untreated plots.

Over time, we observed interesting trends in total species richness in the ground layer. Species richness increased posttreatment, then reached maximums, decreased, and remained relatively stable in the later years of the study. Our long-term study allowed us to perceive this temporal trend, whereas other, shorter studies may not observe these dynamics (Kettenring *et al.* 2011). Species richness may have increased in early years as species took advantage of newly cleared areas created by treatments. Establishment of these species may have been via seed rain or from the existing seed bank. In later years, we observed increasing *E. fortunei* cover along with decreases in species richness. *Euonymus fortunei* may have decreased species richness by preventing the germination, establishment, or both of plants from recently fallen seeds or seeds present in the seed bank. Decreases in species richness may have also reflected depletion of the existing

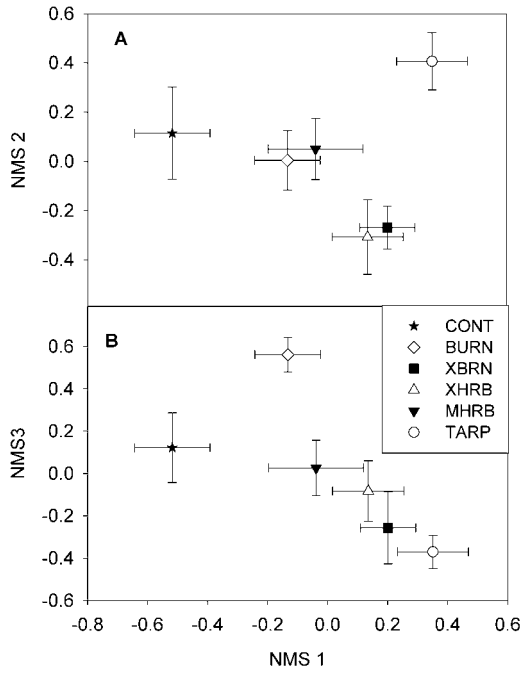

FIG. 4. Nonmetric multidimensional scaling (NMS) ordination depicting average plant community composition (± SE) in 2013 for each treatment type. For descriptions of abbreviated treatments, see Table 1. (A) Three-dimensional model best described the solution; $R^2_{total} = 0.777$ ($R^2_{axis1} = 0.255$, $R^2_{axis2} = 0.252$, $R^2_{axis3} = 0.270$), final instability <0.001, final stress = 16.322. For MRPPs, $A = 0.106$, $P < 0.001$. (A) Depicts axis 1 *vs.* axis. 2. (B) Depicts axis 1 *vs.* axis 3.

seed bank over time (a null hypothesis, wherein impacts to the species community were not directly due to our treatments) or a combination of these factors. Our study did not investigate species propagule limitation, as Kettenring *et al.* (2011) recommended for studies of revegetation after removal of invasive species.

Others have described the ability of *E. fortunei* to outcompete other plants (Randall and Marinelli 1996, Swearingen *et al.* 2002). Increases in *E. fortunei* are likely attributable to both vegetative spread among plots and seed dispersal from untreated locations in the surrounding woods (Randall and Marinelli 1996, Swearingen *et al.* 2002, Remaley 2009), where the plant was still very well established (T.J. Rounsaville, University of Kentucky Arboretum, pers. comm.). We consider vegetative spread to be the primary means of the infiltration of *E. fortunei* into treated plots because, anecdotally, a relative scarcity of fruiting *E. fortunei* plants has been observed in the area. Vegetative reproduction is often associated with rapid invasions (Booth *et al.* 2010). Regardless of the mechanism of spread, the ongoing increase in *E. fortunei* cover indicated the need for long-term management of treated sites.

Other studies have illustrated the role of plant invasions in decreasing species richness and the phenomenon of reinvasion (Hejda *et al.* 2009). When plots are cleared of invasive plants, the act of management itself creates disturbance (Buckley *et al.* 2007). Likewise, in this study, treatments removed existing vegetation and opened establishment sites to be occupied by other plants. Because many invasive plants, and perhaps *E. fortunei*, tolerate and even thrive under disturbed conditions, active management could exacerbate invasions or make way for new invaders (Reid *et al.* 2009). We inventoried several nonnative species in treatment plots, some of which are considered invasive, such as *L. maackii* and *A. petiolata*. Reported values for ground layer total species richness, sapling richness, and sapling density include nonnative species. In our study and in general, increased species richness is not always a positive outcome if new invasions are facilitated. Although invasive species removal may not fully achieve goals, our treatments did restore a site from a near monoculture of *E. fortunei* to a more-diverse plant community.

