Ecological Genetics

ENY 6905 (2 Graduate Credits)

Course instructor: Walter J. Tabachnick wjt@ufl.edu 772-778-7200 x190
Florida Medical Entomology Laboratory
Department of Entomology and Nematology
University of Florida
200 9th St., SE
Vero Beach, FL 32962

Office hours: Monday 1:00 PM – 2:00 PM
Office hours will be conducted by the instructor on the e-Learning Canvas system. Students can contact the instructor using the Chat Room tab.

Venue and time: This course will be managed by e-Learning in Canvas (a broadband internet connection is strongly suggested). See the course schedule for suggested module section review dates. Since this is an online course, lectures may be viewed at any time after the beginning of the semester. Students must view modules and study from them before examination dates on the covered material.

The timeline for modules is provided as a strong suggestion for completing the course by the end of the semester without rushing. If you choose to complete modules faster than the timeline it is your choice. Be advised that the dates for submitting assignments are requirements. If you are late you will lose points for that component of your grade. The dates listed for the exams are final and will not be adjusted.

Course description: This course covers the evolutionary processes that influence genetic diversity within and between natural populations. Students will learn about the factors that shape genetic diversity in natural populations with emphasis on those aspects that are important to the ecology of populations and species.

Course overview: Ecological Genetics is an in-depth introduction to features of genetic diversity and the ecology of natural populations. The course is an overview of genetic variation, its measurement, quantitative genetics, and the forces responsible for the origin and maintenance of genetic variation in natural populations. The focus is on the ecological and evolutionary forces that shape genetic variation within and between natural populations and species. Students will learn about ecological genetic concepts useful for those interested in ecology, conservation, wildlife, and medicine. Students will obtain teaching experience by providing an on-line teaching module on a topic of their choosing with prior approval by the instructor. The course is provided in an online format.

General course Information:

Each major topic subject is comprised of discrete modules to provide distance students shorter sections that are intended to allow better time utilization and a better learning experience using the distance online platform. To facilitate teacher-student interaction, students may contact the instructor using the web Chat Room, via e-mail, or directly via telephone. Questions pertaining to the course organization, course structure and course policies should be sent to the instructor. All course communications will be via the course web site. Students are responsible for all notices and course updates that are posted using these methods and should notify the instructor immediately if they experience any difficulty in electronic communications.

Course objectives: Upon successful completion of this course students shall be able to:

1) Explain the fundamental processes that shape genetic diversity within and between natural populations.
2) Assess the genetic basis of quantitative traits and how to characterize and measure the degree of genetic and environmental variation contributing to quantitative trait variation and the ecological genetics of natural populations.
3) Explain the significance and evolution of adaptations in natural populations that influence the ecology of natural populations and species.
4) Integrate the roles of sexual selection, molecular evolution and neutral evolution into the evolution and ecological genetics of natural populations.
5) Apply ecological genetics to understanding conservation genetics, the evolution and spread of invasive species, the use and application of genetically modified organisms and the evolution of resistance in natural populations to pesticides in plants and insects, and to drug resistance in various pathogens.

Topic outline: The following general topics will be provided in different course modules:

1. **Introduction**
   Ecological Genetics
   Evolutionary Biology
   Basic Genetic Terms
2. **Population Genetics**
   Measuring Genetic Variation: Genetic Markers
   Random Mating: Hardy—Weinberg Equilibrium
   Non-random Mating: Assortative Mating and Inbreeding
   Mutation
   Migration
   Structured Populations and Genetic Drift
   Natural Selection: Single-locus Models
   Synthesis of Population Genetics
   Wright's Shifting Balance Theory

3. **Quantitative Inheritance**
   Mendelian Basis of Continuous Traits
   Types of Gene Action: Additivity, Dominance, Epistasis
   Population Means and Variances
   Breeding Value
   Heritability
   Estimating Additive Variance and Heritability
   Phenotypic Plasticity and Genotype–Environment Interaction
   Correlations among Traits
   Artificial Selection
   QTL Mapping: Molecular Studies of Quantitative Traits
4. **Sexual Selection**
5. **Natural Selection on Phenotypes**
   Definition of Natural Selection; Fitness Functions
   Selective Agents and Targets
   Multiple Traits: Direct and Indirect Selection
   Fitness Components
   Synthesis: Predicting Short-term Multivariate Evolution
6. **Molecular Evolution**
   Nucleotide Substitution Rates
   Neutral Evolution
   Codon Bias
   Genetic Families
   Pseudogenes
7. **Conservation Genetics**
8. **Evolution of Invasive Species**
9. **Ecological Genetics of Genetically Modified Organisms**
10. **Evolution of Resistance to Pesticides, Antibiotics**
11. **Adaptation Paradigm and Ecological Genetics**
    Adaptation
    Exaptation
    Convergent Evolution
12. **Ecological Genetics and Climate Change**
13. **Challenges**

