An Interactive Ecosystem Simulator

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by

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Introduction

Screenshots of the ecosystem simulator

This project is about an ecosystem simulator game that allows players to manipulate the population size of the selected species and observe these species interact with each other. It focuses on reflecting the consequences of human intervention in the ecosystem and the difficulty of maintaining a balanced ecosystem.

I’ve been astonished by how human intervention could easily crash the ecosystem and how difficult it could be to make up for our faults. And many people still hold the thought that we control the world and could determine the death or live of all other creatures as we like. However, the balance of the ecosystem is not something that should be played around with. Even to this day, scientists could not precisely predict the impact of species loss. Humans do not possess sufficient power to reverse the crash of the ecosystem and yet the consequences are not easy to bear. Therefore, it’s critical to raise people’s awareness. And I wish this game could draw people’s attention and hopefully help them become more prudent when it comes to making such decisions.

Many current ecosystem-related games I’ve seen do not focus on this issue. They provide either limited realism or limited species and player interactions. To achieve the goal of this project, the reflection of users’ operation should be considered and be as realistic as possible. This is what the game aims to improve by allowing users to observe species interactions and change their population sizes to see how their actions impact the ecosystem.

Related Work

I researched several ecosystem-related games and categorized them into two types based on their goals.

The first one aims to show players about the competition or predation relations between two species. This kind of game, though follows scientific patterns, often provides limited user interactions.
One example is Biology Simulations LLC, a website that helps students learn about biology. It allows players to set the initial population and displays population changes within 15 generations. But this project updates population changes by “days” instead of generations. In this way, it processes creatures' activities more frequently, allowing players to observe more detailed interactions. Since in the real world, creatures move and eat every day, this approach improves the sense of reality. This project also allows more species to be placed in the ecosystem.

*Biology Simulations LLC’s competition simulator with three adjustable factors*

NetLogo’s Wolf-Sheep Predation allows players to determine more parameters, such as grass growth rate, reproduction rate, and energy gained from food. This provides players with more options and could produce more possibilities. While this project limits the amount of parameters that are adjustable by players to improve the sense of reality of the simulator, as in the real world, humans have limited control over many factors such as how much energy a creature needs and how often they reproduce. Such a limitation is what I want to express through the game. Therefore, I designed that players are only able to determine the initial population and available resources during the setup stage.
NetLogo’s Wolf-Sheep Predation with more adjustable factors

Choosing Species

Note: resource mentioned below includes grass, fruits, and etc. It's consumed by herbivores and omnivores.

Choose up to four species

- Wolf: [Carnivore] Preys mainly on sheep but will eat birds if sheep is not available. This creature lives in large packs.
- Sheep: [Herbivore] Consumes large amount of resources. This creature lives in large flocks.
- Fox: [Omnivore] Preys on birds but also consumes medium amount of resources. This creature lives in small packs.
- House Cat: [Carnivore] Preys on birds. This species evolved through artificial selection. Thus, it's difficult for them to fit into a nature environment.
- Bird: [Herbivore] Consumes small amount of resources. This creature lives in large flocks.

This project offers more species and allows choosing more than two species

Moreover, none of them allow players' intervention during the simulation. Since this project aims to reflect the consequences of human intervention, it's necessary to allow players to manipulate the population size during the game and update their changes in the ecosystem immediately.
Players can add creatures following instructions near the bottom

The second one, on the other hand, includes different genres, such as strategy games and simulators. This type provides more player interactions and offers better graphics and art for user experience.

Ecosystem is a simulator where players could create and modify the ecosystem and observe how creatures evolve. The focus of the Ecosystem game is slightly different from this project. While it aims to show the evolution process without human interruption which may take hundreds of years and over decades of generations, this project aims to reflect short-time changes resulting from human intervention. Thus, the way users interact with the ecosystem is designed differently in this project. Instead of manipulating the ecosystem itself, players change the population size of different species.

