Available online at www.sciencedirect.com
ScienceDirect
Agriculture, Ecosystems and Environment 124 (2008) 229–236
Agriculture Ecosystems & Environment
www.elsevier.com/locate/agee

Habitat relationships of eastern red-backed salamanders (*Plethodon cinereus*) in Appalachian agroforestry and grazing systems

Breanna L. Riedel [a], Kevin R. Russell [a,*], W. Mark Ford [b], Katherine P. O'Neill [c], Harry W. Godwin [c]

[a] *College of Natural Resources, University of Wisconsin-Stevens Point, Stevens Point, WI 54481, USA*
[b] *USDA Forest Service, Northern Research Station, Parsons, WV 26287, USA*
[c] *USDA Agricultural Research Service, Appalachian Farming Systems Research Center, Beaver, WV 25813, USA*

Received 16 February 2007; received in revised form 3 October 2007; accepted 4 October 2007
Available online 19 November 2007

Abstract

Woodland salamander responses to either traditional grazing or silvopasture systems are virtually unknown. An information-theoretic modelling approach was used to evaluate responses of red-backed salamanders (*Plethodon cinereus*) to silvopasture and meadow conversions in southern West Virginia. Searches of area-constrained plots and artificial coverboards that were distributed across a gradient of agricultural conversion and grazing intensity, including hardwood silvopastures, hay meadows, forest edges, and reference forests yielded 2823 salamanders between May 2004 and November 2005. Salamander presence and abundance were positively associated with increasing cover of herbaceous vegetation and negatively associated with the intensity of agricultural disturbance. Although salamander presence and abundance appeared to be negatively influenced by agricultural disturbance when compared to reference forest conditions, the occurrence of red-backed salamanders within agriculturally modified habitats indicates this species may be more resilient to forest conversion than previously thought. This study suggests that herbaceous vegetation retained within some agricultural treatments, in combination with artificial cover, may at least partially mitigate the loss of forest canopy for red-backed salamanders.

Keywords: Appalachians; Agroforestry; Disturbance; Grazing; *Plethodon cinereus*; Red-backed salamanders

1. Introduction

Woodland salamanders of the family Plethodontidae are perhaps the most abundant vertebrates in the moist temperate forests of North America, with the density of red-backed salamanders (*Plethodon cinereus*) and other terrestrial plethodontids often exceeding 1–2 individuals/m^2 (Petranka, 1998). However, many woodland salamander species are restricted to moist and cool environments under downed coarse woody debris and rocks, or in burrows (Grover, 1998; Petranka, 1998). Because of these requirements, many species are associated with microhabitat characteristics indicative of mature and late-successional forests (deMaynadier and Hunter, 1995; Petranka, 1998). Multiple studies have suggested that clearcutting and other timber harvesting practices have caused long-term declines and localized extirpation of woodland salamanders from many southern Appalachian forests (citations in deMaynadier and Hunter, 1995; Russell et al., 2004a). However, there are data to indicate that salamander populations in both the southern and central Appalachians eventually recover from the effects of timber harvest, often within 5–24 years of cutting (citations in Russell et al., 2004a).

In the central Appalachian region, grassland management and pasture-based livestock production account for the majority of agricultural acreage and about 25% of the total regional land use (Buergler, 2004). If woodland salamander

* Corresponding author. Tel.: +1 715 346 2251; fax: +1 715 346 3624.
E-mail address: krussell@uwsp.edu (K.R. Russell).

0167-8809/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.agee.2007.10.001

populations decline at least temporarily after timber harvest, conversion of forests to grasslands and pastures presumably represents a more severe and permanent disturbance. Silvopastures are gaining increased attention as viable multiple-use agricultural systems for the Appalachian forested region (Buergler, 2004). In existing forests, silvopastures are created by heavily thinning stands followed by removal of woody debris and emergent rock to promote growth of herbaceous forage and livestock safety (Buergler, 2004). In contrast with selective harvest methods, however, complete removal of surface cover and direct disturbance from livestock grazing in silvopastures may limit suitability of these habitats for woodland salamanders. Therefore, the objective of this study was to determine how red-backed salamanders responded to traditional pasture and silvopasture treatments within the central Appalachian Mountains of southern West Virginia. The *a priori* expectation was that red-backed salamander responses to forest conversion would reflect the degree to which these treatments resulted in alterations of required microclimates and microhabitats (deMaynadier and Hunter, 1995; Russell et al., 2004a).

