A Title: **Reseeding restored forests: Can seed dispersal mutualisms amplify restoration of American Chesnut (*Castanea dentata*)?**

Christopher M. Tonra, Stephen N. Matthews, and Leila Pinchot

B SUMMARY (100 words)

Seed dispersal is a fundamental mutualism between wildlife and trees. Wildlife, such as birds, often cache abundant seed from trees to enable them to survive the winter, and unrecovered seed ensures dispersal and persistence of tree species. Rapid environmental change can disrupt this critical process, potentially threatening the persistence of the ecosystem. Both the loss of American Chestnut and the declines in Oak-Hickory forest represent historic and contemporary perturbations to plant-animal interactions. Understanding the capacity of Blue Jays, a prolific seed disperser, to facilitate chestnut and oak dispersal, and their seed preferences, is an import piece to sustaining these forests.

C Principal Investigators and Institutional Affiliations

Christopher Tonra: Assistant Professor, School of Environment and Natural Resources, Ohio State University

Stephen Matthews: Assistant Professor, School of Environment and Natural Resources, Ohio State University

Cornelia (Leila) Pinchot: Research Ecologist, USDA Forest Service Northern Research Station

D Duration of Project

One year of initial funding requested.

E Total amount requested

We are requesting $7,906 to support a research technician and supplies to tag Blue Jays and Chestnuts. We recently received additional funding of $49,000 to support a graduate student and field supplies to focus on relationships between Jays and Oaks, and the proposed research here will allow us to add the novel Chestnut component. In total we will be able to more fully consider seed utilization and dispersal of scatter hording bird and large nut producing trees. In addition to the funds requested we also will ask if TACF can provide chestnut seed (n=500) to implement in the feeding and germination trials. Because we are primarily utilizing these seeds during feeding selection trials there are not limitations and can be from open pollinated stock.

F Short and long-term goals of the project

Our short term goals are to build capacity to evaluate important plant animal interactions in forested settings. By considering the role of blue jay's in the dispersal of seed producing trees we can gain a better understanding of how these relationships are critical to sustain healthy forests and can facilitate the restoration of American chestnut. Our long term goals aim to build on these initial results to incorporate how these patterns vary over time as mast cycles undergo natural fluctuations to capture the full dynamic of the system. Understand these relationships will provide needed insights to the processes regulating seed dispersal and regeneration potential of chestnut and oak across the landscape.

G Narrative
Introduction

Plant-animal interactions are a fundamental determinant of ecosystem function and production. Like many systems, historic chestnut and contemporary Oak-Hickory forests of eastern North America consist of trophic interactions that link energy flows from primary consumers to predators. Perhaps overlooked are the essential mutualisms (Bascompte, 2010) that occur via pollination and seed dispersal in this ecosystem. With the success of The American Chestnut Foundation's (TACF) efforts to develop blight-resistant American chestnut, understanding the capacity of these key mutualisms to facilitate establishment and dispersal are important steps as maintaining these mutualisms are essential for sustainable forest productivity, through processes such as gene flow.

Of the multiple species that facilitate seed dispersal of plants, the family Corvidae (jays, crows, and magpies) exemplifies the role plant-animal mutualisms play in ecosystem structure and function across their global distribution (Pesendorfer *et al.*, 2016). Key to this relationship is the benefit the tree receives from scatter hoarding behavior, where seeds are transported and stored in various cache locations for later consumption. Inevitably, a portion of caches are not recovered, and thus may germinate (reviewed in Pesendorfer *et al.*, 2016). Key traits that have evolved in this system can facilitate these interactions. For example, seed size will influence ability to disperse. Palatability and time to germination can facilitate immediate consumption or storage for overwinter. Finally, consistency of seed production across years will mediate wildlife responses. Specifically, dispersal can be enhanced by mast cycles that ensure a lag in population synchrony (i.e. "swamping" hoarders in some years with more seeds than can be consumed to ensure germination). Across the Appalachian forest region, the historic dominance of American chestnut with large seeds and consistent annual seed production provided an abundant food resource (Dalgleish and Swihart, 2012, Diamond et al. 2000). Today these same forests, dominated by oak(*Quercus* sp.) and hickory (*Carya* sp.; key mast producers supporting wildlife) have more varied seed production, with many of the red oak group showing regular biannual mast while others more consistently, albeit lower, annual production of acorn crop. Animal behaviors, such as caching, provide a key mechanism for long distance dispersal, where not only competition from the parent tree is reduced, but genotypes are moved greater distances over heterogeneous landscapes (Sipielski et al. 2008).

