Plant Pollinator Interactions:
An Agent Based Model for Conservation Research

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Abstract

The goal of this project was to create an agent-based simulation that can be used to model the relationship between plant and pollinator populations, and to use this model to investigate the effects of invasive plant species on established populations. The model was developed in the Netlogo agent-based programming environment, and allows the user to specify phenologies, starting populations, and other characteristics of each individual species. These highly customizable parameters ensure the model can be used in future analysis of other scenarios related to plant/pollinator interactions. Analysis of the data gathered from simulations demonstrates that invasive plant species have a significant, detrimental effect on both plant and pollinator species' populations when their phenologies coincide.

Background

**Factors influencing success of a species' population**

- Resources
  - Bee population Is determined by the amount of nectar gathered and stored in the hive the previous season
  - Flower population Is determined by the amount of seeds pollinated the previous season
  - Plant/Pollinator relationship – pollination increases bee pop. as they gather food, and plant pop. as bees visit and pollinate their preferred resource

- Interactions
  - Flowers can contain different amounts of nectar; bees learn to choose the most rewarding flowers
  - Flowers are only pollinated when a bee has just visited a flower of the same species

- Phenologies
  - different plant and pollinator species have different seasonal cycles and will be active and dormant during different times of the year
  - When and for how long bee and flower phenologies overlap affects access to resources
  - If multiple flower or bee species have Overlapping phenologies, this leads to resource competition

Hypothesis

The introduction of an invasive species will directly compete with native flowers for bee visits, resulting in flower population declines. Reduced flower populations will result in population declines for any bee species that depend on those flowers as a nectar resource.

Methods

- **Control Test**
  - Stable interactions among bees and all three native flower species. No invasive.

- **Common Parameters**
  - All starting flower populations set to 50 individuals
  - All starting bee populations set to 12 individuals
  - Flower species 2 phenology set from 0 to 10000 ticks (in-model time units)
  - Flower species 3 phenology set from 10000 to 20000
  - Flower species 4 phenology set from 20000 to 30000
  - Bee species 1 phenology set from 100 to 20100
  - Bee species 2 phenology set from 10000 to 30000
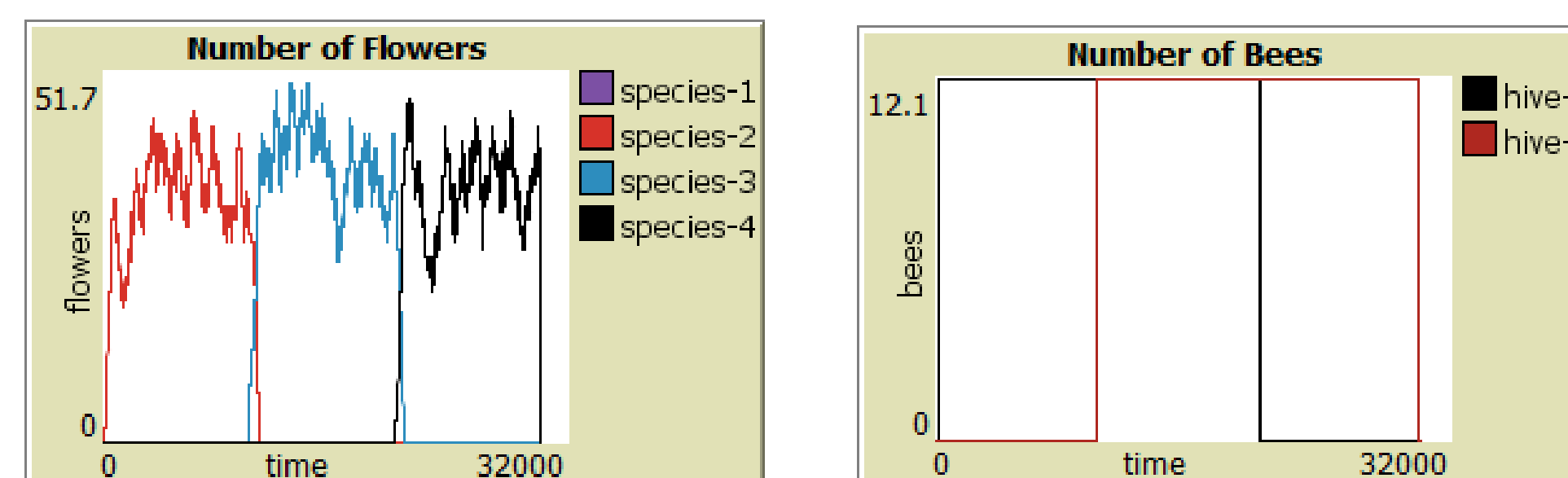

