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Influence of Topography on Local Distributions of *Plethodon cinereus* and *P. richmondi* (Plethodontidae) in Northern Kentucky and Southwestern Ohio

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ABSTRACT

In northern Kentucky and southwestern Ohio, the more drought-tolerant ravine salamander, *Plethodon richmondi*, generally occupied regions with steeper slopes while the red-backed salamander, *P. cinereus*, was located in areas with less relief. On each of six slopes where their ranges overlapped, a relatively higher proportion of *P. richmondi* occurred on the upper area of the slope where drier conditions predominate, and a relatively higher proportion of *P. cinereus* existed on the lower portion of the slope where moist microhabitats are more common. Within the range of *P. cinereus*, four isolated *P. richmondi* populations coexisted with *P. cinereus* on dry nose slopes. The local distributions of *P. cinereus* and *P. richmondi* are related to topographic features affecting soil moisture content.

INTRODUCTION

The geographic ranges of the red-backed salamander, *Plethodon cinereus*, and the ravine salamander, *P. richmondi*, overlap in eight states (Petranka 1998). However, the species usually are not syntopic in their areas of overlap (Highton 1972; Minton 1972; Pfingsten 1989a). Pfingsten (1989b), for example, reported that *P. richmondi* replaces *P. cinereus* in three eastern Ohio counties that contain some of the steepest slopes in the state. The purpose of my study was to investigate the influence of topographic features on the local distributions of the two salamanders in northern Kentucky and southwestern Ohio.

METHODS

From 1991 through 1997, I conducted spring and autumn searches for the presence of *P. cinereus* and *P. richmondi* (*P. electromorphus* sp. nov. according to Highton 1999) at 202 locations in Boone, Kenton, and Campbell counties in Kentucky, and in Hamilton and Butler counties in Ohio. In 1998 and 1999, I returned to six valleyside locations of sympatry and surveyed the salamander population at each as I ascended along a series of switchbacks from the streambank at the bottom to the ridge at the top. Salamanders were found by overturning all manageable surface rocks and fallen logs encountered during my ascent. The animals and cover objects always were returned to their original positions.

RESULTS AND DISCUSSION

Only *P. richmondi* populations were recorded from the rolling land in the unglaciated southern portion of the three Kentucky counties (Figure 1). In the glaciated area of Kentucky, exclusive *P. richmondi* populations were found only in the stream-dissected lands located near the Ohio River in northwestern Boone County and between the Licking and Ohio rivers in northeastern Kenton County and northern Campbell County. In glaciated southwestern Ohio, exclusive *P. richmondi* populations in Hamilton County were found only in the stream-dissected areas between the Great Miami and Ohio rivers and between the Little Miami and Ohio rivers. *Plethodon richmondi* populations in Butler County were located along valley slopes of the Great Miami River and its tributaries.

In total, exclusive populations of *P. richmondi* occurred at 63 sites. Exclusive populations of *P. cinereus* occurred at 111 sites, all located within the glaciated areas of Kentucky and Ohio that are less dissected. In general, *P. richmondi* occupied regions with steeper slopes while *P. cinereus* was located in areas with less relief.

Pfingsten (1989b) characterized *P. richmondi* as a more drought-resistant species, and Thurow (1968) suggested that *P. richmondi* replaces *P. cinereus* at sites that are slightly drier in summer. The contrasting ranges of the two species in northern Kentucky and southwest-

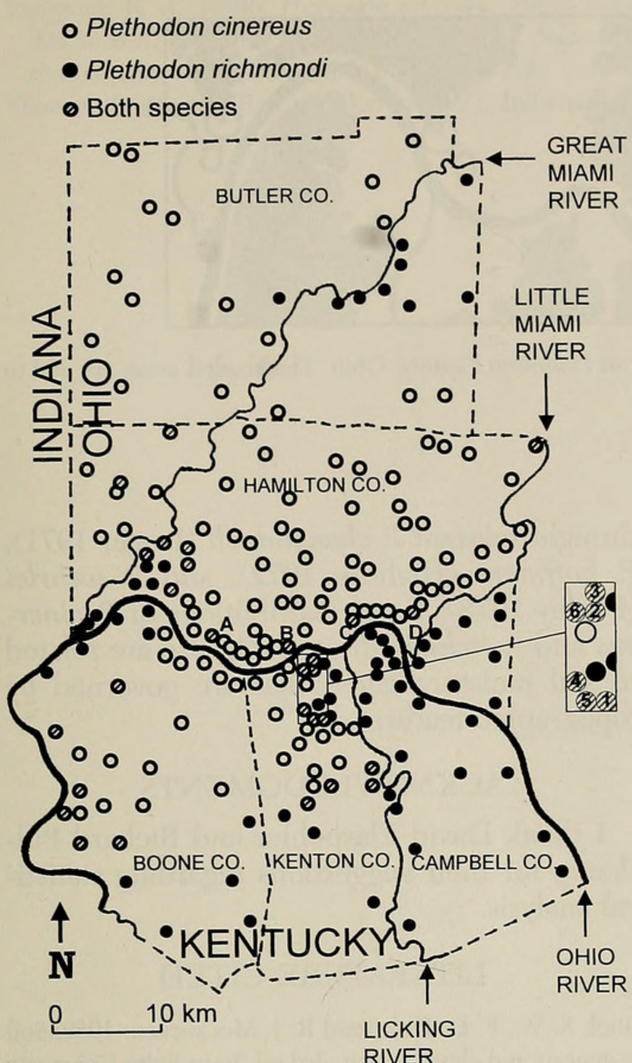

Figure 1. Occurrence of *P. cinereus* and *P. richmondi* in northern Kentucky and southwestern Ohio. The fully forested sympatric sites are labeled 1 to 6. The sympatric sites on nose slopes are labeled A to D.

ern Ohio perhaps are due to soil moisture differences caused by varying slope drainage conditions. *Plethodon richmondi* may be able to tolerate the well-drained, drier conditions found in areas of greater relief where *P. cinereus* is absent.

