Seemed like a good idea at the time: North American beavers in Tierra del Fuego

A Socio-Environmental Synthesis Case Study

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Summary: North American beaver (*Castor canadensis*) were introduced by the Argentine government into southern Patagonia's Tierra del Fuego Archipelago in 1946. This effort was part of a broader initiative to establish exotic furbearers with potential economic value, including American mink (*Neovison vison*) and muskrats (*Ondatra zibethica*). No significant pelt trade was ever developed, but the beavers thrived, and in the 1960's they crossed the Beagle Channel into the Chilean portion of the archipelago. By the mid- 1990s, beaver had also crossed the Strait of Magellan, beginning a northward migration on mainland Chile that continues today, threatening the entire temperate forests of southern South America that are shared between Argentina and Chile. This case uses a socio-ecological systems approach to engage students in contemporary concepts and theories relevant to ecological restoration, invasive species ecology and ecosystem services, with specific learning objectives outlined in Table 1.

Course(s): Ecological Restoration, Invasion Biology, Socio-Ecology, Conservation Biology, "Cornerstone" or other introductory course in interdisciplinary research or SES, Human Dimensions of Natural Resources, Socio-Ecological Theory, Political Ecology. These lessons would work best for smaller courses (fewer than 30 students) or online courses of similar size.

Level: Upper division undergraduates and graduate students

Table 1: SES Learning goals and objectives addressed in this case

GOALS	Learning Outcomes (Activities)
1. Understand the structure and behavior of socio-ecological systems (SES). • Identify and describe the human and environmental components of the SES and their interactions. • Identify and explain the drivers, feedbacks and interaction dynamics of a SES.	Student will identify components of social and environmental problems or issues and link them to multiple disciplines (journal exercise). Students will gain familiarity with a social theory (world risk) and an ecological concept (novel ecosystems) and be able to articulate their relevance to complex socio-ecological problems (Text analysis exercise).
2. Consider the importance of scale and context in addressing socio-ecological problems. • Understand that ecological and social processes often vary across differing contexts, including space, time, and conditions (e.g., economic or political). • Understand that ecological and social processes interact across different scales.	Students will describe a socio-ecological problem that needs to be addressed (Letter writing exercise for a natural resource manager using evidence to make a persuasive argument about the need to address the problem).

3. Be able to find, analyze, and synthesize existing data, knowledge, methods, and ideas • Identify disciplines and approaches relevant to the problem. • Communicate across disciplinary boundaries. • Understand the value of different knowledge sources and ways of knowing.	Students will recognize different theories and uses of theory in academic research. Students will understand the relevance of theory to contemporary socio-ecological problems and be able to link theory to ideas expressed in the work of their peers (lecture, discussion and theory reflection exercise).

Teaching notes

Note on organization and structure: Materials are organized in four 90-minute increments or classes plus one synthetic assignment, but approximate times for individual activities are identified so that materials can be adjusted for shorter or longer class periods. We would describe the time allotted for activities, class discussions, and lectures as aggressive and you may want to slow the pace for undergraduates. This case might serve as a two to four week unit in a 12-16 week course.

Class 1 ***(90 minutes): Socio-Ecological Problem Detection Activity***

Goals: Identify and describe socio-ecological issues and distinguish their parts and relationships.

Outcomes: Students will be able to identify how complex "environmental" or "social" issues are quite often "socio-ecological." Begin to distinguish the human and non-human dimensions of the problem, and the relationships between them (e.g., cause versus effect).

At home: The week before the classroom activity, provide students with the "journal assignment." They should record a list of "complex social or environmental problems." These problems can either be perceived by the student in their own lives, or problems reported in the media or more broadly for society. Examples can be water issues, trash, ex-urban development, etc. For each problem, the student should distinguish whether it has social, political, cultural, economic as well as environmental components. Finally, the relationship between these components should be determined, i.e. whether each is a cause or a consequence of the problem or each other (see worksheet).

In class: Students should bring to class the worksheet with at least 3 problems or issues they detected, whether or not they were able to distinguish multiple components for each. A selection of these will be presented in small groups of 3-4 students to see similarities and differences between problems perceived and collected (25 minutes). The issues students deem most interesting for discussion can be selected to then begin a basic description of the

components found (10 minutes). Students should discuss each and record similarities and differences provided by the other classmates (10 minutes).

Reconvene as a whole class and use the following list of questions to guide the group discussion (25 minutes):

1. What aspects were detected within each dimension?
    a. Describe the social, cultural, political, economic, environmental aspects for each problem.
    b. Record differences or similarities between different students.
2. Which are "drivers" or "causes" of the problem and which are "outcomes" or "effects" that emerge from it?
    a. Do any dimensions relate to each other?
    b. Can you identify causal or effect relationships?

