Invasive Species

(The Feral Hogs)

Research Project Paper

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**Abstract**

When a species into a new environment and have negative consequences in the new habitat, they are called invasive species. For example, Asian carp, brown marmorated stink bug, zebra mussels, and nutria are well-known invasive species. These invasive species impact ecosystems ecologically and economically. Also, they cause problems with our health and tourism. For instance, invasive species compete with native species and lead to their population decline. They also can alter nutrient cycles, and lower crop yields which are the worst for our economy. Because of all these reasons, all of the world are working to remove these invasive species for our clean ecosystem. This is why our model was built for. In our model, we explored the stability of predator-prey ecosystems before and after invasive species were introduced to this ecosystem. We added disruptions such as disease, control number of traps and hunting, and change in weather to see how these disruptions affect the stability of the ecosystem and find the best way to remove invasive species. We started with the default settings from existing models called “Bug Hunt Predators and Invasive Species’ and IQWST Invasive Species Model.’

We looked at four populations including grass, bugs, birds, and invaders within an ecosystem over time by manipulating values for factors that may impact the stability of different populations within a model ecosystem. The main idea was that each agent (bugs and birds) must consume a food source to replenish their energy. Otherwise, they die. To allow the population to continue, each animal and bug must have enough energy to have a litter of offspring. Also, grass grows at a fixed rate. When grass is eaten, a fixed amount of grass energy is deducted from the patch where the grass was eaten.

Then we added invaders and control variables of invaders. It included the number of invaders (the feral hogs), number of traps, invader disease, and invader hunting. We manipulate these settings, so we can look for evidence using mathematical representation to support the sensitivity of the stability of the model to the particular parameter and the average values of each population in a certain condition.

The initial ecosystem was clean, and we observed a balanced ecosystem. This clean ecosystem produced a reciprocal relationship between bugs, birds, and grass. Once invasive species were introduced to this ecosystem, the population of native species was rapidly decreased. Some simulations even showed the declining population of native species. To find a way to save this destructive ecosystem, we simulated our models with control variables of weather, hunter, traps, and diseases. Diseases were the most effective way to remove invasive species. However, it also affected the population of native species, resulting in a decreasing population of native species, so we turned on the weather cold-weather switch. Cold weather, as a control variable of invasive species, was less effective than diseases. However, we still see a decreasing population of invasive species. Then, we moved to control variables of hunter and trap. This time, we had a better result. The population of invasive species was decreased with not much effecting other native species.

Putting all these together, we ended up with the result that a good way of keeping our ecosystem safe from invasive species is placing more hunters and traps in cold weather. This way will remarkably and rapidly decrease the population of invasive species and the reproduction rate of invasive species.

**Introduction**

Ever-increasing globalization and international trade have opened the floodgates for intentional and accidental introductions of invasive species all over the world. Invasive species are defined as when non-native (also known as alien, exotic, or nonindigenous) plants, animals, and pathogens are introduced into a new environment and have negative consequences. Because of these accidental introductions, introducing these species into a new environment may have a variety of negative outcomes in many different ways. For instance, invasive species compete with native species which leads to a population decline of native species, and these invasive species alter the nutrient cycle. Also, invasive species lower crop yields, and disease and pests may destroy livestock and crop. Furthermore, it may have negative impacts on recreation or activities in our nature.

Invasive species spread aggressively and displace or destroy both native and commercially cultivated plants and animals. After habitat alteration, invasive species are the greatest threat to natural ecosystems, agriculture, and aquaculture. For example, invasive species cost Virginia more than $1 billion, while nationally the toll exceeds $120 billion. Across the state, numerous efforts are underway to address the threats posed by invasive species. Also, states are taking action to minimize economic, environmental, and human harm from invasive species by acting on goals such as coordination, prevention, early detection, rapid response, control, research, and education.

The most effective strategy against invasive species is to prevent them from being introduced, detect early, and control them early. This requires better monitoring and controlling of the pathways by which invasive species arrive and this is what our model for. We will explore the stability of predator-prey ecosystems and how this stability is affected when new species are introduced into the ecosystem. We will specifically focus on these questions: How are increases and decreases in the size of each population-related; How does changing the attributes of the bugs, birds, invaders affect the stability and carrying capacity of the ecosystem; How sensitive is the stability of the model to the particular parameters; the way to reduce or remove invasive species and keep our ecosystem safe.

