Bio 133. Foundations of Ecological and Evolutionary Biology
Fall 2015

Participants: Andy Vacca, Animakshi Bhushan, Ashley Lang, Ellie McNutt, Fiona Jevon, Keith Fritschie, Melissa Desiervo, Michael B. Brown, Morgan Peach, Rebecca Finger, Matt Ayres

Participant interests: googledoc
Course web page: http://www.dartmouth.edu/~mpayres/teaching/Bio133_index.htm

Meetings: Thursdays 18:30 – 20:20, LSC 105

ORC description: In this graduate course, students will read and discuss a series of classic and contemporary papers taken from the primary literature on various topics in ecology and evolutionary biology. Each week a series of lectures will be given and a set of 2-4 papers will be discussed covering a different major topic. The papers will be chosen to expose students to the foundations of major ideas and theories in ecology and evolution and to contemporary tests of these major theories. Bio 133 covers topics in ecosystem and community ecology, natural selection and adaptation, and research approaches in ecology and evolution. Offered in alternate (odd) years.

Participant responsibilities for 2015

2. Complete term projects. In each case, participants will work as a team to develop a single product.
   A. Conceive an outline and develop materials for course titled: “The Foundations of Ecology for Ph.D. students”.
      Elements should include:
      1. A conceptual outline
      2. Classic papers
      3. A listing of important theories
      4. A listing of important motivating questions
      5. A partial listing of important technical vocabulary
      6. The frontiers: examples of cool new research, each described with one sentence and a link.
      7. Rewrite the current ORC description of Bio 133 so that it matches your vision

   B. Develop familiarity with the professional accomplishments and expertise of EEES faculty.

   C. Develop a working list of other important stuff that you should learn in grad school.

3. Participate in assorted other activities, most still to be determined by participant interests.
Meeting 1. Foundations of Ecology?

Discussion. What should be the content, structure, and objectives of a PhD course in 2015 about the foundations of ecology and evolutionary biology? One objective is that participants should gain capacity to develop and teach such a course themselves, including 20 years from now when the ideal course content would presumably be different than today.

Introductions. Share google doc. Participants introduce themselves and give examples of favorite theories. What’s a theory? What do theories have to do with ecology?

Develop a syllabus for Dartmouth’s Bio 16, Introduction to Ecology.

Develop objectives for term projects.

Meeting 2. Admireble papers

Faculty-of-the-week: Doug Bolger and Mark Borsuk. See detailed assignment. Record work in Google-doc for faculty-of-week.

Admireble papers. What makes a valuable research contribution? Participants bring examples from their field. Pairs of participants explain the core of each other’s papers (15 min, with a simple graphical abstraction to aid). Reconvene. Each participant explains their colleague’s paper (5 min, with a simple graphical abstraction to aid). See more detailed instructions below.

Meeting 3. Foundations to Frontiers

Faculty-of-the-week: Ryan Calsbeek, Celia Chen, Kathy Cottingham. See detailed assignment. Record work in Google-doc for faculty-of-week.

Foundations to Frontiers:

A. With respect to the topic “Limits to distribution”, work as a team to develop materials for the following categories:
   1. Papers from the primary literature, with citations and links recorded in Google-doc for Literature.
      a. Foundational papers
      b. Exceptional examples
      c. Active frontiers
   2. Listing of prominent theories, recorded in Google-doc for prominent theories.
   3. Listing of important technical vocabulary, to be recorded in Google-doc for technical vocabulary.
      I wouldn’t expect you to complete this during class time, but let’s see what we learn from everyone working on it together for an hour or so. Then you can consider tactics for expanding this to include other core topics.

B. Revisit your draft syllabus from our 1st meeting. Work as a team to decide on ~6-10 other topics, akin to “Limits to distribution”, that you would like represented in your term project (“Develop materials for a course titled ‘The Foundations of Ecology for Ph.D. students’”). We will have 6 more meetings after this week (for a total of 9). We can spend some time on Foundations to Frontiers each week. I guess it will take a bit of time outside of class for you to do a satisfactory job on the project, but I don’t want you to knock yourselves out. I leave it to you to develop an efficient plan for completing the project and learning some stuff along the way. You are welcome to re-arrange the structure that I suggested. Make more or alternative google-docs if you like.

