Graduate Program in Environmental Conservation
Comprehensive Exam Topics

This document provides a comprehensive list of topics associated with the core area requirements for all students seeking candidacy for a Master of Science (MS) degree in Environmental Conservation (ECO). The purpose of this document is to provide students with a comprehensive list of study topics to help in preparation for the comprehensive exam. The actual exam will involve a randomly drawn set of questions from this list of topics (example questions provided below).

All MS students must pass the comprehensive exam to advance to candidacy for an MS degree in ECO. See the student handbook for the graduate program in ECO for a detailed description of the comprehensive exam requirement, including procedures for taking the exam and what to do if part or all of the exam is failed.

This document is organized into six major sections. The first section pertains to the general knowledge requirement for ALL students and is based on two core courses required of ALL ECO graduate students seeking an MS degree: 1) research concepts, and 2) analysis of environmental data. ALL students are responsible for section 1, and a portion of the comprehensive exam (40%) will be allocated to this section. Sections 2 through 6 correspond to the five areas of concentration within the ECO graduate program: 1) Wildlife, Fish and Conservation Biology, 2) Forest Resources and Arboriculture, 3) Water, Wetlands and Watersheds, 4) Environmental Policy and Human Dimensions, and 5) Building Systems. Each section consists of three sub-sections corresponding to the three core topic areas: 1) environmental science, 2) quantitative science, and 3) human dimensions. The topics listed under each sub-section are tailored to match the corresponding concentration. For example, the topics listed under the core topic areas for Wildlife, Fish and Conservation Biology are selected to reflect the basic knowledge expected of all students in this concentration. Each student is responsible for the section corresponding to his/her concentration and a portion of the exam (60%) will be allocated to this section (20% each from the three core topic areas).

IMPORTANTLY, to accommodate the diversity of academic backgrounds among students within each concentration, students will be allowed to choose from among a set of questions within each section of the exam; e.g., "choose 2 of the following 5 questions". Thus, each student will have the opportunity to answer questions pertinent to their particular academic background and still deemed core knowledge for the entire concentration. In addition, we realize that through the course of the program students will gain in-depth knowledge in some, but not all of the topic areas listed in the concentrations below. Thus, we are not expecting students to have mastered each topic area. We do, however, expect students to have at the very least, some general knowledge of the concepts or ideas listed in the general knowledge section and the section corresponding to their concentration. To help in areas where students were not exposed to topics via coursework, we will eventually provide a list of one or two readings for each topic (although this is currently only completed for the building systems concentration). Additionally, we will eventually provide a list of courses regularly offered in ECO or other departments that cover the various topics (although this is currently only partially completed for the water, wetlands and watershed concentration and environmental policy and human dimensions concentration.)
Section 1. General Knowledge Section (All students)

This section consists of two sub-sections or topics based on core courses required of ALL ECo graduate students seeking an MS degree. All students will be required to answer a set of questions drawn at random from each of these subsections. Each sub-section will comprise 20% of the exam questions, for a total allocation of 40% to the general knowledge section. Example questions similar in nature to those that will be given on the exam are provided at the end of each sub-section.

A. Research Concepts

1. Definition(s) of science and other related terms (hypothesis, theory, fact, etc.)
2. History of science: perspective, timeline, important events, issues and people
3. Philosophy of science: major lines of thought, evolution of thought, key people and ideas
4. Science and the scientific method
5. Deductive and inductive approaches and the role of empiricism
6. Approaches to research design (e.g., observational versus experimental)
7. Induction, retroduction, and hypothetico-deductive methods
8. Biological and statistical hypotheses
9. Null hypotheses: approach and issues
10. Formulating research questions, including the question “why?”
11. The concept of reproducibility of results: what is it, who originated it, and its current role
12. Definition and goal of study design
13. Observational/experimental units, statistical population, and scope of inference
14. Sources of variability
15. Pseudoreplication: issues, importance, who brought this to our attention
16. Purpose, approach, and issues related to scientific literature review
17. Basic and advanced experimental design (e.g., simple random, stratified random, etc.)
18. Concepts in basic research design (e.g., randomization, replication, interspersion, control)
19. Issues and trade-offs associated with randomization vs. interspersion of plots
20. Sample size: how defined, why is it important, issues related to

21. Issues related to authorship, co-authorship, and peer-review of scientific papers

Example questions:

1. Who is credited as the founder of modern science, and what 3 premises did he promote?

2. You are going to design an experiment where you are testing mechanical control (label M) vs. chemical control with the product Roundup (label R) of an exotic invasive woodland plant. Your study plot is on a hillside that slopes from right to left in the diagram below. Pretend you had a random numbers table, and label each cell with a treatment (label the 3 columns as well):

