Fall 2021

BIOS 4590A
RESEARCH PROJECT LAB

Instructor:
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Lecture: Cherry Emerson building room 204; Monday 3:30 pm – 4:20pm.
Lab: Boggs room 1-59; Monday: 12:30 pm – 3:15 pm, Wednesday: 12:30 pm - 3:15 pm.

An important note on COVID: This is an unprecedented time. We all agree that the best way for you to learn is face-to-face. If we are required to move to an online format because of a covid outbreak, we are able to help you learn the course content remotely. Whether we meet in-person versus remotely could change depending upon health status of individuals in classroom. You have a definite stake in your personal health and the community's health.

Expectations: Our expectation is that everyone who is eligible will be vaccinated; vaccination significantly reduces likelihood of severe disease, including from the delta variant of SARS-CoV-2. Because the delta variant can be spread by vaccinated individuals, we expect that everyone who is able to should wear a mask, correctly covering mouth and nose, when indoors. Both of these expectations are based on current CDC guidance. As that guidance is updated, we will communicate any new expectations.

Weekly asymptomatic surveillance testing should be part of everyone's regular routine, regardless of vaccination status. Details are here: https://health.gatech.edu/coronavirus/testing.

Course description: Students will gain experience in designing, implementing, and communicating a biology research project, and practical training in modern approaches for biological research. This section will have a scientific theme of ***Causes and Consequences of Biodiversity***. Students will design and run projects to explore how various ecological factors influence one or multiple dimensions of biodiversity (e.g., species diversity, genetic diversity, functional diversity, phylogenetic diversity) and/or how changes in biodiversity influence ecological properties at the species, community, or ecosystem levels.

BIOL 4590 is a 3-credit lab-based course. BIOL 4460 (Communicating Biological Research) is a co-requisite for BIOL 4590 because students will present their research from BIOL 4590 in Communicating Biological Research. Students enrolled in BIOL 4590 can sign up for any section of BIOL 4460 during the same or following semester.

Because this is a lab-based course, attendance and active participation are required. We expect absences to be rare, and each unexcused lab absence will lower your final grade by 5%. Examples of excusable absences include documented illness, death in the family, accident, and sanctioned institute events. If you know that you are going to be absent from a lab, you must let the instructor know ahead of time. Unexcused absences from lecture sessions will lower the course participation grade.

Office hours: By appointment. Please email or consult with instructor or TA during class to set up a virtual meeting. Students are also welcome to visit the instructor to talk about issues other than course material (e.g., career plans).

Optional text: "Writing papers in the Biological Sciences" by Victoria E. McMillan, publisher: Bedford/St. Martin's, fifth (2011) or sixth (2016) edition.

Lab essentials: You will need to wear lab coats, safety glasses and closed-toe shoes whenever we are working in the lab, and you will need a new lab notebook (*not a 3-ring binder*).

Lab safety: Georgia Tech has a strict policy regarding appropriate clothing in laboratories where chemicals and organisms are used or manipulated. Students not conforming with the following requirements will be asked to leave the lab to acquire appropriate clothing. In the laboratory, students must wear

1) **Long pants**.
2) **Closed-toe shoes** that cover the sides and top of the foot.
3) **Lab coats,** when working at the bench. Lab coats must be 100% cotton and cover the wearer to the knees. Students are responsible for keeping their lab coats in good condition and reasonably clean so as to not create a hazard.
4) **Safety glasses**, when working at the bench. Safety glasses must have side shields for splash protection and conform to the wearer's face. Glasses must be worn over prescription glasses and contact lenses. Georgia Tech Biology provides safety glasses for student use in the lab. Safety glasses prevent eye exposure to liquid reagents and breakables, as well as dangerous substances such as bacteria, toxins, acids or UV light.

Evaluation:

Reading assignments and discussion, and lab notebook checks	**20%**
Written reports on planned experiments	**20%**
Independent research project:	
Proposal	**10%**
Preliminary manuscript	**10%**
Final manuscript	**20%**
Course participation	**20%**

Reading assignments and discussion: Students are expected to read each assigned paper, and take turn leading the discussion of these papers.

