REM 625: Risk Assessment and Decision Analysis for Management of Natural Resources

Spring 2017

Instructor:	Dr. Sean Cox		
	School of Resource and Environmental Management		
	Simon Fraser University		
	Office:	TASC I 8425	
	Office hrs:	_____(TBA first class)	
	Tel.: 778.782.5778		
	Email:	spcox@sfu.ca	
Grad Prog Asst:	Iris Schischmanow		
	Office:	TASC I, REM Office	
Classes:	Tuesday	9:30 AM - 11:20 PM	__AQ 5009____
Computer Labs:	Fridays	9:30 AM - 11:20 PM	__AQ 5009____

Course overview

Humans impact the environment in various ways, including exploitation of living and non-living resources, pollution, development, and habitat alteration. Decision-makers often need to make explicit choices about regulating harmful activities, developing resources, and investing in restoration to meet objectives across a broad range of stakeholder values. Decisions can be made via *ad hoc* approaches, usually in response to problems and conflicts as they arise, or by applying the formalism of structured decision-making that anticipates potential problems by explicitly considering objectives, alternative actions, uncertainties, and risks. **Risk Assessment and Decision Analysis** are primary components of structured decision-making approaches because these methods link management decisions to objectives, while taking greatest advantage of available information and research.

Educational Goals for Students

REM 625 introduces risk assessment and decision analysis concepts and techniques by covering a broad range of examples, including (1) conservation of birds, large mammals, and fishes, (2) air and water quality, (3) pest control, (4) toxic chemicals, (5) forest and wildlife management, (6) land use, (7) water-use planning, (8) fisheries management, and (9) monitoring program design.

Class discussions and lectures provide students with a broad perspective on risk assessment and structured decision-making approaches, while hands-on computer labs and assignments provide practical experience applying quantitative methods to realistic decision problems. After completing REM 625, students will be able to:

1. Describe primary sources of uncertainty in environmental systems and management;
2. Explain how uncertainty contributes to risk for environmental management;
3. Quantify uncertainties using Bayesian statistics;

5. Use quantitative decision analysis to rank alternative management actions while taking uncertainties into account;
6. Apply sensitivity analyses to evaluate robustness of decisions;
7. Set research priorities by estimating the value of future research and monitoring information;
8. Assess the advantages and limitations of quantitative decision methods;
9. Communicate uncertainties and risks to scientific and non-scientific audiences.

Optional Texts

Conroy, M.J. and Peterson, J.T. 2013. Decision making in Natural Resource Management: a structured, adaptive approach. Wiley-Blackwell, 456 pp.

Required

Each student must bring a laptop computer to all Friday lab classes.

Course Package

An electronic package will be provided that includes guidelines to assignments, readings, texts, handouts, and presentation slides.

Prerequisites

Students need to have reasonably good understanding of basic statistics, Excel spreadsheets, and various types of graphs. REM 625 is not a course in Bayesian statistics, although we develop and work with some low-dimensional Bayesian estimation procedures. More quantitative courses such as REM 612 and REM 614 introduce multi-parameter models and simulation-based methods for Bayesian estimation.

Format and Grades

The format for REM 625 classes involves lectures, discussions of readings, and hands-on computer laboratories. Student grading is based on the following four criteria:

1. Three major assignments (75%) - computer data analysis and short, explanatory essays assigned approximately every 3 weeks. Please read and adhere to the separate handout, "Guidelines for Assignments". Poorly written assignments will be marked down accordingly.

2. Leading Seminar Discussion (10%) – a summary of at least one paper from the reading package. Each student will give a **15 minute** summary consisting of the following:

a. 3 key points of the paper and why these are important
b. At least 2 of your most constructive suggestions for improving or extending the work along with justification or examples.

The student will then lead a focused class discussion of the paper, encouraging other students to contribute their ideas. Students should refer to the Courseware package "General questions to guide analysis of ..." to prepare themselves.

3. Class Participation (5%) - regular contributions to class discussion demonstrating progress toward the Education Goals listed above.

4. Research Presentation (10%) - a 10-minute seminar during the last week of classes in which you describe your graduate research in the context of a decision analysis.

List of Topics

The following list is a guide to the structure and general order for REM 625. It is not a weekly schedule of classes. Students are responsible for monitoring progress through this schedule and completing the readings before class. M & H = Morgan and Henrion (1990). Other readings are in the Custom Courseware package. Please have the following for every class, including labs: (1) this course outline, (2) list of references, (3) course package, and (4) any handouts.

