Yellowstone Wolves and the Regional Economy

By Michelle Lam

Introduction

In the 1800s, the westward expansion brought settlers and their livestock into direct contact with native predator and prey species. Much of the wolves' prey base was destroyed as agriculture flourished. With the prey base removed, wolves began to prey on domestic stock, which resulted in humans eliminating wolves from most of their historical range. In fact, humans started targeting predators so the "more desirable" wildlife species, such as deer and elk could live.

The gray wolf was present in Yellowstone when the park was established in 1872. By the 1940s, wolf packs were rarely reported and soon wolves had been almost entirely eliminated from the 48 states. This called for immediate attention. The Endangered Species Act that was passed in 1973. The US Fish and Wildlife Service is required by this law to restore endangered species that have been eliminated, if possible. By 1978, all wolf subspecies were on the federal list of endangered species for the lower 48 states except Minnesota.

Wolf population restoration in Yellowstone has become one of the most successful wildlife recovery programs in the history of endangered species conservation. Wolf sightings in the Park and public interest in wolves and wolf education programs have far exceeded initial expectations.

One of the most popular visitor activities in Yellowstone National Park is wildlife sightings. Grizzly bears, wolves, elk, moose, and bison are a few of the most sought-after Park mega fauna. Wolves have been a relatively recent addition to the list. For this project, I will attempt to simulate how wolves, if reintroduced to the Greater Yellowstone Ecosystem, might impact the regional economy.

Brief Literature Review

Between 1991 and 2017 there have been a number of visitor and resident population surveys conducted either within Yellowstone National Park or concerning issues specific to Yellowstone National Park or the Greater Yellowstone Area (GYA). These surveys, addressed the wolf reintroduction issue. This suite of population and visitor surveys were related to perceptions and attitudes towards wildlife specifically targeting the issue of wolves and other Yellowstone area wildlife issues. The first of these studies was a 1991 study of Yellowstone National Park visitors specifically addressing the issue of possible reintroduction of wolves into the GYA (Duffield 1992). In 1993 Duffield, Patterson and Neher conducted a study for the Liz Claiborne and Art Ortenberg Foundation of the likely economic consequences of reintroduction of wolves to the Yellowstone ecosystem (Duffield, Patterson and Neher 2004). This study included a national household phone survey in order to estimate total use value of associated with a recovered wolf population. In 1994 the final EIS on the reintroduction of wolves to Yellowstone and central Idaho replicated and expanded upon the 1994 Duffield et al. study and estimated the economic impacts of wolf reintroduction within a cost/benefit framework. (U.S. Fish and Wildlife Service, 1994; Duffield and Neher 1996). A recent issue of Yellowstone Science provides a summary of research, particularly with respect to wildlife management and wildlife biology, concerning the first 10 years of wolf recovery (in particular see Smith 2005 and White et al. 2005). A recent article (Montag, Patterson, and Freimund 2005), describes the wolf-viewing experience in Yellowstone National Park based on a 1999-2000 visitor survey.

Majority of the attempts I found to find how wolf reintroduction might impact the regional economy were survey based. Unfortunately, since I will be doing a simulation I will not be using the survey approach. Data gathered from these studies are used to help build and analyze my models. It also allowed for a better understanding into tourist preferences which is incredibly important to accurately simulate the benefits to the economy.

Methods

For this simulation, I will be using a predictive deterministic model. My initial attempt was to create a stochastic model to simulate the randomness of wildlife behavior. Unfortunately, due to time limitations I was not able to implement one.

Since economists frequently use gross domestic product (GDP), as a proxy for human well-being. In an economically linked region, this indicator could serve the purpose of developing a flow diagram of the benefits of wolf reintroduction.