Lab notebooks should be handwritten (not typed) in pen and should include original notes you take during the experiment, as well as any preparatory notes you wish to include. Notebooks are graded individually (each student is required to present his/her own notebook). Every page should be numbered (by you if the book doesn't come with numbers). Your notebooks should contain description of the procedures you have performed, and actual/original data. You have to outline experimental steps so that an experienced person (including yourself) should be able to trace your experiments without frequent references to the original detailed procedures or cited references. In addition, it is required that you include all the changes made from the planned procedure, as well as all calculations, measurements/observations, etc.

Written reports on the planned experiment should each be no more than 2 pages of text (single-spaced, 12-point font) plus additional page(s) for figures and references. They should be written in manuscript-style (see recent articles in the journal "Ecology" and instructions for authors for this journal https://esajournals.onlinelibrary.wiley.com/hub/journal/19399170/resources/author-guidelines-ecy for appropriate style). Each student writes their own report, even if they worked in teams for gathering data.

Independent research projects will run from weeks 5-15, in groups of 3-4 people. Groups of students will choose their own project, in consultation with the instructor and TA. Recommended readings and the class discussions are designed to help students come up with an original, manageable project. Although the research will be conducted in groups, each student will write his/her own manuscript, although it is expected that students in each group to work together in analyzing and interpreting their data.

Proposals will be one-page (single-spaced, 12-point font) plans of the project that will be conducted. The proposal should include background and justification (why would anyone want to do this project and why should anyone want to hear about it), a description of hypotheses to be tested (these can be in the form of questions or falsifiable statements), how the hypotheses will be tested (i.e., what experiments will be conducted), and how data will be interpreted. It is also a good idea to include a statement of expected results, and how the results relate to the goals of the project. The proposal can include a few citations, not included in the page limit. If working in a

group, each group of students will submit a single proposal for their project that is approved by all members of the group.

Preliminary manuscripts will consist of the introduction section of the manuscript related to the research of the independent project, written in the style of the journal "Ecology". The introduction should be no more than 4 pages (double-spaced, 12-point font) and should include the background to the research project, why the project is being undertaken (why anyone should care…), and the overall goals of the project. However, it should NOT be written in the future tense as the proposal is written; instead, the introduction should be written as if the project has already been undertaken. Citations should be included at the end of the preliminary manuscript and are not included in the 4-page limit. Feedback from the instructor and TAs on this preliminary manuscript can then be used to improve the introduction for re-submission as part of the final manuscript. If students are working in groups, each student will write his or her own preliminary manuscript.

Final manuscripts will be in the style of the journal "Ecology" and will be no more than 15 pages (double-spaced, 12-point font), plus figures, tables, and citations. The final manuscript must include an abstract, introduction (based upon the preliminary manuscript, with any changes the student wants to make), materials & methods, results, discussion (results & discussion can be combined into one section if desired). Data should be provided in tables and/or figures as appropriate and appropriate legends for tables and figures should be used. There is no limit on the number of citations used; however, students should NOT cite papers that they have not read. Each student will write his or her own final manuscript.

Academic Integrity: Academic dishonesty will not be tolerated. This includes cheating, lying about course matters, plagiarism, stealing classroom materials, or helping others commit a violation of the Honor Code. Students are reminded of the obligations and expectations associated with the Georgia Tech Academic Honor Code and Student Code of Conduct, available online at http://osi.gatech.edu/content/honor-code. While students will collaborate in performing the experiments and collecting the data, each student is expected to write his or her own notebook and manuscript, including creating his or her own tables and figures. Plagiarism includes reprinting the words or ideas of others without citation. As direct quotes are seldom used in scientific writing, you are expected to rephrase the words of others and provide the citation. If this is unclear, please ask your instructor or TAs for help as your write before turning in your assignment.

Learning Accommodations: If needed, we will make classroom accommodations for students with disabilities. These accommodations must be arranged in advance and in accordance with the Office of Disability Services (http://disabilityservices.gatech.edu).

