ECOLOGY SEMINAR AND LIMNOLOGY SEMINAR
Zoology 955 and 956 or Geography 920
Fall Semester 2016

Abrupt Change in Ecological Systems (ACES)

Course Description,
(Version - 12 September 2016 – link to Box corrected)

INSTRUCTORS:

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CREDIT HOURS: 2 (Registration in both Zoology 955 and 956, each 1 credit, or in Geography 920, 2 credits, is required.)

MEETING TIME: The course will meet from **9:55 – 11:45 on Fridays in 158 Birge Hall** (located to the left/east of the 1st floor main lobby at the end of the hallway)

COURSE STRUCTURE:

Class meetings will vary in format and may include: lecture followed by discussion of assigned readings, student-lead discussion of assigned readings, or small-group discussions of the student projects. The final two classes are reserved for presentation of group projects and individual literature reviews.

COURSE DESCRIPTION AND OBJECTIVES:

Science currently lacks a framework for predicting when, where, why, and how surprisingly abrupt and fundamental changes are likely to occur in ecosystems and other complex systems. Rates of environmental change are accelerating, and understanding the consequences of these 21st-century changes for natural resources and human wellbeing is among the biggest challenges in contemporary ecology. The goals of this seminar are to provide students with an overview of the literature, concepts and current research directions in this emerging field. We will cover a range of topics related to understanding and detecting abrupt changes in different ecological systems and at different scales of space and time. We will include conceptual, mathematical, and statistical approaches and assess their applicability in four real-world "model ecosystems", each characterized by complex spatial dynamics and time lags that can mask impending abrupt change. Students will gain practical experience by hands-on analysis of change detection in time-series paleoecological primary data and synthesis of literature to determine whether evidence does or not support abrupt change in an ecosystem of their choice. Students must be prepared to read and discuss current literature, lead discussion of assigned readings, and complete the assigned projects. This seminar one component of a newly funded UW2020 project designed to support and nurture innovative research directions at UW-Madison.

GRADING:
Grades will be based on leading (20%) and participating (15%) in class discussion; and individual student projects, including the proposal (5%), oral presentation (10%) and the written project report (50%). Generally, numerical grades are assigned as follows: 93-100 (A), 88-92 (AB), 82-87 (B), 78-81 (BC).

READING ASSIGNMENTS:
This course emphasizes readings from the primary literature, and papers will be assigned each week for discussion. ***Every student is expected to have read the assignments before class and be prepared to discuss the papers.*** Responsibility for leading discussion will be rotated among small groups of all students. Discussion leaders should raise questions or issues to be discussed; be prepared with an evaluation of the significant contributions of the paper; and facilitate discussion among the group (see additional notes below).

PDFs of reading assignments are posted on Box:
https://uwmadison.box.com/s/5q2pur44u8by3471vqwpa3sz2xk18le8

PARTICIPATING IN DISCUSSION:
Discussions are only effective when everyone is prepared and has perspectives to contribute. ***Everyone is expected to have read the assigned articles before class and given thought to the content and context.*** A good strategy for being prepared is to write down a couple of questions or observations about each paper as you are reading it. The class benefits from the diverse interests and backgrounds of the students, and we learn a lot by listening to one another.

LEADING DISCUSSION:
Small groups of students will have the opportunity to lead the class discussion of assigned readings. All students will have read the papers prior to class, so discussion leader(s) should **not** provide a detailed review of the paper. The discussion leader(s) should provide a brief summary of the main topic of the paper, just to remind everyone of which paper is being considered. Here are some tips for being effective at leading discussion.

i. Summarize for yourself some of the important points about the paper. It's often useful to have a set of questions that you answer while planning discussion. For example, consider the following: What is the main conceptual contribution of the paper? Why might it be important or influential? Is it a representative example? Does it propose a new direction or idea? How does this paper relate to other papers or general concepts with which you are familiar? Are there any new approaches represented? Are there any problems with the study? How does this reflect the current state of the science?

ii. Prepare in advance some <u>open-ended</u> questions that you can pose to the group to get the discussion going. Remember that questions with a "yes" or "no" answer do not facilitate a discussion! Feel free to call on people if there is silence!

iii. Keep the discussion moving by including all members of the group (this means calling on reticent members of the group and gently redirecting away from individuals who may dominate the conversation) and by curtailing discussion that goes off into tangents or dead ends.

iv. Try to summarize and synthesize as things go along. It's often helpful to use a mechanism like, "So far, we've identified the following main contributions of this paper: ….

