ES482: Complex Systems

Instructor: Dr. John Volpe
Office: David Turpin Bldg B258
Class times: Mon. & Thurs. 1-2:20pm MacLauren D281
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Office Hours TBA

Required Text:
Melanie Mitchell. 2009. Complexity: A Guided Tour. Oxford University Press

Overview:
Our natural, built and social environments (and their interactions) are all classic examples of complex systems, composed of multiple interacting "agents," or variables, that drive emergent behavior. This senior-level course will expose you to classical complex systems analysis while exploring the complex-systems approach to environmental problems.

The format of this class is both conventional lecture and student lead discussion. The emphasis here is on exploring they myriad dimensions of complex systems theory and practice. Regardless of your background and interests, you will see direct application of these ideas to your own area of expertise. While nominally based in ecological / environmental contexts the course and assigned materials are designed to be interdisciplinary, with the hope that new ideas will be seeded by readings and peer discussion cutting across academic fields.

Expectations:
It is my intent that this class to stimulate thinking and expand the intellectual horizon of students. The benefits you will reap from this class increase in proportion to your investment in reading and discussion. I hope that you will be sufficiently motivated to engage in both pursuits with enthusiasm and drive.

Grading:
15% Submit three or more questions related to the coming week's reading to the course Moodle website. Due weekly by 4pm of the preceding Friday, starting with readings for week 3. Questions should be roughly distributed across all assigned readings.

15% Select one "case-study" paper and prepare a 10-15 minute presentation (up to 20 minutes including questions) to brief the class. Presentation should focus on the paper's contribution to the field not on reviewing the paper (assume audience has read it)

20% Lead one of the Thursday discussion sessions. You should decide (in collaboration with that week's case-study presenter) whether this session needs to include a mini-lecture based on submitted questions from the class, the primary or supplementary reading(s) or whether you prefer to use the time entirely for discussion … or…?. By noon Wed before the class, post the final ten discussion questions (from the pool submitted by the class) that you will be addressing.

20% Submit answers to the ten final discussion questions in hard copy by start of Thursday's class.

20% Final Assignment: Research Grant Proposal for complex systems research project.

10% Class participation. See me if you must be absent for more than one class.

Class Schedule:

Week 1 Jan 6 & 9 Intro to Course, Complex Adaptive Systems, Ecological CAS, and Gaia

Mitchell, M. 2009. What is complexity?. Chapter 1 (pgs. 3-14)
Mitchell, M. 2009. Defining and measuring complexity. Chapter 7 (pgs. 94-111)

Other Resources:
NSF web page on Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century: Link
Lloyd 2001 IEEE Control Sys Mag (Aug) 7-8
Levin, S. A. 1998. Ecosystems and the biosphere as complex adaptive systems. Ecosystems 1:431-436.
Lenton, T. M. and M. van Oijen. 2002. Gaia as a complex adaptive system. Phil. Trans. R. Soc. Lond. B. 357:683-395.

Week 2 Jan 13 & 16 Nonlinear Dynamics, Chaos & Information I

Mitchell, M. 2009. Dynamics, chaos and predictions. Chapter 2 (pgs. 15-39)
Mitchell, M. 2009. Information. Chapter 3 (pgs. 40-55)
Mitchell, M. 2009. Computation. Chapter 4 (pgs. 56-70)

Other Resources:
Wolfram's Logistic Onset of Chaos Demo
Wolfram's Maxwell's Demon Demo

Week 3 Jan. 20 & 23 Cellular Automata & Information II

Mitchell, M. 2009. Cellular automata, Life and the universe. Chapter 10 (pgs. 145-159)
Mitchell, M. 2009. Computing with particles. Chapter 11 (pgs. 160-168)
Mitchell, M. 2009. Information processing in living systems. Chapter 12 (pgs. 169-185)

Case Study:
J.T. Wootton 2001. Local interactions predict large-scale pattern in an empirically-derived cellular automata. Nature 413:841-844

Other Resources:

What if the universe is a computer simulation?
John Conway's Game of Life (you can set initial configuration)
Simulations back up theory that Universe is a hologram

Week 4 Jan 27 & 30 Game Theory and Pattern Formation

Mitchell, M. 2009. Prospects of computer modeling. Chapter 14 (pgs. 209-224)

Rietkerk, M. and J. van de Koppel. 2008. Regular pattern formation in real ecosystems. Trends in Ecology & Evolution 23:169-175.

Santos, F. C., M. D. Santos, and J. M. Pacheco (2008), Social diversity promotes the emergence of cooperation in public goods games, *Nature*, *454*(7201), 213-216.

Allesina, S., and J. M. Levine (2011), A competitive network theory of species diversity, *Proceedings of the National Academy of Sciences*, *108*(14), 5638-5642.

Case-studies: Both papers, though technical, have straightforward conclusions. Consider both and focus on their combined contribution.

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*(6894), 171-174.

Hauert, C., S. De Monte, J. Hofbauer, and K. Sigmund (2002), Volunteering as Red Queen Mechanism for Cooperation in Public Goods Games, *Science*, *296*(5570), 1129-1132.

Other Resources:

How to Save the Planet: Be Nice, Retaliatory, Forgiving and Clear (2007)

Bascompte, J. and R. V. Sole. 1998. Spatiotemporal patterns in nature. *Trends in Ecology and Evolution* 13:173-174.