(a)

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(High Side) > > > > > GRADIENT > > > > > (Low Side)

(b) In this design, which entity serves as the experimental unit? ______________________

(c) This is an example of what kind of research design? ____________________________
(d) To incorporate 2 gradients into your study, you might use a design called? ____________

B. Analysis of Environmental Data

1. Role of statistics: description versus inference
2. Population (statistical) versus sample
3. Types of environmental data (as it pertains to the choice of statistical model): continuous, count (simple and cross-classified), proportion, binary, time at death, time series, and circular
4. Types of variables based on their relationship: dependent, independent, and interdependent
5. Parameter versus statistic
6. Common measures of central tendency (mean, median, mode), spread (variance, standard deviation, coefficient of variation, range, median absolute deviation, interquartile range) and non-normality (skewness and kurtosis)
7. Accuracy versus precision
8. Quantiles: what are they
9. Common single variable distribution plots (empirical distribution function, empirical cumulative distribution function, histogram, box-and-whisker plot, normal quantile plot)
10. Covariance versus correlation (Pearson's product-moment $r$ and Spearman's $\rho$)
11. Imputation: what is it, and common approaches
12. Data transformation versus standardization: what is a z-score?
13. Statistical outliers: what are they, and approaches for dealing with them
14. Deterministic versus stochastic model
15. Mechanistic versus phenomenological model
16. Probability distribution: what is it, and what is its purpose in statistical models
17. Measurement versus process error
18. Discrete versus continuous probability distribution
19. Probability mass versus probability density function
20. Cumulative probability distribution (especially as it pertains to the calculation of p-values)
21. Quantile distribution (especially as it pertains to identifying critical values of test statistics).
22. Parametric versus nonparametric inference
23. Frequentist versus Bayesian inference paradigms

24. $p$-value: what is it, how is it computed

25. One-sided versus two-sided test (especially as it pertains to the calculation of $p$-values)

26. Alpha, Beta and statistical power

27. Type I versus type II error

28. Ordinary least square estimation

29. Numerical versus analytical solutions to parameter estimation and hypothesis testing

30. Point versus interval estimate

31. Standard error and confidence interval

32. Bootstrap resampling (especially as it pertains to interval estimation)

33. Randomization (Monte Carlo) testing

34. Autocorrelation (spatial and temporal)

35. Interpolation versus extrapolation

36. Penalized goodness-of-fit and model selection

37. Likelihood (and maximum likelihood)

38. Bayes theorem and posterior probabilities

39. Linear models, generalized linear models, generalized additive models

40. Mixed effects, hierarchical or multi-level models

Example questions:

1. (Type of environmental data). In a field study on factors affecting the likelihood of heart rot occurrence in oak trees, you are considering three ways to collect data. What type of dependent data (continuous, count, binary, proportion, time to death/failure, time series, circular) are each of the following:

   a) In a sample of $n$ variable-radius plots, you count how many out of the nearest $m$ oak trees have heart rot (each tree is recorded as "present" or "absent") and measure a suite of independent environmental variables at the plot scale.
b) In a sample of \( n \) oak trees, you determine the presence/absence of heart rot and measure a suite of independent environmental variables at the tree scale.

c) In a sample of \( n \) fixed-area plots, you count the number oak trees with heart rot and measure a suite of independent environmental variables at the plot scale.

2. (Measurement versus process error). In a manipulative laboratory experiment on the effect of saw blade type (independent variable) on the percent of the climbing rope cut by accidental injury (dependent variable), you record considerable variability about the group means (see figure). What are the two types of error represented here and give an example of each in the context of this study?

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**Section 2. Wildlife, Fish and Conservation Biology Concentration**

This section consists of three sub-sections corresponding to the three core topic areas required of ALL ECo graduate students seeking an MS degree. All students in the Wildlife, Fish and Conservation Biology concentration will be required to answer a set of questions drawn at random from each of these sub-sections. Each sub-section will comprise 20% of the exam questions, for a total allocation of 60% to this section. Example questions similar in nature to those that will be given on the exam are provided at the end of each sub-section. General reference books that cover many of the topics are provided at the end.

