Ecology of Flatwoods Salamander Larvae in Breeding Ponds in Apalachicola National Forest[1]

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Abstract: Management of the flatwoods salamander (*Ambystoma cingulatum*), a species in decline throughout its range, is hindered by a lack of information on the habitat requirements of the species. Because Ambystomatids are generally philopatric, preservation of quality natal habitat is important for long-term population health and stability. Conservation of breeding sites in managed landscapes is impeded by insufficient knowledge of the habitat components required for successful larval development. We sampled 10 ponds known to be breeding sites of flatwoods salamanders in the winters of 1992 and 1993 to gather baseline information on the habitat and ecology of the larval amphibian assemblages present. Ornate chorus frog (*Pseudacris ornata*) larvae were the dominant amphibian in both years and exhibited biomass peaks in late winter. Leopard frog (*Rana utricularia*) larvae gained dominance in mid-spring as the ponds approached dry-down. Flatwoods salamander larvae were the dominant urodele, and *Procambarus leonensis* was the most abundant crayfish in both years. Dwarf salamander (*Eurycea quadridigitata*) larvae were more frequently captured in shallower water than other amphibian larvae. Flatwoods salamander and dwarf salamander larvae were captured in quadrats dominated by linear vegetation types. Ornate chorus frog and leopard frog larvae were captured in a greater range of vegetative growth-forms and in quadrats with a higher proportion of detritus cover than flatwoods salamander and dwarf salamander larvae. Mole salamander (*Ambystoma talpoideum*) larvae were captured only in detritus-covered quadrats. Dwarf, flatwoods, and mole salamanders metamorphosed in less than 81, 91, and 159 days, respectively. These results suggest sufficient hydroperiod and

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herbaceous cover are important components of breeding ponds of flatwoods salamanders.

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The flatwoods salamander is ranked as a G2G3 species under the Heritage Ranking System developed by the Nature Conservancy, indicating that this species is "imperiled globally" and is "rare throughout its range" (Fla. Nat. Areas Inventory 1995). This ranking is supported by the Florida Committee on Rare and Endangered Plants and Animals that lists the flatwoods salamander as "rare," and cites destruction of pine (*Pinus* spp.)-wiregrass (*Aristida beyrichiana*) communities and cypress (*Taxodium ascendens*) domes, pesticide use, fire suppression, and the draining and ditching of essential habitat, as the basis for classification status (Ashton 1992). In 1995, the U. S. Fish and Wildlife Service (USFWS) eliminated the category in which the flatwoods salamander was listed (C2) and currently recognizes the taxon as a species of concern (U. S. Fish and Wildl. Serv. 1996, L. LaClaire, pers. commun.).

Reports to the USFWS indicate that the flatwoods salamander is in rapid decline throughout its range (S. H. Bennett, S.C. Wildl. and Mar. Res. Dep., unpubl. rep.; J. C. Godwin, Ala. Nat. Heritage Sect., unpubl. rep.; J. G. Palis, Fla. Nat. Areas Inventory, unpubl. rep.). Flatwoods salamander voucher specimens are known from 17 northern Florida counties, although recent surveys indicate possible extirpation from 5 counties (J. G. Palis, Fla. Nat. Areas Inventory, unpubl. rep.). Of the 82 ponds known as breeding sites of the flatwoods salamander in Florida, 35 are on the Apalachicola Ranger District, Apalachicola National Forest (ANF) (J. G. Palis, unpubl. data).