ABSENCE POLICY:
Attendance is recorded at each class meeting. If you have an *anticipated* absence (e.g., planned conference travel or necessary field work), please let us know before the class that you will miss. If you are *unexpectedly* absent (e.g., illness), please inform us at your earliest convenience. For lecture/discussion classes that are missed, students are responsible for the material that was covered in class and for completing the readings. **A summary of the assigned readings (one single-space page maximum for each assigned paper) should be submitted before (if possible) but <u>no later than one week after the missed class</u>.** The summary should include a brief statement of what was covered in the paper; your thoughts on the primary contribution of the paper, any insights that were new for you, and questions that were raised in your mind by the paper.

ASSIGNMENTS
This seminar includes three complementary project assignments. One is conducted in pairs, one is in small groups, and one is individual.

(1) <u>Case-studies of ACES – a whirlwind tour of ecosystems and approaches</u> (pairs)
As an entrée to the burgeoning studies of abrupt change in ecological systems, we will conduct during Week 3 a quick tour of the literature focused on examples from a wide range of ecosystem types in which abrupt changes have been detected empirically. Papers, each representing a case study, will be assigned to one pair of students. The student pair will read the paper and prepare a 5-minute presentation for the class, summarizing the paper, how change was detected, and how the terminology associated with ACES was used in the paper. Each pair of students should summarize the following: the conclusions for the paper regarding abrupt ecosystem change; types of evidence used to support the conclusions; specific terminology related to abrupt change used in the paper, including the definition used by the authors. In some cases it may be necessary to infer the definition from context.

(2) <u>Quantitative methods for detecting abrupt changes</u> (small-groups)
Detecting abrupt changes in ecological data is an important component of understanding and anticipating ACES and integrating model predictions with data. We will cover the state of the art in change-detection methods during Week 4 using both simulated data and long ecological time

series, then follow up with further hands-on experiences with these methods during Week 5. This will prepare students to apply these methods to real data.

For this exercise, we will begin with long paleoenvironmental and paleoecological datasets drawn from the literature and from the Neotoma Paleoecology Database (www.neotomadb.org). We will focus on the abrupt collapse in hemlock populations in eastern North America during the collapse of the Saharan grasslands to desert in North Africa, both during the mid-Holocene. Students will be briefly introduced to these case studies during Week 3, with further information about the data in Week 6. We'll then discuss the questions that can be asked of the data and assign student teams to apply change-detection methods to the paleo data as a small group project, to be completed in 8 weeks. **Each group will present results to the class on December 9.**

(3) <u>Evidence for ACES – what do we know, and how do we know it?</u> (individual)
Each student will select an ecosystem of their choice and conduct a literature review to seek evidence that does or does not support the occurrence of abrupt change in that system. Students should identify the response variables in which change was examined, the spatial and temporal scales over which ACES were assessed, and the methods used to reach conclusions. Students will provide both a written product and an oral presentation that documents their review.

Written product: Students will generate an annotated bibliography (2-3 sentences for each reference) of at least 15 papers published in the peer-reviewed literature, and a short written synthesis paper (not to exceed 3 pages of single-spaced type with 12-pt Times New Roman font and 1-inch margins; page length excludes the annotated bibliography) summarizing their findings in response to the following questions:

- What is the evidence for abrupt ecological changes in that system?
- What mechanisms underpin change or resilience?
- What predictors were associated with change?
- Why is this abrupt change (or lack thereof) important to society?

Oral presentations (lightning rounds) on December 16: Students will deliver lightning talks on the results of their individual ecosystem of study. Prepare a Powerpoint presentation with visuals, **5 minutes in length**, and be sure to address the points listed in the grading rubric below. You will deliver your presentation to the rest of class and instructors.

- Provide a clear introduction to the system of interest; provide context (20%)
- Demonstrate mastery of ACES concepts including discussion of evidence, mechanisms, and predictors (20%)
- Use of figures, tables, graphics to make points (20%)
- Coherent, organized presentation of ideas (20%)
- Preparation: well-prepared delivery, conforming to time limit, response to questions (20%)

SYLLABUS

(8 September 2016; subject to change)