Class calendar (subject to change):

Week	Date	Topic
1	Aug 23	Introduction to course, biodiversity, and laboratory protist microcosms Protist microcosm experiment protocols
	Aug 25	Protist microcosm experiment protocols; prepare for planned experiment #1
2	Aug 30	Discussion on the two planned experiments **Start planned experiment #1: Competition involving two competing species**
	Sept 1	Planned experiment #1: Competition involving two competing species
3	Sept 6	**No class (Labor Day)**
	Sept 8	Planned experiment #1: Competition involving two competing species
4	Sept 13	Discussion on issues related to your proposal; Discussion on experimental design Finish planned experiment #1: Competition involving two competing species
	Sept 15	Planned experiment #2: predation involving one predator and one prey species--functional response measurement ***proposals due in class***
5	Sept 20	Overview of what's expected for independent projects; Discussion to prepare for start of independent projects Start your independent project
	Sept 22	Independent projects ***written report for planned experiment #1 due in class***

6	Sept 27	Discussion of issues related to independent projects; independent projects
	Sept 29	Independent projects ***written report for planned experiment #2 due in class***
7	Oct 4	Discussion of issues related to independent projects; independent projects
	Oct 6	Independent projects
8	Oct 11	**No class (Fall recess)**
	Oct 13	Independent projects
9	Oct 18	Discussion of issues related to independent projects; independent projects
	Oct 20	Independent projects ***preliminary manuscripts due in class***
10	Oct 25	Discussion of issues related to independent projects; independent projects
	Oct 27	Independent projects
11	Nov 1	Discussion of issues related to independent projects; independent projects
	Nov 3	Independent projects
12	Nov 8	Discussion of issues related to independent projects; independent projects
	Nov 10	Independent projects
13	Nov 15	Discussion of issues related to independent projects; independent projects
	Nov 17	Independent projects
14	Nov 22	Discussion of issues related to independent projects; independent projects
	Nov 24	**No class (student recess)**
15	Nov 29	Discussion of issues related to independent projects; independent projects
	Dec 1	Independent projects
16	Dec 6	***Discussion of issues for manuscript***
	Dec 8	Clean up lab ***Final manuscripts due in class***

Note: Joint poster session for all sections of BIOL 4460 4:30-*6pm, Dec 2.*

An initial reading list on the ecological causes and consequences of biodiversity

General information on biodiversity

Barnosky, A. D., N. Matzke, S. Tomiya, G. O. U. Wogan, B. Swartz, T. B. Quental, C. Marshall, J. L. McGuire, E. L. Lindsey, K. C. Maguire, B. Mersey, and E. A. Ferrer. 2011. Has the Earth's sixth mass extinction already arrived? Nature **471**:51-57.

Ceballos, G., P. R. Ehrlich, A. D. Barnosky, A. Garcia, R. M. Pringle, and T. M. Palmer. 2015. Accelerated modern human-induced species losses: Entering the sixth mass extinction. Science Advances **1:** e1400253

Ceballos, G., P. R. Ehrlich, and R. Dirzo. 2017. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. Proceedings of the National Academy of Sciences of the United States of America **114**:E6089-E6096.

Dirzo, R., H. S. Young, M. Galetti, G. Ceballos, N. J. B. Isaac, and B. Collen. 2014. Defaunation in the Anthropocene. Science **345**:401-406.

Dornelas, M., N. J. Gotelli, B. McGill, H. Shimadzu, F. Moyes, C. Sievers, and A. E. Magurran. 2014. Assemblage Time Series Reveal Biodiversity Change but Not Systematic Loss. Science **344**:296-299.

Fierer, N. and R. B. Jackson. 2006. The diversity and biogeography of soil bacterial communities. Proceedings of the National Academy of Sciences of the United States of America **103**:626-631.

Gaston, K. J. 2000. Global patterns in biodiversity. Nature **405**:220-227.