In many ways, if our goals are to reestablish chestnut to the landscape and sustain productive oak forests and wildlife communities, we must gain a better understanding of the role that plant-animal interactions play in shaping these forests. Across most of the former range of chestnut, Blue Jays (*Cyanocitta cristata*) are vital scatter hoarders of Fagaceous species (Vander Wall 1990). Evaluating the preferences of Blue Jays in selecting and dispersing seeds based on species composition and abundance will provide key insights to developing restoration plans. Appalachian forests face multiple threats (Butler et al. 2015), and forest change and loss could be exacerbated if these threats alter the relationships between trees and their mutualists. Thus, it is critical we elucidate the effect ongoing forest declines while at the same time critically examining opportunities to restore forests and reestablish chestnut, in an integrated approach that considers both trees and services that wildlife provide. Our objectives are to understand 1) how Blue Jay caching behavior, with a focus on distance moved and preference, responds to chestnut and acorn availability, and 2) how caching location can influence germination success. By elucidating how this plant-animal interaction changes with variation in seed abundance, we will be able to predict the ripple effects forest community changes will have in this critically important ecosystem.

Rationale and Significance

Animal dispersal is a fundamental process in forests of nut bearing trees (e.g. McShea *et al.*, 2007). The mechanism of dispersal and co-evolution between trees and wildlife has emerged across the global distribution of many species within the temperate forests (Pesendorfer *et al.*, 2016). For example, in many systems the balance of food consumption by the seed predator is compensated for by the dispersal of large seed away from intraspecific competition of the parent tree, promoting gene flow and genetic diversity (McShea and Healy, 2002). In turn, the diversity of wildlife that depend on nuts (hickory, oak, formerly chestnut) for a portion of their energetic stores is impressive. For example, by some estimates over 90 species of wildlife utilize acorns as a portion of their diet within eastern North America (McShea *et al.*, 2007). In the oak system, the benefits of dispersal trees obtained by scatter hoarding behaviors (Pesendorfer et al. 2016) greatly outweigh the benefits of wildlife species that are larder hoarders, where caches contain as a larder of seeds often in unsuitable germination locations, or those that do not hoard. Chestnuts and Oaks have evolved a combination of considerable secondary structural and metabolic defenses and large seed size to limit direct seed predation (both by invertebrates and vertebrates), while maintaining close mutualistic relationships with scatter hoarding species (Pesendorfer et al. 2016). Jays (several gernera in Corvidae; e.g. Aphelocoma sp., Cyanocitta sp.) have long been linked as essential dispersers of large seeds (Darleyhill and Johnson, 1981). This mutualism has even been linked to rapid expansion of nut-bearing trees, including chestnut, following the retreat of the last ice age (Johnson and Webb, 1989). Thus, these important relationships will certainly be essential to increasing resilience and adaptive capacity of restored chestnut. In particular, understanding how far jays might transport chestnut would improve models predicting American chestnut population expansion, such as that described in Rogstad and Pelikan (2014), and would inform decisions of placement of founder population sites to maximize restoration success. Finally, understanding jay preference for caching site and the fate of chestnuts across cache sites would help guide forest management strategies for American chestnut reintroduction plantings.

