Herpetofaunal Species Richness and Habitat Associations in an Eastern Kentucky Forest

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Abstract: Herpetofaunal species richness and species-habitat associations were estimated by pitfall and funnel-trap sampling in a conventional clearcut, a best-management-practices (BMP) clearcut, forest wildlife clearings, and a mature forest. Species richness was lowest in the mature forest. Slimy salamanders (*Plethodon glutinosus*) were associated with steep slopes and dense shrub cover on clearcuts, red-spotted newts (*Notophthalamus viridescens,* red eft form) with forest canopy, and American toads (*Bufo americanus*) with dense herbaceous cover in forest clearings. Pitfall and funnel-trap sampling did not effectively sample all herpetofaunal species.

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Reptiles and amphibians are important in nutrient cycling and constitute a major portion of vertebrate biomass in some ecosystems (Burton and Likens 1975). Habitat requirements of amphibians and reptiles are often site specific and may vary for a species within its range of distribution (Bury et al. 1980). Clawson et al. (1984) and Campbell and Christman (1982) assessed site-specific habitat relationships by using drift fences and both pitfall and funnel traps to obtain an unbiased sample of reptiles and amphibians, which they then related to specific habitat characteristics.

The few studies on the effects of habitat disturbance on herpetofauna in the midwestern and southeastern United States have dealt largely with surface-mined lands (Myers and Klimstra 1963) or managed forests (Bennett et al. 1979). Forty-

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four species of reptiles and amphibians are indigenous to the Cumberland Plateau of eastern Kentucky (Barbour 1971), but no studies of reptile and amphibian responses to land management have been reported from this region. Our objectives were to examine the richness and abundance of herpetofauna living in 4 areas of different land-management type (clearcut, best-management-practices clearcut, wildlife clearing, and mature forest) in a third-order watershed in the central Appalachians of eastern Kentucky, and to identify habitat associations of common species.

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Methods

Study Area

The study was conducted within the Clemons Fork watershed of Buckhorn Creek in the central Cumberland Plateau on the University of Kentucky's Robinson Forest, Breathitt County, Kentucky. The area is highly dissected by stream erosion through a sandstone-dominated geology, and it is characterized by narrow valley bottoms, narrow ridge-tops, and steep (30%-100%) slopes. Elevations range from 244 to 426 m above mean sea level. The vegetation is a mature 60-year-old mixed mesophytic forest. Ridgetops and south-facing slopes are dominated by chestnut oak (*Quercus prinus*), scarlet oak (*Q. coccinea*), and pines (*Pinus* spp.); and north-facing and mid-south-facing slopes by white oak (*Q. alba*), black oak (*Q. velutina*), hickories (*Carya* spp.), American beech (*Fagus grandifolia*), and yellow-poplar (*Liriodendron tulipifera*). Riparian vegetation is dominated by American beech, eastern hemlock (*Tsuga canadensis*), American sycamore (*Platanus occidentalis*), and river birch (*Betula nigra*). Understory vegetation is composed primarily of Christmas fern (*Polystichum acrostichoides*), Partidge-berry (*Mitcheila repens*), Beggars-tick (*Desmodiun* spp.), Violets (*viola* spp.), strawberry-bush (*Euonymus americana*), and Virginia-creeper (*Parthenocissus quirquefolia*) (Moriarty 1982).

Land-management practices on the watershed have yielded 4 types of habitat that were used as study sites: a conventional clearcut, a best-management-practices (BMP) clearcut, forest clearings for wildlife, and mature forest.

The conventional clearcut was a 15-ha sub-basin on which all woody vegetation had been felled 2 years before our sampling. Merchantable timber had been removed with no attempt to minimize soil or stream disturbance. Sampling was conducted within 15 m of a stream, at midslope, and with 50 m of a ridge top.

The BMP clearcut was a 12-ha sub-basin of the watershed on which all woody vegetation, except that on a 15-m stream buffer-strip, had also been felled 2 years before the sampling. Logging roads were cross-drained, where necessary, to prevent water concentration that could cause mass soil movement, and roads were seeded with a grass-legume mixture to minimize soil erosion. Care was taken during the harvesting operations to avoid repeated skidding of logs along the same pathway, and heavy machinery was not used on steep slopes where soil erosion could have resulted from soil disturbance. Sampling was again conducted within 15 m of a stream, at mid-slope, and within 50 m of a ridge top.