Terra Nil is a strategic game about building a balanced ecosystem from a barren wasteland. It takes the environmental elements into consideration when players attempt to add a new population, such as the abundance of water resources and the existence of related species. I admire its idea that adding a new population requires certain resources and the existence of some related species. Thus, I applied a similar idea to this project. The predation and competition relationships are designed and effective throughout the entire game to restrict the development of related species. While Terra Nil brings players a sense of accomplishment when transforming the wasteland into a diverse environment, players of my game may fail more often since this could leave a deep impression of the difficulty of maintaining a balanced ecosystem.
Design

The goal of this project is to show people the influence of human interventions in an ecosystem. To achieve this, several principles are made and explained below:

Players

*Players can decide the initial state of the ecosystem during the setup*

Although in the real world, people cannot determine the composition of a complex ecosystem, I want to give players more choices to see different interactions under various conditions.

Players determine the initial state: by entering population sizes and the amount of resources
Players can interact with the ecosystem during the game by adding or removing a population

Since in the real world, human activities and environmental changes occur simultaneously, players’ operations should be reflected immediately. This is different from some simulators where players only make decisions at the beginning of the game.

Human intervention is a necessary feature to achieve the goal of this project. This project designs features for players to add or remove a population from the ecosystem. Adding a creature refers to circumstances such as human activities introducing a new population to the environment or increasing the population size of an existing species. Removing a creature refers to circumstances such as human activities eliminating a species from an environment or reducing the population size of a species. Since there are numerous ways that humans impact the environment, I decide not to introduce these various possibilities but use a more direct way to represent the consequences. And introducing a new population or eliminating a population, either intentionally or unintentionally, are two of the most common results of human activities.

Adding: Sheep is set to be the species to be added and an empty tile selected
Adding: A new sheep is added and placed at the selected tile

Removing creature: an existing bird is selected
Choice of Species
This simulator provides a total of five species: wolf, sheep, cat, bird, and fox. And I’ll explain my choices in this section.

First of all, wolf and sheep, cat and bird are two preset combinations in the simulator for players to choose from. Each is inspired by real stories of human activities influencing the ecosystem. The simulator also allows players to choose up to four species to place in the environment.

Wolf and Sheep
This combination is a classic example of a predator and prey relationship and could be seen in many other similar works. However, I did not choose them as the first two species just because they are typical.

The story behind this is the elimination of wolves in Yellowstone in the 1800s. During that period, settlers expanded their activities which eventually overlapped with the territory of native predators. Wolf was one of these predators that preyed on people’s livestock. To prevent further loss, people decided to hunt down all the predators. However, this plan went out of control. Due to the absence of wolves, some species, such as elk and coyote, became rampant. The thriving of these species then led to the decline of smaller creatures, such as birds and beavers. The entire ecosystem thus fell out of balance. In 1975, people began to restore wolves’ population which took them several decades to accomplish the goal.

Thus, I choose this combination to show people that each species plays a role in the ecosystem and people should be prudent to resolve the conflicts between us and them, as it could lead to worse problems and humans may not always have the power to make up for the consequences.

Cat and Bird
Although this is also a predator and prey combination, it's different from the previous one in several ways. First, this combination is an example of introducing new species while the precious story is about reducing existing species. Second, cats here refer to domestic cats which are artificially selected species. They did not walk the path of evolution like other species that resulted from natural selection. This means there isn’t a position for them in the native food chain. Introducing such a species into an environment where encountering wild species is inevitable is more likely to break the current balance and result in greater loss. This combination is inspired by another story, Lyall’s wren.

Lyall’s wren is a small, flightless bird that was once found in New Zealand. Its extinction is attributed to feral cats that were introduced by human activity. In the 1880s, as people started exploring an island that was thought to be Lyall’s wrens’ last refuge, they also brought cats to the island. These flightless birds became ideal prey for the newcomers and cats soon became havoc about the wrens. Only one year later, people were unable to find Lyall’s wren and believed they were extinct.