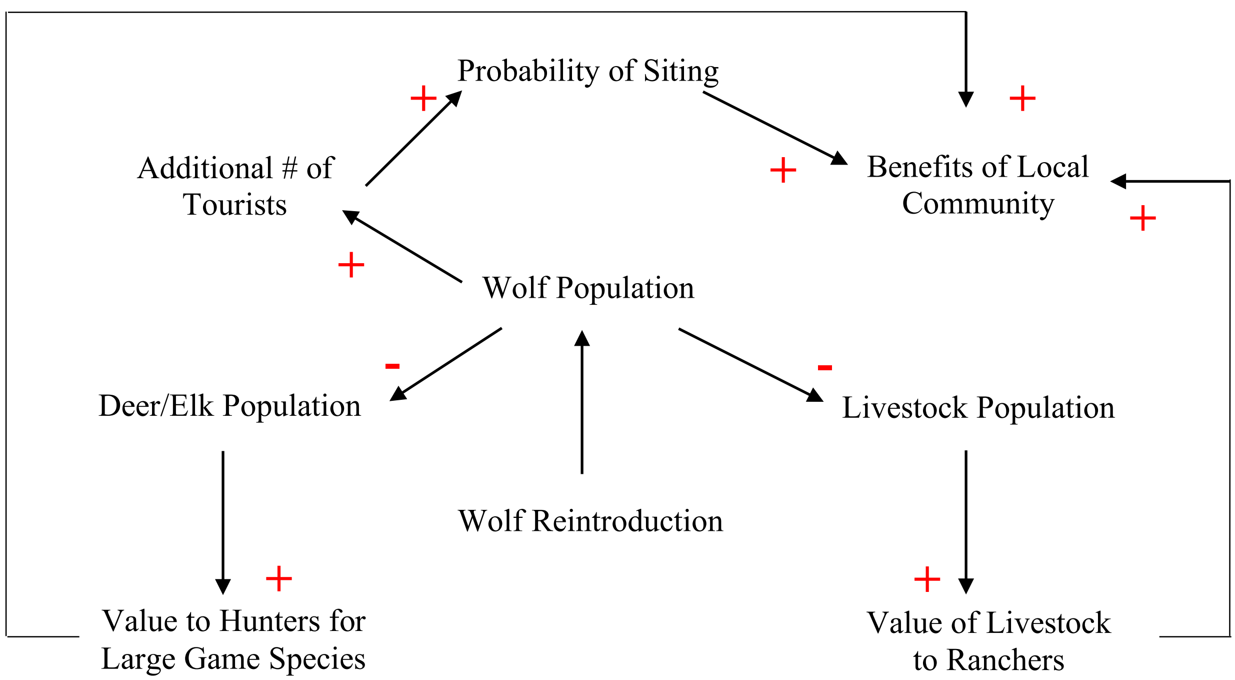


Diagram 1: Flow diagram of the benefits from wolf Population

A simple Lotka–Volterra model was developed first to show the population dynamic of predator-prey-prey interactions (wolf-deer/elk-livestock) from the flow diagram. They are as follows:

Δ Wolf Pop. **w'(t)** $w'(t) = -\lambda w(t) + \mu w(t)d(t) + \rho w(t)l(t) - kw(t)$

Δ Deer/Elk Pop. **d'(t)** $d'(t) = \alpha(t) - \beta d(t)w(t) - Hd(t)$

Δ Livestock Pop. **l'(t)** $l'(t) = \gamma(t) - \delta l(t)w(t) - Sl(t)$

Such that

- $\lambda w(t)$, $\alpha(t)$ and $\gamma(t)$ represent the intrinsic growth at time t
- $\mu w(t)d(t) + \rho w(t)l(t)$, $\beta d(t)w(t)$ and $\delta l(t)w(t)$ represent the interaction between species
- $kw(t)$, $Hd(t)$ and $Sl(t)$ represent the human factors

Environment resources are limited therefore we must implement a carrying capacity for the deer/elk and livestock pollution. These will be in place of the intrinsic growth variables above:

α(t) = (dGrowth * d(t) * (1 – d(t) / dCapacity)
γ(t) =(lGrowth * l(t) * (1 – l(t) / lCapacity)

The populations were then used to find hunter, rancher and tourist values

Hunter Value **hV(t)** *hV(t) = d(t) * 444*

Rancher Value **rV(t)** *rV(t) = l(t) * 2000*

Tourist Value **tV(t)** *tV(t) = w(t) * (14285 / 326)*622*

where the sum was the resulting economic benefit

Econ Benefit **eBenefit(t)** *eBenefit(t) = tV(t) + hV(t) + rV(t)*

Key parameters from past studies and state records were implemented in this model. Choosing parameters:

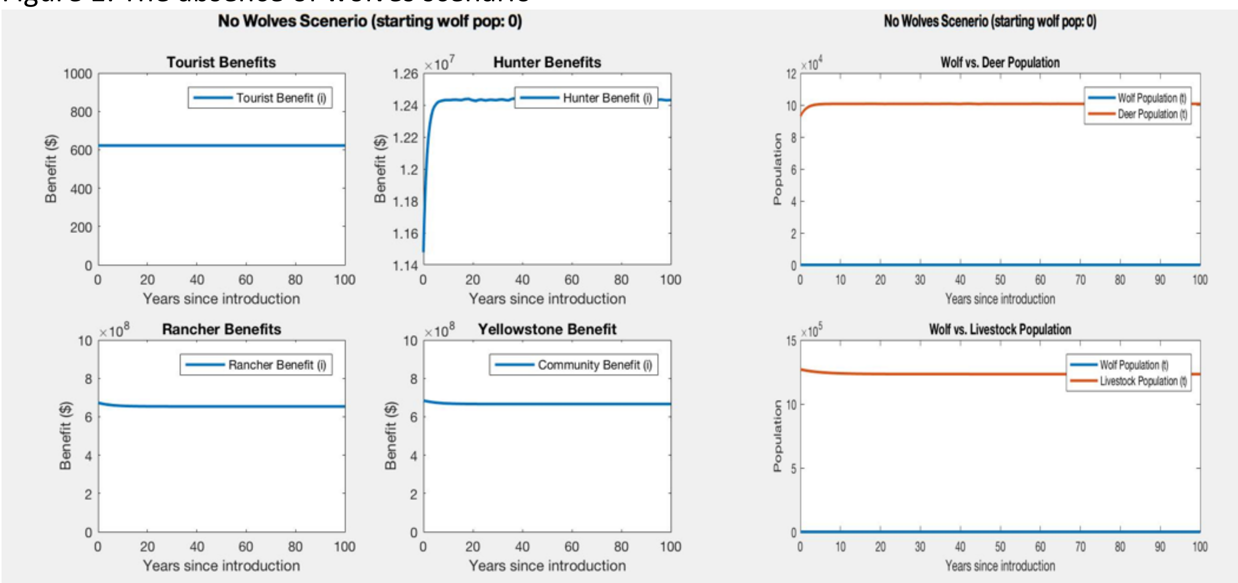
- Deer Carrying capacity : 3,000,000 => given in Wyoming fish and game data
- Deer Growth rate (α) : 1 => a does has 2 offspring on average (every year)
- Deer wolf interaction (β) : 16/ 93000 = 0.00017 => average wolf kills 16 elk/year and there are ~93,000 elks in WY
- Rate Deer get Hunted (H) : 25852/93000 = 0.378 => humans killed that many elk
- Livestock Carrying Capacity: 139,500 => given in Wyoming livestock data
- Livestock Growth rate (γ) : 0.265 => has to match S since pop. is stable
- Livestock wolf interaction (δ) : $6.10*10^{-5}$ => 0.2% cows get killed by wolves. There at 300 wolves, 1.27 million cattle. So (0.002 * 1.27)/300 = 8.47. Therefore 8.47/1,270,000 = $6.10*10^{-5}$
- Rate Livestock get Slaughtered (S) : 2.6/9.8 => 0.265 => in the UK, cattle population is 9.8 million and 2.6 million were slaughtered
- Starvation of wolves(λ) : 0.2=> slow starvation.
- Deer and Livestock benefit to wolf (μ *and* ρ) : $\mu = (\rho*1{,}270{,}000)/93{,}000$ and $\rho = 0.000001$ => Assuming $\mu w(t)d(t) + \rho w(t)l(t)= \lambda w(t)$
- Hunting Wolves rate (k) : 113/328 = 0.345 => Wolves killed / population
- Price per deer : $444 => Wyoming fish and game
- Price per cow : $2000 => Wyoming Livestock Reports
- Value of a wolf to tourist = (0.05/326)*622 => probability of seeing a wolf (given from Yellowstone data) / wolf population * estimated 1 week stay in Yellowstone