Forest clearings created for wild turkey (*Meleagris gallapavo*) were 0.2- to 1-ha openings, all of which were located within 100 m of streams on alluvial soils. Each was disked and seeded with a cover crop of winter wheat (*Triticum aestivum*) the year before sampling, and each was mowed in July and August to maintain herbaceous cover and therefore high abundance of herbivorous insects for turkey broods. Sampling was conducted in the center of 4 wildlife openings.

Mature forest was sampled in a 20-ha sub-basin of the watershed, as on the clearcuts at 3 locations: within 15 m of a stream, at mid-slope, and within 50 m of a ridge top.

Reptile and Amphibian Capture

Reptiles and amphibians were captured using drift-fence, pitfall, funnel-trap systems (Campbell and Christman 1982). Fences were 12 m long and 30 cm high. One fence was placed parallel to the contour at each sampling location within sites of each land-management type. Because of the steep terrain, the "X" pattern described by Campbell and Christman (1982) was not feasible. A pitfall trap (a plastic bucket 28 cm in diameter, 32 cm deep) was placed at the end of each fence, and funnel traps (76 cm long, 20 cm in diameter, end entrances 5 cm in diameter) constructed of window screen were placed on each side of the fence at its midpoint. Traps were checked twice weekly from 25 April to 25 October 1985. All animals were removed and released 5 m from the drift fence. Amphibians were toe-clipped for identification in recaptures.

Habitat Characteristics

Fourteen habitat variables were measured at each trap location: slope (%); aspect; distance (m) to water, logs, and rocks; biomass (g/m^2) of the wood understory, and of grass, fern, and other nonwoody understory; conifer and hardwood tree densities/0.04 ha; canopy closure (%), shrub density/88 m^2; and soil invertebrate biomass (mg/177 cm^2).

Slope and aspect were determined by compass and clinometer readings taken from the center of each fence. Distance to the nearest permanent water source was measured from the center of each fence. Distance to the nearest log (>10 cm diameter) and rock (>15 cm surface diameter) was measured in each of 4 90° quadrants from trap center and averaged for each site.

Vegetation was removed to ground level from 4 1-m^2 plots within each quadrant at a random distance along 4 22-m transects radiating at 45° angles from the center of the fence. The ovendry (60-hour/80° C) biomass (g) of woody grass, fern, and nonwoody (excluding grass fern) ground vegetation <2 m tall was averaged per site. Grass was not separated from other nonwoody vegetation in wildlife clearings because it overwhelmingly dominated the vegetation on these sites.

The number of coniferous or hardwood trees in a 0.04-ha area surrounding the fence were recorded. The percentage of canopy closure of woody vegetation >2 m tall was determined by sighting with an ocular tube at 4-m intervals along each of the 22-m transects (James and Shugart 1971). Shrub density was recorded by counting all the arms-length shrub (<1 cm dbh) contacts recorded while walking the 4 22-m transects. Soil invertebrates were collected at a random distance along each of the 22-m transects. All organic matter within a 177-cm^2 plot was removed to a depth equal to the start of the A2 soil horizon and placed in a Berlese funnel for 72 hours. Invertebrates were oven-dried for 24 hours at 80° C and weighed to the nearest 0.1 mg.

Statistical Analysis

A chi-square goodness-of-fit test was used to detect significant differences among sites in number of captures of individual species with ≥20 captures. Expected values = (number of traps on a given site ÷ total number of traps) × total number of captures of species.

For species with ≥20 captures, habitat variables for captures and non-capture sites were compared by means of *t*-tests. Linear correlations were used to detect associations between habitat characteristics (N = 13) and captures per site for species with ≥20 captures.

Results and Discussion

Species Richness

One hundred and forty-five individuals of 20 species were captured (Table 1). Total captures did not vary significantly among sites ($\chi^2 = 2.6$, df = 3, $p > 0.10$).

Species richness varied among sites, being highest in the wildlife clearings (15 species). It was correlated positively ($r = 0.60$, $P < 0.05$) with biomass of nonwoody vegetation. Wildlife clearings had the highest nonwoody biomass ($\bar{x}$ = 201 g/m^2) (Table 2). Mature forest supported the fewest herpetofaunal species of any land-management type and the lowest biomass of nonwoody vegetation ($\bar{x}$ = 11 g/m^2).

Not surprisingly, as amphibians require free water or humid conditions at some stage in their life cycle (Goin et al. 1978), the proximity of water also affected species richness. More amphibian species were captured in wildlife clearings (11 species) than in sites of other management types (4–7 species), and wildlife clearings were closer to water ($\bar{x}$ = 26 m) than were other sites. Because of confounding factors, it is not clear if distance to water, nonwoody plant biomass, or a combination of the 2 was most important in influencing herpetofaunal species richness.

