Herpetofaunal Drift-fence Survey of Steephead Ravines in 2 River Drainages

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Abstract: A drift-fence survey of the herpetofauna of steephead ravines was conducted over 216 trapping days from 6 June 1995 to 6 June 1996 along first- and second-order streams in the Ochlockonee River, Florida, drainage and along first-and third-order streams in the Apalachicola River, Florida, drainage. Six drift-fence arrays in Apalachicola ravines had 1,223 captures of 34 species, whereas 6 arrays in the Ochlockonee ravine had 2,283 captures of 31 species. In the Ochlockonee ravine, more anurans were captured along the second-order than the first-order stream. In Apalachicola ravines, more Apalachicola dusky salamanders (*Desmognathus apalachicolae*) and turtles were captured along the third-order stream, whereas more southeastern slimy salamanders (*Plethodon grobmani*) and broadhead skinks (*Eumeces laticeps*) were captured along first-order streams. Along first-order streams, significantly more lizards were captured in Apalachicola ravines, whereas more three-lined salamanders (*Eurycea guttolineata*), southern red salamanders (*Pseudotriton ruber*), and anurans were captured in the Ochlockonee ravine. Salamander captures in both river drainages were significantly correlated with precipitation, but because of small sample sizes due to infrequent captures during the cooler months, anuran captures were not correlated with precipitation. Recaptures made up 11.1%–12.8% of anuran and salamander captures in both drainages, whereas reptile recapture rates differed among drainages, with lizards and turtles being recaptured more frequently than snakes. The unique biotic communities in steephead ravines would be severely impacted by land-use practices or recreational activities that resulted in canopy disturbance, erosional siltation, water pollution, or reduction in the quantity of ground water feeding the seeps and streams.

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Steephead ravines occur in deep sands across Florida's Panhandle from the Ochlockonee River west to the Yellow River. Steephead ravines are formed by ground water leaking out on a sloping surface and undercutting the sand, creating a steep-walled amphitheater that erodes headward from the valley bottom (Sellards and Gunter 1918, Sharp, 1938, Means 1975, Wolfe et al. 1988, Means 1991). The floor of steephead valleys may be 30 m below the surrounding flat or gently rolling sandhill habitat, and the sloping sides may be as steep as 45°. Many of the best-developed steepheads occur in the first-order branches (Strahler [1964] classification) of Sweetwater and Beaverdam creeks north of Bristol, Liberty County (Means 1985). First-order streams are nearest to the stream source, whereas second-order streams are formed by the confluence of first-order streams.

Since the 1930s, many herpetologists have collected specimens in Apalachicola River ravines, but only 1 short-term drift fence-survey (ca. 3 months of summer sampling) has been conducted in gully-eroded ravines there (Means and Studenroth 1994). Gully-eroded ravines are formed by the scouring action of rainwater surface runoff, and water flows in the stream channels only during and shortly after a rainfall, unlike the permanent stream flow found in steephead ravines (Wolfe et al. 1988). No surveys have been conducted in the shorter and shallower Ochlockonee River steepheads, which represent the easternmost steephead ravines in the Panhandle (Means 1981), but drift-fence surveys have been conducted in this drainage in upland hardwood forest (Means and Campbell 1981, Enge 1998).

The cool, shaded, humid Apalachicola ravines contain a rich and often unique flora (Harper 1914, Kurz 1933, James 1961) and provide important refugia for northern herpetofauna (Carr 1941, Neill 1957, Means 1977). Many of the endemic and northern aquatic and semiaquatic wildlife taxa in the Apalachicola River drainage are probably present because its headwaters originate deep in the southern Appalachian Mountains, which provided refuge during Pleistocene sea level rises, and the river provided a convenient north-south dispersal route for species (Carr 1940, Neill 1957). The physical and vegetational characteristics of steepheads are relatively constant both within and between drainages, but more studies are needed of the comparative similarities and differences among steepheads (Means 1977).

The objectives of the study were to (1) identify the herpetofaunal taxa occurring in steephead ravines; (2) compare the herpetofaunal communities of steephead ravines in the Ochlockonee and Apalachicola river drainages; (3) identify potential threats to steephead ravine herpetofauna; and (4) assess the effectiveness of drift fences constructed of silt fencing for sampling the herpetofauna of seepage communities.