Hasson, R., A. Lofgren, and M. Visser (2010), Climate change in a public goods game: Investment decision in mitigation versus adaptation, *Ecological Economics*, *70*(2), 331-338.

Week 5 Feb 3 & 6 Evolution

Mitchell, M. 2009. Evolution. Chapter 5 (pgs. 71-87)
Mitchell, M. 2009. Genetics, Simplified Chapter 6 (pgs. 88-93)
Mitchell, M. 2009. Evolution Complexified Chapter 18 (pgs. 273-290)

Case Study:

Sole et al 1999 Criticality and scaling in evolutionary ecology. TREE 14:156-160

Week 6 Feb 10-14 *Reading Break*

Week 7 Feb 17-20 Science of Networks

Mitchell, M. 2009. The science of networks. Chapter 15 (pgs. 227-246)
Mitchell, M. 2009. Applying network science to real world networks. Chapter 16 (pgs. 247-257)

Case Study:

Bascompte, J. 2009. Mutualistic networks. *Frotiers in Ecology and Environment* 7:429-436.

Week 8 Feb 24 & 27 Ecological Networks

Bascompte, J. 2007. Networks in Ecology. *Basic and Applied Ecology* 8: 485-490

Proulx, S.R., D.E.L. Promislow and P.C. Phillips. 2005. Network thinking in ecology and evolution. *Trends in Ecology & Evolution* 20: 345-353.

Case Study:

Poulin, R. 2010. Network analysis shining light on parasite ecology and diversity. *Trends in Parasitology* 26:492-498.

Week 9 March 3 & 6 Power Laws and Self Organized Criticality

Mitchell, M. 2009. The mystery of scaling. Chapter 17 (pgs. 258-272)

Bak, P., and K. Chen (1991), Self-organized criticality, *Scientific American*, *264*(1), 46-53.

West, G.B. and J.H. Brown. 2004. Life's universal scaling laws. Physics Today 57: 36-43.

Case Study:

Bettencourt, L. and G.B. West. 2010. A unified theory of urban living. Nature 467:912-913

Other Resources:

Solow, A.R. 2005. Power laws without complexity. Ecological Letters 8:361-363.

Frigg, R. (2003), Self-organised criticality: what it is and what it isn't, *Studies in History and Philosophy of Science Part A*, *34*(3), 613-632.

Brown, J.H. et al. 2004. Toward a metabolic theory of ecology. *Ecology* 85: 1771-1789

Brown, J. H., V. K. Gupta, B.-L. Li, B. T. Milne, C. Restrepo, and G. B. West. 2002. The fractal nature of nature: power laws, ecological complexity and biodiversity. *Phil. Trans. R. Soc. Lond. B*. 357:619-626.

West, G.B. and J.H. Brown. 2005. The origin of allometric scaling laws in biology from genomes to ecosystems: towards a quantitative unified theory of biological structure and organization. *J Exp Biol* 208: 1575-1592.

Week 10 March 10 & 13 Alternative Stable States & Catastrophic Shifts

Scheffer, M., J. Bascompte, W. A. Brock, V. Brovkin, S. R. Carpenter, V. Dakos, H. Held, E. H. van Nes, M. Rietkerk, and G. Sugihara. 2009. Early-warning signals for critical transitions. *Nature* 461:53-59.

Scheffer, M., et al. 2012, Anticipating Critical Transitions, *Science*, 338:344-348.

Rietkerk, M., S. C. Dekker, P. C. de Ruiter, and J. van de Koppel. 2004. Self-organized patchiness and catastrophic shifts in ecosystems. *Science* 305:1926-1929.

Case-study*:*

Suding, K. N., K. L. Gross, and G. R. Houseman. 2004. Alternative states and positive feedbacks in restoration ecology. *Trends in Ecology & Evolution* 19:46-53.

Other Resources:

Didham, R. K. and C. H. Watts. 2005. Are systems with strong underlying abiotic regimes more likely to exhibit alternative stable states? *Oikos* 110:409-416.

Week 11 March 17 & 20 Odum and the Rise of Systems Ecology

Odum, E.P. The strategy of ecosystem development. *Science* 164: 262-270.

Schneider E.D. and J.J. Kay. 1994. Complexity and thermodynamics. *Futures* 26: 626-647

Free, A. and N.H. Barton 2007 Do evolution and ecology need the Gaia hypothesis? *Trends in Ecology and Evolution* 22: 611-619

Case Study:

May, R.M., S.A. Levin and G. Sugihara. 2008. Ecology for bankers. *Nature* 451: 893-895.

Other Resources:

Abel, T. 2014. Culture in cycles: considering H.T. Odum's 'information cycle'. *International Journal of General Systems*, 43: 44–74.

Week 12 March 24 & 27 Panarchy and Resilience

Hirota, M., M. Holmgren, E. H. Van Nes, and M. Scheffer. 2011. Global Resilience of Tropical Forest and Savanna to Critical Transitions, *Science* 334: 232-235.

Holling, C. S. 2001. Understanding the complexity of economic, ecological, and social systems *Ecosystems 4*: 390-405.Other Resources:

Folke, C. 2006. Resilience: The emergence of a perspective for social-ecological systems analyses, *Global Environmental Change* 16: 253-267.

Case Study:

Lansing et al. 2012. Alternative stable states in a social – ecological system. *Santa Fe Institute, SFI Working Paper*: 2012-08-012 (focus on pages 1-16)