**A. Environmental Science**
1. Intermediate disturbance hypothesis
2. Minimum dynamic area
3. Single Large or Several Small (SLOSS) debate
4. Conservation of species at the core versus periphery of their range
5. Exponential and logistic population growth
6. Metapopulation dynamics
7. Source-sink population dynamics
8. Succession and community concepts (Clements and Gleason)
9. Focal species concepts: keystone, umbrella, indicator, flagship, surrogate
10. Habitat fragmentation
11. Island biogeography
12. Ecological niche
13. Ecological resiliency and integrity
14. Top down versus bottom up regulation
15. Food webs and nutrient flows
16. Functional versus numerical response
17. Trophic cascades
18. Natural selection
19. Adaptive radiation
20. Convergent evolution
21. Theory of punctuated equilibrium
22. Local adaptation
23. Adaptive capacity
24. Genetic drift
25. Inbreeding depression
26. Extinction vortex (demographic vs. genetic causes of population extinction)
27. Effective population size
28. Prominent anthropogenic impacts on ecosystems: what are they?

29. Adaptive (resource) management

30. Role of zoos in conservation

31. Definitions of "urban" and urbanization gradients? (Rebele 1994, Picket et al. 2001)

32. Key characteristics of urban environments: such as urban heat island, high spatial heterogeneity, and elevated basal resources in food webs (Shochat et al. 2006, Pickett et al. 2011)

33. "Ecology in the city" versus "ecology of the city" (Pickett et al. 2001)

34. Diversity versus abundance along urban gradients (McKinney 2002, Shochat et al. 2006)

35. Typical characteristics of urban wildlife (DeStefano & DeGraaf 2003)

36. Socioeconomic drivers of biodiversity (Pickett et al. 2011)

Example questions:

1. (Intermediate disturbance hypothesis). On the plot below, draw a line representing the expectation under the intermediate disturbance hypothesis. Also, briefly describe a mechanism(s) for the hypothesized pattern in the context of a specific example.
2. (Inbreeding depression). In Illinois, the greater prairie chicken population was estimated to be 25,000 in 1933, in 1962 it was 2,000, and in 1993 it was down to 50 individuals. In addition, in 1960 the hatching success rate was 90%, and by 1990 the hatching success rate was down to 74%. Lastly, between 1960-1990 genetic variation in the population declined by 30%. In the early 1990's individuals from Minnesota and Kansas were introduced to the population and shortly thereafter hatching rate success increased to 94%. What genetic phenomenon does this case study demonstrate and what is the mechanism(s) behind the process?

B. Quantitative Science

1. Biological versus statistical significance
2. Population viability modeling (PVA)
3. Spatially explicit population modeling (SEPM)
4. Leslie population transition matrix
5. Decision-support systems (DSS)
6. Remote sensing: sensor resolution; multispectral & hyperspectral data; airborne & satellite sensors; application to wildlife and fisheries science
7. Geographic information systems (GIS): main types of data representation (vector versus raster); metadata; application to wildlife and fisheries science
8. Global positioning systems (GPS): application to wildlife and fisheries science
9. Animal tracking devices: radio telemetry, acoustic telemetry, GPS telemetry, PIT tags, etc.
10. Environmental tracking devices: light, temperature and depth meters, etc.
11. Open source software versus proprietary software, open standards, interoperability
12. Metadata and XML: what are these, and why are they important for quantitative science
13. Database structures: difference between a “flat file” database and a “relational database”; the three types of relationships found in data; the idea of “normalizing” of data
14. Internet technologies: FTP; Http; the so-called “Web 2.0” technologies (such as content management systems); the emerging idea of “cloud computing” and “web services.”

Example questions:

1. (Leslie population transition matrix). You are studying population dynamics of species X and you want to parameterize a Leslie population transition matrix so that you can simulate population growth. Species X is a short-lived species with three distinct life stages: 1) juvenile, 2) sub-adult, and 3) adult. Set up a Leslie matrix for this population, label the cell entries, and define or describe each parameter.

2. (Remote sensing). You are interested in using remote sensing to map habitat conditions for a forest-dwelling species that has an average home range size of 1 ha (100x100 m) and differentiates between coniferous and deciduous forest of varying successional or structural
stages (e.g., early, mid, and late-seral). What are some of the principal considerations in selecting a satellite-based remote sensing product for this application in terms of both spatial and thematic resolution? Also, what is likely to be a key limitation of any satellite imagery in mapping important habitat conditions for this species?

C. Human Dimensions

1. Environmental conservation agencies: names and major responsibilities (e.g., Fish and Wildlife Service, Forest Service, Bureau of Land Management, National Park Service, Bureau of Indian Affairs, Environmental Protection Agency, National Oceanic and Atmospheric Administration, Geological Survey)

2. Environmental conservation laws: date of enactment, purpose, and major regulations (e.g., Lacey Act, Migratory Bird Treaty Act, Endangered Species Act, National Environmental Policy Act, Clean Water Act, Clean Air Act, Pittman-Robertson Act (Federal Aid in Wildlife Restoration), Dingell-Johnson Act (Federal Aid in Sport Fish Restoration))