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Methods

Study Areas

The study area in the Ochlockonee River drainage was on Talquin Wildlife Management Area (WMA) in western Leon County, Florida. The steephead ravine surveyed originated 0.4 km north of State Road 20 and 1.0 km east of Coe's Landing Road. The seepage stream was ≈0.6 km long and flowed northwesterly into Lake Talquin, an impoundment of the Ochlockonee River. Steephead walls were ≈15 m high and had 30°–45° slopes at the headwaters of the stream, but farther downstream, where the drift-fence arrays were located, sidewall slopes were more gradual and the valley was wider.

The 3 sites surveyed in the Apalachicola River drainage were on Robert Brent WMA in northern Liberty County, Florida. Two arrays each were located along 2 first-order steephead streams whose headwaters were 0.75 km apart and situated ≈2 km west of County Road 271. The seepage streams were 0.3 km and 1.2 km north of State Road 12 and flowed westerly for 2.0 and 1.2 km before joining and flowing northwesterly for 1.3 km into Big Sweetwater Creek. Two arrays were farther downstream on terraces along Big Sweetwater Creek, where it was a third-order stream. The closest arrays between the 2 river drainages were 44 km apart.

Sampling Design

Each drift-fence array had 3 arms modified from a design of Jones (1986). A roll of 30.5-m long and 92-cm wide silt fencing (Enge 1997) was used to construct each array. The arms radiated outward from a center point at 120° angles, and 4 funnel traps (86 cm long) constructed of aluminum window screening fastened together with office staples were used per arm. Single-opening funnel traps (25 cm diameter, 6 cm funnel opening) were placed on both sides of each fence at the distal end, and double-opening funnel traps (20 cm diameter, 5 cm opening) were placed ≈2.5 m from the centerpoint on both sides of each fence. To minimize mortality of trapped animals, funnel traps were provided with moistened sponges and shaded by 41 cm square boards of tempered masonite.

For ease of installation and to minimize erosion, arrays were located along relatively flat terraces adjacent to streams preferably in areas with minimal microtopography and low streambanks. Along smaller streams, 1 arm of each array extended partially into the stream or into adjacent seepage areas, whereas the other 2 arms sampled either bottomland forest or slope forest habitat. Farther downstream, arrays were located on terraces adjacent to the larger streams, preferably in or near seepage areas.

In the Ochlockonee drainage, 2 arrays were located >130 m downstream from the headwaters of the first-order stream, where it was 0.5–1.5 m wide and 1–4 cm deep. The other 4 arrays were farther downstream below its confluence with another first-order stream (forming a second-order stream). Arrays were situated partially on 5° slopes and/or in sandy or mucky floodplain areas along the second-order stream, which was typically 1.0–1.8 m wide and 3–20 cm deep.

In the Apalachicola drainage, 2 arrays each were located along 2 first-order streams in different ravines. One arm of each of these 4 arrays intersected the stream and had end traps in the water, whereas the other 2 arms paralleled the stream or ascended sidewalls with 5°–10° slopes. Arrays were ≥60 m downstream from the headwaters of the streams, which were 2.0–3.7 m wide and 3–13 cm deep. The remaining 2 arrays were located at the bottom of a 34-m deep ravine ≈2.4 km straight-line distance downstream from the nearest array in mucky seepage areas on opposite sides of the fast-flowing Big Sweetwater Creek, which was sand-bottomed, 3.7–6.0 m wide, and 10–80 cm deep.

Traps were opened 6 June 1995 and closed 1 August 1995 after 56 days of trapping. Because of time and manpower constraints, subsequent trapping was conducted in alternate months (September/October, November, January, March, May) until trapping was terminated on 5 June 1996. Traps were open for a total of 216 days. Traps were checked twice per week during the initial sampling period, every 4 to 5 days in September/October and May, and every 7 days in November, January, and March, when trapping mortality and capture rates were lower. Captured animals were marked (except for hatchling turtles and small snakes) and released ≈3 m away on the opposite side of the fence. Larval amphibians were not included in capture totals. Precipitation, maximum/minimum air temperature, water temperature, and stream depth were recorded each time traps were checked.