Pereira, H. M., P. W. Leadley, V. Proenca, R. Alkemade, J. P. W. Scharlemann, J. F. Fernandez-Manjarres, M. B. Araujo, P. Balvanera, R. Biggs, W. W. L. Cheung, L. Chini, H. D. Cooper, E. L. Gilman, S. Guenette, G. C. Hurtt, H. P. Huntington, G. M. Mace, T. Oberdorff, C. Revenga, P. Rodrigues, R. J. Scholes, U. R. Sumaila, and M. Walpole. 2010. Scenarios for Global Biodiversity in the 21st Century. Science **330**:1496-1501.

Pimm, S. L., C. N. Jenkins, R. Abell, T. M. Brooks, J. L. Gittleman, L. N. Joppa, P. H. Raven, C. M. Roberts, and J. O. Sexton. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science **344**:1246752.

Vellend, M., L. Baeten, I. H. Myers-Smith, S. C. Elmendorf, R. Beausejour, C. D. Brown, P. De Frenne, K. Verheyen, and S. Wipf. 2013. Global meta-analysis reveals no net change in local-scale plant biodiversity over time. Proceedings of the National Academy of Sciences of the United States of America **110**:19456-19459.

Willig, M. R., D. M. Kaufman, and R. D. Stevens. 2003. Latitudinal gradients of biodiversity: Pattern, process, scale, and synthesis. Annual Review of Ecology Evolution and Systematics **34**:273-309.

Ecological causes of biodiversity

Adler, P. B., J. HilleRisLambers, and J. M. Levine. 2007. A niche for neutrality. Ecology Letters **10**:95-104.

Bell, G. 2001. Ecology - Neutral macroecology. Science **293**:2413-2418.

Bellard, C., C. Bertelsmeier, P. Leadley, W. Thuiller, and F. Courchamp. 2012. Impacts of climate change on the future of biodiversity. Ecology Letters **15**:365-377.

Borer, E. T., E. W. Seabloom, D. S. Gruner, W. S. Harpole, H. Hillebrand, E. M. Lind, P. B. Adler, J. Alberti, T. M. Anderson, J. D. Bakker, L. Biederman, D. Blumenthal, C. S. Brown, L. A. Brudvig, Y. M. Buckley, M. Cadotte, C. Chu, E. E. Cleland, M. J. Crawley, P. Daleo, E. I. Damschen, K. F. Davies, N. M. DeCrappeo, G. Du, J. Firn, Y. Hautier, R. W. Heckman, A. Hector, J. HilleRisLambers, O. Iribarne, J. A. Klein, J. M. H. Knops, K. J. La Pierre, A. D. B. Leakey, W. Li, A. S. MacDougall, R. L. McCulley, B. A. Melbourne, C. E. Mitchell, J. L. Moore, B. Mortensen, L. R. O'Halloran, J. L. Orrock, J. Pascual, S. M. Prober, D. A. Pyke, A. C. Risch, M. Schuetz, M. D. Smith, C. J. Stevens, L. L. Sullivan, R. J. Williams, P. D. Wragg, J. P. Wright, and L. H. Yang. 2014. Herbivores and nutrients control grassland plant diversity via light limitation. Nature **508**:517-520.

Chase, J. M., S. A. Blowes, T. M. Knight, K. Gerstner, and F. May. 2020. Ecosystem decay exacerbates biodiversity loss with habitat loss. Nature:in press.

Chesson, P. 2000. Mechanisms of maintenance of species diversity. Annual Review of Ecology and Systematics **31**:343-366.

Clark, C. M. and D. Tilman. 2008. Loss of plant species after chronic low-level nitrogen deposition to prairie grasslands. Nature **451**:712-715.

Connell, J. H. 1978. Diversity in Tropical Rain Forests and Coral Reefs - High Diversity of Trees and Corals Is Maintained Only in a Non-Equilibrium State. Science **199**:1302-1310.

Crawley, M. J., A. E. Johnston, J. Silvertown, M. Dodd, C. de Mazancourt, M. S. Heard, D. F. Henman, and G. R. Edwards. 2005. Determinants of species richness in the park grass experiment. American Naturalist **165**:179-192.