Date	Topic (lead)	Assigned readings
Sept 9	Introductions, course overview; **ACES at the global scale**, faculty-led discussion; UW2020 ACES project goals (*All*)	Lenton et al. 2008 Barnosky et al. 2012 Steffen et al. 2015 Turner et al. 2015 ACES proposal
Sept 16	**Dimensions of abrupt change**—what do we mean? (*All*)	Carpenter 2003 Kelley et al. 2015 Reyer et al. 2015 Schooler et al. 2011 Williams et al. 2011(pp. 664- 667) & NRC 2013 report (pp. 19-28)
Sept 23	**Case studies of ACES** – a whirlwind tour of ecosystems and approaches (*Student pairs will each read and present on ONE of the assigned readings*)	Barkai and McQuaid 1988 Blindow et al. 1993 Hansen et al. 2013 Kröpelin et al. 2008 Ratajczak et al. 2014 Scheffer et al. 1997 Shuman et al. 2009 Verbesselt et al. 2016 Walker et al. 1981 Wernberg et al. 2016
Sept 30	**Detecting abrupt change** – concepts and statistical methods (*Ives*)	Booth et al. 2012a Dakos et al. 2012 deMenocal et al. 2000
Oct 7	**Applying change-detection methods to simulated data** (*Ives, Carpenter*)	*Problem set – No readings*
Oct 14	**Paleoecoinformatics and Neotoma paleoecology database**–key concepts and accessing data (*Williams*)	Goring et al. 2015 GitHub code (see link below for Oct 14)
Oct 21	Introduction to ACES case studies: **Lakes and Agriculture** (*Carpenter, Kucharik*)	Carpenter et al. 1999 Taranu et al. 2015 Cook et al. 2009 D'Arcy 2010
Oct 28	Introduction to ACES case studies: **Eastern and Western forests** (*Williams, Turner*)	Booth et al. 2012b Williams et al. 2009 Westerling et al. 2011 Donato et al. 2016
Nov 4	Student-led discussion and how these apply in the four ACES study systems (i): **Feedbacks and mechanisms underpinning abrupt change** (*Students*)	Serizawa et al. 2009 Elliott 2012 Johnstone et al. 2016

Nov 11	Student-led discussion and how these apply in the four ACES study systems (ii): **Role of time and space: lagged responses and spatial patterns** (*Students*)	Staver et al. 2011 Hughes et al. 2013 Svenning et al. 2013
Nov 18	Student-led discussion and how these apply in the four ACES study systems (iii): **Resilience or vulnerability to extreme events** (*Students*)	Peters et al. 2004 Lesk et al. 2016 Urruty et al. 2016
Nov 25	—	THANKSGIVING BREAK
Dec 2	Student-led discussion and how these apply in the four ACES study systems (iv): **Evaluating resilience, anticipating ACES, early warning signals** (*Students*)	Thrush et al. 2009 Biggs et al. 2012 Scheffer et al. 2015
Dec 9	**Group presentations: Paleo data time series** (NEOTOMA)	—
Dec 16	**Individual presentations** – lightning talks	—

READINGS

(Subject to change)

Sept 9, Overview: ACES at the global scale

Barnosky, A. D., and many others. 2012 . Approaching a state shift in Earth's biosphere. Nature 486:52-58.

Lenton, T. M., H. Held, E. Kriegler, J. W. Hall, W. Lucht, et al. 2008. Tipping elements in the Earth's climate system. Proceedings of the National Academy of Sciences 105:1786-1793.

Steffen, W., and many others. 2015. Planetary boundaries: Guiding human development on a changing planet. Science 347:736 and 1259855-1.

Turner, M. G., S. R. Carpenter, A. R. Ives, C. J. Kucharik, and J. W. Williams. 2015. Anticipating abrupt ecological change in the 21st century. Proposal submitted to UW2020 WARF Discovery Initiative.

Sept 16, Dimensions of abrupt change: What do *we* mean?

Carpenter, S. R. 2003. Regime shifts in lake ecosystems: pattern and variation. International Ecology Institute, Oldendorf/Luhe, Germany. Chapter 1, Prevalence and importance of regime shifts, pp. 5-17. (*SRC*)

Kelley, C.P., S. Mohtadi, M.A. Cane, R. Seager, and Y. Kushnir. 2015. Climate change in the Fertile Crescent and implications of the recent Syrian drought. Proc. Natl. Acad. Sci. 112:3241-3246. (*CJK*)

Reyer, C., P. O., N. Brouwers, A. Rammig, B. W. Brook, J. Epila, et al. 2015. Forest resilience and tipping points at different spatio-temporal scales: approaches and challenges. Journal of Ecology 103:5-15. (*MGT*)

Schooler, S. S., B. Salau, M. H. Julien, and A. R. Ives. 2011. Alternative stable states explain unpredictable biological control of salvinia in Kakadu. Nature 470:86-89. (*ARI*)

National Research Council. 2013. Abrupt impacts of climate change: Anticipating surprises. National Academy of Sciences, Washington, DC. (read pp. 19-28) (*JWW*)

Williams, J. W., Blois, J. L., and Shuman, B. N. 2011. Extrinsic and intrinsic forcing of abrupt ecological change: Case studies from the late Quaternary. Journal of Ecology 99:664-677. (read pp. 664-667) (*JWW*)

Sept 23, Case studies of ACES: A whirlwind tour of ecosystems and approaches

Barkai, A. and McQuaid, C. 1988. Predator-prey role reversal in a marine benthic ecosystem. Science 242:62-64.

