

Herpetofaunal Drift-fence Survey of Steephead Ravines and Seepage Bogs in the Western Florida Panhandle

FINAL PERFORMANCE REPORT

September 1998–June 2000

Kevin M. Enge

April 2002



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FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION FINAL PERFORMANCE REPORT

HERPETOFAUNAL DRIFT-FENCE SURVEY OF STEEPHEAD RAVINES AND SEEPAGE BOGS IN THE WESTERN FLORIDA PANHANDLE

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Abstract: The herpetofauna of steephead ravines and seepage bogs in Okaloosa or Santa Rosa County, Florida, was surveyed using funnel traps along drift fences for 165 trapping days from 23 September 1998 to 1 September 1999. Four arrays were installed in steephead ravines in the Blackwater River drainage, 10 arrays in ravines in the Yellow River drainage, and 4 arrays in bogs in Blackwater River State Forest. The objectives of the study were to (1) compare the herpetofaunal communities of steephead ravines in different river drainages in the western Panhandle, (2) compare the herpetofaunal communities of steephead ravines in the western Panhandle with those in the Apalachicola and Ochlockonee drainages, and (3) compare herpetofaunal communities found in herb and shrub bogs on Blackwater River State Forest. First-, second-, and third-order steephead streams were sampled. Water temperatures varied more in shrub bogs than in steephead streams, and water temperatures in short, first-order steephead streams usually varied less than in longer first-order streams or in higher order streams. Air temperatures tended to be less variable in ravines than in bogs, but ravines nevertheless experienced considerable variation in air temperatures.

Fourteen amphibian and 23 reptile species were trapped in 2 seepage bogs. Nineteen amphibian and 24 reptile species were trapped in all 7 steephead ravine sites combined. The species composition of amphibian and reptile communities varied between bogs and among steephead ravines in different river drainages. Amphibian or reptile species composition was most similar between steephead ravines in the Blackwater and northern Yellow river drainages, which were in close proximity. Ravines in the northern Yellow River drainage, however, differed from ravines in other drainages by apparently lacking dusky salamanders (*Desmognathus* sp.). Herpetofaunal species composition among ravines was somewhat similar to that found in ravines farther east in the Apalachicola and Ochlockonee river drainages, but 12 species were trapped only in eastern ravines and 13 species only in western ravines. Ravines in western drainages shared more species with shrub bogs than herb bogs, and overall, western ravines and bogs had 13 amphibian and 16 reptile species in common. Salamanders tended to be more abundant in ravines than in bogs, whereas reptiles were more abundant in bogs. Herb bogs were used by some species from the surrounding pine uplands and provided the most suitable habitat for breeding Pine Barrens treefrogs (*Hyla andersonii*), dwarf salamanders (*Eurycea quadridigitata*), southern coal skinks (*Eumeces anthracinus pluvialis*), and several snake species.

During the first month of trapping, which experienced heavy rainfall from Hurricane Georges, >55% of all aquatic salamander species, southern red salamanders (*Pseudotriton ruber vioscai*), and dwarf salamanders were trapped. The most productive months for anurans were the warmer months, when most species bred. April and June were the most productive months for reptiles. Recapture rates ranged from 0% to 20% for anuran species and 0% to 10% for salamander species. The eastern mud turtle (*Kinosternon subrubrum subrubrum*) was the most frequently recaptured species (42%). Lizard species were typically recaptured more frequently (12–34%) than snake species (0–18%). Mortality rates ranged from 0% to 13% for the most frequently trapped anuran species, and from 3% to 12% for salamander species. Reptiles were less prone to desiccation but more prone to drowning than amphibians, and trapping mortality rates ranged from 0% for 5 reptile species to 30% for eastern glass lizards (*Ophisaurus ventralis*).

Information was collected on several target taxa: Pine Barrens treefrog, bog frog (*Rana okaloosae*), one-toed amphiuma (*Amphiuma pholeter*), the undescribed “least” siren (*Siren* cf. *intermedia*; P. E. Moler, Florida Fish and Wildlife Conservation Commission, Gainesville, personal communication), coal skink,

mimic glass lizard (*Ophisaurus mimicus*), Gulf crayfish snake (*Regina rigida sinicola*), Florida pine snake (*Pituophis melanoleucus mugitus*), mole kingsnake (*Lampropeltis calligaster rhombomaculata*), southeastern crowned snake (*Tantilla coronata*), and northern scarlet snake (*Cemophora coccinea copei*). The herpetofauna inhabiting seepage bogs is primarily threatened by improper fire frequency or timing, alteration of hydrology, and siltation and impoundment from roads. The herpetofauna of steephead ravines is potentially threatened by logging, water pollution, and ground-water use. The most obvious threats to ravine herpetofauna, however, are siltation of streams and excessive runoff from dirt roads and cleared lands (e.g., agricultural fields and mines), and impoundment of streams to form ponds. Feral hogs (*Sus scrofa*) may be a problem in some seepage communities. Suppressing fire and planting pines in surrounding uplands and on ravine sidewalls undoubtedly affects upland herpetofauna, but the effects on ravine-dwelling herpetofauna are not so obvious.

INTRODUCTION

Abundant rainfall percolating through the deep, porous sands of Florida's Panhandle accumulates in reservoirs of perched ground water when it encounters relatively impermeable layers of silty marl, clay, or limestone. When these perched water tables are intersected by sloping terrain, seepage habitats sometimes result. If large rivers cut through the deposits of deep sand to the confining substratum, the surficial aquifer may flow out laterally from the steep valley sidewall. This seepage stream will eventually undercut the sand, causing the overburden to slump and form a steep-walled, bowl-shaped depression (i.e., steephead) that gradually erodes headward from the valley bottom (Sellards and Gunter 1918, Sharp 1938, Means 1981, Wolfe et al. 1988). A steephead typically migrates away from the main river at right angles, and secondary steepheads may develop perpendicularly to the main steephead ravine (Means 1985). The low-gradient, flat bottom of steephead ravines may be 35 m below the surrounding flat or gently rolling sandhill habitat, and the sloping sides may be $\geq 45^\circ$ (Means 1981, 1985). Most ravines are formed by gully erosion when rainwater runs off the surface and gradually scours V-shaped gullies that get progressively deeper downstream. Water flows in stream channels at the head of gully-eroded ravines, which appear pointed on topographic maps, only during and shortly after a rainfall, unlike the permanent stream flow found in steephead ravines (Wolfe et al. 1988).

When gentle slopes intersect perched water tables, the ground water trickles out laterally over a broad zone and forms wetlands called seepage slopes (Florida Natural Areas Inventory 1990) or seepage bogs (Folkerts 1991). Boggy meadows on or at the base of a slope are sometimes called herb bogs, whereas shrubby thickets are called shrub bogs (Wharton et al. 1977, Wolfe et al. 1988, Florida Natural Areas Inventory 1990). Historically, herb bogs were maintained by periodic, lightning-started fires that swept downslope from the longleaf pine (*Pinus palustris*) uplands every 5 years or

less. The presence of wiregrass (*Aristida beyrichiana*) and other pyrophytic vegetation helps carry fire into the herbaceous wetlands, which characteristically contain insectivorous plant species, such as pitcher plants (*Sarracenia* spp.) and sundews (*Drosera* spp.). An herb bog is the most floristically rich of pitcher plant habitats (Folkerts 1991) and may contain more plant species per unit area than any other community in the Florida Panhandle (Clewell 1981). In the prolonged absence of fire, fire-sensitive evergreen shrub species typically invade upslope. These shrubs shade out much of the herbaceous vegetation and may eventually dry up much of the bog through increased evapotranspiration, creating a shrub bog (Means and Moler 1978, Means 1990). Shrub bogs are often present downslope of herb bogs where fire is usually inhibited by permanently saturated soil and small stream channels that drain the bog. Shrub bogs that contain many shrub species in a dense thicket probably burn every 3–8 years, whereas shrub bogs that are dominated by a single species, such as large specimens of black titi (*Cliftonia monophylla*), are more open and probably have not burned for 20–50 years (Wharton et al. 1977).

In steephead ravines, the constant flow of high-quality water of relatively constant temperature ($\approx 21^{\circ}\text{C}$; Means 1975, 1981) and the protection of steep valley walls provide wildlife with relatively constant year-round environmental conditions (Means 1975, 1977). Many of the amphibians, particularly salamanders, live on the bottom of the ravines, where leaf litter accumulates in seeps or streams (Wolfe et al. 1988). Seepage bogs are more exposed and have more variable air temperature, relative humidity, and wind than steephead ravines but, nevertheless, may support a diverse amphibian community and provide foraging sites for herpetofauna of surrounding habitat types (Enge 1997a). Bogs provide favorable conditions for amphibian species tolerant of acid water with pHs ranging from 3.5 to 5.0 (Means 1990). In bogs, the very shallow water that slowly seeps from slopes is more quickly affected by ambient temperature than in the higher volume steephead streams, and during seasonal or extended droughts, upslope areas of bogs may dry up.

This study used drift fences to survey the herpetofaunal communities of steephead ravines and herb and shrub bogs in the Yellow and Blackwater river drainages. Comparative data are provided by drift-fence surveys of steephead ravines in the Apalachicola and Ochlockonee river drainages (Enge 1998a). Means (1977) postulated that physical and vegetational characteristics of steepheads are relatively constant both within and among drainages, but more studies are needed of the comparative similarities and differences among steepheads. No drift-fence survey has been conducted in seepage bogs in Florida, but during a 1998 study on Eglin Air Force Base (AFB), some drift fences intersected bogs (D. Printiss, Florida Natural Areas Inventory,

Tallahassee, personal communication). Recent field surveys on Eglin AFB have studied salamander populations in steephead ravines (D. B. Means, Coastal Plains Institute, Tallahassee, personal communication) and inventoried rare herpetofauna (Printiss and Hipes 1999).

Baseline data were collected on herpetofaunal species for possible future monitoring studies, and species were identified in these relatively fragile ecosystems that might be adversely affected by logging, road construction, grazing, stream impoundments, trash dumping, fertilizer and biocide applications, and excessive human recreational use. Species of particular interest that are restricted to seepage habitats in the Panhandle are the Florida bog frog (see Appendix A for scientific names of herpetofaunal species) and Pine Barrens treefrog, both of which are listed as Species of Special Concern. The Florida bog frog, which was first described in 1985 (Moler 1985), is known from ≈ 35 sites in Walton, Okaloosa, and Santa Rosa counties, where it lives in shallow, boggy seepage areas along small seepage streams that are tributaries of the Yellow and East Bay rivers (Moler 1992, Printiss and Hipes 1999). The Pine Barrens treefrog is known from ≈ 150 sites in 4 Florida counties and 22 sites in 3 Alabama counties; this disjunct population is ≈ 900 km from the nearest definitely known populations in the Carolinas (Means 1992b). Several other taxa with high biological (≥ 19) or action (≥ 35) scores (see Millsap et al. 1990; Enge et al., unpublished) inhabit seepage habitats: one-toed amphiuma, four-toed salamander, southern coal skink, Gulf crayfish snake, and “least” siren.

Seepage habitats are important to many amphibian species. Systematic herpetofaunal inventories of these seepage habitats will provide baseline data to document future changes in species composition or relative abundance. Florida is apparently not experiencing the dramatic declines in amphibian populations seen in some parts of the world (e.g., Blaustein and Wake 1990, Wyman 1990, Blaustein et al. 1994, Phillips 1994), but some dusky salamander (*Desmognathus* spp.) populations may be inexplicably declining (Dodd 1998; D. B. Means, personal communication). Surveys, basic life-history studies of sensitive species, and long-term monitoring of herpetofaunal populations need to be initiated within the remaining longleaf pine community (Dodd 1995). Blackwater River State Forest, Eglin AFB, and Conecuh National Forest in southern Alabama contain the largest remaining holding of longleaf pine trees (primarily in sandhill habitat); Eglin AFB alone may contain 2,000 ha of old-growth longleaf pine forest, which would represent $>50\%$ of the old-growth longleaf pine acreage remaining in the world (Means 1996).

This study directly or indirectly addresses several conservation tasks identified by the Florida Fish and Wildlife Conservation Commission’s Bureau

of Wildlife Diversity Conservation (Enge et al., unpublished). It directly addresses the high-priority task of surveying amphibian communities using hillside and stream seepage bogs in the Panhandle. This study also provides a list of species that should be considered when addressing 3 additional conservation tasks: effects of water pollution on amphibian communities using hillside and stream bogs in the Panhandle; effects of stream impoundments on amphibian communities inhabiting stream and associated seepage bog habitats; and effects of forestry practices on amphibian communities on public lands in the western Panhandle. Limited information is provided pertaining to several other conservation tasks: (1) development of recommendations to protect wetland sites with rare herpetofauna, (2) development of management recommendations for Pine Barrens treefrog habitat, (3) habitat use by adult Pine Barrens treefrogs, and (4) population ecology of the Florida bog frog (Enge et al., unpublished). The list of herpetofaunal species generated by this survey should be useful to anyone evaluating the impacts of land-use activities and management strategies on Eglin AFB and Blackwater River State Forest. This information might also be useful to owners of nearby private lands that contain seepage habitats.

OBJECTIVES

The objectives of this study were to (1) compare the herpetofaunal communities of steephead ravines in different river drainages in the western Panhandle (i.e., Yellow and Blackwater rivers); (2) compare the herpetofaunal communities of steephead ravines in the western Panhandle with communities of steephead ravines in the Apalachicola and Ochlockonee drainages; and (3) compare herpetofaunal communities found in herb and shrub bogs on Blackwater River State Forest.

STUDY AREA

Both the Blackwater and Yellow rivers empty into East Bay (part of Pensacola Bay) in Santa Rosa County. The Yellow River is located east of the Blackwater River and flows in a westerly direction through Okaloosa and Santa Rosa counties; therefore, I differentiated between steephead ravines situated in the “northern” and “southern” Yellow River watersheds. Three steepheads on the north side of the Yellow River were sampled: Garnier, Burnt Grocery, and Trawick creeks (Fig. 1). Topographic quadrangle maps were used to estimate the depths and lengths (stream, not straight-line distance) of steephead ravines and the straight-line distance between heads of ravines. One sampling site was in Santa Rosa County at the head of Garnier Creek, which

is 8.8 km SW of the nearest ravine sampled in the Blackwater drainage, the tributary of Adams Mill Creek. The Garnier Creek steephead ravine is 2.9 km long and 27 m deep, and the stream flows southeasterly. One of the heads of Garnier Creek appears to be a gully-eroded ravine stream. Two sampling sites were situated north of road crossings along downstream portions of Burnt Grocery and Trawick creeks. Burnt Grocery Creek is 3.6 km west of Garnier Creek in Santa Rosa County, whereas Trawick Creek is 9.4 km east of Garnier Creek in Okaloosa County. The Burnt Grocery Creek ravine is 3.6 km long and 34 m deep, whereas the Trawick Creek ravine is 4.2 km long and 40 m deep. Both streams flow in a southerly direction into the Yellow River.

Two sampling sites were steephead ravines along Weaver Creek in the southern Yellow River watershed. Weaver Creek flows north for 6 km into Weaver River, a tributary of the Yellow River. This wide steephead ravine on Eglin AFB in Santa Rosa County is 24 m deep. I sampled 2 of the multiple heads of Weaver Creek and a first-order (Strahler's [1964] classification) steephead tributary on the east side of the stream 2.3 km downstream from the headwaters (Fig. 1). Rivulets from 21 separate springs at the head of the main ravine coalesce to form Weaver Creek (K. Studenroth, Marianna, Florida, personal communication).

Two sampling sites were along tributaries of the Blackwater River in Okaloosa County, northwest of Holt (Fig. 1). Both sites were in Blackwater River State Forest, which is located in northeastern Santa Rosa County and northwestern Okaloosa County. I sampled a steephead stream that flows north into Bone Creek and a steephead stream that flows west into Adams Mill Creek, which is a partially impounded steephead tributary of Bone Creek. The 2 steepheads sampled are <1 km apart but differ in orientation and dimensions. The Bone Creek steephead ravine is 700 m long and 33 m deep with multiple heads, whereas the Adams Mill Creek ravine is <200 m long and 30 m deep with a single head.

I selected 2 seepage bogs in Blackwater River State Forest (Fig. 1) that were breeding sites for Pine Barrens treefrogs (J. Godwin, Alabama Natural History Survey, Montgomery, personal communication). Godman's Bog drains into Reedy Creek, a tributary of the Yellow River. Open Bog drains into Bull Pen Branch, a tributary of the Blackwater River. Godman's Bog is on the south side of Curtis Madden Road, 1.4 km east of its junction with Lee Cook Road. This junction is 2.7 km southeast of County Road 189. Open Bog is 0.5 km west of Edie Cotton Road on the south side of a small dirt road that is 2.2 km north of Peadon Bridge Road. Both sites have an herbaceous component and a shrub bog in close proximity.

