Timing of Peak Acorn Yield in Northern Red Oaks at Flat Rock Forest in Relation to Small Mammals

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ABSTRACT

Oak trees can produce pulsed, synchronous and large seed yields; a phenomena coined "masting". Among the diversity of trees in northeastern forests, mast events from northern red oak (*Quercus rubra*) have been linked to wildlife demographics. In years of surplus seeds, oak species may satiate granivores and thus enhanced germination rates occur in those years. Variation in annual seed yield, within populations of northern red oaks has been well studied. However, we sought to better understand the within-year timing of peak sound acorn maturation from a population of northern red oaks near their northern range limit in upstate New York. Further, we compared the timing of sound acorn maturation with small mammal trapping data. We installed then monitored ten seed traps weekly from September 10th to October 30th 2013. We collected acorns via seed traps and counted on-the-ground acorn abundance, and compared these data with small mammal presence. Peak seed rain of sound acorns and maximum small mammal captures, occurred around October 9th, 2013. Deer and white-footed mice (*Peromyscus* spp.) were the most captured granivore species (n =15 captures). When compared to density of acorns collected in seed traps, those on the ground were clearly depredated most likely attributed to small mammals or other acorn predators. The number of sound acorns recorded on the ground during the final week of this study was 75% less than the cumulative number of acorns found in the seed traps during the sampling season. There was no significant relationship between tree size (DBH) and acorn yield. We did however find a significant inverse relationship between crown area and acorn yield. Our baseline data will eventually be used to help understand the mechanics of masting and result in optimization of management practices of valued northern red oak in addition to growing a better understanding of the complex community dynamics of this foundational species.

KEY WORDS: *masting, Quercus* spp.*, Peromyscus* spp.*, forest ecology*

INTRODUCTION

The pulsed, synchronous mass-production of seeds is a phenomenon called "masting", which is an important event that occurs in forested ecosystems (Koenig and Knops 2005). Northern red oak (*Quercus rubra;* hereafter red oak) masting events in northern hardwood forests can provide abundant and critical food resources for animals preparing to overwinter. Red oaks may be especially important in this area because there are few other hard mast producing species present, such as American beech (*Fagus grandifolia*) and hickories (*Carya* spp.) that provide food for granivores. In addition, the range-wide loss of American chestnut (*Castanea dentata*) due to the chestnut blight has made masting events from red oaks even more significant in northern hardwoods (Stephenson 1986). Wildlife such as mice (*Peromyscus* spp.), squirrels (*Sciurus* spp.), black bear (*Ursus americanus*), ruffed grouse (*Bonasa umbellus*), and white-tailed deer *(Odocoileus virginianus)* can increase their survivability and fecundity during mast years (Koenig and Knops 2005, Lashley et al. 2009, Gillen and Hellgren 2013). The ultimate causes of masting is poorly understood and debated, but likely results from a combination of factors, including genetic disposition and abiotic influences such as abundant rainfall and available soil nutrients (Koenig and Knops 2005, Lashley et al. 2009).

Red oaks produce hardy, nutrient-rich acorns that are slow to decay, making them a potential keystone food resource in a forested ecosystem (Leach et al. 2013, Gillen and Hellgren 2013, Keller et al. 2013). Positive relationships between granivore and mast seed (e.g., acorns and beechnuts) abundance have been repeatedly shown, further adding to the significance of this phenomenon (Garneau et al. 2012, Schnurr et al. 2002). Masting creates cascading effects throughout the ecosystem, supporting not only predators, but also parasites and diseases (Ostfeld et al. 1996, Gillen and Hellgren 2013, Lobo and Millar 2013). During years when seed yield is below normal, the decline in food production can result in reduced granivore densities, but also increases the chances of germination during a subsequent masting event (Schnurr et al. 2002). Increased germination results from a lag in functional response time among granivores; an effective predator satiation technique (Schnurr et al. 2002).