Vegetation Description

The Ochlockonee steephead ravine had 10°–30° slopes containing slope forest vegetation (see Fla. Nat. Areas Inventory 1990) consisting of predominantly xeric-adapted, deciduous trees at the top of the slope and mesic-adapted trees, such as swamp chestnut oak (*Quercus michauxii*), white oak (*Q. alba*), pignut hickory (*Carya glabra*), American beech (*Fagus grandifolia*), southern magnolia (*Magnolia grandiflora*), spruce pine (*Pinus glabra*), eastern hornbeam (*Carpinus caroliniana*), eastern hophornbeam (*Ostrya virginica*), and sweetgum (*Liquidambar styraciflua*), farther downslope. Bottomland forest habitat occurred along the second-order stream on the valley floor, where typical vegetation consisted of mesic-adapted tree species, sweetbay (*Magnolia virginiana*), tulip poplar (*Liriodendron tulipifera*), and red maple (*Acer rubrum*). The 2 arrays along the first-order stream had ≈80% canopy cover of mesic-adapted trees and 10%–20% shrub cover. Grasses and sedges covered ≈5% of the area, and sphagnum (*Sphagnum* spp.), other mosses, and various ferns covered another 5%. The 4 arrays along the second-order stream had 80% canopy cover of mesic- and hydric-adapted species and 25%–50% shrub cover that included canopy species, wax myrtle (*Myrica cerifera*), muscadine grape (*Vitis rotundifolia*), sparkleberry (*Vaccinium arboreum*), elderberry (*Sambucus canadensis*), American holly (*Ilex opaca*), and Virginia willow (*Itea virginica*). Grass/sedge and herbaceous ground cover ranged from 5% to 75% and often included netted chain fern (*Woodwardia areolata*), Virginia chain fern (*W. virginica*), southern shield fern (*Dryopteris ludoviciana*), lizard's-tail (*Saururus cernuus*), and marsh pennywort (*Hydrocotyle umbellata*).

The ridgetops above Apalachicola arrays had been planted in sand pine (*Pinus clausa*) on sandhill sites. The major vegetative difference from the Ochlockonee ravine was the presence of a dense evergreen shrub layer of predominantly star anise (*Illicium floridanum*) and large gallberry (*Ilex coriacea*) along the lower slopes and first-order streams. Additional shrubs on slopes besides those found in Ochlockonee ravines were wild olive (*Osmanthus americana*), sweetleaf (*Symplocos tinctoria*), flowering dogwood (*Cornus florida*), and witch hazel (*Hamamelis virginiana*). Arrays along first-order Apalachicola streams had ≈80% canopy cover, 40%–50% evergreen shrub cover, and 5%–20% woody ground cover. The slopes above Big

Sweetwater Creek differed from first-order streams in containing mountain laurel (*Kalmia latifolia*), Sebastian bush (*Sebastiana fruticosa*), and Florida yew (*Taxus floridana*) in the shrub layer. Arrays along Big Sweetwater Creek had 60%–75% canopy cover, 40%–60% shrub cover of mountain laurel, fetterbush (*Lyonia lucida*), sweet pepperbush (*Clethra alnifolia*), star anise, wax myrtle, American holly, large gallberry, and Virginia willow. Woody ground cover was 15%–20%, and sphagnum and other mosses carpeted 20% of the surface.

Results and Discussion

Comparisons Between Stream Orders

Water Temperature. The constant flow of high-quality water of relatively constant temperature (≈21 C) in steephead streams and the protection of steep valley walls provide relatively constant year-round temperature and humidity (Means 1975, 1977). Much of the ravine-dwelling herpetofauna, particularly salamanders, occurs on ravine bottoms along seeps or streams where leaf litter accumulates (Wolfe et al. 1988). Steephead streams in the Panhandle have a diverse salamander community that utilizes different adult and larval microhabitats and has aquatic larval periods ranging from 6 months to 3 years (Means 1974, Means and Karlin 1989). The constant water flow in steephead streams allows salamanders, particularly ones with longer larval periods, to live year-round all the way to the headwaters (Wolfe et al. 1988).

I found relatively constant year-round water temperatures only at the source (seepage slope) of Ochlockonee steephead streams and in Apalachicola first-order steephead streams (5 C annual variation). Ambient air temperature affected the water temperature, especially in wintertime, of Ochlockonee first-order streams at the array locations (>130 m downstream of the source) because of low volume of flow. Water temperatures in the Ochlockonee first-order stream ranged from 8.3–23.3 C, whereas a short, first-order stream in the vicinity had a greater volume of flow and a more restricted temperature range (18.9–20.0 C) that was probably near the temperature of the ground water in the subterranean perched aquifer. Water temperature ≥60 m downstream from the headwaters of Apalachicola first-order streams ranged from 18.3–23.3 C. Their greater volume of flow and closer proximity to the source apparently accounted for the more constant water temperature than in the Ochlockonee stream. Annual variations in water temperature were 11.1 C in the second-order Ochlockonee stream and 15.3 C in the Apalachicola third-order stream.