EXPERIMENTAL DESIGN. The experimental design of this study may have influenced our ability to interpret results. No buffers were established between individual plots or between the study site and surrounding vegetation. Still, we did not find significant differences in any vegetative characteristic based on plot location, including *E. fortunei* cover. Other limitations include our low sample sizes and omission of control plots from the original 2003 randomized block design. Despite limitations, our study revealed different impacts of treatments, including long-term changes in plant species richness and composition due to *E. fortunei* removal and recolonization.

Our findings may not be independent of the study area's history of invasive species management. Before and during this study, the study area experienced treatment of *L. maackii* via cutting and direct application of glyphosate. Under this management regime, the study area forest was a dynamic system undergoing structural adjustment and succession in

response to removal of both *E. fortunei* and *L. maackii*. Changes in forest structure reflected in this study may be due to the combined effects of removing both species. We chose to focus on *E. fortunei* because of the apparent vigor with which it recolonized the study area and because it is an understudied invasive species.

Indeed, this study revealed a forest whose species composition and structure changed following treatment to reduce *E. fortunei*. Increased richness and an emerging sapling layer demonstrate that, whereas tree regeneration had been virtually halted under an *E. fortunei*–dominated system, treatment was associated with increased woody species regeneration. Tree regeneration was probably accomplished through a combination of seed rain and establishment of seeds from the seed bank.

MANAGEMENT IMPLICATIONS. These results reinforced the importance of the management of invasive species, including *E. fortunei*, in restoring forest biodiversity and structure. The TARP treatment stood out among treatments, a notable finding given that TARP has not been widely reported as an *E. fortunei* control method. By 2013, TARP contained the highest total species richness and lowest *E. fortunei* cover, although these differences were not statistically significant. Plant communities present in TARP were also spatially separated by NMS ordination. The TARP treatment appeared to operate differently in *E. fortunei* suppression compared with other treatments. Other treatments were associated with increased total species richness in the year immediately following treatment, whereas the plant community in TARP took longer to develop but was more persistent over time, likely because of TARP's ability to kill belowground biomass of all species present. Given enough treatment time (in this case 6 mo), TARP may have killed *E. fortunei* rootstock by combined light-exclusion and systemic herbicide addition. After this lag in species richness, plants were able recolonize, and species richness increased in TARP. Other treatments not experiencing this temporal lag may not eliminate rootstock as fully as the TARP treatment did. The TARP treatment was unique but has drawbacks: it is inefficient to apply TARP to large areas, all vegetation is killed indiscriminately (including newly established native herbaceous and woody species), and plastic coverings are unsightly and collect standing water. The Forest Park Forever Nature Reserve in St. Louis, MO, has attempted to overcome both aesthetic and water retention issues by using quilts made of canvas and nylon as alternatives to plastic tarps (Schenkenberg 2014).

Within our study site, an urban forest fragment with a history of disturbance, vegetative spread of *E. fortunei* into treatment plots from surrounding areas was a significant long-term factor that resulted in a loss of species richness and sapling density. Land managers facing field conditions similar to those present at our study site may find our results relevant. Of course, management choices should be site specific. For follow-up treatments in places where propagule pressure is high, we suggest methods that control spread of *E. fortunei* from untreated areas. Treatment at these zones must avoid disturbing newly established species. If the affected area is small, removal might be best accomplished manually or through use of plastic tarps despite their drawbacks. If the area to be treated is larger, immediate application of glyphosate to stems cut close to the ground (Remaley 2009), as in our XHRB treatment condition, may be more easily implemented. Winter application of herbicide to evergreen *E. fortunei* foliage may be one way to avoid negatively affecting newly established native species that are dormant during winter. Overall, our results suggest that active retreatment of sites is critical for native species colonization and overall restoration success.

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Invasive plants *Euonymus fortunei* and *Lonicera maackii* reduce *Festuca arundinacea* germination and *Brasica rapa* growth.

