QUANTITATIVE METHODS FOR STUDYING SOCIAL-ECOLOGICAL SYSTEMS

PhD Programme in Sustainability Science at Stockholm Resilience Centre

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Feb 15-28, 2019

Where: Room: 239
When: Discussion: 1000-1030; **Lectures:** 1030-1200; **Workshops** 1300-1500
Requirements: a laptop, an open mind
Software: R (http://www.r-project.org/, http://www.rstudio.com/)
netlogo (https://ccl.northwestern.edu/netlogo/index.shtml)
Ucinet (http://www.analytictech.com/)

Course overview:
10 days over two weeks, each day will consist of one morning discussion focusing on the previous day's reading/homework, followed by a lecture on new material and finally a hands-on workshop in the afternoon. Lectures will focus on key social-ecological concepts and quantitative approaches and methods used to describe and analyze them. Key point – in the topics listed below, we aim to balance giving students new tools with which to perform quantitative analyses, and the concepts that are core to Social-ecological science. Our overarching aim is to make students aware that these quantitative approaches exist, and give them insights when, where and for what certain approaches or methods can be used, what kind of questions can be addressed with each, which data and skills are needed, as well as clarify the language with which to talk to experts in these approaches.

Core Teaching Concepts:
1) Philosophy of quantitative analysis and research design
2) Numbers, data, exploratory data analysis and statistics
3) Dynamical systems (equilibrium, stability, feedbacks, bifurcation, stocks and flows/dynamical systems models)
4) Complex Adaptive Systems (emergence, self-organization, adaptation, networks, interacting agents/agent-based modelling)
5) Analysing and modelling human behaviour (optimization, game theory, behavioural experiments, adaptation and learning)

Learning outcomes:
- Understanding of how to conduct quantitative analysis of Social-Ecological Systems (SESs), and how to model (in the broadest sense).
- A vocabulary to talk with researchers doing ecological, economic, social-ecological modelling of SES using statistical, mathematical or computational approaches.
- Overview of quantitative methods available for studying SES, particularly formal modelling, empirical analysis and methods from complexity science.
- Understanding of when and how different approaches can be used, their potentials and limitations.
- Understanding of different conceptualizations of SES, different approaches and their implications (e.g. what do we learn from a theoretical model, from a statistical analysis, etc.)

SCHEDULE (Please note reading assignments and additional information for exercises below)

Date	Class	Topic
Week 1: Philosophy, Complexity Theory, Dynamical Systems, Data analysis		
Day 1 Friday Feb 15, 2019 (Maja & Steve)	Morning discussion and lecture (1000-1200)	<u>Philosophical Foundations</u> Motivation for the course + SES history What is modelling? How do I design a quantitative research approach? Course purpose, review course material
	Afternoon discussion and lecture (1300-1500)	<u>Intro to Dynamical Systems and Complex Adaptive Systems</u> Key concepts and their underlying foundations Graphical representations
Day 2 Mon, Feb 18, 2019 (Steve)	Morning Discussion (1000-1030)	Review reading assignment
	Morning Lecture (1030-1200)	<u>Dynamical system models in practice</u> Uses of dynamical system models Common building blocks Deductive and inductive approaches Parametric and non-parametric approaches Numerical analysis
	Afternoon workshop (1300-1500)	Develop dynamical model of course case study
Day 3 Tue, Feb 19, 2019 (Ingo)	Morning Discussion (1000-1030)	Review reading assignment
	Morning lecture (1030-1200)	<u>Introduction to data</u> Introduction to DATA, the various forms it can take. Exploratory data analysis.
	Afternoon workshop (1300-1500)	Introduction to scientific computing with R Perform simple exploratory data analysis on course case study.
Day 4 Wed, Feb 20,	Morning Discussion (1000-1030)	Review reading assignment

2019 (Ingo)	Morning lecture (1030-1200)	<u>Philosophy of statistical modelling (linear-, non-linear models)</u>
	Afternoon workshop (1300-1500)	Develop statistical model of dynamical model case study
Day 5 Thu, Feb 21, 2019 (Steve, Ingo)	Morning Discussion (1000-1200)	<u>Student Day</u> Students present 5-10 mins of their own research, and what kind of quantitative tools they are looking to use. Class provides advice following previous week's learning. Student group work / discussion on how what they have learned might impact their research
	Afternoon (1300-1500)	Continue student group work / discussion.
Week 2: Complex adaptive systems approaches: Networks, Agent-based modelling, Strategy and Game theory		
Day 6 Fri, Feb 22, 2019 (Örjan)	Morning Discussion (1000-1030)	Review reading assignment
	Morning Lecture (1030-1200)	<u>Networks</u> Introduction to the idea of systems described as nodes and links, and how that relates to CAS. Examples from SES: social networks, fragmented landscapes (metapopulations)… etc. Introduction to network analysis, What can it show, what is it good (and not so good) for? What kind of data is needed, what kind of analyses are available, common pitfalls?
	Afternoon workshop (1300-1500)	Perform network analysis on data from a case of small-scale fishery in east Africa
Day 7 Mo, Feb 25, 2019 (tbd)	Morning Discussion	Review reading assignment
	Morning Lecture	<u>Tbd – networks?</u> most likely network applications in SES
	Afternoon	tbd

