Nature's Balance: Lessons from Kaibab

🟩 Abstract

The story of the Kaibab Plateau is more than a cautionary tale — it is a living learning laboratory. In the early 20th century, well-intentioned human intervention in this northern Arizona ecosystem disrupted the delicate balance between deer and their natural predators. The result was a dramatic boom and collapse of the deer population, revealing the unseen power of feedback loops in complex systems. This article uses the Kaibab story to explore how systems thinking and simulation modeling help us anticipate unintended consequences, make better decisions, and design sustainable solutions. It is not just about what happened — it's about what we can learn to avoid repeating the same mistakes.

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🔑 Keywords

Kaibab Plateau; predator-prey dynamics; ecosystem collapse; systems thinking; simulation; environmental education.

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Introduction

What happens when we remove the predators in a seemingly fragile ecosystem? The Kaibab Plateau answers this with a dramatic story. In the early 1900s, humans decided to protect the deer population by eliminating their natural enemies — wolves, coyotes, and mountain lions. Initially, this seemed like a success. Deer numbers soared from 4,000 to over 90,000. But the land could not support such a population. Overgrazing destroyed vegetation, and the deer began to starve. Eventually, the population collapsed. This event, though tragic, gives us a valuable opportunity to learn. By modeling these events using system dynamics, we can understand how well-intended actions can lead to systemic failure. This is a call to embrace holistic thinking, anticipate ripple effects, and move from intuition to systemic insight.

Context and Simulation Task

This model explores one of the most iconic cases of ecosystem collapse caused by human intervention: the Kaibab Plateau deer population explosion and subsequent crash in early 20th century Arizona. Originally documented by Kormondy (1976) and modeled by Goodman (1974), the case remains a powerful example of how disrupting predator-prey dynamics can lead to catastrophic environmental consequences.

The Kaibab Plateau spans approximately **727,000 acres** north of the Grand Canyon. In **1907**, a bounty was placed on natural predators —cougars, wolves, and coyotes— and over **8,000** were exterminated within two decades. The deer population, which had been around **4,000**, exploded to **over 100,000 by 1924**. This unchecked growth led to extreme overbrowsing and the depletion of food reserves, causing the death of **60% of the herd** within two consecutive winters.

Using historical data, this simulation is built on the following core assumptions:

- **Area**: 800,000 acre
- **Initial deer population**: 4,000 Deer
- **Food required per deer**: 2,000 Food/year
- **Maximum food available**: 480 million Food
- **Feeding cycle**: 1 year

This model faithfully recreates the boom and collapse cycles, offering an invaluable **learning lab** for understanding unintended consequences in complex systems. It is designed to enhance **systems thinking** and support **environmental education** through experiential learning.

Foundations of Ecological Collapse: Deer, Food Supply, and Balancing Loops

This section documents the core structure of the model, composed of two key **stocks**: the **deer population** and the **available food supply (forage)**. Initially in balance, this system was radically disrupted by the **mass extermination of natural predators**, which triggered the **exponential growth of the deer**.

This unchecked population boom placed growing pressure on the limited food supply, activating two critical **balancing feedback loops**:

1. **Loop B4: Food Consumption** – As the deer population increases, so does food consumption, which depletes the available forage.
2. **Loop B1, B2: Starvation Deaths** – As food becomes scarce, deer mortality rises, slowing down population growth.

These mechanisms show how ecosystems respond with negative feedback when natural checks are removed. The model allows us to visualize and quantify these dynamics over time.