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Introduction

- Non-native plant species that are introduced into a new region can act as invaders, altering the native ecosystem. (Gorchov, 2003)
- Plants are capable of competing with one another via allelopathy, in which a plant releases phytochemicals that can interfere with the growth of competitors. (Inderjit, 1996)

Wintercreeper
Euonymus fortunei

- Wintercreeper and honeysuckle are established invaders.
- Evaluation of the "invasional meltdown" hypothesis.

Amur Honeysuckle
Lonicera maackii

Hypotheses

❖ Fresh, ground leaves of Amur honeysuckle and wintercreeper will reduce rate of germination and total number of seeds germinating in target plant species.

❖ Wintercreeper slurries will reduce plant growth and alter biomass allocation of target plant species.

❖ Combining leaf surries will cause meltdown effect, therefore causing a combined slurry to further decrease germination and growth capacity in target plants.

Methods

Germination Study

❖ Leaf slurries of 20:1 wintercreeper (WC), 20:1 wintercreeper honeysuckle (WCHS), 5:1 WC, and 5:1 HS were created.

❖ Twenty seeds of native *Festuca arundinacea* were subjected to the prepared slurries or pure water. Slurries were used to keep filter paper with x # seeds damp.

❖ Germination was checked daily.

❖ Shoot length measured after 13 days.

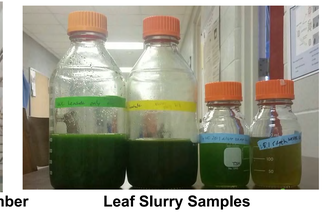
Growth Study

❖ 30 total specimens of *Brasica rapa* were cultivated and subjected to treatment with the 5:1 WC slurry, the 5:1 WCHS slurry or pure water.

❖ Specimens were watered with 50 mL 20% solution of WC slurry, 20% solution of WC/HS slurry or distilled water for a 6 week period.

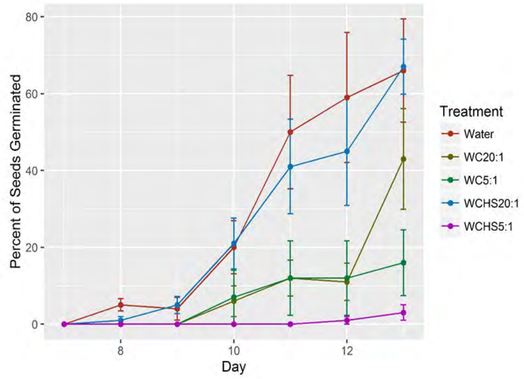
❖ Specimens collected after 6 weeks. Shoot length, root length, biomass and R:S ratio were measured.

Experimental units in growth chamber



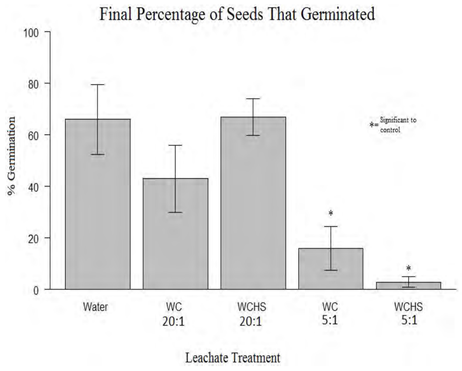
Leaf Slurry Samples

Wintercreeper and Honeysuckle reduced rate and % germination



❖ Over a 2 week period, both the concentrated leaf slurries reduced the average rate of fescue germination ($p < .001$).

Figure 1.1: Percentage of seeds germinating through 13 days for with water, a 20:1 dilution of wintercreeper slurry, 5:1 dilution of wintercreeper slurry, 20:1 dilution of wintercreeper/honeysuckle slurry, or 5:1 dilution of wintercreeper/honeysuckle slurry.

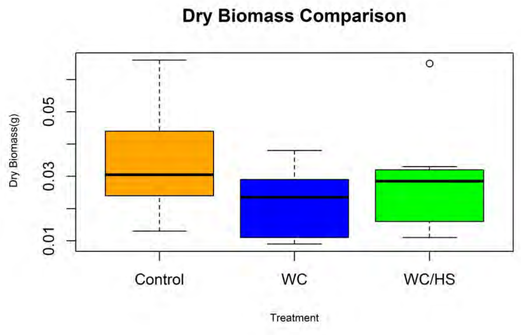


❖ Only the 5:1 concentrated slurries significantly reduced germination ($p < .001$).