Prerequisites: A course in ecology, General Ecology PCB 4043C or equivalent and a course in genetics, Genetics AGR 3303 or equivalent, or permission of the instructor.

Required and recommended textbooks and materials: Lectures and required reading materials other than the required textbook will be posted on the e-Learning Canvas site along with suggestions for further reading for students interested in more information on topics of interest.

Required Materials: a standard scientific calculator, access to PowerPoint with narrative capabilities.

Required Textbook:
Conner, J.K. and Hartl, D. L. 2004. A Primer of Ecological Genetics. Sinauer Associates, Inc.; Sunderland, Mass.

Student evaluation: Grading will be based on student performance as measured by the total percentage earned of total points on the following assignments that make up the evaluation criteria:

Evaluation Criteria	Points
Exam 1	125
Exam 2	125
Report	100
PowerPoint Module	100

Exams: Exam 1 (midterm) and Exam 2 (final exam) will include short answer, problems and essay questions as provided during the course in the assigned problems. Exams will be provided to students on the online e-learning Canvas site. Each exam will be provided to all students on the same day and at the same pre-arranged time. Students will have 2 hours to complete the exam once the exam has started. Exams are open book/notes, but will be individual efforts. Each student will log in to each exam separately. Students will be graded on the completeness of their answers, accuracy, as well as their demonstrating their insight and ability to use course information.

NOTE: Although exams are open book/notes students should not assume that this will help someone who has not done due diligence in preparing in advance for the examination. The exams will be comprehensive and therefore students who need to rely on notes and books to look up many answers or review notes to gain understanding during the exam will likely be unable to complete the examination in the allotted time. Open book exams mean that students need no memorize equations though if the material is thoroughly used for study finding equations and their use should not require substantial time during the exam.

A good exam grade will require due diligence, i.e., prior study.

<u>Class Teaching Project and Paper:</u> Each student will select a topic as the subject for preparing a PowerPoint presentation and a paper. The PowerPoint presentation will be similar to an online module that will be made available by the instructor to the entire class during the final two weeks of the course.

1. Students will each select a specific topic that illustrates an ecological genetics concept discussed in the course.
2. The topic will be selected from among the "suggested readings" provided by the instructor or the student can select another paper and topic with the instructor's approval.
3. The topic can be addressed using one of the suggested readings as the basis or another approved reading to convey or illustrate an interesting and/or significant aspect of ecological genetics. Additional current literature should be cited to convey the major points.
4. Students will obtain approval for their topic and the paper from the instructor no later than week 8 of the semester.
5. To avoid duplication of topics and/or papers student requests will be approved by the instructor on a first request basis. The instructor will provide the class with a weekly update of which topics or papers have already been assigned.
6. Students will provide the instructor with their topic, the selected suggested reference to use as the basis of the project, and a brief description of the major points they intend to convey to the class with a justification of their importance in learning about ecological genetics
7. The written report must be at least 5, but no more than10 double-spaced pages in length not including the reference list, tables, graphs and figures.
8. The written report will be due during Week 15.
9. Students will prepare a 15-20 minute PowerPoint presentation on the same subject as their written report. The PowerPoint will include a voice narrative provided by the student.
10. The PowerPoint is to be prepared in the format of the course modules provided by the instructor, i.e., start with goals of the module, present issues, data, and examples, conclude with a summary of major points.
11. Each student PowerPoint will be completed by Week 11 and will be provided to the instructor no later than the Friday of Week 11. The instructor will provide the submitted module to the entire class using the course web site as part of the course modules viewed by the class. Material provided in the student PowerPoints will be included on the Final Exam.
12. Students will be responsible for the material provided in the student presentations.
13. Students will be graded on their report and presentation for clarity, ease of understanding, accuracy, and presentations will also be graded for conveying major points using concise clear verbal and pictorial

methods, and creative use of PowerPoint as a vehicle for teaching their colleagues.