The close association between scatter hoarders and seed-bearing trees highlights the importance of maintaining functional biodiversity, and demonstrates the critical need to understand plant-animal interactions in a time of rapid change and active restoration. Therefore, revealing how these processes shape pattern of species demography and distributions of both seed producers and their dispersers are essential. A key component to the mutualistic benefits of scatter hoarding is that mast cycles ensure that there are years with high and low availability of specific oak species, such that in high mast years production will exceed consumption. It is critical that we understand how mast cycles of oaks may influence dispersal probability and eventual germination rates of reintroduced chestnuts. The behaviors of Blue Jays (*C. cristata*) and other scatter hoarders show a preponderance of caching more food resources than will be retrieved. Darleyhill and Johnson (1981) found that 56% of oak acorn crops were moved by Blue Jays and only 20% of that was consumed, leaving the rest the opportunity to germinate. However during low mast years most of cached resource will be consumed (Kelly and Sork, 2002). Jays are regularly observed consuming and utilizing a variety of species, and there appears to be a tradeoff between consumption and storing (Moore and Swihart, 2006), depending on availability. Therefore, the reintroduction of American chestnut with less variability in mast on an annual bases has the potential to reshuffle this dynamic and provide insights to how the mutualisms have been perturbed when chestnut was removed from the forest post blight.

Dispersal of seeds by scatter hoarders are clearly a key benefit that animals are providing in Eastern deciduous systems. In particular, Blue Jays are key to this benefit and have been show to distribute seeds over larger areas with dispersal distances that can range from hundreds to thousands of meters, while other mammalian scatter hoarding is much more limited (e.g. Pesendorfer *et al.*, 2016). In heterogeneous landscapes, such as Mediterranean systems, long distance dispersal of acorns by jays is critically important to facilitate movement across otherwise unsuitable conditions (Gomez, 2003). This benefit is of great relevance to chestnut restoration, given our currently fragmented landscape of the eastern United States, where forest loss leaves many trees dependent on avian dispersal of larger body seeds to increasingly isolated suitable locations. The movement away from the parent tree serves two critical functions: 1) reducing competition from parent tree (with light levels being critical for recruitment and growth) and 2) preventing accumulation of seeds under the parent tree, which makes them more susceptible to insect damage. Jays are important, not only for moving seeds across the landscape, but the act of caching them facilitates establishment of nut-bearing trees. By burying seeds into the soil they are protected from disturbance, insects, burning, and predation. Evidence of direct selection for cache locations that are optimal for germination is variable (Garcia *et al.*, 2002; Sipes *et al.*, 2013), but the act of actively moving and burying is a clear benefit. Numerically, an individual Blue Jay can cache 3000-5000 seeds in a season (Smith *et al.* 2013), scaling up to a tremendous capacity for population growth.

Clearly, the interactions between jays and nut bearing trees are a critical component of the persistence of these forest ecosystems. The mutualisms have develop and persisted in the face of dramatic forest change when the American chestnut was removed from the system. As we begin to push towards reintroduction of chestnut it becomes critical to evaluate how the dynamic between a primary scatter hoarder, in Blue Jays, may respond to the return of the chestnut to Oak-Hickory forests. While Heinrich (2014) clearly demonstrates the potential for Blue Jays to facilitate both dispersal and subsequent germination success of chestnut how this association is influenced by other food sources is need. Therefore, we are proposing a study that quantifies seed selection of chestnut and acorn under differing densities as well as track caching location and germination to examine resulting demographic and behavioral responses of Blue Jays. These data will shed light on an important plant-animal interaction and provide guidance to the ability of Blue Jays to facilitate chestnut dispersal from founder populations across a heterogonous landscape.

Approach

Hypotheses, predictions, and tests

Hypothesis 1 – Scatter hoarders disperse seeds proportional to their availability.

Prediction 1 – When acorns are more abundant, Jays will disperse fewer chestnuts.

Test 1 – We will establish feeding stations at our study sites that vary in the relative abundance of acorns and chestnuts. Camera traps will be used to monitor feeders and determine which seeds jays are removing. We will use linear mixed models to test the prediction that removal rate of each seed type will be proportional to its availability.

Alternative outcomes – If Jays chose chestnuts over acorns, even when they are less abundant, we will conclude that they actually prefer (i.e. are selecting for) chestnut seeds. This would mean Blue Jays would have a positive influence on restoration, even in oak mast years.

Hypothesis 2– Where and how are acorns and chestnuts deposited that may make them more suitable to be viable.