Control Phenology

- **Test Parameters**
  - Test 1 – Flower species 1 (invasive) set to align with flower species 2's phenology (0 to 10000 ticks)
  - Test 2 – Flower species 1 set to species 3 (10000 to 20000)
  - Test 3 – Flower species 1 set to species 4 (20000 to 30000)
  - Test 4 – Flower species 1 set to overlap species 2 and 3 (5000 to 15000)
  - Test 5 – Flower species 1 set to overlap species 3 and 4 (15000 to 25000)
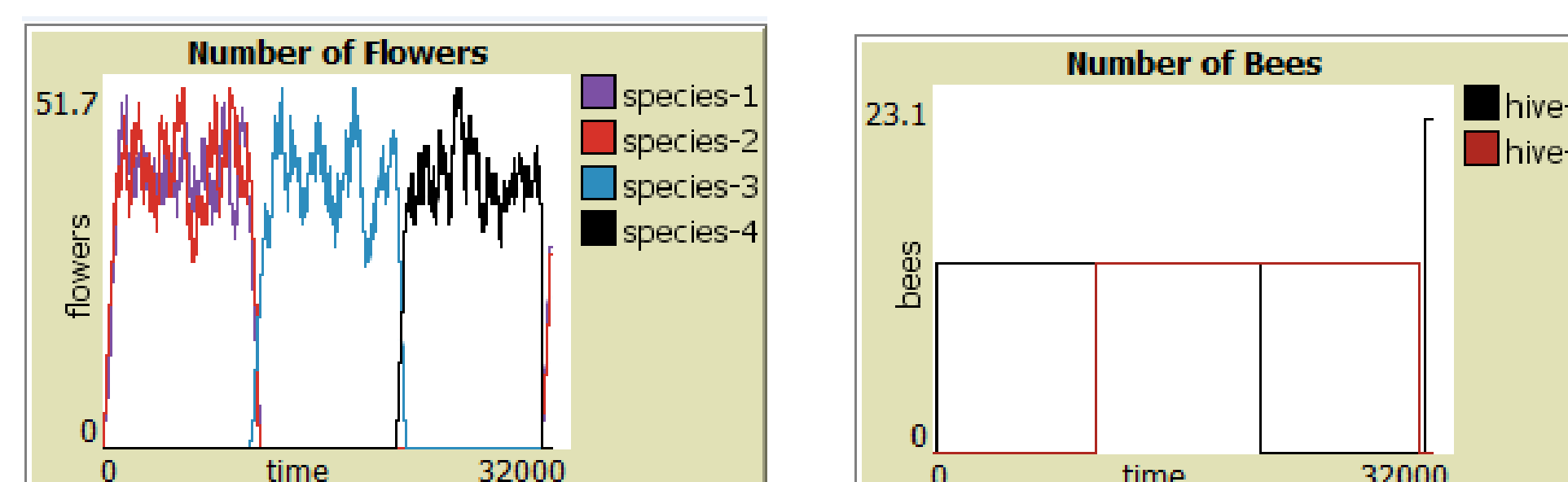
Test 1 Phenology

Each test was repeated five times, each time left to run through five seasonal cycles. The populations at the end of this time were recorded and analyzed.