Damschen, E. I., L. A. Brudvig, M. A. Burt, R. J. Fletcer, N. M. Haddad, D. J. Levey, J. L. Orrock, J. Resasco, and J. J. Tewksbury. 2019. Ongoing accumulation of plant diversity through habitat connectivity in an 18-year experiment. Science **365**:1478-1480.

DeMalach, N., E. Zaady, and R. Kadmon. 2017. Light asymmetry explains the effect of nutrient enrichment on grassland diversity. Ecology Letters **20**:60-69.

DeMalach, N., E. Zaady, and R. Kadmon. 2017. Contrasting effects of water and nutrient additions on grassland communities: A global meta-analysis. Global Ecology and Biogeography **26**:983-992.

Descamps-Julien, B. and A. Gonzalez. 2005. Stable coexistence in a fluctuating environment: An experimental demonstration. Ecology **86**:2815-2824.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology Evolution and Systematics **34**:487-515.

Fahrig, L. 2017. Ecological Responses to Habitat Fragmentation Per Se. Pages 1-23 *in* D. J. Futuyma, editor. Annual Review of Ecology, Evolution, and Systematics, Vol 48. Annual Reviews, Palo Alto.

Haddad, N. M., L. A. Brudvig, J. Clobert, K. F. Davies, A. Gonzalez, R. D. Holt, T. E. Lovejoy, J. O. Sexton, M. P. Austin, C. D. Collins, W. M. Cook, E. I. Damschen, R. M. Ewers, B. L. Foster, C. N. Jenkins, A. J. King, W. F. Laurance, D. J. Levey, C. R. Margules, B. A. Melbourne, A. O. Nicholls, J. L. Orrock, D. X. Song, and J. R. Townshend. 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. Science Advances **1**: e1500052.

Harpole, W. S., L. L. Sullivan, E. M. Lind, J. Firn, P. B. Adler, E. T. Borer, J. Chase, P. A. Fay, Y. Hautier, H. Hillebrand, A. S. MacDougallm, E. W. Seabloom, R. Williams, J. D. Bakker, M. W. Cadotte, E. J. Chaneton, C. J. Chu, E. E. Cleland, C. D'Antonio, K. F. Davies, D. S. Gruner, N. Hagenah, K. Kirkman, J. M. H. Knops, K. J. La Pierre, R. L. McCulley, J. L. Moore, J. W. Morgan, S. M. Prober, A. C. Risch, M. Schuetz, C. J. Stevens, and P. D. Wragg. 2016. Addition of multiple limiting resources reduces grassland diversity. Nature **537**:93-96.

Harpole, W. S. and D. Tilman. 2007. Grassland species loss resulting from reduced niche dimension. Nature **446**:791-793.

Hautier, Y., P. A. Niklaus, and A. Hector. 2009. Competition for Light Causes Plant Biodiversity Loss After Eutrophication. Science **324**:636-638.

Hautier, Y., E. W. Seabloom, E. T. Borer, P. B. Adler, W. S. Harpole, H. Hillebrand, E. M. Lind, A. S. MacDougall, C. J. Stevens, J. D. Bakker, Y. M. Buckley, C. Chu, S. L. Collins, P. Daleo, E. I. Damschen, K. F. Davies, P. A. Fay, J. Firn, D. S. Gruner, V. L. Jin, J. A. Klein, J. M. H. Knops, K. J. La Pierre, W. Li, R. L. McCulley, B. A. Melbourne, J. L. Moore, L. R. O'Halloran, S. M. Prober, A. C. Risch, M. Sankaran, M. Schuetz, and A. Hector. 2014. Eutrophication weakens stabilizing effects of diversity in natural grasslands. Nature **508**:521-525.

Hubbell, S. P. 1997. A unified theory of biogeography and relative species abundance and its application to tropical rain forests and coral reefs. Coral Reefs **16**:S9-S21.

Jiang, L. and P. J. Morin. 2005. Predator diet breadth influences the relative importance of bottom-up and top-down control of prey biomass and diversity. American Naturalist **165**:350-363.

Kerr, B., M. A. Riley, M. W. Feldman, and B. J. M. Bohannan. 2002. Local dispersal promotes biodiversity in a real-life game of rock-paper-scissors. Nature **418**:171-174.