Prediction 2 – Jays will cache seeds in sites more suitable to germination than random sites.

Test 2 – Using radio telemetry of tagged jays and tags placed in hollowed out seeds we will locate caches and plant viable seeds in these locations. We will pair these with random planting locations and use linear mixed models to compare germination rates.

Alternative outcomes – If germination rates do not differ between cache and random locations we will conclude that while Jays may facilitate long distance dispersal, they do not enhance recruitment of tree progeny.

Study sites

We will establish two replicate plots of 5-ha in the following Ohio State Wildlife Areas: Waterloo and Fox Lake in Vinton County, Ross Lake Wildlife Area in Ross County. We will also establish two plots in Vinton Furnace State Experimental Forest, where long term research to understand forest management strategies to sustain oak is ongoing (Hutchinson *et al.*, 2008) and experimental chestnut planting have been established. We have approximately 10 years of acorn abundance data from all of these sites from Ohio Division of Wildlife and U.S. Forest Service which will allow us to control for important background densities of acorns turn the feeding trials.

Study species

The Blue Jay is a widespread species in the eastern United States in the Family Corvidae. Blue Jays are known to be a prolific scatter-hoarding disperser (i.e. caching seeds for later consumption over a wide spatial area) of acorns of multiple oak species (Richardson et al., 2013; Pesendorfer et al., 2016). Blue Jays cache seeds in appropriate sites for germination and often fail to retrieve them, due to mortality or non-use. In our study area the major oak species that depend on wildlife dispersal are northern red (*Q. rubra*) and white oak (*Q. alba*). We will therefore, considered chestnut and the two oaks in our study design detailed below.

Field data collection

Feeding choice trials – Focusing at our two study plots in Vinton Furnace State Experimental Forests we will conduct 20 trials at each site. Following Pons and Pousas (2007a) we will start by placing 10 seeds of each white oak, red oak, and chestnuts on 5 elevated feeding stations at least 500 meters apart designed to exclude mammalian removal. Then the abundance of red and white oak acorns and chestnut will be manipulated at assigned stations to quantity seed selection by increasing (doubling) the assigned species' seed abundance as well as trials with only one species available. Stations will be monitored with video recorders to quantify visits and removal of individual seeds. Stations will also be checked 2 times a day and reaming seeds will be counted.

Seed Tracking - Pons and Pousas (2007b) developed a method of tracking seed dispersal of oaks by Eurasian Jays (*Garrulus glandarius*), by placing nanotag transmitters (model NTQB-1; Lotek Inc.) inside hollowed out acorns in Europe. This method was subsequently validated for Blue Jays in North American oaks by Sipes et al. (2013). Following these studies, we will establish a feeding platform within each 5-ha plot, with baffles to exclude mammalian species. We will place both tagged (n= 10 per plot) and untagged chestnuts and acorns on the feeder in September of each year. We will check the feeders every 1-2 days. When tagged seeds are removed we will systematically search the area in concentric circles from the feeder until we find either the cached acorns, or the remains of consumed ones. We will also monitor feeding stations from at least 25 meters for 7 hours per week in order to record visual removal and subsequent dispersal of seed both tagged and untagged from the feeding stations. We will then measure the proportion consumed and the distance dispersed for caches. At the cache location we will monitor if any seed are consumed and quantify physical location of the cache site (including depth of seed deposition, leaf litter volume, light levels reaching the forest floor). Based on these metrics we will also replicate these physical conditions and plant seed of oak and chestnut that will be enclosed in predator proof guards to quantify germination success. These trial plantings will be paired with random placement of seeds within 20 meters of the initial cache site.

Blue Jay tagging - During the post-breeding period, we will use feeding stations baited with peanuts to trap both juvenile and adult jays in bow-net traps. By marking a representative sample of individuals we will be able to quantify spatial and temporal distribution of birds and will be essential to relate our feeding trials to the distribution and density of birds. Each tagged bird will be fitted with a USGS numbered aluminum band and a unique combination of 3 colored plastic bands, such that individuals can be distinguished. We will affix a 1.5 gram (<3% of body mass) digital nanotag transmitter (model NTQB-6-1; Lotek Inc.) to 20 adults and 20 juveniles in each year of the study. Tags will be attached using a leg-loop harness (Rappole and Tipton 1992). We will also collect data on body size (wing chord), body mass, age, and a feather for DNA sexing in Tonra's lab in Kottman Hall. Using body mass and body size we will be able to estimate body condition using scaled mass index (Peig and Green, 2009), which removes variation in mass due to structural size.