Table 1. Number of captures of reptiles and amphibians and the expected number[a] (in parentheses) on 4 sites of different land-management type, Robinson Forest, Breathitt County, Kentucky, April to October 1985.

Species	Clearcut Conventional (*N* = 3)	Clearcut BMP[b] (*N* = 3)	Wildlife clearing (*N* = 4)	Mature forest (*N* = 3)	Total
Amphibians					
American toad (*Bufo americanus*)	9(8.5)	3(8.5)	22(11.4)	3(8.5)	37
Red-spotted newt (*Notophthalamus viridescens*)	3(7.8)	12(7.8)	6(10.5)	13(7.8)	34
Slimy salamander (*Plethodon glutinosus*)	11(5.5)	5(5.5)	4(7.4)	4(5.5)	24
Red salamander (*Pseudotriton ruber*)	3	3	0	1	7
Gray treefrog (*Hyla versicolor*)	0	0	4	0	4
Fowler's toad (*Bufo fowleri*)	1	0	3	0	4
Northern dusky salamander (*Desmognathus fuscus*)	1	2	0	0	3
Seal salamander (*Desmognathus monticolus*)	0	1	2	0	3
Northern two-lined salamander (*Eurycea bislineata*)	0	0	3	0	3
Green frog (*Rana clamitans*)	1	0	1	0	2
Bullfrog (*Rana catesbiana*)	0	0	2	0	2
Other[c]	0	1	2	0	3
Total	29(29.1)	27(29.1)	49(38.8)	21(29.1)	126
Reptiles					
Five-lined skink (*Eumeces fasciatus*)	5	3	1	0	9
Fence lizard (*Sceloporus undulatus*)	3	0	0	0	3
Box turtle (*Terrapene carolina*)	0	0	1	2	3
Garter snake (*Thamnophis sirtalis*)	0	0	1	1	2
Other[d]	0	1	1	0	2
Total	8	4	4	3	19
Total individuals	37(33.5)	31(33.5)	53(44.6)	34(33.5)	145
Total species	9	9	15	6	20

[a]Expected value is given only for species with ≥20 captures. Expected value = (number of traps on site ÷ total number of traps) × total number of captures of a species.
[b]BMP = best management practices.
[c]One capture each of long-tailed salamander (*Eurycea longicauda*), wood frog (*Rana sylvatica*), and mountain chorus frog (*Pseudacris brachyphona*).
[d]One capture each of northern copperhead (*Agkistrodon contortrix*) and black racer (*Coluber constrictor*).

Table 2. Habitat variables on 4 sites representing different types of land management, Robinson Forest, Breathitt County, Kentucky, August 1985.

Habitat variable	Clearcut Conventional (N = 3) $\bar{x}$	Clearcut Conventional (N = 3) SE	Clearcut BMP[a] (N = 3) $\bar{x}$	Clearcut BMP[a] (N = 3) SE	Wildlife clearing (N = 4) $\bar{x}$	Wildlife clearing (N = 4) SE	Mature forest (N = 3) $\bar{x}$	Mature forest (N = 3) SE
Slope (%)	50	20	30	20	10	10	40	30
Distance (m) to								
Water	139.3	184.3	102.1	66.9	26.0	33.7	15.6	6.6
Logs	3.5	1.9	5.4	1.5	31.6	18.2	15.9	12.2
Rocks	12.1	13.5	4.8	1.9	27.9	18.2	17.6	7.3
Biomass (g/m^2)								
Woody	29.2	19.9	45.7	55.4	9.8	17.0	5.8	5.8
Grass	1.9	2.6	0.5				15.8	21.7
Fern	5.9	8.3	2.2	1.6	0.0	0.0	2.3	3.2
Other	80.7	57.1	25.0	25.3	201.3	60.0	11.1	28.4
Hardwoods/0.04 ha	20.6	29.2	30.0	29.0	0.0	0.0	8.3	3.2
Conifers/0.04 ha	0.3	0.4	0.0	0.0	0.0	0.0	4.3	3.3
Canopy closure (%)	12	11	25	23	10	10	40	31
Shrub density/88 m^2	57.6	10.1	53.6	32.9	20.0	34.1	14.0	5.7
Soil invertebrate biomass (mg/177 cm^2)	34.7	20.8	25.3	22.7	18.0	7.5	38.1	9.6

[a]BMP = best management practices.