What else should we do? Your other assignment for this week’s meeting is to start a working list of “Other topics that could be fun in Bio 133”. Some of you made good suggestions in response to an email before classes began. Be expansive. If we have a generous list of possibilities it will be easier to pick the ones that will be most entertaining. I’ll work with you to find ways we can learn about the stuff you want to. I imagine more activities in Bio 133 like last week’s “admireble papers” exercise, but with a range of learning objectives. I’m also reluctant to suggest it, but I think we might want a google-doc for this.
Meeting 4. Foundations to Frontiers

Faculty-of-the-week: Michael Cox and Jerry DeSilva.

Foundations to Frontiers: I will give you most of our meeting time to work on this
Two thought problems:

a. Give an example of a notable change in paradigm during the last 50 years in the science of ecology. For example, we now understand that plants defend themselves against organisms that would eat them with constitutive defenses, inducible defenses, and by calling out to the enemies of their enemies.

b. Give an example of a long time staple in the foundations of ecology that is as important today as ever. For example, the theory that is represented by Life Tables.

Meeting 5. Structure of knowledge

Faculty-of-the-week: Mike Dietrich, Nate Dominy, Andy Friedland

Structure of knowledge: For this week’s meeting, come with two theories from your area of expertise: one a bedrock theory and other an interesting up-and-coming theory. Be prepared to explain them to your colleagues and to be empowered by learning the favorite theories of others. Further instructions enclosed. Structure-of-knowledge.pdf.

Structure of activities at meeting time:

Guest grad student this week (Alison Greggor). Each participant introduces the person next to them. 5 min
Faculty of week: 20 min
Breakout groups to share theories (4 theories x 5 min = 20 min)
Plenary meeting (11 people x 1 theory x 5 min = 55 min)

Meeting 6. Powerful questions, competing hypotheses, and strong inference

Faculty-of-the-week: Frank Magilligan, Rich Howarth, Anne Kapuscinski

Powerful questions, competing hypotheses, and strong inference: For this week’s meeting, bring an example from your field of:

1. A powerful research question
2. A set of multiple working hypotheses
3. Strong inference

Be prepared to explain your examples and to discuss:

1. What makes a good research question?
2. What are the benefits of working with competing hypotheses? Do good ecologists work this way in practice?
3. What are general tactics for conducting research that yields strong inference?

As background reading, see:

Three examples of multiple working hypotheses from my own work. Questions.Hypoths.StrongInference.pdf

Structure of activities at meeting time:

Faculty of week: 20 min
Hand out copies of BHT to everyone. Thanks Craig.
Mini-lecture / discussion by Matt on theories, hypotheses, etc. (30 min)
Sharing and discussion of (1) questions, (2) hypotheses, (3) strong inference (50 min)

Meeting 7. New classics: Connecting theories, models, & data

Faculty-of-the-week: Jackie Hatala-Mathes, Mark McPeek, Laura Ogden

New classics: Connecting theories, models, & data: Identify one paper for each of your topic areas below that you will nominate as a “new classic”. It should be a paper you would want to incorporate into a course like Bio 16 when you are teaching it. Such papers that I have used this term in Bio 16 include conditional interactions between juniper and mistletoe; trophic cascades from Orcas; habitat selection in Pemphigus aphids; and evolution of twinning in humans. From the parlance of your Foundations to Frontiers project, your paper should be both an exceptional example and an illustration of an active research frontier. It does not have to be brand new; anything within 10 or even 20 years is fine. Your papers should describe primary research and include data. I’ll give you a few minutes at the start to sketch a simple abstraction on the board that you will help you explain the paper during our discussion. Be prepared to:

1. Identify the one or two most prominent theories that provide context for the work;
2. State the question that was addressed by the research in a way that would grab the interest of ecology students;
3. Identify and explain a model employed by the authors to evaluate the data with respect to theory;
4. Explain the outcome in terms of a result that was obtained and a result that could have been obtained but was not;
5. Characterize the strength of inference;
6. Summarize in a sentence or two the broad conclusions for the science of ecology.