Recommended Problems: Several recommended problems are provided to allow students practice in applying the information after the relevant modules and readings. Though recommended, completing these problems is not part of the grade or student performance. It is strongly advised that students complete the problems as they will see similar problems on the exams. Answers to the problems will be provided by the instructor via the on-line course site.

Policy related to class attendance: The course is offered through e-learning in Canvas. Lectures are recorded comprised of discrete modules and made available from the start to the end of the semester. As a result no specific class attendance is taken and students can view the various modules at their convenience. However, students are expected to participate any on line discussion topics and must do so within the week that the discussion topic is placed on line and open. Students are expected to view lecture modules, read course materials in the textbook, complete the approval process for their PowerPoint presentation by the due date, and provide a completed PowerPoint module that can be distributed to the entire class by the instructor by the due date.

Policy related to make-up exams or other work: In general, acceptable reasons to make-up exams or other course related work is limited to serious illness, family emergencies, military obligation, or court imposed legal obligations. Students who have excused absences for University sponsored groups must arrange for missed examinations ahead of the exam with the lead instructors. Other reasons may also be approved but will be taken into consideration on a case-by-case basis.

Requirements for class attendance and make-up exams, assignments and other work are consistent with university policies that can be found at: https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx

Grades and Grade Points: This course does NOT utilize "plus" or "minus" grades. Although the following link is for the undergraduate catalog, it applies to graduate students. For information on current UF policies for assigning grade points, see https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx
The grading scale for this course is as follows:

Grading scale

% of Total Points	Total Points	Grade
90-100	405-450	A

80-89.99	360-404	B
70-79.99	315-359	C
60-69.99	270-314	D
<60	<270	F

Online Course Evaluation Process: Student assessment of instruction is an important part of efforts to improve teaching and learning. At the end of the semester, students are expected to provide feedback on the quality of instruction in this course using a standard set of university and college criteria. These evaluations are conducted online at https://evaluations.ufl.edu. Evaluations are typically open for students to complete during the last two or three weeks of the semester; students will be notified of the specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results.

Each online distance learning program has a process for, and will make every attempt to resolve, student complaints within its academic and administrative departments at the program level. See http://distance.ufl.edu/student-complaints for more details.

Academic Honesty: In 1995 the UF student body enacted an honor code and voluntarily committed itself to the highest standards of honesty and integrity. When students enroll at the university, they commit themselves to the standard drafted and enacted by students.

The Honor Pledge: **We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity.**
On all work submitted for credit by students at the university, the following pledge is either required or implied: **"On my honor, I have neither given nor received unauthorized aid in doing this assignment."**

Students should report any condition that facilitates dishonesty to the instructor, department chair, college dean, Student Honor Council, or Student Conduct and Conflict Resolution in the Dean of Students Office. *(Source: 2011-2012 Undergraduate Catalog)*

It is assumed all work will be completed independently unless the assignment is defined as a group project, in writing by the instructor.

This policy will be vigorously upheld at all times in this course.

Software Use: All faculty, staff and students of the university are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against university policies and rules, disciplinary action will be taken as appropriate.

Campus Helping Resources: Students experiencing crises or personal problems that interfere with their general well-being are encouraged to utilize the university's counseling resources. The Counseling & Wellness Center provides confidential counseling services at no cost for currently enrolled students. Resources are available on campus for students having personal problems or lacking clear career or academic goals, which interfere with their academic performance. *University Counseling & Wellness Center, 3190 Radio Road, 352-392-1575,* **www.counseling.ufl.edu/cwc/**

Counseling Services
Groups and Workshops
Outreach and Consultation
Self-Help Library
Training Programs
Community Provider Database
Career Resource Center, First Floor JWRU, 392-1601, **www.crc.ufl.edu/**

Services for Students with Disabilities: The Disability Resource Center coordinates the needed accommodations of students with disabilities. This includes registering disabilities, recommending academic accommodations within the classroom, accessing special adaptive computer equipment, providing interpretation services and mediating faculty-student disability related issues.
0001 Reid Hall, 352-392-8565, **www.dso.ufl.edu/drc/**

Plagiarism: Plagiarism is a serious violation of the Student Honor Code. The Honor Code prohibits and defines plagiarism as follows: Plagiarism. A student shall not represent as the student's own work all or any portion of the work of another. Plagiarism includes (but is not limited to):

a. Quoting oral or written materials, whether published or unpublished, without proper attribution.
b. Submitting a document or assignment which in whole or in part is identical or substantially identical to a document or assignment not authored by the student. (University of Florida, Student Honor Code, 15 Aug. 2007 <http://www.dso.ufl.edu/judicial/honorcode.php>)

University of Florida students are responsible for reading, understanding, and abiding by the entire Student Honor Code (http://www.dso.ufl.edu/sccr/honorcode.php).

