Title: Using a cascading food web case study to assess the ecological and economic impacts of management decisions

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Abstract:

The rationale for conserving biodiversity and ecosystems depends on values related to our own personal interests and involvement. The value of an ecosystem can be argued from the standpoint of its economic and recreational benefits to humankind. The benefits people obtain from an ecosystem are called ecosystem services. Assigning a monetary value to goods and services provided by nature can be challenging, but is an imperative step when determining how to manage our natural resources. As informed citizens, students should be able to understand and interpret the value of a working ecosystem and the cascading implications of disturbances. We use a case study to introduce students to complex ecological interactions, the value of ecosystem services, and how management decisions can affect them. The case described by Spencer et al. (1991) illustrates cascading food web dynamics in the Flathead Lake, MT, ecosystem before and after human alteration. It provides students with a real-world example to apply their knowledge of basic ecological concepts in order to build an appreciation for the complexity of ecosystems, and to deal with ecosystem services in a concrete context. Students will learn to model cascading food web interactions and the associated changes due to human interventions. This case serves as a building block for students to develop modeling skills that illustrate complex ecological interactions and synthesize information from the literature.

Learning objectives:

Student goals

- Identify and describe ecosystem services
- Create a model of a food web that includes the biotic interactions
- Using a case study, predict outcomes of disturbances related to management decisions
- Explain the change/loss of ecosystem services due to ecosystem disturbances

Instructor goals

- Use active homework to determine the background knowledge of students
- Identify students' concept of ecosystem services and associated values
- Use an evidence-based case study to introduce and reinforce the importance of ecological interactions and the cascading effects of ecosystem disturbances

Timeframe:

Instructors should allow adequate time to:

- Prepare to introduce what an ecosystem is and examples of ecosystem services.
- Prepare i-clicker technology and slides with clicker questions.
- Discuss the significance of economics in our decision making and management of our natural landscapes. We suggest using local examples to encourage student participation and interest.
- Prepare to guide students through model building activity. May take more time depending on how familiar your students are with modeling.
- Gather examples of other case studies pertaining to the effects of human alteration on ecosystem services. We suggest the following:

    1) climate change processes
    2) invasive species introductions
    3) land-use/land-cover changes

Class time: This activity is designed for an 80 minute lecture period.

List of materials:

Spencer et al. (1991)

- i-clicker technology
- Colored pens/pencils/markers
- Carbonless paper for drawing models and working in groups.
    - This item is not necessary, but is suggested so that students can retain a copy of their work if you should decide to collect their models and/or group work.
- Projection tool (e.g., visualizer, overhead projector)

Procedure and general instructions (for instructor).

Lesson Plan

This active learning exercise is structured around the *learning cycle* which is an instructional design used to engage students with a question or problem, explore the problem interactively, and then explain the ecological significance of the results (Brandsford et al. 1999). This design allows students to construct their own understanding during the investigation while participating in scientific inquiry.

Pre-lecture assignment

Distribute/post online Spencer et al. (1991) "Shrimp stocking, salmon collapse, and eagle displacement" during the lecture period prior to this activity or earlier. Instruct students to read the paper and be prepared to model the food web interactions in class. Have students print a copy to bring to class, and label the organisms in Figure 1 as either primary producers, consumers, or predators

Engagement (15 minutes at the beginning of class)

Describe to the students that ecosystem services are the benefits people obtain from ecosystems (Daily et al. 1997; Millennium Ecosystem Assessment, 2005). Using the think/pair/share model (Johnson et al. 1998), ask students to think to themselves of an ecosystem service that they value. Then have groups compile examples onto one piece of carbonless paper so that they can retain a copy if you should decide to collect their responses. Introduce students to the four broader categories outlined in the Millennium Ecosystem Assessment which include:

- *regulating services* that affect climate, floods, disease, wastes, and water quality
- *provisioning services* such as food, water, timber, and fiber
- *cultural services* that provide recreational, aesthetic, and spiritual benefits
- *supporting services* such as soil formation, photosynthesis, and nutrient cycling

Have students determine in which of these four categories each of their ecosystem services fit. Give students a scenario such as; the government is allocating $300 of stimulus money per household per

year to the enhancement of an ecosystem service. Ask students which ecosystem services they would be willing to protect, and for how much? Use i-clickers to tally student responses (Appendix A). Once all students have assigned a monetary value to the services you can reveal the ranking of the ecosystem services determined by the class. You may want to discuss the reasons why they choose to allocate the money into the different categories.

