Effects of silviculture on predation and dispersal of oak (*Quercus*) acorns by small mammals

Kenneth F. Kellner* and Robert K. Swihart*

***Forestry and Natural Resources, Purdue University**

Abstract

Silvicultural techniques such as shelterwood harvests are often used with the goal of promoting oak (*Quercus*) regeneration, with mixed success. Harvesting may also have indirect impacts on animals that play an important role in the early life stages of oak. For example, small mammals like the gray squirrel *(Sciurus carolinensis*) are acorn predators that also play an important role as acorn dispersal agents. The effects of silviculture-induced change in forest structure on patterns of seed dispersal by small mammals are not well understood, but may be important for successful oak regeneration. To address this question, we tracked the fate of tagged acorns placed beneath oaks at 5 control (unharvested) and 5 shelterwood plots located within the Hardwood Ecosystem Experiment. Acorns were divided between two exclosure types: one allowing access to all small mammals, and one that excluded squirrels but allowed mice and chipmunks. Over three years (2010-2012) a total of 3600 black and 2400 white oak) acorns were placed in the exclosures in late Fall. The following March of each year, 40 x 40 m square areas centered on the release points were systematically searched for tags using metal detectors, and the dispersal distance and fate of relocated acorns was determined. Data were analyzed using a logistic – lognormal mixture model. We found that acorns in shelterwood harvests were less likely to be removed by dispersal agents, and the acorns that were removed were dispersed further in shelterwoods relative to acorns at unharvested sites. Acorns that squirrels could not access were less likely to be removed and were not dispersed as far from the source. These results provide evidence that dispersal may be altered following shelterwood harvest with potential implications for oak regeneration.

Introduction

- Silvicultural techniques, such as **shelterwood harvest** (Fig. 1) are used to promote oak regeneration[1]
- Silviculture can greatly **alter habitat** for animals including small mammals (Fig. 1)[2]
- Small mammals are important as predators and **dispersal agents** of oak acorns (Fig. 2)[3]
- Behavior may be altered following harvest; for example **predation risk may increase** with reduced cover[4]
- Little is known about the effects of timber harvest on dispersal of acorns, with implications for regeneration

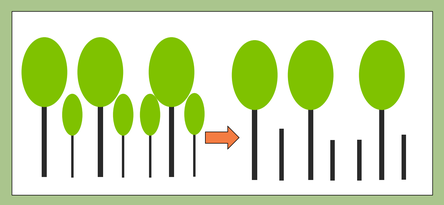

Figure 1. Example of the first phase of a shelterwood harvest technique; the midstory is removed

Peromyscus leucopus | *Sciurus carolinensis* | *Tamius striatus*

Figure 2. Common small mammal acorn predators

Objective

Determine the short-term effects of shelterwood harvests on acorn predation and dispersal by small mammals.

Hypotheses

1. Acorns in shelterwood harvests are **less likely** to be removed by predators due to reduced cover
2. Dispersal distances will **vary** between treatments
3. Removed black oak acorns are **more likely** to be cached and will be dispersed farther

Methods

- 2 silvicultural treatments:
  - **Shelterwood**: midstory of stand removed (Fig. 1)
  - **Control**: unharvested
- 10 study plots centered on trees
  - Divided between treatments
  - Each sampled for 1-2 years
- Study plots (Fig. 3)
  - Tagged acorns supplied to squirrels in fall
  - Tags relocated in spring using metal detector[3]
  - 1600 m^2 searched at each plot
- Dispersal distance, direction, fate, and microsite recorded for each located tag (Fig. 5)

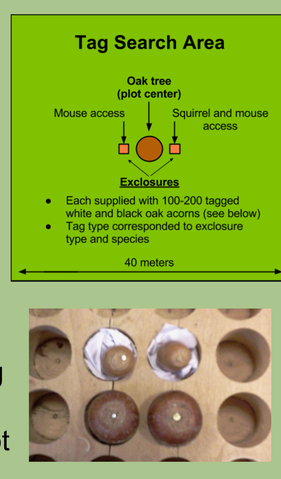

Figure 3. Study plot diagram and example of tagged acorns

Analysis

- **Mixture model** (Fig. 4)
  - Simultaneous modeling of removal and dispersal processes
  - Covariates include treatment, species, and exclosure type
- **GLMMs** connect removal probability and dispersal to covariates
- Fit in **Bayesian framework**

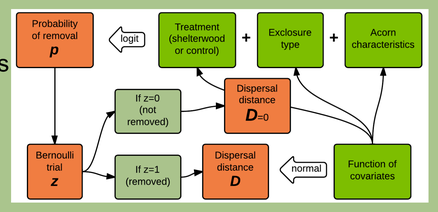

Figure 4. Mixture model structure. The model contains two subunits: removal (Bernoulli) and dispersal (Normal).