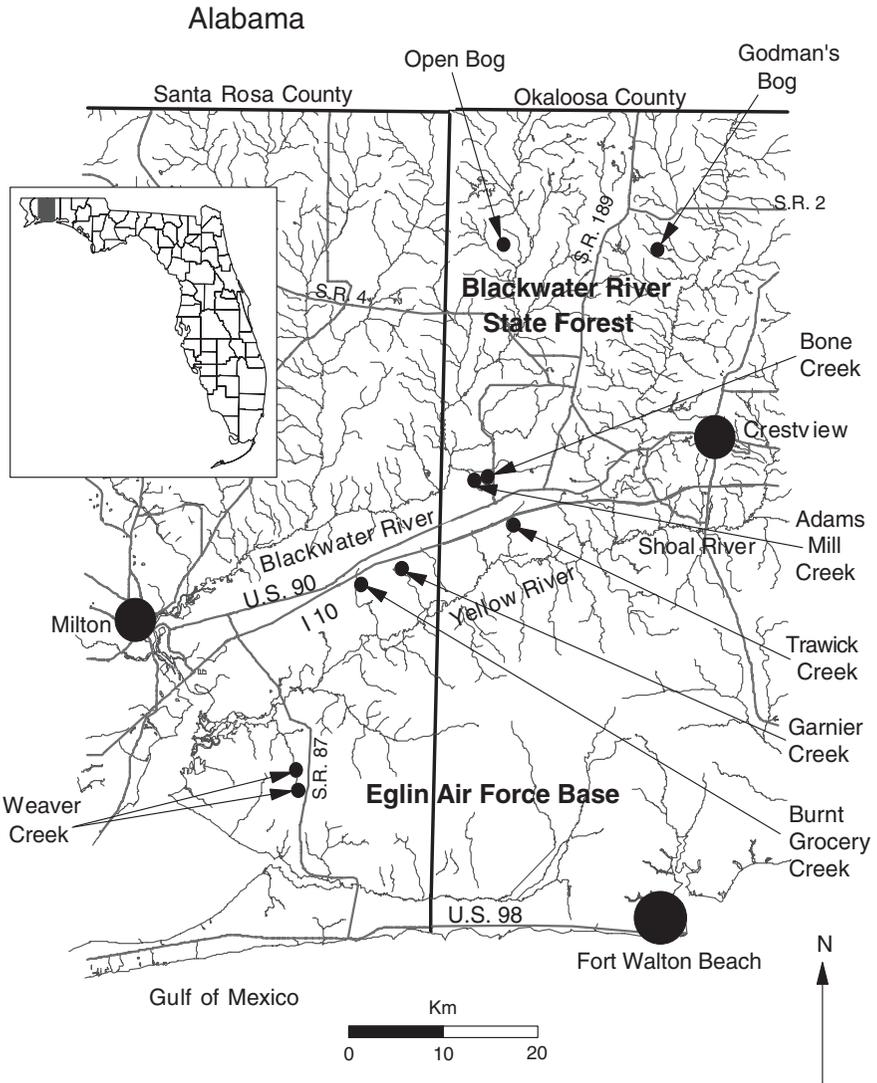


Fig. 1. Locations of the study areas, each of which had 2 drift-fence arrays, in eastern Santa Rosa County and western Okaloosa County, Florida.

METHODS

Array Design and Location

Each drift-fence array consisted of 3 silt fences (see Enge 1997*b*) that met at a center point at 120° angles. A 30.5-m-long roll of silt fencing was used for each array to duplicate the methodology used in a previous survey of steephead ravines (see Enge 1998*a*). Each array had 6 double-opening (86 cm long, 20 cm diameter) and 6 single-opening (86 cm long, 25 cm diameter) funnel traps constructed of aluminum window screen fastened together with office staples. A single-opening funnel trap was placed on each side of the fence at the end of each arm of the array. A double-opening funnel trap was placed on each side of the fence near the midpoint of each arm. Traps situated in deep water in streams were held in place by sticking an L-shaped wire stake through the bottom of the front of the trap (Enge 1997*b*).

I identified potential steephead ravines from topographic maps and visited them to determine their suitability as study sites. I selected sites based upon river drainage, Strahler's stream order, habitat appearance (e.g., presence of seepage areas), terrain, ease of drift-fence installation, accessibility, proximity to other sites, and ownership. I determined Strahler's stream order for Adams Mill, Bone, Garnier, and Weaver creeks by walking from the location of the arrays to the head of the stream, but this was not feasible for Burnt Grocery and Trawick creeks. The stream order at the array location for the latter 2 creeks was determined from topographic maps, which may be inaccurate. I assumed that small "fingers" of topographic contour lines at the heads of the streams and their tributaries represented first-order streams, although these small streams were not delineated on maps. I had intended to sample both first-order streams and second- or third-order streams along the same steephead ravines in the Blackwater and Yellow river drainages, as was done in the Apalachicola and Ochlockonee river drainages (see Enge 1998*a*), but site visits indicated that this was not feasible in most ravines because of problems with accessibility, ownership, or habitat.

I typically installed arrays in seepage areas along relatively flat terraces adjacent to portions of the stream, especially in sphagnum and mucky areas with small pools and rivulets. Whenever feasible, I ran at least 1 arm of the array partially into the main stream channel. Water was permitted to flow underneath portions of arms that intersected fast-flowing streams. The center points of different arrays were never closer than 50 m.

I installed 4 arrays in steephead ravines draining into the Blackwater River. Two arrays were placed along the Adams Mill Creek tributary, which

was a short, first-order stream. One array was placed along a first-order segment and 1 array along a second-order segment of the Bone Creek tributary. Visually, these 2 streams appeared to have smaller volumes of flow than first- and second-order streams in the Yellow River drainage.

I installed 6 arrays in steephead ravines draining into the north side of the Yellow River. The 3 steephead ravines, from east to west, were Trawick, Garnier, and Burnt Grocery creeks. Array locations along Trawick and Garnier creeks were ≈ 9.3 km apart, whereas arrays along Garnier and Burnt Grocery creeks were ≈ 3.6 km apart. I installed 2 arrays ≥ 100 m downstream of the head (the steephead, not the gully-eroded head) of Garnier Creek, upstream of a powerline crossing. I also installed 2 arrays each 1.2 km downstream of the head of Burnt Grocery Creek and 2.4 km downstream of the head of Trawick Creek. I did not sample the head of Trawick Creek because of inaccessibility to roads, and I could not obtain landowner permission to sample the head of Burnt Grocery Creek. Garnier Creek was crossed by a road farther downstream, but this portion of the stream was unsuitable for drift-fence installation because the narrow strip of streamside vegetation was very dense. Also, flat seepage areas were absent because the ravine sidewalls, which were planted in pines, came too close to the stream. Arrays along Trawick Creek were ≈ 4.1 km from arrays along Bone Creek's tributary; these were the closest sets of arrays between the Yellow and Blackwater river drainages.

On Eglin AFB, I sampled the head of Weaver Creek using 2 arrays. Suitable areas for drift-fence installation could not be found farther downstream along the main stream, so I instead sampled a large, first-order tributary of Weaver Creek using 2 arrays. The closest sets of arrays between the northern (i.e., Burnt Grocery Creek) and southern (i.e., Weaver Creek's tributary) Yellow River watersheds were 15.6 km apart.

I placed 1 drift-fence array in the herb portion and 1 array in the shrub portion of both Godman's and Open bogs for a total of 4 seepage-bog arrays. I followed the same path each time during site visits in order to minimize trampling of vegetation and seepage areas. The 2 bogs were separated by ≈ 12.4 km and situated in different river drainages. The closest steephead arrays to Open Bog were ≈ 18.7 km away along Bone Creek's tributary.

I used a Trimble Navigation GPS Pathfinder Basic+ unit (Trimble, Sunnyvale, California, USA) to determine the latitude and longitude coordinates of the center points of all 18 drift-fence arrays and the sources of some of the steephead streams that were surveyed (Table 1). Straight-line distances between arrays and between arrays and stream sources were determined using these coordinates.

Table 1. Locations of center points of drift-fence arrays and heads of steephead ravines in Okaloosa or Santa Rosa County, Florida.

Array	Site	Array Center Point		Head location
		Latitude	Longitude	
1	Trawick Creek	30°41'54.18"N	86°44'05.64"W	
2	Trawick Creek	30°41'56.45"N	86°44'03.08"W	
3	Garnier Creek	30°40'04.75"N	86°49'33.41"W	30°40'08.84"N, 86°49'33.01"W
4	Garnier Creek	30°40'03.32"N	86°49'32.32"W	
5	Burnt Grocery Creek	30°39'21.17"N	86°51'38.52"W	
6	Burnt Grocery Creek	30°39'23.20"N	86°51'37.12"W	
7	Adams Mill Creek tributary	30°43'50.59"N	86°45'55.74"W	30°43'50.59"N, 86°45'53.98"W
8	Adams Mill Creek tributary	30°43'49.52"N	86°45'57.31"W	
9	Bone Creek tributary head	30°43'52.46"N	86°45'18.09"W	30°43'52.74"N, 86°45'17.35"W
10	Bone Creek tributary downstream	30°44'04.58"N	86°45'19.32"W	
11	Weaver Creek	30°30'29.38"N	86°54'48.16"W	
12	Weaver Creek	30°30'27.95"N	86°54.45.74"W	
13	Weaver Creek tributary	30°31'23.16"N	86°54'48.03"W	30°31'24.85"N, 86°54'45.67"W
14	Weaver Creek tributary	30°31'21.94"N	86°54'50.39"W	
15	Open Bog (herbaceous)	30°53'57.45"N	86°44'31.25"W	
16	Open Bog (shrub)	30°53'55.05"N	86°44'33.25"W	
17	Godman's Bog (herbaceous)	30°53'44.28"N	86°36'44.96"W	
18	Godman's Bog (shrub)	30°53'42.13"N	86°36'46.81"W	

Data Collection and Analysis

I installed drift-fence arrays in September 1998. Traps were open for 165 days from 23 September to 1 November 1998, 1 February to 6 March 1999, 31 March to 1 May 1999, 31 May to 1 July 1999, and 1 August to 1 September 1999. I opted not to trap from November through January because relatively few individuals and species of herpetofauna were captured in the coolest months during another study of steephead ravines, and only 1 unique species was captured during winter (see Enge 1998a). Of the target taxa, only the four-toed salamander breeds during cool weather, whereas the Pine Barrens treefrog, bog frog, and target reptile taxa are spring and summer breeders.

I typically checked traps every 5 days, but trap-check intervals ranged from 3 to 8 days. Traps were provided with a moistened sponge and tempered masonite or tileboard shade covers to minimize mortality of trapped animals. I marked and released captured animals ≥ 2 m away on the opposite side of the fence using the methodology recommended by Enge (1997a). Handling and marking of trapped animals were consistent with established field research guidelines (Anonymous 1987). Target taxa were weighed, measured, and

individually marked. I did not mark small snakes and hatchling turtles because of the possibility of injury. I commonly trapped larval amphibians but did not include them in capture totals. I deposited voucher specimens of notable species in the Florida Museum of Natural History at the University of Florida, Gainesville, and I collected tissue samples of some species for electrophoretic or mtDNA analysis.

I recorded precipitation from rain gauges each time the traps were checked at Garnier Creek, Trawick Creek, Adams Mill Creek, the head of Weaver Creek, and the 2 seepage bogs (Fig. 2). The proximity of many of the sites

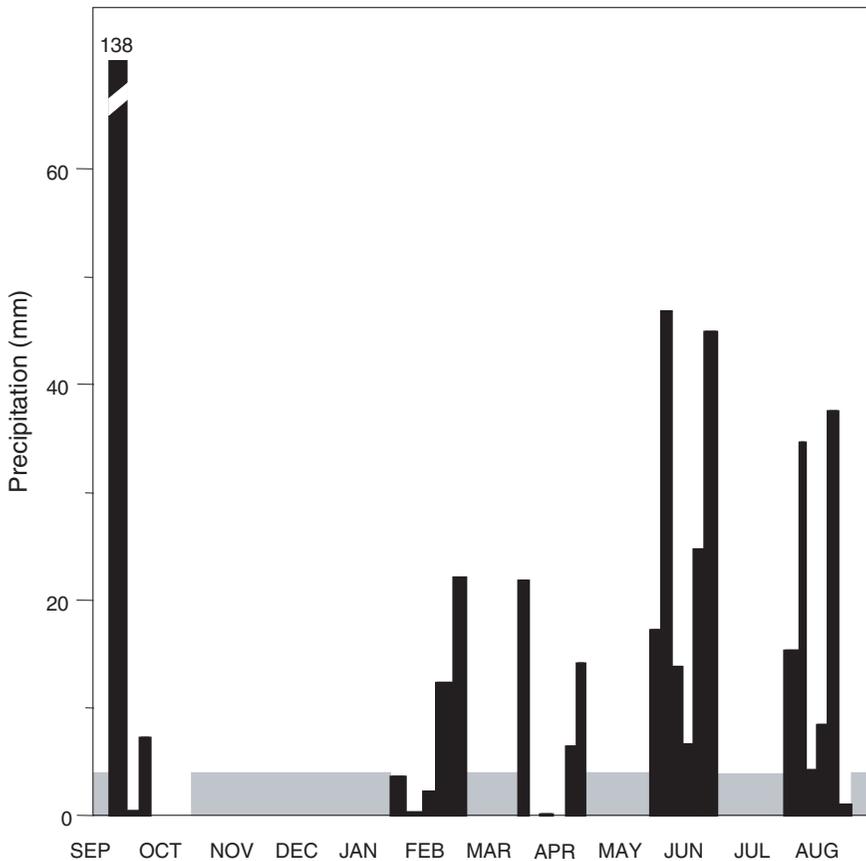


Fig. 2. The average precipitation recorded from 6 rain gauges each time traps were checked in Okaloosa or Santa Rosa County, Florida. The width of the black bars corresponds to the interval between site visits (3–8 days) during the 5 trapping periods. Gray areas represent periods not sampled.

minimized local variations in precipitation, and the nearest rain gauges were used for precipitation data at sites lacking rain gauges. Air temperatures in the shade were recorded every hour at Garnier Creek, Weaver Creek, and the shrub portion of Open Bog using StowAway™XTI temperature data loggers (Onset Computer Corporation, Pocasset, Massachusetts, USA). I recorded air temperatures from mercury maximum-minimum thermometers that were affixed to tree trunks 1 m above the ground. Air temperatures were recorded each time the traps were checked in the shrub portion of Open Bog and in ravines along Trawick, Garnier, Adams Mill, Bone, and Weaver creeks. Each time a site was visited, I recorded relative stream depths from permanently placed PVC pipes marked in centimeters, and stream water temperatures using a handheld, pocket case mercury thermometer. Water temperatures were also recorded every hour at Garnier and Burnt Grocery creeks using StowAway™XTI temperature data loggers.

I collected habitat data around each array and characterized the habitat of adjacent slopes and ridgetops in April, June, and August 1999. Vegetative data were collected within a 15-m radius of the center point of each array using ocular estimation of percent cover in 4 layers: canopy, shrub, ground cover, and moss. I used Braun-Blanquet (1932) cover classes: <1, 1–5, 6–25, 26–50, 51–75, and 76–100%. I considered the canopy layer to consist of trees >5 m tall and the shrub layer to be vegetation 1–5 m tall. Ground cover was grasses, sedges, forbs, and woody vegetation <1 m high. I recorded the predominant plant species in each layer based upon cover classes and the presence of fallen logs, stumps, snags, or burrows within 15 m of the center point of each array. I used a tape measure to determine distances from arrays to nearby seeps or streams. I also used a tape measure to record the width of streams and a meter stick to record water depths in late April 1999.

All capture data were entered into dBase and summarized using SAS (SAS Institute 1988). Linear regression analysis of anuran and salamander capture data with average precipitation per trapping period was conducted using SigmaStat for Windows 1.0. Species composition between different areas was compared using the Jaccard similarity coefficient, which counts each species equally regardless of relative abundance (Southwood 1978). The Jaccard similarity coefficient is calculated using the formula: $C_j = c/(a + b - c)$, where c = the number of species shared by both habitats, a = the number of species in Habitat A, and b = the number of species in Habitat B (Magurran 1988). For these comparisons, I included species observed along fences or anurans heard calling in ravines or bogs, but I omitted anuran species heard calling from nearby upland areas.

RESULTS

Habitat and Array Descriptions

Seepage Bogs.—Four arrays were situated in bogs imbedded in sandhill habitat at Blackwater River State Forest. Arrays 15 and 16 were at Open Bog where the surrounding pine stand, which was ≈ 62 years old, was typically burned every 4 years during the cool season and had last been burned in February 1995. Arrays 17 and 18 were at Godman's Bog where the surrounding pines, which were ≈ 57 years old, were typically burned every 3 years during the cool season and had last been burned in February 1998. The uplands around both bogs had a canopy of longleaf and slash (*Pinus elliotii*) pines, a shrub layer containing mostly gallberry (*Ilex glabra*) and persimmon (*Diospyros virginiana*), and a ground cover of predominantly wiregrass and bracken fern (*Pteridium aquilinum*). The oak species (*Quercus* spp.) in the uplands differed between the 2 sites. Uplands near Open Bog had a shrub layer of sand post (*Q. margaretta*), laurel (*Q. hemisphaerica*), and live (*Q. virginiana*) oaks. Uplands near Godman's Bog had a subcanopy of water (*Q. nigra*) and southern red (*Q. falcata*) oaks, and a shrub layer of southern red, laurel, and bluejack (*Q. incana*) oaks.

Array 15 was on a gentle slope in the extensive herbaceous portion of Open Bog. Slash pines were scattered throughout the bog, but none was in the immediate vicinity of the array. The predominant plant species in the various layers around each array are listed in Appendix B, and the percent cover of each layer is given in Appendix C. Array 16, which was 91 m from Array 15, was entirely encompassed by a wide shrub bog along the seepage stream that drained Open Bog. The stream was 0.6–2.3 m wide and 2–15 cm deep, and it often bifurcated as it wound among trees and root hummocks. One fence intersected the stream, and another fence partially abutted the stream. There were also several seepage areas along or adjacent to fences.