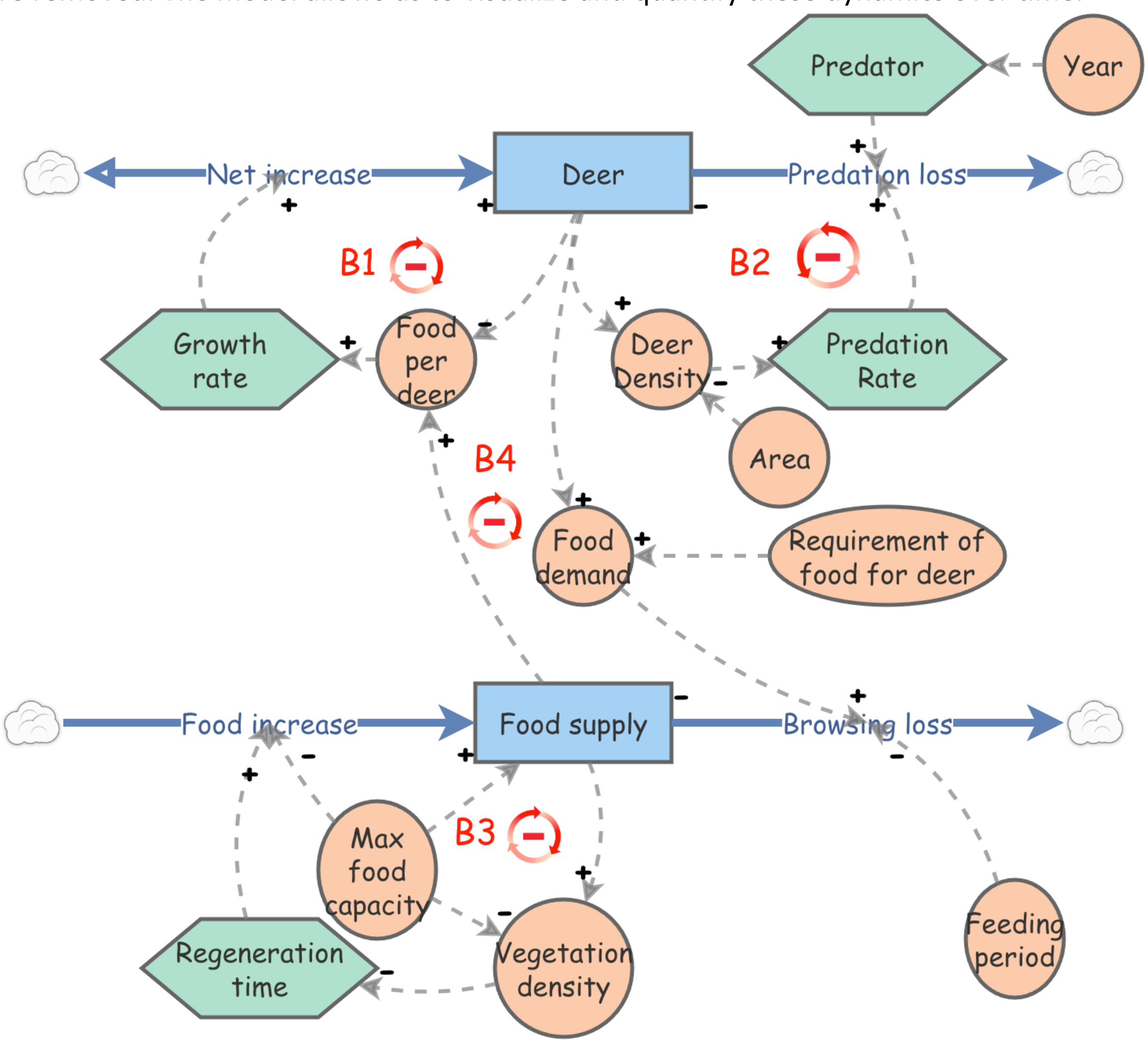


Figure 1: Core structure of the Kaibab simulation: deer population, food supply, and predators connected through balancing feedback loops that illustrate the effects of ecological imbalance.