Flatwoods salamanders occur in pine flatwoods-wiregrass habitat, from the coastal plain of South Carolina to Marion County, Florida, west to Mobile County, Alabama (Ashton 1992). More than 97% of the original longleaf pine (*P. palustris*) ecosystem in North America and 90% in Florida is destroyed, leaving the remainder fragmented (Bechtold and Knight 1982, Frost 1993). As much as 41% of the former longleaf pine forests are converted to intensively-managed slash pine (*P. elliottii*) pulpwood plantations (Sheffield et al. 1983). The U. S. Forest Service manages ANF for longleaf and slash pine sawtimber production. Long timber rotations and ecosystem management practices may in part explain the persistence of flatwoods salamanders in ANF. The National Forest Management Act of 1976 requires the U. S. Forest Service to maintain diversity of forest ecosystems (90 Stat. 29949, et seq.; 16 U. S. C. 1601–1614) which implies monitoring and management responsibilities; however, insufficient data exist on the flatwoods salamander to accurately assess impacts of forest management practices on this species. The objectives of this study were to acquire baseline data on habitat and ecology of the larval amphibian assemblages by comparing the relative abundance and dominance of larval amphibians and crayfish in known breeding ponds of the flatwoods salamander and to compare habitat use among larval amphibians. This study is one component of an effort to establish baseline data to monitor and manage the flatwoods salamander in Florida.

Methods

The study was conducted on the Apalachicola Ranger District, ANF, Liberty County, Florida. Apalachicola Ranger District contains 228,163 ha comprised of natural pine flatwoods and planted stands of longleaf and slash pines, black gum (*Nyssa biflora*), titi (*Cyrilla racemiflora* and *Cliftonia monophylla*) and cypress wetlands (*Taxodium distichum* and *T. ascendens*), and natural savannas (Clewell 1971). ANF has been managed for sawtimber and pulpwood since U. S. Forest Service acquisition in 1936, and more recently for wildlife and recreation (Clewell 1971).

Previous investigation by J. G. Palis (unpubl. data) identified 25 breeding ponds of the flatwoods salamander in ANF prior to 1992; 10 were selected for study. All ponds selected had flatwoods salamander larvae in 1991. Ponds were in wiregrass savannas or mature longleaf pine-wiregrass communities not disturbed by recent silvicultural practices other than fire. Ponds that were not reasonably accessible and those that were affected by adjacent disturbances were excluded from this study.

Ponds varied in overstory and understory composition and size. Black gum was the dominant overstory species in ponds 1301 and 7709, and was co-dominant with pond cypress in pond 9801. Pond cypress was co-dominant with yaupon holly (*Ilex myrtifolia*) in pond 7802, and was the dominant species in the remaining 6 ponds (2901, 7601, 7703, 7710, 7712, 7801). Ponds 1301, 7703, and 7709 had detritus basins with most herbaceous vegetation restricted to the littoral zone; the remaining ponds had herbaceous basins. Pond size ranged from 0.04 ha (pond 9801) to 0.9 ha (pond 2901) (avg. = 0.39 ha. ± 0.27 SD). All ponds were < 1 m in depth.

Ponds were surveyed during daylight hours from February to May 1992 and January to May 1993. The difference in survey initiation between years was due to delayed pond inundation in 1992. Pond surveys were conducted weekly in 1992 and 3 times per week in 1993. The order that ponds were sampled was rotated to adjust for differences in periodicity among species. Each survey included dipnet sweeps of 6 randomly placed 1-m^2 quadrats in the 6 small ponds (< 0.5 ha) and 10 1-m^2 quadrats in the 4 large ponds (≥ 0.5 ha). Each 1-m^2 quadrat was swept in an overlapping zigzag pattern to capture any organisms exposed in the previous motion. The dipnet hoop was 40.6 cm wide and 45.7 cm long with 4-mm nylon mesh.

Captured fauna were counted and identified to the lowest taxonomic level possible. Amphibians were weighed to the nearest 0.05 g using a 5-g Pesola spring scale. Each urodele was measured with a 100-mm ruler while restricted in a plastic bag containing a small amount of water. During this process snout-vent length (measured to vent posterior), total length, and developmental data were recorded. All animals not kept as voucher specimens were released immediately. Voucher specimens are curated at the Florida Museum of Natural History and the Florida Division of Plant Industry.

Water depth, percentage of dead vegetation, and percent cover of vegetation growth-forms (e.g., emergent scapose, floating leafy, submergent tufts; Radford et al. 1981) were determined in each 1-m^2 quadrat. Habitat data were collected prior to dipnet collection. Microhabitat of amphibians was determined only for species recorded in both years. To assess trends in habitat use, quadrat habitat data were combined for all captures of a species and presented as mean and standard deviation of each habitat variable.

