TITLE: It's a Puma-eat-Deer-eat-Grass World!

Subtitle: Trophic Cascades and Predator-Prey Dynamics

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Field tested with: 11th and 12th grade Environmental Studies AP students, Watsonville High School, Watsonville, CA

Module Type: Lab activity to follow a lecture.

Duration: Two class periods: a lecture, homework, one class section for the actual activity, and homework after the lab activity

Key materials:

- Plant and animal cards (grass, deer, and puma, see attached)
- Dice
- Coins
- Notebook and 3 colors of pen
- 3 envelopes – one for each species card

Concepts: trophic cascades, species interactions, ecological dynamics

Skills:
Students will learn:

- The importance of top carnivores, ecosystem dynamics, and species interactions.
- How to make predictions about what will happen when dynamics are altered
- Data visualization and interpretation

Science Education Standards: (abbreviated list of key national and CA standards you engage)
•**National:** Science As Inquiry; Science and Technology; Science in Personal and Social Perspectives
•**California:** Biology-Life Sciences: 6. Ecology (ecosystem changes); Investigation and Experimentation
HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.
HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

Overview:

High school students should be familiar with the concept of food chains. In this project, we add a little complexity by learning about trophic cascades and how the different elements of the food chain may interact. We will explore the importance of top-down regulation and how predators may regulate the habitats in which they live. This project is an opportunity for students to learn about ecosystem properties such as:

- How predators and prey interact.
- How human activities may disrupt ecosystem integrity.
- How to formulate predictions and hypotheses (in this case about ecological dynamics).
- Engaging in argument from evidence – making and interpreting simple graphs and use evidence from self-generated data to formulate arguments.
- Formulating their own hypotheses and constructing estimations based on their own data.

(NOTE: Can include an informative and attractive original image)

Navigate: Background Materials &Time Starting Point Procedures Standards Supplemental

Background for Teachers

(limited to one page)

Why this matters:

Human persecution and development have threatened large carnivore populations worldwide, however, carnivores are critical to maintain balanced, healthy ecosystems.

Assumed background:

Students should already know:

- How to make simple graphs
- The definition of a basic food chain

Scaffolding supplements:

This is a great little 3-part YouTube video series introducing top-down versus bottom-up dynamics and trophic cascades:

Part I:
http://www.youtube.com/watch?v=cz5tFQVYFBs

Part II:
http://www.youtube.com/watch?v=yk-m-fMaojY

Part III:
http://www.youtube.com/watch?v=TcLbiSLAMU8

All together, the videos are 4:44. These clips were put together by Stephen Thomas, a professor from Michigan State University, who focuses on how to teach science to non-scientists.

Module Description

Materials:

- Grass cards – 100 per group
- Deer cards – 50 per group
- Puma cards – 20 per group
- Dice – one per group
- Coins – one per group
- Habitat – a desk top or designated lab table space where the animals can “interact” or the grass can “grow”
- Notebook

Preparation:

- Create lecture on trophic cascades.
  - The following paper (available on Google Scholar) provides a great overview and figures that can be used in addition to the videos cited later:
    - Estes, J. A., J. Terborgh, J. S. Brashares, M. E. Power, J. Berger, W. J. Bond, S. R. Carpenter, T. E. Essington, R. D. Holt, and J. B. C. Jackson. 2011. Trophic downgrading of planet earth. Science **333**:301-306.

- Make or gather cards for student groups.
- Watch the instruction video and try the game **before** class.

Timeline:

Part I: Introduction – lecture on trophic cascades (45 min. to an hour total including #1-7 below)

1. Depending on the length of the class period, this lab would ideally take place over two classes. In the first class, the teacher would lecture about food webs, top-down versus bottom-up processes, trophic cascades, and behavior-mediated trophic cascades. (45 min. to 1 hr.)
2. Video on trophic cascades – Part I (2 min.)
3. Discussion of question for Part I (3 min.)
   - Discussion question: How might species reduce or eliminate the effects of a toxic primary producer? That is to say, how might an herbivore avoid being affected by poisons in the plants they eat?
   - Answer: The herbivore could sequester the toxin or become immune. In this case the plant wastes energy making the toxin and potentially increases the abundance of the herbivore.
4. Video on trophic cascade – Part II (2 min.)
5. Discussion of question for Part II (3 min.)
   - Discussion question: Knowing what you know about bottom-up effects, what relationship would you predict between the higher trophic levels? Or, to put it a bit differently, how would the poisonous grass affect the aphids that feed on it? How do you think the poisonous grass would affect the parasitoids that lay their eggs in aphids?
   - Answer: The poisonous grass would have no negative effect on aphid reproduction, but it did decrease parasitoid fecundity.
   - How does that work?! The aphids used the poisons in their food to help defend themselves against parasitoids by sequestered the toxins in their own bodies to help poisons in the parasitoids.
6. Video on trophic cascade – Part III (2 min.)
7. Summary discussion of trophic cascades and homework (see handout #1) (5 min.)