ECOLOGICAL GENETICS
COURSE SCHEDULE
ALS 6905, 2 credits

Modules

		READING	RECOMMENDED PROBLEMS*
Week 1			
1.	Introduction, What is Ecological Genetics	Chapter 1	
2.	Evolution Fact and Theory		
3.	Evolution Adaptation, Speciation		
Week 2			
4.	Genetics Review		
5.	Measuring Variation, Molecular Polymorphism	Chapter 2	
6.	Population Genetics – Hardy Weinberg	Chapter 2	2.1-2.5
Week 3			
7.	Population Genetics – Mutation	Chapter 3	
8.	Population Genetics – Migration	Chapter 3	
9.	Population Genetics – Non-Random Mating, Inbreeding	Chapter 3	3.1
Week 4			
	Student Presentation and Report Suggestions (Chat Room)		
10.	Population Genetics – Drift	Chapter 3	
11.	Population Genetics – Population differentiation, F	Chapter 3	3.2, 3.3
Week 5			
12.	Population Genetic – Selection	Chapter 3	
13.	Population Genetics – Frequency dependent, Migration/selection, mutation/selection	Chapter 3	3.5-3.7
14.	Population Genetics – Selection	Chapter 3	
Week 6			
15.	Neutral Evolution		
16.	Neutral Evolution		
	Population Genetics – Review Modules 1-16 (Chat Room)		
Week 7			
II.	**EXAM 1 (MIDTERM)**		
Week 8			
	APPROVAL FOR TOPIC FOR COURSE PROJECT DUE		
17.	Quantitative Genetics – Introduction	Chapter 4	
18.	Quantitative Genetics – Measuring Variation, h^2	Chapter 4	
19.	Quantitative Genetics – Breeding, ANOVA	Chapter 4	4.1-4.3

Week 9

20.	Quantitative Genetics – Genetic Correlation	Chapter 5	
21.	Quantitative Genetics – QTL Mapping	Chapter 5	5.1, 5.4
22.	Natural Selection on Phenotypes	Chapter 6	6.1

Week 10

23.	Selection Interactions		
24.	Kin Selection		
25.	Sexual Selection		

Week 11

26.	Sexual Selection Models		
27.	Sexual Selection Fitness		
28.	Evolution of Sex		

Week 12 **STUDENT NARRATIVE POWERPOINT MODULE DUE**

29.	Invasion Genetics		
30.	Conservation Genetics	Chapter 7	
31.	Conservation Genetics	Chapter 7	

Week 13

32.	Genetically Modified Organisms	Chapter 7	
33.	Resistance – Insecticide, Pesticides, Antibiotics	Chapter 7	
34.	Climate Change	Assigned	

Week 14

35.	Adaptation Paradigm and Ecological Genetics	Assigned	
36.	TBA (To Be Announced) Student Modules		

Week 15 **STUDENT WRITTEN PROJECT REPORTS DUE**

37.	TBA Student Modules		

Week 16

EXAM 2 (FINAL EXAM)

Answers to problems will be provided to student's ca. 1 week after the week in which they were recommended. Modules are of varying lengths but average ca. 30-50 minutes.

PDF files (low resolutions) of the PowerPoint slides in each module are provided to assist in review of the material and time management.

Suggested Readings for Course Projects

STUDENTS SHOULD SELECT TOPICS THAT ARE RELATED TO THEIR INDIVIDUAL INTERESTS. THE FOLLOWING READINGS ARE MEANT TO OFFER SUGGESTIONS.

Genetic Diversity

Caplins, S. A., K. J. Gilbert, C. Ciotir, J. Roland, S. F. Matter and N. Keyghobadi. 2014. Landscape structure and the genetic effects of a population collapse. Proc Biol Sci. 281(1796).