Nowadays, predation by outdoor domestic cats is still the first direct, human-caused threat to birds in the United States and Canada. A study suggests that outdoor domestic cats kill 1.3-4.0 million birds and 6.3-22.3 billion mammals annually. The extinction of 63 species of birds, mammals, and reptiles could be attributed to feral cats. The goal of this combination is to help people have a better understanding of the threats outdoor domestic cats bring to other species.

**Fox**

This is an omnivore species that preys on birds and small mammals but also consumes fruits. The first reason is to add an omnivore to the current species, increasing the diversity of the ecosystem. The second reason is to make a comparison with the cat-bird combination. The combination of foxes and birds is much easier to keep a balance.

**Implementation**

**Programming Environment**

The project is programmed in HTML and Javascript and uses CSS styling. The game consists of two parts: the setup part where players determine the initial state of the ecosystem and the game part where the actual interactions happen. The setup part is written in Javascript while the core game part is built using Phaser 3.

Phaser 3 is a game engine written in Javascript. The game framework provides sufficient functionalities for the design of this project and is easy to use. Unity and Unreal engine were also considered but I decided to use Phaser 3. The first reason is it’s programmed with a language I’m more familiar with and I prefer not to spend extra time learning a new one. The second reason is this project focuses on concepts rather than designs of elements like beautiful UI and graphics. Unity and Unreal are undoubtedly powerful engines containing abundant features. However, this project is designed to be a 2D game that doesn’t require features like collision detection or physical interaction. It's not aiming to deliver gorgeous graphics either. Therefore, this project may not take advantage of most features provided by Unity and Unreal engines.
To visualize the changes in populations, the game uses Phaser 3 Tilemap objects. Tilemap is useful for displaying repetitive images. Since in the ecosystem, different populations may occur and display repeatedly during the game, I found this can improve the performance. Each tile represents a pack or a flock of a species and a corresponding image is used for identification. Initially, I plan to use one tile to represent one creature. However, during the testing, I found the space is limited but to keep a balanced ecosystem, a larger population size is needed. Therefore, now each tile refers to a pack that consists of some members.

I followed the Phaser 3 official examples to implement the feature for adding or removing a population. Their examples provide a convenient way to select tiles and use keys to determine the kind of tiles to add. It's a helpful guide to implementing the desired feature.

To display the changes in population sizes over time, the project uses plotly.js to visualize the data. Plotly.js is a free, open-source graphing library for Javascript, Python, etc. This tool offers various charts and plots. The project uses a line chart. As in the ecosystem, interactions between different species could be reflected by the changes in their population sizes, line chart makes it easier to visualize the relations between different species. Plotly.js offers renaming and coloring features for different lines, making it simpler to differentiate species. Plotly.js also provides basic features such as zooming in the graph to view details.
A population graph generated using plotly.js

Species Activities
This is the core part of the game which determines the interactions and changes in populations.
Some important concepts need to be introduced first.

Health and Death Rate
In the game, each pack or flock has a health value. Health value determines how healthy the population is, indicating the likelihood of occurrences of weak, sick individuals. Health value is reduced as the pack needs to maintain their daily activities and will be further impacted if the pack cannot ingest sufficient food. Another attribute is the death rate which is impacted by health value. The higher the health value, the lower the death rate. Creatures in an unhealthy pack are more likely to die.

**Resources**

The resources attribute involves all plants that are consumed by herbivores and omnivores. Its initial value is determined during the setup. During the game, it will regrow over time. However, the amount it regenerates depends on its current amount. This means the fewer resources left, the less it regrows. It’s designed this way to approach plants’ regrowth in the real world.

**Time**

To help evaluate the sustainability of the ecosystem, I used time rather than generations to track the game’s duration. The simulator updates each pack’s status by “day”. This is designed to increase the sense of reality, as creatures’ activities occur every day in the real world.

![Image](image.png)

*Information about days, resources, and the selected pack is available in the right upper corner*

**Daily Activity**

In every update, the code iterates through all the packs to check their status, processing their daily activities.