3. Environmental conservation pioneers: names and major contributions (e.g., Aldo Leopold, Gifford Pinchot, John Muir, Theodore Roosevelt, E.O. Wilson)

4. History of natural resource conservation in the United States

5. Role of non-governmental organizations (NGOs) in wildlife and fish conservation

6. Conservation easement: what is it and how is it used in wildlife and fish conservation

7. Nuisance wildlife: what are they and what are some management options

8. Conflict resolution methods

Example questions:

1. (Environmental conservation agencies). A federal dam on the Connecticut River has been proposed for removal to improve aquatic connectivity and ecosystem integrity. Atlantic salmon, an federally endangered anadromous fish species, is known to migrate past the dam. Also, dwarf wedge mussels, also federally endangered, are known to occur in the river segment below the dam. Briefly, what federal agencies would have a principal role in the review and permitting of the dam removal project, and what would be their major responsibilities?

2. (Conservation easement). Let's say that you are an active conservationist seeking to protect land and natural resources from development in the Connecticut River valley in Massachusetts. The land is almost entirely privately owned and is used for a variety of purposes, including agriculture and forestry. A chief threat to the biodiversity of the region is the increasing development of
natural lands by urban growth. What is a conservation easement (i.e., how does it work) and how might this tool be employed to address this threat?

**General reference books and articles:**


Section 3. Forest Resources and Arboriculture Concentration

This section consists of three sub-sections corresponding to the three core topic areas required of ALL ECo graduate students seeking an MS degree. All students in the Forest Resources and Arboriculture concentration will be required to answer a set of questions drawn at random from each of these subsections. Each sub-section will comprise 20% of the exam questions, for a total allocation of 60% to this section. Example questions similar in nature to those that will be given on the exam are provided at the end of each sub-section.

A. Environmental Science

1. Compartmentalization of Decay in Trees (CODIT)
2. Right tree, right place
3. Installation & establishment
4. Pruning
5. Tree nutrition
6. Plant health care (PHC) and Integrated Pest Management (IPM)
7. Sustained yield
8. Forest health (disease and insect vectors)
9. Forested watersheds
10. Silviculture

Example questions:

1. (Right tree, right place). Trees are often planted in such a way that they will become liabilities in the landscape (e.g., frequently needing to be pruned). Describe three scenarios where a particular tree species would become a liability, violating the principle of “right tree, right place.” Suggest two alternative species that would not become liabilities in the scenario you described.
2. **(Silviculture).** Define silviculture and describe how it is used to produce public benefits.

**B. Quantitative Science**

1. Tree inventory
2. Forest inventory
3. Tree risk assessment
4. Tree valuation (CTLA)
5. Benefits provided by trees (iTREE)
6. Remote sensing: sensor resolution; multispectral and hyperspectral data; airborne and satellite sensors; application to forestry and arboriculture
7. Geographic Information Systems (GIS): main types of data representation (vector versus raster); metadata; application to forestry and arboriculture
8. Global Positioning Systems (GPS): application to forestry and arboriculture

*Example questions:*

1. **(Tree risk assessment).** The house in Amherst that you and several friends rent has a few large trees. Describe four key elements that you would assess to determine the risk each tree presents. In addition, if the landlord has a limited budget, how would you suggest prioritizing remedial action?

2. **(GIS).** You have been hired as a technical consultant by a consortium of non-governmental conservation organizations, such as The Nature Conservancy and Trustees of Reservations, to prioritize forest parcels for conservation in the state of Massachusetts. Briefly discuss how you might use GIS to aid you in this endeavor with respect to data storage, management and analysis.

**C. Human Dimensions**

*Safety:*

1. ANSI Z.133
2. OSHA 1910.269
3. EHAP
4. PPE
Legal:

5. MGL Chapter 87
6. Negligence & liability
7. “Shall” versus “should”
8. EPA labels for pesticides

Other:

9. Benefits provided by trees
10. Ownership patterns and landowner characteristics
11. Land use history of southern New England
12. 3rd party certification of forests and forest products

Example questions:

1. (Negligence & liability). A recent tree failure on campus killed a student, whose estate is now suing the University. A secretary who’s desk overlooks the location of the tree failure did not notice anything unusual about the tree a few days before it failed, but the tree had recently been inspected by the campus arborist, who noticed fruiting bodies around the buttress roots. Was the secretary or campus arborist negligent for not taking action in this situation? Briefly justify your answer.