Oaks are greatly valued by many species, including humans. They are harvested selectively for high quality timber, further selecting for a pulsed reproductive strategy in the form of predictable masting cycles (Lashley et al. 2009). For wildlife, in addition to serving as a keystone food resource, oaks also provide habitat for birds and mammals (Kellner et al. 2013). Forest ecologists and managers are concerned about the future of these ecosystems, especially given the difficulties associated with oak regeneration. Oaks are slow-growing and exhibit intermediate-intolerance to shade and thrive when dominant in the canopy. Because red oaks compete with shade-tolerant species, such as sugar maple *(Acer saccharum)*, red maple *(A. rubrum),* and American beech, their seedlings often struggle to meet sunlight demands necessary for recruitment into the canopy (Gillen and Hellgren 2013). For these reasons, oaks thrive following disturbances (e.g., forest fires, clearcutting) that reduce competition (Abrams 1992, Gillen and Hellgren 2013, Kellner et al. 2013). The dependence of wildlife for food and habitat, and the human desire for quality timber, attests to the severity of dwindling oak populations and years of limited acorn production.

Our objectives were to establish baseline data on acorn yield at Cobblestone Hill of Flat Rock forest and examine if there was a relationship between yield and tree size (i.e., DBH, canopy area). Also we sought an estimate of timing of peak acorn maturation at Cobblestone Hill. Our final objective was to acquire an understanding of small mammal presence and determine if there was any relationship between the number of small mammals trapped and the timing of peak acorn maturation. We also compared on-the-ground with seed trap data to infer evidence of acorn predation. We expected to find more small mammals captures and evidence of seed predation in our ground plots around the time of peak acorn fall. It is anticipated that in subsequent years, further data on seed yield will be acquired to determine the conditions of a true masting event at Cobblestone Hill, in addition to acquiring a trend regarding small mammal presence.

METHODS

Site Description

The location of our study site was Cobblestone Hill, which is part of Flat Rock forest located in Altona, New York (Fig. 1). The property is owned by the William H. Miner Agricultural Research Institute, and is used specifically for ecological and environmental research. Our study location was located at approximately 43.84’N, -73.57’W. This region receives an average annual rainfall of 81 cm and an average temperature range of 35-55°F. This forested area is considered a northern hardwood forest. Soils at our study location are primarily deep, well-drained stony spodosols formed from glacial deposits. Tree species include red oak, American beech, sugar maple, and striped maple *(A. pennsylvanicum),* among others. Understory species include doll's eyes *(Actaea pachypoda),* Indian cucumber root *(Medeola virginiana)*, and false Solomon's seal *(Maianthemum racemosum)*. The forest floor is abundant with many cobbles, decaying logs, and stumps, which provide habitat for many small mammals.