Array 17 was in the herbaceous portion of Godman's Bog, downslope of sandhill habitat. This bog differed from Open Bog in that it was on a steeper slope, was smaller, and lacked white-topped pitcher plants (*Sarracenia leucophylla*) (Appendix B). Seepage occasionally ceased around the array, unlike the continuously saturated soil around Array 15 in Open Bog. There was no canopy cover (Appendix C), although slash and longleaf pines occurred in the vicinity. The end of 1 arm of the array was 2 m from a patch of largeleaf gallberry (*Ilex coriacea*), and the end of the arm farthest downslope was 3 m from the edge of a shrub bog.

Array 18 was in the shrub bog, 82 m from Array 17. A prescribed burn in February 1998 had killed most of the aboveground portions of shrubs, but many shrubs had coppiced. One arm paralleled the burned edge of the shrub bog and was ≤ 2 m from the stream. Another arm traversed the unburned portion of the shrub bog and intersected the stream; it terminated 2.5 m from the far edge of the shrub bog. The remaining arm traversed the burned, drier margin of the shrub bog. This shrub bog differed from that in Open Bog by being much narrower, having a slope bordering 1 side, and containing few seepage areas adjacent to the stream. After a heavy rainfall, there was substantial surface runoff, which occasionally knocked down the center of the array and the fence in the stream, often ripping 1 of the fences away from the center stake. The stream was typically 0.5–1.0 m wide and 5–12 cm deep, and it flowed continuously throughout the study. However, when I visited the site on 25 September 1999, the stream had ceased flowing and contained only a few shallow pools. Shrub cover was much denser along the stream than in burned areas away from the stream, where gallberry predominated because the more fire-sensitive shrubs, primarily swamp titi (*Cyrilla racemosa*), had been killed. Sphagnum moss (*Sphagnum* spp.) was confined to the stream margins.

Steephead Ravines in the Blackwater River Drainage.—On Blackwater River State Forest, arrays 7 and 8 were situated along a 167-m-long tributary of Adams Mill Creek, whereas arrays 9 and 10 were along a longer tributary of Bone Creek. Both ravine streams had sand bottoms and fast-flowing water, but flat areas with seeps and sphagnum moss were also present. Both steephead ravines were surrounded by sandhill habitat with dense wiregrass and an open canopy of longleaf pines that were ≈ 76 years old. The uplands were typically burned every 4 years during the cool season and had last been burned in January 1994. The band of ravine hardwood vegetation was typically wider along the Bone Creek than along the Adams Mill Creek steephead. The Adams Mill Creek ravine was shorter and shallower, and sandhill vegetation almost abutted the stream in places. The uplands along Adams Mill Creek had a canopy of longleaf pine, turkey oak (*Quercus laevis*), and sand post oak; a shrub layer of canopy species and live, bluejack, and laurel oaks; and a dense ground cover of predominantly wiregrass, bracken fern, and gopher apple (*Licania michauxii*).

Array 7 was 46 m downstream from the head, which consisted of a 6-m-high hillside with seeps at its base. Two arms intersected the sand-bottomed stream, which was 3–10 cm deep and 1.2–1.6 m wide, and $\approx 50\%$ of the fencing was in shallow, mucky seepage areas. The fence farthest from the stream terminated at the edge of the pines along the ravine bottom, but the end of the fence was still 4 m from sandhill vegetation and situated in a dense thicket of largeleaf gallberry.

Array 8 was 53 m downstream from Array 7. The sand-bottomed stream was narrower (0.7–1.3 m wide) and faster with more defined banks than at Array 7. The stream was 3–14 cm deep, but some holes below small waterfalls were up to 20 cm deep. Downstream of Array 8, the stream remained narrow (typically <1.3 m wide) with discrete banks, but it became deeper (10–15 cm deep) and more winding. Sphagnum moss coverage was greater than around Array 7 (Appendix C) and was not confined to stream margins. Atlantic white cedar (*Chamaecyparis thyoides*), which was absent where the arrays were, became a dominant component of the canopy farther downstream. At a straight-line distance of 108 m downstream of Array 8, the stream entered Adams Mill Creek, which appeared to be a second-order stream. Adams Mill Creek, which was 1.4–3.5 m wide and 10–45 cm deep, was impounded a short distance upstream of the confluence.

The tributary of Bone Creek, which was only 1 km from the preceding ravine, was deeper and had multiple heads. The uplands here had a canopy of longleaf pine and turkey oak; a shrub layer of bluejack oak, laurel oak, turkey oak, and persimmon; and a dense ground cover of mostly wiregrass, gopher apple, and bracken fern. The upper portion of the ravine slope above Array 9 had a dense canopy of water oak, laurel oak, and American holly (*Ilex opaca*), and a shrub layer of sparkleberry (*Vaccinium arboreum*), laurel oak, and Florida anise (*Illicium floridanum*).

Array 9 was along a first-order stream only 21 m downstream from its head, which was a 4.5-m-high hillside. The segment of the sand-bottomed stream intersected by 1 arm of the array was 1–7 cm deep and 0.7–1.2 m wide. I considered this segment a first-order stream, although 2 small streams of approximately equal size joined 8 m above the intersecting fence. The 2 streams came from the same head but differed in that one was sand-bottomed and fast-flowing, whereas the other one was mud-bottomed, slow-flowing, and fed by mucky seeps. Approximately 50% of the fencing was in seepage areas, which were often in the form of small, winding rivulets carpeted with dead leaves and mostly containing shallow water, although some small pools were up to 24 cm deep.

Array 10 was 375 m downstream from Array 9. I considered this segment a second-order stream because another first-order stream joined it \approx 50 m below Array 9 (another first-order stream entered just above Array 10). The stream between the 2 arrays was very winding and often had steep banks and small waterfalls. There were numerous thickets of black titi, much of which was dead. One arm of the array terminated in the sand-bottomed stream, which was 1.3–2.5 m wide and 6–15 cm deep, although some holes were up to 40 cm deep. Another arm terminated 2 m from the edge of the titi canopy, or 6 m from

the shrub edge that delineated where sandhill vegetation began. A narrow seep intersected 1 fence and flowed along two-thirds of another fence.

Steephead Ravines in the Yellow River Drainage.—Steephead ravines in the Yellow River drainage differed from those in the Blackwater River drainage in the abundance of Atlantic white cedar, which was often the dominant canopy species. The 6 arrays in the northern Yellow River watershed were on privately owned land, and upland areas had been densely planted in sand pine (*Pinus clausa*), often quite close to ravine streams. Laurel oak was a common component of sand pine plantations near Trawick Creek, but the shrub layer also contained yaupon (*Ilex vomitoria*) and Spanish bayonet (*Yucca aloifolia*), and ground lichens (*Cladonia* spp.) carpeted much of the ground. Slash pine plantations near the head of Garnier Creek had a sparse pine canopy due to poor survival, unlike the dense canopy of adjacent sand pine plantations. Turkey oaks dominated the canopy of slash pine plantations, which also contained laurel and live oaks. Slash pine plantations had a shrub layer of various oaks, persimmon, and yaupon; the predominant ground cover was bracken fern, greenbriar (*Smilax* spp.), and gopher apple. Turkey oaks were also present in the canopy of sand pine plantations, which had a sparse shrub layer of turkey and live oaks, persimmon, yaupon, and greenbriar. The sparse ground cover in sand pine plantations consisted mostly of gopher apple, bracken fern, wiregrass, broomsedge (*Andropogon virginiana*), and ground lichens. Uplands along Burnt Grocery Creek were planted in sand pine, but laurel and turkey oaks were also present in the canopy. The shrub layer consisted primarily of laurel oak and sparkleberry, with lesser amounts of yaupon, Spanish bayonet, greenbriar, turkey oak, sand post oak, and persimmon. The ground cover was mostly laurel oak, yellow jessamine (*Gelsemium sempervirens*), gopher apple, greenbriar, and ground lichens.

Arrays 1 and 2 were situated on the west side of a third-order portion of Trawick Creek, which frequently divided into several streams that occasionally flowed underground. Array 1 was 94 m and Array 2 was 192 m north of the Broxson Road bridge. One arm of Array 1 terminated in a sand-bottomed, fast-flowing stream that was 2–3 m wide and 4–30 cm deep. This same arm ran along the edge of a smaller, leaf-bottomed stream that flowed through the center of the array and was 1.2–1.5 m wide and 9–13 cm deep. Another arm terminated in a shallow seep, and the third arm ran along the length of a shallow seep and part of the small stream, which was typically 13–19 cm deep because its water was partially backed up by the fence.

Array 2 was 98 m farther upstream where the main stream divided into 2 streams. One arm terminated at the stream juncture, where 1 stream was 2.4 m wide and the other 3.2 m wide. The main stream was narrower and 25–55

cm deep, whereas the streams it divided into were slower flowing and 5–15 cm and 12–20 cm deep. Another arm was completely situated in a small, shallow stream and seepage area, as was the center of the array.

Array 3 was in a broad, sphagnous, mucky area along a second-order portion of Garnier Creek. Just upstream was the confluence of a first-order stream from a gully-eroded ravine and a first-order stream that originated 102 m away in a steephead with actively eroding walls ≈ 7.5 m high. The gully-eroded stream was longer, slow-moving, and muck-bottomed, whereas the steephead stream was narrower, fast-flowing, and sand-bottomed. The end of 1 arm of the array was 6.5 m from the second-order stream. A smaller stream was intersected by the array, and 2 arms were either in this stream or in associated muck-bottomed seepage areas that contained water 12–22 cm deep. The third arm traversed an extensive bed of sphagnum moss.

Array 4 was 53 m downstream from Array 3, and 1 arm intersected the main channel of Garnier Creek, which was 1.3–2.8 m wide and 6–28 cm deep. Another arm terminated in the stream, and the other arm intersected a small stream and associated seepage areas. There was less sphagnum moss, shrub, and ground cover than at Array 3 (Appendix C) because most of the area surrounding the array was covered by sand-bottomed streams or shallow, leaf-covered seepage areas and stream backwaters.

Arrays 5 and 6 were on the flat terrace along the east side of what the topographic map indicates is a second-order portion of Burnt Grocery Creek. However, Burnt Grocery Creek appeared to have a greater volume of flow than third-order Trawick Creek and much greater flow than the other second-order streams sampled. Array 5 was 95 m north of the Blue Barnes Road bridge, and Array 6 was 72 m upstream from Array 5. One arm of Array 5 ascended the gently sloping sidewall of the ravine, which was vegetated with mature planted sand pines. The other 2 arms were in seepage areas and terminated 1 m from Burnt Grocery Creek, which was 25 m wide and ≤ 80 cm deep. The stream here contained tree islands and had a mostly mucky bottom with narrow, sand-bottomed channels. The water was clear, and both emergent and submergent vegetation were present. One arm of Array 6 terminated 0.7 m from Burnt Grocery Creek, another arm paralleled the stream ≈ 5 m away, and the third arm ascended a slope. The stream by Array 6 was 40 m wide, but ≈ 20 m of this was an island. The stream was ≈ 50 cm deep with a mucky bottom near the array, but elsewhere the stream was >1 m deep and had a sand-bottomed main channel.

Four arrays were along Weaver Creek in the southern Yellow River watershed. Uplands at the head of Weaver Creek were natural but had not

burned recently. Large laurel and live oaks dominated the overstory, but some areas had remnant, large longleaf pines. Other canopy species were water oak, pignut hickory (*Carya glabra*), and sand pine. The shrub layer contained laurel oak, sparkleberry, and sand pine, and the ground cover consisted of laurel oak, gopher apple, bracken fern, and ground lichens. Farther downstream along the tributary of Weaver Creek that was sampled, the upland vegetation indicated a higher fire frequency, although the fires were not as frequent as in uplands at Blackwater River State Forest. The canopy here consisted of laurel oak, longleaf pine, and live oak, and the shrub layer was laurel oak, yaupon, beautyberry (*Callicarpa americana*), southern magnolia (*Magnolia grandiflora*), sparkleberry, and saw palmetto (*Serenoa repens*). Ground cover was mostly laurel oak, wiregrass, and ground lichens.

Arrays 11 and 12 were 78 m apart at the head of Weaver Creek in different springs. The hillside above the arrays was ≈ 23 m high, and the slope was $\geq 45^\circ$. Shrub diversity was high due to assorted microhabitats that included broad, sand-bottomed areas with shallow water, root-laced hummocks of trees, and steep slopes with drier soil. Approximately 50% of the area had shallow, flowing water over a mostly exposed sand bottom, although areas with stiller water had leaf accumulations over sand. The head of the stream was only 11 m from the nearest fence. None of the water was >6 cm deep, and most of the stream had only 0.5–2.5 cm deep water. All arms of the array were in streams, but 2 arms approximately paralleled the base of a slope that was 2.0–4.5 m away.

Array 12 was at the base of a ridge that divided 2 steephead streams whose sources were 13 and 16 m away from the nearest fence. One arm completely intersected 1 of the major streams and terminated where it joined another smaller stream only 5 m downstream from its source; another arm partially intersected this stream and terminated 1 m from the second major stream; and the third arm ascended a 45° slope along the ridge. The intersected stream had a sand and small-gravel bottom, and the water was 1–4 cm deep. About 25% of the area had shallow water over sand, and 15% of the area had shallow water over dead leaves. Mosses at arrays 11 and 12 were primarily confined to exposed tree roots.

Arrays 13 and 14 were along a first-order tributary of Weaver Creek ≈ 1.7 km downstream from the head of Weaver's Creek. The head of the tributary is a steep 3.5-m-high hillside, but the valley bottom is approximately another 2.5 m below the surrounding terrain. A second major spring laterally feeds the stream 10 m downstream from the head but has not yet developed into a steephead. This second spring accounts for the high volume of flow in this short, first-order stream. Array 13 was 82 m downstream from the head. One arm of Array 13 extended 1.1 m into the tributary, which was sand-bottomed, fast-flowing, 3–4 m wide, and 1–17 cm deep. Another arm intersected a small

seepage stream that was mostly sand-bottomed, 2–2.5 m wide, and 0.5–6 cm deep. Sphagnum moss was restricted to the small seepage stream.

Array 14 was 74 m from Array 13 along 2 smaller streams that emerged from the ground near the array and were littered with dead bushes and fallen black titi trees. One arm of Array 14 extended 3.7 m into what appeared to be a stream branch flowing away from the main stream. This branch was 5.3 m wide and 12–20 cm deep where it was intersected by the fence and had a sand bottom, although a layer of detritus (mostly dead leaves) covered the bottom. The second arm of the array extended 2.3 m into a 3.2-m-wide stream that was 18–40 cm deep and had a detrital substrate. The third arm traversed terrestrial habitat and terminated 13 m from the main stream along which Array 13 was located.

Temporal Variation in Abiotic Variables

Precipitation typically influenced water levels in bog streams more than in steephead streams. Stream depths recorded by gauges must be considered relative because the zero points of gauges were not necessarily even with stream bottoms, especially in muck substrates. Water levels in the low-volume first-order streams in shrub bogs varied 15.5 cm in Godman's Bog and 8 cm in Open Bog during the course of the study (Table 2). The steeper slopes at Godman's Bog probably contributed to greater surface runoff into the stream. The highest water level was recorded in Godman's Bog after Hurricane Georges dropped at least 16.0 cm of rain, whereas the highest water level in Open Bog was recorded after 6.2 cm of rain in August. Precipitation among sites was often variable, especially during summer thunderstorms.

Water-level fluctuations in steephead streams showed no obvious correlation with Strahler's stream order. Some streams exhibited minimal water-level fluctuations. The 2 shallow streams I monitored at the head of Weaver Creek varied only 1 cm annually, whereas the first-order tributary of Weaver Creek, which had a higher volume of flow, varied 3 cm annually at Array 13. Water levels in the second-order portion of Garnier Creek varied only 3.0 cm annually \approx 150 m downstream of the head. Annual water-level fluctuations recorded along stream braids of the third-order Trawick Creek were \leq 5 cm, which were equivalent to the first-order tributary of Adams Mill Creek (Table 2).

In contrast, water levels in both first- and second-order portions of Bone Creek's tributary varied 8.5 cm annually. Water levels in the second-order Burnt Grocery Creek varied 11.5 cm annually at Array 6 (Table 2), which was \approx 1.5 km downstream from the head. Streams with greater water-level fluctuations presumably had more surface runoff after heavy precipitation or had water back up during peak flow events.

Water temperatures of streams were recorded each time traps were checked. Temperatures varied among streams depending upon their volume of flow and distance downstream from the source. Ground-water temperatures were probably 20.0–21.1°C, but air temperature often affected surface-water temperature such that downstream portions of steephead streams exhibited greater fluctuations in water temperatures than did upstream portions. Water temperatures in steephead streams varied less than in shrub-bog streams (Table 3), which had less seepage flow and more extreme air temperatures (Table 4).

Data loggers in Garnier and Burnt Grocery creeks recorded water temperatures at hourly intervals, but sampling was not continuous due to dead batteries and animal damage to external temperature probes (Table 5). Garnier and Burnt Grocery creeks had a maximum daily change in water temperature of 4.2°C on 13 April and 12 February, respectively. Water temperatures in both these streams were similar and fluctuated less than in nearby Trawick Creek (Table 3), which was a higher order stream. As expected, data loggers

Table 2. Maximum and minimum relative depths of streams (in cm) each month of trapping in steephead ravines and seepage bogs in Okaloosa or Santa Rosa County, Florida.