1. Overview of the course **(M & H -- Preface, Chap. 1, 3; Cohan et al. 1984)**

2. What is environmental risk assessment and why do we need it?
   (Anonymous 1997; Apostolakis 2004; Power and McCarty 2002)
   - Relationship between risk assessment and risk management

3. Uncertainty in natural resource systems – sources and implications **(M & H -- Chap. 4)**
   A. Sources
      (1) Partial observability of natural systems
      (2) Biased and imprecise observations
      (3) Poorly understood system complexity
      (4) Biased and imprecise forecasts of natural and social system dynamics
      (5) Unexpected deviation from management actions
      (6) Unstated management or stakeholder objectives
   B. Management implications of uncertainties

4. Approaches to making resource management decisions in the presence of uncertainty (**Rosenberg 2007**)
   A. Ignore uncertainties and use best estimates – Certainty Equivalence
   B. Take uncertainties into account qualitatively
   C. Take uncertainties into account quantitatively
   D. Relation between the precautionary principle and the precautionary approach
   E. Use of best available science **(Government of Canada 2000, 2002)**

5. Decision analysis (a quantitative method)
   A. Introduction to structured decision-making and decision analysis ("statistical decision theory")
   B. Eight components of decision analysis
   C. Examples of decision analysis and acknowledging uncertainty **(Allison et al. 2004; Drechsler 2000; Maguire 2004; Parkhurst 1984 -- only pp. 105-114 and 121-124; Reckhow 1994; Render and Stair 1988 -- only pages 144-149; Robb and Peterman 1998; Starfield and Herr 1991; M & H pp. 192-198)**
   D. Relations among risk analysis, risk management, and decision analysis

6. Describing and quantifying uncertainty **(M & H -- pp. 73-86 and scan pp. 87-101)**
    A. Purpose: establish degrees of belief in alternative states of nature
    B. Advantages and limitations of:
        (1) Classical hypothesis testing
        (2) Confidence intervals
        (3) Edwards' views on testing hypotheses
        (4) Likelihood profiles
        (5) Bayesian posterior probabilities
            a) Examples **(Wade 2000; Ellison 1996; Crome et al. 1996;** also scan for chapters of interest to you in Howson and Urbach 1993 and Hilborn and Mangel 1997)
        (6) Expert judgment **(M & H -- Chap. 6, 7);**
            (also see Goldstein and Hogarth 1997 and Connolly et al. 2000 if this topic is of interest to you)

7. Advanced topics in quantitative procedures for decision analysis
    A. Evaluating quality of management decisions
    B. Quantitatively defining management objectives
        - Simple graphical tools (hierarchies)
        - Link between objectives and indicators
        - Formulating probabilistic objectives (to reflect uncertainty in obtaining the target/goal)
        - Tradeoffs
        - Quantifying utility **(Moore and Thomas 1976, pp. 169-176; Nair and Sicherman 1980)**
    C. Complex management actions -- sequential decisions
    D. Choosing model(s) for calculating outcomes **(Holling et al. 1978, Chap. 7; M & H -- Chap. 11)**
    E. Comparing several cases of assumptions, parameter values, etc.
        (1) Sensitivity analysis
        (2) Classification and regression trees
        (3) Analysis of scenarios
    F. Role of Monte Carlo simulation (scan for chapters of interest to you in Vose 1996)
    G. Bayesian analysis for many parameters (Markov Chain Monte Carlo [MCMC] and other methods) **(Harwood and Stokes 2003)**

8. The value of reducing uncertainty (**Gregory et al. 2006**)
    A. Value of information **(M & H -- Chap. 12; ; Render and Stair 1988 -- only pages 149-157)**
        (1) EVIU - the expected value of including uncertainty
        (2) EVPI - the expected value of perfect information
        (3) EVSI - the expected value of sample information
            a. Active adaptive management to obtain sample information
            b. Design of pilot projects

(scan for chapters of interest to you in Walters 1986)

9. Communicating uncertainties and risks **("Balloon joke", M & H -- Chap. 9)**
    Topics below are relevant to:
        (1) Eliciting probabilities from experts or others
        (2) Reporting your results of risk assessments and decision analyses to make them readily understood
    A. Results of decision analyses
    B. Special challenges to communicating about uncertainties and risks
        (1) Perception of risk **(**scan for chapters of interest to you in Glickman and Gough 1990)
        (2) Confusion arising from six interpretations of the term "probability" **(Anderson 1998)**
        (3) Cognitive illusions
    C. Other ways to improve communication
        (1) Thorough documentation
        (2) Presentation appropriate to the audience
    D. Hierarchical information systems
    E. Gaming with simulation models
    F. Workshops

