Simulation of oak early life history and interactions with timber harvest via an individual-based model, SOEL

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Introduction

- Oaks are valuable as a source of **timber** and as a **food resource** for wildlife
- Oaks are **failing to regenerate** in eastern forests, partly as a result of changing disturbance regimes
- **Trophic interactions** act as biotic filters early in the oak lifecycle, and also affect regeneration (Fig. 1)

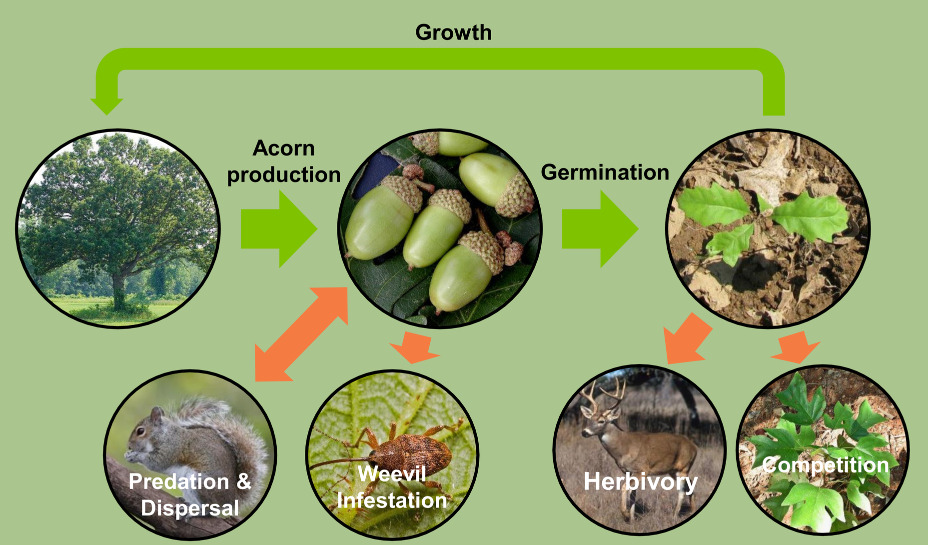

Fig. 3. Diagram of the oak life cycle showing key trophic interactions in oak early life history

- Silviculture can **emulate natural disturbance** and promote oak regeneration
- This disturbance will also affect predators, dispersal agents, and herbivores of oak; how will oak regeneration be affected by this interaction?

Objective

Develop a **S**imulation model of **O**ak **E**arly **L**ife history (SOEL) to test predictions about the interactions of animals and silviculture on oak regeneration

SOEL Overview

Key Model Features

- Individual-based and spatially explicit model
- Simulates growth, survival, reproduction, and harvest
- Tracks light availability in three dimensions
- Two oaks species (black and white), and two competitors (sugar maple and tulip poplar)
- One submodel applied to all species and an early life history submodel applied only to oak (Fig. 2)