For this simulation, the MATLAB ODE function was used to solve the Lotka–Volterra model. Four different scenarios were analyzed: absence of wolves, introduction of wolves, absence of livestock, and changing wolf preference for deer/elk and livestock. All of which occurred over a 100-year period. Some key assumptions made in this simulation are there is a natural growth of deer, data found in WY database is update-to-date, all wildlife stay in Yellowstone and wolves will kill the most preferred out of deer and livestock.

Results and Discussion

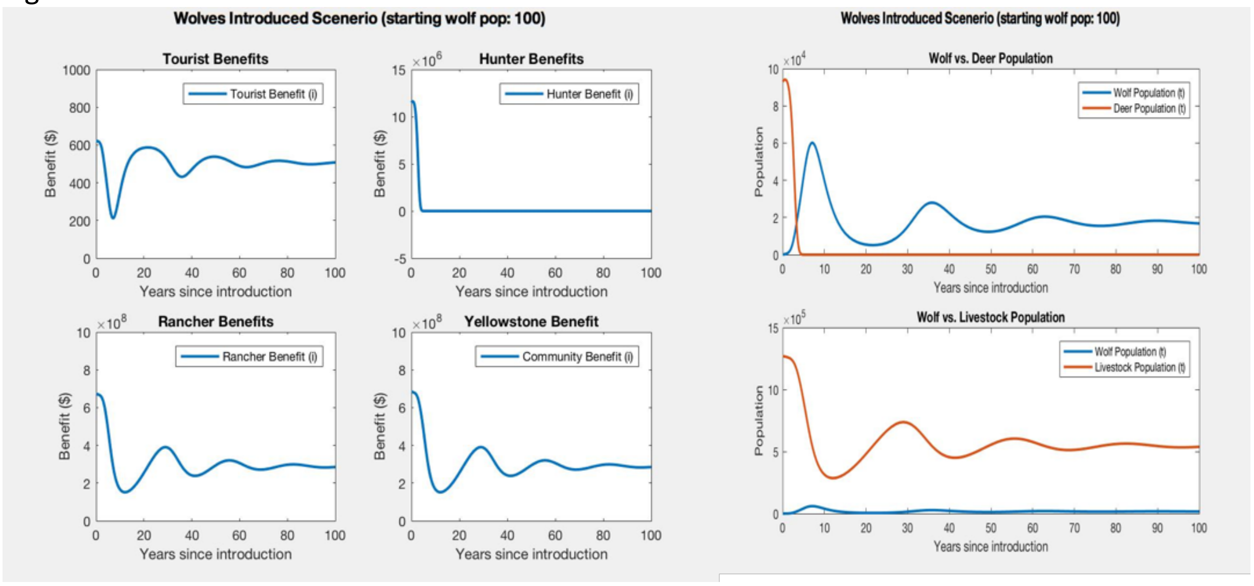
In a scenario where no wolves were introduced (figure 1), all populations and benefits became stabilized (hit equilibrium). This was essential because we must make sure that no outside factors will be manipulating my data other than wolves.

