Image: Washington Department of Ecology

Using System Maps to Analyze Complex Social-Environmental Issues: A Case Study of Geoduck Aquaculture in the Puget Sound

By

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SUMMARY

This case provides a framework and tools for analyzing and understanding complex socio-environmental systems, using geoduck aquaculture in the Pacific Northwest as an example system. After completing this case, students will be able to use the socio-environmental system framework and apply it to other environmental issues. Geoduck (giant clam, *Panopea generosa*) aquaculture is a complex issue in the Puget Sound. Specific concerns have centered on aspects of aquaculture that may disturb ecological communities, habitats, and ecosystem processes. The issue is complicated by a complex permitting process, limited scientific information to guide decision making, and vocal public opposition to certain aspects of geoduck farming. As geoduck aquaculture is local to the Pacific Northwest and parts of the western coast of California, a more localized example may be more appropriate for courses in other parts of the country, but many of the activities would be appropriate across most contexts.

CASE STUDY LEARNING OBJECTIVES AND SES LEARNING GOALS

Specific Case Study Student Learning Objectives (SLOs)

The case is intended to provide a framework and tools for analyzing and understanding complex socio-environmental systems. Using the geoduck aquaculture issue as an example, students will:

1. Identify and describe the social and environmental components of an S-E system.
2. Synthesize social and environmental components into an S-E system map.
3. Identify and describe the feedbacks and interactions in an S-E system.
4. Use system maps to identify leverage points that can change system outcomes.
5. Evaluate management alternatives
6. Understand the S-E system framework so as to be able to apply it to different issues.

Relationship between Specific Case Study SLOs and General Learning Goals for SES Case Studies

	SLO 1	SLO2	SLO3	SLO4	SLO5	SLO6
Concept 1: Understand the structure and behavior of socio-environmental systems.	X	X	X	X		X
Concept 2: Consider the importance of scale and context in addressing socio-environmental problems.					X	X
Competency 1: Co-develop research questions and conceptual models in inter- or trans-disciplinary teams.		X			X	X
Competency 2: Find, analyze, and synthesize existing data and ideas.		X			X	X

CLASSROOM MANAGEMENT OVERVIEW

Intended courses: Integrated synthesis course in Environmental Studies.

Intended level: Upper-level undergraduate students, graduate students

Time: This case is built around fourteen 50-minute sessions to be taught over 8-10 weeks during one quarter or one semester. Information and activities needed to complete the case will be introduced sequentially throughout the course. The full case consists of seven modules. Modules 1 through 4 serve as the core of this case. Depending on time, the instructor can choose to teach just the core or expand to Module 5, 6 and/or Module 7 for advanced materials.

	Module	Time	Activity	Assignment
Core	Module 1: Introduction	1 x 50 minutes	Lecture Group activities	#1 Reading summary
	Module 2: The S-E System Framework	2 x 50 minutes	Lecture Group activities	#2 Basic system map drawn with software
	Module 3: Building Expertise in Components of S-E Systems	1 x 50 minutes	Presentation demonstration	
		2 x 50 minutes	Group activities	#3 Expert group white paper + Presentation + Detailed sub-system map
	Module 4: Master S-E System Map and Reflecting on Systems Thinking	1 x 50 minutes	Synthesis of sub-system maps, in-class writing, lecture	
Extension	Module 5: Problem/ Solution Trees and Leverage Points	2 x 50 minutes	Group activities, In-class assignment	#4 Problem/Solution Trees in-class assignment
	Module 6: Scenario Analysis	1 x 50 minutes	Group activities	#5 Evaluation of management proposals
	Module 7: Rapid Assessment Exercise	Work week	Group activities	#6 Rapid assessment report
		2 x 50 minutes	Presentations of Rapid Assessments	
		2 x 50 minutes	Presentations of Rapid Assessments	

MODULE ACTIVITIES LIST, ASSIGNMENTS, AND EVALUATION

Module	Activity	Assignment	Evaluation
Module 1	(a) Introduction to the case study: geoduck aquaculture in the Puget Sound	Assignment #1	5 points
Module 2	(b) Basic system mapping	Assignment #2	10 points
Module 3	(c) Expert group white paper + Presentation	Assignment #3	20 points
	(d) Detailed sub-system map		
Module 4	(e) Synthesize master system map (analysis of strengths and weaknesses)		
	(f) Identify and describe critical interactions		
Module 5	(g) Problem/Solution Tree in-class assignment	Assignment #4	5 points
Module 6	(h) Read press release + identify policy questions		
	(i) Match system map to press release		
	(j) Problem set: Evaluating 3 management proposals	Assignment #5	15 points
Module 7	(k) Rapid assessment	Assignment #6 (paper + presentation + system map)	40 points
		Participation	5 points
			Total: 100 points

MODULE 1: INTRODUCTION, BACKGROUND & CONTEXT

INTRODUCTION (USE FOR HOOKING YOUR STUDENTS INTO THIS TOPIC)

It was a typical autumn morning in Olympia, WA – somewhat foggy and lightly misting, but warm with the promise of afternoon "sunbreaks." Maria Bennett dropped her bike bag in the corner of her office at the Washington Department of Natural Resources (DNR), and turned on the computer at her desk. Last night's public meeting on the DNR's geoduck aquaculture leasing proposal had lasted long past 10pm, with a standing-room only crowd, all of whom wanted to express their views. As an Environmental Planner with the state for the last four years, Maria had never experienced such controversy over a resource management issue.

Her phone's message light was blinking, so she clicked into her voice mail, and discovered she had several messages from state legislators, two from county commissioners, and one from her boss, DNR Director Steven Rhoads. The message from Director Rhoads asked, "Where are we on the geoduck issue? Let's talk strategy as soon as possible….I've got time at 10am today, so I will see you then."

Maria glanced at the clock, it was 9:10am. She sighed, took a long sip of her latte, and turned to her computer and began drafting some notes in preparation for her meeting with Director Rhoads.

At the end of this case, students will be able to: 1) Analyze and explain the complexities of the geoduck social-environmental system and other complex social-environmental systems; 2) Develop realistic recommendations for management approaches that take that complexity into account, and 3) Critically develop, evaluate, and adapt recommendations.