Limitations and potential pitfalls

Our field methods for tracking, in particular detecting dispersed seeds, may be limited if dispersal distances are very large (as search area would need to increase exponentially). However, (Sipes *et al.*, 2013) found distances of Blue Jay dispersal be small enough that they detected >85% of all tagged acorns. We will be relying on natural variation in acorn crop to produce the predicted variation in Blue Jay survival, which could be a pitfall if variation in the former is low. However based on long term data from Ohio Division of Wildlife, over the past 10 years , variation has been substantial on an every-other year basis, thus we expect we can count on substantial fluctuation during the study. We will be limited in our ability to control the density of Blue Jay during our feeding trial. However, as part of the broader study we will be tracking individuals Blue Jay movements and can account for density and activity of Blue Jays throughout our study area as well as being able to utilize these data to locate additional cashing locations.

E. REFERENCES

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Siepielski, A. M., Benkman, C. W. 2008. A seed predator drives the evolution of a seed dispersal mutualism. Proceedings of the Royal Society B: Biological Sciences 275(1645): 1917-1925.

Sipes, A.R., Lichti, N.I., Swihart, R.K., 2013. Acorn germination is not enhanced near cache sites relative to random locations. Canadian Journal of Zoology-Revue Canadienne De Zoologie 91, 529-532.

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H Timeline

Activity	2018 SU	AU	2019 WI	SP	**SU**	**AU**
OBJ 1:Seed Choice Trial	x	x	x	X	X	
Establishment of field sites and materials	X	X			X	
Data collection-Seed trials and Bird tracking		X	X	x	X	
Survival data analyses				X	X	
OBJ 2: Dispersal and germination opportunity		X	X	X	X	
Data collection-acorn caching		X	X	X	X	
Caching data analyses			X	X	X	
Submit manuscripts					X	x
Prepare final project report					x	x

I How results will be measured and reported

The primary aim for the project will be to prepared a peer-reviewed manuscript presenting the results of the project. We also will engage in outreach via presentations and reports to disseminate the important interactions and mutualisms between blue jays and seed producing trees.

J Budget narrative

The funds requested will provide needed personal to manage the experimental trial and to purchase tags to track chestnut seed dispersal. Other contributing funds that will be essential to the project were recently secured to conduct the core study of the mutulisam between oak and blue jay. These contributing funds of $49,000 will support a graduate student, travel funds for conducting the research and field supplies to monitor blue jay and acorns. The funds requested here will allow us to add an important chestnut component to the project and provided needed information about the ability of blue jays to distribute seed across the landscape. In addition, the PIs are also committing to supplement up to an additional 10 tags

($1,700) that can be used to mark additional chestnuts to increase power of the dispersal trials for chestnut.

PERSONNEL	COST	F&A Rate	F&A	COST + F&A
Res Assistant (temp Salary 2.5 months @ $1,600/month)	4,000	0%	0.00	4,000
Fringes (12.7%)	508	0%	0.00	508
Subtotals	**4,508**		**0.00**	**4,508**
Supplies				
Twenty Lotek nano tag ($170 each) for tracking Chestnuts dispersal	3,400	0%	0.00	3,400
Subtotals	**3,400**		**0**	**3,400**
Totals	**7,908**		**0**	**7,908**

K Brief CV (2 pages each)

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Education

Ph.D., Biology, Dec 2011, **University of Maine**, Orono, ME
  Advisors: Dr. Rebecca Holberton and Dr. Peter Marra

M.S., Wildlife Biology, May 2006, **Humboldt State University**, Arcata, CA
  Advisor: Dr. Matthew D. Johnson