Figure 1: The absence of wolves scenario



As wolves got introduced, the deer population immediately went extinct and hunters no longer gained any benefits. On the other hand, livestock and wolf populations reflected a damped oscillator; as livestock population decreased wolf population increase and vice versa. Benefits for the two scenarios reflected those of the population (figure 2).

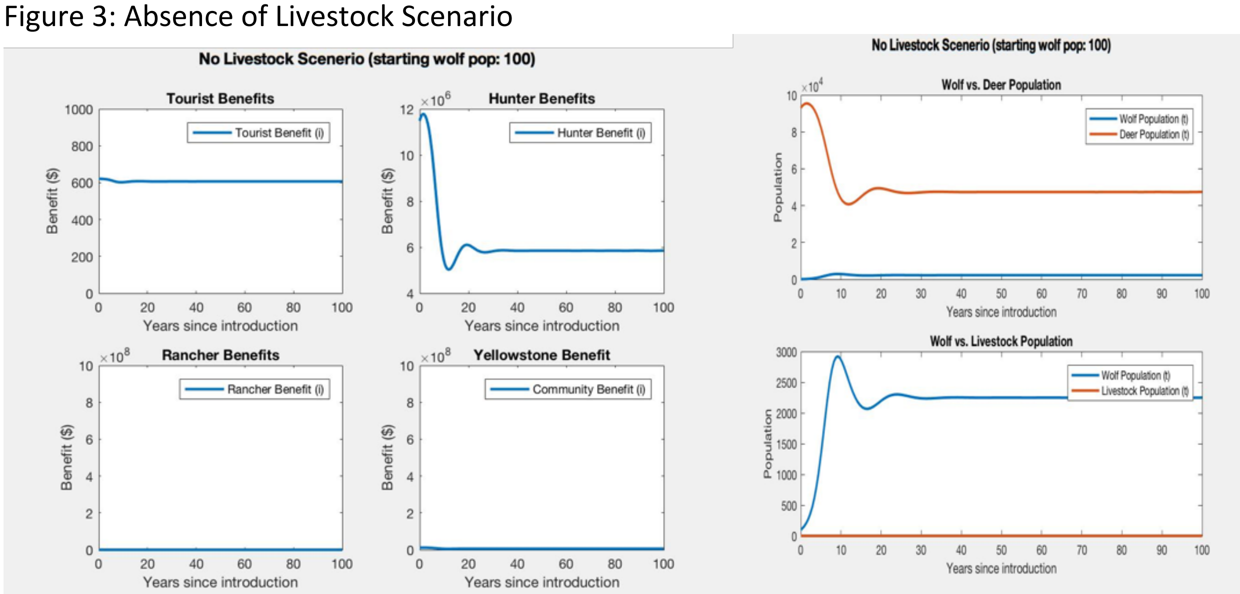
Figure 2: Wolf Introduction Scenario



Based on the two scenarios, it appeared that livestock was the main driver of the overall economic benefits. This wouldn't accurately represent a real-life scenario. Hunting in Wyoming has a large impact on the economy so what is the impact of livestock in my current model?