BACKGROUND & CONTEXT: THE GEODUCK AQUACULTURE ISSUE

Geoducks (pronounced gooey-ducks) are a saltwater clam native to the west coast of North America. For many generations geoduck **aquaculture** ('agriculture in the water' or growing clams for human food) has been part of the coastal community and economy. The value of geoduck clams increased dramatically in the 1990s, and the number and extent of aquaculture activities intensified as it became a highly lucrative product with strong international market demand in Asia. Even though it is regulated at the local, state and federal levels, geoduck aquaculture activities have increased dramatically, and there is potential for considerable expansion on privately owned tracts and on public lands managed by the Washington Department of Natural Resources (DNR).

Geoduck aquaculture is a complex issue in the Puget Sound. Specific concerns have centered on aspects of aquaculture that may disturb ecological communities, habitats, and ecosystem processes. The issue is complicated by a complex permitting process, limited scientific information to guide decision making, and vocal public opposition to certain aspects of geoduck farming. Other concerns center on access and use of public shorelines, property rights, noise, and view shed impacts. In addition, treaties signed with western Washington Indian tribes in 1854 and 1855 reserve the right for tribes to harvest fish and shellfish from all usual and accustomed fishing areas in common with Washington citizens. A 1994 court decision upheld rights to harvest up to 50 percent of the harvestable surplus of shellfish from natural shellfish beds.

In August of 2013, the DNR announced a pilot program that would allow geoduck aquaculture on a small number of state-owned aquatic lands. The proposal indicated that DNR would enter into lease agreements with applicants once all environmental review and permitting processes were complete. Several public meetings followed the pilot program announcement, in addition to increased media coverage.

CLASS PLAN

The purpose of this module is to introduce the geoduck aquaculture issue and set the stage for using system maps as a tool to analyze complex socio-environmental issues. The instructor presents a set of PowerPoint slides and/or videos to introduce the issue, and students begin to identify what they know and do not know about the system.

1. Discussion of course objectives
2. Introductory lecture and description of objectives for this case study for students
3. Video (see options below)
4. Paired student brainstorming
5. Class discussion

This module should take one 50 minute class.

LEARNING GOAL/OBJECTIVE/OUTCOME

Goal: The goals are for students to become familiar with 1) the geoduck aquaculture issue, and 2) the general concept of system maps.

Objective: Students will understand the multiple components of the geoduck aquaculture system and gain an appreciation for the complexity of the issue.

Outcome: Students will understand the geoduck aquaculture issues well enough to build upon this knowledge in terms of social-ecological systems in future classes.

ACTIVITIES

A. Geoduck aquaculture is introduced to the class through the PowerPoint or videos.

B. After PowerPoint and/or video(s), teacher asks students: "What more would you like to know about this issue?" Students brainstorm ideas individually and write a list, then share with neighbor to develop a longer list of ideas.

C. In small groups or individually, students discuss:
   i. What are the effects of this situation?
   ii. What are the major concepts/drivers/actors in this situation?
   iii. Place concepts/drivers/actors onto post-its, begin arranging into a "map" of the situation.

D. Class Discussion: Instructor gathers some of the ideas from small groups with entire class, puts together a class list of major concepts/drivers/actors.

LECTURE INFORMATION

This module can be introduced in several ways, depending on the time available for this lesson. The instructor could present the PowerPoint slides (attached) that briefly introduce the issue, or the instructor could have students view some or all of the following videos in class or at home:

- Video from NOAA: (no narrative) http://vimeo.com/67923139
- Video from Taylor Shellfish (with narrative) http://on.aol.com/video/geoduck-farming-of-taylor-shellfish-516936437
- "Dirty Jobs" video http://www.youtube.com/watch?v=iZhQLoYIbJ4

ASSIGNED MEDIA/READINGS

A. If videos not viewed in class, then have students view some of the three different videos. (Links provided above.) Ask students to submit a one paragraph description of each video.
B. Read: Ahearn, A. (2012) Farming geoducks: a mixed bag for tidal critters. Oregon Public Broadcasting. http://earthfix.opb.org/water/article/geoduck-farming-heddy/ March 6, 2012, KUOW.
C. Read: Ostrom, E. (2009) A general framework for analyzing sustainability of social-ecological systems. *Science*. 325:419-422.

HOMEWORK/GRADING RUBRIC

Assign readings with reading summary for the Ahearn and Ostrom readings to prepare students for the next module. See assignment 1 in the appendix.

ADDITIONAL RESOURCES

For these additional resources, see the attached documents for this case study.

1. PowerPoint background info on geoduck issue
2. Two PDFs explaining regulatory/permitting process for shellfish aquaculture