The first thing to do is increase each pack’s age and reduce its health value, as it loses some energy to maintain its daily activities. Then it checks the feeding requirement. Herbivores eat almost daily, thus, the function would check for the availability of resources every day and feed them if there are sufficient resources. If there are no available resources left, herbivores’ health levels will be further decreased as a result of hunger. Large predators, like wolves, hunt frequently. However, this doesn’t guarantee catching prey and they are able to bear hunger for a longer time. Thus, wolves’ predation is processed every 7 days. When they need to hunt, predators will search for prey in surrounding areas. Each predator has its own moving range and if the pack could find food within that range, it will move close to the victim and eat the amount of food it needs. The pack can restore its health level from predation. However, if it cannot find any prey within range, it’ll try to move toward the nearest available prey. This will also impact its health value as a result of long-distance travel and hunger.
Then, the function checks if the pack can reproduce. This is determined by how often the species reproduce and if the pack is healthy enough. If the pack meets all the requirements, the number of offspring will be calculated based on its current population. If the pack exceeds the maximum number of members, it will be split into two packs. Reproduction also reduces the health level, since newborns are more vulnerable, reducing the overall “strength” of the pack.

Lastly, the death rate will be updated based on the pack’s current health value. A healthy pack will result in a smaller death rate, and vice versa. Then, individuals will be determined to be alive or dead according to the death rate. If all members in a pack are dead, that pack will be marked as dead and will disappear from the map.

**Daily activity for a pack**
- Increase age
- Decrease health level as a result of daily activities
- Eat if the pack needs (see feeding process below for detail)
- Reproduce if the pack needs and is healthy enough to do so (see reproducing process below for detail)
- Update death rate by its current health level
- Determine if any individuals will die based on the death rate
- Mark the pack dead if all members are dead

**Feeding process**
- Check for feeding requirement
  - If need to take food
    - For herbivores and omnivores, check available resources
      - Sufficient resources: reduce the available resources by the amount they need
      - Insufficient resources: reduce their health level
    - For omnivores and carnivores, calculate the total amount of prey required to feed the pack
      - Check for prey in surrounding areas
        - Find prey within range: move close to its victim and restore health level
        - No prey within range: move towards the closest prey and further decreases health level

**Reproducing process**
- Check if it’s the species breeding season and if the pack is healthy enough
  - Yes: calculate the number of offspring based on the population size
    - If the population has not reached its upper limit, increase the population
    - If the population exceeds the limit, split it into two packs
  - No: do not reproduce
Analysis / Verification

The goal of this project is to help more people gain a deeper understanding of how aggressive human intervention could be and raise their awareness of the importance of maintaining a balanced ecosystem. I asked players to give feedback about the game. I also received comments from the platforms where I upload the playtest. The simulator is evaluated by players’ feedback and whether it could reflect species interactions as expected. Please see Appendix C for population graphs gathered from testing and Appendix D for players’ responses.

I evaluate the game by testing if it could produce reasonable interactions between species. I tested the circumstances of the wolf-sheep and cat-bird combination and found it could successfully reproduce the two tragic stories that inspired me. I also tested fox-bird combinations and found they could survive much longer than cat-bird combinations.

With around 6 to 7 packs of wolves and 30 flocks of sheep, on average, they could survive for over 7 years. However, if there are no wolves, the sheep will soon exhaust all resources and die from hunger. Without cats, birds could live happily for a long time. However, if even one pack of cats is introduced, the birds won’t survive for over two years. But with 3 packs of foxes and 15 flocks of birds, the ecosystem could last for over 8 years.

The game concept is praised by many players but, earlier during the development, they found themselves lost too fast. In response to this, I added guides and background stories to improve their game experience. After the update, no similar issue is mentioned. Little complaints were received for the population graph. Players felt it helps them understand the change in populations. Some players thought choosing the proper population size is difficult and in response, I added tips concluded from testing.

In general, the game’s idea of showing the consequences of human intervention is successful. And some features effectively improve players’ game experience.