Blindow, I., Anderson, G., Hargeby, A., Johansson, S. 1993. Long-term pattern of alternative stable states in two shallow eutrophic lakes. Freshwater Biology 30:159-167.

Hansen, G. J. A., A. R. Ives, M. J. Vander Zanden, and S. R. Carpenter. 2013. Are rapid transitions between invasive and native species caused by alternative stable states, and does it matter? Ecology 94:2207-2219.

Kröpelin, S., Verschuren, D., Lézine, A.-M., Eggermont, H., Cocquyt, C., Francus, P., Cazet, J.-P., Fagot, M., Rumes, B., Russell, J. M., Darius, F., Conley, D. J., Schuster, M., von Suchodoletz, H., and Engstrom, D. R. 2008. Climate-driven ecosystem succession in the Sahara: The past 6000 years. Science 320:765-768.

Ratajczak, Z., J. B. Nippert, and T. W. Oeheltree. 2014. Abrupt transition of mesic grassland to shrubland: evidence for thresholds, alternative attractors, and regime shifts. Ecology 95:2633-2645.
Scheffer, M., S. Rinaldi, A. Gragnani, L. R. Mur, and E. H. vanNes. 1997. On the dominance of filamentous cyanobacteria in shallow, turbid lakes. Ecology 78:272-282.
Shuman, B. N., Newby, P., and Donnelly, J. P. 2009. Abrupt climate change as an important agent of ecological change in the Northeast U.S. throughout the past 15,000 years. Quaternary Science Reviews 28:1693-1709.
Verbesselt, J., et al. 2016. Remotely sensed resilience of tropical forests. Nature Climate Change Published online 5 Sept 2016, DOI: 10.1038/NCLIMATE3108
Walker, B.H., D. Ludwig, C.S. Holling and R.M. Peterman. 1981. Stability of semi-arid savanna grazing systems. Journal of Ecology 69: 473-498.
Wernberg, T., et al. 2016. Climate-driven regime shift of a temperate marine ecosystem. Science 353:169-172.

Sept 30, Detecting abrupt change – concepts and statistical methods)

Booth, R. K., Brewer, S., Blaauw, M., Minckley, T. A., and Jackson, S. T. 2012a. Decomposing the mid-Holocene *Tsuga* decline in eastern North America. Ecology 93:1841-1852.
Dakos, V., S. R. Carpenter, W. A. Brock, A. M. Ellison, V. Guttal, A. R. Ives, S. Kefi, V. Livina, D. A. Seekell, E. H. van Nes, and M. Scheffer. 2012. Methods for detecting early warnings of critical transitions in time series illustrated using simulated ecological data. PLoS ONE **7**.
de Menocal, P., J. Ortiz, T. Guilderson, J. Adkins, M. Sarnthein, L. Baker, and M. Yarusinsky. 2000. Abrupt onset and termination of the African Humid Period: rapid climate responses to gradual insolation forcing. Quaternary Science Reviews 19:347-361.

Oct 7, Applying the change-detection methods to simulated data

Homework analysis instead of readings.

Oct 14, Paleoecoinformatics and Neotoma paleoecology database: Key concepts and accessing data

Goring, S., Dawson, A., Simpson, G., Ram, K., Graham, R. W., Grimm, E. C., and Williams, J. W. (2015) Neotoma: A programmatic interface to the Neotoma Paleoecological Database. Open Quaternary 1:1-17.
GitHub code at https://github.com/NeotomaDB/Workshops/tree/master/UW_ACES2016 (9/1/2016 status: still in development)

Oct 21, ACES Study systems: Lakes and agriculture

Lakes:

Carpenter, S.R., D. Ludwig and W.A. Brock. 1999. Management of eutrophication for lakes subject to potentially irreversible change. Ecological Applications 9: 751-771.
Taranu, Z.E. and 14 others. 2015. Acceleration of cyanobacterial dominance in North Temperate-subarctic lakes during the Anthropocene. Ecology Letters 18: 375-384.