Species Composition and Relative Abundance. The variability of water temperatures throughout the year in Ochlockonee first-order streams apparently did not affect the presence of any amphibian species, because all species present along first-order Apalachicola steephead streams were also present along the Ochlockonee stream (Table 1). Amphibian species richness of first- and second-order Ochlockonee streams was similar (Table 1), despite differences in numbers of arrays used. In the Ochlockonee steephead, more anurans ($t = 3.34$, $P = 0.03$, df $= 4$) were captured

Table 1. Herpetofauna captured 6 June 1995–5 June 1996 by 2 drift-fence arrays along first-order (1st) and 4 arrays along second-order (2nd) steephead streams in the Ochlockonee River drainage, Leon County, Florida, and 4 arrays along first-order and 2 arrays along third-order (3rd = Big Sweetwater Creek) steephead streams in the Apalachicola River drainage, Liberty County, Florida. X indicates an observation rather than a capture. Taxa names follow Collins (1997).

	Ochlockonee		Apalachicola	
Taxon	1st	2nd	1st	3rd
Amphibians				
Florida cricket frog (*Acris gryllus dorsalis*)	2	9	0	0
One-toed amphiuma (*Amphiuma pholeter*)	0	2	0	0
Southern toad (*Bufo terrestris*)	17	31	22	13
Apalachicola dusky salamander (*Desmognathus apalachicolae*)	40	64	45	63
Southern two-lined salamander (*Eurycea cirrigera*)	151	308	428	118
Three-line salamander (*E. guttolineata*)	75	925	1	1
Eastern narrowmouth toad (*Gastrophryne carolinensis*)	10	16	0	0
Four-toed salamander (*Hemidactylium scutatum*)	0	1	0	0
Cope's gray treefrog (*Hyla chrysoscelis*)	0	2	0	7
Green treefrog (*H. cinerea*)	1	4	0	0
Squirrel treefrog (*H. squirella*)	1	0	0	X
Central newt (*Notophthalmus viridescens louisianensis*)	2	31	0	0
Southeastern slimy salamander (*Plethodon grobmani*)	8	5	42	2
Spring peeper (*Pseudacris crucifer*)	1	10	1	14
Little grass frog (*P. ocularis*)	X	0	0	0
Rusty mud salamander (*Pseudotriton mantanus floridanus*)	0	0	0	45
Southern red salamander (*P. ruber vioscai*)	23	29	3	15
Bullfrog (*Rana catesbeiana*)	0	0	1	2
Bronze frog (*R. clamitans clamitans*)	30	171	17	105
Southern leopard frog (*R. sphenocephala utricularius*)	34	147	2	2
Eastern spadefoot (*Scaphiopus holbrookii*)	6	13	0	1
Reptiles				
Southern copperhead (*Agkistrodon contortrix contortrix*)	0	0	2	3
Florida cottonmouth (*A. piscivorus conanti*)	0	1	1	2
Green anole (*Anolis carolinensis*)	5	24	28	2
Northern scarlet snake (*Cemophora coccinea copei*)	0	0	0	1
Snapping turtle (*Chelydra serpentina*)	0	10	0	3
Racer (*Coluber constrictor*)	7	4	11	1
Southern ringneck snake (*Diadophis punctatus punctatus*)	5	8	10	3
Corn snake (*Elaphe guttata*)	0	0	1	1
Gray rat snake (*E. obsoleta spiloides*)	0	1	4	0
Five-lined skink (*Eumeces fasciatus*)	2	2	0	0
Broadhead skink (*E. laticeps*)	4	5	147	5
Eastern mud snake (*Farancia abacura abacura*)	0	2	0	0
Eastern mud turtle (*Kinosternon subrubrum subrubrum*)	0	22	0	6
Eastern hognose snake (*Heterdon platirhinos*)	0	0	1	0
Eastern coachwhip (*Masticophis flagellum flagellum*)	0	0	1	0
Banded water snake (*Nerodia fasciata fasciata*)	0	1	7	3
Queen snake (*Regina septemvittata*)	0	0	1	3
Southern fence lizard (*Sceloporus undulatus undulatus*)	0	0	1	0
Ground skink (*Scincella lateralis*)	3	3	18	0
Dusky pigmy rattlesnake (*Sistrurus miliarius barbouri*)	0	0	1	0
Florida redbelly snake (*Storeria occipitomaculata obscura*)	3	2	2	1
Gulf Coast box turtle (*Terrapene carolina major*)	0	X	1	0
Eastern garter snake (*Thamnophis sirtalis sirtalis*)	0	0	1	0
Unidentified lizard	0	0	1	0
Grand total	430	1,853	801	422