Use a brief explanation (15 minutes) to transition from ecosystem services to the cascading food web from the Spencer et al. (1991) article. Discuss the significance of economics in our decision making and management of our natural landscapes. Government entities use the concept of ecosystem services to construct and implement management decisions. It is more likely that an ecosystem will be maintained in its natural state if it provides the most services to us that way. In this case (Spencer et al. 1991), the Montana Fish and Game was trying to enhance an ecosystem service by introducing the opossum shrimp.

Exploration (30 minutes): In groups of four, ask students to draw a model of the **natural** Flathead Lake food web (Panel 1, solid lines). Provide the following instructions for the elements of the model:

1. Generate a list of the biotic organisms and the services being provided by the Flathead Lake ecosystem
2. Place each structure (organism or service) in a box
3. Draw arrows representing the relationship between two or more structures, with arrows pointing in the direction of the energy flow
4. Add symbols (+ or -) to denote if the biomass of the organisms and the ecosystem services increased or decreased.
5. Use your homework assignment to aid in labeling the energy source, primary producers, consumers, and predators.

Using the same diagram, but a different color pen, ask students draw the arrows connecting the **desired** food web interactions of the Montana fish and game (Panel 2, dashed lines). Now, using a third color pen, have students draw the lines connecting the food web interactions with the **actual** outcome of opossum shrimp introduction (Panel 3, dotted lines). Students should include a key to indicate which colors are associated with the natural, desired, and realized food webs and write a figure legend that describes the function of the model. Have several groups share their versions of the food web and have them defend their diagrams against other groups that may have different versions using a projection tool (e.g., visualizer, overhead projector). You may or may not choose to collect the models for points, contingent on whether or not the students will be assessed on their modeling abilities on a subsequent exam.

Explain (15 minutes): Provide more case study examples from which students can use their basic model to make predictions about the impacts and outcomes of these cases. This will allow students to

broaden their experience with other possible disturbances. This would also be a good time to introduce how cultural background, social demographic, and regional association can influence the services people value and how this affects good management decisions and the maintenance of ecosystem integrity.

Final note

Spencer et al. (1991) provide a very intriguing example of how changes to a natural ecosystem can have cascading effects and can alter the ecosystem services that humans value. The instructional potential of this paper is extensive and its use depends on the learning goals of your students. The topic of ecosystem services can be controversial and often difficult to introduce without bias. However, using the scientific literature as an active teaching tool provides students with an evidence-based example and guided practice with reading scientific literature.

Procedure and general instructions (for students).

Before class read Spencer et al. (1991) "Shrimp stocking, salmon collapse, and eagle displacement"

- Print out a copy of the article to bring to class
- In Figure 1 of the paper, label the organisms as either primary producers, consumers, or predators
- There will be clicker questions and a 1-minute paper at the beginning of class to assess your comprehension of the assigned reading material

Suggestions and materials for assessing student learning.

Formative assessments using i-clicker or similar technology: This activity can be done at the beginning of class to assess the students understanding of the reading or after the activity to test their gained knowledge on the topic, or both.

1. What ecosystem services were supposed to be gained by introducing opossum shrimp?

A. Bird/wildlife viewing
B. Lake trout population/fishing
C. Salmon population/fishing
D. A and C

2. What ecosystem services were lost due to the opossum shrimp introduction?

A. Bird/wildlife viewing
B. Lake trout population/fishing
C. Salmon population/fishing
D. A and C

Assessment for assigned reading comprehension 1-minute paper (Angelo and Cross 1993)

1. Why did the introduction of opossum shrimp cause an increase in salmon in other ecosystems, but not the Flathead Lake ecosystem?