Topic areas and people

1. Limits to distribution - Ellie, Ani
2. Historical ecology - Fiona, Melissa
3. Behavioral ecology - Ani, Ashley
4. Population ecology - MBB, Keith
5. Species interactions - Ellie, Fiona
6. Community ecology - Keith, Morgan, MBB
7. Ecosystem ecology - Ashley, Andy
8. Physiological ecology - Andy, Rebecca, Melissa
9. Global change and ecology in Anthropocene - Morgan, Rebecca

Please put your citation and a link in the Google Doc “New Classics”


For this week’s meeting, bring three interesting examples from your field of using statistics to draw inferences about nature from data. Bring one example from each of the following schools of statistical inference:

1. Frequentist statistics
2. Information theory and multi-model comparison
3. Bayesian statistics

Enclosed are some references that you should be aware of and might even want to look at. This is truly a frontier. I welcome additional references that would be of value to the next cohort of EEES students. Also enclosed are some visualizations of historical use in primary and secondary literature of technical vocabulary from statistics.
### Bio 133: Participant interests

<table>
<thead>
<tr>
<th>Participant</th>
<th>Research interests</th>
<th>A paper you admire</th>
<th>An interesting research question that you’d like to answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animakshi Bhushan</td>
<td>animal communication, social behavior, behavioural ecology, sensory ecology</td>
<td>von Frisch, Karl. &quot;Decoding the language of the bee.&quot; Science (1974).</td>
<td>How do social calls drive bats to coordinate and communicate with each other when foraging in a group? Which determines which individual (in the group) will claim food during flight?</td>
</tr>
<tr>
<td>Ashley Lang</td>
<td>Ecosystem ecology; climate change; forest biogeochemistry; global carbon cycling; plant-soil interactions</td>
<td>Prentice, J. Colin, Martin T. Sykes, and Wolfgang Cramer. &quot;A simulation model for the transient effects of climate change on forest landscapes.&quot; Ecological modelling 65.1 (1993): 51-70.</td>
<td>How will climate change affect carbon cycling in temperate forests? What changes (biotic/abiotic disturbance, species shifts) will occur, and which will have the greatest impact?</td>
</tr>
<tr>
<td>Fiona Jevon</td>
<td>Ecosystem ecology; forest biogeochemical cycling; long term forest stand dynamics; climate change; carbon and nitrogen interactions</td>
<td>D’Amato, Anthony W., John B. Bradford, Shawn Fraver, and Brian J. Palik. &quot;Forest management for mitigation and adaptation to climate change: insights from long-term silviculture experiments.&quot; Forest Ecology and Management 262, no. 5 (2011): 803-816.</td>
<td>How do forest biogeochemical cycles respond to extreme precipitation events? Will extreme precipitation cause positive or negative feedback to occur in any of these cycles?</td>
</tr>
<tr>
<td>Morgan Peach</td>
<td>soil carbon; soil solution; managed forest-field systems; urban ecology; constructed plant-soil-microbe systems; ecosystem services; regenerative design</td>
<td>Alberti, Marina, and John M. Marzluff. &quot;Ecological resilience in urban ecosystems: linking urban patterns to human and ecological functions.&quot; Urban ecosystems 7, no. 3 (2004): 241-265.</td>
<td>What is the capacity of a plant-soil-microbe system (when integrated with infrastructure of urban ecosystems) to cleanse air and water, sequester carbon, collect and degrade pollutants, as well as re-use excess nutrients?</td>
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Bio 133: Properties of admirable papers?

What are the general properties of high impact publications? One criterion is that a good paper points to a version of nature that fundamentally differs from an alternative possibility that seemed credible and perhaps sufficient before you read the paper.

In advance of our first meeting, read both papers associated with your group below. One was nominated as an admirable paper by yourself and the other by your colleague. For this exercise we will break into the groups identified below for ~30 minutes and then reconvene to share what we have learned. During the breakout time, your job is to (1) smoothly and efficiently explain to your colleague the most interesting single message from your paper, and (2) listen, ask questions, and absorb from your colleague the single most interesting message from their papers. When we reconvene, each of you will smoothly explain (in 5 minutes) the interesting non-trivial message from your colleague’s paper. To help your colleague appreciate and communicate your paper, suggest to them a very simple graphical abstraction (“cartoon”) and/or very simple verbal message (“tweet”) that can be put on the whiteboard in a few seconds and will help them convey the most important point.

