Title: Identifying and Targeting Intervention Strategies for Allegheny Woodrat (*Neotoma magister*) Recovery

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Abstract: Allegheny woodrats (*Neotoma magister*, NEMA) are experiencing a protracted decline in the northern half of their range. These declines are, in part, rooted in the concomitant loss of American chestnut trees (*Castanea dentata* (Marsh.) Borkh.), as well as other mast producing species such as butternut (*Juglans cinerea* L.), and gypsy moth impacts on oaks (*Quercus* L.). In addition, limited availability of hollow trees for den sites outside of the woodrats primary foraging areas may increase interactions with raccoons, which are hosts for a pathogenic raccoon roundworm (*Baylisascaris procyonis*) known to cause woodrat mortality. Woodrat populations have been evaluated on an annual and semi-annual basis in Pennsylvania since 1982 and Maryland since 1990, providing valuable insights into dynamics over a 25-year period at extant and extirpated sites. The relationships between woodrat population dynamics and abiotic forest conditions and biotic pathogen loads have been speculated, but there have been few long-term studies to address these speculations. We propose a two-tiered study that will: 1. Determine interactions between woodrat populations and forest dynamics using dendrochrology, mast production data, and inventories; 2. Evaluate the occurrence and distribution of raccoons using remote camera, raccoon latrine prevalence, and incidence of raccoon roundworm parasite load in raccoon feces. Direct impacts of this study will be a targeted assessment of the highest need areas for management intervention. Forest inventories will determine locations where supplemental plantings of mast producing species will be the most beneficial. Evaluation of raccoon activity patterns and parasite load will result in areas in greatest need of dispersion of Ivermectin bait stations.

Project Description:

a. **Priority RCN Topic 5:** Design and Implement Conservation Strategies for NE Species of Greatest Conservation Need. Alleghany Woodrat.
b. **States Involved:** This project will be conducted in Maryland, Pennsylvania, and New Jersey.
c. **Date:** The start date is January 1, 2016 and will extend until December 31, 2017
d. **Goals, objectives, and tasks:**

Goal 1: ***Identify and target areas where supplemental plantings of mast producing trees would most benefit woodrat populations.***

Allegheny woodrats (*Neotoma magister*, NEMA) are experiencing a protracted decline in the northern half of their range. Consequently, they are regionally extinct in CT, MA, NY and DC. A single population exists in NJ. They are listed as state-endangered in IN, OH, MD, NJ and NY; state-threatened in PA; and declines have also been documented in VA and WV (Natureserve 2014). Forest compositional changes from exotic pests and pathogens have decimated populations of American chestnut (*Castanea dentata* (Marsh.) Borkh.), butternut (*Juglans cinerea* L.), and oak species (*Quercus* L.). Reduction of these mast-producing hardwood species has particularly severe consequences in the northeast on food supply of the Allegheny woodrat, whose populations are already severely impacted by other ecological factors. Restoration protocols for reintroduction plantings of American chestnut are in development throughout the Appalachian region and our project will prioritize woodrat sites in which planting chestnuts would have the greatest potential to increase the quality of the woodrat habitat.

We propose to examine ecological factors associated with Allegheny woodrat sites (extant and extirpated) and to use these data to prioritize supplemental planting of mast producing species including blight-resistant American chestnuts and butternuts to sites with the greatest potential for benefiting woodrat conservation. Hoffman (2010) indicates optimal Allegheny woodrat habitat is characterized by a high diversity of hard mast trees within an intact forest landscape. In addition, Hoffman (2010) states that habitat sites with lower-hard-mast-tree diversity could be improved by planting additional hard mast tree species to buffer the effects a mast failure could impose on woodrat populations. Our project will link Allegheny woodrat population dynamics over the past 25 years to availability of food sources using dendrochronology, mast production data for wildlife agencies, and forest inventories.

Objective 1: To determine relationships between Allegheny woodrat populations status across PA, MD, and NJ in relation to forest conditions on extant and extirpated sites using:

a) mast production data from wildlife agencies;
b) forest assessment at woodrat sites:
    i. dendrochronological assessment for the past 25 years and
    ii. current mast densities, crown condition and vigor of mast producing trees

Goal 2: ***Identify and target woodrat colonies most vulnerable to infestation by the raccoon roundworm.***

Mortality risks for woodrats also are associated with raccoon roundworm parasite load and mammalian predators. Remote cameras will be used to evaluate the occurrence and distribution of raccoons and other potential mammalian predators of woodrats. The occurrence and density of raccoon latrines will serve as another index. Scats collected from latrines will be examined to determine the extent at which raccoons are infected with raccoon roundworm (B. Roundworm is suspected, but not verified, at one of the largest remaining woodrat locations in Pennsylvania, the Chestnut Ridge Complex which includes the Youghiogheny River. Roundworm has been verified at sites in both New Jersey and Maryland.

