INVESTIGATOR'S ANNUAL REPORT

United States Department of the Interior

National Park Service

All or some of the information you provide may become available to the public.

OMB # (1024-0236)
Exp. Date (11/30/2010)
Form No. (10-226)

Reporting Year:	**Park:**	**Select the type of permit this report addresses:**
2009	Shenandoah NP	Scientific Study

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Project Title (maximum 300 characters):

How are arthropod communities affected by varying deer densities?

Park-assigned Study or Activity #:	**Park-assigned Permit #:**	**Permit Start Date:**	**Permit Expiration Date:**
SHEN-00351	SHEN-2008-SCI-0010	May 19, 2008	Dec 31, 2009

Scientific Study Starting Date:	**Estimated Scientific Study Ending Date:**
May 19, 2008	Dec 31, 2009

For either a Scientific Study or a Science Education Activity, the status is:

Completed

For a Scientific Study that is completed, please check each of the following that applies:

__ A final report has been provided to the park or will be provided to the park within the next two years

__ Copies of field notes, data files, photos, or other study records, as agreed, have been provided to the park

__ All collected and retained specimens have been cataloged into the NPS catalog system and NPS has processed loan agreements as needed

Activity Type:

Research

Subject/Discipline:

Animal Communities / Wildlife

Purpose of Scientific Study or Science Education Activity during the reporting year (maximum 4000 characters):

In the wake of the white-tailed deer (Odocoileus virginianus) recovery from near extinction in the early 1900â s forest ecosystems are faced with severe browsing pressure from a high abundance of white-tailed deer that is altering plant species composition, reducing diversity, and restricting forest regeneration. This study focused on the trophic cascade effects intense browsing has on the forest ecosystem at 3 sites to quantify the response of woody plant species, breeding birds, and arthropods. Each site is comprised of a 4

hectare deer exclosure, and paired with a 4 hectare open control plot

In forests with high deer density understory vegetation is dramatically reduced thus leaves that would have contributed to the leaf litter are removed from the system. Soil moisture is conserved by the leaf litter, creating a relatively moist microhabitat and substrate forage for arthropods and other invertebrates (Levings and Windsor 1985). Invertebrates living in the leaf litter are crucial components of decomposition and nutrient cycling, and in addition are an important food resource for secondary consumers (Dunham 2008).

Similarly, the invertebrates in the leaf litter should be negatively affected by a decrease in both primary productivity and leaf litter accumulation (Levings and Windsor 1985). A decrease in the invertebrate density could result in a bottom-up cascade affecting the passerine bird community. Most passerines require invertebrates for feeding their young in order to provide a high protein diet for rapid growth (Moreby and Stoate 2000). A reduction in the invertebrate population may decrease the foraging ability of passerines negatively affecting a brood pairâ s ability to successfully fledge young (Heaney and Monaghan 1995). Breeding birds can also be affected by the simplification of the understory vegetation structure by reducing cover for ground nesting birds and reducing perch space for male courtship and territorial displays.

I predicted that the exclusion of deer would release woody shrubs and trees from browsing pressure, resulting in an increase of woody species abundance and diversity. An increase in understory density coupled with greater leaf litter accumulation in the exclosures may provide a more productive habitat for the arthropod community. Therefore, I expect a greater density and biomass of arthropods inside the exclosures. Because most breeding birds require invertebrates to feed their young, coupled with a denser understory structure for cover, and perch availability for males to attract mates, I propose that as the substrate forage potential, and understory density increases, the diversity, and overall abundance of breeding birds will increase within the exclosures compared to the controls.

Woody species â ¥ 1 cm diameter at breast height (DBH) was inventoried to quantify species composition and densities. The age of trees was calculated from the DBH. Trees 18 years or older were estimated to have a DBH of at least 5 cm. The leaf litter arthropod community was surveyed from 10 randomly-selected non-repeating subplots within each 4 ha plot. All leaf litter within a 1 mÂ² area to a depth that includes the uppermost surface of the humus layer was collected monthly from June 2008 through October 2008. Arthropods were sorted into 6 taxa groups. Spiders (Araneae) â ¥ 0.5 mm, ants (Formicidae) â ¥ 0.5 mm, centipedes (Chilopoda) â ¥ 0.5 mm, millipedes (Diplopoda) â ¥ 0.5 mm, beetles (coleoptera) â ¥ 2, and all other arthropods â ¥ 2 mm were counted and weighed. Breeding bird census using the spot mapping method was conducted in all plots during the month of June through the first week of July when detection rates are stable and at their maximum in this region (Ralph et al. 1993; McDonald pers. com.).