Site	Oct 1998		Feb 1999		Apr 1999		Jun 1999		Aug 1999	
	Max.	Min.								
Trawick Creek										
Array 1	29.0	25.0	27.0	25.0	28.0	26.5	27.5	25.0	29.5	26.0
Array 2	11.0	9.5	13.0	12.0	14.0	13.0	13.0	11.0	14.5	10.0
Garnier Creek										
Array 3	18.5	18.0	16.5	16.0	17.5	17.0	17.0	16.0	18.0	17.0
Array 4	18.0	17.0	16.5	15.5	16.0	15.5	16.0	15.0	17.0	15.0
Burnt Grocery Creek										
Array 5	33.5	29.0	29.0	28.0	28.0	27.0	36.5	29.0	23.5	19.0
Array 6	17.5	13.0	17.0	12.0	15.0	14.0	16.5	12.0	12.0	6.0
Adams Mill Creek tributary										
Array 7	8.5	8.0	10.0	6.0	6.5	6.0	7.5	5.0	6.0	5.5
Array 8	13.0	12.5	13.0	12.0	10.0	9.5	12.0	9.0	9.0	8.0
Bone Creek tributary										
Array 9	8.0	5.5	14.0	6.0	10.5	6.5	12.5	10.0	13.5	9.0
Array 10	20.0	15.5	19.5	12.5	17.0	16.0	19.0	18.0	24.0	18.0
Weaver Creek										
Array 11	2.0	1.0	1.0	1.0	1.0	1.0	1.5	1.0	1.0	1.0
Array 12	6.0	5.0	6.0	5.5	5.0	5.0	6.0	5.5	6.0	5.0
Weaver Creek tributary										
Array 13	14.0	11.5	12.0	11.0	12.5	12.0	13.5	12.5	12.0	11.5
Array 14	26.0	22.5	19.0	18.0	18.5	17.0	19.0	17.0	18.0	17.0
Open Bog										
Array 16	17.5	15.0	19.0	15.5	17.0	16.0	18.0	17.0	23.0	18.0
Godman's Bog										
Array 18	29.0	16.0	25.5	13.5	15.0	13.5	19.0	13.5	21.0	17.0

Table 3. Maximum and minimum water temperatures (°C) of streams each month of trapping in steephead ravines and seepage bogs in Okaloosa or Santa Rosa County, Florida.

Site	Oct 1998		Feb 1999		Apr 1999		Jun 1999		Aug 1999	
	Max.	Min.								
Trawick Creek										
Array 1	25.3	18.9	20.8	12.2	23.5	18.7	26.7	22.2	26.7	23.3
Array 2	25.6	18.9	21.1	12.8	24.3	18.7	27.1	22.5	26.9	24.1
Garnier Creek										
Array 3	22.8	19.4	20.6	13.9	22.1	17.5	22.5	21.3	22.8	22.6
Array 4	22.8	19.4	20.6	15.6	21.9	17.7	22.5	21.1	22.5	22.2
Burnt Grocery Creek										
Array 5	22.2	20.8	21.1	18.7	21.9	17.1	22.5	20.9	23.5	21.4
Array 6	22.2	20.8	20.6	15.3	23.0	14.7	25.9	22.4	28.2	24.8
Adams Mill Creek tributary										
Array 7	23.3	18.3	19.7	17.1	20.5	18.7	22.0	20.1	22.5	21.0
Array 8	23.3	18.3	19.7	17.1	20.3	18.5	22.0	20.3	22.5	21.2
Bone Creek tributary										
Array 9	23.0	19.4	20.0	16.3	20.1	18.5	22.0	19.9	23.5	21.0
Array 10	23.9	19.4	19.4	16.3	20.5	18.1	22.0	20.2	24.0	21.8
Weaver Creek										
Arrays 11 and 12	21.7	18.9	20.5	16.7	20.9	17.9	21.7	20.3	21.7	20.3
Weaver Creek tributary										
Array 13	21.7	19.4	20.5	18.7	20.1	18.7	21.7	19.9	21.7	20.1
Array 14	21.7	19.4	20.5	18.7	20.1	18.5	21.7	20.2	21.7	20.3
Open Bog										
Array 16	21.1	18.3	17.8	10.0	19.7	16.1	22.7	19.7	25.0	22.9
Godman's Bog										
Array 18	25.6	18.6	15.6	11.5	20.3	16.9	23.9	20.9	29.7	23.5

Table 4. Highest maximum and lowest minimum air temperatures (°C) recorded by a maximum-minimum thermometer each month of trapping in steephead ravines and a seepage bog in Okaloosa or Santa Rosa County, Florida.

Site	Oct 1998		Feb 1999		Apr 1999		Jun 1999		Aug 1999	
	Max.	Min.								
Trawick Creek	28.9	16.1	26.1	-3.9	31.7	1.1	31.7	13.3	33.9	19.4
Garnier Creek	31.1	5.6	26.7	-5.6	33.3	1.1	31.1	15.0	31.1	18.3
Adams Mill Creek tributary					33.9	-0.6	32.2	14.1	32.8	19.4
Bone Creek tributary	29.4	4.4			30.6	1.1	32.2	14.1	32.2	19.4
Weaver Creek	25.0	13.3	23.9	0.6	31.1	3.3	30.6	14.4	32.2	18.9
Open Bog	30.6	2.8	26.1	-5.0	32.8	-0.6	33.3	13.3	36.7	19.4

recorded higher maximum and lower minimum water temperatures than did handheld thermometers (Table 3), which were used only during site visits.

Stream temperatures fluctuated much less than did air temperatures. Air temperatures of $<0^{\circ}\text{C}$ occurred in bogs and some steephead ravines (Table 4), but stream temperatures never dropped below 12.2°C in ravines and 10.0°C in bogs (Table 3). Air temperatures in the shadiest shrub bog reached 36.7°C (Table 4), and higher temperatures were undoubtedly attained elsewhere in more open shrub and herb bogs. Air temperatures in steephead ravines, however, never exceeded 33.9°C (Table 4), and water temperatures never exceeded 27.1°C (Table 3). During the months of trapping, air temperatures varied 41.7°C at Open Bog, which was nearly 4°C more than air temperatures varied in ravines along Trawick and Garnier creeks (Table 4). The huge steephead at Weaver Creek had only 31.6°C annual variation in air temperature (Table 4), but its maximum daily variation in air temperature (26.5°C on 13 April) was higher than that recorded at Open Bog (23.7°C on 19 April). Open Bog exhibited the greatest fluctuation in air temperature during most months of trapping, whereas Weaver Creek usually had the least monthly fluctuation (Table 4). Steephead ravines may ameliorate annual or monthly extremes in air temperatures, but some ravines may exhibit greater daily variations in air temperature than shrub bogs. Maximum-minimum thermometers usually recorded more extreme air temperatures (Table 4) than did data loggers at the same site (Table 5).

Table 5. Maximum and minimum air or water temperatures ($^{\circ}\text{C}$) collected hourly by StowAway data loggers in steephead ravines and a seepage bog in Okaloosa or Santa Rosa County, Florida, October 1998 through August 1999.

Site	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Aug.
Garnier Creek air										
Maximum	33.5	28.7					32.0			30.1
Minimum	3.1	0					9.0			19.2
Garnier Creek water										
Maximum	24.3	21.1	21.4	18.7		20.3	22.8	22.4	22.8	23.5
Minimum	16.9	16.2	14.8	13.0		14.8	15.9	17.2	19.7	21.1
Burnt Grocery Creek water										
Maximum	24.2	21.0	21.3	19.6	20.7	19.6	21.0	21.4	21.7	
Minimum	16.8	16.1	15.5	14.0	16.1	16.8	18.2	19.3	20.3	
Weaver Creek air										
Maximum					24.7	25.7	34.3			30.8
Minimum					0.5	2.9	7.6			19.5
Open Bog air										
Maximum					23.8	26.0	32.3	30.5	33.0	33.2
Minimum					-2.0	-0.3	1.0	7.0	15.0	19.0

Temporal Variation in Captures

Traps were opened on 23 September 1998 and first checked on 30 September. Hurricane Georges deluged the Panhandle on 27–28 September with 76.2 cm of rain in Crestview, which is east of the study area, and 40.6 cm of rain in Pensacola to the west. On 29 September, the Blackwater River at Baker in Okaloosa County crested at a record 8.76 m, which was 5.41 m above flood stage. The least amount of rainfall recorded at my study sites after the hurricane was 12.4 cm at Weaver Creek, and the maximum was >16.0 cm (the rain gauge was full) at Godman's Bog. Despite damage to arrays and displaced traps from the hurricane, I trapped a total of 295 amphibians and 26 reptiles during the first 7 days of the study. Thus, 17.5% of all amphibians ($n = 1,685$) and 5.6% of all reptiles ($n = 462$) were trapped during 4.2% of the study's time.

During the first 39 days of the study, which I have designated October, I trapped 76.1% ($n = 46$) of all aquatic salamanders: one-toed amphiuma, two-toed amphiuma, and "least" siren (Table 6). Most southern red (71.7%) and dwarf (55.2%) salamanders were also trapped in October (Table 6). Gravid red salamanders were observed from 21 August through 1 November, after which trapping was discontinued until February. Recently metamorphosed red salamanders (45–50 mm snout-vent length [SVL]) were trapped from 1 March through 16 April, and a large larva (42 mm SVL) was trapped on 1 September. The reddish, undescribed dwarf salamander that primarily inhabited bogs was apparently gravid from October through possibly 10 April. Gravid individuals of the nominate species of dwarf salamander, which was less common in bogs than in ravines, were observed from 27 April through 15 June. A larval dwarf salamander ready to metamorphose was trapped in a bog on 10 April, and a recent metamorph was trapped on 22 April. Southern two-lined salamanders were trapped most often in February and October (Table 6). Gravid females or males with cirri were trapped from 17 October through 16 April, and recent metamorphs (19–24 mm SVL) were trapped in June.

I trapped most bronze frogs and eastern narrowmouth toads in June and August (Table 6), which were relatively wet months (Fig. 2). Gravid bronze frogs were observed from 6 March through 25 June, and many of the captures from late April through August represented metamorphs. Gravid female cricket frogs were trapped from 1 March through 25 June, and the peak month for captures was April (Table 6).

Linear regression indicated a positive correlation between salamander captures for all sites combined and the average amount of precipitation per trapping period ($F = 43.4$, $P < 0.0001$, $df = 29$), which explained 59% of the

Table 6. Standardized capture rates (i.e., mean number trapped per week) for the most frequently trapped taxa ($n \geq 5$) from 18 drift-fence arrays in steephead ravines and seepage bogs in Okaloosa or Santa Rosa County, Florida, during 5 sampling periods from October 1998 through August 1999. The total number of captures per sampling period appears in parentheses.

Taxon	Oct 1998	Feb 1999	Apr 1999	Jun 1999	Aug 1999
Anurans					
Southern cricket frog	3.3 (18)	4.2 (20)	10.6 (47)	4.7 (21)	2.9 (13)
Southern toad	0.9 (5)	0	1.6 (7)	4.1 (18)	2.7 (12)
Eastern narrowmouth toad	1.8 (10)	0	0.4 (2)	6.8 (30)	4.5 (20)
Pine Barrens treefrog	0	0	1.4 (6)	2.0 (9)	0
Bullfrog	1.1 (6)	0.2 (1)	0	0.4 (2)	0
Bronze frog	11.7 (65)	6.2 (29)	12.2 (54)	27.8 (123)	17.8 (79)
Pig frog	0.4 (2)	0.2 (1)	0.4 (2)	1.1 (5)	1.1 (5)
Florida bog frog	0.7 (4)	0.2 (1)	0.2 (1)	1.4 (6)	0
Southern leopard frog	0.7 (4)	0.2 (1)	1.1 (5)	0.4 (2)	0.9 (4)
Salamanders					
Two-toed amphiuma	2.2 (12)	0	0	0.4 (2)	0
One-toed amphiuma	0.9 (5)	0	0	0.2 (1)	0
Spotted dusky salamander	9.3 (52)	4.4 (21)	7.4 (33)	13.3 (59)	4.1 (18)
Southern two-lined salamander	19.0 (106)	21.0 (100)	14.4 (64)	11.5 (51)	4.7 (21)
Three-lined salamander	1.3 (7)	0	0	0.4 (2)	0.7 (3)
Dwarf salamander	10.4 (58)	4.0 (20)	3.4 (14)	2.7 (12)	0.2 (1)
Southeastern slimy salamander	0.7 (4)	0	0.7 (3)	3.4 (15)	0.4 (2)
Southern red salamander	42.4 (261)	8.3 (39)	3.4 (15)	4.1 (18)	4.7 (21)
"Least" siren	3.2 (18)	0.6 (3)	0.4 (2)	0.7 (3)	0
Turtles					
Eastern mud turtle	0.5 (3)	1.3 (6)	1.8 (8)	2.7 (12)	0.9 (4)
Lizards					
Green anole	1.4 (8)	0.4 (2)	0.4 (2)	1.1 (5)	0
Southern coal skink	0.4 (2)	0.2 (1)	0.2 (1)	1.6 (7)	1.4 (6)
Broadhead skink	0.9 (5)	0	2.7 (12)	3.8 (17)	3.8 (25)
Eastern glass lizard	0	0	0.9 (4)	0.4 (2)	0.9 (4)
Ground skink	0.2 (1)	0.4 (2)	2.3 (10)	3.8 (17)	0.9 (4)
Snakes					
Cottonmouth	1.4 (8)	0.4 (2)	2.5 (11)	1.6 (7)	0.4 (2)
Northern scarlet snake	0	0	0	2.3 (10)	1.8 (8)
Southern black racer	0.9 (5)	0.6 (3)	5.6 (25)	2.5 (11)	2.5 (11)
Southern ringneck snake	2.0 (11)	0.2 (1)	1.6 (7)	4.7 (21)	1.4 (6)
Corn snake	0.5 (3)	0.4 (2)	0	0.3 (1)	0.2 (1)
Banded water snake	2.3 (13)	1.3 (6)	2.5 (11)	2.5 (10)	4.1 (18)
Gulf crayfish snake	0.9 (5)	0.2 (1)	0.4 (2)	0	3.2 (14)
Eastern ribbon snake	0	0.2 (1)	2.7 (12)	0.3 (1)	0.2 (1)
Eastern garter snake	1.1 (6)	0	0.4 (2)	0.4 (2)	0

observed variation in capture totals. Anuran captures were also correlated with precipitation ($F = 13.8$, $P = 0.0009$, $df = 29$), but precipitation explained only 30% of the observed variation.

Most reptile species exhibited peak activity in April and June, and over twice as many southern black racers were trapped in April as in any other month (Table 6). On 16 April, 5 adult racers were trapped at Array 17 in Godman's Bog, and 4 adult racers (3 in 1 trap) were trapped at Array 7 along Adams Mill Creek's tributary. All northern scarlet snakes were trapped in June and August, but 12 of 15 eastern ribbon snakes were trapped in April. The relatively high capture rates for banded water snakes, crayfish snakes, and black racers in August and October were primarily due to young-of-the-year. Crayfish snakes were not trapped in June, whereas 14 of 22 captures came from August. Most coal skinks were trapped in June and August, and most ground skinks were trapped in April and June (Table 6). These 2 skink species were sometimes trapped in February, whereas broadhead skinks first appeared in April and remained active at least through October. Most captures of broadhead skinks in August and October consisted of young-of-the-year.

Sampling Efficiency

Combining captures from ravines in all river drainages, 11 amphibian and 16 reptile species were trapped both in ravines and bogs during this study. Eight amphibian and 8 reptile species were trapped only in ravines, whereas 2 amphibian and 7 reptile species were trapped only in bogs.

Recapture rates of the most frequently trapped ($n \geq 5$) anuran species ranged from 0% for the Pine Barrens treefrog and southern leopard frog to 20.0% for the southern toad. Mortality rates of trapped anurans ranged from 0% for the pig frog to 13.3% for the Pine Barrens treefrog. Among frequently trapped salamander species, the spotted dusky salamander had the highest recapture rate and lowest mortality rate, whereas the southeastern slimy salamander shared the lowest recapture rate and had the highest mortality rate (Table 7).

The eastern mud turtle was the most frequently recaptured species (Table 7). Lizards were typically recaptured more frequently than other groups and had mortality rates ranging from 0% for the green anole to 30.0% for the eastern glass lizard. After trapped skinks were released on the opposite side of the fence, they were often recaptured the next time traps were checked as they tried to return to the other side of the fence. The most frequently recaptured snake species were the banded water snake, corn snake, and racer (Table 7). Although cottonmouths were not marked, I recognized some

Table 7. Recapture and mortality rates for the most frequently trapped taxa ($n \geq 5$) in steephead ravines and seepage bogs in Okaloosa or Santa Rosa County, Florida (some taxa were not marked).

Taxon	Recapture rate		Mortality rate	
	%	n^a	%	n^a
Anurans				
Southern cricket frog	6.5	114	12.6	119
Southern toad	20.0	36	9.5	42
Eastern narrowmouth toad	9.4	53	9.7	62
Pine Barrens treefrog	0	15	13.3	15
Bullfrog	12.5	8	0	9
Bronze frog	9.4	320	12.0	350
Pig frog	13.3	15	0	15
Florida bog frog	9.1	11	8.3	12
Southern leopard frog	0	15	6.2	16
Salamanders				
Two-toed amphiuma			7.1	14
One-toed amphiuma			0	6
Spotted dusky salamander	10.3	165	2.7	183
Southern two-lined salamander	3.5	315	7.3	341
Three-lined salamander	0	10	8.3	12
Dwarf salamander	3.1	96	6.9	102
Southeastern slimy salamander	0	21	12.5	24
Southern red salamander	8.9	304	8.8	329
“Least” siren			3.8	26
Turtles				
Eastern mud turtle	42.4	33	3.0	33
Lizards				
Green anole	11.8	17	0	19
Southern coal skink	18.8	16	5.9	17
Broadhead skink	26.8	56	1.7	59
Eastern glass lizard			30.0	10
Ground skink	34.5	29	8.6	35
Snakes				
Cottonmouth			0	30
Northern scarlet snake	0	15	0	18
Southern black racer	11.8	51	5.4	55
Southern ringneck snake			4.3	46
Corn snake	16.7	6	14.3	7
Banded water snake	17.6	51	1.7	58
Gulf crayfish snake	0	7	9.1	22
Eastern ribbon snake	0	15	0	15
Eastern garter snake	0	10	0	10

^aDiscrepancies in sample sizes between recapture and mortality rates for a taxon were due to animals escaping before their recapture status could be confirmed, or to animals with missing limbs, multiple missing toes, or confusing marks.

individuals that had been captured previously and suspect that cottonmouths had relatively high recapture rates. I did not recapture any marked scarlet, eastern garter, or eastern ribbon snakes. Snakes typically had low mortality rates in traps, although 9.1% of crayfish snakes were killed (Table 7).