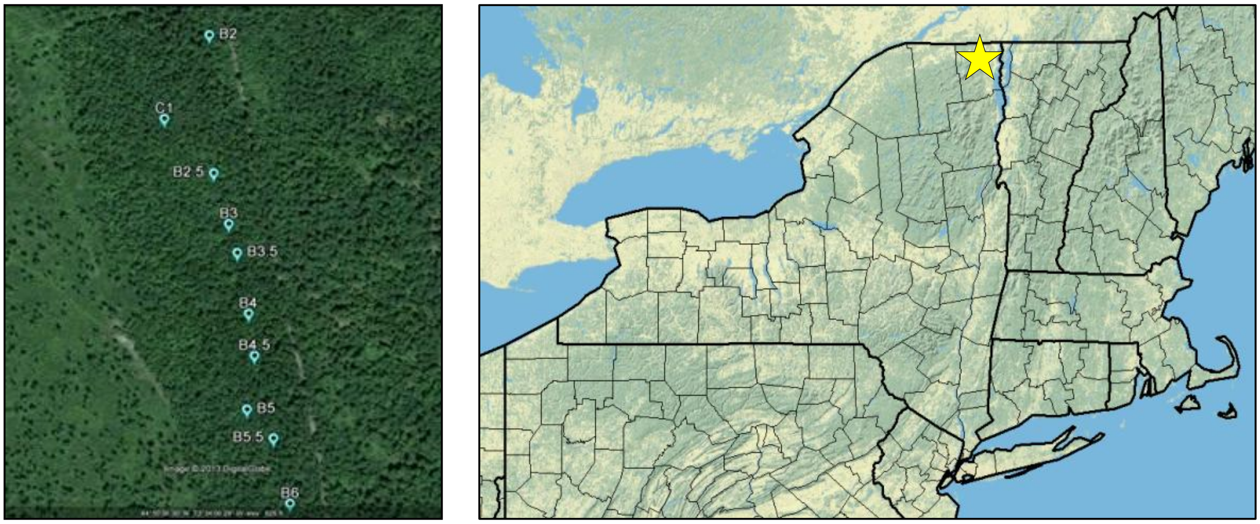

Figure 1. Location of Cobblestone Hill (yellow star) relative to the State of New York (right), and plot locations (left) signifying center of plots where study trees are located within Cobblestone Hill.

We installed ten 1 m^2 seed traps in a south to north trajectory on Cobblestone Hill adjacent to the sandstone pavement barren known as the Altona Flat Rock in Clinton County, New York on August 31st 2013. Plots were selected by choosing one random coordinate within Cobblestone Hill, and from that coordinate, nine other plots were placed systematically (Fig.1). Each plot had a radius of 25 m. Within plots, a single seed trap was placed under a randomly selected red oak. We randomly numbered all red oaks within each plot, while another person chose a random number for the selected study tree. The diameter at breast height (DBH) was recorded for each tree and the canopy area was calculated by measuring the diameter of the canopy, north to south and east to west. Square seed traps (1 m^2 quadrat) were constructed from four 0.3 x 1.22 m treated pine boards. Metal electrical conduit poles were cut and fitted to seed traps to elevate them as a means to prevent ground herbivory. Netting for the traps was comprised of fiberglass screening, which was stapled to the perimeter of the seed trap. Seed traps were checked a week later and monitored weekly thereafter until October 30, 2013.

We began sampling ground plots during the third week of the study (September 18th). Ground plots were randomly placed under the canopy of our sample trees and were checked on subsequent seed trap sampling days. To acquire the same fixed area of sampling for each plot, a 0.56 m^2 hula hoop was used. Abundance of sound and unsound acorns (partial and whole) was quantified and unsound acorns were removed from the ground plot. We made adjustments to the ground plot data to present data on a 1 m^2 scale to facilitate comparisons with seed traps. To estimate predation in ground plots, we compared the cumulative number of sound acorns in the seed traps to the number of sound acorns found in the ground plots each week.

When seed data were collected from seed traps, if no mature acorns were present, the number of caps and immature acorns was recorded. If there were mature acorns present in the trap, all acorns, including the caps and immatures, were collected in a bag and labeled with date and unique trap identification. Samples were brought to a lab and stored frozen until further inspection. In the lab, all acorns were placed in a bucket of water for a float test to distinguish unsound (float) from sound (sink) acorns (Allen et al. 2001, Lashley et al. 2009). Following this procedure, we classified damage as insect, wildlife, or fungal by exposing the inside of the acorns (Straub 2012). Acorns that were whole or had less than 50% damage were oven dried to a constant mass at 64˚C for 48 hours and then were weighed to the nearest 0.0001 g.

Small mammal trapping was conducted weekly, weather permitting, until October 9, 2013. Four Sherman live traps (1 large (3 x 3.5 x 9") and 3 small (2 x 2.5 x 6.5")) were placed around each of the seed traps (n = 40) corresponding to four cardinal directions. They were placed radially approximately three meters away from the seed traps and were baited with cracked sunflower seeds. Supplemental cotton balls were provided as bedding as temperatures declined, according to conditions specified in NYS DEC permit #1205 (Dr. Danielle Garneau) to collect and possess for educational purposes. Species were identified and gender, weight, and tail and body length measurements were recorded for individuals.