2. (Land use history of southern New England). You are giving a talk at an international forest resources conference about your thesis research on the role of climate and landform in determining the distribution of plant communities in southern New England. In the introduction and background, to provide the necessary historical context for your research, you need to briefly describe the human land use history of southern New England in relation to land cover. In this context, briefly describe the dominant periods of human land use in southern England beginning with the early European settlers, including the period dates (roughly) and the dominant land cover patterns that characterized each period.
Section 4. Water, Wetlands and Watersheds Concentration

This section consists of three sub-sections corresponding to the three core topic areas required of ALL ECo graduate students seeking an MS degree. All students in the Water, Wetlands and Watersheds concentration will be required to answer a set of questions drawn at random from each of these subsections. Each sub-section will comprise 20% of the exam questions, for a total allocation of 60% to this section. Numbers in the parenthesis after each topic refer to the course that covers the basics of each topic (see course list at the end of the section). Example questions similar in nature to those that will be given on the exam are provided at the end of each sub-section.

A. Environmental Science

1. Water properties (3)
2. Water budgets (1,2)
3. Surface runoff (1,2)
4. Groundwater recharge (1,2)
5. Precipitation process (1,2)
6. Soil processes (1,2)
7. Land use hydrology (1,2)
8. Hydrologic pathways of Stream flow (1,2)
9. Riparian functions (1,2)
10. Hyporheic functions (1,2,4)
11. Eutrophication process (1,2)
12. Sediment dynamics (1,2)
13. Hydric soils formation and characteristics (1,4)
14. Wetland classification and National Wetland Inventory (4)
15. Wetlands - status and trends (4)
16. Biological adaptation to aquatic conditions (4)
17. Wetland ecosystem development and succession (4)
18. Wetland functions and evaluation (1,4)
19. Wetland restoration and replication (2,4)

Example questions:

1. (Hyporheic functions). Discuss the role of hyporheic zones in aquatic food webs.

2. (Hydric soils formation and characteristics). Describe the chemical reducing sequence that takes place within saturated soils after oxygen is fully consumed and no longer available for microbial respiration. How do these biogeochemical processes affect wetland water quality functions and hydric soil morphology?

3. (Wetland functions and evaluation). Briefly explain why wetlands are referred to as “kidneys of the landscape” in terms of their geographic setting AND list three ways in which they improve water quality.

B. Quantitative Science

1. Water balance equations (1,2)
2. Hydrologic equations in practice (1,2)
3. Hydrograph analysis (1,2)
4. Frequency analysis of rainfall (1,2)
5. Spatial analysis of water resources using GIS (2)
6. Sediment modeling (2)
7. Runoff estimation (2)
8. Riparian (stream-side) survey (1,2)
9. Stream flow analysis (1,2)
10. Wetland delineation (4)
11. Wetland water balance (1,4)
12. Water demand analysis (3)
13. Demand forecasting (3)
14. Water planning and permitting methods (3)
15. Groundwater assessment and safe yield (2,3)
16. Water supply assessment (3)
17. Discount rates, cost benefit analysis (2,3)
18. Sustainable versus safe yield (2,3)
19. Probability assessment of disasters (2)

Example questions:

1. (Water balance equations). A lake in Massachusetts is declining in volume over years and the water supplier is worried about this. How would you develop a water budget for the lake, and how would you use this budget in identifying the water loss problem facing the lake?

2. (Hydrograph analysis). Describe a hydrograph and how it is useful in flood analysis. Give specific examples.

3. (Water planning and permitting). Can National Wetlands Inventory (NWI) wetland maps be used to establish the boundaries of jurisdictional wetlands. Why or why not?

C. Human Dimensions

1. Dublin-Rio principles (3)
2. Water as a basic right (3)
3. Markets and pricing (2,3)
4. Demand side management (3)
5. Water pricing (3)
6. Spatial and temporal water use patterns (2,3)
7. Water appropriation (inter-sectoral and jurisdictional) (3)
8. Watershed and water quality: TMDL’s, 303d listing, clean water act (2,3,4)
9. Federal wetland regulations and the 404 process (2,3,4)  
10. International programs for wetland conservation  
11. Water quality regulation: pollution trading, best available technology/best practice (2,3)  
12. Water quality standards (2)  
13. Emerging contaminants (2)  
14. Dams: benefits and drawbacks (2,3)  
15. Instream flows, environmental water rights (2,3)  
16. Conservation strategies (2,3,4)  
17. Water markets (2,3)  
18. Wetland mitigation banking (2,4)  
19. Watershed planning methods (2)  
20. Failure: government and markets (3)  
21. Common pool resources (3)  
22. Water institutions (3)  
23. Water security (3)  

Example questions:

1. (Conservation strategies). Explain the four types of strategies used to conserve wetlands at the national level in the U.S. Which one of the four do you think is most effective? Why?