2. Methods

The study was conducted at the USDA Agricultural Research Service's Appalachian Farming System Research Center (AFSRC) near Beckley, in Raleigh County, West Virginia. The AFSRC occurs within the Allegheny Mountain and Plateau physiographic province of the central Appalachians (Riedel, 2006). All work was carried out at three AFSRC experimental farms. Reba (51 ha; 884-m elevation) and School (22 ha; 884-m elevation) Farms included woodlands, ungrazed meadows, and traditional pastures. Reba Farm also included silvopasture plots that were rotationally grazed. The third site, Peters Farm (21 ha; 841-m elevation), was the least intensively managed farm, with no livestock grazing. Data were collected within 13 sites distributed across the three farms that represented a continuum of forest conversion and grazing intensity: reference woodlands ($n = 3$), woodland edges ($n = 3$), silvopastures ($n = 3$), ungrazed hay meadows ($n = 2$), and grazed pastures ($n = 2$).

Reference woodland plots were $\geq$40 years old with no cutting for $\geq$25 years and no known history of grazing. Silvopastures were created from existing woodlands between 1997 and 2002 by reducing basal area (cross-sectional area of all overstory trees) from 19.1 m^2/ha to 6.7 m^2/ha. Ungrazed meadows and pastures had been converted from existing woodlands for $\geq$25 years, and pastures had been actively grazed for $\geq$5 years. Residual overstory trees on woodland and silvopasture plots primarily consisted of mixed mesophytic-Allegheny hardwoods (Riedel, 2006) dominated by sugar maple (*Acer saccharum*), red maple (*A. rubrum*), and black cherry (*Prunus serotina*). White oak (*Quercus alba*), black oak (*Q. velutina*), and blackgum (*Nyssa sylvatica*) occurred on the less mesic, somewhat drier aspects, whereas eastern hemlock (*Tsuga canadensis*) and rosebay rhododendron (*Rhododendron maximum*) dominated riparian areas. Ground cover of woodland plots consisted of herbaceous species, woody debris, and abundant emergent rock. However, essentially all woody debris and rocks were removed from silvopasture, meadow, and pasture plots. Common herbaceous or grassy species within pasture and silvopasture plots included cinquefoil (*Potentilla recta*), orchardgrass (*Dactylis glomerata*), ryegrass (*Lolium perenne*), tall fescue (*Festuca arundinacea*), and white clover (*Trifolium repens*).

Silvopastures were grazed by sheep at a density of 12–24 sheep/ha with a 5–7 day rotation and 25–35 day rest period. Traditional pastures at Reba farm were grazed by beef cattle at a density of 2.5 cattle/ha with a 3 day rotation and 27 day rest period, whereas pastures at School Farm were grazed by goats at a density of 7 goats/ha with a 2 week rotation and 30 day rest period. Ungrazed meadows and grazed pastures were mowed one and two times per year, respectively. Nitrogen–phosphate–potassium fertilizer (19–19–19) was applied to silvopastures and grazed meadows at a rate of 37 kg/ha/year. Ungrazed meadows were not fertilized during the study, although sulfur and lime historically had been applied to these sites for pH adjustment. Pesticide use was limited to applications of glyphosate herbicides along fence lines.

Between 2002 and 2004, arrays of 20 wood coverboards (Monti et al., 2000; Hyde and Simons, 2001) were established in each of the 13 sites. Because salamanders may avoid newly installed coverboards (Monti et al., 2000), arrays were established at least 1 month prior to data collection. Arrays at edge sites consisted of two rows of boards parallel to the woodland edge. One row was placed approximately 10 m inside and the other row an equal distance outside the woodland boundary. Each row consisted of 10 boards spaced approximately 15 m apart. A 4×5 grid of boards was established at each of the remaining 10 sites, with boards spaced approximately 15 m apart. Coverboards consisted of three white oak boards, with two boards on the bottom and one board placed on top for a total dimension of 30 cm × 46 cm × 5 cm. All surface debris was removed from under the boards so that each board lay flush against the topsoil.

Coverboards were checked weekly from 17 May to 10 August 2004, and then again 1–2 times monthly between September and December. In 2005, coverboards were checked once in March and April, weekly during 30 May–2 August, and then again monthly from September to November. Searches were performed during the day, and an attempt was made to check all boards over the course of 2 days to avoid time since rainfall effects. Salamanders were marked for individual recognition by toe-clipping or injecting a small amount of fluorescent elastomer (Northwest Marine Technology Inc., Shaw Island, WA, USA) at up