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Effects of Trails on Eastern Redback Salamander (*Plethodon cinereus* Green)

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Abstract. Human disturbance can have negative effects on terrestrial amphibian populations. Recent work suggests that trails in natural areas can have variable effects on terrestrial salamander abundances and distributions. We studied the effects of unmaintained and maintained trails on the abundance of different morphs (striped and unstriped) and age classes (adult and juvenile) of eastern redback salamanders (*Plethodon cinereus* Green) in a local biological reserve. Salamanders were found in higher abundances near a maintained trail for total salamanders, and for adult and juvenile striped salamanders. There was no relationship between the distance from the maintained trail edge and the abundance of adult or juvenile unstriped salamanders. In general, we found no significant relationship between salamander abundances and distance to an unmaintained trail (except for a weak positive relationship with the number of juvenile striped salamanders). Eastern redback salamanders may prefer habitat near maintained trails when microhabitats created by the clearing of recreational pathways are available (i.e., potentially higher amounts of cover objects). Our results suggest that forest habitat near maintained and unmaintained trails can provide suitable habitat for woodland salamanders, at least for the relatively low traffic trails we studied.

Keywords. Edge effects, habitat preference, human disturbance, *Plethodon cinereus*, trail maintenance

Introduction

Habitat loss and forest degradation pose significant threats to terrestrial amphibian populations (Fahrig, 2002; Marsh and Beckman, 2004). The elimination of continuous habitat, either through deforestation or the creation of roads or trails, is often associated with a significant decrease in habitat quality and an increase in edge effects, both of which have been found to negatively affect terrestrial amphibian populations (Murcia, 1995; deMaynadier and Hunter, 1998). In a landscape that is continually subjected to human activity, it becomes increasingly important to understand the implications of habitat disturbances for terrestrial amphibians, especially terrestrial salamanders, as they may serve as important indicators of both environmental and habitat quality (Welsh and Droege, 2001; Davic and Welsh, 2004).

Roads have been found to significantly affect the abundance and distribution of salamanders. In particular, salamanders tend to be less abundant near roads (deMaynadier and Hunter, 2000; Marsh and Beckman, 2004; Semlitsch et al., 2007). These effects appear to be related to abiotic conditions, such as soil moisture and cover object area, rather than food availability (Marsh and Beckman, 2004; Semlitsch et al., 2007; but see Marsh, 2007). The amount of traffic also appears to be important as gated roads have less of an effect on *Plethodon cinereus* Green abundance than ungated roads (Marsh, 2007). In addition, roads can act as a barrier to movement for terrestrial salamanders (e.g., Marsh et al., 2005; but see Gibbs, 1998).

Less is known about how walking trails, such as those used in recreational or natural areas, may impact terrestrial salamander populations. Davis (2007) found salamander abundance was greatest near trail edges, as vegetation and microhabitat availability was highest near these areas. Given that many natural areas or recreational areas frequently have trails running through otherwise good salamander habitat, we need a better understanding of how such trails may affect salamander populations.

We investigated the relationship between maintained and unmaintained trail edges and the abundance of eastern redback salamanders (*Plethodon cinereus*) in the Denison University Biological Reserve in Granville, Ohio. We predicted that salamander abundance would be greatest farther from trail edges. Furthermore, we predicted that maintained trails would have a more significant effect on salamander abundance than unmaintained trails since maintained trails would have a higher degree of human disturbance and potentially poorer habitat quality adjacent to the trail.

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Table 1. Results of multiple regressions for each group of *Plethodon cinereus*. Overall model r^2 values as well as slopes for each independent variable are given. NS = not significant; * = P < 0.05; ** = P < 0.01; *** = P < 0.0001.

Group	r^2 for Overall Model	Distance from Unmaintained Trail Edge	Distance from Maintained Tail Edge	Interaction between Unmaintained and Maintained Tails
Total Salamanders	0.282	0.002^{NS}	-0.015***	0.00005^{NS}
Adult Striped Salamanders	0.209	-0.003^{NS}	-0.009***	0.00005^{NS}
Juvenile Striped Salamanders	0.231	0.003*	-0.005***	$< 0.0001^{NS}$
Adult Unstriped Salamanders	0.009	0.0004^{NS}	-0.0003^{NS}	$< 0.0001^{NS}$
Juvenile Unstriped Salamanders	0.018	0.0003^{NS}	$< 0.00005^{NS}$	$< 0.0001^{NS}$