per array in the second-order (100.8 ± 19.7) than in the first-order (51.0 ± 4.2) stream. Mean numbers of salamanders captured per array in the second-order (340.8 ± 223.6) and first-order (149.5 ± 54.4) Ochlockonee streams were not significantly different ($t = 1.13$, $P = 0.32$, $1-\beta = 0.07$, df = 4) because of the high variance in captures among arrays. High variability in captures among arrays occurred despite the close proximity of arrays, which sampled diverse microhabitats.

In the Apalachicola River drainage, significantly more Apalachicola dusky salamanders ($t = 3.66$, $P \leq 0.05$, df = 4) were trapped along the third-order stream than along the 2 first-order streams. In contrast, more southeastern slimy salamanders ($t = 4.22$, $P \leq 0.01$, df = 4) were trapped along first-order streams than the third-order stream. Apparent differences between stream orders in the mean number of captures per array were not statistically significant for any other amphibian species because of the high variance in captures among arrays. Although > 6 times more anurans were captured per array along the third-order streams (72.0 ± 24.0) than along first-order streams (10.8 ± 5.6), this difference was not significant (Mann-Whitney rank sum test; $T = 11.0$, $P = 0.13$, $N_1 = 2$, $N_2 = 4$). Three more species of amphibians were captured along Big Sweetwater Creek than along first-order streams (Table 1).

In the Ochlockonee steephead, there were no differences between stream orders in the mean number of turtles ($t = 2.43$, $P = 0.07$, $1-\beta = 0.39$, df = 4), lizards (Mann-Whitney rank sum test; $T = 7.0$, $P = 1.00$, $N_1 = 2$, $N_2 = 4$), or snakes ($t = 0.24$, $P = 0.82$, $1-\beta = 0.05$, df = 4) captured per array. No reptile species was unique to the first-order stream, whereas 5 species were only captured along the second-order stream (Table 1). In Apalachicola steepheads, more broadhead skinks ($t = 7.57$, $P < 0.01$, df = 4), were captured per array along first-order (36.8 ± 5.9) than third-order (2.5 ± 2.1) streams. More lizards ($t = 11.5$, $P < 0.001$, df = 4) were captured per array along first-order streams (48.8 ± 5.3) than along Big Sweetwater Creek (3.5 ± 0.7), whereas more turtles ($t = 4.3$, $P \leq 0.01$, df = 4) were captured along Big Sweetwater Creek (4.5 ± 2.1) than along first-order streams (0.3 ± 0.5). Eight reptile species were only captured along first-order streams, whereas 3 species were only captured along Big Sweetwater Creek (Table 1).

Comparisons Between River Drainages

Species Composition and Relative Abundance. The herpetofaunal communities in steephead ravines in the 2 river drainages might be expected to differ in composition and relative abundance of various species because of differences in microhabitats and geological history. Near their headwaters, Apalachicola steephead ravines had greater depth, steeper slopes, more leaf litter, and a denser shrub understory than the Ochlockonee steephead ravine. First-order Apalachicola seepage streams tended to be larger, have more uniform temperatures, and contain more leaf beds and fewer mossy and mucky areas than Ochlockonee seepage streams. The fish faunas of the 2 river drainages are quite different because they have been physiographically independent for a long time, although Telogia Creek, a tributary of the Ochlockonee River, appears to have been captured from the Apalachicola River (Gilbert 1987). I found the amphibian species composition of steephead ravines in the 2 drainages to be similar, although relative abundance often differed. Some species captured in only 1 river drainage were relatively abundant there. For example, the eastern narrowmouth toad (*Gastrophryne carolinensis*) and eft stage of the central newt (*Notophthalmus viridescens*) were common in the Ochlockonee ravine, whereas the rusty mud salamander (*Pseudotriton montanus*) was common along Big Sweetwater Creek (Table 1).