2. (Composite of many topics). The Mississippi River drains over 40% of the U.S. and Canada and is the most extensive navigation artery in North America. Yet, the river itself and the communities that live along it are faced with many resource management challenges and is typical of most major river systems. Briefly discuss at least 4 major ways in which the system has been modified and discuss the problems associated with these modifications to the river.

3. (Federal wetland regulations and the 404 process). Distinguish between Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act. Be sure to identify what activities are regulated by each, AND identify what federal agencies have authority for implementing each?
Potential Courses (Course numbers are referred in topics listed above):

1. Forest and Wetland hydrology
2. Watershed science and Management
3. Water Resources Management and Policy
4. Wetland assessment and field techniques
5. Ecosystem Modeling and simulation
Section 5. Environmental Policy and Human Dimensions Concentration

This section consists of two sub-sections corresponding to the three core topic areas required of ALL ECo graduate students seeking an MS degree. All students in the Environmental Policy and Human Dimensions concentration will be required to answer a set of questions drawn at random from each of these subsections. Each sub-section will comprise 20% of the exam questions, for a total allocation of 60% to this section; however, for the purpose of this concentration, the environmental science and human dimensions sub-sections have been combined into a single sub-section worth 40%. Example questions similar in nature to those that will be given on the exam are provided at the end of each sub-section.

A. Quantitative Science

1. Key issues related to survey design and implementation
2. Qualitative data analysis: ideas on when it might be useful
3. Remote sensing: sensor resolution; multispectral & hyperspectral data
4. Geographic Information Systems (GIS): main types of data representation (vector vs raster); metadata
5. Open source software versus proprietary software, open standards, interoperability
6. Metadata and XML: what are these and why are they important for quantitative science
7. Database structures: the difference between a “flat file” database and a “relational database”; the three types of relationships found in data; the idea of “normalizing” of data
8. Awareness of key Internet technologies: what are they and why are they important (e.g., FTP; HTTP; the so-called “Web 2.0” technologies such as content management systems, the emerging idea of “cloud computing”, and “web services”)
9. Cost/benefit analysis
10. Nonmarket valuation techniques
11. Estimation of common pools: inventory and use rates
12. Optimization of resource use concept
Example questions:

1. (Key issues related to survey design and implementation). You work for a city in Massachusetts that is considering the deployment a bank of solar panels for energy production on some public land (over a landfill, perhaps). To help decide whether to move forward with the project they ask you to implement a survey of local residents to gauge citizen reaction to such an idea. Describe key steps and issues related to implementing such a survey.

2. (Database structures). You work as a park ranger for a national park that has a campground. One of your responsibilities is to run recreational programs for campground visitors. In any given two week period people staying at individual camp sites may sign up for these ranger programs. To justify the costs for running the program, you are chartered with creating a database to store general information about program participants. What would the primary advantage of using a relational database over a spreadsheet to maintain this data?

B. Environmental Science and Human Dimensions

Key concepts:
1. The "theory of goods": private, public, toll and club, common pool resource (CPR)
2. Government failure, market failure
3. The concept of “collective action”
4. The “tragedy of the commons”
5. Common-pool resource theory
6. Conceptual foundations of “sustainability ” (and the Brundtland Report)
7. Malthus and the surrounding debates
8. The “precautionary principle ” and surrounding debates
9. Environmental determinism and surrounding debates (e.g., environmental possibilism)
10. Methodological individualism, rational choice and Simon’s bounded rationality
11. Adaptive management, adaptive governance
12. Collaborative governance
13. Social capital
14. Environmental justice: key debates; different views on justice (outcome/procedural/social/redistributive)
15. Polluter pays versus victim pays principles
16. Types of scarcity: resource, social, adaptive
17. Environmental kuznets curve
18. Positivism, structural functionalism, situated knowledge, constructivism
19. Pareto efficiency and Coase’s Theorem
20. Policy economics: discount rates, cost/benefit analysis, wtp/wta and contingent valuation (as these are core, albeit contested elements in environmental policy making)
21. Approaches to conceptualize and analyze socio-ecological systems

Readings:
(1) Ostrom, E. 2009. A general framework for the study of socio-ecological systems. Science. 325. 419-422.)