Results

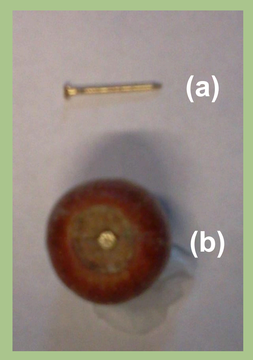

Figure 5. Examples of relocated (a) consumed and (b) surviving acorns

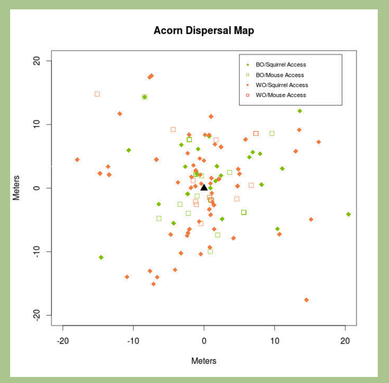

Figure 6. Example map of relocated acorns at one control tree (2011-12)

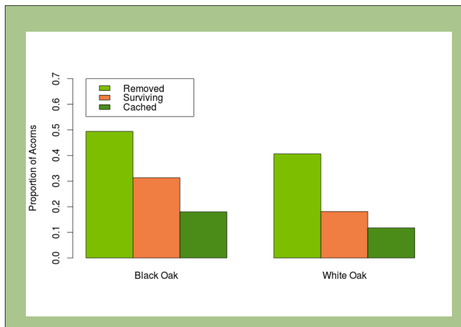

Fig 7. Relocated acorn fates; categories are not mutually exclusive. Cached acorns have the best chance of germination.

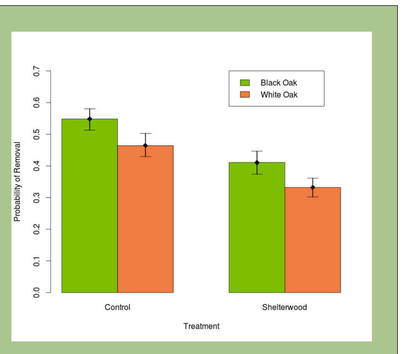

Fig 8. Mean acorn removal probability by treatment and species. Error bars are 95% credible intervals.

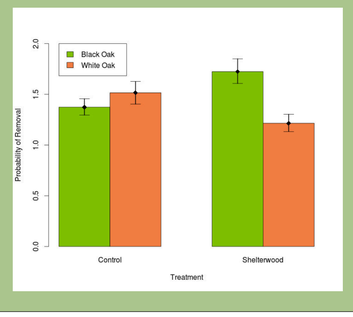

Fig 9. Mean acorn dispersal distance by treatment and species. Error bars are 95% credible intervals.

Results

Parameter	Mean	SE	2.5%	97.5%
Probability of Removal Covariates				
Black Oak	1.37	0.14	1.10	1.63
Squirrel Access	1.48	0.11	1.26	1.69
2012 Effect	1.82	0.18	1.47	1.94
2013 Effect	2.15	0.19	1.81	2.50
Shelterwood	-0.37	0.11	-0.58	-0.15
Dispersal Distance Covariates				
Black Oak	0.15	0.07	0.01	0.28
Squirrel Access	0.15	0.07	0.04	0.27
Acorn Cached	0.27	0.08	0.12	0.43
2012 Effect	0.83	0.09	0.65	1.00
2013 Effect	0.71	0.09	0.54	0.88
Shelterwood	0.31	0.06	0.19	0.36

Table 1. Estimated parameter values for the mixture model. Important covariates (i.e., 95% credible interval does not include 0) are highlighted in orange.

Discussion

Hypothesis 1:

SUPPORTED

- Acorns were less likely to be removed by predators at the shelterwood sites (Table 1, Fig. 8)
- Less vegetative cover may increase perceived predation risk, meaning less time spent foraging[5]
- Important not to conflate removal with predation, since some removed acorns survive (Fig. 7)

Hypothesis 2:

PARTIALLY SUPPORTED

- Overall, acorns were dispersed further in the shelterwood sites (Table 1)
- However, white oak was not dispersed as far in the shelterwoods (Fig. 9)
- Potentially due to germination schedule differences[7]
- Greater range of dispersal distance should favor oak establishment

Hypothesis 3:

SUPPORTED

- Black oak acorns were generally dispersed further and were more likely to be cached (Fig. 7 & 9)
- Likely reflects reduced perishability relative to white oak[7]
- Overall, a large percentage of acorns were removed while few were cached (Fig. 7) – are small mammals helping or hurting oak regeneration?

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Hardwood Ecosystem Experiment

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