Comparing mean captures per array of species along first-order streams between the 2 river drainages, significantly more three-lined (t = 13.4, $P < 0.001$, df = 4) and southern red (t = 4.44, P ≤ 0.01, df = 4), salamanders were captured in the Ochlockonee drainage, whereas more broadhead skinks (t = 7.56, $P < 0.01$, df = 4) were captured in the Apalachicola drainage. The scarcity of three-lined salamanders in Apalachicola steephead ravines (N = 2) was unusual because they accounted for 43.8% of all herpetofaunal captures (N = 2,283) in the Ochlockonee ravine, and this was reported to be one of the most common salamander species at the bottom of gully-eroded Apalachicola ravines in another study (Means and Studenroth 1994). Significantly more anurans (t = 8.75, $P < 0.001$, df = 4) were captured per array along the Ochlockonee first-order stream (51.0 ± 4.2) than along Apalachicola first-order streams (10.8 ± 5.6), which was primarily due to the scarcity of the southern leopard (*Rana sphenocephala*) and bronze (*R. clamitans*) frogs along Apalachicola first-order streams (Table 1). There was no difference (t = 0.59, P = 0.59, df = 4, $1-\beta$ = 0.05) in the mean number of salamanders captured per array along first-order streams in the 2 river drainages.

Ochlockonee arrays captured 18 amphibian and 13 reptile species, whereas Apalachicola arrays captured 13 amphibian and 22 reptile species (Table 1). Twice as many snake species were captured in Apalachicola as in Ochlockonee ravines, but additional trapping probably would have yielded more snake species, especially in the Ochlockonee ravine. There were no significant differences in numbers of snakes captured between different stream orders within a river drainage nor between first-order streams in the 2 river drainages. Numerically, snakes were a minor component of the herpetofaunal community in steephead ravines, accounting for only 1.4% of all herpetofaunal captures in Ochlockonee ravines and 4.2% of all captures in Apalachicola ravines. The southern copperhead (*Agkistrodon contortrix*) appears to be largely restricted to ravines and floodplain forests in the Apalachicola River drainage, although there is a questionable record for the Ochlockonee River drainage north of the western end of Lake Talquin (Means 1992). Lizards dominated reptile captures in the Apalachicola steepheads because of the abundance of broadhead skinks. Turtles were scarce in first-order streams in both river drainages, occurring more frequently in downstream portions. The southern two-lined salamander (*Eurycea cirrigera*) was a predominant component of the herpetofaunal community in both river drainages.

The topographic gradient of slope forest habitat encompasses a broad soil moisture gradient that is potentially suitable for a wide spectrum of herpetofauna. Near the top of the slope, conditions are relatively dry and favor herpetofauna characteristic of xeric upland habitat. Farther down the slope, the vegetation is more characteristic of upland hardwood forest, and the increased soil moisture favors a more diverse amphibian community. Near the bottom of the slope, the bottomland forest habitat is suitable for semiaquatic amphibians, particularly along streams or seeps. Although only the lower slopes of ravines were sampled during this study, some reptiles more characteristic of xeric uplands (e.g., eastern coachwhip [*Masticophis flagellum*], eastern hognose snake [*Heterodon platirhinos*], and southern fence lizard [*Sceloporus undulatus*] were occasionally captured in Apalachicola ravines. Most terrestrial amphibian species (e.g., southeastern slimy salamander, eft stage of the central newt, eastern spadefoot [*Scaphiopus holbrookii*]) were trapped along arms of arrays on slopes adjacent to first-order streams.

Species composition of the amphibian community in the Ochlockonee steephead ravine was similar to that recorded from 2 other studies in the same drainage in Gadsden County, Florida. One study inventoried captures in September/October from a pipeline trench traversing slope forest habitat along a gully-eroded ravine (Enge et al. 1996), and the other was a drift-fence survey of upland hardwood forest and associated seepage streams (Enge 1998). The pipeline survey was much more effective than drift fences at capturing hylids (*Acris, Hyla,* and *Pseudacris* spp.), which comprised 67% of all herpetofaunal captures, including 2 species not recorded during this study (Enge et al. 1996). Amphibian and reptile species composition of the upland hardwood forest was similar to that of steephead ravines, with southern two-lined and three-lined salamanders being the most common species (Enge 1998). Both of these other studies captured bullfrogs (*Rana catesbeiana*) and marbled salamanders (*Ambystoma opacum*), which might have been detected in the steephead ravine with additional sampling.