B.A., Anthropology, May 1999 **State University of New York, Albany**, NY

Research interests: conservation biology, physiological ecology, behavioral ecology, population biology, stable isotope ecology, animal migration, habitat ecology

Appointments and Awards

Asst. Professor, School of Environment and Natural Resources, The Ohio State Univ. (2014-present)

George Didden Conservation Biology Fellowship, Smithsonian National Zoo (2014)

Post-doctoral Fellowship, Smithsonian Conservation Biology Institute (2012)

Outstanding Student Research Presentation Award, American Ornithologist Union (2011)

Graduate Prize in Animal Biology, University of Maine School of Biology and Ecology (2011)

Research Assistantship, University of Maine School of Biology and Ecology (2007-2010)

Teaching Assistantship, Humboldt State University Dept. of Wildlife and Dept of Biology (2004-2006)

Fellowships and Grants

Ohio Sea Grant, *Emerald ash borer tree mortality and invasive species penetration into forested wetlands in the Lake Erie coastal zone: developing habitat restoration priorities*, $9,933 (2016)

Columbus Audubon Society, *Thinking inside the box: Evaluating the relative value of natural vs. artificial cavities in habitat patches of varying size for Prothonotary Warblers*, $5,000 (2016)

U.S. Fish and Wildlife Service, *Stopover Ecology and Migratory Connectivity of the Rusty Blackbird (Euphagus carolinus)*, $10,000 (2016)

Ohio Division of Wildlife, *Responses of colonial wading bird populations within the Lake Erie Marsh Focus Area to cormorant control and wetland management*, $237,482 (2015, 2016)

Ohio Division of Wildlife: *Population ecology and habitat relationships of Sora and Virginia rails in northwestern Ohio*. Amount received: $158,311 (co-PI, PI: Bob Gates; 2015-2016)

<u>Peer-reviewed Publications</u> *(* - indicates undergraduate author*)

13. Tonra, C.M., K. Sager-Fradkin, and P.P. Marra. 2016. Barriers to salmon migration impact body condition, offspring size, and life history variation in an avian consumer. **Ecography** DOI: 10.1111/ecog.02014
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11. Marra, P.P., E.B. Cohen, S.R. Loss, J. Rutter, and C.M. Tonra. 2015. A call for full annual cycle research in animal ecology. **Biology Letters** 11: 20150552.
10. Tonra, C.M., C. Both, and P.P. Marra. 2015. Incorporating site dependence and year-specific deuterium ratios (δ^2H) from precipitation into geographic assignments of a migratory bird. **Journal of Avian Biology** 46: 266-274.
9. Tonra, C.M., K.L.D. Marini*, P.P.Marra, R.R. Germain, R.L. Holberton, and M.W. Reudink. 2014. Color expression in experimentally regrown feathers of an overwintering migratory bird: implications for signaling and seasonal interactions. **Ecology and Evolution** 4: 1222-1232.
8. Tonra, C.M., P.P. Marra, and R.L. Holberton. 2013. Experimental and observational studies of seasonal interactions between overlapping life history stages in a migratory bird. **Hormones and Behavior** 64: 825–832.
7. Croston, R.*, C.M. Tonra, S.K. Heath, and M.E. Hauber. 2012. Flange color differences in brood parasitic Brown-headed Cowbirds from nests of two host species. **Wilson Journal of Ornithology** 124: 139-145.
6. Tonra, C.M., P.P. Marra, and R.L. Holberton. 2011. Early elevation of testosterone advances migratory preparation in a songbird. **Journal of Experimental Biology** 214: 2761-2767.
5. Tonra, C.M., P.P. Marra, and R.L. Holberton. 2011. Migration phenology and winter habitat quality are related to circulating androgen in a long-distance migratory bird. **Journal of Avian Biology** 42: 397-404.
4. Angelier F., C.M. Tonra, R.L. Holberton, and P.P. Marra. 2011. Short-term changes in body condition in relation to habitat and climate in American redstarts during the non-breeding season. **Journal of Avian Biology** 42: 355-341.
3. Angelier F., C.M. Tonra, R.L. Holberton, and P.P. Marra. 2010. How to capture wild passerine species to study baseline corticosterone levels. **Journal of Ornithology** 151: 415-422.
2. Tonra, C.M., M.D. Johnson, M.E. Hauber, and S.K. Heath. 2009. Does nesting habitat influence hatching synchrony between brood parasitic brown-headed cowbirds (*Molothrus ater*) and two hosts? **Ecography** 32: 497-503.
1. Tonra, C.M., M.E. Hauber, S.K. Heath, and M.D. Johnson. 2008. Ecological correlates and sex differences in early development of a generalist brood parasite. **Auk** 125: 205-213.