Objective 2: To prioritize areas in greatest need of dispersion of Ivermectin using bait stations and long-term forest management practices by determining the following:

i. raccoon occurrence and distribution at woodrat sites using trail cameras;
ii. raccoon latrine prevalence; and
iii. incidence of raccoon roundworm (*Baylisascaris procyonis*) parasite load.

e. **Methods:**

Woodrat Population

Populations of woodrats have been the subject of ongoing monitoring in PA since 1982, and MD and VA since 1990 (Wright 2008 & Mengak et al. 2008). Sites in Maryland include the following locations which have been monitored frequently over the past 25 years by Dan Feller. Monitored annually are sites at Savage River State Forest's High Rock Area in Garrett County, Dan's Mountain Wildlife Management Area and Fort Hill Nature Conservancy Preserve in Allegany County. Every other year the following locations also have been monitored: Indian Springs Wildlife Management Area in Washington County and Frederick City Watershed in Frederick County. Additional, possibly historic sites, have not been monitored in over 10 years including Potomac State Forest in Garrett County and the Outdoor Club Barren, Green Ridge State Forest Town Hill, and Narrows Park in Allegany County. Maryland has a total of 31 potential active sites which will be visited, many of which haven't been monitored in several years. In Pennsylvania, we will partner with Greg Turner and Jerry Hassinger with the on-going Mammal Atlas project data. In NJ there are four historic sites (Valent 2003). The single remaining site in the Hudson Palisades has been monitored periodically since 1987 and contacts approximately 20-30 individuals (New Jersey Department of Environmental Protection 2005). Sites in New Jersey have been negatively impacted by raccoon roundworm (LoGiudice 2008). We will collaborate with Gretchen Fowles, Kathleen LoGuidice, and Randy Fitzgerald in New Jersey. The lack of interstate collaboration has been noted as an obstacle for conservation (Wright 2008) and our aim is to assist in facilitating future collaborations among all states within the range.

Data from inactive and active woodrat sites and populations surveys over the past 25 years provide valuable information on population stability and will be used as critical long-term information for incorporation into this project. Supplemental live-trapping at a selected sample of woodrat sites (n = ~5 active sites/state with paired historic sites, where available) have provided population assessments through mark-recapture, gender ratios, juvenile/sub-adult/adult ratios, weight, and reproductive condition. Woodrats were uniquely marked for identification of individuals using tattoos for subsequent recaptures. Camera traps will be used for ongoing monitoring of persistence and activity patterns of woodrats among seasons. In Pennsylvania, the Mammal Atlas project has sites state-wide with camera traps.

Goal 1: ***Identify and target areas where supplemental plantings of mast producing trees would most benefit woodrat populations.***

a) Several mast inventories will be used to collect current and historic data on mast production near woodrat sites. In Maryland, mast production data is collected by the Wildlife and Heritage Service within the Department of Natural Resources. The wildlife agency annually monitors the number of acorns on branches from both black (red) and white oak groups. Several of these oak monitoring sites are near woodrat populations. For example, mast production data has been collected from the Fishing Creek area of the City of Frederick Watershed near an active woodrat location. In Pennsylvania, Pennsylvania Game Commission and Department of Conservation and Natural Resources Bureau of Forestry were asked to rate the abundance and productivity of 28 fruit and nut bearing plants during 2006, 2008, 2011, and 2012 (Ternent and Kibe 2013). Additional mast analysis will use techniques described in Abrams et al. (2013).

b) Forest inventories will be completed on both active and inactive woodrat sites. Though woodrats may forage as far as 300-400 m from nest sites, typical foraging is within 100 m of the edge of outcrops. Sites for forest inventories will include nested plots within 100m, 200m, and 300m from nest sites. Dendrochronological assessment will determine tree vigor and evidence of last spring frost, for the past 25 years and related to available data on mast production. Sites will be evaluated for basal area, stems per acre, and species composition using SILVAH oak protocols (Brose et al. 2003). Dominant mast producing trees will be evaluated for crown vigor as it relates to mast production and impact of gypsy moth defoliation and placed into productivity classes (Bellocq et al. 2005). Crowns classification will be determined using the United States Forest Service Inventory and Analysis protocols. Acorn traps and exclusion cages will also be placed at study sites to quantify acorn production and

predation by mammals (Bellocq et al. 2005). Acorns will be sorted by red and white oak grouping and floated to determine viability (Olsen 1974). Woodrat populations will be correlated to mast crop years (after Mengak and Castleberry 2008). Potentially important food sources will also be monitored including hickory (*Carya* spp. Nutt.), mountain-ash (*Sorbus americana* Marshall), and other species. Data on surviving American chestnut seedlings will be collected in conjunction with Sara Fitzsimmons, Regional Science Coordinator for the American Chestnut Foundation. Butternut trees will be evaluated for relative disease condition based on existing protocols.