The two species were found together at 28 sites, including 24 valley slopes where their local ranges overlapped. To ascertain if *P. cinereus* and *P. richmondi* populations exhibited different distribution patterns in these areas of overlap, I surveyed the sympatric salamander communities on the six slopes that were fully forested (Figure 1, sites 1–6).

The number of animals captured at the sites ranged from 28 to 184, reflecting differences in slope length and in the number of cover sites provided by surface litter (Table 1). On five of the six slopes there was a significant difference between the distribution of the two species (Kolmogorov-Smirnov Test, $P < 0.05$). On all six slopes the ratio of *P. cinereus* to *P. richmondi* was greater among the first third of the salamanders counted than among the remaining animals recorded further uphill (sign test, $P < 0.05$).

The slope sampling data indicate a relationship between salamander distribution and soil moisture conditions related to topographic features. Compared to the upper two-thirds of a forested valley slope, the soil on the lower third of the slope holds the greatest moisture (Thomas and Anderson 1993). The soil on the lower portion is deeper, receives more runoff, and is less exposed to factors causing evaporation. On each valley slope where sympatric *P. cinereus* and *P. richmondi* were surveyed, a relatively higher proportion of *P. cinereus* occurred on the lower portion of the slope where moist microhabitats are more common, while a relatively higher proportion of *P. richmondi* existed on the upper area of the slope where drier conditions predominate.

Finally, at four of the 28 sites of sympatry

Table 1. Significance and comparisons of different distributions of *P. cinereus* and *P. richmondi* in uphill counts on six valley slopes in Kenton County, Kentucy. Significance of different distributions is based on the Kolmogorov-Smirnov Test; n.s. is non-significant.

Slope	Date	*P*	Total count	*P. cinereus* : *P. richmondi* ratio	
				First third of count	Remainder of count
1	30 Mar 98	n.s.	28	9:1 (9.0/1)	10:8 (1.3/1)
2	18 Apr 98	0.007	70	19:5 (3.8/1)	16:30 (0.5/1)
3	25 Apr 98	0.001	65	19:3 (6.3/1)	19:24 (0.8/1)
4	29 Apr 98	0.032	184	58:4 (14.5/1)	95:27 (3.5/1)
5	2 Apr 99	0.033	132	37:7 (5.3/1)	66:22 (3.0/1)
6	25 Apr 99	0.049	83	26:2 (13.0/1)	40:15 (2.7/1)

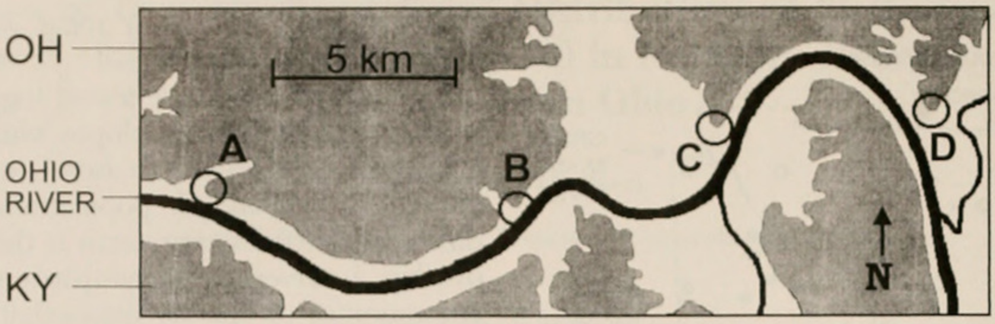

Figure 2. Map of nose slopes A to D above the Ohio River in Hamilton County, Ohio. The shaded areas are 200 to 285 m above sea level.

the *P. richmondi* population was isolated from any adjoining population of the same species (Figure 1, sites A-D). All these sites were located on nose slopes, named for their resemblance to the convexity of a human nose (Figure 2). *Plethodon richmondi* probably was able to coexist with *P. cinereus* on these nose slopes because varying soil moisture alternately favored one species over the other.

A nose slope is formed where the side slope of a river valley is incised by a tributary leading to the river. The resulting promontory has the river side slope along one edge and the tributary side slope along the other. The two side slopes are connected at the tip of the promontory by the nose slope.

Downhill flows of storm runoff on a side slope are roughly parallel (Hole and Campbell 1985). In contrast, water disperses as it flows downhill on a convex nose slope, causing drier soil conditions on a nose slope than on the adjacent side slopes. The relative dryness of a nose slope also is due in part to its greater exposure to desiccating air currents at the end of the promontory (Thomas and Anderson 1993).

Evaporation caused by sunlight also may contribute to the aridity of nose slopes (Buol et al. 1989). In the Northern Hemisphere, south- and west-facing slopes are drier and north- and east-facing slopes are moister. The west aspect of nose slope A and the south aspect of nose slopes B-D probably help to promote the frequent reduction of soil moisture content to levels that permit *P. richmondi* to coexist with *P. cinereus*.

Substrate moisture differences caused by variations in the landscape are responsible for the separation of *P. cinereus* from the more drought-tolerant *P. shenandoah* (Jaeger 1971), *P. hoffmani* (Highton 1972), and *P. wehrlei* (Pauley 1978). Local distributions of *P. cinereus* and *P. richmondi* probably also are related to soil moisture levels that are governed by topographic features.

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