Results

Flower Populations After 5 Seasons

Bee Populations After 5 Seasons
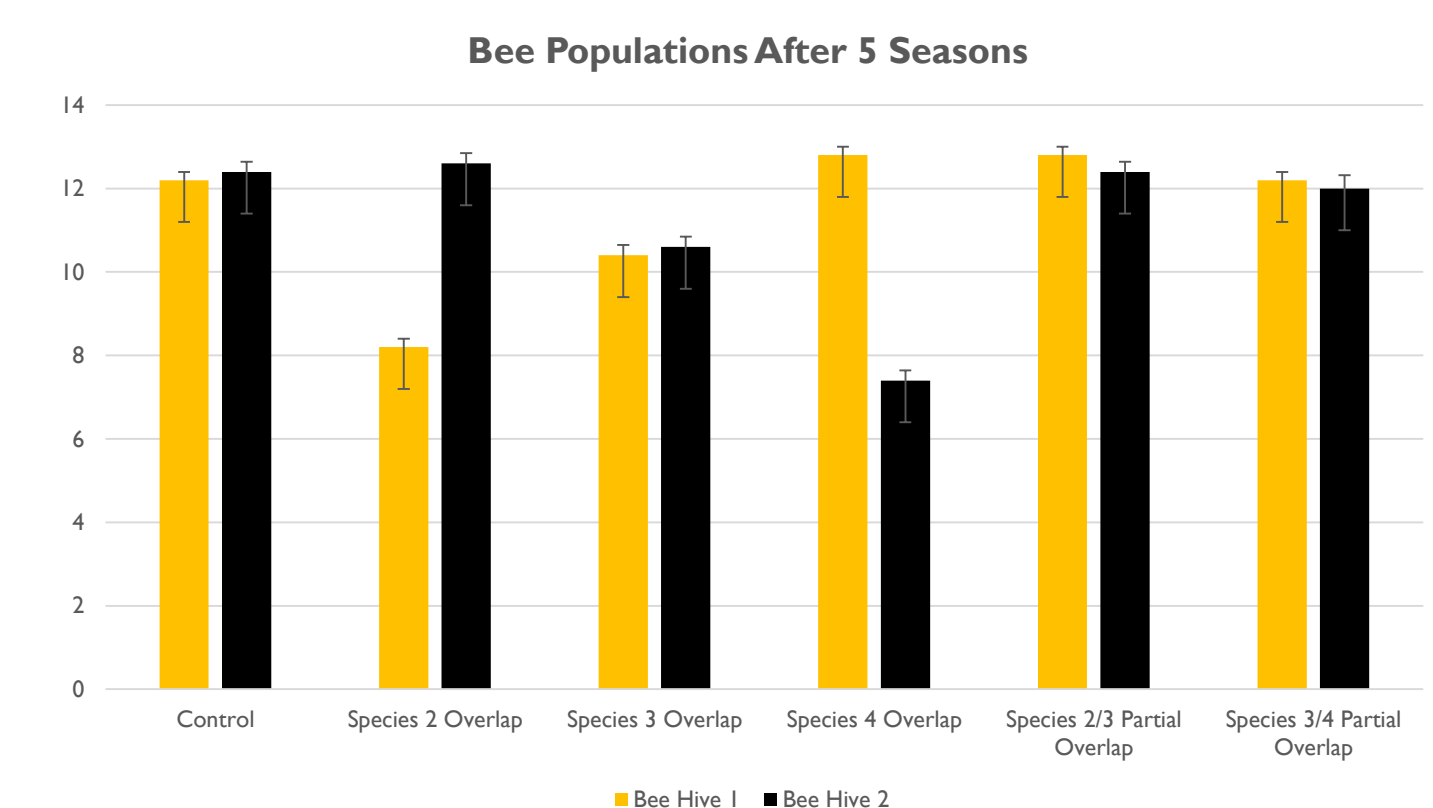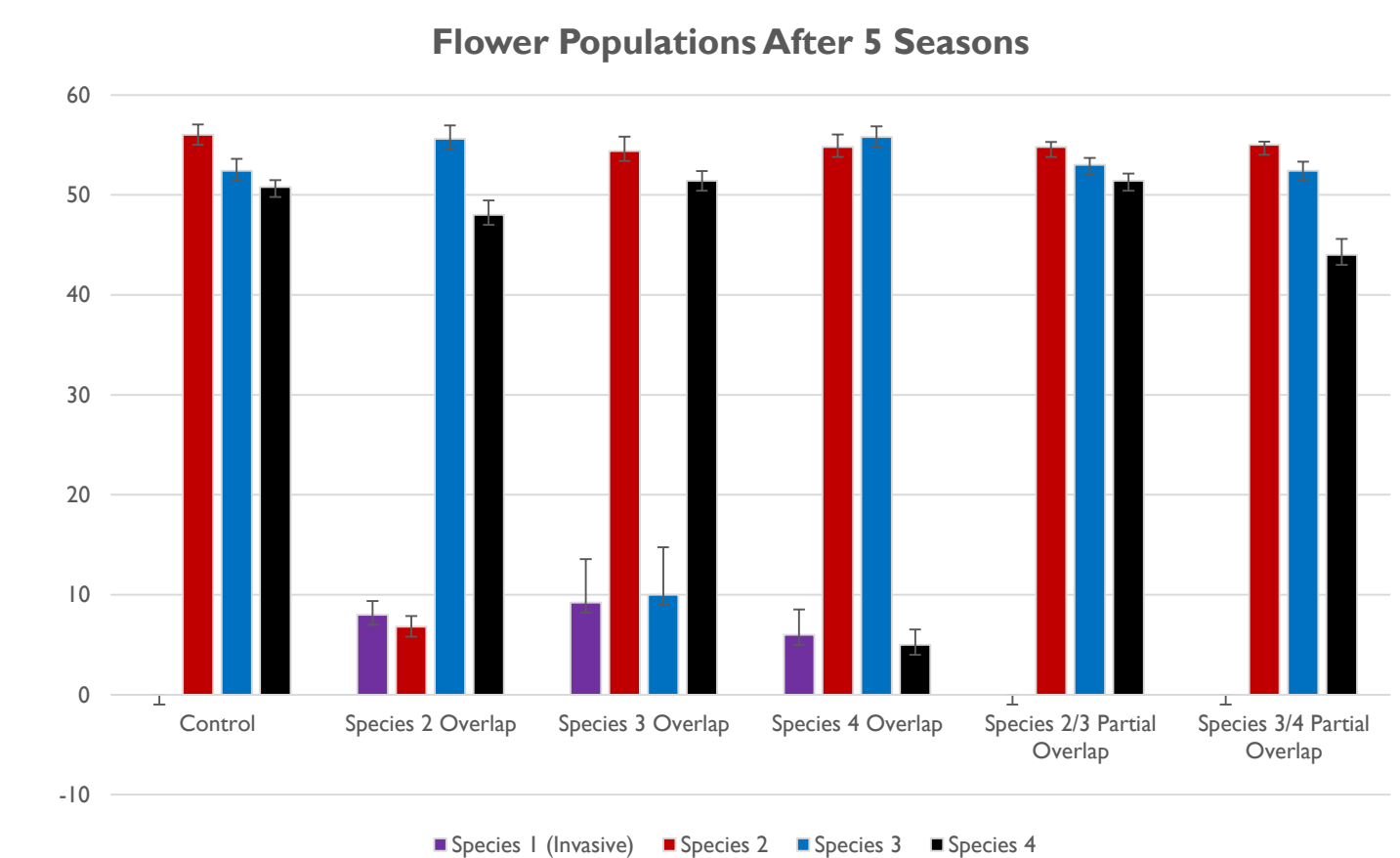
Analysis and Conclusion

In every case tested, with the exception of test 4, the introduction of an invasive species led to significant decline in at least one population. When the invasive's phenology was matched with one of the native flower species', the two species directly competed for bee visits. This led to a decrease in the populations of both species, which would in turn lead to a decrease in the population of the bee species that depended on those flower populations for food. The reduced bee population would then further strain the competition for resources between the invasive and native flowers, resulting in another hit to both their populations and a feedback loop, which would likely continue until all three species died out.

The exception to this came in test two, where the invasive was matched with a flower whose phenology overlapped with both bee species, whose populations were comfortably sustained by two other natives. Instead of all three species heading for extinction, either the native or the invasive would die out as the other began to recover.

In both cases 4 and 5, the invasive died out completely by the fifth season, and in case 4 it had no significant impact on the final populations of any native species. This indicates that the timing of a species' seasonal cycle is important, not just its length.