MODULE 2: THE SOCIO-ENVIRONMENTAL SYSTEM FRAMEWORK

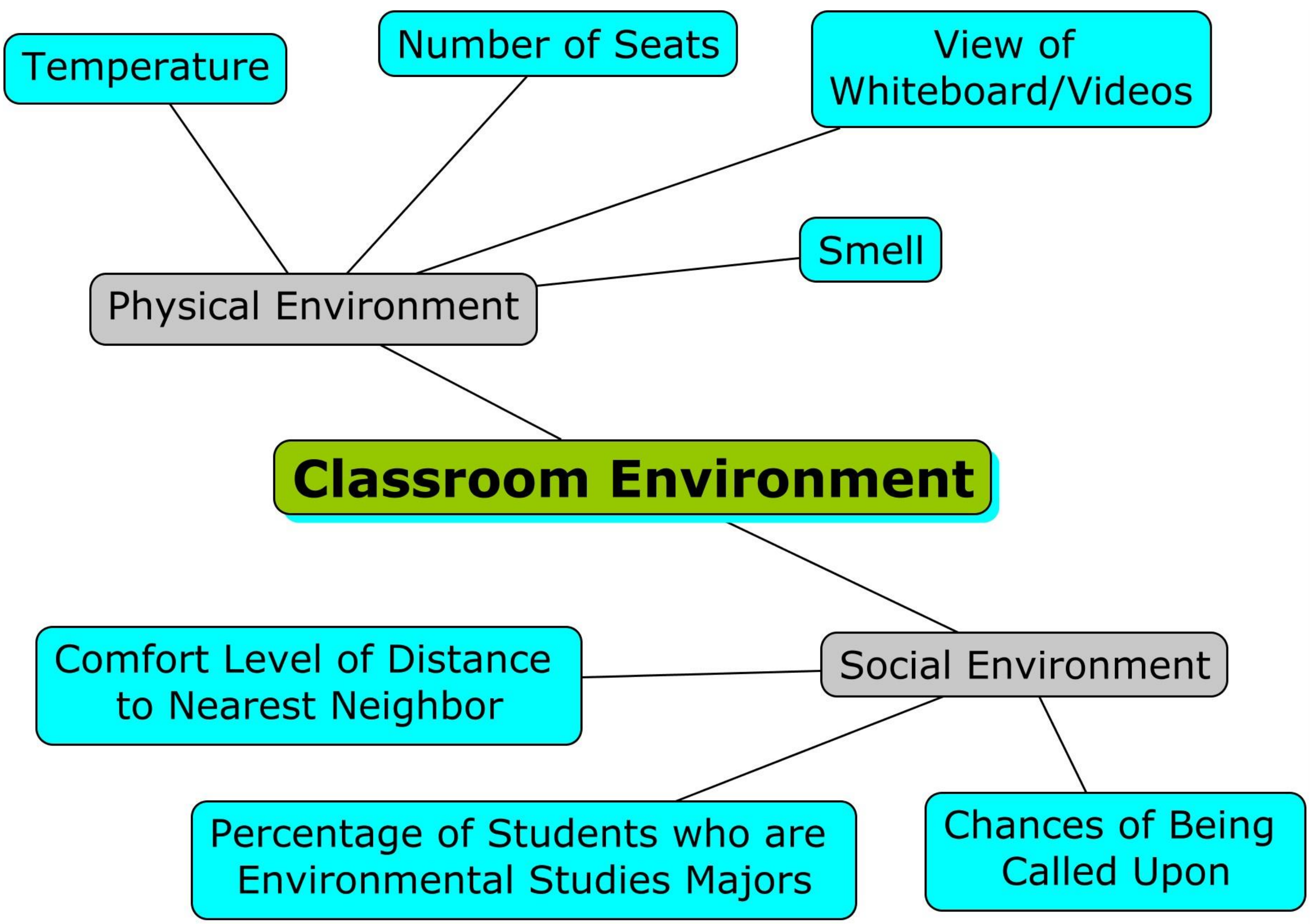
CLASS PLAN

This module introduces systems thinking as a framework to analyze complex socio-environmental problems. The module challenges the students to organize the content knowledge about geoducks developed in Module 1 and through Assignment 1 within a socio-environmental (S-E) system framework.

We offer two options for introducing students to systems thinking: A short lecture on basic systems concepts and/or a classroom-based exercise.

- The lecture offers a definition of a system and introduces the basic system concepts of inter-relationships, structure, perspective/boundaries, feedback loops, etc. The lecture also explores the benefits of a systems approach (see Lecture Information below).

- A helpful exercise to begin the discussion of S-E systems is a simplified example in which you ask the class to work in pairs to develop a simple concept map (on paper) of the classroom social-environmental system (e.g., How many students are in the classroom? What are the majors of the students? How many professors? How large is the classroom? Is the room full? etc.). Allow students about five minutes to discuss their basic concept maps and then you can begin to build the concept map in CMAP as a demonstration tool.



Sample CMAP System Map of a Classroom

Then, as a class, ask students what would happen if 100 more students were added to the class.

- What would the impacts be on the classroom environment? (e.g., more trash in the trashcan, crowded spaces, not enough seats for everyone, etc.).
- What would the impacts be on the social environment? (e.g., competition for seats, bias of new students vs. existing students, breakdown by major, etc.)
- What are other perturbations that could change the system? What would they impact?

Continue to add all of these perturbations to the CMAP systems map. Then, connect this back to S-E systems. We can visualize the complex system through a series of connections and components in systems maps, and we can also begin to identify the impacts of perturbations to the system using the maps.

After this exercise is completed, ask students to work in pairs to consider a basic system map of geoduck aquaculture in Puget Sound. In Assignment 1, they will have started to put together some components of the geoduck aquaculture system map. Ask them to combine their maps and add in any additional ideas.

The homework assignment for this module is to develop a CMAP file and system map for the geoduck aquaculture social-environmental system. This is fairly complex, so you should allow for time in class for explanation of expectations and any questions.

This module should take two 50 minute class periods.

LEARNING GOALS/OBJECTIVES/OUTCOMES

Goal: The goal of this module is for students to understand the inextricable connections of social-ecological systems.

Objective: Students will apply knowledge about geoduck aquaculture from Module 1 and the S-E readings to translate the general concept of S-E systems to a specific issue.

Outcome: Students will identify specific components of the geoduck aquaculture S-E system and the connections among those components.

ACTIVITIES

A. Short lecture on basic system concepts

B. System mapping applied to a simpler case to show how to do it (e.g. if 100 more students added to the classroom, what are the effects?) with CMAP demonstration

C. In-class review of Assignment 1

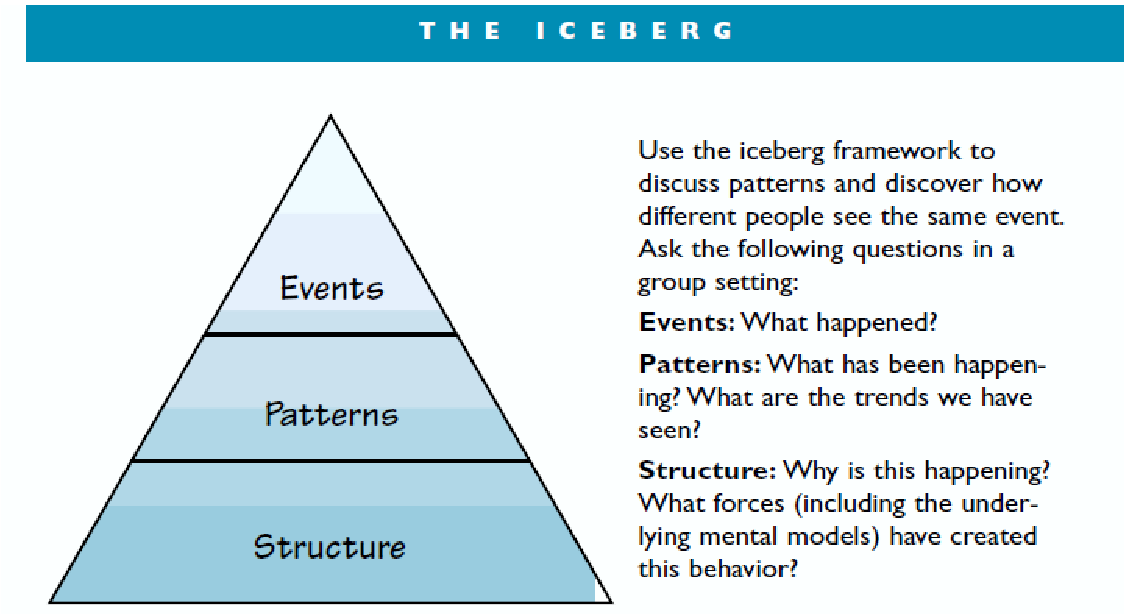
D. Short brainstorm on geoduck aquaculture with a partner