The Story Behind Wolf and Sheep Combination

The Elimination and Restoration of Wolf

Sheep, that’s been kept domestically for thousands of years, is a valuable livestock for human. People have dedicated a lot to protect these animals. However, in the 1800s, settlers came across an issue as a result of westward expansion: native predators who prey on their livestock. This conflict eventually led to the elimination of wolves.

From late 1800s to early 1900s, predators, involving wolves, are killed in Yellowstone, resulting in a total disaster. In the 70 years of the wolves’ absence, the Yellowstone’s ecosystem fell out of balance. Smaller predators’ and elks’ population exploded, causing small creatures, such as songbird and beavers, unable to feed themselves. Then, had people realized the important role wolves played in the ecosystem and the necessity of restoration. 1975, the long process to restore wolves in Yellowstone began. The reintroduction began in 1995. However, many factors, like human harvest, prey densities and abundance of other predators, impact its effect. Although people had worried about the reintroduction may harm current elk and deer population, it’s been proved now that reintroduced wolves helped stabilize the ecosystem.

This is a profound lesson about the heavy price human may pay for attempting to eliminate certain species from the ecosystem. Similar voices have never disappeared. The thought of eliminating mosquitoes is brought up from time to time. Nowadays, predicting species loss in complex ecosystem is still a great challenge. Even though some species have always been headaches, people should also be prudent when they attempt to dramatically reduce a species’ population, as the consequences could be
Main modifications made based on players’ feedback:

1. I added a guide and background stories for the preset combinations to walk players through the game and help them gain a full picture.
2. I improved the styling of the web pages and rearranged the layout to make it look cleaner, as players suggest for better styling.
3. I added fox, as players wish there were more species. The reason for this choice is explained in the design section
4. I added a skip feature to immediately jump to the end of the game, as some players don’t want to wait but want to view the result sooner.

Future Work

I accomplished the goal I set for the project and added some additional features that weren’t planned. However, I don’t think this game has reached its limit. So many factors are involved in species interactions and the ecosystem consists of numerous species and resources. The current project only involves a few of them. With more research and professional knowledge in biology and ecology, more elements could be added and the sense of reality could be further improved.

Conclusion

In this project, I created an ecosystem simulator that provides more sense of reality compared to some similar games and interactive features. I’m proud to generate such a simulator where players could reproduce two tragic human interventions in the ecosystem. Although reproducing historical events may not be pleasant, I believe this is a good way to raise people’s awareness and could help them be more prudent when they encounter similar issues in the future. I’m glad I managed to express my thoughts through the game and hear from players that they love the concepts.
Appendix A: Link to the GitHub Code
https://github.com/Sahra-Zhou/ecoSim

Appendix B: Link to the Game
https://ecosimulator.netlify.app/

Appendix C: Population Graphs

Wolves and sheep survived for around 10 years

Without wolves, sheep went rampant and exhaust all resources
**Birds survived for 4000 days (over 10 years)**

With one pack of cats (initially 8 members), birds died out in 300 days (less than one year).

**Foxes and birds survived much longer, for almost 3000 days**
Appendix D: Players' Feedback

I LOVE the concept of this game. Trying to find a balance is cool. But it was frustrating to lose so fast before I really knew what was going on.

Cool I really like the concept of this game, but I lost so fast it was hard to get a full picture of the game. I think the guide can be shortened and simplified. I'd love to play future draft as it gets easier to use and understand.

Players love the concept but feel they get lost too fast

Comments received from a CS student

It seems organized but could use a bit of styling

It is clear and easy to use but it is a little bit boring and some of the text, especially for the navigation links, is on the small side

Clear but maybe add more styling would be nice

Players ask for better styling

I tried using 10 cats and 60 birds, but they all died pretty quickly. I tried a few more combinations and had better luck with the sheep and wolves, but they all died quickly so my games didn't last long.

I found it easy to get something that works, but maybe have even more tips/suggestions to make it easier to create a balanced ecosystem

Players ask for tips

Bibliography