2. How did the feeding behavior of the salmon in Flathead Lake influence the outcome of the opossum shrimp introduction?

Rubric for one-minute paper

Student response	Point value
Accurate response and demonstrates interconnections of concepts	4
Accurate response but shows no interconnections of concepts	3
Accurate but incomplete response	2
Unclear or unrelated information	1

Summative assessments:

1. Provide a photo or description of an ecosystem, ask students to provide at least one ecosystem service from each of the four categories outlined in the Millennium Ecosystem Assessment.

- *regulating services* that affect climate, floods, disease, wastes, and water quality
- *provisioning services* such as food, water, timber, and fiber
- *cultural services* that provide recreational, aesthetic, and spiritual benefits
- *supporting services* such as soil formation, photosynthesis, and nutrient cycling

2. Assign a homework assignment for students to read Richardson et al. (2009) "The jellyfish joyride: causes, consequences and management responses to a more gelatinous future."

Students should:

1. Generate a list of the biotic organisms and the services being provided by the ecosystem in Richardson et al. (2009).

2. Place each structure (organism or service) in a box

3. Draw arrows representing the relationship between two or more structures, with arrows pointing in the direction of the energy flow

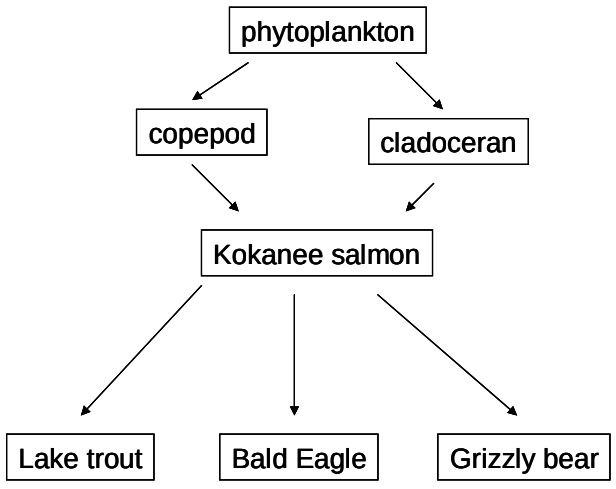
4. Add symbols (+ or -) to denote if the biomass of the organisms and the ecosystem services increased or decreased.

Rubric for Homework Model

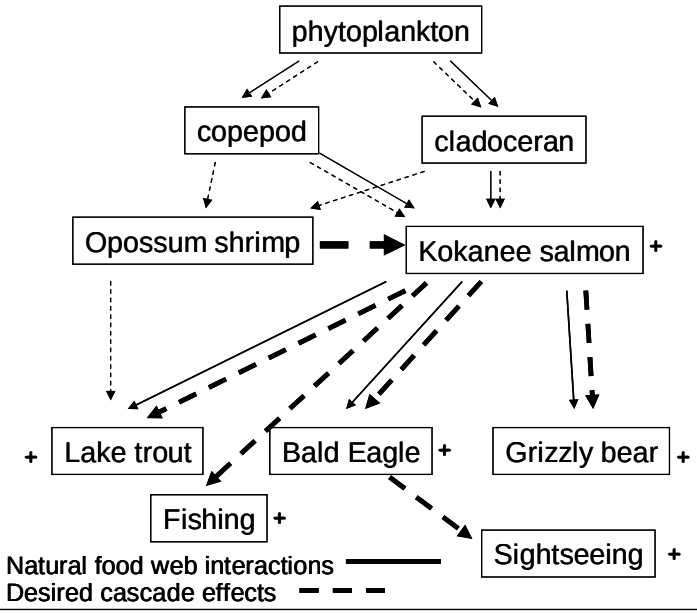
Level of Achievement	General Approach	Comprehension
Exemplary **7-10 pts**	• Addresses the question. • Provides a relevant, justifiable answer. • Presents information in a logical order. • Uses acceptable style and grammar (no errors).	• Demonstrates an accurate and complete understanding of the question. • Appropriately labels food web structures and interactions • Energy flow is in the appropriate direction • Connects cascading interactions with disturbances and the impacts on ecosystem services
Adequate **4-6 pts**	• Does not address the question explicitly, although does so tangentially. • Provides a relevant and justifiable answer. • Presents arguments in a logical order. • Uses acceptable style and grammar (one error).	• Demonstrates accurate but only adequate understanding of question • Does not label all structures and interactions within the food web • Does not demonstrate a complete understanding of energy flow through a food web • Connects cascading food web interactions with disturbances but not the loss of ecosystem services
Needs Improvement **1-3**	• Does not address the question. • Provides no relevant answers • Indicates misconceptions. • Is not clearly or logically organized. • Fails to use acceptable style and grammar (two or more errors).	• Does not demonstrate accurate understanding of the question. • Incorrectly or does not label structures and interactions within food web • Demonstrates misunderstanding of energy flow through a food web • Does not connect cascading food web interactions with disturbances or the loss of ecosystem services
No Answer		