The papers are of 2-3 basic types: primary research, review, or synthesis. For primary research, the interesting message should be a research result. For a research result to be interesting, there had to have been a different possible result that did not occur, but theoretically could have, and which would generated a fundamentally different message from the paper. A good way to convey this is if your cartoon or tweet can be simply adjusted to alter the message (e.g., crossing out an arrow of causality in a cartoon of system parts, or a bargraph in which two bars could have been about the same but were in fact different). When the paper is a review or meta-analysis, you can probably apply the same tactic for communicating the central message: data indicates that the world is this way even though it could not have been that way. If the paper is a synthesis, the central message may be a general theoretical model. Again, seek to develop a very simple graphical abstraction and be able to explain it with reference to an alternative theoretical model (one that that cannot also be true at the same time for the same system, but which could be otherwise regarded as a valid possibility).

Also, develop for each paper a short list of critical technical vocabulary that may not be immediately understood by a non-specialist but which is crucial to understanding and explanations. Be ready to add your technical vocabulary to a list that we will build during the discussions. Papers below are also at the googledoc for participant interests.

<table>
<thead>
<tr>
<th>Team</th>
<th>Paper 1</th>
<th>Paper 2</th>
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EEES Faculty of the Week for Bio 133, Fall 2015

24 Sept  Doug Bolger, Mark Borsuk
1 Oct  Ryan Calsbeek, Celia Chen, Kathy Cottingham,
8 Oct  Michael Cox, Jeremy DeSilva,
15 Oct  Mike Dietrich, Nate Dominy, Andy Friedland,
22 Oct  Frank Magilligan, Rich Howarth, Anne Kapuscinski
29 Oct  Jackie Hatala-Mathes, Mark McPeek, Laura Ogden
5 Nov  Kevin Peterson, Nick Reo, Chris Sneddon
12 Nov  Hannah ter Hofstede, Ross Virginia, DG Webster

For each faculty-of-the-week, do a little research on who they are and what they do. Provide one interesting descriptive statement about them. Be creative, but something like the following:

Colleague X showed ..., Colleague X developed ..., Colleague X leads ..., etc.

A theme in Colleague X’s work is ..., One question that Colleague X is working on now is ...

If you can, include one or two relevant urls (e.g., to a cool paper).

Prior to our meeting time, insert your descriptive statement for each faculty of the week into the google doc at the link below. We’ll look at them together at the start of class and save the growing document as a product of our work.
https://docs.google.com/document/d/1H1gYODqqEhXx47sJvEFwICQVoxbsJEHxfDV2e5jEe9E/edit?usp=sharing

Matthew Ayres: Professor of Biological Sciences; Co-chair Ecology & Evolutionary Biology Graduate Program; Associate Director Institute of Arctic Studies at the Dickey Center for International Understanding.

Douglas Bolger: Professor of Environmental Studies, Adjunct Professor of Biological Sciences.

Mark Borsuk: Associate Professor of Engineering, Thayer School of Engineering

Ryan Calsbeek: Associate Professor of Biological Sciences, Co-chair Ecology & Evolutionary Biology Graduate Program.

Celia Chen: Research Professor of Biological Sciences.

Kathryn Cottingham: Professor of Biological Sciences; Co-chair Ecology & Evolutionary Biology Graduate Program.

Michael Cox: Assistant Professor of Environmental Studies

Jeremy DeSilva: Assistant Professor of Anthropology

Michael Dietrich: Professor of Biological Sciences; Affiliated Faculty, Women’s and Gender Studies Program; Adjunct Professor Center for Biology and Society Arizona State University; Editor in Chief, Journal of History of Biology

Nathanial Dominy: Associate Professor of Anthropology, Adjunct Associate Professor of Biological Sciences.

Andrew Friedland: The Richard and Jane Pearl Professor in Environmental Studies, Adjunct Professor of Biological Sciences, and Director of Earth, Ecosystem, and Ecological Sciences (EEES)

Richard Howarth: Professor and Chair of Environmental Studies, Editor-in-Chief of Ecological Economics

Anne Kapuscinski: Professor and past Chair of Environmental Studies, Sherman Fairchild Distinguished Professor in Sustainability Science, Adjunct Professor of Biological Sciences, Editor-in-Chief of the Sustainability Transitions domain in Elementa: Science of the Anthropocene.

Frank Magilligan: Professor of Geography and Earth Sciences.

Jaclyn Hatala Matthes: Assistant Professor Department of Geography, Adjunct Assistant Professor Biological Sciences.

Mark McPeek: David T. McLaughlin Distinguished Professor of Biological Sciences.

Laura Ogden: Associate Professor of Anthropology.

Kevin J. Peterson: Professor of Biological Sciences.