❖ There was little difference between the WC only and combined slurries.

Figure 1.2: Final % germination across the 5 groups.

Wintercreeper and Honeysuckle did not affect total biomass



❖ The leaf slurries did not significantly decrease the biomass of the specimens.

❖ The combined leaf slurries had a similar effect as the WC only slurry.

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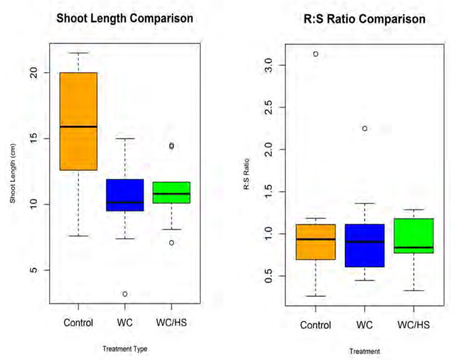
Figure 2: Final dry biomass of *B. rapa* plants grown with water, wintercreeper leaf slurry, or combined wintercreeper and honeysuckle leaf slurry.

Wintercreeper reduced shoot length, but not root:shoot



❖ Both the WC only and combined slurries significantly decreased the shoot growth of the specimens ($p < 0.01$)

❖ The similarities between the R:S ratio across the 3 groups suggest that dedication to root growth was additionally altered.

Figure 3: Shoot length and R:S ratio comparisons of *B. rapa* grown with water, wintercreeper leaf slurry or combined wintercreeper honeysuckle leaf slurry.

What does this mean?

❖ Wintercreeper appears to possess a minor allelopathic effect that reduces shoot length and delays germination of targeted plant species.

❖ The impacts on shoot growth and germination may feed into wintercreeper's light isolation strategy

❖ Combination of two native species (invasional meltdown) has no notable extra potency

Future Questions

❖ What impact does wintercreeper allelopathy have on native plants in the field?

❖ How would allelopathic effects influence plant communities over time?

❖ How are phytochemicals released by invaders impacting other parts of the community (arthropods, microbial, etc.)?

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L. Maackii image by Jay Sturner from USA (Amur Honeysuckle (Lonicera maackii)) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons
E. fortunei image by James H. Miller, USDA Forest Service, Bugwood.org [Public domain], via Wikimedia Commoms

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We wish to thank the Transylvania University Biology Program and the TU 2015 Fall Term Ecology class for help in the design and implementation of the study. We also thank the Ecological Research and Education Center, where the study took place.

January 14, 2017

To the Bingham Renewal Committee,

I write in support of Professor Sarah Bray. I believe she has asked me to do this because of my position in the Humanities, rather than the Sciences, because in the spring of 2015 she and I taught an interdisciplinary course together that took students to Peru, and because a significant number of Spanish majors are also Biology majors.

While Professor Bray and I have known each other for several years, and I knew that she was a reader, it was not until we prepared for our Peru course that I got to see how close and sensitive a reader she is. The course itself was split between time spent in the classroom in Transylvania and time spent hiking through the Andes in and out of various microclimates and time spent in a nature preserve in the Amazon. As part of the course assignments, we had the students read *Tropical Nature: Life and Death in the Rain Forests of Central and South America* by Adrian Forsyth and Ken Miyata, *The Geography of Plants* by Alexander Humboldt, and selections of *The Voyage of the Beagle* by Charles Darwin, along with some poems set in Peru and some travel writing based on travels in Peru. We had multiple reasons for choosing the texts we did: Humboldt because his was the central metaphor for the class and because his work on the biogeography of plants in the Andes was central to his conceiving of isothermal lines, Darwin because his is a classic of science and travel writing, Forsyth and Miyata because they were scientists running labs, doing field work, collecting and analyzing data, and at the same time wrote a book that exemplary as a model for scientists who would like to write for an educated readership. In our class discussions, Professor Bray brought both science questions (as in, how would a field researcher obtained these insights, what have learned about tropical ecology over the last thirty years, etc.) to bear on the discussion of these texts but also rhetorical, compositional questions as well (how is this argument being made, how does this metaphor work).