E. Explanation of homework assignment

LECTURE INFORMATION

System: A set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristics set of behaviors, often classified as its "function" or "purpose." The word function is generally used for a non-human system and the word purpose for a human one, but the distinction is not absolute, since so many systems have both human and non-human elements (Meadows 2008: 15 and 188).

Events/Patterns/Structure: "Systems thinking often involves moving from observing events or data, to identifying patterns of behavior over time, to surfacing the underlying structures that drives those events and patterns" (Goodman 1997:6).



Inter-relationships: How things are connected and with what consequence. In particular systems approaches look at the following aspects of inter-relationships:

- Dynamic aspects (where inter-relationships affect the behavior of a situation over a period of time);
- Nonlinear aspects (where the scale of an 'effect' is apparently unrelated to the scale of the 'cause;' often, but not always caused by feedback)
- The sensitivity of inter-relationships to context
- Massively entangled inter-relationships (distinguishing the behavior of 'simple,' 'complicated and 'complex' inter-relationships) (Williams 2009:4).

Stock and Flow: A stock is the accumulation of material or information that has built up in a system over time. A flow is material or information that leaves a stock over time (Meadows 2008:187-188). Stocks generally change slowly, even when the flows into or out of them change suddenly. Therefore stocks act as delays or buffers or shock absorbers in systems (Meadows 2008:23).

Feedback loops: A feedback loop is a closed chain of causal connections from a stock…and back again through a flow to change the stock. There are two kinds of feedback loops, balancing (or negative) loops and reinforcing (or positive) loops. A balancing feedback loop is a stabilizing, goal seeking, regulating feedback loop because it opposes or reverses whatever direction or change is imposed on the system. A reinforcing feedback look is an amplifying or enhancing feedback loop because it reinforces the direction of change. Reinforcing feedback loops can be both vicious cycles and virtuous cycles (Meadows 2008:187, 189).

Linear and nonlinear relationships: A linear relationship is a relationship between two elements in a system that has constant proportion between cause and effect and so can be drawn with a straight line on a graph. A non-linear relationship is a relationship between two elements in a system where the cause does not produce a proportional (straight line) effect (Meadows 2008:187).

Perspectives: Perspectives highlight the notion that a situation can be 'seen' in different ways and that this will affect how the system is understood. Perspectives also draw the focus away from the 'system' as it supposedly exists in real life and allows us alternative ways of understanding the situation – what it might be like, could be like or even should be like (Williams 2009:5).

[NOTE: A useful game to introduce the idea of perspective is "Circles in the Air" from The Systems Thinking Playbook (Sweeney and Meadows 1995)]

Boundaries: A boundary differentiations between who or what is 'in' and who or what is 'out,' what is deemed relevant and irrelevant, what is important and what is not, who benefits and who is disadvantaged. Conversations about boundaries raise questions about entrenched values, control of resources, expertise, ethics (Williams 2009:6).

ASSIGNED MEDIA/READINGS

A. Video on using CMAP (https://www.youtube.com/watch?v=TMNq_oCFyi8)
B. Read: Goodman, Michael (1991) "Systems Thinking as Language." *The Systems Thinker*, 2(3):1-2.
C. Read: Goodman, Michael (1997) "Systems Thinking: What, why, when, where, and how." *The Systems Thinker*, 8(3):6-7.
D. Read: Williams, Bob (2009) "Thinking Systematically" *Capacity.org* 37(September):4-6.

HOMEWORK/GRADING RUBRIC

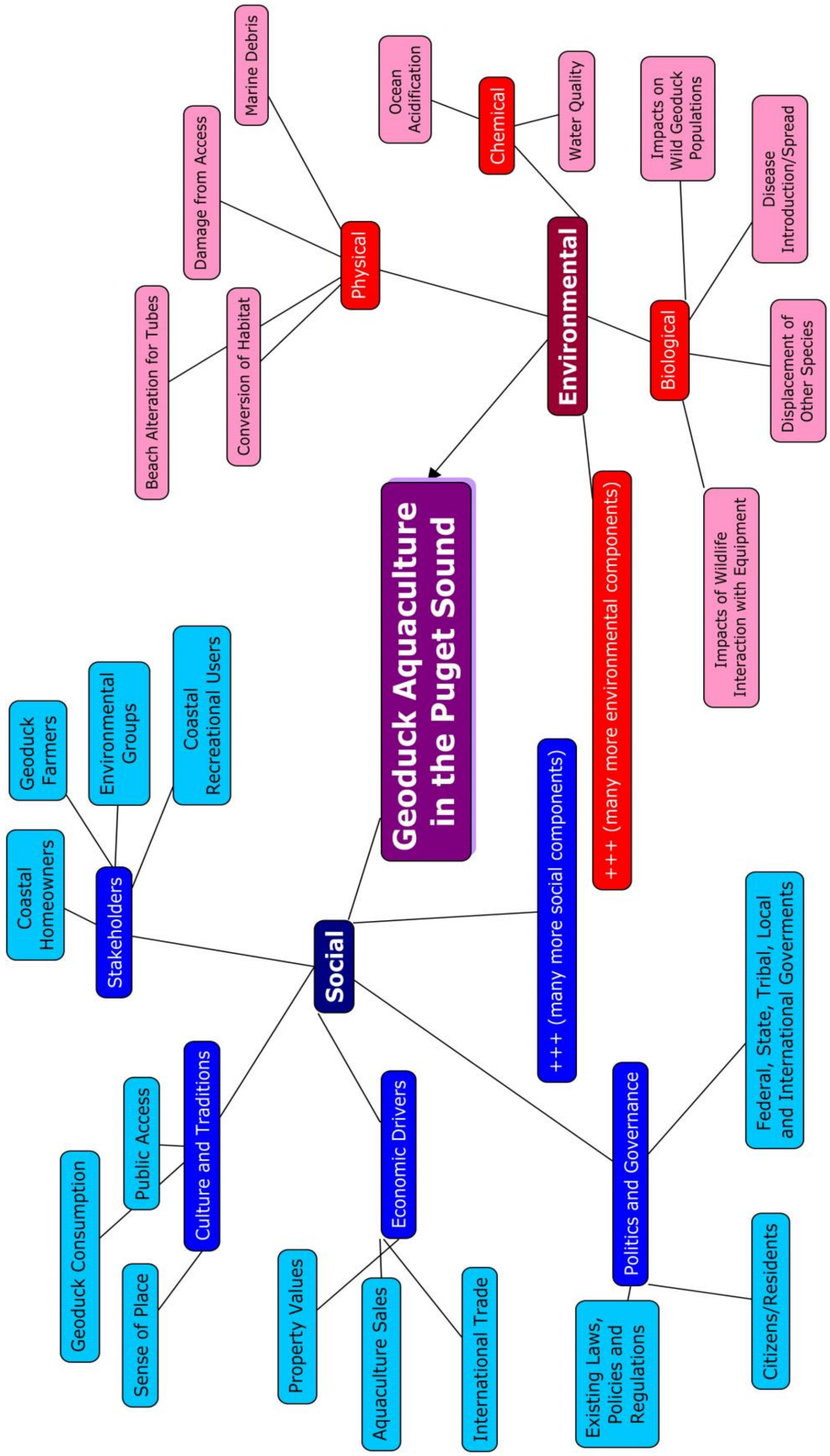
The assignment for this module asks students to go to the CMAP site and to put their geoduck aquaculture system map into a file and picture format. See Sample Geoduck Aquaculture System Map in Other Resources Below and Assignment 2 at the end of this document for the assignment handout. The deliverable is system map and a table of identified components and some of their connections to other components.