Nicholas Reo: Assistant Professor of Environmental Studies and Native American Studies, Adjunct Assistant Professor Biological Sciences

Chris Sneddon: Associate Professor of Geography and Environmental Studies

Hannah ter Hofstede: Assistant Professor of Biological Sciences.

Ross Virginia, Myers Family Professor of Environmental Science; Director of Institute of Arctic Studies at the Dickey Center for International Understanding; Adjunct Professor of Biological Sciences.

DG Webster: Assistant Professor of Environmental Studies

Olga Zhaxybayeva: Assistant Professor of Biological Sciences and Adjunct Assistant Professor of Computer Science.
Hi Bio 133,
Here are some more resources for your project in designing what Bio 133 should really be.

2. Input this fall on the content of Bio 133 from alumni and yourselves. Input-on-content.pdf
3. A few “Resources for Grad Students” from me here: http://www.dartmouth.edu/~mpayres/teaching/gradprogram/

Matt

For Foundations-to-Frontiers, use whatever resources you can think of. Ask your major advisor for input. Ask your colleagues. Troll for syllabi and reading lists from ecology courses elsewhere. Here’s another resource for you from http://www.esa.org/esa/

**NOTABLE PAPERS OF THE LAST CENTURY**: Notable research reports from ESA journals are open access for the rest of 2015. Discover or rediscover these seminal papers and join the conversation! Members are invited to read and submit commentaries. Browse the centennial collections for: *Ecology*, *Ecological Monographs*, *Ecological Applications*, *Frontiers*, *Ecosphere*.

Matt

See enclosure for the usage of “evolution”, “ecology”, and “ecosystems” in the global English literature since 1800. This came up briefly in our meeting last week.
Three examples of multiple working hypotheses
Matt Ayres

Research question #1: Why are stands of longleaf pine less susceptible to southern pine beetle than stands of loblolly pine?
H1. Null hypothesis. Within forests, D. frontalis infestations occur within stands of longleaf pine and loblolly pine in proportion to their abundance. The conventional wisdom that there are fewer infestations with longleaf is a false impression created by the low abundance of longleaf pine in the contemporary landscape.
H2. Compared to loblolly pines, the resin defenses of longleaf afford better protection against bark beetles.
H3. Greater inter-tree spacing in longleaf stands compared to loblolly limits the ability of D. frontalis to aggregate during attacks and dampens population growth as a result.
H4. The searching behavior of dispersing adults of D. frontalis is biased against stands of longleaf pine compared to stands of loblolly pine.
H5. When struck by lightning, longleaf pines are less suitable than loblolly pines for colonization by D. frontalis and its fungal associates.

Research question #2: What produces positive density-dependence (Allee effect) in the population dynamics of D. frontalis? i.e., why do large infestations grow more than small infestations?
H1. The apparent phenomenon is actually just exponential growth and not truly an Allee effect.
H2. When local populations are larger, tree-specific attack rates are greater, resin defenses of trees are more quickly depleted, and per capita reproductive success is greater.
H3. Small infestations are more likely to collapse due to an interruption in attacks (from demographic stochasticity and variance in emergence times).
H4. In relatively small infestations, there is increased mortality of attacking adults because it is difficult for beetles to locate trees with a favorable (low to moderate) density of adults already present.

Research question #3: Why are there large fluctuations in the abundance of some forest insects?
H1. The populations cycle due to delayed density-dependent feedback from specialist predators.
H2. The populations cycle due to delayed density-dependent feedback from inducible plant defenses.
H3. The populations fluctuate due to density-independent effects from climatic variation.
H4. The populations fluctuate due to density-independent variation in host quality, natural enemies, mutualists, or competitors.
Bio 133: The Structure of Knowledge

What is the structure of knowledge? Is knowledge organized in similar ways across the various subdisciplines of ecology? What about more broadly across the natural and social sciences? Ralph Lewis (links below) argues that theories are the structure of scientific knowledge. Do you agree? Consider this definition of theory offered by Pope John Paul (1997): “A theory is a metascientific elaboration, distinct from the results of observation but consistent with them. By means of it a series of independent data and facts can be related and interpreted in a unified explanation. A theory's validity depends on whether or not it can be verified; it is constantly tested against the facts; wherever it can no longer explain the latter, it shows its limitations and unsuitability. It must then be rethought.”