Because of the nature of that class, I was also able to see how Professor Bray lectures and structures assignments. We spent about a week and a half at Transylvania before going in country covering material we thought would be important for students to have so that they would arrive in country knowing enough to see and understand some of what they were seeing. After all, once in country, our principal activities were going to be hiking and the journaling. To that extent, when we weren't discussing our texts, we had lectures and student presentations on plant distribution, global climate change, and the effects of deforestation in the Amazon. Given the fact that it was an elective and had no pre-recs, everybody from First Years to Seniors enrolled, which there were large knowledge gaps in the class. Professor Bray, to overcome this, modified her typical lecture and wove in questions directed to seniors who had already had knew the material. The questions she asked both of upper-class students and the first and second years, were not just confirmation questions. That is, they did not just try to assess whether they knew and understood the material, but they asked of them to formulate hypothesis based on some of the readings we had done and the new information provided.

While I do not go fishing for dirt on colleagues, given that we are a small college and professors have close relationships with students, it is easy to know whom students admire because of their knowledge, care, and teaching and who they think are not worth taking. As I have already said, Biology and Spanish share a number of students. And, many of those students I think to be exemplary all admire Professor Bray. Both because of her teaching in the class, as well as her teaching in the lab and in the field. Indeed, one need only look at her C.V. and note things like Contributed Presentations and Research Supervision to note how committed Professor Bray is to mentoring undergraduate research.

Not wanting to rely solely on the one class one class we co-taught and praise of students whom I believe to be model scholars in both the Sciences and the Humanities, I observed this week her Sophomore seminar. Professors Bray, Duffin, and Wagner have written and published an article on the pedagogy and rationale of that course. It is a toolkit course that gives beginning Biology majors what they will need to succeed. They cover statistical analysis, the gathering of data, the genre of the academic science article and poster presentation, among other things. The class I observed was a workshop on how to use and code in R, a statistical programming language that students will need to analyze and represent data. Her handouts were clear and precise. They walked the students through the process of importing data and starting to code. The class was divided into a 20-minute lecture and a 30 minutes for students to work in R and practice the concepts and skills she had taught them. A senior biology major was in the class as a peer mentor. He is taking a ¼ credit class on teaching Biology. Rather than simply dive into coding, Professor Bray began class with an image of graph from the 1930s, where the researcher had drafted the lines by hand, and because of that had drawn and redrawn, erased and scribbled out lines. She presented the image as an allegory of knowledge construction and asked the students to think a little bit about the relationship between knowledge production and dissemination.

I say this to note how, though a scientist, very much concerned with giving students the knowledge and skill-set to be undergraduate researchers, she also approaches her task as a historian of science. This can be seen in graph as well as in her use of Humboldt and Darwin and *Tropical Nature*. I really do believe that Professor Bray is a great teacher. She is dedicated and conscientious scientist intent on grooming young biologists, on passing on to them the skills and knowledge they need to be researchers. She is also a good lecturer who structures her classes well and who clearly presents students with her expectations regarding their assignments. I truly do believe that she is model teacher and merits renewal .

Sincerely,

Jeremy Paden, PhD
Associate Professor of Spanish and Latin America
Transylvania University

Thursday, January 12, 2017

Dear Bingham Review Committee;

I would like to offer my strong support for Dr. Sarah Bray's renewal of her Bingham Teaching Award. I feel very qualified to comment on her teaching ability since I have worked closely with her since she joined our biology program in 2007. Over the years I watched, and learned, as Sarah developed her scholar-teacher persona. For those of us faculty at an undergraduate teaching institution the typical strategy is to develop effective lecture notes and assignments and master the material for the courses we are aligned with and then once that foundation has been established we work to develop an active and dynamic research program. Consequently, it is teaching where risk-adverse and tried-and-true approaches dominate while the area of research is where the faculty employs dynamic, creative and risk-prone approaches. I saw this in my own career and in many of my cohorts. However, when Sarah joined the Biology Program I saw a totally different approach to the scholar-teacher model. Sarah applied her critical and quantitative skills to both her teaching and her research making both amazingly successful.

One of the best documented examples of Sarah's strength as a scholar-teacher is in the development of our sophomore course called *Biologist Toolkit*. Instead of going through the details of the course, I encourage you to read the article about the class Sarah et al. published in *CourseSource*. What I want to point out is that as Sarah was teaching this course for the first time, she was collecting data on student attitudes towards different components of the course. Not only that, she collected data on student attitudes pre- and post-course. This is a perfect example of Sarah applying her research mind to her teaching. She is not content thinking that her assignments, her lectures and activities work, she takes the effort to quantify the effectiveness of the various aspects of her course and then uses that information to improve the course. This is particularly impressive when you recognize she does all of this without any institutional support for collecting data like this. Sarah writes the surveys, develops ways in which the students can anonymously respond to the surveys and then she statistically analyses the data. Ultimately she takes this information and uses it to guide her in improving her teaching effectiveness.