Materials and Methods

Our study site was located in Granville, Licking Co., Ohio on the Denison University Biological Reserve (40°05'00N, 82°31'05"W), in an area characterized by a mix of coniferous and deciduous forest. This three-week study was conducted in April 2010 and included one of two peaks in surface activity for *P. cinereus* in the study area, the other being in the fall (G.R. Smith, pers. observ.), thus the results of our study will likely reflect a typical response for this population. The study site consisted of 8 coverboard transects, each consisting of 21 cover board sites (each site had a pair of cover boards) separated by 3-4 meters, and running across a transition between an abandoned pine plantation and a beech-maple deciduous forest. At each cover board site, there was a new (≈ 2 years old) and an old (≈ 6-7 years old) cover board. Once per week, we checked for the presence of salamanders under cover boards, which served as an index of salamander abundance. We recorded the morph type (striped or unstriped), and age/size class (adult or juvenile differentiated based on size with adults > 3.5 mm SVL and juveniles < 3.5 mm SVL) for each salamander found. We also measured the distance from each cover board site to the nearest maintained trail and to the nearest unmaintained trail. For our analyses, we averaged the abundances of each morph type and age for each cover board site over the three weeks. We used multiple linear regressions with distance from unmaintained trail, distance from maintained trail, as well as their interaction as the independent variables for each group of salamanders (juvenile striped, adult striped, juvenile unstriped, and adult unstriped), as well as the total number of salamanders.

Results

We made a total of 421 salamander sightings across the three observation days. Total salamander mean abundance was significantly greater near the maintained trail (Table 1). Distance from the unmaintained trail edge and the interaction between the two types of trails were not significant (Table 1).

The mean abundance of adult striped salamanders was greater near the maintained trail edge (Table 1). Distance from the unmaintained trail edge and the interaction between the two types of trails had no effect on the mean abundance of adult striped salamanders (Table 1).

The mean abundance of juvenile striped salamanders near the maintained trail was significantly higher (Table 1). There were more juvenile striped salamanders farther from the unmaintained trail edge (Table 1). The interaction between the two types of trails had no effect on the mean abundance of juvenile striped salamanders (Table 1).

We found no significant relationships between mean abundance of adult unstriped salamanders and distances from either trail type or their interaction (Table 1). In addition, mean abundance of juvenile unstriped salamanders was unaffected by the distance from either trail type or the interaction term (Table 1).

Discussion

With respect to maintained trails, *P. cinereus* were found in higher abundances near the trail for total salamanders, and for adult and juvenile striped salamanders. Our results suggest that frequent human interference associated with maintained trail edges (e.g., pedestrian traffic, mowing) does not negatively affect the abundance salamanders in our study area. This contrasts with previous studies on the effects of roads that found a positive relationship between salamander abundance and the distance from road edges (deMaynadier and Hunter, 2000; Marsh and Beckman, 2004; Semlitsch et al., 2007). However, our results are consistent with another study on the effects of pedestrian trails on salamander abundances. Davis (2007) found more terrestrial salamanders near maintained trail edges, and suggested that this resulted from a greater availability of microhabitats along trail edges due to the clearing of fallen trees from recreational trail ways. Similarly, our study site is frequently maintained by maintenance personnel of the Denison University Biological Reserve, who remove all fallen trees from designated walking trails and place the debris along the sides of the trails. It is therefore likely that our study replicates the results of Davis (2007) in that salamander abundance was greatest along maintained trail edges, where microhabitat availability may be higher due to the clearing of trails.

Interestingly, there was no relationship between the distance from the maintained trail edge and the abundance of adult or juvenile unstriped *P. cinereus*. The lack of a relationship between the distance to trails in the unstriped morph compared to the striped morph suggests differential effects of the maintained trail on these two morphs. The unstriped morph of *P. cinereus* tends to be more associated with warmer habitats than the striped morph (Greer, 1973; Lotter and Scott, 1977; Gibbs and Karraker, 2006; Anthony, Venesky and Hickerson, 2008; but see Petruzzi, Niewiarowski and Moore, 2006), but they do not appear to have different preferences for other abiotic characteristics (e.g. soil moisture, relative humidity; Anthony, Venesky and Hickerson, 2008). Thus, the differences between these two morphs in their response to the maintained trails may reflect these ecological differences.

In general, we found no significant relationship between salamander abundance and distance to the unmaintained trail (except for a relatively weak positive relationship with the number of juvenile striped morph salamanders). This result suggests that unmaintained trails likely have little effect on salamanders. Indeed, the unmaintained trail was very narrow (≈ 0.5 m wide), and did not differ much from trails formed by white-tailed deer (*Odocoileus virginianus*) found throughout the biological reserve (G. Smith, pers. observ.). In addition, the unmaintained trail did not provide any supplementation of cover objects as happened along the maintained trail.

In conclusion, our results suggest that recreational trails traversing natural areas can alter terrestrial salamander abundances, probably by increasing microhabitat availability near the trails, which is in agreement with Davis (2007). However, our results suggest that the effect of recreational trails can vary within a population (e.g., between morphs), and perhaps also suggest that the effects of trails likely also vary among species of terrestrial salamanders; although additional study is needed. In addition, the trails we studied have relatively low foot traffic, with very few visitors using the trails. Additional studies examining the effects of recreational trails on other species of terrestrial salamanders, and examining the effects of traffic volume would be useful, and provide us with a better understanding of the consequences of such trails in natural or recreational areas.

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