Between 44.8% and 72.0% of the total number of species captured at each of the 9 sites was trapped in October, the first month of the study. An average of only 1.9 new species (range 0–4) was documented per site during the next sampling period in February. April was over twice as productive as February, yielding an average of 4.1 new species (range 3–5) per array. In June, an average of 3.2 new species (range 1–7) was added per array. June was particularly productive in the bogs, where 6–7 new species were trapped, primarily upland species entering the bogs. In August, the last month of trapping, 1.7 new species (range 1–2) were added per array. A few new species were still being documented at all sites at the end of the study. Although the herpetofaunal inventories of these sites were not complete, the rate at which new species were being added had declined.

Data Collected on Target Taxa

The following taxa were targeted for more detailed data collection because their biological scores were ≥ 17 : narrowmouth toad (18.6), Pine Barrens treefrog (24), bog frog (26.3), one-toed amphiuma (17.3), mimic glass lizard (17), northern scarlet snake (18.3), Florida pine snake (23.7), and southeastern crowned snake (20). Target taxa with high action scores (≥ 35) are the “least” siren (35), coal skink (35), Gulf crayfish snake (40), and mole kingsnake (40) (Millsap et al. 1990).

One Pine Barrens treefrog was trapped along the edge of each shrub bog, whereas 13 were trapped in herb bogs (Table 8). The 5 treefrogs trapped in the herbaceous portion of Godman’s Bog were along the fence farthest downslope near a shrub-lined drain, and 7 of 8 treefrogs trapped in the herbaceous portion of Open Bog were along the fence farthest downslope where standing, shallow water was often present. Five males and 10 females were trapped, and none was recaptured. Six frogs were trapped on 5 April after 5.5 cm of rainfall, and the remaining 9 frogs were trapped on 3 different occasions in June after rainfall ranging from 1.4 to 6.1 cm. This species was apparently trapped only after descending to the ground to breed. One trap contained 1 male and 3 females, and twice females spawned in traps. One trap contained developing eggs and a male treefrog, but the female had apparently escaped. Males measured 37.4 ± 1.44 mm SVL (range 35–43 mm) and weighed 3.50 ± 0.197 g (range 2.8–4.0 g), whereas 8 females measured 39.8 ± 0.96 mm SVL (range 36–44 mm) and weighed 4.44 ± 0.714 g (range 3.7–5.5

Table 8. Herpetofauna captured 23 September 1998–1 September 1999 in Blackwater River State Forest, Okaloosa County, Florida (X indicates taxon observed but not captured). Each column represents captures by 1 drift-fence array, except 2 arrays were present along Adams Mill Creek.

Taxon	Open Bog		Godman's Bog		Blackwater's ravines		
	Herbaceous	Shrub	Herbaceous	Shrub	Adams Mill Creek	Bone Creek head	Bone Creek downstream
Anurans							
Southern cricket frog	14	2	19	13	30	5	2
Southern toad	7	0	1	3	2	0	0
Eastern narrowmouth toad	9	6	11	6	5	0	6
Pine Barrens treefrog	8	1	5	1	0	0	0
Pinewoods treefrog	0	0	X	X	0	0	0
Barking treefrog	0	0	0	0	X	0	0
Northern spring peeper	0	0	1	0	0	0	X
Southern chorus frog	X	0	0	0	0	0	0
Bullfrog	2	1	0	0	1	1	0
Bronze frog	3	9	2	8	22	26	25
Pig frog	0	0	0	0	11	2	1
Southern leopard frog	0	1	1	0	0	1	4
Eastern spadefoot	0	0	0	0	1	0	0
Unidentified	1	0	2	2	1	0	0
Salamanders							
Two-toed amphiuma	0	0	0	0	0	2	0
One-toed amphiuma	0	0	0	0	0	0	3
Spotted dusky salamander	0	0	0	1	87	38	5
Southern two-lined salamander	1	8	0	0	26	8	11
Three-lined salamander	0	1	0	0	2	0	4
Dwarf salamander	37	6	15	6	19	1	10
Southeastern slimy salamander	0	0	0	1	4	1	0
Southern red salamander	6	21	27	5	33	13	14
"Least" siren	0	0	0	0	6	0	1
Turtles							
Eastern mud turtle	2	7	1	1	1	0	0
Loggerhead musk turtle	0	0	0	0	0	0	1
Gulf Coast box turtle	0	1	1	0	0	0	0
Lizards							
Green anole	0	0	1	0	3	0	0
Southern coal skink	8	0	5	3	0	0	0
Broadhead skink	0	10	2	10	5	3	4
Mimic glass lizard	1	0	0	0	0	0	0
Eastern glass lizard	3	0	5	2	0	0	0
Ground skink	5	2	15	4	0	0	0
Snakes							
Cottonmouth	0	0	1	1	2	2	0
Northern scarlet snake	2	3	2	1	2	0	2
Southern black racer	3	2	17	8	12	1	3
Southern ringneck snake	3	1	0	3	2	3	1
Corn snake	1	0	2	2	0	0	0
Gray rat snake	0	0	0	0	0	1	0
Eastern hognose snake	0	0	0	0	2	0	0
Mole kingsnake	1	0	0	0	0	0	0
Eastern coral snake	0	0	0	0	X	X	0
Banded water snake	0	1	2	2	12	4	6

Table 8. Continued.

Taxon	Open Bog		Godman's Bog		Blackwater's ravines		
	Herbaceous	Shrub	Herbaceous	Shrub	Adams Mill Creek	Bone Creek head	Bone Creek downstream
Snakes (continued)							
Florida pine snake	0	0	1	1	0	0	0
Gulf crayfish snake	4	7	1	2	0	2	1
Queen snake	0	0	0	0	0	0	1
Dusky pigmy rattlesnake	0	X	1	1	0	0	1
Florida redbelly snake	1	0	1	1	0	0	0
Southeastern crowned snake	0	0	0	1	0	0	0
Eastern ribbon snake	0	2	0	2	2	0	1
Eastern garter snake	6	2	2	0	0	0	0
Rough earth snake	1	0	0	0	0	0	0
Unidentified	1	0	1	0	0	0	0
Grand total	130	94	145	91	293	114	107

g). Females were significantly heavier than males ($t = 2.98$, $df = 11$, $P = 0.012$). Two females were not measured because one had been killed by fire ants, and another had been recently eaten by a garter snake, which was forced to regurgitate it.

Florida Bog frogs were trapped at both arrays along Garnier Creek and both arrays along Weaver Creek's tributary (Table 9). Garnier Creek and downstream portions of Weaver Creek are known bog frog sites, but Weaver Creek's tributary is a new locality (P. E. Moler, personal communication). Most frogs were trapped along streams or in sphagnum mats, but 1 frog trapped along Weaver Creek's tributary was 8 m from the nearest stream in an area with almost no ground or shrub cover and only a thin litter layer of black titi leaves. Four frogs were trapped in both October and June, 2 in July, and 1 in early March and April (Table 6). The snout-vent lengths of 12 trapped bog frogs were 40.9 ± 1.71 mm (range 30–50 mm), and the weights of 10 frogs were 5.5 ± 0.93 g (range 1.7–10.8 g). The only recapture was first trapped on 8 October and recaptured on 6 March. This frog had the same length (38 mm SVL) when recaptured, but its mass had dropped from 3.8 to 3.3 g. I could not distinguish between sexes. Breeding males did not have noticeably swollen thumbs or large tympanums. Most large individuals had a yellowish tinge on the throat, even ones I suspected were gravid females. I could not discern eggs through transparent patches of skin in the inguinal region, as can be done with gravid bronze frogs.

Table 9. Herpetofauna captured 23 September 1998–1 September 1999 by 2 drift-fence arrays each in steephead ravines in the Yellow River drainage along Trawick Creek, Okaloosa County, and Garnier Creek, Burnt Grocery Creek, and 2 sites along Weaver Creek, Santa Rosa County, Florida (X indicates taxon observed but not captured).

Taxon	Trawick	Garnier	Burnt Grocery	Weaver head	Weaver tributary
Anurans					
Southern cricket frog	5	X	4	19	6
Southern toad	7	2	12	1	7
Eastern narrowmouth toad	6	2	0	4	7
Cope's gray treefrog	0	0	0	0	1
Bullfrog	3	0	1	0	0
Bronze frog	50	46	76	46	37
Florida bog frog	0	8	0	0	4
Pig frog	1	0	0	0	0
Southern leopard frog	1	3	0	3	2
Unidentified	0	0	1	0	1
Salamanders					
Two-toed amphiuma	1	1	7	0	3
One-toed amphiuma	3	0	0	0	0
Spotted dusky salamander	0	0	0	46	6
Southern two-lined salamander	47	10	57	165	9
Three-lined salamander	5	0	0	0	0
Dwarf salamander	0	3	8	0	0
Southeastern slimy salamander	2	0	5	5	6
Southern red salamander	26	9	39	117	19
"Least" siren	2	13	0	0	4
Turtles					
Eastern mud turtle	18	2	0	0	1
Florida cooter	0	1	0	0	0
Loggerhead musk turtle	X	0	0	0	0
Gulf Coast box turtle	1	0	X	0	0
Lizards					
Green anole	2	0	2	X	9
Southern coal skink	0	1	0	0	0
Broadhead skink	2	6	7	1	9
Ground skink	0	0	0	3	4
Snakes					
Cottonmouth	8	7	0	8	1
Northern scarlet snake	1	0	0	2	3
Southern black racer	0	1	1	4	2
Southern ringneck snake	4	9	1	13	6
Corn snake	0	0	0	0	1
Gray rat snake	0	0	2	0	0
Eastern mud snake	0	0	1	0	0
Eastern hognose snake	1	0	0	0	0
Eastern coral snake	1	1	0	0	0
Banded water snake	11	2	3	10	3
Rough green snake	0	0	0	1	0
Gulf crayfish snake	1	2	0	0	2
Dusky pigmy rattlesnake	0	0	X	1	X
Florida redbelly snake	0	0	0	1	0
Eastern ribbon snake	3	1	1	0	3
Eastern earth snake	0	0	0	0	1
Grand total	211	130	228	450	156

Although the narrowmouth toad has a relatively high biological score, it is common in many habitats. Narrowmouth toads were most commonly trapped in herb and shrub bogs (Table 8), but they were also present in ravines along Garnier, Trawick, and Weaver creeks (Table 9). All 62 captures represented adults, and 48.4% were trapped in June and 32.3% in August (Table 6).

Three one-toed amphiumas were trapped in Array 1 along a third-order portion of Trawick Creek (Table 9), and 3 were trapped along a second-order portion of Bone Creek's tributary (Table 8). Five amphiumas were trapped on 1 October during flooded conditions resulting from Hurricane Georges (Table 6). The traps where these specimens were captured were situated away from the main stream in seepage areas that were normally shallow. The other amphiuma was trapped on 25 June in the main stream channel of Bone Creek's tributary, the same place where the only loggerhead musk turtle and queen snake were trapped during this study (Table 8).

Fifteen of 26 "least" sirens were trapped immediately after Hurricane Georges in 6 arrays along Garnier ($n = 10$), Trawick ($n = 1$), Adams Mill ($n = 3$), and Bone ($n = 1$) creeks. At 3 of these arrays (2, 7, and 10), only 1 individual was trapped in shallow seeps that briefly flooded during the hurricane, and no siren was subsequently trapped at these arrays. Seven sirens were trapped immediately after the hurricane along Garnier ($n = 6$) and Adams Mill creeks in beds of sphagnum moss, in which none was subsequently captured because of insufficient water depths. One siren was later captured at the other array along Trawick Creek in the main stream, and 4 were trapped along Weaver Creek's tributary in traps that were completely submerged in a deep seepage stream, which had a sandy bottom covered with detritus. Sirens were trapped later in the study in deep seepage areas along Garnier ($n = 3$) and Adams Mill ($n = 3$) creeks.

Coal skinks were most common in herb bogs, although 3 were trapped (1 was a recapture) in the shrub portion of Godman's Bog (Table 8), and 1 was trapped near the head of Garnier Creek in an area of dense sphagnum moss. Those trapped in shrub bogs were in areas of low shrubs regenerating after fire, not in the taller, denser shrubs along the stream. At both arrays in herb bogs, coal skinks were trapped along all 3 fences, ranging from drier upslope areas to wetter downslope areas. One individual was trapped in February, 1 in April, 7 in June, 6 in August, and 2 in October (Table 6). Of the 17 captures, 3 were recaptures. Seven adults measured 51 ± 1.7 mm SVL (range 45–58 mm) and weighed 3.6 ± 0.46 g (range 2.2–5.9 g). Two mostly black juveniles were trapped in August; the largest one was trapped on 16 August and measured 39 mm SVL and weighed 1.3 g.

Crayfish snakes were trapped in 4 steephead ravines along first-order streams and higher order streams, but they were most frequently trapped in herb and shrub bogs (Table 8). Suitable prey in the form of small crayfish was abundant in many of the streams, and crayfish burrows were common in bogs. None of the 22 snakes trapped was a recapture. The five adults I measured ranged from 390 to 490 mm SVL and 28.3 to 58.5 g. Neonates trapped on 8 and 21 August measured 140–148 mm SVL and weighed 2.4–3.0 g. On 21 August in a shrub bog, 6 neonates were trapped along with a female, which apparently had given birth in the trap. The female measured 402 mm SVL and weighed 34.6 g, and her offspring measured 146 ± 0.8 mm SVL and weighed 2.9 ± 0.03 g. A snake that was apparently young-of-the-year was trapped on 30 September and measured 179 mm SVL and weighed 3.9 g.

In Godman's Bog, a male pine snake was trapped on 5 June in the herbaceous portion, and a female was trapped on 1 September in the shrub portion. Both snakes measured 138 cm SVL, but the male weighed 980 g and the female 800 g. The anterior half of the dorsum of each snake had a dark brown wash that obscured most of the blotches. Another unusual capture was a male mole kingsnake (61 cm SVL; 98 g), which was trapped in the upslope herbaceous portion of Open Bog on 1 July. A mimic glass lizard was also trapped here on 27 October. Another upland species, the southeastern crowned snake, was trapped in the shrub portion of Godman's Bog on 7 October in the trap farthest from the stream among regenerating shrubs.

Four scarlet snakes were trapped in herb bogs and 4 in shrub bogs (Table 8), which was not unexpected because of the proximity of these bogs to pine uplands. However, the capture of 10 scarlet snakes at the bottom of steephead ravines was unexpected. Four of these snakes came from seepage areas at the head of Weaver Creek, along Trawick Creek, and along the second-order tributary of Bone Creek (2 individuals). Two snakes were trapped in a shallow stream at the head of Weaver Creek. Ten captures occurred in June and 8 captures in August (Table 6). Four were juveniles (195–238 mm SVL), 8 were adult females, and 6 were adult males.

Comparisons Between Blackwater's Bogs and Ravines

Sixteen amphibian species and 17 reptile species were trapped in steephead ravines in the Blackwater River drainage (Table 8), whereas 14 amphibian species and 23 reptile species were trapped in seepage bogs in Blackwater River State Forest (Table 8). The bogs sampled were situated in the Blackwater and Yellow river drainages. Bogs had greater herpetofaunal diversity than steephead ravines, despite some of the most species-rich ravines in this study being situated in Blackwater River State Forest. Thirteen

amphibian and 11 reptile species were trapped or observed in both bogs and ravines. The species composition of Blackwater's bogs and ravines was more similar for amphibians ($C_J = 0.62$) than for reptiles ($C_J = 0.39$). Some of the species that were not captured in a particular habitat would undoubtedly have been captured with more intensive sampling, but some of the apparent differences in species composition between habitats were probably valid. For example, Pine Barrens treefrogs were restricted to bogs, whereas one-toed amphiumas and loggerhead musk turtles were found only in ravines.

Although only limited sampling was conducted in bogs and steephead ravines at Blackwater River State Forest, some comparisons of the relative abundance of herpetofaunal species can be made. Bogs appear to provide more favorable conditions for the following amphibian species: southern toad, narrowmouth toad, Pine Barrens treefrog, and dwarf salamander (Table 8). Steephead ravines appear more suitable to the bronze frog, amphiumas (*Amphiuma* spp.), spotted dusky salamander, two-lined salamander, and slimy salamander (Table 8). Reptile species that appear to favor bogs over ravines are the mud turtle, coal skink, eastern glass lizard, ground skink, corn snake, crayfish snake, and garter snake. The banded water snake is the only reptile species that had substantially more captures in ravines than bogs. Red salamanders were common in both bogs and ravines. The only other common salamander in herb bogs was the dwarf salamander, which was apparently represented by 2 species. Amphibian communities were more similar between Blackwater's shrub bogs and ravines ($C_J = 0.62$) than between herb bogs and ravines ($C_J = 0.48$). Reptile communities, however, were not very similar between ravines and either herb ($C_J = 0.37$) or shrub ($C_J = 0.40$) bogs.