RESULTS

Red oaks in our study ranged from 39.1-79.1 cm DBH (Table 1). Three trees (30%) had multiple stems. B5 and B4.5 had three stem trees and B3.5 had five stem trees with three of them standing dead. The number of sound acorns for individual trees ranged from 0-43 (Table 1). There was no significant relationship between tree size (DBH) and acorn yield (R^2 = 0.3215, P = 0.0874; Fig. 2). We found a significant inverse relationship between crown area and acorn yield (R^2 = 0.5928, P = 0.00918; Fig. 3).

Table 1. Diameter at breast height (DBH), canopy area and number of acorns per trap from ten northern red oak trees sampled at Cobblestone Hill, fall 2013.

Tree ID	DBH (cm)	Canopy area (m^2)	Whole sound acorns (trap)
B6	59.4	243.3	43
B5.5	73.1	189.9	27
B5	49.5	358.0	0
B4.5	46.7	330.1	0
B4	57.2	253.1	2
B3.5	39.1	216.4	0
B3	45.2	177.9	3
B2.5	42.4	91.6	17
B2	49.8	113.1	28
C1	40.6	133.8	4

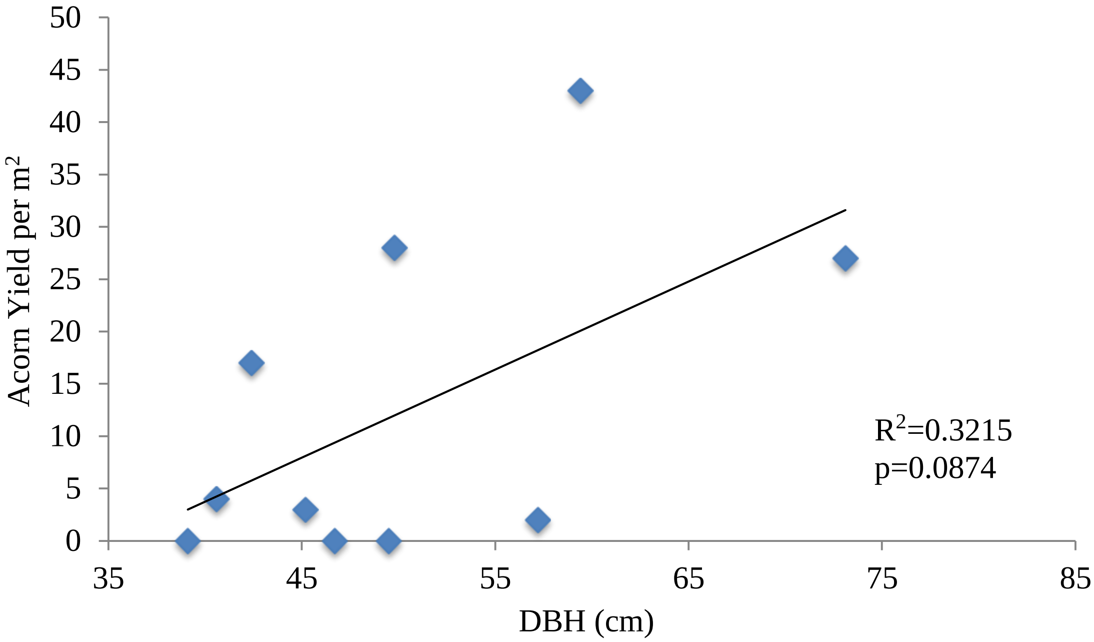

Figure 2. Relationship between tree size (diameter at breast height) and the number of sound acorns observed from the 1 m^2 seed traps from ten northern red oaks at Cobblestone Hill, fall 2013.