In preparation for our meeting, outline two theories from your discipline by writing out the key postulates. On the next pages find a few examples from my teaching and research. One of your theories should be a foundation concept in your discipline and the other an interesting up-and-coming theory. To make it easy, here is a powerpoint template designed for one slide per theory. Be prepared to explain each of your theories in just a few minutes. Also, consider their context in the broader structure of knowledge and their utility in bringing order to knowledge.

The readings below are optional but might be of interest now or later. Every scientist should read Forscher's metaphor about bricks and edifice. Lewis gives suggestions for parsing theories; note that he was influenced by George Miller, who argued that human brains do well at handling about 7 things (e.g., postulates?) at a time. McComas discusses the use of theories in high school biology texts...Turchin and Belovsky et al consider the state of theory in ecology theory.


The magical number seven, plus or minus two: some limits on our capacity for processing information. by George A. Miller, originally published in The Psychological Review, 1956, vol. 63, pp. 81-97

Some additional readings on theory in ecology and evolutionary biology here
Appendix 1. A few examples of theories (according to Matt Ayres)
Notice that all have the general structure of having a modest number of postulates (often about 5), which, if true, permit some statements about nature that are more general than any of the postulates by themselves (“Therefore, ...”). Theories do not have to be true, just logical.

1. PHENOLOGICAL RACE HYPOTHESIS (Ayres 1993)
   Postulates
   P₁: Mature leaves are of lower nutritional quality for insect herbivores than immature leaves.
   P₂: Insects have lower survival and fecundity when they eat leaves of lower nutritional quality.
   P₃: Insect development rate is temperature-dependent.
   P₄: Leaf maturation rate is temperature-dependent.
   P₅: Insect development and leaf maturation have different temperature responses.
   Therefore, insect herbivores that feed in the spring are engaged in a developmental race with their host plants. Depending on the temperatures, the insects or the leaves might complete development first. Insect abundance tends to increase when they win the developmental race.

2. LIEBIG’S LAW OF THE MINIMUM
   Postulates
   P₁: Plant growth requires many different resources (e.g., H₂O, sunlight, N, P, K, CO₂)
   P₂: The relative availability of different essential resources may vary dramatically from site to site and year to year
   P₃: Each resource fills unique physiological needs of the plant
   P₄: One resource cannot be substituted for another.
   Therefore, plant growth is limited by the one resource that is least available relative to physiological needs of the plant. However, the limiting resource can vary depending upon the environment.

   Postulates
   P₁: Plants will allocate resources towards growth until water, nutrients, or carbohydrates limit further growth
   P₂: Tissue growth is negatively associated with tissue differentiation because:
       1. They compete for the same pool of carbohydrates
       2. Differentiation processes require mature intracellular architecture
   P₃: Sink-limited plants tend to be differentiation-dominated; source-limited plants tend to be growth-dominated
   P₄: Differentiation dominated plants have relatively high allocation to secondary metabolism
   Therefore, plant growth tends to be inversely related to defense. Water or nutrient limitations tend to increase plant defenses, even as they constrain plant growth.
4. A THEORY OF ANTHROPOGENIC CLIMATE CHANGE

Postulates

P₁: Atmospheric concentrations of CO₂ are increasing.

P₂: Anthropogenic combustion of fossil fuels account for the increases in CO₂.

P₃: CO₂ is permeable to shortwave radiation (e.g., incoming sunlight) but tends to reflect longwave radiation (e.g., radiant heat from the surface of the earth). That is, CO₂ is a greenhouse gas.

P₄: Realistic simulations of atmospheric dynamics, ocean current systems, and global energy flux indicate that the increases in CO₂ will lead to meaningful climate warming and significant alterations of precipitation patterns.

P₅: The attributes of individuals, populations, communities, and ecosystems will change as a result of projected alterations in temperature, precipitation, CO₂, and cloud cover.

Therefore, human combustion of fossil fuels is altering the planetary ecosystem, and a continuation of current patterns in human energy use will have global impacts (probably some of them deleterious) on biodiversity, agriculture, forestry, recreation, water supplies, ocean levels, disease, economics, urban geography, and other aspects of human society.

5. THEORY OF EVOLUTION BY NATURAL SELECTION (DARWIN 1859)

Postulates

P₁: All populations have potential for exponential growth

P₂: Resources are limited therefore not all individuals survive and reproduce

P₃: Individuals within a population vary

P₄: Some variable traits have a heritable basis

P₅: Some heritable traits are linked to fitness

Therefore natural selection occurs and the fit of organisms to their environment tends to improve.