Herbaceous portions of Open Bog and Godman's Bog did not have very similar community composition for amphibians ($C_J = 0.41$) or reptiles ($C_J = 0.48$). Similarly, shrub portions of the 2 bogs did not have very similar community composition for amphibians ($C_J = 0.38$) or reptiles ($C_J = 0.47$). However, if species lists from herbaceous portions of the 2 bogs are combined and compared with species lists from shrub portions, herb bogs and shrub bogs had similar amphibian ($C_J = 0.69$) and reptile ($C_J = 0.74$) community composition. The overall species composition of Open Bog versus Godman's Bog (shrub and herb portions combined) was more similar for reptiles ($C_J = 0.62$) than for amphibians ($C_J = 0.50$). Nine species at Open Bog and 8 species at Godman's Bog were represented by only a single capture (Table 8), and at least 2 anuran species (i.e., pinewoods treefrog and southern chorus frog) that bred in the bogs were not trapped.

At Open Bog, the amphibian species composition was somewhat similar between the herb and shrub portions ($C_J = 0.67$), but the reptile species

composition was dissimilar ($C_J = 0.39$). In contrast, at Godman's Bog, both amphibian ($C_J = 0.67$) and reptile ($C_J = 0.70$) communities were somewhat similar between the herb and shrub portions.

Comparisons of Ravines Among Different Watersheds

Twenty amphibian and 25 reptile species were trapped or observed by arrays in steephead ravines in the 3 watersheds. The species composition of amphibian and reptile communities in steephead ravines was most similar between the northern Yellow River watershed (i.e., ravines on Champion International land) and Blackwater River drainage (Table 10). The only trapping differences for amphibian species between these drainages was the lack of Florida bog frogs in the Blackwater drainage (Table 8) and the lack of dusky salamanders and eastern spadefoots in the northern Yellow watershed (Table 9). Species composition of reptiles was not very similar between ravines in other watersheds sampled during this study (Table 10). Amphibian communities in the northern and southern (i.e., Weaver Creek ravines) Yellow River watersheds were more similar than between the southern Yellow River watershed and Blackwater River drainage (Table 10).

Table 10. Comparisons of amphibian (upper triangular matrix) and reptile (lower triangular matrix) species composition among steephead ravines in 5 Florida watersheds using Jaccard similarity coefficients (C_J). The Apalachicola and Ochlockonee data are from Enge (1998a).

	Ochlockonee	Apalachicola	Northern Yellow	Southern Yellow	Blackwater
Ochlockonee		0.57	0.46	0.45	0.54
Apalachicola	0.52		0.43	0.42	0.52
Northern Yellow	0.43	0.43		0.71	0.79
Southern Yellow	0.43	0.48	0.46		0.55
Blackwater	0.36	0.48	0.75	0.52	

DISCUSSION

Influences on Trapping Mortality and Efficiency

Most mortality of trapped amphibians in ravines was caused by desiccation, which explains why the more terrestrial species (e.g., narrowmouth toad and slimy salamander) had the highest mortality rates (Table 7). The southern toad is terrestrial, but it is less prone to desiccation than the other amphibian species. Most salamanders had low mortality rates because they tended to stay in seepage areas or streams, but some species (two-lined and red salamanders) would move up slopes or between seeps during rainy conditions and sometimes desiccate before the traps were checked. Red salamanders in herb bogs were observed using crayfish burrows, which apparently provided suitable refugia to escape heat and desiccation. Bronze and cricket frogs would also range away from water and sometimes desiccate. Much of the mortality of species that were common residents of herb bogs—cricket frog, dwarf salamander, coal skink, ground skink, eastern glass lizard, southern ringneck snake, corn snake, and racer—was apparently due to predation by red imported fire ants (*Solenopsis invicta*) or heat stress, although some amphibians desiccated. Trapped snakes and large lizards were occasionally killed by raccoons (*Procyon lotor*) or opossums (*Didelphis virginiana*), and a few amphibians and aquatic snakes (plus 1 mud turtle) drowned in submerged traps. Crayfish were frequently trapped and might have been responsible for killing some of the smaller amphibians and reptiles.

Most amphibian species were trapped most frequently during their breeding seasons, which were the warmer months for most anuran species and the cooler months (i.e., February and October) for two-lined, red, and dwarf salamanders. Most aquatic salamander species were trapped in October after rainfall from Hurricane Georges flooded the area. Increased water depths and volumes of flow of streams at some sites either stimulated aquatic salamanders to emerge or washed them from their mucky retreats. Many reptile species were captured most frequently during April and June, which corresponded with their breeding seasons and increased levels of activity, such as long-distance movements by males.

Pine Barrens treefrogs were not recaptured because they were primarily arboreal and were trapped only when they descended to breed. They were mostly trapped in open seepage areas, and they probably climbed over fences that intercepted their movements elsewhere. Leopard frogs were not recaptured because they were transitory in the habitats trapped, whereas bronze frogs, cricket frogs, and southern toads were year-round residents in

these habitats. Dusky salamanders had high recapture rates because individuals frequently encountered fences intersecting their apparently small home ranges. The high recapture rate for mud turtles indicates that individuals have restricted home ranges. Scarlet snakes were not recaptured because they were apparently just moving through bogs and ravines, which were atypical habitats for this upland species. Seepage habitats provide abundant prey for garter and ribbon snakes, but these snakes tend to be active foragers and might not have defined activity areas. Ribbon snakes are semiariboreal and might not be susceptible to capture in shrubby habitats except while on the surface searching for mates during the breeding season. Six of 10 garter snakes were trapped in mid-October in herb and shrub bogs, whereas 12 of 15 ribbon snakes were trapped in April in shrub bogs and ravines (Table 6).

Seepage Bog Herpetofauna

The lack of leaf litter and woody debris in herb bogs provides seemingly little surface cover for herpetofauna, although clumps of dense wiregrass and other ground cover may provide above-ground refugia. The sunny aspect of herb bogs would appear to provide stressful environmental conditions for amphibians, which prefer shadier and cooler conditions than most reptile species. Some non-burrowing amphibians in herb bogs probably move into adjacent shrub bogs to escape high temperatures, at least during the daytime. Many amphibians and reptiles, however, probably use the abundant burrows of crayfish—*Cambarus*, *Procambarus*, (Hobbs 1942, Wolfe et al. 1988), and *Fallicambarus* (Folkerts 1991)—as refugia. I occasionally observed red salamanders peering from and entering crayfish burrows in herb bogs. Sufficient rainfall occurred during my study to maintain continuously saturated soil conditions in most portions of the bogs, but during seasonal or extended droughts when the soil of bogs may dry (Wolfe et al. 1988), crayfish burrows may provide important refugia for moisture-dependent animals (Enge 1997a). Seepage bogs remain saturated longer than most other pitcher plant habitats (Folkerts 1991). During droughts, some bog animals are probably forced to move downslope to find permanent water in stream channels draining the bog. Some animals inhabiting surrounding pine uplands might escape desiccation during droughts by moving into bogs, although most sandhill species are adapted to xeric conditions. The dense, shallow root system of wiregrass may be important in preventing desiccation of amphibians burrowing in xeric soils (Means 1996).

The amphibian community of bogs was dominated by cricket frogs, narrowmouth toads, dwarf salamanders, and red salamanders. The bronze frog and two-lined salamander were relatively common, especially in shrub bogs. Southern toads, leopard frogs, and young bullfrogs were occasionally

captured in both types of bogs, but the few captures of dusky, three-lined, and slimy salamanders came only from shrub bogs. Pine Barrens treefrogs were captured only in April and June while breeding, and 13 of 15 came from herb bogs. The single capture of a spring peeper in an herb bog was unusual, although this species could possibly breed in downstream portions of shrub bogs. I occasionally heard calling southern chorus frogs at Open Bog and pinewoods treefrogs at Godman's Bog, but these species were never trapped.

Snakes more characteristic of surrounding upland habitats occasionally traveled through bogs or entered them to drink or forage. The vegetative physiognomy of herbaceous portions of bogs did not differ much from sandhills in that both had a dense, grassy ground cover and scattered shrubs and pine trees. The saturated soil of bogs was not aversive to most reptile species. It would be more unusual to find sandhill reptiles in the interior of shrub bogs, whereas edges of shrub bogs, especially if situated at the base of a slope, might be utilized. The following upland reptile species were trapped in bogs: crowned snake, scarlet snake, mole kingsnake, and pine snake. Arrays in bogs occasionally trapped hispid cotton rats (*Sigmodon hispidus*) and young marsh rabbits (*Sylvilagus palustris*), which are potential prey items for pine snakes. Reptile species that probably do equally well in uplands and bogs are the box turtle, green anole, broadhead skink, ground skink, mimic glass lizard, eastern glass lizard, racer, corn snake, pigmy rattlesnake, Florida redbelly snake, and rough earth snake. Species that probably prefer the wetter conditions or more abundant amphibian prey present in bogs are the mud turtle, coal skink, cottonmouth, ringneck snake, banded water snake, crayfish snake, garter snake, and ribbon snake. Coal skinks were more abundant in herb bogs, whereas broadhead skinks were more abundant in shrub bogs, although 2 neonates were trapped in herb bogs. The 2 *Thamnophis* species apparently segregated the habitat, with garter snakes inhabiting herb bogs and occasionally shrub bogs, and semiarborescent ribbon snakes inhabiting only shrub bogs.

The dissimilarity in reptile species composition between herb and shrub portions of Open Bog was probably due to the array in the shrub bog being situated completely in the shady interior with its tall, dense shrubs. In contrast, 2 fences of the shrub bog array at Godman's Bog were situated in more sunny, open conditions where shrubs were regenerating after a fire 6 months before the study. This area of shrub regeneration provided reptiles with conditions more similar to those present in herb bogs.

I believe that most of the differences in herpetofaunal species composition between the 2 bogs were not due to their location in different river drainages but instead to differences in topography, vegetative structure and density, and

seepage flow. Additional trapping would probably have resulted in more similar species lists for the 2 bogs because many species were represented by a single capture. Some of these “rare” species were undoubtedly present in both bogs and would have been detected during longer or more intensive sampling. The variability in species composition between the 2 bogs indicates that more bogs would need to be sampled in order to develop a comprehensive list of species utilizing bogs.

Steephead Ravine Herpetofauna

The topographic gradient present along ravine slopes 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 xerophilic herpetofauna characteristic of xeric hammock or sandhill habitats. 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 (Enge 1997a). Aquatic salamanders (i.e., *Amphiuma* spp. and “least” siren) may inhabit mucky areas along some steephead streams.

Many salamanders live along ravine bottoms where leaf litter accumulates in seeps or streams (Wolfe et al. 1988). Streams in the Panhandle have a diverse salamander community that uses 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). The most common salamander species along first-order steephead streams are red, two-lined, and dusky salamanders. Captures of three-lined salamanders along first-order streams, such as in Adams Mill Creek during this study and in drainages farther east (Enge 1998a), indicate that individuals of this species sometimes wander away from suitable breeding habitat, which typically consists of floodplains along major creeks (Means 2000).

Bronze, bog, and cricket frogs are apparently the only anuran species that breed in first-order steephead streams, but other species, such as the southern toad, may breed in nearby pools. Young pig and bullfrogs apparently disperse along small steephead streams that are seldom utilized by adults.

The configuration of ravines and the presence of year-round canopy cover due to many evergreen tree and shrub species help ameliorate extremes in temperature and relative humidity during the wintertime and provide relatively

cool and moist conditions during the summertime, especially on north-facing slopes (Wolfe et al. 1988). However, I found high daily fluctuations in ambient air temperature in some ravines. Temperatures and water levels of steephead streams tend to fluctuate more the farther downstream from the source (Enge 1998a), so the most constant environmental conditions are at the head of ravines. Typical amounts of rainfall have very little effect on the water level of steephead streams, because the primary source of water is a perched aquifer, and the porous sands of surrounding well-vegetated uplands prevent any substantial runoff downslope. The saturated soils present along the stream terraces of downstream portions of steephead streams would typically have ≤ 3 cm of standing or flowing water during rainfall, but this layer of water would quickly drain into the main stream or would pool in shallow depressions that often contained sphagnum moss.

The more stable microclimate provided by streams and seepage areas is probably important to some amphibian species. Cool, moist conditions are preferred by many amphibian and some reptile species, such as skinks. Broadhead skinks and green anoles are the most common arboreal lizards in steephead ravines, but ground skinks may be common on ravine sidewalls if abundant leaf litter is present. Heliophilic terrestrial reptiles, however, are relatively rare in ravines because of limited sunlight penetration to the forest floor. Fallen logs and hardwood leaf litter provide cover for many species of terrestrial amphibians and reptiles (Enge 1997a).

Small, first-order steephead streams are relatively unproductive for turtles, but higher order streams are used by mud turtles, common snapping turtles, and loggerhead musk turtles (Wolfe et al. 1988, Enge 1998a). In addition to the adult loggerhead musk turtle trapped in Bone Creek's tributary, a hatchling was dip-netted from Trawick Creek. Box turtles may use ravine sidewalls and streamside seepage areas.

Semiaquatic and aquatic snakes that prey upon fishes and amphibians (e.g., cottonmouth and banded water snake) are relatively common in some steephead ravines, but the most common snake is probably the ringneck, which primarily preys upon earthworms and small amphibians (Barbour 1950, Myers 1965). Ringneck snakes can live in a variety of terrestrial and wetland habitats (Myers 1965, Enge 1997b), and they are often captured in traps sitting in shallow seeps and small streams (personal observation). *Regina* spp., which are crayfish-eating specialists, are often present in steephead streams. The arboreal gray rat snake and rough green snake and the semiarboreal corn snake are undoubtedly present in many ravines, but they are seldom trapped because of their climbing proclivities. Ribbon snakes were relatively common in steephead ravines, but garter snakes were apparently absent, despite abundant

prey and seemingly suitable habitat, especially along downstream portions of ravines. One garter snake, however, was captured during intensive sampling of steephead ravines farther east (Enge 1998a). Small, litter-dwelling species, such as redbelly and smooth earth snakes, may be present in ravines.

Terrestrial, wide-ranging snake species may forage in ravines or cross through them. The most common of these terrestrial species is the racer, but other species that sometimes enter ravines are the scarlet snake, eastern hognose snake, pigmy rattlesnake, and eastern coachwhip (Enge 1998a). Eastern kingsnakes have not been trapped in ravines, but they probably occur there. Several upland species that were trapped in bogs—*Ophisaurus* spp., mole kingsnake, pine snake, and crowned snake—probably sometimes enter ravines, which often have upland vegetation near the stream because of periodic fires. In Blackwater River State Forest, upland herpetofauna would probably be more prone to cross steephead ravines or to enter them to drink or forage for food because of the comparatively shallow configuration of ravines and the narrow strip of hardwood vegetation that typically separated steephead streams from sandhill vegetation. This probably explains the capture of an adult and neonate eastern hognose snake in one of the ravines (Table 8). Other snake taxa that typically inhabit xeric upland communities and might be expected to occasionally frequent bogs and ravine slopes are the eastern indigo snake, eastern diamondback rattlesnake, and southern hognose snake (Enge 1997a).

I was surprised to trap scarlet snakes at the bottom of several steephead ravines, often in shallow water some distance from the base of the slope. Scarlet snakes are typically found in terrestrial habitats, although they are occasionally trapped during dry periods in marshes and swamps (see Enge 1997b). Hydric conditions would not appear to provide suitable habitat for this semifossorial species, which might have been dispersing (4 were juveniles) or searching for food in the form of reptile eggs.

Comparisons With Other Studies

Steephead Ravines.—More intensive drift-fence surveys were previously conducted in steephead ravines in the Ochlockonee and Apalachicola drainages (Enge 1998a). The Blackwater (2,227 km²) and Yellow (3,626 km²) rivers have smaller drainage areas than the Ochlockonee (5,957 km²) and Apalachicola (51,800 km²) rivers (Bass 1983). The headwaters of the Blackwater and Yellow rivers are located in Alabama, whereas the Ochlockonee and Apalachicola rivers originate in Georgia. The Apalachicola River differs from the other rivers in being an alluvial river with its headwaters in the southern Appalachian Mountains, whereas the other 3 rivers are sand-bottomed streams restricted to the Gulf Coastal Plain (Beck 1965, Bass and Cox 1985).

At least 14 species were common to steephead ravines in all 5 watersheds or drainages: southern toad, bronze frog, leopard frog, dusky salamander (*Desmognathus* spp.), two-lined salamander, slimy salamander, red salamander, mud turtle, green anole, broadhead skink, cottonmouth, racer, ringneck snake, and banded water snake. Ravines in the eastern (i.e., Apalachicola and Ochlockonee) and western (i.e., Blackwater and Yellow) drainages had 14 amphibian and 17 reptile species in common. Twelve herpetofaunal species were trapped only in steephead ravines in eastern river drainages, and 13 species were trapped only in western river drainages.

Comparisons of species composition among watersheds or drainages are complicated by differences in sampling intensity, seasonality, and stream orders. Five amphibian and 9 reptile species were only documented from 1 of the 5 watersheds. More species that are uncommon in ravines or are seldom trapped by drift fences were probably caught in the 2 eastern drainages because these ravines were sampled more intensively (6 arrays per drainage for 216 days; Enge 1998a). The western ravines surveyed during this study were sampled for fewer days, but a total of 2 more arrays was used. Although each of the western ravine sites was not sampled as intensively, by sampling 7 sites I probably increased the number of species detected because of greater gamma (landscape) diversity.