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Professional Preparation

2004-2008	Ph.D., Natural Resources, Ohio State University, Columbus, Ohio
2000-2003	M.S., Wildlife Ecology, University of Maine, Orono, Maine
1993-1997	B.S., Wildlife Biology, Frostburg State University Frostburg, Maryland

Professional appointments

2014-	The Ohio State University	Assistant Professor
2011-2014	The Ohio State University US Forest Service, Ohio	Research Assistant Professor
2008-2011	The Ohio State University US Forest Service, Ohio	Post-Doctoral Researcher

AWARDS

U.S. Department of Agriculture Forest Service Chief Award, 2016
U.S. Department of Agriculture Forest Service Certificate of Merit, 2007
Student Travel Award, American Ornithologists' Union, 2006
Outstanding Wildlife Ecology Graduate Student Award, University of Maine, 2003
Howard Mendall Memorial Award, Department of Wildlife Ecology, University of Maine, 2002

PUBLICATIONS

Selected Journal peer-reviewed (* represent graduate student advisee articles)

Matthews, S.N. and Iverson, L.R. 2016 Managing for Delicious Ecosystem Service Under Climate Change: can United States Sugar Maple (Acer saccharum) Syrup Production be Maintained in a Warming Climate? International Journal of Biodiversity Science, Ecosystem Services & Management. In press

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Education:

University of Tennessee, Knoxville, TN, Natural resources Ph.D., 2011
Yale School of Forestry and Environmental Studies, New Haven, CT, Master of Forestry, 2008
Oberlin College, Oberlin, OH, Biology, B.A., 2003

Professional Experience:

2014 to present: Research Ecologist, USDA Forest Service, Northern Research Station, Delaware, OH
2012-2014: Research Fellow, The Pinchot Institute for Conservation, Milford, PA
2011-2012: Postdoctoral Fellow, The University of Tennessee, Knoxville, TN
2008-2011: Graduate Teaching Assistant, The University of Tennessee, Knoxville, TN
2006-2008: New England Regional Science Coordinator, The American Chestnut Foundation, New Haven, CT
2004-2005: Research Technician, University of Tennessee Tree Improvement Program, Grand Junction, TN

Grants Received:

2017: Forest Service State and Private Forestry funding opportunity, 2017. Developing a framework for restoring American elm along the urban-rural gradient in the United States. $190,000. Co-investigator.
2017: Region 9/Northeastern Area/Northern Research Station Youth Engagement Funding Request, 2017. Invasive shrub removal and restoration of degraded urban riparian forests. $4,633. Co-investigator.
2016: Planting American Chestnut Trees in National Forests. Submitted by The American Chestnut Foundation. Funded by the National Forest Foundation in the amount of $4,807. Collaborator.
2015: Defining methods for reintroducing American chestnut to oak-hickory forests of the Allegheny Plateau. Funded by The American Chestnut Foundation in the amount of $1,650 in 2015 and $5,200 in 2016. Co-investigator.
2015: Restoring Dutch elm-disease tolerant American elm in the Eastern United States. Funded by the Manton Foundation in the amount of $1,432,609. Co-investigator.

Selected Publications:

Pinchot C.C., Schlarbaum S.E., Clark S.L., Saxton A.M., Sharp A.M., Schweitzer C.J., Hebard FV. 2017. Growth, survival, and competitive ability of chestnut (Castanea Mill.) seedlings planted across a gradient of light levels. New Forests *in press*.
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L. Conflict of interest

The PI's do not have any conflict of interests for the proposed study.