Model table

No	Tipo	Name	Formula / Value	Units
1	Stock	Deer	Initial value: 4000	Deer
2	Stock	Food supply	Initial value: [Max food capacity]	Food
3	Flow	Net increase	[Deer]*[Growth rate]	Deer/ Year
4	Flow	Predation loss	[Predator]*[Predation Rate]	Deer/ Year
5	Flow	Food increase	([Max food capacity]-[Food supply])/[Regeneration time]	Food/ Year

6	Flow	Browsing loss	if ([Food demand]>=[Food supply]/[Feeding period]) then
			[Food supply]/[Feeding period]
			else
			[Food demand]
			end if
				Food/ Year

7	Variable	Year	Years()	Year
8	Variable	Area	800000	Acre
9	Variable	Deer Density	[Deer]/[Area]	Deer/ Acre
10	Variable	Food per deer	[Food supply]/[Deer]	Food/ Deer
11	Variable	Requirement of food for deer	2000	Food/ (Deer* Year)
12	Variable	Max food capacity	400000000	Food
13	Variable	Vegetation density	[Food supply]/[Max food capacity]	Unitless
14	Variable	Feeding period	1	Year
15	Variable	Food demand	[Deer]*[Requirement of food for deer]	Food/ Year

Nonlinear Function 1: Deer Population Growth vs. Daily Food Intake

This function defines the net growth rate of the deer population based on food availability. If daily intake drops to 500 Food/deer, the population declines by 15% per year; if it reaches 1500 Food/deer, the population grows by 15% annually.

Name: Growth rate

Type: Converter, Interpolation: Linear, Unit: Unitless, Input sourcce: Food per deer

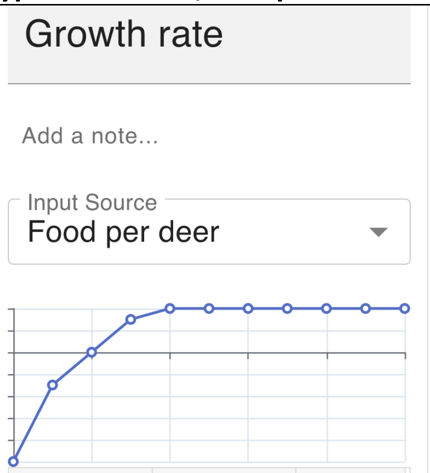


Figure 2: The functions for the (net) growth rate of the deer population

Food per deer	Growth rate
0	-0.5
500	-0.15
1000	0
1500	0.15
2000	0.2
2500	0.2
3000	0.2
3500	0.2
4000	0.2
4500	0.2
5000	0.2

Nonlinear Function 2: Predation Rate Based on Deer Density

This function represents the number of deer hunted per predator per year. At high deer densities, each predator may hunt up to 56 deer annually. As deer density decreases, the number of prey captured also drops. This nonlinear relationship captures how hunting efficiency depends on prey availability.

Name: Predation Rate

Type: Converter, Interpolation: Linear, Unit: Unitless, Input sourcce: Deer Density

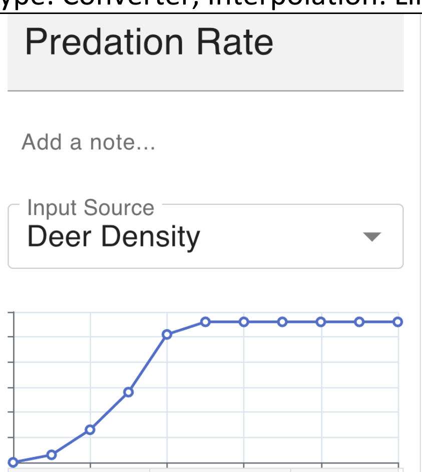


Figure 3: Table function for predation rate

Deer Density	Predation Rate
0.000	0
0.005	3
0.010	13
0.015	28
0.020	51
0.025	56
0.030	56
0.035	56
0.040	56
0.045	56
0.050	56

Nonlinear Function 3: Regeneration Time of the Food Supply

This function represents how the time required to regenerate the food supply is affected by ecosystem degradation. Normally, regeneration takes 1 year, but if the system is overbrowsed and damaged, regeneration can take up to 35 years. The table function captures the long-term impact of resource overuse on ecosystem recovery.