ADDITIONAL RESOURCES

CMAP is a free, online software that allows anyone to do basic systems mapping. It is available through http://cmap.ihmc.us/ and the website also has a video tutorial for using the software (https://www.youtube.com/watch?v=TMNq_oCFyi8). There are a number of academic articles and sample case studies that have used CMAP and some of those papers are also included as references on the site (http://cmap.ihmc.us/Publications/).

Meadows, Donella (2008) "Chapter 3: Why Systems Work So Well" and "Chapter 4: Why Systems Surprise Us." In Diana Wright, ed. *Thinking in Systems: A Primer*. White River Junction, VT: Chelsea Green Publishing.

Sample Geoduck Socio-Environmental System Map



MODULE 3: BUILDING EXPERTISE IN THE COMPONENTS OF S-E SYSTEMS

CLASS PLAN

Based on the system map created in Module 2, the instructor will guide students to think in greater depth about components of S-E systems. An example list of components includes: ecological, environmental, economic, social, cultural, and policy dimensions. Instructor will demonstrate debriefing information on one/two component(s) of the S-E system to the class, including an example of a two-page white paper and a system map of the components (see “Assignment 3-1” for details). Another option is to invite guest lecturers to form a panel of experts on this case and provide students with more in-depth information on the case from multiple dimensions.

Students will be broken into groups and each group will research one component of the S-E system. These groups will be called “expertise groups.” Each group will consist of 3-5 students. Depending on class size, the components can be sub-divided into more categories. For example, the ecological component can be divided into habitat conditions, species competition, diseases, etc.

NOTE: The instructor will need to allow time for students to work on group projects. For the class periods, the instructor will demonstrate how to present the group project and/or invite a panel of experts to give mini-lectures on this case from multiple dimensions. If time allows, leave some class period for students to do group work.

This module should take one 50 minute class + out of class group work time.

LEARNING GOAL/OBJECTIVE/OUTCOME

Goal: For students to have a more in-depth understanding of components within S-E systems.

Objective: Identify and describe environmental and social components in S-E systems

Outcome: Ability to synthesize information on one component of the S-E system and to present a concise summary

ACTIVITIES

A. Lecture on developing white papers and on more in-depth understanding of the different components within the S-E system (by either the instructor or guest speakers).
B. Students are broken into groups and given a component to become “experts” on.
C. Group work on concept map and white paper by “expertise” group

LECTURE INFORMATION

The instructor or invited guest lecturers will demonstrate debriefing information on one/two component(s) of the S-E system to the class. This includes examples of how to develop a two-page white paper and utilize the system maps that they developed previously. White papers are reports that aim to provide information for readers to understand an issue, solve a problem, or make a decision. White papers are often used by government agencies and businesses. The intended audiences are governmental officials, legislators, business managers, and other decision-makers.

NOTE: The instructor will need to allow time for students to work on group projects. For the class periods, the instructor will demonstrate how to present the group project and/or invite a panel of experts to give mini-lectures on this case from multiple dimensions. If time allows, leave some class period for students to do group work.

ASSIGNED MEDIA/READINGS

Instructor will pre-select references for each group (ecological, environmental, economic, social, cultural, and policy) to synthesize. Each group is required to find two additional references related to their topic. Each group will prepare a two-page white paper and a system map of the chosen component. See "Assignment 2" for details.

HOMEWORK/GRADING RUBRIC

Students will work in groups to develop a white paper on one component of the S-E system which will also include a detailed system map of that component. See Assignment 3.

ADDITIONAL RESOURCES

Selected background references for the Geoduck Case white paper.

Washington Sea Grant Geoduck Research Program (this website has research reports on the current state of the geoduck aquaculture): http://wsg.washington.edu/research/geoduck/

Washington State Department of Natural Resources Geoduck Aquaculture Discussion Forum (this website has citizen inputs on the issue about geoduck aquaculture on state-owned tidelands): http://www.dnr.wa.gov/BusinessPermits/Topics/ShellfishAquaticLeasing/Pages/aqr_ac_aquaculture_dialogue_description.aspx

Published research articles:

Brown, R. A., and Thulesen, E. V. 2011. Biodiversity of Mobile Benthic Fauna in Geoduck (Panopea generosa) Aquaculture Beds in Southern Puget Sound, Washington. Journal of Shellfish Research, 30(3):771-776.