Crespi, B. J. 1989. Causes of assortative mating in arthropods. Anim. Behav. 38: 980-100.

Keller, L. F. and D. M. Waller. 2002. Inbreeding effects in wild populations. Trends Eco. And Evol. 17:230-241.

Hughes, A. R., B. D. Inouye, M. T. Johnson, N. Underwood and M. Vellend. 2008. Ecological consequences of genetic diversity. Ecol Lett. 11(6): 609-23.

Gene Flow

Crispo, E. 2008. Modifying effects of phenotypic plasticity on interactions among natural selection, adaptation and gene flow. J. Evol. Biol. 21(6): 1460-1469.

Ellstrand, N. C. 2014. Is gene flow the most important evolutionary force in plants? Am. J. Bot. 2014 Apr 21;101(5):737-753.

Sexton, J. P., S. B. Hangartner and A. A. Hoffmann. 2014. Genetic isolation by environment or distance: which pattern of gene flow is most common? Evolution 68(1): 1-15.

Via, S. 2012. Divergence hitchhiking and the spread of genomic isolation during ecological speciation-with-gene-flow. Philos Trans R Soc Lond B Biol Sci. 367(1587):451-60.

Selection

Anderson, J. T., M. R. Wagner, C. A. Rushworth, K. V. Prasad and T. Mitchell-Olds. 2014. The evolution of quantitative traits in complex environments. Hered. 112(1): 4-12.

Gilks, W. P., J. K. Abbott and E. H. Morrow. 2014. Sex differences in disease genetics: evidence, evolution, and detection. Trends Genet. 30(10): 453-463.

Leinonen T., R. J. McCairns, R. B. O'Hara and J. Merilä. 2013. Q(ST)-F(ST) comparisons: evolutionary and ecological insights from genomic heterogeneity. Nature Rev. Genet. 14(3): 179-190.

Nosil, P., D. J. Funk and D. Ortiz-Barrientos. 2009. Divergent selection and heterogeneous genomic divergence. Mol. Ecol. 18(3): 375-402.

Stearns, S. C., S. G. Byars, D. R. Govindaraju and D. Ewbank. 2010. Measuring selection in contemporary human populations. Nature Rev. Genet. 11(9): 611-622.

Wade, M. J. and S. Kalisz. 1990. The causes of natural selection. Evolution44: 1947-1955.

Adaptation

Anderson, J. T., J. H. Willis and T Mitchell-Olds. 2011. Evolutionary genetics of plant adaptation. Trends Genet. 27(7): 258-266.

Ayala, D., A. Ullastres and J. Gonzalez. 2014. Adaptation through chromosomal inversions in *Anopheles*. Front. Genet. 5: 1-10.

Chapman, M. A., S. J. Hiscock and D. A. Filatov. 2013. Genomic divergence during speciation driven by adaptation to altitude. Mol. Biol. Evol. 30(12): 2553-2567.
Savolainen, O., M. Lascoux, and J. Merila. Ecological genomics of local adaptation. Nature Rev. Genet. 14: 807-820.
Stern, D. L. 2013. The genetic causes of convergent evolution. Nat. Rev. Genet. 14(11): 751-764.
Storz, J. F. 2005 Using genome scans of DNA polymorphism to infer adaptive population divergence. Mol. Ecol. 14(3): 671-688.
Welch, J. J. and C. D. Jiggins. 2014. Standing and flowing: the complex origins of adaptive variation. Mol. Ecol. 23: 3935–3937.

Quantitative Inheritance

Fu W., T. D. O'Connor and J. M. Akey. 2013. Genetic architecture of quantitative traits and complex diseases. Curr. Opin. Genet. Dev. 23(6): 678-683.
Lawson, H. A., J. M. Cheverud and J. B. Wolf. 2013. Genomic imprinting and parent-of-origin effects on complex traits. Nat. Rev. Genet. 14(9): 609-617.
Mackay, T. F. 2014. Epistasis and quantitative traits: using model organisms to study gene-gene interactions. Nat. Rev. Genet. 15(1): 22-33.
Mackay, T. F. C. 2009. Mutations and quantitative genetic variation: lessons from *Drosophila*. Phil. Trans. R. Soc. B 365: 1229–1239.
Meyer, R. S. and M. D. Purugganan. 2013. Evolution of crop species: genetics of domestication and diversification. Nature Rev. Genet. 14(12): 840-852.
Schielzeth, H. and A. Husby. 2014. Challenges and prospects in genome-wide quantitative trait loci mapping of standing genetic variation in natural populations. Ann. N. Y. Acad. Sci. 1320(1): 35-57.
Solberg Woods L. C. 2014. QTL mapping in outbred populations: successes and challenges. Physiol. Genomics. 46(3):81-90.
Vinkhuyzen, A.A., N. R. Wray, J. Yang, M. E. Goddard and P. M. Visscher. 2013. Estimation and partition of heritability in human populations using whole-genome analysis methods. Annu Rev Genet. 2013;47:75-95.