Name: Regeneration time

Type: Converter, Interpolation: Linear, Unit: Unitless, Input sourcce: Vegetation density

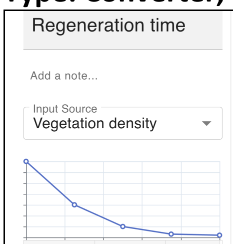


Figure 4º. The table function for regeneration time of the food supply

Vegetation density	Regeneration time
0.00	35
0.25	15
0.50	5
0.75	1.5
1.00	1.0

Nonlinear Function 4: Predator Population Over Time (PREDATOR Time Function)

This function models how the population of predators (cougars, coyotes, and wolves) declines over time due to the bounty policy introduced by humans. The function assumes a linear decrease in predator numbers starting in 1907, which severely reduced natural predation pressure on the deer population. This decline contributed to the unchecked exponential growth of deer. Predation Loss depends on both deer density and the predator population provided by this time-based function.

Name: Predator

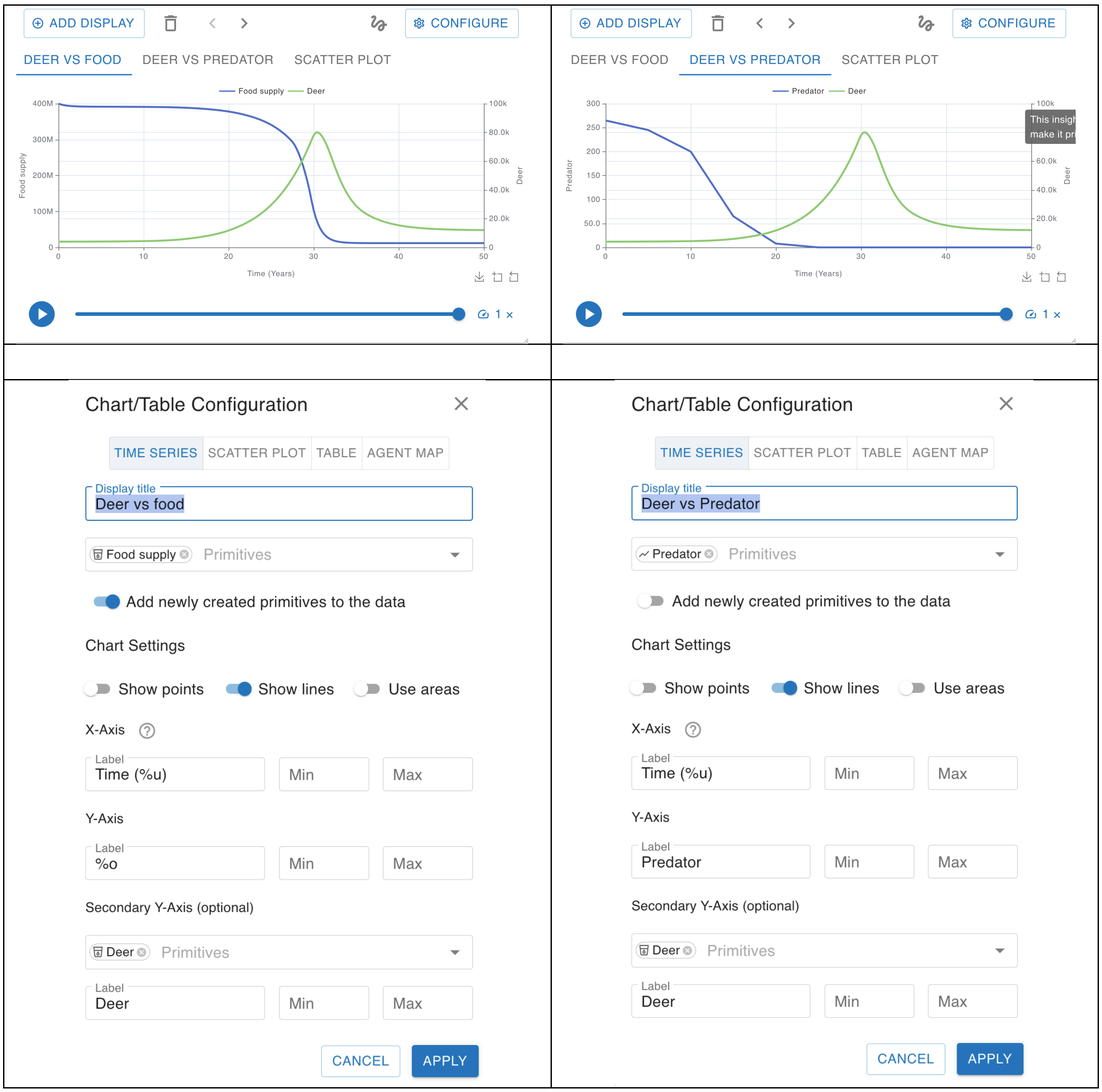
Type: Converter, Interpolation: Linear, Unit: Unitless, Input sourcce: Year