McDonald, P. S., Galloway, A. W. E., McPeek, K. C., and VanBlaricom, G. R. In press. Effects of geoduck (Panopea generosa) aquaculture on resident and transient macrofauna communities of Puget Sound, Washington, USA. Journal of Shellfish Research.

McPeek, K. C., McDonald, P. S., and VanBlaricom , G. R. In press. Aquaculture disturbance impacts the diet but not ecological linkages of a ubiquitous predatory fish. Estuaries and Coasts.

Straus K. M., McDonald P. S., Crosson L. M., and Vadopalas B. 2013. Effects of geoduck aquaculture on the environment: a synthesis of current knowledge. Produced for the 2013 Washington State legislature. Washington Sea Grant Technical Report WSG-TR 13-02, 46 pp.

VanBlaricom, G. R., Price, J. L., Olden, J. D., and McDonald, P. S. In press. Ecological effects of the harvest phase of geoduck clam (Panopea generosa Gould, 1850) aquaculture on infaunal communities in southern Puget Sound, Washington USA. Journal of Shellfish Research.

Washington Sea Grant. 2013. Final Report: Geoduck aquaculture research program. Report to the Washington State Legislature. Washington Sea Grant Technical Report WSG-TR 13-03, Washington Sea Grant, Seattle. 122 pp.

MODULE 4: MASTER SYSTEM MAP AND REFLECTING ON SYSTEMS THINKING

CLASS PLAN

This module is developed in the context of one 50-minute class session. In this session, students will evaluate a master system map synthesized from the different sub-system maps created in Module 3 and discuss the challenges of assembling a master system map and brainstorm linkages between different sub-systems

1. Discussion: Synthesize master system map from sub-system maps (25 mins)
   - Option A: Instructor does synthesis ahead of class, using the sub-system maps handed in during previous session and starts class with a visual of a synthesized concept map. Students will be asked to critique the master systems map, suggestion new connections, missing elements, deleting connections, arrow directionality, arrow thickness, etc.
   - Option B: Instructor displays sub-system maps and draws connections between sub-systems based on student suggestions. Discussion will also focus on missing elements, deleting connections, arrow directionality, arrow thickness, etc.

2. In-class writing assignment: Self-reflection about devising the sub-system maps and assembling the sub-system maps into a master systems map (25 mins)
   - Prompt for writing assignment: Identify two strengths and two weaknesses of a systems thinking approach. Draw on your experiences generating sub-system maps and our class discussion of assembling the master system map.
   - Writing assignment followed by discussion of answers between pairs of students and then the class as a whole. Generate a list on the board regarding the strengths and limitations of a systems map
   - Instructor adds items to final list based on literature review (see table under Lecture Information section below)

LEARNING GOALS/OBJECTIVES/OUTCOMES

Goals: For students to understand the strengths and weaknesses of S-E system approaches.

Objectives: To reflect on the challenges of drawing system maps.

Outcomes: To be able to list multiple strengths and weaknesses of systems thinking

ACTIVITIES

A. Systems synthesis activity in which the master systems map is developed to combine the individual sub-systems maps developed in the previous module

B. Activity on reflecting on strengths and weaknesses of systems approaches

INFORMATION FOR IN-CLASS DISCUSSION

Strengths of Systems Thinking	Weaknesses of Systems Thinking
• Supports thinking about complexity and interdependence (Goodman 1991) • Facilitates learning through visuals (Goodman 1991) • Adds precision (Goodman 1991) • Forces explicitness of mental models (Goodman 1991) • Allows examination and inquiry (Goodman 1991) • Embodies a holistic view (Goodman 1991) • Supports thinking about trade-offs (Goodman 1997) • Encourages shared learning/understanding (Goodman 1997)	• Does not produce final answers (Ison 2008) • Accepts that inquiry is never ending (Ison 2008) • May lose touch with aspects beyond the logic of the system (Ison 2008) • Embodies a worldview (Goodman 1991)

ASSIGNED MEDIA/READINGS

A. Read: Ison, R. L. (2008) "Systems thinking and practice for action research." In Peter W. Reason and Hilary Bradbury, eds. *The Sage Handbook of Action Research Participative Inquiry and Practice* (2nd edition). London, UK: Sage Publications, pp. 139–158.

HOMEWORK/GRADING RUBRIC

NA

ADDITIONAL RESOURCES

Meadows, Donella (2008) "Chapter 3: Why Systems Work So Well" and "Chapter 4: Why Systems Surprise Us." In Diana Wright, ed. *Thinking in Systems: A Primer*. White River Junction, VT: Chelsea Green Publishing.

MODULE 5: PROBLEM/SOLUTION TREES AND LEVERAGE POINTS

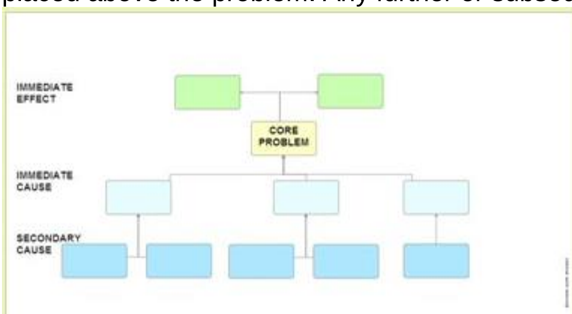
CLASS PLAN

This module is developed in the context of two 50-minute class sessions.
Session 5.1: Developing Problem and Solution Trees (Adapted from "Problem Tree/Solution Tree Analysis" http://evaluationtoolbox.net.au/index.php?option=com_content&view=article&id=28&Itemid=134)

In this session, the instructor and students collaboratively use the master system map to identify a core problem and its causes and effects as the first step to selecting a preferred means to intervene in a system.

1. Brainstorm core problems and select one as the focus of analysis (10 mins)
   a. Ideally core problems should be specific problem (e.g. saving water inside the home) that they seek to overcome if change is to occur. A vague or broad problem (e.g. saving water) will have too many causes for an effective and meaningful project to be developed. The core problem is written down in the middle of the board.
   b. This also serves as an opportunity to revisit the idea of "perspectives" introduced in the previous lecture. Different stakeholders may look at the same system and identify different core problems. Challenge students to adopt the perspective of different stakeholders and identify a core problem from the perspective of that stakeholder.