22. Approaches to conceptualize and analyze socio-economic systems
Policy and administrative processes:
23. The policy process theories: problem definition /agenda setting, formation and legitimization, implementation, assessment and reformulation, termination

24. Theories of policy formation: public choice, bureaucratic, advocacy coalition

25. Types of regulatory policy: executive, judicial, legislative, market-based (what are each of these and what are the motivations and drawbacks/critiques of each)

26. The concept of "rule making"

27. The debates over science and its interaction with the policy process

28. General approaches to policy analysis (e.g., Eugene Bardach’s “Eightfold path ”)

29. Program evaluation: what is it

30. Approaches to conflict resolution

31. E-government: what is it

History, organizations, laws and pioneers:
32. History of natural resource conservation in the United States

33. The general role Non-Governmental Organizations (NGOs) play in environmental conservation

34. Environmental conservation agencies: names and responsibilities (e.g., Fish and Wildlife Service, Forest Service, Bureau of Land Management, National Park Service, Bureau of Indian Affairs, Environmental Protection Agency, National Oceanic and Atmospheric Administration, Geological Survey, Nuclear Regulatory Commission)

35. Environmental conservation laws: date of enactment, purpose, and major regulations (e.g., Migratory Bird Treaty Act, Endangered Species Act, National Environmental Policy Act, Clean Water Act, Clean Air Act)

36. Environmental conservation pioneers: names and major contributions (e.g., Aldo Leopold, Gifford Pinchot, John Muir, Theodore Roosevelt, E.O. Wilson)

Example questions:
1. (Theory of goods). How we manage a natural resource is often based on how we treat it as a “good.” Use the table below to describe the characteristics of the four general categories of goods. Label A-F appropriately.

   (A)
2. (Social capital). Define the concept of “social capital”. What concepts fall within it? Why is this concept important to environmental management?

3. (Public policy process theories). There are a number of competing theories related to the public policy process. For example, Kindon’s “Multiple Streams” theory or Baumgartner and Jones’s “Punctuated Equilibrium” theory. Describe these and any other theories of the policy process you think are important.

**Potential courses that discuss some of these concepts:**

**Quantitative Science:**
1. Introduction to GIS for Natural Resource Conservation (Bradley, Schweik)
2. Advanced GIS (Finn)
3. Information Technology for the Public and Nonprofit Sectors (Schweik)
4. Introduction to Remote Sensing (Finn; Yu - Geosciences)
5. (Social Science) Research Methods (Sociology or Public Policy)

**Environmental Science and Human Dimensions:**
1. Environmental Conservation - Watershed science and Management (Randhir)
2. Environmental Conservation - Water Resources Management and Policy (Randhir)
3. Environmental Conservation - Case Studies in Environmental Conservation (Kittredge)
4. Economics – The Political Economy of the Environment (Jim Boyce)
5. Geoscience. Geography, policy and the environment (Eve Vogel)
6. Legal Studies? Dispute Resolution?
7. Political Science: Public Management (Fountain)
8. Public Policy; Politics of the Policy Process (US - McDermott; International: Mednicoff);
9. Public Policy and Administration: Non-profit management (Bushouse)
10. Public Policy and Administration: Qualitative data analysis (Harper)
11. Regional Planning: Theory & Practice of Public Participation
12. Regional planning: Growth Management
13. Resource economics: Environmental & Resource Economics (Tom Stevens)
Section 6. Building Systems Concentration

This section consists of three sub-sections corresponding to the three core topic areas required of ALL ECo graduate students seeking an MS degree. All students in the Building Systems concentration will be required to answer a set of questions drawn at random from each of these sub-sections. Each sub-section will comprise 20% of the exam questions, for a total allocation of 60% to this section. Suggested readings are provided for select topics. Example questions similar in nature to those that will be given on the exam are provided at the end of each sub-section.

A. Environmental Science

1. Vectors, forces and moments
   Readings:
   (1) “Statics and Strength of Materials for Architecture and Building Construction” – Onouye and Kane, Chapter 2;

2. Structural properties of materials
   Readings:
   (1) “Building Construction: Principles, materials and systems” – M. Mehta et. al, Chapter 4

3. Structural equilibrium
   Readings:
   (1) “Statics and Strength of Materials for Architecture and Building Construction” – Onouye and Kane, Chapter 3;

4. Constitutive behavior of construction materials
   Readings:
   (1) “Statics and Strength of Materials for Architecture and Building Construction” – Onouye and Kane, Chapter 5

5. Thermodynamics
   Readings:
   (1) Thermodynamics: An Engineering Approach (Cengel), Chapter 6, "The second law of thermodynamics", pp 277-330.
   (2) ASHRAE Fundamentals, Chapter 2, "Thermodynamics and refrigeration".