Assignment: Students should read the *Scientific American* article "Argentina and Chile Decide Not to Leave It to Beavers" by Katie Worth, 10 March 2014. (http://www.scientificamerican.com/article/argentina-and-chile-decide-not-to-leave-it-to-beavers/)

Class 2 ***(90 minutes): Reading and Response Activity***

Goals: Identify disciplines, theories and approaches relevant to defining and addressing socio-ecological problems; Communicate across disciplinary boundaries; Understand the value of different knowledge systems and ways of knowing

Learning objectives: Students will identify different points of view from responses to a published article and link those views to world risk theory and the novel ecosystem concept.

Group activity: Students should come to class having read the *Scientific American* article "Argentina and Chile Decide Not to Leave It to Beavers", by Katie Worth, 10 March 2014. Ask students to work in pairs or groups of three, and pass out Student Handout 2. This handout displays actual comments posted online in response to Worth's (2014) article. Instruct students to make a bullet list of the main points raised in the comments and to send that list to you by e-mail. Next, ask students to compose their own replies to at least 2 of the comments. While students are composing comments, compile the bullets into a single word doc (40 mins).

Group report-back and concept clustering: Bring the class back together and review compiled list of main points. Ask clarifying questions about points as necessary. Ask one person from each group to select one of the comments from their group that they see and explain. Ask students if they note any commonalities among points and cluster in student-defined groups if appropriate. Solicit any additional ideas not already mentioned (30 minutes).

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Class Discussion Question: In what other contexts have you heard similar comments/arguments made? (List) What is similar? What is different? What were some of your own replies to comments? What did you support or critique? (15 minutes)

Introduce two worksheets and assignment (*World Risk and Novel Ecosystems)* (5 minutes).

Assignment: Students should read the two briefs and write a concise 1 page response that describes how ideas in the briefs shed light on the perspectives presented in the article and reader comments, or their own personal responses.

Class 3 ***(90 minutes)*** Theory and Socio-Ecological Research: Why should I care?

Goals: Understand the different kinds of data and research methods used by relevant disciplines in the natural and social sciences.

Learning objectives: Students will understand the use of theory in social and ecological research; students will understand that different disciplines generate different questions about socio-ecological systems.

Students should come to class having read the two handouts on World Risk and Novel Ecosystems and completed the 1 page response.

Class Discussion Questions: What do you think about the explanatory power of each theory? What are the limits of each? Which do you find more compelling? How does each engage ecological ideas? Ideas about human behavior? (20 minutes)

Lecture: Theory and Socio-Ecological Research (30 minutes) and discussion (20 minutes).

Watch brief video*, The Flight South*, on beaver introduction from Canada into Argentina in 1946 http://youtu.be/0yA9HVT68p8 (10 minutes)

Assignment: Students will compose a persuasive letter to a resource manager tasked with making the decision about whether or not to import beaver in 1945 (The year before beaver introduction in Argentina), drawing upon your knowledge of socio-ecological systems in 2014. Address both human and environmental dimensions. Offer your advice, particularly addressing the motivations of past managers as you imagine them. Use evidence-based arguments. 2 pages maximum (10 minutes to introduce assignment)

Class 4 ***(90 minutes)*** Theory reflection

Goals: Understand the different kinds of data and research methods used by relevant disciplines in the natural and social sciences.

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Learning objectives: Students will understand the use of theory in social and ecological research; students will understand that different disciplines generate different questions about socio-ecological systems and will be able to identify the relevance of theory in original works.

Group letter sharing: Students will gather in groups of 3-5 and have their letters (assignment) on hand. Pass out Student Handout 5 to each student. Students should rotate letters within their group, completing the table. This assignment can be varied based on the time available. With 5 students, this exercise could take as long as 40 minutes (at 10 minutes each paper), though 20-30 minutes (2-3 papers each student) is likely long enough to expose students to a range of ideas without becoming too cumbersome (20-40 minutes). Groups compare notes and identify interesting examples (10 minutes)

Group report-back and discussion: Have each group briefly report back on highlights. Have **Theory and SE Research** powerpoint on hand for discussion.

Discussion questions (40 minutes):

1. What new insights does theory bring to SE cases/problems/questions?
2. Did theory help you identify new dimensions of the case? If so, what?
3. How have your perceptions of the case changed over the past week(s)?
4. Could you see using theory in another case you have learned about or in your own research?