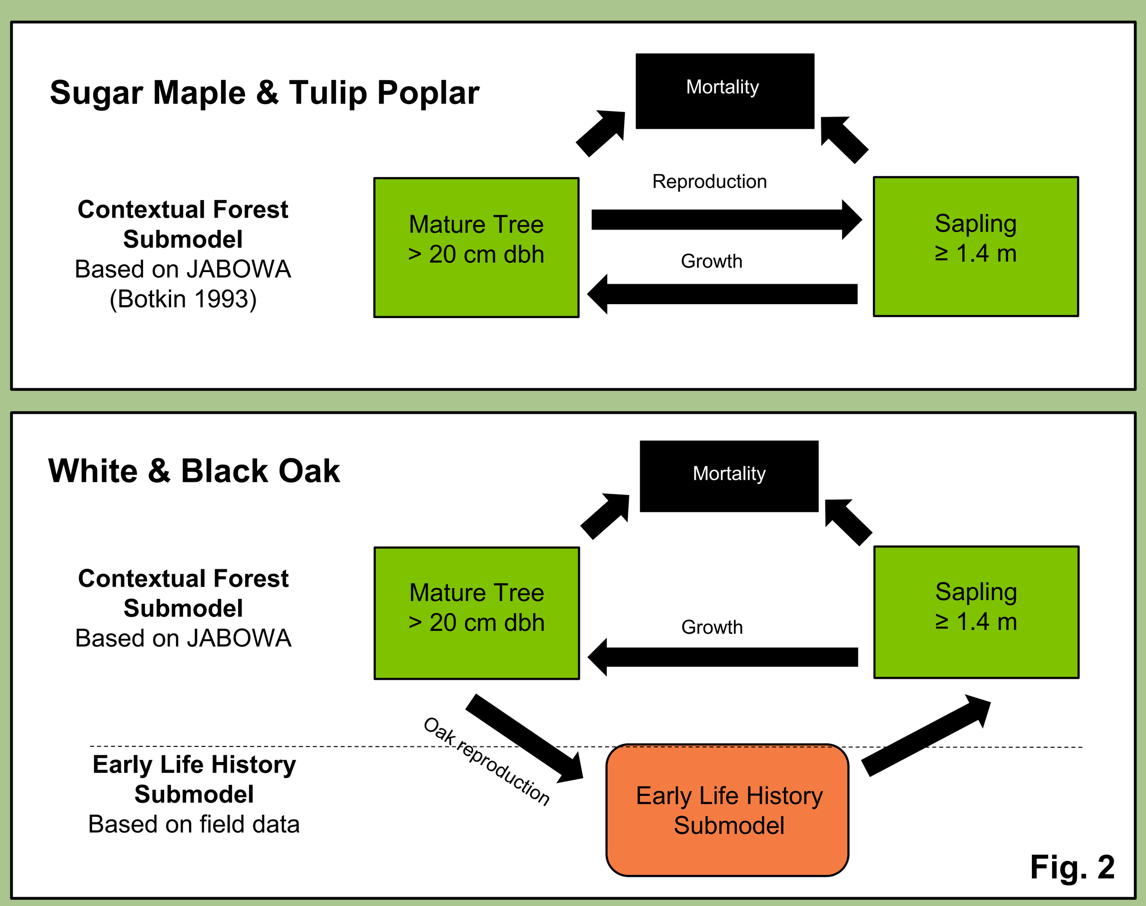

Fig. 2

SOEL Overview

Early Life History Submodel

- Tracks individual oaks from acorn to sapling
- Parameterized with field data from the Hardwood Ecosystem Experiment (Fig. 4)

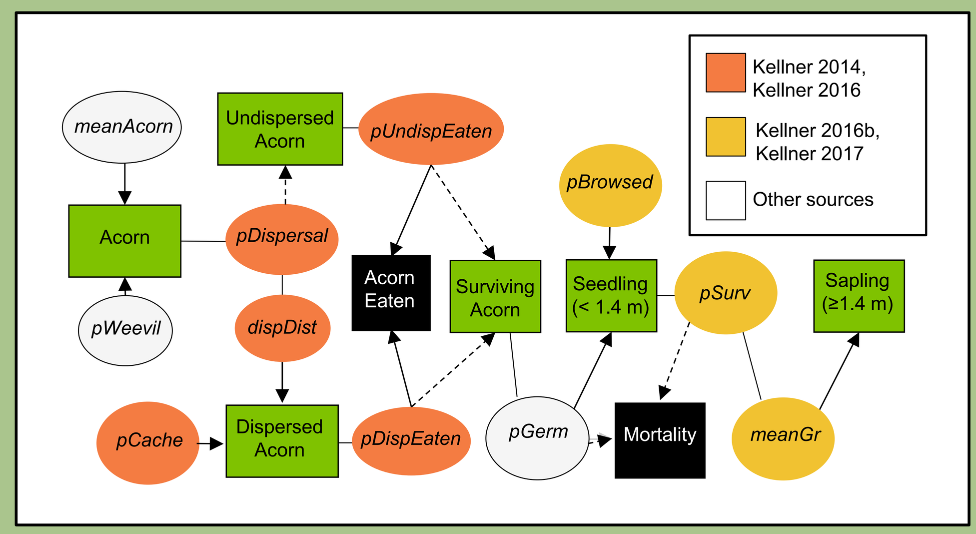

Fig. 3. Diagram of the early oak life history submodel and the sources for individual parameter values