Broader Impact

I am very lucky to be part of a Biology program with talented faculty who utilize diverse approaches to teaching and research. When I reflect on Sarah Bray I am struck by how her

addition to the program has been such a positive influence on the biology program curriculum and culture. Sarah was the catalyst to get us to adopt a new approach to our core courses and she championed and developed our unique sophomore *Biologist Toolkit* course. I have taught the course and I know first-hand how effective this course is in teaching our students quantitative skills and allowing them to take ownership of analyzing and graphing their own data.

Sarah has also influenced me personally in how I teach my courses and the material I present within my courses. My graduate school training did not involve using phylogenetic approaches to developing and testing hypothesis in evolution. In contrast, Sarah's graduate training was very strong in modern analysis of phylogenetic data. Over the years she has taught me how to think and teach phylogenetic approaches which has now become an important component of my upper-level courses in evolution and animal behavior. In fact, Sarah and I spent last summer writing a chapter for our introductory biology textbook that uses phylogenetic data to hypothesize the evolution of flightless birds like ostriches, emus and cassowaries. I know my teaching over the years has improved and diversified because of my conversations with Sarah about specific courses and/or material within a course.

Last year I wanted to develop a podcast that introduced the public to Charles Darwin and his seminal book *On the Origin of Species* (OoS) and asked Sarah if she would work with me on the project. I invited Sarah because I wanted the podcast to review what Darwin originally said but also contextualize the material to modern scientific information and Sarah is a voracious reader and tends to keep up with the scientific literature better than I. My plan was for us to dedicate each episode to a single chapter of OoS and summarize the chapter using Darwin's own words and then show how his ideas have held up to modern scientific research. Working with another colleague, Dr. Josh Adkins, we completed Season 1 of *Discovering Darwin*[1] in August 2016 and Sarah was, as I expected, invaluable to the project. In those podcasts we discussed wide ranging topics and Sarah always brought to the conversation relevant recent research which she was able to summarize and explain in manner that was both informative and entertaining. Our podcast was picked up by the local community radio station (93.9 WLXU) and our episodes are now played every Monday night from 8-9 pm increasing our audience and allowing us to introduce Darwin and his ideas about evolution to the Lexington community and beyond. When I first proposed making the podcast I never realized how much work and time would be invested in researching and preparing for each episode. Luckily for me Sarah and Josh were amazingly generous with their time and they stuck with me throughout the entire project. Sarah dedicated the time to the project because she felt it is important that we make evolution and Darwin's ideas accessible to the general public. We are gearing up to begin recording Season 2 of *Discovering Darwin: Darwin the Adventurer*.

I have also worked closely with Sarah when I team teach our Tropical Ecology course which is a travel course to Belize. When I consider that course I realize that some of the

[1] http://discoveringdarwin.blogspot.com/

distinctive aspects of the course are in response to Sarah's desire to engage our students as scientists in the field. Sarah developed an assignment where students are required to write in their journal a daily hypothesis that is based upon observations they had made that day. This assignment was in response to Sarah's assessment that our biology majors may be strong in designing experiments and analyzing data but are actually weak in developing testable hypothesis. The last time we went to Belize we instituted a field research project that groups of three students would conduct during a single day and then analyze and present their findings after dinner that night. It is always fun to watch the students draw by hand on the chalkboard their graphs and results and share their findings with others. These activities developed from Sarah's commitment to make our students into actively engaged scientists.

Conclusion

When I consider faculty for tenure I often play in my mind the *It's a Wonderful Life* game where I try to envision the program and university in an alternative world where that faculty member was never a part of the campus. How would we be different? Would we be significantly less than we are with them? With Sarah Bray the differences are so stark it does not take much imagination to realize how much better the Biology program, our students, and even myself are because of her contribution to the Biology Program and the university at large. Sarah is an amazing teacher, scholar and colleague who continually raises the bar of expectations for our students and ourselves, her fellow faculty members.

Best regards;

James Wagner
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