Findings and status of Scientific Study or accomplishments of Science Education Activity during the reporting year (maximum 4000 characters):

I tested direct and indirect effects of high deer density in forest ecosystems. Statistical analyses were performed using program R (ver. 2.10.1) and SPSS (ver. 17.0). The independent variable for all analyses was the presence or absence of deer (two levels). I used NMDS with the Bray and Curtis dissimilarity metric to test woody stem density, and breeding bird diversity by presence / absence of deer matrix. P values are based on 999 permutations and alpha is set at 0.05. Data were cube root transformed to meet assumptions of sphericity and homogeneity of variances. I used a balanced model 1 (fixed effect) doubly-multivariate repeated measures two-way ANOVA to simultaneously test arthropod abundance (six levels) and biomass (six levels) as dependent variables.

NMDS ordination results showed a significant relationship between woody stem density and deer ($r^2 = 0.874$, $p = 0.001$). The stem density of shrubs (exclosure mean = 1233.55 stems per ha, control mean = 581.57 stems per ha), and saplings (exclosure mean = 1242.73 stems per ha, control mean = 471.38 stems per ha), were more than twice as abundant within the deer exclosures as in the controls. Woody vines (exclosure mean = 6.12 stems per ha, control mean = 18.37 stems per ha) were twice as numerous in the presence of deer. The stem densities of mature trees (exclosure mean = 691.77 stems per ha, control mean = 731.56 stems per ha) were similar in the presence or absence of deer. NMDS ordination results of breeding birds were strongly affected by site but not by deer or stem density.

The ANOVA indicated that arthropod densities were strongly affected by deer for the following taxa: spiders ($F = 31.599$, $df = 1, 38$, $p < 0.001$), beetles ($F = 5.597$, $df = 1, 38$, $p = 0.023$), centipedes ($F = 40.200$, $df = 1, 38$, $p < 0.001$), and millipedes ($F = 16.806$, $df = 1, 38$, $p < 0.001$). Biomass of spiders ($F = 21.386$, $df = 1, 38$, $p < 0.001$), and centipedes ($F = 20.318$, $df = 1, 38$, $p < 0.001$), were also significantly greater within the exclosures.

White-tailed deer are having a strong direct effect on woody species in forests. As predicted older trees that pre-existed the construction of the deer exclosures were not affected by deer presence or absence. In contrast, the marked difference in the number of younger trees and shrubs suggests that the browsing pressure by white-tailed deer at the current density is limiting forest regeneration. Although deer did not affect the breeding bird population it may be that sufficient time has not yet passed for successional changes between treatments to alter forest structure enough to affect forest breeding bird habitat preferences. Alternatively, the scale of the deer exclosure (four hectares) may be appropriate for vegetation and arthropods, but inadequate for studying birds that may perceive their environment on a larger scale. Similarly, arthropods do not appear to be influenced by top down forces from birds. Forest

understory density and litter abundance may be driving community changes in arthropod density and biomass. Preliminary analysis of leaf litter biomass suggests a greater decomposition rate in the presence of deer, resulting in a loss of substrate habitat. Results of forest woody species composition turnover, litter biomass, soil quality, and vesicular arbuscular mycorrhizae density as a response to white-tailed deer density are pending further analysis.

References:

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Heaney, V., and P. Monaghan. 1995. Proc. R. Soc. Lond. B 261, 361-365.

Levings, S. C., and D. M. Windsor. 1985. J. of A. Eco. 54:61-69.

Liemgruber, P. W., W. J. McShea, and J. H. Rappole. 1994. J. of Wild. Mgmt 58:254-260.

Moreby, S. J., and C. Stoate. 2000. Bird Study 47:320â 331.

Ralph, J. C., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Gen. Tech. Rep. PSW-GTR-144. Forest Service, U.S.D.A., 41 P.

For Scientific Studies (not Science Education Activities), were any specimens collected and removed from the park but not destroyed during analysis?
Yes
If "Yes", identify where the specimens currently are stored:
Arthropod specimens stored at Towson University, MD.

Funding specifically used in this park this reporting year that was provided by NPS (enter dollar amount):	**Funding specifically used in this park this reporting year that was provided by all other sources (enter dollar amount):**
$0	$0

List any other U.S. Government Agencies supporting this study or activity and the funding each provided this reporting year:

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