

ESTIMATING THE EFFECTS OF HETEROGENEOUS COMPETITION IN AN AGENT-BASED ECOLOGICAL MODEL USING GIS RASTER COLOR

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ABSTRACT

It is hypothesized that inter-species competition is one of the main factors that determine the range and distribution of Sensitive joint-vetch (SJV), a rare, tidal wetlands annual. The precise effects of this competition, however, are poorly understood by ecologists and difficult to quantify. We have constructed a detailed, agent-based simulation of SJV in its Holts Creek, Virginia, habitat. In order to shed light on these landscape-scale effects, we propose a new method of distinguishing poor from high quality plots that uses GIS to correlate the pixel color of an individual m^2 plot to its propensity for sustaining SJV. This propensity is then used to determine the vital rates of a given plot and is applied to all plants within it. Results indicate that inter-species competition plays a limiting, though by no means exclusively important, role in the spatial arrangement and rarity of SJV.

1 INTRODUCTION

Sensitive joint-vetch is a federally threatened tidal wetlands annual with a global range from southern New Jersey to central North Carolina. It has been extirpated from two states in its historic range, Pennsylvania and Delaware. As a rare plant, it is in conservationists' interests to determine and implement the most promising methods for preserving it. This is ripe territory for ecological modeling, as it can better inform decision makers and enable them to see underlying patterns and emergent properties in empirical data.

Ecologists have hypothesized that there are several factors in the decline of the plant. SJV is a poor competitor and thus less competitive patches (i.e. fewer stems of other species) increase survival and fecundity. It is therefore keenly vulnerable to changes in habitat quality. If this is the case, some possible conservation strategies may include:

- creating new, non-competitive plots by cutting existing flora
- adding seeds to existing plots
- increasing average plant fecundity by cutting vegetation in existing plots

We seek to help decide which approach is the most likely to succeed and how best to implement it. To this end, we have constructed a detailed agent-based simulation of SJV in its Holts Creek, New Kent County, Virginia, habitat that is designed to test several hypotheses about the plant. One of these is that inter-species, heterogeneous competition is the primary factor controlling abundance and distribution of SJV populations. To validate this simulation from a pattern-oriented modeling perspective, we seek to test whether it can reproduce two known patterns that SJV exhibits:

1. Two general categories of populations: high performing populations that have reached carrying capacity (estimated at about 50 plants/ m^2), and mediocre populations that do not reach it.
2. Constrained growth: in its Holts Creek habitat, realistic meta-population counts range from the high hundreds to mid-thousands.

2 ESTIMATING COMPETITION AND VITAL RATES

Although there is no reliable empirical data on inter-species competition *per se*, we do have thorough, empirically derived distributions for SJV's vital rates (probability of germination, probability of seedling survival to adulthood, and fecundity) in a "typical competition" setting. We also have contemporary rasterized aerial photography of the marsh, as well as population coordinates. Because the red color band can be used as a rough measure of how much photosynthesizing biomass is present in an area, we attempt to correlate the frequency of SJV occurrence on different levels of "red" reflection to different probabilities within the empirically derived vital rate distributions.

To obtain an approximation of landscape scale competition inside Holts Creek, we:

1. Isolate the marsh in Holts Creek in raster form by clipping USDA orthoimagery using the USGS Hydrography dataset waterbody.
2. Find all squares (m² plots) within 3m of SJV populations. Each such plot has a "redness level."
3. For each distinct redness level (0 – 255), divide the SJV frequency by the overall Holts Creek frequency and normalize the result, creating a "SJV propensity" for each level of redness. For example, there are 7045 plots in Holts Creek with redness level 135, of which 38 are near SJV populations. On the other hand, there are 178,460 plots with redness level 100, of which 89 have SJV. After dividing to get the propensity, we discover that red value 135 is 11 times more likely to contain SJV than red value 100 is (normalized propensity[135] = 0.041, propensity[100] = 0.004.)
4. Estimate the vital rates (germination, seedling survival, and fecundity) for plants on that plot. The propensity values for plots are converted to quantiles based on their empirical distribution, and the quantile for each plot can then be mapped to each vital rate distribution.
5. Each agent (seed or plant) in the model uses the estimated vital rates thus derived from its plot.

3 RESULTS

Aggregating over many simulation runs, we have observed that in about 65% of plots reached by SJV that it could not take a foothold. For 23% of the plots, the population size slowly grew or fell over many years. 12% of the plots were high performing, and easily reached carrying capacity. In all, this conformed very realistically to the real-life phenomenon of high-performing populations and mediocre populations (as well as great swaths of land where SJV is unable to grow.) Therefore, we conclude that our simulation reproduces observed pattern #1.

Observed pattern #2, however, was not reproduced. Our simulated SJV saw unbounded exponential growth. Although only 35 percent of plots can sustain SJV, there are roughly 13.6 million plots in Holts Creek. Therefore, we conclude that there must be other factors in addition to those embodied in a plot's propensity that affect SJV abundance and distribution. Some possibilities may include tidal inundation, environmental stochasticity, or soil nutrient composition, and this will form the next stage of our investigation. Additionally, future work will include comparing this methodology with vegetation indexes to determine the best measure of a plot's propensity.

4 REFERENCES

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