	workshop	
Day 8 Tue Feb 26, 2019 (Maja)	Morning Discussion (1000-1030)	Review reading assignment
	Morning Lecture (1030-1200)	<u>Agent-based modelling</u> Agents, environment, interactions Self-organization, emergence, adaptation, agent-based modelling Discuss the issue of scale and mean-field models; bottom-up versus systems-level modelling Examples from SES: fishery, common pool resource management
	Afternoon workshop (1300-1500)	Intro to agent-based modelling using Netlogo. Experiment with selected SES models Predator Prey system as ABM, comparison with dynamical system version.
Day 9 Wed Feb 27, 2019 (Maja)	Morning Discussion	Review reading assignment
	Morning Lecture	<u>Human Decision Making</u> Homo economicus versus other theories Introduction to optimization (maximize, minimize) Basic Bioeconomics and Game theory Behavioural experiments Modeling adaptation and learning
	Afternoon workshop	Exploring human behaviour course case study
Day 10 Thurs Feb 28, 2019 (all)	Morning discussion 1000-1200	<u>Course Review</u> Overview of course material – review key concepts Student evaluations

Reading assignments and information for exercises:

All reading should to be read before the course day as we start the day with a discussion of the readings. Papers will be made available before the course.

Day 1 - Introduction
Epstein, J.M., 2008. Why model? Journal of Artificial Societies and Social Simulation 11, 12.

Arthur, E.W.B., Durlauf, S., Lane, D., 1997. Process and Emergence in the Economy 14. (or alternatively Page, S.E., 2015. What Sociologists Should Know About Complexity. Annual Review of Sociology 41, 21–41)

Scheffer, M., & Carpenter, S. R. (2003). Catastrophic regime shifts in ecosystems: Linking theory to observation. Trends in Ecology and Evolution. doi:10.1016/j.tree.2003.09.002

Day 2 – Dynamical Systems
Lade, Steven J., et al. "Resilience offers escape from trapped thinking on poverty alleviation." *Science Advances* 3.5 (2017): e1603043.

Day 3 – **Data and data analysis**
Zuur, A. F, E. N Ieno, and C. S Elphick. 2010. "A Protocol for Data Exploration to Avoid Common Statistical Problems." Methods in Ecology and Evolution 1 (1): 3–14.

Optional:
May, Robert M. 2004. "Uses and Abuses of Mathematics in Biology." Science 303 (5659): 790–93. https://doi.org/10.1126/science.1094442

Myers, Ransom A., and Boris Worm. 2003. "Rapid Worldwide Depletion of Predatory Fish Communities." Nature 423 (6937): 280–83. https://doi.org/10.1038/nature01610.

Exercise: please have R installed

Day 4 – **Time series analysis**
Jassby, Alan D., and Thomas M. Powell. 1990. "Detecting Changes in Ecological Time Series." Ecology 71 (6): 2044–52.

Day 5 – no reading, preparation of speed talks

Day 6 - Networks
Janssen, M. A., Ö. Bodin, J. M. Anderies, T. Elmqvist, H. Ernstson, R. R. J. McAllister, P. Olsson, and P. Ryan. 2006. Toward a network perspective on the resilience of social-ecological systems. *Ecology and Society* **11**(1): 15.

Exercise: The workshop is based on Bodin, Ö., B.I. Crona (2017) "Social Networks: Uncovering Social–Ecological (Mis)matches in Heterogeneous Marine Landscapes" In Gergel, S.E. & Turner, M.G., "Learning Landscape Ecology: A Practical Guide to Concepts and Techniques", Springer-Verlag, New York.

Install Ucinet prior to workshop (download free trial version at http://www.analytictech.com /ucinet/). The software only runs on Windows. If you are using Apple, either install Windows (dual boot/boot camp), or install emulation software like "Parallel Desktop", or download and use the free software "WineBottler" (see instructions at the link above)

Day 7 – Networks
tbd

Day 8 – Agent-based modelling
Schlüter, M. et al. (in review). Agent-based modelling. Book chapter in Biggs et al. (in prep). A guide to navigating Methods for Studying Social-Ecological Systems.

Taylor, R., Besa, M.C., Forrester, J. 2016. Agent-based modelling: A tool for addressing the complexity of environment and development policy issues 24.

Exercise: Please install netlogo.

Day 9 – Human behaviour
Chapters 8 and 9 in Anderies, J.M. and Janssen, M. 2013. Sustaining the commons. Center for Behaviour, institutions and environment. http://sustainingthecommons.asu.edu

Schlüter, M., Baeza, A., Dressler, G., Frank, K., Groeneveld, J., Jager, W., Janssen, M.A., McAllister, R.R.J., Müller, B., Orach, K., Schwarz, N., Wijermans, N., 2017. A framework for mapping and comparing behavioural theories in models of social-ecological systems. Ecological Economics 131, 21–35. doi:10.1016/j.ecolecon.2016.08.008

Optional:
Chapter 3 in Gintis, H., 2009. The bounds of reason: game theory and the unification of the behavioral sciences. Princeton University Press, Princeton, N.J.

Day 10 – No reading