In the Apalachicola River drainage, a short-term herpetofaunal survey of bottomland forest habitat along gully-eroded ravines in the Rock Creek Tract of Torreya State Park (Means and Studenroth 1994) found similar species to this survey, but the species list was much smaller (e.g., no turtles or snakes), probably because of limited sampling. The only species captured in gully-eroded ravines but not in steephead ravines were the eastern narrowmouth toad and southeastern five-lined skink (*Eumeces inexpectatus*). The eastern narrowmouth toad breeds in ephemeral wetlands, which might have been limited in the vicinity of the ravines along first-order streams, but suitable breeding habitat should have been available along Big Sweetwater Creek.

Seasonality of Captures. In both watersheds, more herpetofaunal species were captured during the warmer months (May, June, July, September/October) than during the cooler months (November, January, March). The most productive months for amphibian captures were July and September/October in both watersheds. Salamanders dominated amphibian captures during the cooler months, and the most productive months for anuran captures were May, June, and July. Many of the amphibian species were typically captured in greatest numbers during their breeding seasons. Most reptiles were captured during the warmer months; no lizards were captured during November and January. Sampling was conducted during the cooler months to detect winter-breeding amphibians, but the four-toed salamander (*Hemidactylium scutatum*) was the only winter-breeding species captured only in November or January.

Salamander captures per week were significantly correlated with the amount of precipitation in the Ochlockonee ($F = 24.0$, $P < 0.001$, df = 30) and Apalachicola ($F = 6.87$, $P < 0.05$, df = 30) steepheads, but there was no relation between weekly anuran captures and precipitation in the Ochlockonee ($F = 2.50$, $P = 0.12$, df = 30, $1-\beta = 0.33$) and Apalachicola ($F = 0.19$, $P = 0.67$, df = 30, $1-\beta = 0.06$) steepheads. Salamanders were captured regardless of air temperature, but anurans were captured primarily during warmer weather. The seasonality of anuran captures partially accounted for the low correlation between anuran activity and precipitation.

Sampling Efficiency

During the first month of trapping, June, 74.2% of the total number of species ($N = 31$) were captured in the Ochlockonee study area but only 52.9% of the total number of species ($N = 34$) in the Apalachicola sites. However, after 2 months of trapping, 73.5% of the total number of species had been captured in the Apalachicola sites. Relatively few new species were added in November, January, and March in either drainage. However, during the last month of trapping, May, 2 new species (one-toed amphiuma [*Amphiuma pholeter*] and five-lined skink [*Eumeces fasciatus*]) were added in Ochlockonee ravines and 4 new species (eastern spadefoot, Gulf Coast box turtle [*Terrapene carolina*], northern scarlet snake [*Cemophora coccinea*], and eastern coachwhip) in Apalachicola ravines. The addition of new species during the last month of trapping indicates that the trapping intensity (i.e., 6 arrays trapping for 216 days over the course of 1 year) was probably insufficient to compile a comprehensive species list of the herpetofauna occurring in steephead ravines.

Calculations of capture rates included recaptured individuals. Marked individuals represented 12.8% of all salamander captures ($N = 1{,}574$) in the Ochlockonee ravine. A similar proportion (11.9%) of recaptures was found for 646 salamander captures in the Apalachicola ravines. Of the more common salamander species captured in the 2 river drainages, the overall proportion of recaptures ranged from 9.4% for the southern red salamander ($N = 64$) to 15.8% for the Apalachicola dusky salamander ($N = 190$). Recapture rates of the 2 most common salamander species were 14.1% for the three-lined salamander ($N = 960$) and 11.0% for the southern two-lined salamander ($N = 905$).

Proportions of all anurans recaptured were also similar in the Ochlockonee (11.1%; $N = 434$) and Apalachicola (12.1%; $N = 157$) ravines. Recapture rates among commonly captured anuran species were more variable than among salamander species. The proportion of recaptures ranged from 0% for the spring peeper ($N = 23$) to 20.3% for the southern toad (*Bufo terrestris*) ($N = 69$). Only 3.9% of 154 southern leopard frog captures were recaptures, whereas 11.5% of 279 bronze frog captures were recaptures. Leopard frogs were probably more transitory than bronze frogs, which resided along the streams. Lizards and turtles were recaptured more frequently than snakes. No snakes ($N = 12$) were recaptured in Ochlockonee ravines, whereas 6.3% of 32 snake captures in the Apalachicola ravines represented recaptures. In contrast, recaptures accounted for 15.0% of lizard captures ($N = 40$) in Ochlockonee ravines and 49.5% of lizard captures ($N = 184$) in Apalachicola ravines.