Results

Biomass of flatwoods salamander larvae exceeded that of dwarf salamander larvae at the end of the 1992 winter hydroperiod (Fig. 1). Flatwoods salamanders were the dominant urodele larvae during the 1993 winter hydroperiod (Fig. 2). The decline in biomass of flatwoods salamander larvae in early March 1992 and February 1993, followed by a steady increase, likely reflected the appearance of a second hatch represented by smaller, less-developed larvae. Mole salamander larvae and the larvae and adults of central newt (*Notophthalmus viridescens louisianensis*) were not observed in 1992 but were captured in 1993.

Biomass of ornate chorus frog larvae showed this anuran to be dominant throughout most of the winter hydroperiod of 1992 and 1993 (Figs. 1, 2). Biomass of ornate chorus frog larvae peaked in late March in 1992 and early February in 1993, then declined during the remainder of each hydroperiod. Leopard frog larvae gained dominance as the ponds approached dry-down in each year. Southern chorus frog larvae (*Pseudacris nigrita nigrita*) accounted for a small portion of anuran biomass in the ponds in 1992, but were not captured in 1993. Abundance of *Procambarus leonensis* was greater than *P. kilbyi* in both years, but by a smaller amount in 1993. Both species of crayfish had notably greater numbers of captures than *P. pygmaeus* (Figs. 1, 2).

Flatwoods salamander, leopard frog, and ornate chorus frog larvae were captured at similar depths, but dwarf salamander larvae were captured more frequently in shallower water (Fig. 3). A comparison of microhabitat variables associated with capture sites showed that larvae of all 4 species examined were captured most in areas dominated by linear vegetation (Fig. 3), which includes variable categories "sedge" and "tufts" growth-forms. The "sedge" growth-form category was mostly comprised of species in the genus *Rhynchospora*, but commonly included *Andropogon, Aristida, Carex,* and *Dicanthelium*. The "tufts" growth-form category was predominantly *Eriocaulon compressum* and *E. decangulare*. Flatwoods salamander and dwarf salamander larvae were not captured in quadrats with a high proportion of detritus or open water; however, leopard frog and ornate chorus frog larvae were more likely to occur in open water (Fig. 3). Because mole salamander larvae were only captured in 1993 in pond 1301, they were excluded from graphical comparison; however, all captures (N = 8) were from the center of a pond characterized by open water, a detritus substrate, and a maximum depth of 30 cm. Microhabitat selectivity could not be statistically analyzed due to bias between captures and capture effort. For example, a total of 7,200 quadrats were dipnetted over 2 years, resulting in an average of 225 quadrats

