Computationally Modeling the Trophic Cascade in Yellowstone National Park

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Purpose: The purpose of this project is to computationally model and computationally characterize the top-down trophic cascade occurring in Yellowstone National Park since the reintroduction of grey wolves in 1995-1996.

Importance: The project is important because it will serve as an outline for future efforts to anticipate trophic cascades. Environmental policy makers can look at the model when considering extirpating a predatory species or regulating the hunting practice of apex predators. It will be a computational structure of a physical system which can be altered or expanded to be of use in understanding other ecosystems, and the effects of human interaction with them. More generally, trophic cascades are examples of a class of system where dynamics play a key role in understanding computational behavior.

Overview: In the late 1800s, predation from wolves on domestic livestock in the Greater Yellowstone area began to cause concern for the success of agriculture in the surrounding areas. In the early 1900s, predator control of the wolves was practiced until they were completely extirpated in 1926. In the decades following wolf absence, the ecosystem of Yellowstone changed drastically. Some unexpected effects have been landscape changes along river banks and greater canopy cover in the forest areas. Since wolf reintroduction in 1995 and 1996, a trophic cascade has been occurring. A trophic cascade is an ecological phenomenon that occurs when a top predator is added or removed from an ecosystem and causes the next level of predation or herbivory to decrease, releasing the next trophic level of primary producers such as plants to increase causing many ecological results.

For this project, I plan to compare two computational models. The first will represent two components: (1) the population dynamics, and (2) the behavioral dynamics of plants and animals contributing to the trophic cascade; the other will only represent the population dynamics of these species. For the first model, I plan to use a variation of Lotka-Volterra equations to account for population dynamics and pursuit-evasion algorithms to model the location and distribution of the animal and plant species. The second model will only use the Lotka-Volterra equations to describe the ecosystem. For both models, I will analyze the sensitivity of perturbing the presence of an apex predator, in this case the extirpation or reintroduction of wolves. Because substantial data for the animals and plants in Yellowstone may be difficult to acquire, we are taking the approach of creating the models, and analyzing simulations of perturbations representative of wolf extirpation and reintroduction. From this, we will hopefully be able to see which model better explains the phenomenon in Yellowstone.

Because it is hypothesized that the behavior and population dynamics of elk and wolves are the main cause of the trophic cascade, I will be studying their relationship most closely. However, trophic cascades usually indicate the release (or suppression, in this case release) of primary producers from intense herbivory and so I will also study the dynamics of aspen and cottonwood trees. Time allowing, I will further my analysis to include the dynamics of other animals in Yellowstone, such as bears, beavers and hawks.

The elk herds or wolf packs generally stay in areas that are (mostly) mutually exclusive from other elk herds or wolf packs, respectively. I will divide the park into regions defined by the area covered by elk herd and wolf pack pairs. There are several environmental and human influences that one would think might affect the issues discussed above. In my research, I have found little evidence to suggest that recreational hunting, harsh winters, fires or warming climate have had any significant effect on population or the behaviors of the animals.

Thesis Committee: My faculty advisor is Sean Warnick. I have been involved in his research lab for one year and have taken his Linear Programming and Convex Optimization class. Dr. Warnick has extensive experience modeling complex systems including biological systems. My faculty reader is Zach Aanderud. I took an environmental biology class from him. He is currently working with my advisor on a project and
has experience in understanding computational models of biological systems. My Department Honors Coordinator is Seth Holladay and he will also be on my committee.

**Timetable:** I have already begun on this project studying the results that ecologists have gathered in the twenty years of wolf presence. Currently, I am working on building the two models. I plan to have this completed by June 1st, 2017 and I will present it to my colleagues in my lab. Once I have the models, I will need to develop a methodology for fitting my model to Yellowstone animals. This means categorizing the population levels and behavioral ranges of the animals according to the data I can collect. I expect to have this methodology completed by August 1st, 2017. Finally, I will use this information to create a simulation of Yellowstone, this will be completed by September 1st, 2017. I will then need to analyze the results of my simulation and determine the reliability of the models. I will have completed my honors thesis by February 1st, 2018. By January 2018, I will also have generalized my results to systems for which cascading effects have a role and submitted these results for review to the 2018 American Control Conference and the 2018 Conference on Decision and Control.

**Funding:** I plan to travel to Yellowstone to meet with some of the experts in the ecological research and to gain familiarity and knowledge of the ecosystem I will be modeling. I am requesting $1000 from the Honors program to provide for travel to and boarding in Yellowstone for a week. I will be traveling by car and have estimated this cost to be $120, the hotel I will be staying in will cost $800 for five nights. Whatever funding I do not spend on travel or boarding costs will go toward a Yellowstone park pass to use that week. Whatever funding is not spent on travel, boarding or a park pass will go back to the honors program.

I also plan on presenting this paper at the either or both the American Control Conference or the Conference on Decision and Control. For these conferences, I am requesting an additional $1000 from the Honors program. I also have received an ORCA grant of $1500 in February 2017.

**Scholarly Sources:**


J. Winnie and S. Creel, “The many effects of carnivores on their prey and their implications for trophic cascades, and ecosystem structure and function,” *Food Webs*, vol. 9, pp. , 2016