Levine, J. M. and J. HilleRisLambers. 2009. The importance of niches for the maintenance of species diversity. Nature **461**:254-U130.

Li, S. P., P. D. Wang, Y. J. Chen, M. C. Wilson, X. Yang, C. Ma, J. B. Lu, X. Y. Chen, J. G. Wu, W. S. Shu, and L. Jiang. 2020. Island biogeography of soil bacteria and fungi: similar patterns, but different mechanisms. Isme Journal **14**:1886-1896.

Lubchenco, J. 1978. Plant species diversity in a marine intertidal community: importance of herbivore food preferences and algal competitive abilities. American Naturalist **112**:23-39.

Newbold, T., L. N. Hudson, S. L. L. Hill, S. Contu, I. Lysenko, R. A. Senior, L. Borger, D. J. Bennett, A. Choimes, B. Collen, J. Day, A. De Palma, S. Diaz, S. Echeverria-Londono, M. J. Edgar, A. Feldman, M. Garon, M. L. K. Harrison, T. Alhusseini, D. J. Ingram, Y. Itescu, J. Kattge, V. Kemp, L. Kirkpatrick, M. Kleyer, D. L. P. Correia, C. D. Martin, S. Meiri, M. Novosolov, Y. Pan, H. R. P. Phillips, D. W. Purves, A. Robinson, J. Simpson, S. L. Tuck, E. Weiher, H. J. White, R. M. Ewers, G. M. Mace, J. P. W. Scharlemann, and A. Purvis. 2015. Global effects of land use on local terrestrial biodiversity. Nature **520**:45-50.

Paine, R. T. 1966. Food web complexity and species diversity. American Naturalist **100**:65-75.

Stevens, C. J., N. B. Dise, J. O. Mountford, and D. J. Gowing. 2004. Impact of nitrogen deposition on the species richness of grasslands. Science **303**:1876-1879.

Violle, C., D. R. Nemergut, Z. C. Pu, and L. Jiang. 2011. Phylogenetic limiting similarity and competitive exclusion. Ecology Letters **14**:782-787.

Wright, S. J. 2002. Plant diversity in tropical forests: a review of mechanisms of species coexistence. Oecologia **130**:1-14.

Ecological consequences of biodiversity

Cadotte, M. W., B. J. Cardinale, and T. H. Oakley. 2008. Evolutionary history and the effect of biodiversity on plant productivity. Proceedings of the National Academy of Sciences of the United States of America **105**:17012-17017.

Cardinale, B. J., J. E. Duffy, A. Gonzalez, D. U. Hooper, C. Perrings, P. Venail, A. Narwani, G. M. Mace, D. Tilman, D. A. Wardle, A. P. Kinzig, G. C. Daily, M. Loreau, J. B. Grace, A. Larigauderie, D. S. Srivastava, and S. Naeem. 2012. Biodiversity loss and its impact on humanity. Nature **486**:59-67.

Cardinale, B. J., D. S. Srivastava, J. E. Duffy, J. P. Wright, A. L. Downing, M. Sankaran, and C. Jouseau. 2006. Effects of biodiversity on the functioning of trophic groups and ecosystems. Nature **443**:989-992.

Cottingham, K. L., B. L. Brown, and J. T. Lennon. 2001. Biodiversity may regulate the temporal variability of ecological systems. Ecology Letters **4**:72-85.

Crutsinger, G. M., M. D. Collins, J. A. Fordyce, Z. Gompert, C. C. Nice, and N. J. Sanders. 2006. Plant genotypic diversity predicts community structure and governs an ecosystem process. Science **313**:966-968.

Hector, A. and R. Bagchi. 2007. Biodiversity and ecosystem multifunctionality. Nature **448**:188-190.