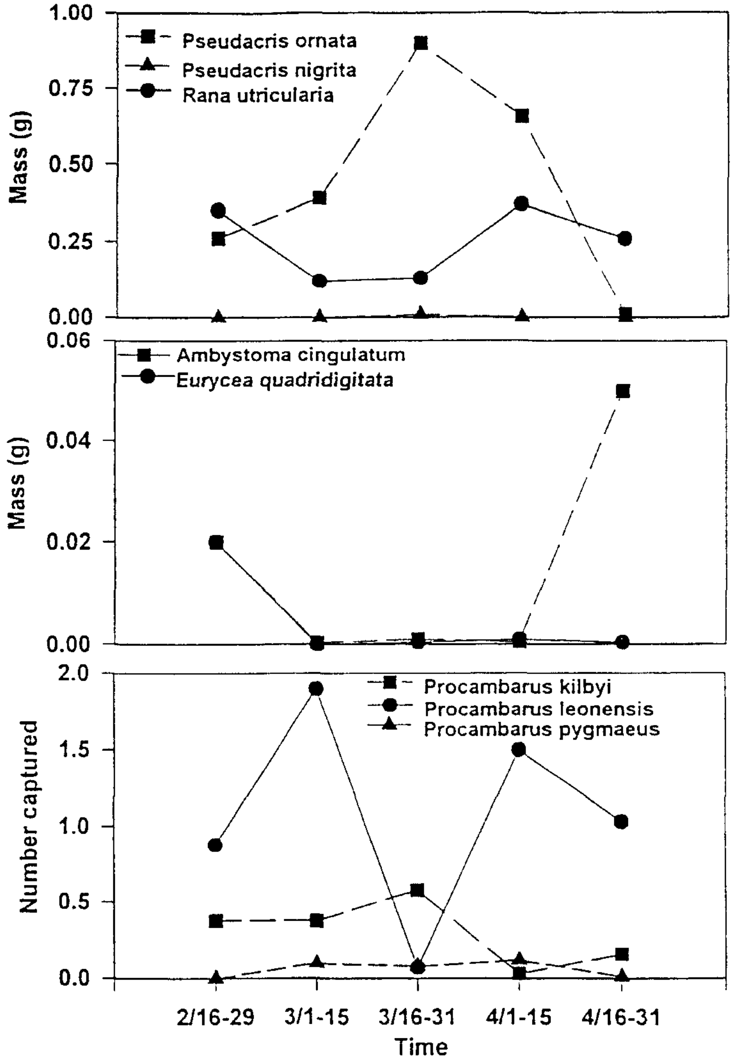

Figure 1. Biomass-per-unit-effort and catch-per-unit-effort of amphibians and crayfish from February to May 1992, Apalachicola National Forest, Florida.

sampled for each flatwoods salamander larva captured. Similar biases exist for all amphibians in this study.

Discussion

Biomass-per-unit-effort of flatwoods salamander larvae peaked twice in each sampling year (Figs. 1, 2). Low points in the curves correspond to new surges of small,

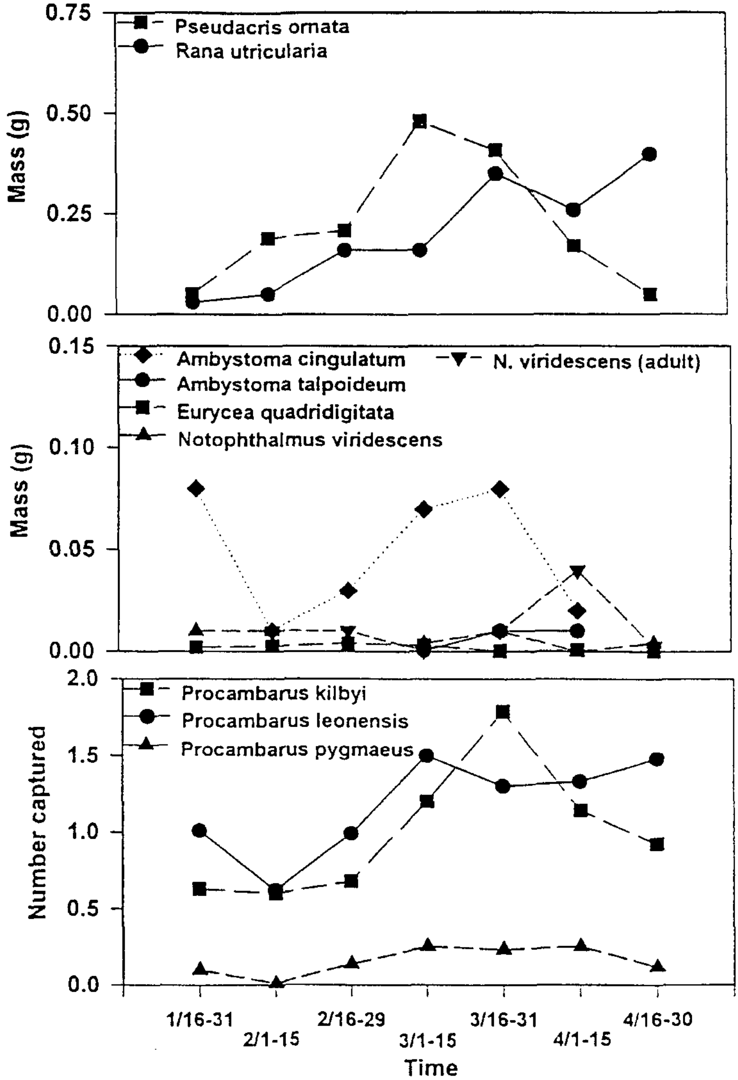

Figure 2. Biomass-per-unit-effort and catch-per-unit-effort of amphibians and crayfish from January to May 1993, Apalachicola National Forest, Florida.