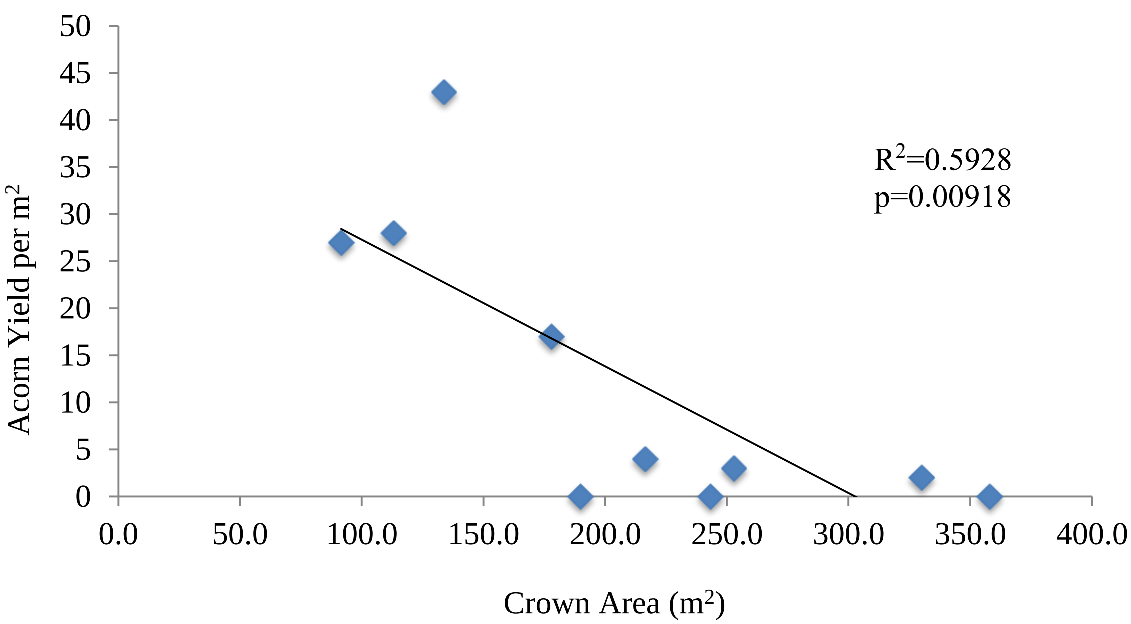

Figure 3. Relationship between tree size (crown or canopy area) and the number of sound acorns observed from the $1m^2$ seed traps from ten focal northern red oaks at Cobblestone Hill, fall 2013.

The number of sound acorns from ground plots increased until October 9th then declined thereafter (Fig. 4). The proportion of unsound acorns was greatest at the beginning of the study (Fig. 4). Cumulative number of sound acorns collected from seed traps was about 75% greater than sound acorns collected on the ground by October 30th (Fig. 5).