Part II: Trophic cascades lab.

1. Briefly discuss homework and introduce lab. (15 min.)
   - There is a video available online that walks the students through one round of the game to help introduce the lab. **[fill in URL for video]**
   - Have the students watch the video and follow along with the instructions.

2. Lab activity (40 min.)
3. Wrap up and discussion of what students observed in lab. (10 min)
4. cleanup (5 min.)

Starting Point For Inquiry:

The idea of trophic cascades was first popularized by Hairston, Smith and Slobodkin's1960 paper introducing the green world hypothesis. They suggest that the world is green because predators reduce the number of herbivores, which allows plants to proliferate. The term "trophic cascade" was coined by Robert Paine in 1980 to describe the effect that predators have on subsequent trophic levels. As in the green world hypothesis, predators suppress prey numbers, thereby releasing the subsequent trophic level from predation, be that herbivory or carnivory. When a top predator is removed, the prey abundances increase, as does their resource consumption. These different dynamics can play out in many different ways on the landscape and the game the students are going to play is meant to explore some of these dynamics.

The example we will use in the trophic cascade game is pumas, deer, and grass in a meadow ecosystem. In this habitat, the pumas eat the deer, and the deer eat the grass. When there are many pumas, the population of deer will shrink. With few deer in the meadow, the grass will grow more abundant because they are released from herbivory. The large puma population will have an indirect positive effect on the grass. However, if the deer population is low, pumas won't have enough prey to eat, and their population will soon shrink as well. When the pumas decline, the deer population will grow. As the deer population grows, they will eat more grass and have a negative direct effect on the grass.

In some cases, the predator doesn't need to consume the prey to have strong impacts on subsequent trophic levels. Sometimes having a predator around scares the prey into behaving in a certain way – perhaps staying out of a particular type of habitat. Plants living in the avoided habitat are protected from being eaten and grow more abundant. This is what we call an indirect trophic cascade.

Schmitz et al. (1997) demonstrate this concept with a study on spiders, grasshoppers, and plants. They created three groups:

Group 1: plants and grasshoppers

Group 2: plants, grasshoppers, and spiders

Group 3: plants, grasshoppers, and "risk" spiders. These "risk" spiders had their mouths glued shut so they could not actually kill and eat the grasshoppers, but they could scare the grasshoppers into hiding

What they found was that the plants in group 1 were heavily browsed by grasshoppers. This is no surprise because there was no predator to eat the grasshoppers. They also found that the plants in groups 2 and 3 grew at about the same rate. Even though the spiders in group 3 couldn't eat the grasshoppers, the grasshoppers hid from them and only came out to eat when they needed to.

Grasshoppers aren't the only ones affected by indirect trophic cascades. Gardeners and farmers have been capitalizing on this effect for hundreds of years. If you want to keep crows from eating your corn, what do you do? You build a scarecrow, or put out dummy snakes or plastic owls. These are examples of how we used indirect trophic cascades in our every day life.

If you aren't a farmer, why are these dynamics important? Human persecution and development have threatened large carnivore populations worldwide. Humans have

transformed between one third and half of the world's land surfaces, and as the human population grows, development continues to swallow open space that predators need to survive. Low birth rates and large home ranges make carnivores more sensitive to habitat loss than other species and are often among the first casualties when land is developed. To make matters worse, government-sponsored large-scale predator eradication projects further reduce carnivore populations.

There are many important ecosystem services that carnivores provide, including slowing disease spread, increasing carbon sequestration, changing wildfire cycles, etc., each of which has important consequences for human health, safety, and economic security. These topics are beyond the scope of this lesson, however this lab intends to introduce one way in which carnivores are important in helping maintain balanced, healthy ecosystems.

Though carnivores often capture our imaginations, many students don't understand their ecological importance. This module helps demonstrate why it is so important that we 1) understand predator-prey dynamics, 2) understand why these dynamics are important to ecosystem health, and 3) conserve carnivore species in order to maintain ecosystem function and integrity.