Conservation/Invasion Genetics

Allendorf, F. W., P. A. Hohenlohe and G. Luikart. 2010. Genomics and the future of conservation genetics. Nat. Rev. Genet. 11(10): 697-709.
Bohmann, K., A. Evans, M. Thomas, P. Gilbert, G. R. Carvalho, S. Creer, M. Knapp, D. W. Yu. and M. de Bruyn. 2014. Environmental DNA for wildlife biology and biodiversity monitoring. Trends in Ecol. Evol. 26(6): 358-367.
Burdon, J. J., P. H. Thrall and L. Ericson. 2013. Genes, communities & invasive species: understanding the ecological and evolutionary dynamics of host-pathogen interactions. Curr Opin Plant Biol. 16(4): 400-405.
Ernest, H. B., T. W.Vickers, S. A. Morrison, M. R. Buchalski and W. M. Boyce. 2014. Fractured genetic connectivity threatens a southern California puma (*Puma concolor*) population. PLoS One. 9(10):e107985.
Moritz, C. 1994. Defining ‘Evolutionary Significant Units’ for conservation. Trends Ecol. Evol. 9: 373-375.

Parker, I. M., J. Rodriguez and M. E. Loik. 2003. An evolutionary approach to understanding the biology of invasions: local adaptation and general purpose genotypes in the weed Verbascum Thapsus. Conserv. Biol. 17: 59-72.

Ecological Genetics of Infectious Disease

Biek, R. and L. A. Real. 2010. The landscape genetics of infectious disease emergence and spread. Mol. Ecol. 19(17): 3515–3531.

Carroll, S. A., J. S. Towner, T. K. Sealy, L. K. McMullan, M. L. Khristova, F. J. Burt, R. Swanepoel, P. E. Rollin and S. T. Nichol. 2013. Molecular evolution of viruses of the family Filoviridae based on 97 whole-genome sequences. J. Virol. 87(5): 2608-2616.

Gire, S. K. et al. 2014. Genomic surveillance elucidates Ebola virus origin and transmission during the 2014 outbreak. Science 345: 1369-1372.

Holmes, E. C. 2013. What can we predict about viral evolution and emergence? Curr Opin Virol. 3(2): 180–184.

Moya, S., S. F. Elana, A. Bracho, R. Miralles and E. Barrio. 2000. The evolution of RNA viruses: A population genetics view. Proc. Nat. Acad. Sci. USA 97(13): 6967-6973.

Tabachnick, W. J. 2013. Nature, nurture and evolution of intra-species variation in mosquito arbovirus transmission competence. Int. J. Environ. Res. Public Health 10: 249-277.

Ecological Genetics and Climate Change

Franks, S. J., and A. A. Hoffmann. 2012. Genetics of climate change adaptation. Annu. Rev. Genet. 46: 185-208.

Hoffman, A. A. and C. M. Sgro. 2011. Climate change and evolutionary adaptation. Nature: 470: 479-485.

Pauls, S. U., C. Nowak, M. Bálint and M. Pfenninger. 2013. The impact of global climate change on genetic diversity within populations and species. Mol. Ecol. 22(4): 925-946.

Shaw, R. G. and J. R. Etterson. 2012. Rapid climate change and the rate of adaptation: insight from experimental quantitative genetics. New Phytol. 195(4): 752-765.

Wymore, A. S., A. T. Keeley, K. M. Yturralde, M. L. Schroer, C. R. Propper and T. G. Whitham. 2011. Genes to ecosystems: exploring the frontiers of ecology with one of the smallest biological units. New Phytol. 2011 Jul;191(1):19-36.