Example food web models (for instructor use):

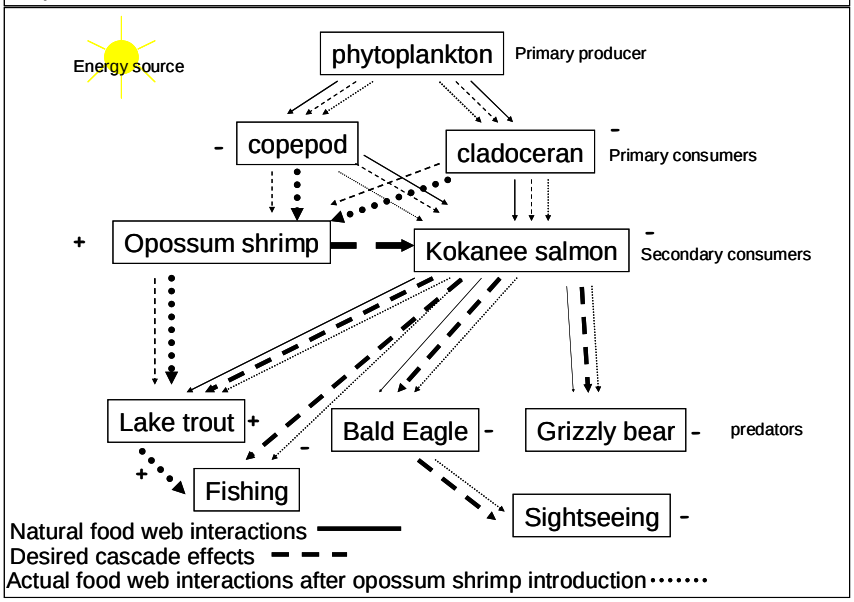
Panel 1: Example of the natural Flathead river-lake food web



Panel 2: Example of the Flathead river-lake food web with the natural food web and the desired food web of the Montana Fish and Game.



Panel 3: Example of the Flathead river-lake food web before and after the opossum shrimp introduction and the Montana Fish and Game's expected outcome.



Appendix A: (for instructor use):

Clicker Question 1.- one vote per group. *Provisioning services:* How much money did your group allocate to services such as food, drinking water, and timber?

A. 0-60
B. 60-120
C. 120-180
D. 180-240
E. 240-300

Clicker Question 2. Regulating services: How much money did your group allocate to services that affect climate, flood control, disease, and waste water treatment?

A. 0-60
B. 60-120
C. 120-180
D. 180-240
E. 240-300

Clicker Question 3. *Cultural services:* How much money did your group allocate to services that provide recreational and aesthetics.

A. 0-60
B. 60-120
C. 120-180
D. 180-240
E. 240-300

Clicker Question 4. *Supporting services:* How much money did your group allocate to services such as soil formation, photosynthesis, and nutrient cycling?

A. 0-60
B. 60-120
C. 120-180
D. 180-240
E. 240-300

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