Goal 2: ***Identify and target woodrat colonies most vulnerable to infestation by the raccoon roundworm.***
i. A minimum of 5 trail cameras will be placed be dispersed within 200m of active woodrat sites from September-November for a total of 10-14 trap nights per camera. To avoid attracting raccoons or other predators to woodrat sites, cameras will not be baited. Instead cameras will be placed along trails or other "natural" travel-ways (for raccoons and other predators) adjacent to woodrat sites. The actual number of cameras used may vary (always greater than or equal to 5 per site) in an adaptive manner based on the size and complexity of each woodrat site. The number of cameras per site will be based partially on the size of the site to have an equal camera density among woodrat sites. Although the focus is on raccoons, we also will use cameras to assess the occurrence of other potential predators of woodrats and trails sets generally will facilitate this goal.

ii. We will use occupancy modeling to portray likelihood of a woodrat site being occupied by raccoons (and other predators) and incorporate probability of daily detection per site and per camera as an index of raccoon (and other predator) density for comparison among sites.

iii. Extirpated sites in Ohio were positively correlated with the presence of *B. procyonis* positive raccoon scats, whereas, raccoon scat at extant sites were *B. procyonis* negative (Mollohan and LeCount 2004). In releases survival rates were higher in areas in areas categorized as low exposure sites and lowest in low compared to high exposure sites which were heavily used by raccoons and contained many infected feces (LoGiudice 2008). Fall sampling is idea to catch the highest egg shedding potential (Page et al. 2005). In addition latrine analysis is more effective than fecal analysis (Page et al. 2005). Preferentially sampling latrines, rather than single scats, reduced the possibility of inadvertently sampling opossum scats rather than raccoon scats.

Raccoon scats will be collected from raccoon latrines at woodrat sites during September-November. We will use time searches at each site for specific hours and use research expertise for identifying latrines. We will evaluate the bases of large tree, flat rocks surfaces, and fallen logs. Disposable gloves will be worn and all scat will be double-bagged and grabbed with the bag inside out and sealed. These samples will be stored at −20°C prior to being examined for the eggs of the raccoon roundworm. Roundworm eggs will be identified by microscopic examination following centrifugal fecal flotation in Sheather sugar solution (Kazacos 2001). We will identify eggs as those of the raccoon roundworm based on size and morphologic appearance. From this identification, each sample will be classified as positive or negative. Prevalence will be portrayed as frequency of occurrence of eggs per sample, per woodrat site, and samples per woodrat site.

f. **Products and Outcomes:**

- **Goal 1.** ***Identifying and targeting areas where supplemental plantings of mast producing trees would most benefit woodrat populations.***—We will provide a priority ranking of Allegheny woodrat sites for enrichment plantings of mast producing species, including blight-resistant American chestnuts. Areas will be identified based on: 1) the historical assessment of mast-production surveys; 2) forest inventories; 3) dendrochronology; and 4) associations among these forest parameters and status of associated woodrat populations. From these assessments we will define areas and types of tree plantings that will provide the greatest benefit to woodrat populations. Information from forest inventories will also be used to influence forest management decisions near these sites. This would include management activities such as crop tree release of oak and hickory species or controlled burning to reduce the prevalence of red maple.

- **Goal 2.** ***Identifying and targeting woodrat colonies most vulnerable to infestation by the raccoon roundworm***.—Our study will be the first to document raccoon and other mammalian predator activity in active woodrat habitat in relation to forest habitat conditions. Of particular concern is the potential for raccoons to transmit raccoon roundworm to woodrats. Identifying woodrat colonies with high raccoon populations and those where raccoons have high incidences of raccoon roundworm infestation will focus efforts to mitigate the potential adverse effects of the roundworm on woodrat populations. Specifically, raccoons will be targeted for treatment with Ivermectin in areas where their populations high and individuals are frequently infected with the raccoon roundworm. Forest management decisions can be evaluated in areas with high raccoon densities to reduce forest fragmentation near woodrat sites and to increase the number of large den trees at sites outside of the primary foraging area.

We aim to develop specific protocols to assist in regional collaborations. We will develop methods for camera investigates of raccoon activity in woodrat sites without the use of bait and methods for scat analysis. Developing specific site evaluation criteria should assist in prioritizing sites at highest risk to extirpation.