6. Energy
   Readings:
   (2) ASHRAE Fundamentals, Chapter 34, “Energy Resources”
   (3) ASHRAE Fundamentals, Chapter 35, “Sustainability”
7. Wood light-frame construction (floor, roof, wall assemblies)
   Readings:
   (1) “Building Construction: Principles, materials and systems” – M. Mehta et. al, Chapter 13
8. Lumber and engineered wood products (manufacturing, benefits and applications)
   Readings:
   (1) “Building Construction: Principles, materials and systems” – M. Mehta et. al, Chapter 12
9. Structural insulated panels
   Readings:
   (1) “Building Construction: Principles, materials and systems” – M. Mehta et. al, Chapter 15
10. Photosynthesis and CO$_2$
    Readings:
    (1) "Climate Change 2001: The Scientific Basis” - Summary,
        http://www.grida.no/publications/other/ipcc_tar/?src=/CLIMATE/IPCC_TAR/wg1/
        http://www.grida.no/CLIMATE/IPCC_TAR/wg1/pdf/WG1_TAR-FRONT.pdf

Example Questions:

1. (Constitutive behavior of construction materials). Stress-strain curves embody the characteristic mechanical behavior of construction materials. Draw, in a single comparative graph, a typical compressive stress-strain curve for: i) ductile rolled steel, ii) concrete, and iii) timber. Compare and contrast the three curves with respect to the critical structural properties.

2. (Photosynthesis). What are the steps that lead from the photosynthetic reaction within a tree leaf to the production of wood? What role does Carbon-Dioxide (CO$_2$) play in this process? Discuss the impacts of this process on the Earth’s atmosphere and the well-being of humans.

B. Quantitative Science

1. Structural loads on buildings
   Readings:
   (1) “Building Construction: Principles, materials and systems” – M. Mehta et. al, Chapter 3
2. Environmental benefits of wood
   Readings:
   (1) Wood handbook, Chapter 1,
        http://www.fpl.fs.fed.us/document/fplgtr/fplgtr190/chapter_01.pdf;
   (2) “Science Supporting the Economic and Environmental Benefits of Using Wood and Wood Products in Green Building Construction” – M Ritter et. al,
3. Factors that influence physical and mechanical behavior of wood
   Readings:
   (1) “Design of wood structures” – Breyer et. al, Chapter 4.14-4.21
4. Building Information Modeling (BIM)
   Readings:
   (1)“Green BIM” - Chapter 2, Krygiel / Nies, Sybex;
5. Building energy loads

Readings:
(2) ASHRAE Fundamentals, Chapter 17, “Residential Cooling and Heating Load Calculations”
(3) ASHRAE Fundamentals, Chapter 18, “Non-Residential Cooling and Heating Load Calculations”

6. Climate responsive building design

Readings:
(3) Heating, Cooling, Lighting (Lechner), Chapter 10, “Passive Cooling”, pp. 245-278.

7. HVAC systems

Readings:
(4) Mechanical and Electrical Systems in Buildings (Janis & Tao), Chapter 4, “Cooling Production Equipment and Systems”, pp. 107-139.

8. Economics and Building Decision-Making

Readings:

Example Questions:

1. (Building information modeling). What are the possible advantages of using Building Information Modeling (BIM) for building planning? Name five specific benefits that a planner could see if they switched to a BIM-based process. Are there any drawbacks or hampering factors that could prevent the success of such an approach?
2. HVAC systems. Buildings consume up to 40% of the energy used in the United States. A significant portion of this energy is needed to run HVAC systems in buildings, to ensure occupant comfort. Calculations to size HVAC systems are typically based on design loads (i.e., the maximum energy loads the system can handle). These rely on a number of base assumptions, like the number of degree days in a region. Explain why design load calculations often result in oversized systems. How might one correct for the inaccuracies in design load calculations?

C. Human Dimensions

1. Green building rating systems
   Readings:
   (1) Guide to Green Building Rating Systems (Reeder)
   (2) Sustainable Construction (Kibert), Chapter 3, “Green Building Assessment”, pp. 55-78.

2. Energy policy

3. LEED Rating system
   Readings:

4. Residential Energy Conservation (Retrofit) Policy
   Readings:

5. Building environmental impacts
   Readings:
   (1) Ecological Design (Sim Van Der Ryn)

6. Building codes on building energy

7. Public policy on building energy

8. The building delivery process (phases of how buildings come into being)
   Readings:
   (1) "Building Construction: Principles, materials and systems' – M. Mehta et. al, Chapter 1

9. Material certification systems (FSC, SFI, etc.)
   Readings:
   (1) FSC International Standard: “FSC Principles and criteria for forest stewardship” FSC-STD-01-001 (version 4-0) EN
10. Conceptual foundations of "sustainability" (and the Brundtland Report)

Example Questions:

1. (LEED rating system). What are the pros and cons or limitations of the LEED Rating system in promoting environmental and energy efficiency goals (i.e., reductions in GHG emissions)?

2. (Public policy on building energy). Identify three public policies (currently operating or not) that can influence building energy use. Which of these has the greatest likelihood of rapidly reducing energy use in new buildings or existing buildings? Why?