Detailed Procedure:

Part I: Introduction – lecture on trophic cascades and videos

- Refer to the paper and videos listed in Supplemental Materials section. There is also a short homework for students to complete the night before the lab activity (see TC homework.docx in supplementary materials)
- This lecture and discussion should cover food webs, top-down versus bottom-up processes, trophic cascades, direct and indirect trophic cascades.
- The teacher can show a short 3-part video series (see supplemental information) on trophic cascades.
- After each video segment, the class should have a short discussion:
    - Discussion question for Part I: How might species reduce or eliminate the effects of a toxic primary produce?
        - Answer: The herbivore could sequester the toxin or become immune. In this case the plant wastes energy making the toxin and potentially increases the abundance of the herbivore.
    - Discussion question for Part II: Knowing what you know about bottom-up effects, what affect would you predict about aphids that feed on poisonous grass and parasitoids that lay their eggs in aphids?
        - Answer: There was no ill effect on aphid reproduction, but there was a dramatic decline in parasitoid fecundity.
- After all three videos, the class should have a short summary discussion of trophic cascades and the expectations for the assigned homework (see TC homework.docx)

Part II: Lab Activity

- The teacher should remind the students about what they learned last class period by asking questions about the homework.
    - Have students volunteer to explain the homework problems (draw the diagrams on the board or tell the instructor how to).
- The instructions for the lab are attached (see TC Lab Instructions.docx):

Assessment Methods:

Each student will graph their group's work and will use this graph to answer series of questions about the data they collected in relation to the dynamics of the ecosystem. Students who have mastered this material will be able to describe the dynamics they observed and explain how different scenarios may impact the relationships of species in this habitat type. Students should further be able to extend these concepts to other ecosystems and predict the dynamics and explain how these dynamics may shift if the variables are changed.

After lab questions: These questions should be written up as homework.

1) Graph the population size of each species over time on one set of axes with each species in a different color.

2) How high did your deer population need to be before the pumas could sustain themselves?

3) If every square on the board were filled with grass, what would the limiting factor for the deer population be?

4) Under what conditions are the pumas locally extirpated? Use your data to explain this with numbers.

5) What happened to the grass population as the puma population grew? Use your data to explain this with numbers?

6) What might happen if we suddenly added 20 deer? What would happen to the grass population and what would happen to the puma population?

7) Thinking about the Zion National Park example from your homework, what might happen if we added human presence to the game? Please explain what would happen to each population, the pumas, deer, and grass.

Possible pitfalls:

- The lab directions can be tricky to follow. Make sure that you have tried the game out beforehand so you know how it should work. I have made a video to make the instructions clearer, but it is important for teachers to try a round or two before class anyway.
- There will be a lot of variety in outcomes – make sure students understand that there is no "correct" outcome and that everyone will get a different answer.

Glossary:

Keystone species: a species that exerts influence over the habitat that is disproportionate to its abundance.

Limiting resource: this is the factor that sets the cap on a population, it is the resource that is most scarce and as such, only allows the population to reach a certain size

Carrying capacity: the maximum population size of the species that the environment can sustain indefinitely

Locally extirpated: extinct within a certain area, but not necessarily in all areas

Dynamic equilibrium: the condition of a system in which all factors are balanced, but still moving in relation to one another

Sequester: a processes in which an organism accumulates a compound and stores it in its own tissues

Fecundity: the ability of an organism to reproduce.

Science Education Standards Addressed

National Science Standards (NSES)

A. Science As Inquiry (p.175-176)
E. Science and Technology (p.192-193)
F. Science in Personal and Social Perspectives (p.198-199),

California Public Schools Standards (SCSCPS)

Biology-Life Sciences**,** 6. Ecology: Stability in an ecosystem is a balance between competing effects.

> **b.** Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size (p. 54).

Investigation and Experimentation, 1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing content in the other four strands, students should develop their own questions and perform investigations. Students will:

> **a**. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
> **c**. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.

NSES (http://www.nap.edu/catalog/4962.html)
SCSCPS (http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf);

Guide to supplemental materials

Provide an annotated list of supplemental materials that are appropriate to the module. For each, provide the name of the file and a brief description of the contents and how it is used. The actual supplemental materials may be appended in ready-to-use formats at the end of the document or be stand-alone-document.

Lectures

See attached powerpoint lecture outline: TC Lecture.pptx

Graphics

TC Animal Cards.docx

Labs (or Activities)

See Lab Activity

Worksheets

TC Lab Instructions.docx
TC Lab Handout.docx
TC Homework.docx

Videos

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Discussion question: How might species reduce or eliminate the effects of a toxic primary produce?
Answer: The herbivore could sequester the toxin or become immune. In this case the plant wastes energy making the toxin and potentially increases the abundance of the herbivore.

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Discussion question: Knowing what you know about bottom-up effects, what affect would you predict about aphids that feed on poisonous grass and parasitoids that lay their eggs in aphids?
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