Results from this project will also be used to leverage additional external funding for various related projects from State Wildlife Grants, PA Wild Resources Grants, US Forest Service, State and Private Forestry, the American Chestnut Foundation, and other funding sources. Outcomes will be presented at the fall meeting of the Northeast Fish and Wildlife Diversity Technical Committee (NEFWDTC) in September 2017 and the annual Northeast Fish & Wildlife Conference in April 2018. Additional presentations and posters will be presented at the Maryland/Delaware Chapter meetings of The Wildlife Society. Additional possible presentations include the American Society of Mammologist, National Ecological Observatory Network's Small Mammals Technical Working Group, The American Chestnut Foundation's Annual Meeting, The Society for Conservation Biology, and the Ecological Society of America depending on meeting locations.

Allegheny woodrat decline throughout the Appalachians has been attributed to reduced food supply, weather, an increase in great horned owl predation, and lethal infestation by raccoon roundworm. Current thinking is that a suite of stresses may be acting together. Maryland and Pennsylvania have a vast resource of long-term monitoring of the species that has yet to be analyzed and associated with existing additional data. Many sites in both of these states are in need of monitoring to determine their present status. Our proposed study will integrate long-term data sets to determine relationships and links to various forest dynamics including food availability identify areas where planting of supplemental mast producing are likely to benefit woodrat populations. We will also aid in developing and enhancing processes of minimizing the transmission of raccoon roundworm to woodrats. This integrated approach will add considerably to understanding factors contributing to woodrat population declines, but more importantly devise approaches that have potential to mitigate or revers these declines.

g. **Budget:**

	Project Budget		Academic Year Effort	Summer Effort	Total Salary	Total Benefits	RCN Request	FSU Cost Share
FSU Personnel: Ten-month appointment (faculty)								
	Sunshine Brosi	2016	10%	40%	11,818	2,822	6,226	8,414
		2017	10%	40%	11,818	2,822	6,226	8,414
	Tom Serfass	2016	30%*	40%	22,681	4,498	9,244	17,935
		2017	30%*	40%	22,681	4,498	9,244	17,935
			* Spring semester					
Penn State Altoona Personnel: Ten-month appointment (faculty)								
	Carolyn Mahan	2016-2017			2,928	234	3,162	0
MSU Personnel: Ten-month appointment (faculty)								
	Randy Fitzgerald	2016-2017			1,300		1,300	1,056
Student Personnel								
	Graduate Students (2)	2016	50%	100%	6,000	480	6,480	9,500
		2017	50%	100%	6,000	480	6,480	9,500
	Undergraduate Students (2)	2016			6,000	480	6,480	0
		2017			6,000	480	6,480	0
Total Personnel					97,227	16,794	61,322	74,867
Travel								
	DOMESTIC - Site visits, project required conferences						6,000	0
Other Direct Costs								
	Materials & Supplies						5,000	0
Total Direct Costs							72,322	72,755
Indirect Costs (38%)							27,482	27,647
Total Costs							**99,804**	**100,402**

Qualifications of Individuals and Organizations:

Frostburg State University

Sunshine L. Brosi is an associate professor of forest ecology. She has extensive experience in monitoring forests, butternut, and chestnuts, experience in dendrochronology, and GIS. She has five years of experience in woodrat monitoring.

Tom Serfass has extensive experience with detecting and monitoring mammalian predators and contributed to a chapter in *The Allegheny Woodrat*, 2008.

Penn State, Altoona, Carolyn Mahan has extensive experience in monitoring small mammalian populations across forest composition and has evaluated parasites in scat samples.

Maryland DNR Natural Heritage, Dan Feller, Regional Ecologist, has monitored woodrat populations in western Maryland since the early 1990s. Dan has an extensive data set on population dynamics and is experienced in trapping and handling woodrats. Dan has two publications on woodrats including a chapter in *The Allegheny Woodrat*, 2008. He has 25 years of small mammal research experience.

PA Game Commission Bureau of Wildlife, Greg Turner is the Endangered Mammal Specialist and has extensive experience trapping and handling small mammals including woodrats.

Pennsylvania DCNR, Tom Hall has surveyed and inventoried forest health including butternuts and chestnuts throughout Pennsylvania.

Montclair State University, Randy Fitzgerald is an associate professor of environmental studies. Randy has experience with small mammal populations in New Jersey and the use of cameras for monitoring populations.

NJ Endangered & Nongame Species Program, Gretchen Fowles is a GIS Specialist and biologist and has experience with woodrats and bobcats in New Jersey. Gretchen has experience with scat sampling, the use of cameras for monitoring populations, and GIS modeling.

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