Agriculture:

Cook, B.I., R.L. Miller, and R. Seager. 2009. Amplification of the North American "Dust Bowl" drought through human-induced land degradation. Proc. Natl. Acad. Sci. 106: 4997-5001.

D'Arcy, A. 2010. The potato in Ireland's evolving agrarian landscape and agri-food system. Irish Geog. 43: 119-134.

Oct 28, ACES Study systems: Eastern and western forests

Eastern forests:

Booth, R. K., Jackson, S. T., Sousa, V. A., Sullivan, M. E., Minckley, T. A., and Clifford, M. J. 2012b. Multi-decadal drought and amplified moisture variability drove rapid forest community change in a humid region. Ecology 93:219-226.

Williams, J. W., Shuman, B., and Bartlein, P. J. 2009. Rapid responses of the Midwestern prairie-forest ecotone to early Holocene aridity. Global and Planetary Change 66:195-207.

Western forests:

Westerling, A. L., M. G. Turner, E. A. H. Smithwick, W. H. Romme, and M. G. Ryan. 2011. Continued warming could transform Greater Yellowstone fire regimes by mid-21st century. Proceedings of the National Academy of Sciences 108:13165-13170.

Donato, D. C., B. J. Harvey, and M. G. Turner. 2016. Regeneration of lower-montane forests a quarter-century after the 1988 Yellowstone Fires: a fire-catalyzed shift in lower treelines? Ecosphere 7(8) Article e01410.

Nov 4, Feedbacks and mechanisms underpinning abrupt change

Elliot, G. P. 2012. Regime shifts drive abrupt changes in regeneration dynamics at upper treeline in the Rocky Mountains, USA. Ecology 93:1614-1625.

Johnstone, J. F., C. D. Allen, J. F. Franklin, L. E. Frelich, B. J. Harvey, P. E. Higuera, M. C. Mack, R. K. Meentemeyer, M. R. Metz, G. L. W. Perry, T. Schoennagel, and M. G. Turner. 2016. Changing disturbance regimes, climate warming and forest resilience. Frontiers in Ecology and the Environment 14:369-378.

Serizawa, H., T. Amemiya, and K. Itoh. 2009. Patchiness and bistability in the comprehensive cyanobacteria model (CCM). Ecological Modelling 220: 764-773.

Nov 11, Role of time and space: lagged responses and spatial patterns

Hughes, T. P. C. Linares, V. Dakos, I. A. van de Leemput, and E. H. van Nes. 2013. Living dangerously on borrowed time during slow, unrecognized regime shifts. Trends in Ecology and Evolution 28:149-155.

Staver, A. C., S. Archibald, and S. A. Levin. 2011. The global extent and determinants of savanna and forest as alternative biome states. Science 334:230-232.

Svenning, J.-C., and Sandel, B. 2013. Disequilibrium vegetation dynamics under future climate change. American Journal of Botany 100:1266-1286.

Nov 18, Resilience or vulnerability to extreme events

Peters, D.P.C., R.A. Pielke Sr., B.T. Bestelmeyer, C.D. Allen, S. Munson-McGee, and K.M. Havstad. 2004. Cross-scale interactions, nonlinearities, and forecasting catastrophic events. Proc. Natl. Acad. Sci. 42: 15130-15135.

Lesk, C. P. Rowhani, and N. Ramankutty. 2016. Influence of extreme weather disasters on global crop production. Nature, DOI:10.1038/nature16467.

Urruty, N., D. Tailliez-Lefebvre, and C. Huyghe. 2016. Stability, robustness, vulnerability and resilience of agricultural systems. A review. Agron. Sustain. Dev. 36:15. DOI 10.1007/s13593-015-0347-5

Dec 2, Evaluating resilience, anticipating ACES, early warning signals

Biggs, R., et al. 2012. Towards principles for enhancing the resilience of ecosystem services. Annual Review of Environment and Resources 37:421-448.

Scheffer, M., S. Carpenter, V. Dakos and E. van Nes. 2015. Generic indicators of ecological resilience. Annual Review of Ecology Evolution and Systematics 46:145-167.

Thrush, S., J. Hewitt, P. Dayton, G. Coco, A. M. Lohrer, A. Norkko, J. Norkko, M. Chiantore. 2009. Forecasting the limits of resilience: integrating empirical research with theory. Proceedings of the Royal Society B 282:3209-3217.