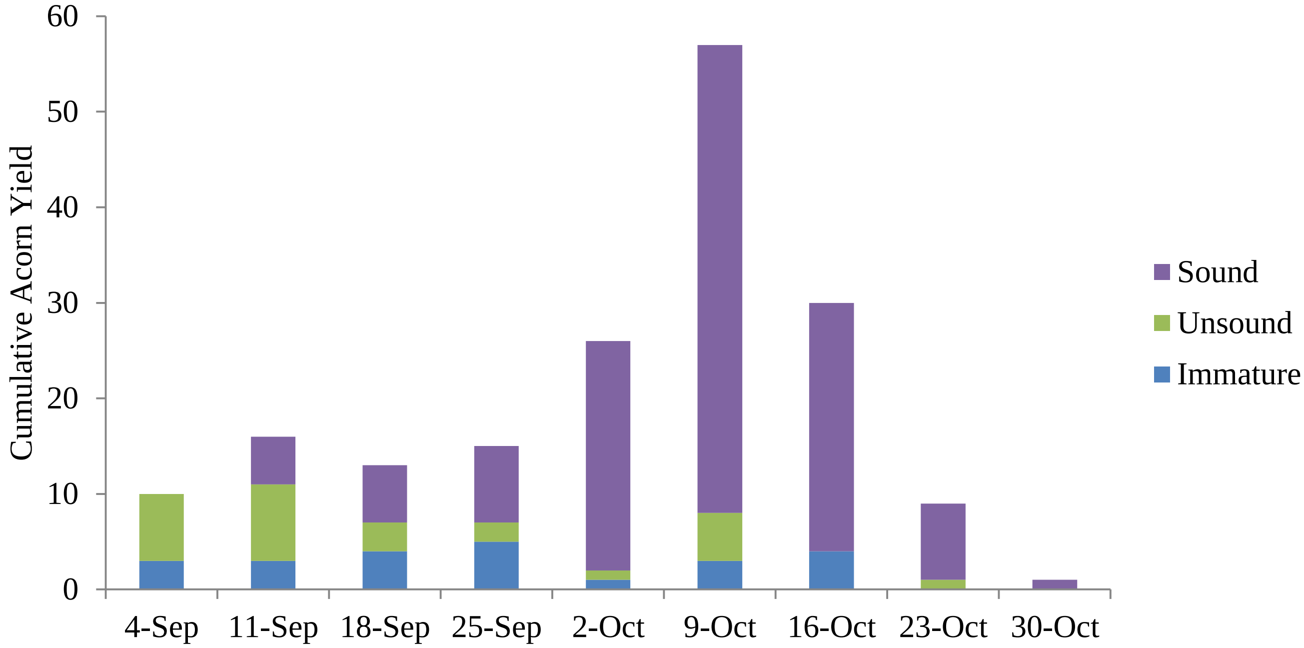

Figure 4. Abundance of sound (whole and partial), unsound (whole and <50% damage), and immature (>50% cap) acorns from seed traps at ten focal northern red oaks at Cobblestone Hill by week, fall 2013.

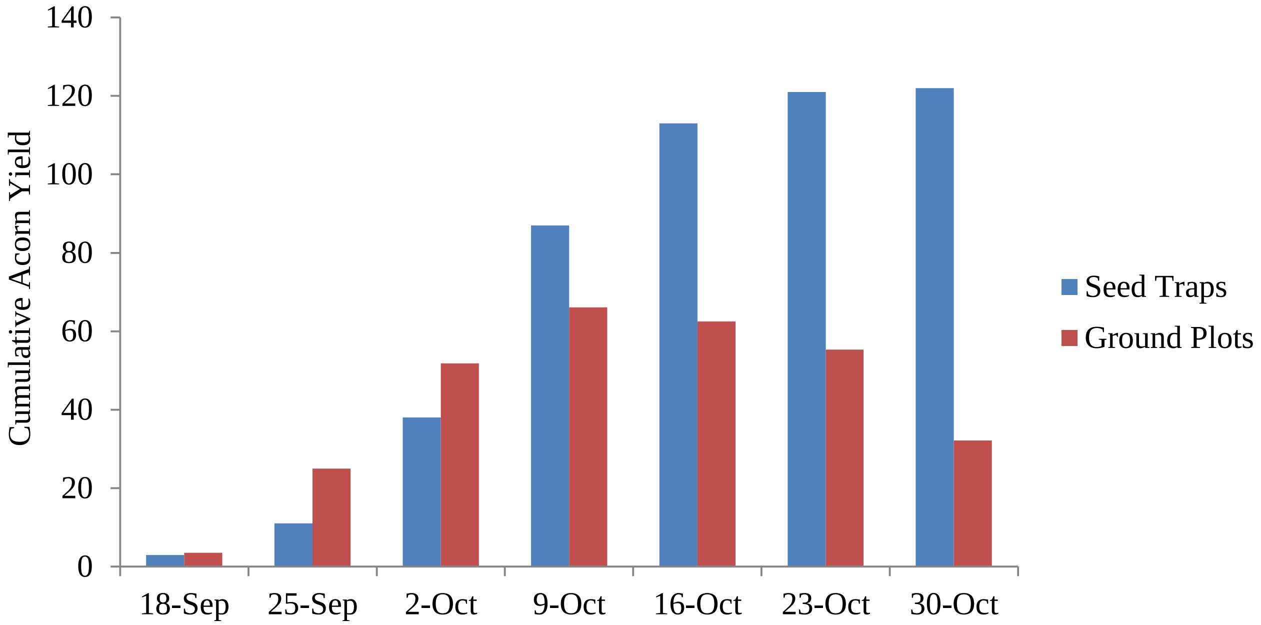

Figure 5. Cumulative sound whole acorn abundance in seed traps at all trees over time and number of whole sound acorns in ground plots at ten focal northern red oaks sampled at Cobblestone Hill during each visit, fall 2013.