**Background**

Efforts at invasive species control remain challenged by highly fragmented control efforts among governments and organizations. Because invasive species are problems that all of the worlds have and directly connected to our nature, many works are in progress to monitor the ecosystem and work to remove invasive species if it reaches a certain level of problems. Therefore, the simulation of an ecosystem is important, and many agent-based models are already produced. Our model will modify a couple of those agent-based models put together and add invaders of the feral hog, the most destructive invasive animal to solve the questions we have.

**Methodology**

Because many factors can control the invasive species which can be helpful to save our nature and ecosystem, we built our model. Our model was modified from the existing agent-based models of Netlogo which is called ‘Bug Hunt Predators and Invasive Species’ and ‘IQWST Invasive Species Model.’ We will keep some of the initial settings from these two models. Those initial settings include the number of bugs, number of birds, number of invaders to add (the number of feral hogs in our model), amount of grassland, amount of food invaders eat, amount of food bugs eat, minimum reproduction energy of birds, percent of bugs to remove and switch for constant simulation length.

In addition to the initial setting, we will add control variables of the feral hog that we found from reality. Those control variables are invader disease, percent of invader die by disease, trap, the number of traps, cold weather, percent of invader move in weather, invader hunting, percent of invader kills by the hunter.

We will simulate five different cases with control variables. We will take a look at four populations including grass, bugs, birds, and invader within an ecosystem over time by manipulating values for factors that may impact the stability of different populations within a model ecosystem. The basic idea of our model is that each bird, bug, and invader must consume a food source to replenish their energy. Otherwise, they die. To allow the population to continue, each animal and bug must have enough energy to have a litter of offspring. Also, grass grows at a fixed rate. When grass is eaten, a fixed amount of grass energy is deducted from the patch where the grass was eaten. By manipulating these settings, we can look for evidence using mathematical representation to support the sensitivity of the stability of the model to the particular parameter and the average values of each population in a certain condition.

**Result**

Invasion 01 – Before Invasive Species are Introduced

First, we simulated at default settings without introducing invaders to see how our normal ecosystem suppose looks like. Overall, in invasion 01, we observed a balanced ecosystem. Each bug lost one unit of energy and they consumed a food source (grass) to replenish their energy. When they ran out of energy, they died. To allow the population to continue, each bug had enough energy to have an offspring. When that threshold was reached, the offspring and parent split the energy amongst themselves. As same as birds, each bird lost one unit of energy and they consumed a food source (bug) to replenish their energy. Birds used their energy to reproduce, and they died when they ran out of energy. This cycle produced a reciprocal relationship between bugs, birds, and grass. Therefore, there wasn’t any dramatic population change.

Invasion 02 – Initial Invasion

In invasion 02, we introduced our invaders, feral hogs. The hogs are indirect competitors of the bugs. They eat grass and bugs. They reproduce following the same rules as bugs and birds. With the same rules, feral hogs with original inhabitants were initialized. We add five invaders with 55 of min-reproduce-energy-invader and 4.0 of amount-invaders-eat. Without adding any control variables of the feral hog, we first looked at what happens immediately when invasive species are added to the ecosystem. The first thing we noticed was that the population of bugs and birds were dramatically decreased. While the population of birds and bugs were decreasing, the population of invaders was increased from 5 to 30~40. Meanwhile, the grass population followed a similar population curve as the native population. This simulation showed the most common negative impact of invasive species which population decline of native species.

Invasion 03 – Diseases

One natural way of declining the population of invasive species is the disease. Like we never expect of invasive species, we can’t expect when, why, or how will diseases come. However, we will see how diseases will affect our ecosystem with invaders. Like the previous simulation, we start with our initial setting and five invaders. Then, we put on invader disease and set the percent of invaders to die by disease as 51 which is a little bit more than half. Because we simulate each case more than twenty times, we could observe two different patterns of the result. The first pattern of the result is that we could see invaders have completely died with a decreasing population of birds. The second pattern of the result is that we could see the decreasing population of invaders with no changes in the bird’s population. The population of bugs was increased in most simulations telling invader diseases have no effects on bugs population, and the grass population followed a similar population curve as the native population. This result tells that invader diseases are dangerous and effective in killing invaders. Based on different types of diseases, the level of effect killing invaders will be different and birds may also affect by invader disease.