less-developed larvae captured. Delayed metamorphosis is a recognized strategy for surviving the effects of competition and predation when hydroperiod is sufficiently long (Wilbur 1980, Semlitsch et al. 1988, Scott 1990); however, we suggest it would be a poor strategy for these larvae. Flatwoods salamander larvae likely occur at densities too low to trigger a density-dependent response and delayed metamorphosis seems to offer them no advantage. Because they hatch upon pond inundation, flat-

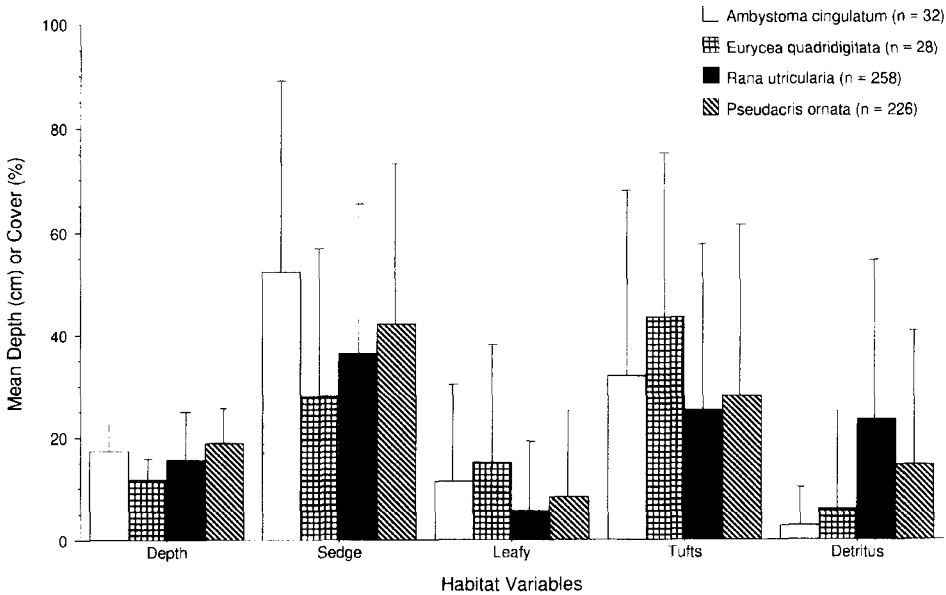

Figure 3. (± SD) depth and percent cover of vegetation growth-forms and associated numbers of captures of amphibian larvae in 1992 and 1993, Apalachicola National Forest, Florida.

woods salamander larvae have an initial size advantage over some insect predators that must hatch from smaller eggs (Wilbur 1980). Competition and predation risks probably increase over time as anuran larvae hatch, newts enter the ponds, and predaceous insect larvae and crayfish young increase in size. It is more likely that the cooccurence of 2 size classes of flatwoods salamander larvae was a result of later hatching dates for the smaller larvae. Anderson and Williamson (1976) observed differences of 3 weeks between flatwoods salamander hatching dates due to increasing water levels inundating some eggs later than others. Palis (1995) encountered 2 size classes of flatwoods salamander larvae produced by a 1-month interval between partial and entire pond inundation. We suggest egg deposition dates may also influence time of hatching. Some adults may migrate to ponds after ponds begin to fill and deposit eggs higher in the basin above the water. Eggs laid prior to inundation would have started hatching. Disparity in egg deposition dates would be expected when differences in adult migration distance exist; flatwoods salamanders can travel up to 1,700 m to a pond (Ashton 1992).