6. FICK’S LAW OF DIFFUSION

\[
R = D \cdot A \cdot \frac{\Delta p}{d}
\]

Where:

- \( R \) = Rate of diffusion (moles / sec)
- \( D \) = Diffusion constant; value depends upon material through which diffusion is occurring (cm² / sec)
- \( A \) = Area across which diffusion is occurring (cm²)
- \( \Delta p \) = Difference in partial pressures or concentration across diffusion surface (mm Hg or moles / cm³)
- \( d \) = Distance a molecule must travel to reach the area of lower concentration; e.g., membrane thickness (µm)

Therefore, the effect of \( D, A, \Delta p, \) and \( d \) on diffusion of O₂ is as described by the equation, which permits understanding of the adaptations of organisms for oxygen acquisition.
Bio 133: Frontiers of statistics in Ecology & Evolution

For this week’s meeting, bring three interesting examples from your field of using statistics to draw inferences about nature from data. Bring one example from each of the following schools of statistical inference:

1. Frequentist statistics
2. Information theory and multimodel comparison
3. Bayesian statistics

Below are some references that you should be aware of and might even want to look at. This is truly a frontier. Think wild, wild west. I welcome additional references that would be of value to the next cohort of EEES students. Following are some visualizations of historical use in primary and secondary literature of technical vocabulary from statistics.


Evaluate their thesis that “tests of statistical null hypotheses have relatively little utility in science and are not a fundamental aspect of the scientific method.”


Awesome recreational reading.


Some other references


Related editorial in *Nature* by Regina Nuzzo: "*P* values, the gold standard of statistical validity, are not as reliable as many scientists assume."

Why is the *P* value under attack now after reigning for decades? Is this a trajectory or just a blip? For a somewhat different viewpoint see editorial in *Nature* by Jeffrey T. Leek and Roger D. Peng: *P* values are just the tip of the iceberg.


Is Forber in agreement with Popper (and frequentists?) that we tend to learn the most when we eliminate possibilities?

http://www.dartmouth.edu/~mpayres/teaching/gradprogram/bayesian.htm
http://www.dartmouth.edu/~bio125/meet5.htm

Biol 152. Fall 2014. “Bayesian methods for statistical modeling and inference in ecology.” Nina Lany. Last year, Nina Lany (then finishing her PhD) developed and taught our first ever EEB course on Bayesian statistics. It overflowed with students, including many from other departments. Within this package, you can find Nina’s syllabus, which, among other things, contains more readings on Bayesian stats than I offered you.

Make a note that Bio 152, to become EEES 152, is a course number for courses developed and taught by PhD candidates in our program. Nina’s was a terrific success. Consider the possibilities for yourself a couple years from now.
From publication of Bayes Theorem in 1763 (shortly after death of Thomas Bayes who derived it)

See closeup of recent on next page

Google books Ngram Viewer
Invention of frequentist statistics by Ronald A. Fisher, who also invented the word “Bayesian” (as a derogatory descriptor of those who used Bayes Theorem).

Invention of information theory (1948) by Claude E. Shannon of Bell Labs.

Invention of “information criteria” (now AIC) by Hirotugu Akaike. Akaike (1974) is reported by Wikipedia to be “the 73rd most-cited research paper of all time.”
History of information theory in EEB

ecology AND (Akaike OR AIC OR information criteri*) in Web of Science

evolution AND (Akaike OR AIC OR information criteri*) in Web of Science
Bayes* AND ecology in Web of Science

Bayes* AND evolution in Web of Science (excluding some research areas that were apparently noise in the search)

History of Bayes theorem in EEB
An explosion in application of “mixed models”
AIC = -2 \log(\text{likelihood}(\hat{\theta})|\text{data}) + 2K

P(A|B) = \frac{P(B|A)P(A)}{P(B)}
I think a good take-home message might be that the model you choose is independent of the method you choose to analyze it (frequentist vs Bayesian vs other choices). There is a lot of misconception about this. The model for linear regression (or hierarchical logistic regression or any other model) is the same whether you use Bayesian or frequentist inference on the parameters.