	Percent Emergence		Total New Seedlings		Sapling Density	
Parameter	S	U	S	U	S	U
meanAcorn	0.074	0.00	0.448	0.18	0.247	0.08
pWeevil	0.028	0.00	0.049	0.00	0.014	0.09
pDispersal	0.059	0.12	0.012	0.25	0.047	0.06
dispDist	0.039	0.02	0.044	0.04	0.012	0.04
pCache	0.863	0.64	0.484	0.41	0.290	0.22
pDispEaten	0.138	0.00	0.153	0.00	0.190	0.00
pUndispEaten	0.118	0.01	0.077	0.01	0.140	0.01
pBrowse	0.00	0.18	0.069	0.01	0.038	0.11
meanGr	0.114	0.00	0.129	0.00	0.295	0.15
pSurv	0.102	0.07	0.061	0.05	0.155	0.10

Table 1. Sensitivities (S) and uncorrelated proportion of sensitivity values (U) for oak regeneration metrics to early life history parameters. Notable sensitivity values are highlighted.

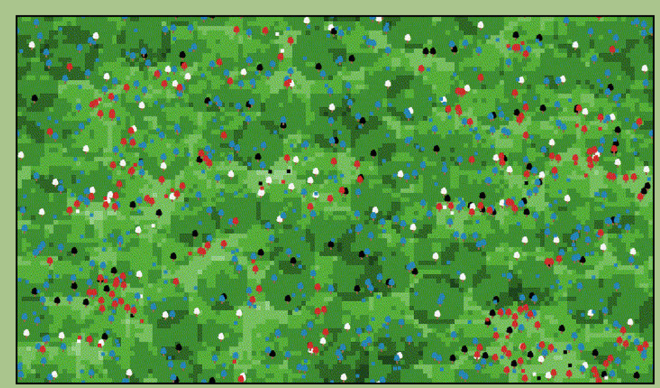

Fig. 4. Top-down visualization of the model implemented in NetLogo (Wilensky 1999). Colored icons are individual trees and the shade of green corresponds to available light at a point in space

Case Study

- SOEL can connect changes in individual parameters with ultimate consequences for oak regeneration (e.g., density of competitive stems)
- We know that midstory removal harvest impacts seed predation parameters (Kellner et al. 2014, 2016)
- What are the short-term consequences of this indirect effect of harvest on oak regeneration metrics? (Fig. 5)

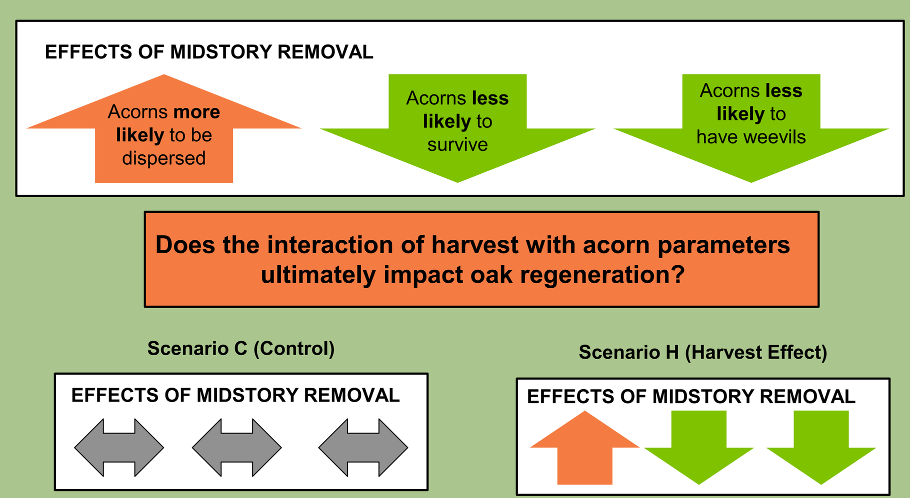

Fig. 5. Summary of case study, showing effects of midstory removal harvest on seed predation parameters and two alternative scenarios either including (H) or not including (C) these effects