Mole salamander larvae were not observed in 1992, but were captured in pond 1301 in 1993. Earlier inundation in 1993 likely contributed to that pond's suitability for mole salamander reproduction because mole salamanders are known to initiate breeding migration as early as October (Semlitsch 1981). Pond 1301 was more suitable for reproductive success of mole salamanders in 1993 because of an increased winter hydroperiod (159 days) from that in 1992 (82 days); the minimum time needed for mole salamanders to metamorphose is reported to be 145 days (Semlitsch 1987*a*). However, due to site and climate variations, larval periods in this study may not always correspond with those reported in the literature. For example, Semlitsch (1980) stated that dwarf salamander larvae require approximately 140 days to emerge, but a pond in this study produced dwarf salamander metamorphs in <81 days. Semlitsch's (1980) study sites had relatively stable water levels, whereas factors associated with dry-down likely triggered dwarf salamander metamorphosis in this study. Metamorphosis of flatwoods salamander usually was complete before April (91 days), even though ponds continued to hold water.

Diversity and abundance of amphibian larvae reflected the available habitat in a pond. Ornate chorus frog larvae and leopard frog larvae appear to be generalists because they were captured at a greater range of depths and habitat variables than other amphibians. Flatwoods salamander and dwarf salamander larvae were found in quadrats dominated by sedges or pipewort tufts, with very little detritus. It is not known whether their occurrence in linear vegetation is an intentional effort to camouflage their striped bodies or simply reflects the dominant understory vegetation growth-form in the study ponds (Sekerak 1994). Dwarf salamander larvae generally occupied quadrats that were shallower than those occupied by flatwoods salamander or mole salamander larvae. Mole salamander larvae were found only in detritus-covered quadrats even though vegetated areas were available. This microhabitat type provides a background against which their blotchy skin is difficult to see when the larvae are not hiding in the leaf litter. Similar findings are reported for these species by other researchers (Caldwell et al. 1980; Semlitsch 1980, 1987*b*; J. G. Palis, Fla. Nat. Areas Inventory, unpubl. rep.).

The uncertainty in detecting flatwoods salamander larvae makes identifying flatwoods salamander breeding ponds difficult and could result in breeding ponds being misclassified as inactive. We present efforts and results from 1 pond surveyed during this (C. M. Sekerak, unpubl. data) and a concurrent study (J. G. Palis, unpubl. data) to illustrate. Pond 7703 was first identified as a flatwoods salamander breeding pond in 1991 when a larva was captured by Palis after 3 dipnet sweeps. In 1992, no flatwoods salamander larvae were captured by Palis (210 dipnet sweeps) or Sekerak (120 dipnet sweeps). Palis did not capture a larva in 1993 (260 dipnet sweeps), although Sekerak captured 1 (480 dipnet sweeps). Palis captured 1 larva in 1 sweep in 1994, and no larvae in 300 sweeps in 1995. Identical survey methods were used by both researchers, with the exception that Palis selectively surveyed herbaceous areas only.

Management Implications

Kautz (1984) suggests that the presence of species listed as endangered or threatened should be of key concern before sites are disturbed. This puts amphibians such as the flatwoods salamander at a disadvantage, because they are difficult to detect and may not always be found at the same location from year to year. Further, the response of this species to habitat disturbance is not fully understood; however, the effect of habitat loss can be deduced from presumed extirpation of flatwoods salamander from previously known localities (S. H. Bennett, S. C. Wildl. and Mar. Res. Dep., unpubl. rep.; J. C. Godwin, Ala. Nat. Heritage Sect., unpubl. rep.; Means et al. 1996; J. G. Palis, Fla. Nat. Areas Inventory, unpubl. rep.).

Given that the factors involved in rendering habitat unsuitable for flatwoods salamanders has yet to be identified, conservation efforts should include forest management practices that best maintain ecosystem integrity (Palis 1996) within 1,700 m of known or potential breeding ponds of this species. In addition, our results indicate that sufficient hydroperiod and graminaceous groundcover are important habitat components of flatwoods salamander larvae. We recommend maintaining natural hydrologic conditions and native herbaceous vegetation within wetlands that are part of a watershed where this species is known or suspected to occur.

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