Species-Habitat Associations

Slimy salamanders.—Captures of slimy salamanders (Table 1) differed more than expected ($\chi^2 = 7.3$, df = 3, $P < 0.10$) among sites, 46% occurring in the conventional clearcut. Captures per site were correlated positively with slope ($r = 0.57$, $P < 0.05$) and biomass of woody ground vegetation ($r = 0.50$, $P < 0.10$). Slimy salamanders have been reported to be tolerant of a wide diversity of conditions (Barbour 1971). At our sites, 13 of 24 captures occurred at 5 traps placed in 2-year-old clearcuts.

Red-spotted newts.—Captures of the terrestrial (red eft) form of red-spotted newt (Table 1) differed more than expected among sites ($\chi^2 = 10.5$, df = 3, $P < 0.05$), 74% occurring in the BMP and mature-forest sites. There were no significant associations between red-spotted newt captures and any habitat characteristic. Apparently this species is also tolerant of a wide range of conditions, but it was most abundant (21 of 34 captures) where there was a forest canopy (on the trap site in the BMP riparian strip and the 3 sites in mature forest; Table 2).

American toads.—American toad captures (Table 1) differed more than expected among sites ($\chi^2 = 17.9$, df = 2, $P < 0.01$), 62% occurring in the wildlife clearings. Captures were positively correlated ($r = 0.67$) with the biomass of nonwoody vegetation. Captures were not consistent among wildlife clearings (range: 1–17 toads/site), but it appears that clearings with high nonwoody plant biomass may be particularly good habitat for American toads, which are insectivorous and may respond to high abundance of herbivorous insects (Table 2).

Sampling Effectiveness

Vogt and Hine (1982) reported that fences <15 m long did not result in enough captures to make their use worthwhile, but Campbell and Christman (1982) reported satisfactory results using 4 7.6-m drift fences per site arranged at 90° angles. The fences we used were 12 m long and could not be set at 90° angles because of steep slopes and dense slash in clearcuts; however, our sampling system seemed effective for several species of amphibians, although longer fences might increase sample sizes.

Campbell and Christman (1982) and Gibbons and Semlitsch (1981) reported that the pitfall-trap technique has inherent biases against some species. In particular, large snakes and tree frogs (Hylidae) can easily escape capture by climbing out of the pitfalls, but these species can be captured with funnel traps. Bush (1959) reported 13 species of snakes in our study area. All but 3 of these (*Storeria occipitomaculata*, *Diadophis punctatus*, and *Carphophis amoenus*) are commonly large enough to preclude their capture in pitfall traps.

Species that may have a natural wariness of pitfalls in their environment are rarely captured in pitfall traps. For example, box turtles (*Terrapene carolina*) are frequently captured near drift fences but seldom in pitfall traps (Gibbons and Semlitsch 1981). Most box turtles are too large to fit through the 5-cm diameter opening in the funnel traps used in this study, so it is likely that captures of this species are not representative of its actual population.

In their comparison of field techniques for analyzing herpetofaunal communities, Campbell and Christman (1982) conclude that standardized trapping will never, ". . . replace the snake collector with potato rake and cloth sack if maximum information on faunal composition is one of the objectives of the survey." During the course of the study, we observed several species in the vicinity of the trapping array that were not captured by either pitfalls or funnel traps [e.g., black rat snake (*Elaphe obsoleta*) and timber rattlesnake (*Crotalus horridus*)]. A combination of pitfall trapping and time-constrained sampling might have provided a better estimate of species richness on our study areas.

Management Implications

Responsible managers should consider the impacts of their management practices on all species. Reptiles and amphibians are a critical component of the food web in many ecosystems and are preyed on by all classes of vertebrates. Land-management practices will likely differentially affect herpetofaunal species. In our study, species richness was high in wildlife clearings and clearcuts, both of which had high nonwoody plant biomass. Areas near water on these sites supported more species than upslope areas. There was no difference in species richness between BMP and conventional clearcuts.

Future land management of our study area would benefit herpetofaunal species if clearings and clearcuts were designed to encourage the growth of nonwoody vegetation near water. Grass-legume mixtures could be seeded after clearing or cutting. The production of herbaceous plants and the insect herbivores that feed on them probably helps to provide food and cover for a variety of herpetofaunal species. Undoubtedly, this land-management practice would benefit some species but harm others, so mature forest should be left for species with other requirements.

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