Along the same lines, you might want to highlight how similar Bayesian and frequentist methods really are - they are both statistical, which means they have an underlying model. Algorithmic (non-statistical) techniques such as machine learning regression trees do not have an underlying model and therefore cannot be used to infer process from pattern (i.e. it’s generally not possible to use them to map between theory, model and data, although they are awesome when the task at hand is accurate prediction for a specific problem).

My top reasons to try a Bayesian approach are:
1. Writing a model in the BUGS language (or STAN or another probabilistic programming language) is a great way to understand/articulate the model you’re using to describe how the world works. I didn’t really understand linear regression or ANOVA until I wrote out the models in BUGS.
2. Some really powerful tools for inference in a Bayesian framework have been developed.
3. Expert opinion and prior knowledge are important sources of information that we don’t have to ignore.
4. I like how intuitive it is to directly calculate the probability that a parameter has a certain value.

Here's a few papers on including informative priors/expert opinion, although that’s not personally why I use Bayesian mode of inference
Potential reasons to go Bayesian, according to Matt

• When it permits the model to match the natural structure of the system under study (especially when there are hierarchies of interacting distributions and functions).

• When it facilitates computational solutions (e.g., fitting complex mixed models that would require weeks of cluster time to solve by ML).

• When there are informative priors (especially when the relevant data are growing year by year; e.g., fish and wildlife management, range management).

• When it aids in communication (e.g., making it easier to describe what we know rather than what we have rejected).

• Mathematical purity of using Bayes Theorem over a hodgepodge of other techniques.

• Bayes theorem is the antidote to a frequentist approach to statistics that is flawed at the core (“p-values don’t really mean what people think.”) Note that this is contentious -- at least. I would describe it as an extreme viewpoint of the fanatical fringe.
Bayesian methods for statistical modeling and inference in ecology

Intellectual motivation:
Bayesian analysis is a tool available to ecologists that can be useful, and Bayesian approaches are increasingly being used as a method for learning from data. This seminar will provide both theoretical and pragmatic introduction to Bayesian approaches to inference in ecological studies, emphasizing the construction of probabilistic models that articulate our idea of how ecological processes work. Additionally, we will use tools that facilitate best practices in collaborative code-writing and version control.

Objectives:
1. Develop literacy in Bayesian methods through readings and lecture
   - Theory
   - Statistical distributions; choice of prior; conjugate priors
   - MCMC: Metropolis Hastings & Gibbs sampling
   - Read some methods and applications papers
2. Develop competency in Bayesian methods though hands-on activities
   - Construct a probability model that clearly describes an ecological process
   - Implement general and generalized linear models using the BUGS model language and open-source software (e.g. OpenBUGS, JAGS, R)
   - Implement mixed and/or hierarchical models
   - Implement ‘occupancy’ or ‘survival’ state-space models
3. Use tools (e.g. github) for collaboration and version control

Syllabus:
Oct 13 – Nov 14th (5 weeks x 2 meetings per week X 1.5 hours)
We will cover objectives 1 & 2 in order.

Reading List:


Plus additional current papers selected by participants.

Course leader: Nina Lany
Faculty advisors: Kathy Cottingham, Matt Ayres
Preliminary list of Participants: Carissa Aoki, Braden Elliott, Zak Gezon, Tom Kraft, Nina Lany, Tyler Pavlowich, Chelsea Vario, Marcus Welker. Additional interest in coming to some or all sessions from Lixi Kong, Kes Schroeder, Aaron Weed, D.G. Webster.
Follow-up to: *Biostats in 2015: The wild, wild west.*

I encourage you all to:

1. Become proficient with the theory and practice of multimodel inference via information theoretic approaches. For many of us, multimodel inference now competes with null hypothesis testing as the tool of more frequent use.
2. Become one with the simple expression and interpretation of Bayes Theorem. At least so far, this is not a tool of daily use for most of us, but the well-heeled ecologist needs at least a simple understanding. See enclosure.
3. Work through the calculations of some simple statistical model, e.g., a linear regression, via:
   a. Ordinary least squares (OLS to its friends)
   b. Maximum likelihood (ML to friends)
   c. Bayes theorem with non-informative priors;
4. Compare results of hypothesis testing with OLS vs. maximum likelihood
5. Compare metrics of information content (e.g., AIC) with solutions from OLS vs. maximum likelihood.

For understanding the relations between maximum likelihood and OLS, I like:

For multimodel inference, I like:

\[ \text{AIC} = -2 \log (\text{likelihood}(\hat{\theta}|\text{data})) + 2K \]