10. Benefits and limitations of quantitative methods of decision making
    (Maguire and Boiney 1994)

11. Conclusions, review of main themes, and final recommendations

Reading Package

- **Allison**, C., R.C. Sidle and D. Tait. 2004. Application of decision analysis to forest road deactivation in unstable terrain. *Environmental Management* 33(2): 173–185.
- **Anderson**, J.L. 1998. Enhancing communication about uncertainty. B.C. Ministry of Forests Research Program, Victoria, Extension Note 22, pp. 1-6.
- **Anonymous**. 1997. Risk and the inadequacy of science. *Nature* 385:1.
- **Apostolakis**, G.E. 2004. How useful is quantitative risk assessment? *Risk Analysis* 24(3): 515-520.
- **Cohan**, D., S.M. Haas, D.L. Radloff and R.F. Yancik. 1984. Using fire in forest management: Decision making under uncertainty. *Interfaces* 14(5):8-19.
- **Crome**, F.H.J., M.R. Thomas and L.A. Moore. 1996. A novel Bayesian approach to assessing impacts of rain forest logging. *Ecological Applications* 6(4):1104-1123.
- **Drechsler**, M. 2000. A model-based decision aid for species protection under uncertainty. *Biological Conservation* 94:23-30.
- **Ellison**, A.M. 1996. An introduction to Bayesian inference for ecological research and environmental decision-making. *Ecological Applications* 6(4):1036-1046.
- **Harwood**, J. and K. Stokes. 2003. Coping with uncertainty in ecological advice: lessons from fisheries. *Trends in Ecology and Evolution* 18(12):617-622.

- **Maguire**, L.A. 2004. What can decision analysis do for invasive species management? *Risk Analysis* 24(4):859-868.
- **Maguire**, L.A. and L.G. Boiney. 1994. Resolving environmental disputes: A framework incorporating decision analysis and dispute resolution techniques. *Journal of Environmental Management* 42:31-47.
- **Nair,** K. and Sicherman, A. 1980. Making Decisions on Environmental Problems. *Environment International* 3, pp.11-21. ISSN 0160-4120. Pergamon Press Ltd.
- **Parkhurst**, D.F. 1984. Decision analysis for toxic waste releases. *J. of Environmental Management* 18:105-130.
- **Power**, M. and McCarty, L.S. 2002. Trends in the development of ecological risk assessment and management frameworks. *Human and Ecological Risk Assessment* 8:7-18.
- **Reckhow**, K.H. 1994. Importance of scientific uncertainty in decision making. *Environmental Management* 18(2):161-166.
- **Robb**, C.A. and R.M. Peterman. 1998. Application of Bayesian decision analysis to the management of a sockeye salmon fishery. Can. J. Fish. Aquat. Sci. 55:86-98
- **Rosenberg**, A.A. 2007. Fishing for certainty. Nature 449:989.
- **Gregory,R.**, Failing, L., and Higgins, P. 2006. Adaptive management and environmental decision making: a case study application to water use planning. *Ecological Economics*, 58:434-447.
- **Starfield**, A.M. and A. M. Herr. 1991. A response to Maguire. Conservation Biology 5(4):435.
- **Wade**, P.R. 2000. Bayesian methods in conservation biology. *Conservation Biology* 14(5):1308-1316.

Additional Readings not discussed in class

- **Clemen**, R.T. 1996. Expected value of imperfect information. Chapter 12, pages 435-451 in: Making Hard Decisions: An Introduction to Decision Analysis. 2nd edition. Duxbury Press, Belmont, Calif. 664 pp. ISBN 0-534-26034-9. **[This is for computer lab #9]**
- **Davis**, M. 1997. Scientific Papers and Presentations. Academic Press, (excerpts of pp. 263-268, Appendix 11, Editorial -- tips on oral presentations). 296 pp. ISBN 0-12-206370-8.
- **Dixon**, W.J. and F.J. Massey. 1983. Introduction to Statistical Analysis. 4th edition. McGraw Hill, New York. 678 pp. ISBN 0-07-017073-8. (excerpts of pp. 80-81 on Confidence-interval estimate of the mean).
- **Government of Canada. 2000**. A framework for science and technology advice: Principles and guidelines for the effective use of science and technology advice in government decision making. Communications Branch, Industry Canada, pp.1-18.
- **Government of Canada. 2002**. Science and technology advice: A framework to build on. A report on federal science and technology. Communications Branch, Industry Canada, pp.20-25.
- **Holling**, C.S. (ed.). 1978. Chapter 7: Model invalidation and belief. Pp. 95-105, in *Adaptive Environmental Assessment and Management*. Wiley, New York. 377 pp. ISBN 0-471-99632-7.