Case Study

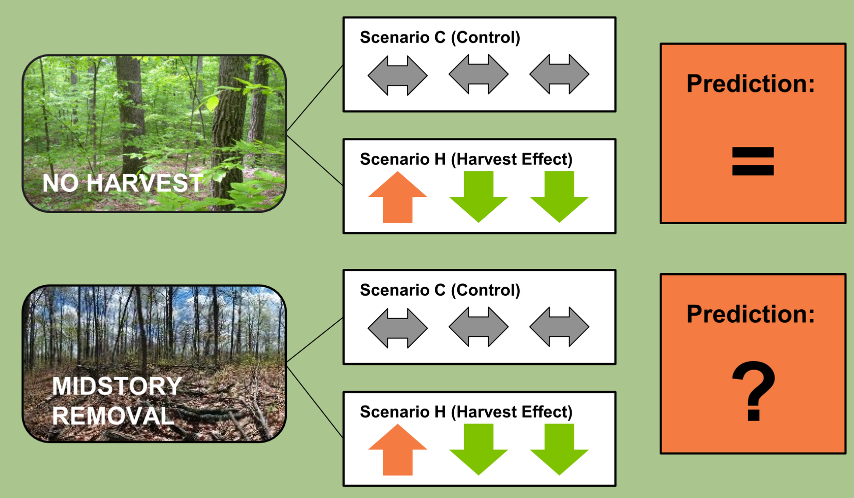

Fig. 6. Predicted response of oak regeneration metrics under the two different model scenarios(H and C) and harvest regimes

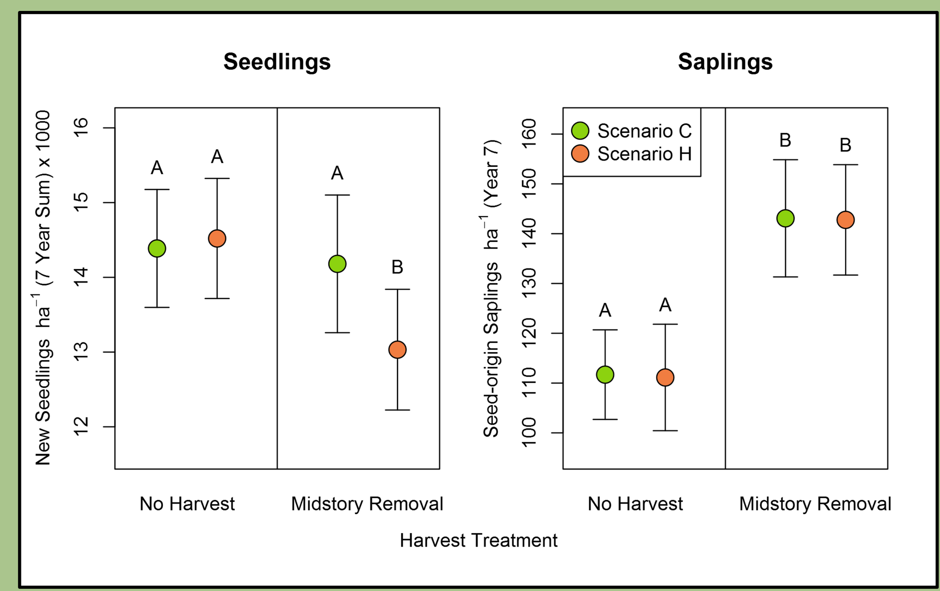

Fig. 7. Simulated oak regeneration metrics under the two different scenarios (C: no harvest interaction and H: harvest interaction) and harvest regimes. Different letters represent significant differences between the means.

Discussion

Parameter Sensitivity

- Regeneration metrics were highly sensitive to **acorn production** and **caching parameters**
- Effect declined with oak life stage (acorn → sapling) and **seedling-level parameters** became more important

Case Study

- Inclusion of midstory removal harvest effects on predation parameters reduced total new seedlings by **8%** over 7 years post-harvest, relative to the control (Fig. 7)
- However, at the conclusion of the simulation, there was **no residual effect** on sapling density
- In this case, acorn fate-midstory removal harvest interactions may not be an important concern for managers
- However: this may change with **greater levels of harvesting disturbance** (e.g., future shelterwood phases or controlled burns)

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Hardwood Ecosystem Experiment

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