Peromyscus spp. were the most commonly trapped species (*n* = 15 captures) closely followed by short-tailed shrew (*Blarina brevicauda*; *n* = 13), and lastly southern red-backed vole (*Myodes gapperi*) (*n* =3; Table 2). Sound acorn yield peaked simultaneously with the number of small mammal captured on approximately October 9th (Fig. 6).

Table 2. Abundance of captured mammals, percent gender, and range and species-specific average of measurements for small mammals captured at Cobblestone Hill, fall 2013.

Species	Total Captures	Gender %(m/f/u)	Weight Min-Max (g)	Average Weight (g)	Length Min-Max (cm)	Average Length (cm)
Blarina brevicauda	13	7.7/76.9/15.4	14-23	18.2	7.5-11.5	9.8
Peromyscus spp.	15	33.3/46.7/20.0	15-24	19.0	12.5-18	14.8
Myodes gapperi	3	0.0/33.3/66.7	5-9	6.7	9.5-13	11.3

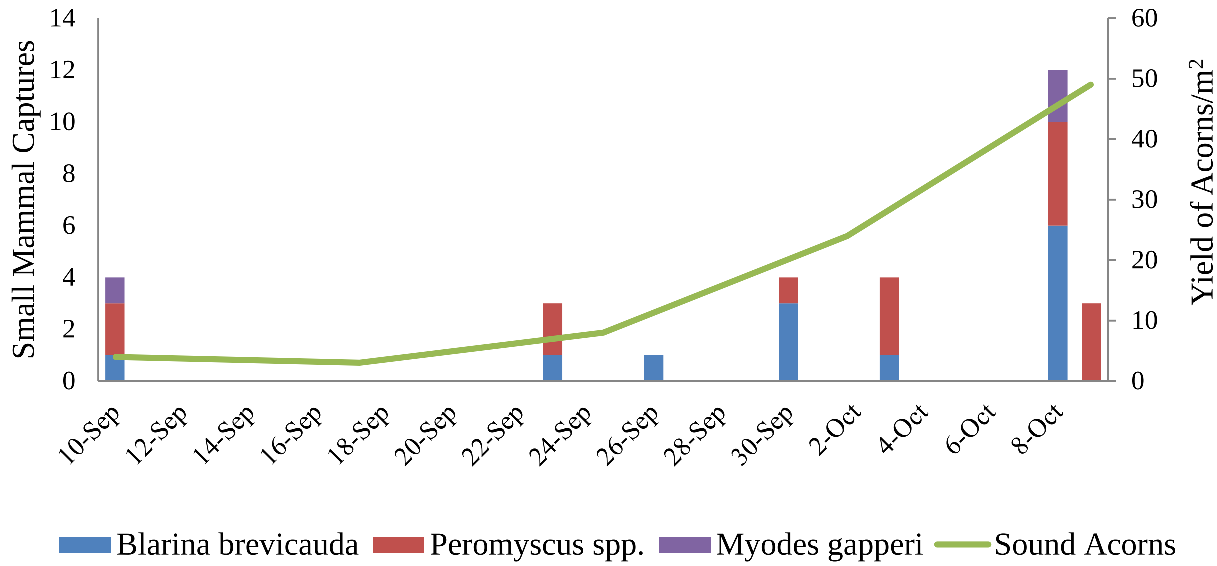

Figure 6. Yield of sound acorns (seed traps) and captures of small mammals (*Peromyscus* spp. combined) at ten focal northern red oaks sampled at Cobblestone Hill during each visit, fall 2013.