The dissimilarity in lizard recapture rates between the 2 river drainages was attributable to the abundance of broadhead skinks in Apalachicola ravines. Overall, 55.8% of 154 broadhead skink captures in the 2 river drainages represented recaptures compared to 13.3% of green anole (*Anolis carolinensis*) captures (*N* = 45) and 15.6% of ground skink (*Scincella lateralis*) captures (*N* = 32). Recapture rates might have been higher had there been no trapping mortality (6.1% for salamanders, 7.8% for anurans, 3.4% for turtles, 7.5% for lizards, and 2.1% for snakes), and recapture rates for salamanders were probably biased because of regeneration of toes during the study. Highest mortality occurred in trapped central newts (24.2%), green anoles (22.0%), southeastern slimy salamanders (19.3%), and bronze frogs (10.2%), primarily from desiccation.

Threats to Steephead Ravines and Management Implications

Although this study did not examine water quality, relative humidity, and soil characteristics, knowledge of the life history requirements of many of the herpetofaunal species found in the rare and vulnerable steephead habitat allows one to speculate concerning the potential impacts of various land-use practices and human activities. The aquatic and semiaquatic wildlife community along seepage streams may be affected by poor water quality resulting from the application of fertilizers or biocides on the surrounding uplands, or the dumping of hazardous wastes and other refuse within the drainage basin or steephead (Fla. Nat. Areas Inventory 1990). Illegal dumping of trash down easily accessible ravines is a common practice in the Panhandle (pers. observ.), but I suspect it is more of an aesthetic problem than a threat to wildlife, unless toxic materials or metal corrosion pollutes the streams.

The steepheads in this study occurred on lands formerly or presently owned by St. Joe Corporation, and ridges had been logged of longleaf pine and replanted in sand or slash pine. The latter species was often stunted because of unsuitable site conditions. Deforestation of adjacent uplands may result in increased erosion and sedimentation of the ravines, and the steep ravine slopes are very susceptible to erosion from even minor habitat disturbances, such as foot traffic. Logging of uplands or the upper slopes of ravines may increase insolation levels along streams, which may lead to higher temperatures and lower humidities unfavorable to herpetofauna preferring cool, moist conditions. Another byproduct of opening the canopy is increased shrub and/or emergent herbaceous vegetation along streams (Fla. Nat. Areas Inventory 1990).

The recent increase in prices for hardwood timber may make it economically feasible for commercial forestry operations to extract hardwood trees from the upper slopes of steepheads. The steep slopes have precluded the use of heavy logging equipment in the past and enabled most steepheads to retain their natural vegetation, although southern red cedars (*Juniperus silicicola*) have been removed from most ravines to make pencils (Means 1977, 1981). Timber harvesting of upland areas or hydrological manipulations may affect groundwater seepage; changes in the quantity of water entering seepage streams will alter the streamside and aquatic biotic communities. These first-order seepage streams are used by the larvae of several salamander species. Logging of hardwoods on the slopes would decrease shading, reduce leaf litter, increase soil-surface temperatures, reduce humidity, and reduce soil-surface moisture (Bury 1983, Ash 1988, Raphael 1988, Welsh 1990), conditions unfavorable for many of the amphibian species, especially if erosion results in sedimentation of streams (Corn and Bury 1989). Timber harvesting of southern Appalachian forests (Ash 1988, Petranka et al. 1993) and South Carolina bottomland swamps (Phelps and Lancia 1995) adversely affected many salamander populations. The sunnier, drier conditions resulting from logging may benefit some lizard and snake species, especially those characteristic of the adjacent xeric uplands.

Impoundment of ravine streams has occurred in the Panhandle to create ponds for residential communities and for watering livestock. The larvae of most ravine-dwelling salamander species require flowing water or seepage areas and would be eliminated from impounded sections of streams. Impoundment would also interfere with movements of amphibians, reptiles, and fishes along streams and could adversely affect wildlife by changing the temperature and oxygen-carrying capacity of the water downstream.

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