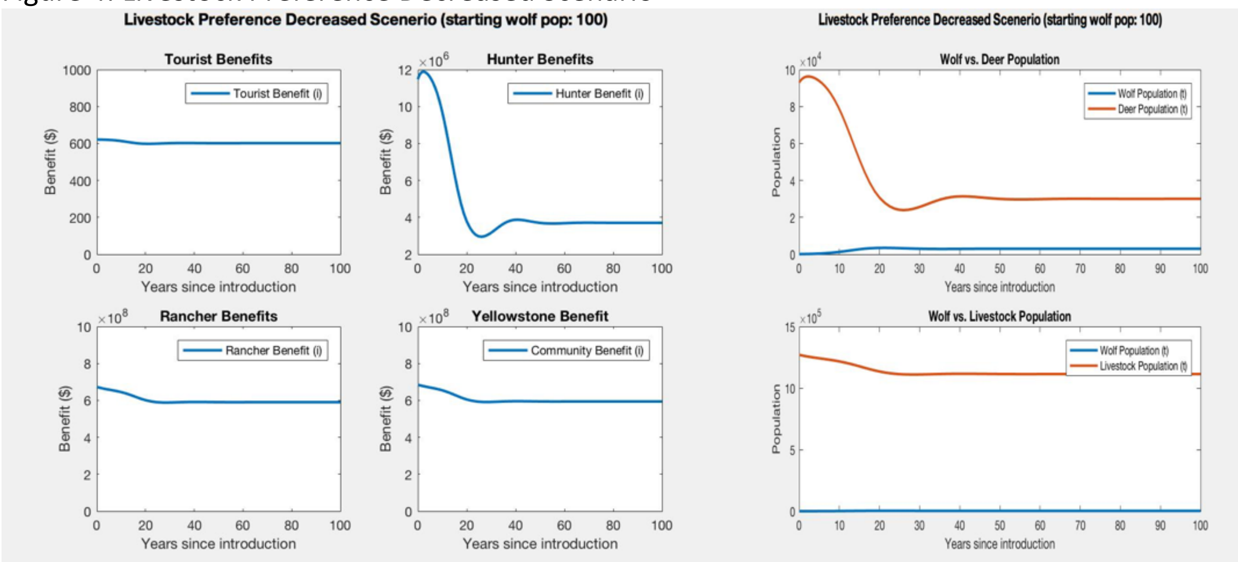
To find the impact of livestock, I set the population to zero (figure 3). Deer/elk population survived as expected and began to co-exist with the wolves after 25 years.

Figure 3: Absence of Livestock Scenario



This leads to my next question of whether there is a policy that limits the number of livestock or if can we change the wolves' preference for deer/elk and livestock such that none of the populations go extinct (to maximize benefits for everyone). It appears that as long as the livestock population exists, the deer/elk population will go extinct. My theory is that with the current parameters and where livestock population exists, wolves exhibit a rapid numerical increase in response to abundant prey. Though, if we decrease the livestock value to wolves (figure 4), for example ranchers start guarding their land from wolves, we reach a scenario where all three populations can co-exist because now the wolf population is more stabilized.

Figure 4: Livestock Preference Decreased Scenario



Summary/ Policy Recommendations

Wolves may not be typically thought of as a source of income, but it appears that they provide positive economic benefits by giving local economies a considerable boost. According to my results, rancher should use considerable measures to protect their livestock to discourage wolves and to minimize their population growth. Not only will this maximize their benefits they will also be a more balanced ecosystem.

Future Work

Any study of human behavior is subject to unforeseen real-world events that can frustrate the most carefully designed study protocols. This simulation was no exception. We cannot know the exact sequence of events that will occur subsequent to wolf recovery. This was the reason why I originally wanted to implement a stochastic model. With the unpredictable climate in Yellowstone National Park, there are certain to be large confidence intervals surrounding any projections for animal populations in the park.

I did not attempt to model livestock conflicts resulting from wolf recovery. However, after wolves have become established, we might expect some wolves to disperse from Yellowstone National Park each year. We can be reasonably certain that some of these dispersing wolves will get themselves into trouble from time to time. Conflicts are likely to be most severe following initial release because translocated wolves are likely to disperse, although strategies for release may reduce such problems.

Wolves will compete for game with hunters, and there will be differences of opinion as to whether wolves or hunters should be given priority. Hunters have very mixed opinions on whether wolf recovery is good or bad. We cannot know the consequences of wolf recovery until it actually takes place. Yet, we believe that the understanding of ungulate population biology and wolf predation is adequate to predict reasonable bounds for the expected population responses.

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