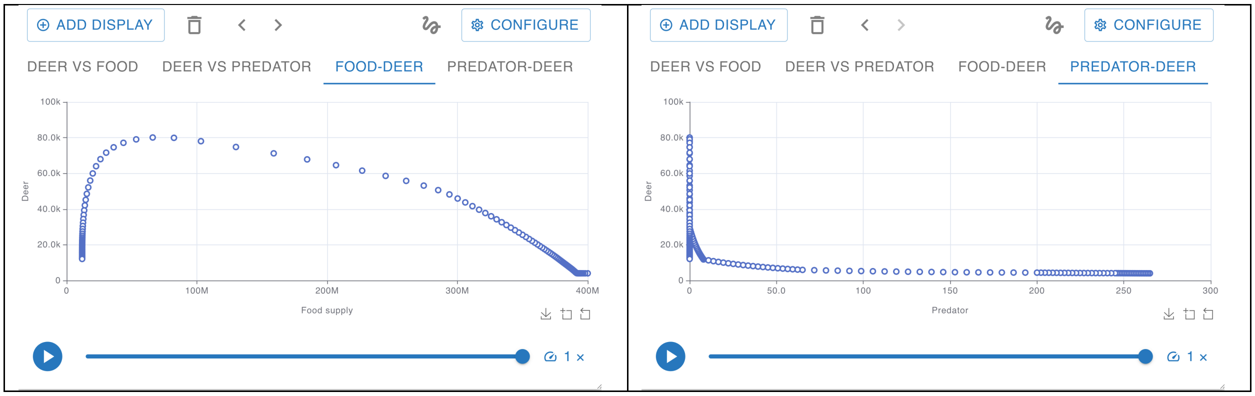
Figure 5: the PREDATOR time function

Year	Predator
0	265
5	245
10	200
15	65
20	8
25	0
30	0
35	0
40	0
45	0
50	0

Graphival result – Simulated Impact of Predator Removal on Deer and Food Supply

This graph illustrates the simulation results showing the near-eradication of predators, the exponential growth of the deer population, and the subsequent collapse due to food depletion. The model aligns with historical data: without predators, deer overpopulate, overbrowse, and degrade their habitat, leading to starvation and long-term population decline.





Model Registration & Settings

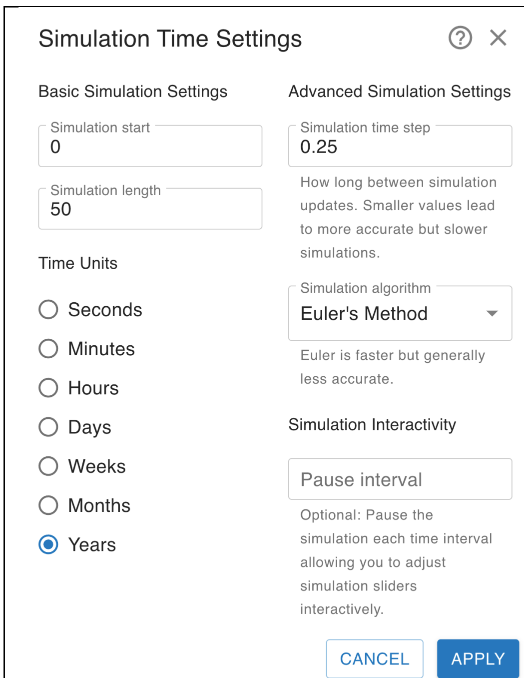


Figure 6: Model settings: Temporal and simulation parameters (duration, time steps, and interactivity options) that govern the run.