DISCUSSION

Our goal was to establish a baseline dataset of red oak acorn and small mammal abundance in a northern hardwood forest. The rationale for collecting baseline data was that most studies with acorn masting normally require at least three years of acorn data to establish any meaningful trends (Keller et al. 2013). Data on the sizes of study trees were recorded to determine if any correlation between tree size and number of acorns existed in our study area. Additionally, we sought to estimate the timing of peak acorn drop occurring at our study site for future studies. Our last goal was to assess whether there was any relationship between small mammal and acorn abundance.

Variation in seed yield per tree ranged from 0-43 acorns per seed trap per individual red oak tree. No significant correlation between DBH and number of acorns was observed. We did however find an inverse correlation between crown area and number acorns produced. According to most studies, the variation in acorn production between trees seems to be uncorrelated (Lashley et al. 2009). Seven of our ten study trees yielded acorn mast. In previous studies it was found on average that half of oak trees were prolific in a given year (Greenberg et al. 2002, Lashley et al. 2009). We also do not know what the classification of a good versus poor acorn producer would be in our study area due to the absence of annual data. Our study trees were all about the same size in DBH, thus most likely of similar age (even-aged forest). Oak seedlings were scarce at our study site, which indicates that oak regeneration may be scant in the future at Flat Rock forest, like many eastern hardwood forests in the United States (Lorimer 1993, Marquis et al. 1976). Without simulating a natural disturbance regime through silvicultural management, we may slowly lose oaks in northern hardwood forests (Abrams 1992, Lorimer 1993).

The timing of peak sound acorn yield occurred during the week of October 9th, which was concomitant with the peak of small mammals trapped. *Peromyscus* spp. are common granivores, thus their increased trappability should correlate with acorn pulses (Lobo and Millar 2013; Schnurr et al. 2002). However, it was difficult to determine the cause of the peak in small mammal capture, as it might be a function of weather (i.e., heavy storm the evening prior thereby reducing foraging opportunities). As the number of sound acorns recorded in ground plots declined over time with respect to the seed traps, we can assume seed predation by granivores occurred. We cannot conclude that predation was only due to small mammals because white-tailed deer, gray squirrels (*Sciurus carolinensis*), and birds such as blue jays (*Cyanocitta cristata*) are all known to eat acorns and are present in this forest ecosystem. In future studies, we could further determine what species are foraging for acorns by monitoring trail cameras. Many studies similar to ours have contributed to understanding how the pulsed event of masting affects the dynamics of local and regional wildlife populations (Gillen and Hellgren 2013, Keller et al. 2013, Leach et al. 2013, Lobo and Millar 2013, Schnurr et al. 2002, and Straub 2012).

Potential sources of error include misclassification of acorns into sound and unsound categories in the field (ground plots). Misclassification could cause the removal of sound acorns from ground plots which would skew predation estimates. Human activity and scent at the plots potentially posed a disturbance that might have resulted in fewer small mammal captures. In the future, alteration of the monitoring schedule might be more effective (e.g., more frequently as peak approaches). Additionally, ground plot sampling should commence coincident with seed trap monitoring. Finally, we might grow this survey to compare among sites to assess site-specific and regional trends in mast and small mammal abundance. Most importantly, improvements in study design should include marking animals, such that abundance estimates can be measured. Additionally, field collection of saliva from *Peromyscus* spp. (e.g., deer mice, white-footed mice) to accurately determine species using salivary amylase gel electrophoresis techniques is appropriate. Lastly, commencing small mammal trapping earlier in the summer into fall to enhance trapping efforts would be beneficial.

Acorn masting is one of nature's phenomena still under scrutiny (Koenig and Knops 2005). Obtaining a better understanding of the northern hardwood forest ecosystems may facilitate a better understanding of acorn masting and assist with the management and conservation of these foundation species within the forest. Our study has revealed a positive relationship between peak timing of acorn maturation and small mammal captures. Additionally, ground plots revealed evidence of acorn removal most likely due to predation. With the loss and decline of other masting trees, such as the American chestnut and the American beech, the northern red oak is an important foundational tree species in need of long-term research and monitoring.

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