Amphibian community composition between Ochlockonee and Apalachicola ravines was slightly more similar ($C_J = 0.57$) than that between either of these eastern ravines and any western ravines ($C_J = 0.42\text{--}0.54$) (Table 10). Similarly, reptile community composition was slightly more similar between Ochlockonee and Apalachicola ravines ($C_J = 0.52$) than between any of the eastern and western ravines ($C_J \leq 0.48$) (Table 10). The greatest similarity in amphibian community composition existed between the northern Yellow River ravines and both the southern Yellow and Blackwater river ravines ($C_J \geq 0.71$), whereas only the northern Yellow and Blackwater river ravines had very similar reptile communities ($C_J = 0.75$) (Table 10). No strong correlation existed between the proximity of river drainages and the similarity of their ravine-dwelling herpetofaunal communities.

Some of the observed differences in species composition among watersheds may have been due to past geological events. Distributions of fishes, amphibians, and turtles in the Panhandle probably reflect interglacial rises in sea level that embayed the Escambia–Blackwater–Yellow River basin, the Choctawhatchee–Alaqua basin, and the Apalachicola River basin (Neill 1957). The Apalachicola River was embayed farther inland than any other river, forming a broad saltwater channel during long periods of the Pleistocene that presented an important barrier to the east-west distribution of many

species (Neill 1957). Many of the endemic and “northern” aquatic and semi-aquatic wildlife taxa in the Apalachicola, Choctawhatchee, and Escambia rivers are present because populations were probably able to survive during Pleistocene sea level rises by retreating to the headwaters in higher country, whereas rivers with headwaters in lowlands (e.g., the Ochlockonee River) were inundated by seawater and lack endemics (Neill 1957). Present-day herpetofaunal communities of ravines in the Apalachicola and Ochlockonee drainages are mostly similar, with the notable exception of the southern copperhead (Enge 1998*a*).

Most of the differences in herpetofaunal species’ assemblages among drainages, however, are probably due to differences in physical attributes of steepheads that favor the presence of certain species. Steephead attributes that might influence herpetofauna are orientation, depth, and width of the ravine; extent of stream terrace or floodplain; steepness of slopes; stream flow, size, and substrates; presence and abundance of sphagnum moss; presence and extent of shallow seeps or mucky areas; amount of insolation; density of canopy, shrub, and ground cover; extent and composition of litter layer; and presence of woody debris and snags. Other factors that might influence the herpetofauna of steephead ravines are distance from the main river, habitat types in surrounding uplands, and the proximity of ponds that can serve as breeding sites for amphibians.

The captures of some species could be considered incidental because they are not very susceptible to capture by drift fences because of their arboreal nature or large size: Cope’s gray treefrog, Florida cooter, box turtle, corn snake, gray rat snake, and rough green snake. These species are undoubtedly also present in steephead ravines in other river drainages than those in which they were trapped. Observed differences among watersheds in the species composition of reptiles may be less meaningful than for amphibians because reptiles are often more difficult to detect by trapping than amphibians due to their lower population densities. Incidental captures of small numbers of specimens, especially of upland species, during limited sampling are probably not meaningful for comparative purposes. Even the failure to trap certain species that are relatively common in many steephead ravines does not infer that those species are absent from all ravines in that watershed. For example, cricket frogs and narrowmouth toads were not trapped in the Apalachicola drainage, and ground skinks were not trapped in ravines in the northern Yellow River watershed, despite their presence in these areas.

Weaver Creek differed from other watersheds in this study in apparently lacking bullfrogs, pig frogs, one-toed amphiumas, three-lined salamanders, and dwarf salamanders (Table 9). This difference, however, may have been

due to sampling of only first-order streams. Some of these species undoubtedly were present farther downstream along Weaver Creek. In other drainages, pig frogs, bullfrogs, and three-lined salamanders were trapped along high-order streams or along short first-order streams near suitable downstream habitat. For example, an impoundment of Adams Mill Creek was situated ≈ 100 m from the nearest array along the first-order tributary of Adams Mill Creek, and this impoundment provided suitable breeding habitat for pig and bullfrogs. The sites trapped along Weaver Creek also contained unsuitable habitat for dwarf salamanders.

Steephead ravines in the Ochlockonee drainage differed from those in all other drainages in containing green and squirrel treefrogs, four-toed salamanders, and central newts (Enge 1998a). The presence of the 2 treefrog species indicates the presence of a nearby pond, because streams provide unsuitable breeding sites. I was hoping to capture four-toed salamanders, especially at the head of Garnier Creek, which had extensive mats of sphagnum moss and numerous rivulets and seeps. Other sites also contained seemingly suitable habitat, but no specimens were captured. Four-toed salamanders have been found at 3 localities on Eglin AFB in Walton County (Means 1992a, Printiss and Hipes 1999). Trapping during cooler months might have detected four-toed salamanders or spring peepers in steephead ravines during this study, because these species are winter breeders.

Steephead streams in the Blackwater and Yellow river drainages differed from the Ochlockonee and Apalachicola river drainages in containing the undescribed “least” siren, which is known only from the Yellow, Blackwater, and East Bay river drainages (P. E. Moler, personal communication). This small siren inhabits seeps and seepage streams and can be readily differentiated from other sirens by their uniform coloration and reddish gills. I trapped rusty mud salamanders only along a third-order stream in the Apalachicola drainage (Enge 1998a), but this did not necessarily reflect distributional differences among watersheds. Mud salamanders tend to be found in mucky areas along the floodplains of third-order or greater streams (Means 2000), and the site I trapped along Burnt Grocery Creek was the only other place that provided apparently suitable habitat for this species.

Bog frogs were trapped only in the Yellow River drainage, which agrees with the findings of Moler (1992). In the Blackwater River drainage, extensive seepage areas along second-order portions of Bone Creek’s tributary appeared to provide suitable habitat for bog frogs, but no bog frogs were trapped or observed there. Another possibly meaningful difference in species composition among watersheds is the apparent lack of dusky salamanders in the northern Yellow River watershed (Table 9). The lack of dusky salamanders

in 2 of the ravines was not totally unexpected because higher order streams were trapped, and the small seeps that provide suitable larval habitat were rare or absent. Garnier Creek, however, provided apparently suitable habitat for dusky salamanders, but none was trapped there.

For comparisons of species composition among watersheds using similarity coefficients, I considered dusky salamanders in the Apalachicola and Ochlockonee river drainages—*Desmognathus apalachicolae*—to be the same species as those farther west. I am calling these western populations *D. fuscus conanti* based upon range maps (Conant and Collins 1991), although the taxonomy of Panhandle *Desmognathus* has not been resolved (D. B. Means, personal communication). Dusky salamanders from the eastern and western river drainages appeared phenotypically similar to me, although there was considerable variation in coloration and pattern depending upon age, sex, and substrate. The *Desmognathus* I trapped during this study, however, are probably an undescribed species that differentiated from other populations during higher sea levels when it became isolated in deep steephead valleys on the northwest side of Eglin AFB (Means 2000). Means (1974) stated that the greatest interdeme variation in *fuscus* was observed between the Blackwater and Yellow river drainages, and he hypothesized that this variation reflected adaptations to different selective pressures in different types of ravines. However, Means thought that steephead ravines in this area were restricted to the Yellow River drainage, but I found several small steephead ravines in the Blackwater River drainage in the southeastern corner of the state forest. The *Desmognathus* I trapped here did not superficially appear different from those trapped on Eglin AFB. I did not closely examine the 1 *Desmognathus* trapped in a shrub bog in the northeastern corner of Blackwater River State Forest.

One-toed amphiumas were trapped only at 1 site in the Blackwater and northern Yellow river watersheds. One-toed amphiumas might have been present along other streams, but 5 of the 6 captures occurred immediately after Hurricane Georges. Within 2 weeks of Hurricane Georges, 12 of 14 two-toed amphiumas were also trapped. Documentation of amphiumas along steephead streams could be considered fortuitous during this study because of flooding from the hurricane. Although 58% of the “least” sirens ($n = 26$) were trapped immediately after Hurricane Georges, they were also trapped sporadically throughout the year in seepage streams regardless of precipitation. In the eastern river drainages, no two-toed amphiumas were trapped, and one-toed amphiumas were only trapped in the Ochlockonee drainage, despite their presence in higher order streams in the Apalachicola drainage (Stevenson 1967, Means 1977).

Hatchling common snapping turtles were captured only in downstream portions of Ochlockonee and Apalachicola ravines, although snapping turtles

were undoubtedly present in some of the streams in the western ravines. Five-lined skinks were captured only in Ochlockonee ravines, whereas 1 southern fence lizard, 1 coachwhip, 1 garter snake, and 5 southern copperheads were trapped only in Apalachicola ravines (Enge 1998a). The fence lizard and coachwhip are upland species, whereas the copperhead is restricted in Florida to the upper Apalachicola drainage and the northern reaches of Okaloosa, Santa Rosa, and Escambia counties (Gloyd and Conant 1990; Means 1992c, 1998). Steephead ravines in the Ochlockonee and Apalachicola drainages differed from those in the 2 drainages in this study in apparently lacking Gulf crayfish snakes and ribbon snakes.

Queen snakes were present along a third-order steephead stream in the Apalachicola drainage (Enge 1998a), but only 1 specimen was trapped along a second-order steephead stream in the Blackwater drainage during this study. Although additional sampling might have detected more queen snakes, the Gulf crayfish snake was apparently the crayfish-eating specialist in both steephead ravines and bogs during this study. A few mud snakes were captured in second-order steephead streams in the eastern (Enge 1998a) and western (Table 9) Panhandle. Suitable prey existed along some of the steephead streams (e.g., *Amphiuma* spp. and “least” sirens), but mud snakes are probably more common along larger streams and their floodplains.

Seepage Bogs.—The only comparable drift-fence survey of seepage bogs along the Gulf coast was conducted in 5 bogs and adjacent upland pine forests in the Angelina National Forest in eastern Texas (Reid and Whiting 1994). Eleven species of amphibians and 17 species of reptiles were trapped in Texas bogs, whereas I trapped 14 amphibian and 23 reptile species in Florida bogs. Comparisons of the species composition of Florida and Texas seepage bogs can be made if one allows for species differences due to geographic ranges (e.g., *Bufo*, *Thamnophis*). Bogs in Florida and Texas are somewhat similar in amphibian species composition ($C_J = 0.47$). Most of the species trapped in Texas bogs were also found in Florida bogs, but Texas had a depauperate salamander fauna in that it lacked dusky, two-lined, three-lined, slimy, and red salamanders. The dwarf salamander was the most common amphibian species in both Florida (23.5%; $n = 272$) and Texas (47.0%; $n = 89$) bogs. The second and third most common amphibian species in Texas bogs were the narrowmouth toad (15.7%) and bronze frog (14.5%), which were also common in Florida bogs (11.8% and 8.1%, respectively).

Bogs in Florida and Texas are dissimilar in reptile species composition ($C_J = 0.33$). However, if 8 reptile species that were trapped only in Texas upland forests are included, the similarity between Florida and Texas bogs increases ($C_J = 0.41$). Ground skinks constituted 50.3% of reptile captures ($n = 324$) in

Texas bogs, followed by coal skinks (18.5%), six-lined racerunners (8.6%), green anoles (7.7%), and fence lizards (4.6%). Ground and coal skinks were the second and fourth most frequently trapped reptile species in Florida bogs. I failed to trap racerunners and fence lizards in bogs, although they were common in adjacent uplands and undoubtedly entered bogs occasionally, especially during dry conditions.

MANAGEMENT IMPLICATIONS

Prior to European settlement, longleaf pine communities covered over 60% of the upland areas in the southeastern Coastal Plain (Wahlenberg 1946), but today they cover <2% of their original area (Ware et al. 1993). Extensive portions of this ecosystem have been lost to agriculture and urbanization, and intensive forestry has converted the open longleaf pine stands to dense slash, loblolly (*Pinus taeda*), and sand pine plantations and successional forests of mixed pines and hardwoods (Means and Grow 1985, Ware et al. 1993). Some of the largest and best remaining examples of longleaf pine-dominated sandhill communities exist on Blackwater River State Forest and Eglin AFB, and these 2 areas also contain most of the seepage slope communities remaining in Florida.

Most of the Blackwater watershed is heavily forested and protected in Blackwater River State Forest, Florida, and in Conecuh National Forest, Alabama, and the river is relatively unspoiled and highly scenic. The Yellow River and its major tributary, the Shoal River, are relatively unpolluted and drain forested and agricultural lands (Bass and Cox 1985). Timber harvesting occurs in both watersheds, and logging of upland areas may affect the quantity and quality of water entering seepage streams and thus alter the streamside and aquatic biotic communities. If buffer zones of hardwood forest are retained along streams traversing cleared upland habitat, many herpetofaunal species can be preserved in an area, although some upland species may be eliminated (Enge 1998b).

The steephead ravines studied in Blackwater River State Forest and Eglin AFB had natural upland communities, although fire suppression had allowed the invasion of large hardwood trees and sand pines into uplands along Weaver Creek. Prescribed burns at 4-year intervals had created a natural ecotone between the open sandhill habitat and the hardwood-dominated forest along ravine slopes in Blackwater River State Forest, and sandhill habitat often came close to the stream on the steeper sidewall where broad seepage areas were absent. When the unburned upper slopes of valley are vegetated by hardwoods, the streams and seeps are less accessible to pineland-dwelling

animals. Fire is probably the best method for maintaining early successional communities along small streams that are utilized by bog frogs (Moler 1992), although a possible alternative is periodic mowing of shrubs, such as has occurred at a breeding site along a powerline corridor crossing Dean Creek (P. E. Moler, personal communication).

Upland areas above steepheads on most private lands in the Yellow River drainage had been logged of longleaf pine and replanted in sand or slash pine, and valley sidewalls farther downstream were extensively planted in pines. The sand pines formed dense plantations with little ground cover, and they bore no resemblance to the original sandhill community with its sparse pines and dense, species-rich ground cover. The effects on ravine-dwelling herpetofauna of fire suppression and pine plantations in uplands and on valley sidewalls are unknown, but deforestation of uplands adjacent to steephead ravines may result in increased erosion and sedimentation of ravines. A sand road leading down to the head of Garnier Creek was heavily eroded, but the forested buffer zone along the bottom of the ravine had prevented sedimentation of the stream.

Steep valley 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 were removed from most ravines to make pencils (Means 1977, 1981). 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 (Enge 1998_a). Logging of hardwoods on ravine slopes would lead to conditions unfavorable for many amphibian species: decreased shade, reduced leaf litter, increased soil-surface temperatures, and reduced soil-surface moisture (Bury 1983, Ash 1988, Raphael 1988, Welsh 1990). Many salamander populations were adversely affected by timber harvesting of southern Appalachian forests (Ash 1988, Petranka et al. 1993) and South Carolina bottomland swamps (Phelps and Lancia 1995). Deforestation of slope forests can increase surface erosion and lead to sedimentation of seeps and streams (Corn and Bury 1989), which are especially important to larval amphibians. An intact canopy is important in ameliorating temperature and humidity extremes and in preserving the cool, moist conditions preferred by many of the characteristic plant and animal species. Increased insolation can create an unfavorable microclimate for certain amphibian species and cause excessive vegetative growth along the streams (Wolfe et al. 1988, Florida Natural Areas Inventory 1990). Although opening the canopy is probably detrimental to salamander species, some anuran species, such as bog and cricket frogs, may benefit. The sunnier, drier conditions resulting from logging may also benefit lizard and snake species, especially those characteristic of the adjacent xeric uplands.

Selective logging with minimal site disturbance would be the least detrimental type of timber harvest to amphibians inhabiting the upper valley walls or adjacent hardwood-dominated uplands (Dodd 1991). Silvicultural Best Management Practices (BMPs) suggest retaining buffer zones of trees ranging from 11 to 90 m wide between clearcuts and streambanks in order to protect water quality and streamside habitats (Hoehn 1998). The steep slopes of steephead ravines would require wide buffer zones to prevent erosion into streams. In general, recommended riparian buffer zones of at least 15–30 m wide on each side of streams (e.g., Corbett et al. 1978, Newbold et al. 1980, Budd et al. 1987) are probably inadequate to conserve some wildlife species and prevent erosion (Binford and Buchenau 1993, Noss 1993, Spackman and Hughes 1995). A 168-m buffer zone was recommended on each side of rivers in east central Florida to protect wetland wildlife habitat (Brown et al. 1990). Such streamside management zones in harvested areas can provide suitable habitat and possible movement corridors for wildlife species (Rudolph and Dickson 1990, Noss 1993, Dupuis et al. 1995, Enge 1998*b*).

Ravine streams have been impounded to create farm ponds or lakes in residential developments, which inundates seepage habitats and the suite of amphibian species dependent upon them. The larvae of most ravine-dwelling salamander species require flowing water or shallow seeps 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 (Wolfe et al. 1988, Enge 1998*a*). Culverts under roads need to be periodically cleared of debris or enlarged so that seepage streams are not inadvertently impounded by roads.

A less obvious threat to the aquatic and semiaquatic wildlife community along seepage streams is deteriorating water quality due to 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 (Means 1981, Florida Natural Areas Inventory 1990). Nationwide, agricultural practices accounted for impairment of water quality in 72% of the stream miles assessed by the Environmental Protection Agency (1994), and they were the leading cause of nutrient enrichment in rivers and lakes (Puckett 1995). The most significant threat identified for imperiled freshwater fauna in the eastern United States was agricultural nonpoint pollution causing streambed sedimentation and suspended sediment loading and nutrient loading (Richter et al. 1997). Illegal dumping of trash down easily accessible ravines is a common practice in the Panhandle, but it is typically more of an aesthetic problem than a threat to wildlife, unless toxic materials or metal

corrosion pollutes the streams (Enge 1998a). The Garnier Creek steephead contained a defunct moonshine still that consisted of rusty 55-gallon drums.