2. Identify the causes and effects (10 mins)
   a. Once the core problem has been identified, students will use the master system map to consider what the direct causes and direct effects of the problem are. Effects are negative consequences from a core problem. Causes are drivers of a core problem.
   b. The immediate causes to the problem are placed in a line below that of the core problem. The immediate effect is placed above the problem. Any further or subsequent effects are placed above the line of immediate effects.



   c. Each cause statement needs to be written in negative terms, i.e. how the cause exacerbates the problem. (Examples: Lack of information about AC operation may lead the AC temperature to be set too low; decreased production of geoduck on state land will lead to increased geoduck production on private land).
   d. There are a couple of ways to undertake the exercise. Causes and effects can be separated between immediate versus subsequent. Students can either collectively brainstorm all the negative statements about the problem at hand, and a facilitator writes each negative statement down on a piece of paper. The statements would then be placed on a wall, for the students to analyze and reorder. Alternatively, students could work through the cause and effect on a sequential basis, starting from the core problem.

3. Develop a solution tree (10 mins)
   a. A solution tree is developed by reversing the negative statements that form the problem tree into positive ones. For example, a cause (problem tree) such as "lack of knowledge" would become a means such as "increased knowledge." The solution tree demonstrates the means-end relationship between objectives. It is advisable to go through the solution tree and check to see if all the statements are clear, and if there are any missing steps between a means and an end. If so, you may need to revise both the problem and solution trees by adding more statements.

4. In class writing assignment: In pairs, students repeat exercise at the end of class for another core problem (30 mins) See Assignment 4 in Assignments. (See "Problem Tree/Solution Tree Analysis" for example problem and solution trees: http://evaluationtoolbox.net.au/index.php?option=com_content&view=article&id=28&Itemid=134)

Session 5.2: Selecting preferred interventions

In this session, students will use the solution tree to evaluate different leverage points for intervening in a system. This session will also introduce some general theory about leverage points and system interventions.

1. Activity: Selecting and assessing interventions (30mins)
    a. Using solution tree from previous session, students first identify a list of possible interventions.
    b. Write out the causal chain through which each intervention will affect the preferred outcome.
    c. Comparatively assess the characteristics of each intervention. Characteristics to be considered include targeted group for the intervention, type of intervention (see Lecture Information).

Comparing possible interventions

Interventions	Target audience	Action to be taken	Time horizon	Scale of impact	Ease of change (1-Easy to 5- Difficult)
Option 1					
Option 2					
Option 3					
…					

2. Lecture: Leverage points (see Lecture Information) (30 mins)
    a. The exercise above will be used to identify the ideas of leverage points in general.
    b. The lecture will draw primarily on Meadows. D. (1999) “Leverage Points: Ways to intervene in a system.” Hartland, VT: The Sustainability Institute.

LEARNING GOALS/OBJECTIVES/OUTCOMES

Goals: For students to strategize about how to intervene in S-E systems.

Objectives: 1. Develop a problem/solution tree based on a master systems map
2. Identify preferred interventions using solution tree.

Outcomes: Students will have converted the geoduck system map into a geoduck problem/solution tree and will be able to identify trade-offs between various solution possibilities related to the geoduck conflict.

ACTIVITIES

A. Identifying core problems in the geoduck system.
B. Discussion of perspectives
C. Development of a problem tree by identifying causes and effects
D. Development of a solution tree
E. In-class writing assignment
F. Selecting and assessing interventions activity
G. Lecture about leverage points

LECTURE INFORMATION

The following list is duplicated from Meadows (1999), who identifies 12 places to intervene in a system, ranked in order of increasing effectiveness:

12. Constants, parameters, numbers (such as subsidies, taxes, and standards)

11. The sizes of buffers and other stabilizing stocks, relative to their flows

10. The structure of material stocks and flows (such as transportation networks, population age structures)

9. The lengths of delays relative to the rate of system change.

8. The strength of negative feedback loops, relative to the impacts they are trying to correct against.

7. The gain around driving positive feedback loops.

6. The structure of information flows (who does and does not have access to what kinds of information).

5. The rules of the system (such as incentives, punishments and constraints).

4. The power to add, change, evolve, or self-organize system structure.

3. The goals of the system.

2. The mindset or paradigm out of which the system—its goals, structures, rules, delays, parameters—arises.

1. The power to transcend paradigms.

ASSIGNED MEDIA/READINGS

MDF (2005) "Problem tree analysis." Ede, The Netherlands: MDF Training and Consultancy.

Snowdon, W. et al. (2008) "Problem and solution trees: A practical approach to identifying potential interventions to improve popular nutrition" *Health Promotion International* 23(4): 345-353.

Meadows, Donella (1999) "Leverage Points: Ways to intervene in a system." Hartland, VT: The Sustainability Institute.

HOMEWORK/GRADING RUBRIC

There is an in-class assignment to develop a Problem Tree/Solution Tree. See Assignment 4 in the Assignments Section.

ADDITIONAL RESOURCES

Wolstenholme, E.F. (2003) "Towards the definition and use of a core set of archetypal structures in system dynamics" *Systems Dynamics Review* 19(1):7-26.

MODULE 6: SCENARIO ANALYSIS

CLASS PLAN

The instructor will introduce an actual proposal or decision being considered in environmental governance of the coastal socio-ecological system. In this case study, the Washington Department of Natural Resources (WDNR) is currently running a pilot geoduck aquaculture leasing initiative on state-owned aquatic lands (Activity 1). Students will read the WDNR's press release for the pilot project (see below). Following this reading, students should work in pairs to identify the policy action in question. In order for students to be able to apply this policy problem to their socio-ecological system map, it is very important for the students to understand the decision that the WDNR is making: whether or not to allow a geoduck mariculture pilot project on state aquatic lands.

The instructor should then give a brief lecture on the mariculture project (see Lecture Information section) to provide additional background.

After deciding upon the decision, have students utilize the system map to understand the various possible implications of the proposal.

Ask students to bring out their system map while simultaneously projecting the system map that they developed in the previous module for the class. After comparing their maps with their lecture notes and the press release, have them work in pairs again to consider the following questions:

1. What components of the system map are directly identified in the press release?

2. What are important components of the system map that are not included in the press release, but that were highlighted in the lecture?

3. What do you see about the relationship between the case study and the proposal?

This should rely heavily upon the use of the comprehensive case study that was developed in the previous module. This should be available for projecting on screen and for students to access.

Allow time at the end of class for discussion of the homework assignment (Assignment 5).