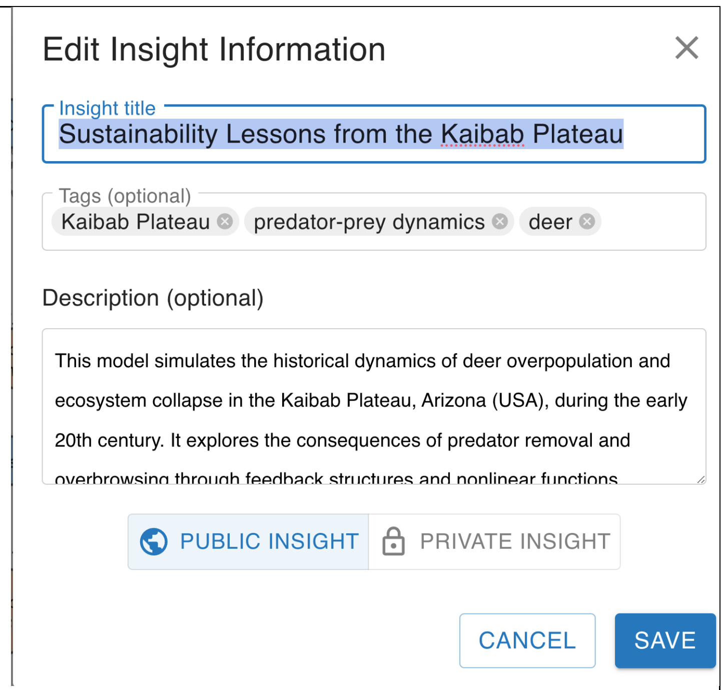


Figure 7:Model registration: Key metadata (title, author, date, and keywords) to categorize and locate the model.

🧠 Metadata in English

📄 **Model Metadata**
Title: *Sustainability Lessons from the Kaibab Plateau*
Description:
This model simulates the historical dynamics of deer overpopulation and ecosystem collapse in the Kaibab Plateau, Arizona (USA), during the early 20th century. It explores the consequences of predator removal and overbrowsing through feedback structures and nonlinear functions.
Authors: Pedro Dagoberto Almaguer Prado & Ramiro Luis Almaguer Navarro
Keywords: Kaibab Plateau, ecosystem collapse, predator-prey dynamics, overbrowsing, environmental sustainability, deer, food supply, nonlinear functions, simulation, historical model.
Language: English
Last updated: June 2025
Version: 1.0
Model type: Stock & Flow simulation
Time unit: Years
Simulation period: 50 years
Model purpose: Educational and policy-learning tool
References: Goodman (1974), Kormondy (1976)

🌍 Conclusion

The story of the Kaibab Plateau is not just an ecological lesson — it is a living metaphor for human systems. When natural constraints are removed — as happened with the predators — uncontrolled growth may initially appear as success. Yet, abundance without awareness depletes the very environment that sustains it.

This model does more than simulate a historical event; it unveils how decisions detached from system structure can lead to collapse, even when driven by good intentions. In the realms of business, public policy, and international relations, this insight is crucial: fostering growth without understanding the invisible dynamics that regulate it can destroy the ecosystem that supports life itself.

Lasting peace, sustainable prosperity, and social well-being demand what this model teaches us: systemic vision, respect for natural feedback loops, and the wisdom to intervene without disrupting the delicate balance that keeps all actors in the system alive.

References

Book: System Zoo 2 Simulation Models Climate Ecosystems Resource. Volume 2, Author: Harmut Bossel 2007, pp118-120, Printed and published by books on demand GmbH Norderstedt Germany, ISBN 978-3-8334-8423-0