- **Keeney**, R.L. 1982. Decision analysis: An overview. *Operations Research* 30(5):803-837.
- **Moore**, P.G. and H. Thomas. 1976. The Anatomy of Decisions. Penguin Books, New York. 243 pp. ISBN 014080952X (excerpts of pp. 20-30 and 169-176 on basic decision analysis and on assessing utility).
- **Pearce**, D.W. and R.K. Turner. 1990. Discounting the future (Pp. 211-213 on discount rates) in *Economics of Natural Resources and the Environment*. Johns Hopkins University Press, Baltimore, Maryland. ISBN 0-8018-3986-6. 392 pp. ISBN 0-8018-3987-4 (pbk.)
- **Render**, B. and R.M. Stair. 1988. Decision trees and utility theory. Pp. 144-157, in *Quantitative Analysis for Management*. Allyn and Bacon, Boston. 792 pp. ISBN 0-205-10566-1.
- **Sokal**, R.R. and F.J. Rohlf. 1969. Biometry. W.H. Freeman, San Francisco, Calif. 776 pp. ISBN 0-7167-0663-6. (excerpts of pp. 120-121, 138-143, Chapter 7: Estimation and hypothesis testing).

Books available in SFU Burnaby Campus Library (not on reserve)

Conroy, M.J. and Peterson, J.T. 2013. Decision making in natural resource management: a structured, adaptive approach. Wiley-Blackwell 456 pp.

Burgman, M.A. 2005. *Risks and Decisions for Conservation and Environmental Management*. Cambridge University Press, N.Y., 488 pp.

Clemen, R.T. and T. Reilly. 2001. *Making Hard Decisions with Decision Tools*. 2nd rev. ed. Duxbury Press/Thomson Learning, Pacific Grove, Calif.

Connolly, T., H.R. Arkes, and K.R. Hammond (eds.). 2000. *Judgment and Decision Making: An Interdisciplinary Reader*. 2nd ed., Cambridge University Press, 786 pp.

Efron, B. 1986. Why isn't every one a Bayesian? *American Statistician* 40(1):1-11.

Glickman, T. and M. Gough (eds.). 1990. *Readings in Risk.* Resources for the Future, Washington, D.C., 262 pp.

Goldstein, W.M. and R.M. Hogarth (eds.). 1997. *Research on Judgment and Decision Making: Currents, Connections, and Controversies*. Cambridge University Press, 750 pp.

Hilborn, R. and M. Mangel. 1997. *The Ecological Detective: Confronting Models with Data*. Monographs in Population Biology 28, Princeton University Press. 315 pp.

Holling, C.S. (ed.). 1978. Chapter 7: Model invalidation and belief. Pp. 95-105, in *Adaptive Environmental Assessment and Management*. Wiley, New York.

Howson, C. and P. Urbach. 1993 (either the 1989 or 1993 edition*). Scientific Reasoning: The Bayesian Approach*. Open Court, Chicago.

Morgan, G. and M. Henrion. 1990. *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*. Cambridge University Press, 332 pp.

Punt, A.E. and R. Hilborn. 1997. Fisheries stock assessment and decision analysis: The Bayesian approach. *Reviews in Fish Biology and Fisheries* 7(1):35-63.

Suter, G.W. 1993. Chapters 1 and 2. Pp. 3-47, *in* G.W. Suter (ed.) *Ecological Risk Assessment*. Lewis Publishers, Boca Raton, Florida, 538 pp.

U.S. Environmental Protection Agency (EPA). 1998. Guidelines for ecological risk assessment. Risk Assessment Forum, Washington, D.C. EPA/630/R-95/002F. 188 pp. (available on line at http://www.epa.gov/ncea/raf/pdfs/ecotxtbx.pdf).

Vose, D. 1996. *Quantitative Risk Analysis: A Guide to Monte Carlo Simulation Modelling*. Wiley, New York. 328 pp.

Walters, C.J. 1986. *Adaptive Management of Renewable Resources*. MacMillan, New York. 374 pp.

Computer lab topics

A simple decision analysis in an Excel spreadsheet

Bayesian statistical analysis to describe uncertainties in states of nature; using posterior probabilities in a simple decision analysis

Full Bayesian decision analyses

Using a stochastic model to generate outcomes

Analysis of sensitivity to uncertainties in a model's structure, management objectives, parameter values, probabilities, etc.

Multi-attribute utility and decision analysis

Asymmetric loss functions and probability distributions

Estimating the value of new research information

(REM625-2017)