LEARNING GOALS/OBJECTIVES/OUTCOMES

Goals: For students to understand that something affecting one component of a social-environmental system will affect components throughout the system.

Objectives: 1. To identify case specific points of entry into system.
2. To create and evaluate management alternatives

Outcomes: Students will be able to trace perturbations at any point of entry throughout the social-environmental system.

ACTIVITIES

A. In-class reading of WDNR press release.
B. Lecture
C. Utilize the system map to understand the various possible implications of the proposal (work in pairs, then class-wide discussion).
D. Discussion of homework assignment.

LECTURE INFORMATION

In addition to the information covered in the release, the lecture should cover the relevant agency involved (WDNR, www.dnr.wa.gov), their role in geoduck aquaculture governance, and the larger reasons behind the proposal (for a complete set of information needed, see http://www.dnr.wa.gov/BusinessPermits/Topics/ShellfishAquaticLeasing/Pages/aqr_aqua_geoduck_aquaculture.aspx#purpose).

ASSIGNED MEDIA/READINGS

1. This lesson relies heavily upon the use of the comprehensive case study that was developed in the previous module. This should be available for projecting on screen or for students to access.

2. Washington Department of Natural Resources Press Release

http://www.dnr.wa.gov/BusinessPermits/News/Pages/2013_08_02_dnr_announces_trial_geoduck_aquaculture_leases_nr.aspx

HOMEWORK/GRADING RUBRIC

The assignment for this module asks students to identify point of entry for perturbations to the social-environmental system and to trace the effects of those perturbations throughout the system. See Assignment 5.

ADDITIONAL RESOURCES

An example of an additional perturbation to the system is the 2013 ban of imported geoduck by the Chinese government. There are a number of public media articles that describe the impacts of this, including: http://earthfix.opb.org/flora-and-fauna/article/four-weeks-in-locals-feel-the-pain-of-chinas-shell/

MODULE 7: RAPID ASSESSMENT

CLASS PLAN

The purpose of this exercise is to have students apply the SES framework to a different issue through conducting a 'rapid assessment' of that issue, and present their analysis orally and/or in writing. Instructor assigns issues to be assessed to small groups, who then use a class session (or more, depending on time) to conduct rapid assessment of the issue. Teams create a system map of the issue, write a brief report/paper analyzing the issue; and/or make a brief presentation on their issue assessment.

This exercise is useful at the end of the course, and can be extended for use as a 'final' or 'synthetic' exercise. For example, if doing class presentations on each issue, the instructor can facilitate pulling out similarities and differences among cases for entire class discussion. Alternatively, students can be assigned to do individual thinking/writing to synthesize and compare particular aspects of cases, such as:

- Are there commonalities/differences in maps (e.g., types of information available or missing, nature of relationships and connections, etc.)?
- Why do you think the similarities/differences occur?
- What are strengths/limitations of using SES framework to understand complex environmental issues?
- Other questions as appropriate

LEARNING GOAL/OBJECTIVE/OUTCOME

Goal: The goal of this exercise is to have students understand how the SES framework that they learned about through the geoduck case study can be applied to other issues or cases.

Objective: Students will understand the usefulness of the SES framework as a tool for understanding and grappling with complex issues.

Outcome: Students will be able to apply the SES analytical framework to a different issue.

LECTURE INFORMATION

This module does not include a formal lecture, although the instructor will want to take a short amount of time to introduce or briefly describe each case, and provide context for the activities and assignment(s). The class may have been brainstorming or tracking other current issues (local, state, federal) in the region throughout the semester/quarter, and those may be appropriate issues to use for this exercise. If not, then instructor may identify and choose issues to be assigned to small groups or individuals. Issues can be current and contemporary, but need to have 'enough' material available online so that students can quickly find information and do the assessment. Below are a just few example issues, with web links to information sources.

Example Issue	Online Resources
Yellowstone National Park winter use plan	ww.nps.gov/yell/planyourvisit/winteruse.htm ww.nationalparkstraveler.com/2008/11/yellowstone-national-park-releases-winter-use-proposal
Blanchard Mountain Proposal	ww.blanchardmountain.org/ ww.conservationnw.org/oldgrowth/blanchard-mountain-agreement
Brightwater Treatment Plant	ww.kingcounty.gov/environment/wtd/Construction/North/Brightwater.aspx eattletimes.nwsource.com/html/localnews/2004316832_brightwaternew31m.html eattletimes.nwsource.com/html/localnews/2010291437_brightwater18m.html

ACTIVITIES

Students are organized into small teams (minimum 3, maximum 5). Using the course materials relating to SES framework and conceptual mapping, teams will conduct a rapid, yet critical analysis and evaluation of one of the cases. Specific activities include:

a. Create a system map of the issue, clearly identifying the "decision point" or proposed action
b. Identify areas/connections in the map that appear to be strong/weak
c. Identify possible effects if decision is adopted/implemented (using system map)
d. Identify additional information needed to complete system map, or understand issue more fully
e. Depending on time available, teams give short presentations (3-5 mins) with class discussion, OR have teams turn in a written product. Can do in-class presentation or use discussion board for comments on presentations. In-person presentations and discussions more effective
f. A 2-3 page report/paper is due on the day of the presentation (write up includes systems map and addresses questions b, c, d above)

ASSIGNED MEDIA/READINGS

Each case has several initial web links or other resources provided. These web links are not comprehensive, and teams will need to identify additional web links and other sources of information on the case. Students are responsible for identifying (and citing!) sources of information for each case.

HOMEWORK/GRADING RUBRIC

Homework Assignments may include:

1. **Create system map** – Rubric for grading map would be same (scale of less –to—more comprehensive) as earlier rubric used for system map evaluation, keeping in mind the time limitations for the assignment ("rapid" assessment might be only two hours to work on, or two days).

2. **Short report/paper addressing questions b, c, and d** – The assignment asks students to analyze connections in their system map, identify possible effects of the decision, and identify information needed to understand system. The rubric given earlier for the white paper can be used again for this paper. See Assignment #3..

3. **Prepare/deliver short presentation** – See Assignment #3. Rubric includes timeliness of presentation, ability to communicate key points in short time, response to questions

See Assignment 6 for details and rubric.

ADDITIONAL RESOURCES

No additional resources. Each instructor identifies initial web links and resources for the cases selected. Instructor might take a few minutes to 'introduce' each case and provide context for the exercise.

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