Hector, A., B. Schmid, C. Beierkuhnlein, M. C. Caldeira, M. Diemer, P. G. Dimitrakopoulos, J. A. Finn, H. Freitas, P. S. Giller, J. Good, R. Harris, P. Hogberg, K. Huss-Danell, J. Joshi, A. Jumpponen, C. Korner, P. W. Leadley, M. Loreau, A. Minns, C. P. H. Mulder, G. O'Donovan, S. J. Otway, J. S. Pereira, A. Prinz, D. J. Read, M. Scherer-Lorenzen, E. D. Schulze, A. S. D. Siamantziouras, E. M. Spehn, A. C. Terry, A. Y. Troumbis, F. I. Woodward, S. Yachi, and J. H. Lawton. 1999. Plant diversity and productivity experiments in European grasslands. Science **286**:1123-1127.

Hooper, D. U., E. C. Adair, B. J. Cardinale, J. E. K. Byrnes, B. A. Hungate, K. L. Matulich, A. Gonzalez, J. E. Duffy, L. Gamfeldt, and M. I. O'Connor. 2012. A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature **486**:105-108.

Hughes, A. R., B. D. Inouye, M. T. J. Johnson, N. Underwood, and M. Vellend. 2008. Ecological consequences of genetic diversity. Ecology Letters **11**:609-623.

Isbell, F., V. Calcagno, A. Hector, J. Connolly, W. S. Harpole, P. B. Reich, M. Scherer-Lorenzen, B. Schmid, D. Tilman, J. van Ruijven, A. Weigelt, B. J. Wilsey, E. S. Zavaleta, and M. Loreau. 2011. High plant diversity is needed to maintain ecosystem services. Nature **477**:199-202.

Jiang, L. and Z. C. Pu. 2009. Different Effects of Species Diversity on Temporal Stability in Single-Trophic and Multitrophic Communities. American Naturalist **174**:651-659.

Kennedy, T. A., S. Naeem, K. M. Howe, J. M. H. Knops, D. Tilman, and P. Reich. 2002. Biodiversity as a barrier to ecological invasion. Nature **417**:636-638.

Levine, J. M. 2000. Species diversity and biological invasions: relating local process to community pattern. Science **288**:852-854.

Levine, J. M. and J. HilleRisLambers. 2009. The importance of niches for the maintenance of species diversity. Nature **461**:254-257.

Loreau, M. and A. Hector. 2001. Partitioning selection and complementarity in biodiversity experiments. Nature **412**:72-76.

McCann, K. S. 2000. The diversity-stability debate. Nature **405**:228-233.

McGrady-Steed, J., P. M. Harris, and P. J. Morin. 1997. Biodiversity regulates ecosystem predictability. Nature **390**:162-165.

Naeem, S., J. E. Duffy, and E. Zavaleta. 2012. The Functions of Biological Diversity in an Age of Extinction. Science **336**:1401-1406.

Petchey, O. L. and K. J. Gaston. 2006. Functional diversity: back to basics and looking forward. Ecology Letters **9**:741-758.

Tan, J. Q., Z. C. Pu, W. A. Ryberg, and L. Jiang. 2012. Species phylogenetic relatedness, priority effects, and ecosystem functioning. Ecology **93**:1164-1172.

Tilman, D. 1999. The ecological consequences of changes in biodiversity: A search for general principles. Ecology **80**:1455-1474.

Tilman, D., F. Isbell, and J. M. Cowles. 2014. Biodiversity and Ecosystem Functioning. Pages 471-493 *in* D. J. Futuyma, editor. Annual Review of Ecology, Evolution, and Systematics, Vol 45.

Tilman, D., P. B. Reich, J. Knops, D. Wedin, T. Mielke, and C. Lehman. 2001. Diversity and productivity in a long-term grassland experiment. Science **294**:843-845.

Tilman, D., P. B. Reich, and J. M. H. Knops. 2006. Biodiversity and ecosystem stability in a decade-long grassland experiment. Nature **441**:629-632.

Xu, Q., X. Yang, Y. Yan, S. Wang, M. Loreau, and L. Jiang. 2021. Consistently positive effect of species diversity on ecosystem, but not population, temporal stability. Ecology letters, in press.

Yachi, S. and M. Loreau. 1999. Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. Proceedings of the National Academy of Sciences of the United States of America **96**:1463-1468.