Ravine streams that cross under dirt roads often experience extensive sediment runoff. Some of the range roads on Eglin AFB are severely eroded near stream crossings, where slopes can exceed 10% (U.S. Air Force 1997). The judicious use of silt fences or hay bales may temporarily help control erosional runoff into streams from dirt roads or other site disturbances. Paving dirt roads at stream crossings and installing wing culverts on either side are effective but costly techniques for reducing erosion (U.S. Air Force 1997).

Clearings, mines, or borrow pits in upland areas adjacent to seepage streams can cause gully erosion and high surface runoff after heavy rains, resulting in large, unnatural fluctuations in stream levels and sediment-laden water. Pristine seepage streams do not exhibit such water-level fluctuations and cloudy water, and many stream-dwelling species are not adapted to such conditions. For example, breeding habitat for Florida bog frogs along impacted streams may be periodically submerged by ≥ 50 cm of water, which discourages breeding and possibly impacts larvae using shallow rivulets that serve as developmental areas (Printiss and Hipes 1999). The silt load accompanying these influxes of water may bury amphibian eggs, clog the gills of larvae, cover seepage areas, and alter the topography and vegetation of the stream bottom and margins. Eglin AFB has 165 clay borrow pits, 28 of which are considered active. The headwalls of these borrow pits may erode 90 m upslope, and the gullies can be up to 30 m wide and 12 m deep (U.S. Air Force 1997). At least 1 severely eroded borrow pit is present along a downstream portion of Weaver Creek, and the topographic map indicates that a clay borrow pit is present along a steephead tributary of Trawick Creek, north of Interstate 10. Several of the severely eroded borrow pits on Eglin AFB are currently being rehabilitated by installing contoured catch basins that are revegetated with native grasses and equipped with a drain in the bottom. These catch basins, which are arranged in a stair-step fashion from ridgetops down to the stream, are generally effective, unlike installing berms at the top of a pit (U.S. Air Force 1997).

Feral hogs (*Sus scrofa*) can seriously uproot stream margins and seepage areas, possibly affecting water quality (Singer et al. 1984). Hogs are omnivores and prey upon vertebrates (Wood and Barrett 1979), although the extent of their predation on herpetofauna is unknown. In deciduous forests in the Great Smoky Mountains, rooting by hogs apparently did not affect salamander densities (Singer et al. 1984). None of the sites I studied appeared to be disturbed by hogs, but many habitats (including seepage streams and slopes) on Eglin AFB

have been extensively damaged by hogs (Printiss and Hipes 1999). Shallow seepage areas provide important larval habitat for some salamander species (Means 1974, Means and Karlin 1989). Rooting by hogs in shallow seeps in ravines on Eglin AFB may partially explain why dusky salamanders have disappeared and populations of other salamander species with short larval periods have declined in ravines where they were common in the 1970s (D. B. Means, personal communication). The deeper pools created by hogs may allow larvae of the red salamander to enter these shallow seeps and eat the smaller larvae of other salamander species (D. B. Means, personal communication).

By 1982, humans had destroyed or severely altered an estimated 97% of the pre-Columbian acreage of Gulf coast bogs through drainage for pine monoculture or agriculture, fire suppression, alteration of fire periodicity and seasonality, grazing, pond construction, and urbanization (Folkerts 1982). Since then, the rate of destruction has increased significantly, and additional damage has been done by off-road vehicle traffic and increased herbicide use in forests and along highways (Folkerts 1991). Bogs upstream of roads are sometimes flooded by inadvertent damming of the seepage streams that drain the bogs. Bogs downslope of roads are sometimes silted in by runoff of clay, silt, and sand from the roads, especially after heavy rains and recent road-grading activities.

Seepage wetlands in areas with high relief and sloping water tables are especially vulnerable to drainage by surface excavations. Seepage wetlands can be threatened by stormwater ponds, borrow pits, man-made lakes, and mining operations in upland areas up to 1.6 km away. These large excavations can permanently reduce ground-water levels by extensively increasing the "void space" previously occupied by the ground water, increasing evaporational losses due to conversion of ground water to surface water, and permanently reducing recharge. Seepage wetlands are also threatened by active ground-water withdrawals for irrigation of golf courses and agricultural fields, and by residential, industrial, and municipal wells. Even shallow firelines that are trenched parallel to the margins of seepage-slope habitats can significantly alter the lateral flow of ground water by converting it to surface water, which is subject to higher rates of evaporation (Bacchus 1995). Reduction in ground water feeding seepage bogs will shorten the hydroperiod and, thus, affect herpetofaunal populations (particularly amphibian species that breed in seepage pools and streams) and allow encroachment of upland plant species. Fortunately, this area of Florida has the highest annual average surplus (46 cm) of rainfall over potential evapotranspiration (Winsberg 1992).

Herb bogs on seepage slopes are dependent upon the frequent fires characteristic of surrounding longleaf pine-wiregrass communities to

maintain their open conditions (Folkerts 1982, Means 1990). Without fire, hardwood encroachment into herb bogs leads to increased evapotranspiration and lower ground-water levels, eliminating seepage pools that provide larval habitat for species like the Pine Barrens treefrog (Means and Moler 1978, Means 1990). Growing-season fires are more natural and are more effective at killing hardwoods (Robbins and Myers 1992, Hermann 1995). Initial cool fires in winter may be necessary to reduce fuel loads in bogs that have become degraded through fire suppression, but winter fires and annual burning are apparently detrimental to pitcher plants (Hermann 1995, Johnson and Hipes 1997). The 2 bogs I studied typically burned when the surrounding uplands were prescribed burned every 3 or 4 years since at least 1978. These burns occurred from September through February, but the uplands around Open Bog are scheduled for burning in May or June 2000 (J. D. Klempa, Florida Division of Forestry, Milton, personal communication). Plowed firelines used to control fires in the vicinity of seepage bogs can alter the local hydrology (Hermann 1995).

Most bog flora and fauna would probably benefit from selective logging of nearby upland pine forests with high densities of trees, if the logging was conducted above the seepage zone and ground-cover disturbance was minimal. Opening up the canopy would encourage wiregrass growth (Means 1997) and may increase downslope seepage through reduced evapotranspiration. Care needs to be taken that the use of heavy equipment does not alter the hydrology of the bogs or cause erosional runoff and subsequent siltation of bogs.

Fragmentation of upland habitats and loss of bogs decrease local herpetofaunal diversity. Bog species (e.g., Pine Barrens treefrog) that have undergone local population extinctions, possibly as a result of severe droughts or habitat degradation due to fire suppression, may be precluded from recolonizing suitable habitat because of unfavorable surrounding habitat and large distances between bogs. Another threat to bog herpetofauna is red imported fire ants, which primarily prey upon eggs and small individuals with limited mobility. Fire ant colonies were present in longleaf pine uplands, but were most numerous on seepage slopes in Blackwater River State Forest. Trapped animals were sometimes killed by fire ants, and fire ants have been suggested as a possible factor in declines of certain herpetofaunal species in the southeastern Coastal Plain (Mount 1981).

Knowledge of the wildlife community dependent upon steephead ravines is needed in order for land managers to assess the potential impacts of land-use practices and recreational activities that cause canopy disturbance, erosional sedimentation, stream impoundment, water pollution, or reduction in

the quantity of ground water feeding seeps and streams. On private lands, the ridgetops adjacent to ravines or upslope of seepage bogs are presently mostly in pine plantations, but incentives could be provided to landowners to restore the natural sandhill or upland pine community, and the corresponding natural fire regime.

More intensive surveys are needed of seepage slopes to document differences in herpetofaunal composition within bogs and between bogs. I surveyed the herpetofauna of seepage bogs, but there are other types of pitcher plant habitats (see Clewell 1981, Folkerts 1991) that have not been surveyed. There are also steephead ravines in the Choctawhatchee River drainage, which is between the Apalachicola River and the western ravines, that have not been surveyed using drift fences. Drift-fence surveys of both degraded and pristine steephead ravines on Eglin AFB would help document differences in herpetofaunal composition or relative abundance and might help determine the cause(s) of apparent declines in some ravine-dwelling salamander populations. Additional studies are needed of the ecology of the Florida bog frog and habitat use of the Pine Barrens treefrog, especially outside the breeding season, and of the effects of feral hogs on herpetofaunal populations using seepage habitats. In areas where hogs are especially destructive, an aggressive hog removal program could be implemented (Printiss and Hipes 1999).

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Appendix A. List of common and scientific names of amphibian and reptile taxa mentioned in the text.

Common name (scientific name)

Anurans

- Southern cricket frog (*Acris gryllus gryllus*)
 Southern toad (*Bufo terrestris*)
 Eastern narrowmouth toad (*Gastrophryne carolinensis*)
 Pine Barrens treefrog (*Hyla andersonii*)
 Cope's gray treefrog (*H. chrysoscelis*)
 Green treefrog (*H. cinerea*)
 Pinewoods treefrog (*H. femoralis*)
 Barking treefrog (*H. gratiosa*)
 Squirrel treefrog (*H. squirella*)
 Northern spring peeper (*Pseudacris crucifer crucifer*)
 Southern chorus frog (*P. nigrita nigrita*)
 Bullfrog (*Rana catesbeiana*)
 Bronze frog (*R. clamitans clamitans*)
 Pig frog (*R. grylio*)
 Florida bog frog (*R. okaloosae*)
 Southern leopard frog (*R. sphenoccephala*)
 Eastern spadefoot (*Scaphiopus holbrookii holbrookii*)

Salamanders

- Two-toed amphiuma (*Amphiuma means*)
 One-toed amphiuma (*A. pholeter*)
 Spotted dusky salamander (*Desmognathus fuscus conanti*)
 Southern two-lined salamander (*Eurycea cirrigera*)
 Three-lined salamander (*E. guttolineata*)
 Dwarf salamander (*E. quadridigitata*)
 Four-toed salamander (*Hemidactylum scutatum*)
 Central newt (*Notophthalmus viridescens louisianensis*)
 Southeastern slimy salamander (*Plethodon grobmani*)
 Rusty mud salamander (*Pseudotriton montanus floridanus*)
 Southern red salamander (*P. ruber vioscai*)
 "Least" siren (*Siren cf. intermedia*)

Turtles

- Common snapping turtle (*Chelydra serpentina*)
 Eastern mud turtle (*Kinosternon subrubrum subrubrum*)
 Florida cooter (*Pseudemys floridana*)
 Loggerhead musk turtle (*Sternotherus minor minor*)
 Gulf Coast box turtle (*Terrapene carolina major*)

Lizards

- Green anole (*Anolis carolinensis*)
 Six-lined racerunner (*Cnemidophorus sexlineatus sexlineatus*)
 Southern coal skink (*Eumeces anthracinus pluviialis*)
 Five-lined skink (*E. fasciatus*)
 Broadhead skink (*E. laticeps*)
 Mimic glass lizard (*Ophisaurus mimicus*)
 Eastern glass lizard (*O. ventralis*)
 Southern fence lizard (*Sceloporus undulatus undulatus*)
 Ground skink (*Scincella lateralis*)

Snakes

- Southern copperhead (*Agkistrodon contortrix contortrix*)
 Cottonmouth (*A. piscivorus*)
 Northern scarlet snake (*Cemophora coccinea copei*)
 Southern black racer (*Coluber constrictor priapus*)
 Eastern diamondback rattlesnake (*Crotalus adamanteus*)
 Southern ringneck snake (*Diadophis punctatus punctatus*)
 Eastern indigo snake (*Drymarchon corais couperi*)
 Corn snake (*Elaphe guttata guttata*)
 Gray rat snake (*E. obsoleta spiloides*)
 Eastern mud snake (*Farancia abacura abacura*)
 Eastern hognose snake (*Heterodon platirhinos*)
 Southern hognose snake (*H. simus*)
 Mole kingsnake (*Lampropeltis calligaster rhombomaculata*)
 Eastern kingsnake (*L. getula getula*)
 Eastern coral snake (*Micrurus fulvius fulvius*)
 Banded water snake (*Nerodia fasciata fasciata*)
 Rough green snake (*Opheodrys aestivus*)
 Florida pine snake (*Pituophis melanoleucus mugitus*)
 Gulf crayfish snake (*Regina rigida sinicola*)
 Queen snake (*R. septemvittata*)
 Dusky pigmy rattlesnake (*Sistrurus miliarius barbouri*)
 Florida redbelly snake (*Storeria occipitomaculata obscura*)
 Southeastern crowned snake (*Tantilla coronata*)
 Eastern ribbon snake (*Thamnophis sauritus sauritus*)
 Eastern garter snake (*T. sirtalis sirtalis*)
 Rough earth snake (*Virginia striatula*)
 Eastern earth snake (*V. valeriae valeriae*)
-

Appendix B. Plant species in the ground cover (G), shrub layer (S), and canopy (C) around each of 18 arrays in Okaloosa or Santa Rosa County, Florida. The predominant species in each layer are denoted by boldface type.

Taxa	Seepage bogs				Blackwater River ravines				Northern Yellow River ravines						S. Yellow River ravines			
	15	16	17	18	7	8	9	10	1	2	3	4	5	6	11	12	13	14
<i>Acer rubrum</i>				S		G						S						
<i>Andropogon</i> spp.			G															
<i>A. glomeratus</i>				G														
<i>Aristida beyrichiana</i>	G		G															
<i>Arundinaria gigantea</i>			G			G	G											
<i>Cephalanthus occidentalis</i>				G										G				
<i>Chamaecyparis thyoides</i>									C	C	SC	SC	C	C				GSC
<i>Clethra alnifolia</i>				S		GS	G							S				
<i>Cliftonia monophylla</i>	S	GSC			GSC	GSC	GS	SC	SC	S	SC	GSC	GSC	GSC			GSC	GSC
<i>Cornus foemina</i>										S								
<i>Ctenium aromaticum</i>	G																	
<i>Cyperus</i> spp.																		G
<i>Cyrilla racemiflora</i>				GSC														
<i>Dichromena latifolia</i>	G		G															
<i>Drosera capillaris</i>	G		G															
<i>D. tracyi</i>	G		G															
<i>Eleocharis</i> spp.			G															
<i>Eriocaulon</i> spp.	G	G	G			G			G	G	G	G	G	G				
<i>Euthamia minor</i>	G		G															
<i>Gaylussacia mosieri</i>	G		G	G														
<i>Hamamelis virginiana</i>			G				GS							S				
<i>Helenium</i> spp.																		
<i>Hydrocotyle</i> spp.									G	G	G	G						
<i>Hypericum</i> spp.	G		G							G								
<i>Ilex cassine</i>						GS												
<i>I. coriacea</i>	S		S	GS	GS	GS	GS	GS	S				GS	S	S	S	GS	
<i>I. glabra</i>	GS		S	S														
<i>I. myrtifolia</i>					GS													
<i>I. opaca</i>															SC	GSC		

Appendix B. Continued.

Taxa	Seepage bogs				Blackwater River ravines				Northern Yellow River ravines						S. Yellow River ravines				
	15	16	17	18	7	8	9	10	1	2	3	4	5	6	11	12	13	14	
<i>Quercus hemisphaerica</i>																		C	C
<i>Q. nigra</i>															C	C			
<i>Rhexia alifanus</i>	G		G	G															
<i>R. lutea</i>	G		G																
<i>Rhus toxicodendron</i>					S									G					
<i>Rhynchospora</i> spp.	G		G				G	G			G	G					G	G	
<i>Sagittaria latifolia</i>										G									
<i>Sarracenia flava</i>	G		G	G															
<i>S. leucophylla</i>	G	G		G									G						
<i>S. psittacina</i>	G		G																
<i>Scleria</i> spp.	G		G				G												
<i>Serenoa repens</i>																			S
<i>Smilax</i> spp.	S	S	GS	S	GS	GS	S		S		S		S	S	GS	S			S
<i>Sphagnum</i> spp.		G		G	G	G	G	G	G	G	G	G	G		G		G		
<i>Tofieldia racemosa</i>	G																		
<i>Toxicodendron radicans</i>						G			G				G	G					
<i>Utricularia</i> spp.	G	G																	
<i>Vaccinium arboreum</i>																			S
<i>V. corymbosum</i>		G					S				S	S	S	S	S	S			GS
<i>Viburnum nudum</i>												S							
<i>Vitis</i> spp.							GS									S	S		
<i>Woodwardia areolata</i>							G				G	G			G				
<i>Xyris</i> spp.	G	G	G	G		G		G	G	G	G	G	G	G					
Unidentified mosses															G	G			

Appendix C. Percent cover in various vegetative layers around each of 18 arrays in Okaloosa or Santa Rosa County, Florida.

Percent cover	Seepage bogs				Blackwater River ravines				Northern Yellow River ravines						S. Yellow River ravines			
	15	16	17	18	7	8	9	10	1	2	3	4	5	6	11	12	13	14
Canopy																		
<1	X		X															
1-5																		
6-25				X														
26-50		X																
51-75					X	X	X	X		X	X	X	X	X	X	X	X	X
76-100									X									
Shrub																		
1-5	X		X															
6-25									X									
26-50				X	X	X				X		X		X		X		X
51-75		X					X	X			X		X	X		X		X
Ground																		
1-5		X							X								X	
6-25					X	X	X					X			X	X		X
26-50				X				X			X		X	X				
51-75																		
76-100	X		X															
Moss																		
<1	X		X															X
1-5		X		X				X	X								X	
6-25					X		X			X		X	X	X	X	X		
26-50						X					X							



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