Synthesis Assignment: Each student will consider a socio-ecological question or problem that interests him or her (or a theory) and write a reflective essay on the following question:

Using any materials from this course, apply the theories learned or a new theory to a socio-ecological case of interest (you may use a new theory, a new case, or both, but not the theories AND case presented in this unit). Use your first journal reflection for ideas of possible cases. How can theory/concepts shed light on your socio-ecological case and vice-versa? Where are the limits of theory/concepts in shedding light on your case? 5 pages maximum, not including references.

This synthesis assignment could be extended to be a final course assignment. Additional theories and concepts are listed in Appendix A for advanced students or for students with a keen interest in extending to other theories/concepts.

Introduction and Background

North American beaver (*Castor canadensis*) were introduced into Argentina's Tierra del Fuego region in the late 1940s in what would become a failed government-led attempt to establish a fur trade. The beavers thrived, and by the 1990's they had crossed the Strait of Magellan beginning a northward migration on mainland Argentina and Chile that continues today.

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Through direct cutting by beaver and flooding-associated mortality, riparian forests on Tierra del Fuego have been transformed by beaver. Beavers also cause significant damage to roads because they block culverts to induce flooding and, in so doing, undermine transportation infrastructure and impede travel. Expansion of the beaver's range into mainland South America will likely cause similar damages with possible additional effects on hydro-electric dams and agriculture, which exist farther north. Land ownership in the Tierra del Fuego region is mixed, with large sheep and cattle ranches (*estancias*) in addition to extensive national parks and public lands, private forests and urban areas.

A variety of techniques have been applied by the Argentine and Chilean governments to control beaver populations, including instituting a beaver-tail bounty to incentive trapping, subsidizing commercialization of pelts, and conducting trapping beavers in national parks to prevent further population expansion. Unfortunately, these efforts have not had their desired effects or were not conducted at a sufficient scale to address the problem. In response, the governments of Chile and Argentina have made invasive beavers the focus of a bi-national eradication agreement. While this bi-national work has received funding from the Global Environmental Facility, little progress has been made towards on-the-ground control or eradication and key questions about the nature of landowner attitudes, the structure of supportive policies and the viability of restoration scenarios remain.

Classroom Management

Required student preparation and suggested instructions are provided above, along with estimated times for each activity and assignment described within the 90 minute time slot.

Table 2: Summary of case-related activities and handouts

Day	Activity Name	Class time (minutes)	Handouts
1	Problem Detection Journal and Group Discussions	90	Handout 1: Environmental or Social Problem Journal (pre-class homework)
2	Reading and Response Activity	90	Handout 2: Article Comments (in class)
3	Theory and Socio-Ecological Research: Why should I care?	90	Handout 3: Theory reflection (in class); Handouts 4 and 5: Overviews (homework)
4	Theory reflection	90	Handout 5: Theory reflection (in class)
n/a	Synthesis essays		Appendix A (optional)

Assessment

This assessment rubric may be applied to all assignments as appropriate. This may be applied to oral discussion or written work in combination with writing and other rubrics.

Table 3: Assessment Rubric

Goal	1 (high)	2	3 (low)
Understand the structure and behavior of socio-ecological systems (SES)	Student is able to identify and describe nuanced human and environmental components of an SES Student demonstrates ability to identify and explain complex drivers, feedbacks and interaction dynamics	Student is able to identify and describe core human and environmental components of an SES Student demonstrates ability to identify and explain a few drivers, feedbacks and interaction dynamics of a SES	Student is able to identify simple human and environmental components of an SES Student demonstrates ability to identify and explain obvious drivers, feedbacks and interaction dynamics of a SES
Consider the importance of scale and context in addressing socio-ecological problems	Student demonstrates an understanding that ecological and social processes often vary across differing contexts, including space, time, and conditions (e.g., economic or political) and that this variability has implications for research. Student draws linkages to new theories or concepts and is able to articulate differences between social and ecological approaches	Student demonstrates an understanding that social and environmental dimensions differ in context and scale but also interact. Student draws is able to articulate differences between social and ecological approaches and relate them to their own interests.	Student demonstrates an understanding that complex issues have social and environmental dimensions. Student makes basic connections between theory and concepts presented in the course and SES issues.

	and relate them to their own interests		
Be able to find, analyze, and synthesize existing data, knowledge, methods, and ideas	Student articulates relevance of different disciplines to SES issues and problem solving Student communicates respectfully and articulately across disciplinary boundaries Student communications reflect value for different knowledge sources and ways of knowing.	Student articulates relevance of different disciplines to SES issues Student communicates respectfully across disciplinary boundaries Student communications reflect a basic understanding of different knowledge sources and ways of knowing.	Student articulates relevance of one or few disciplines to SES issues Student communicates respectfully within their discipline Student communications reflect limited understanding /cognizance of different knowledge sources and ways of knowing.

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