Invasion 04 – Cold Weather

In this case of simulation, we added a cold-weather switch to see if cold weather effect invaders. We turned on the weather switch and set the percent of weather that levels from favorable to harsh to 23%. The result was similar to invasion 03 (disease), but we only see one pattern of the result this time. Overall, in cold weather, we saw a decreasing population of bugs, birds, and grass, and the population of invaders was completely declined. This result tells how feral hogs are hard to survive in cold weather, so doing something in this weather will be much helpful to remove invasive species.

Invasion 05 – Hunter & Trap

Because the negative impacts of invasive species keep increasing, the government permits to hunt and place traps for these species. In some countries, like South Korea, they even pay money when people catch invasive species. We want to apply this reality to our model and see how effective it is. To simulate our model, we increased the number of invaders from 5 to 30, suppose the number of invaders was increased in a small town and neighbors decided to hunt. First, we set the 30 percent of hogs that will have all their hogs immediately removed when the invader-hunting button is pressed, and we place 10 traps that will be randomly set on when the trap button is pressed. Overall, the population of invaders decreased from 30 to 5, and the population of birds was also decreased which was also killed by hunters and traps by mistake. Because the population of birds and invaders decreased, the population of bugs and grass were increased.

**Summary / Conclusion**

As a result, we checked how invasive species are destructive, and how chances are high of the geographic range of these destructive species are rapidly expanding. We found out that introducing invasive species that have the same diet as bugs and birds can destroy the population of bugs and birds. We also noticed that invasive species are still dangerous and can destroy our ecosystem although invasive species don’t have the same diet as bugs and birds.

In our model, we visualized the stability of the predator-prey ecosystem when invasive species are introduced. In reality, many factors control invasive species. We added some of those factors to see how the stability of the ecosystem changes. Before invasive species are introduced, when we simulated at default settings without invaders, we observed a balanced ecosystem which is the initial ecosystem of our model. We could see the reciprocal relationship between bugs, birds, and grass. When the initial invasion of feral hogs with original inhabitants was initialized in our model, the population of bugs and birds were dramatically decreased while the population of invaders was increased from 5 to 30~40, meaning a high reproduction rate of invaders. The grass population followed a similar population curve as the native population. Overall, in this initial invasion, we noticed a common negative impact of invaders, destroying native species and crops. Then, we moved to the next simulation, attacks of invader disease. When there was a disease attack with 51% of invaders die in this simulation, we could see that invaders have completely died as well as a decreasing population of birds telling how invader diseases are dangerous to both invasive species and native species. Because animals were affected, the population of bugs and grass increased telling diseases have no effects on the population of bugs and grass. We also introduced cold weather to our model. We turned on the weather switch with a 23 percent invader move in the weather. As the result, the overall population of bugs, birds, grass, and invaders were either declined or decreased. Invaders were hard to survive in cold weather. Lastly, we placed hunters and traps to control the number of invaders. Overall, the population of invaders were decreased but didn’t completely remove, and the population of birds was also decreased which was also affected by hunters and traps. Putting all results together, we ended our model with the best idea of removing invasive species for clean nature and ecosystem. That is placing more hunters and traps in cold weather when the number of invaders was already decreased. This way will remarkably decrease or decline the population of invaders and the reproduction rate of invaders. For future work, we can also extend our model to get helpful insights for the ecosystem with invasive species. First, we can add an invasive plant or invasive predator. Also, the amount of food a predator or a bug eats can be adjusted so that faster food consumption also corresponds to high metabolism which develops a competitive disadvantage for rapid food consumption in some environments. Furthermore, traits, such as minimum reproduction energy, can be inherited in offspring and subject to slight random changes from mutations.

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