Survey of Winter-breeding Amphibian Species

Final Report

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EXCUTIVE SUMMARY

Objectives of this project were to determine population trends, current occurrence on public lands, and possible reasons for extirpation or decline of populations of 5 amphibian Species of Greatest Conservation Need: striped newt (*Notophthalmus perstriatus*), eastern tiger salamander (*Ambystoma tigrinum*), frosted flatwoods salamander (*A. cingulatum*), gopher frog (*Lithobates capito*), and ornate chorus frog (*Pseudacris ornata*). We surveyed for these species from July 2010 through December 2014 using a combination of dipnet surveys, automated recording units (ARU), call surveys, and road surveys on rainy nights. We compiled all past records (from museums, databases, and the literature) and present observations of these species into an Excel database containing 1,596 records. Dipnet survey data, including locality and habitat information for surveyed wetlands, were entered into an Access database. During this project, 226 individuals participated in dipnet surveys for a total of 600 person-days, excluding the Principal Investigator.

We dipnetted 1,179 unique ponds on 118 conservation lands and on private lands in 12 counties. Using all methods, we documented gopher frogs in 237 ponds (including 183 new ponds) in 30 counties (Flagler and Liberty were new counties). We documented striped newts in 46 ponds (including 24 new ponds) on 10 conservation lands. Sites on the Spring Creek Unit of Big Bend Wildlife Management Area (WMA) and Triple N Ranch WMA represent range extensions and county records for Taylor and Osceola counties. No striped newts were detected in the panhandle, even though we surveyed 59 suitable ponds at historical sites. For frosted flatwoods salamanders, we dipnetted 244 ponds on 27 conservation lands and found larvae in 3 of 25 known ponds in St. Marks National Wildlife Refuge, 1 of 5 known ponds on adjacent Flint Rock WMA, and 5 new ponds and 15 of 56 known ponds in Apalachicola National Forest. In addition to dipnet surveys for ornate chorus frogs, we drove 677 km along 23 call routes in the northern peninsula and deployed 93 ARUs at sites in the peninsula and panhandle to detect calling frogs. Using all methods, ornate chorus frogs were detected in the panhandle in 60 ponds on 7 conservation lands and on private land in Jackson County, whereas they were found in the peninsula in 19 ponds on 6 conservation lands in Alachua, Clay, Lafayette (new county record), Putnam, and Taylor counties. Tiger salamanders were dipnetted in only 1 new and 2 known ponds. Road surveys found tiger salamanders moving on 3 rainy nights from 26 November 2013 through 1 January 2014 in Hernando, Levy, and Marion counties.

Examination of the characteristics of all known breeding ponds (detected by this or past studies) revealed differences in preference for each species. The 396 known gopher frog breeding ponds ranged in size from 0.01 to 42.27 ha (mean 1.92 ha), whereas 124 striped newt ponds ranged in size from 0.02 to 12.22 ha (mean 1.01 ha) and were significantly smaller than gopher frog ponds. Depression marsh was the most common wetland habitat used by breeding gopher frogs (59.9%) and striped newts (50.4%). The 38 known tiger salamander ponds ranged in size from 0.04 to 20.65 ha (mean 1.69 ha), and 232 ornate chorus frog ponds ranged in size from 0.01 to 13.65 ha (mean 0.78 ha). GIS analyses of land cover within 300 m of breeding ponds indicated

that sandhill is the most common land cover for gopher frogs (31%) and striped newts (44%), particularly in the panhandle. Upland pine forest comprised 40% of land cover around tiger salamander ponds, and flatwoods comprised 35% of land cover around extant flatwoods salamander ponds. Land cover around extant ornate chorus frog ponds varied. Fishes, primarily eastern mosquitofish (*Gambusia holbrooki*), were present in 17.2% of gopher frog and 11.5% of striped newt ponds. Fishes were present in 78.9% of flatwoods salamander and 46.0% of ornate chorus frog ponds (primarily ponds in flatwoods habitat). Crayfishes were present in <40% of gopher frog and striped newt ponds.

Computer-generated (primarily Maxent) models of potential habitat were developed for the gopher frog (258,722 ha), striped newt (158,706 ha), tiger salamander (842,564 ha), and ornate chorus frog (1,231,746 ha). Only 21–50% of the potential habitat identified by models occurs on conservation lands, with the ornate chorus frog having the least habitat and the striped newt the most habitat. Apalachicola National Forest, Ocala National Forest, and Withlacoochee State Forest rank in the top 10 in terms of potential habitat for all 4 species. A rules-based GIS model for the gopher frog identified 6 times more potential habitat than the computer-generated model.

Our analyses of long-term climate data revealed marked differences between the panhandle and peninsula. Most drought indices showed a significant trend of increasing drought over time in the peninsula (excluding the northern peninsula) but not in the panhandle. The biggest change in drought indices occurred in NOAA's North Central and South Central climate divisions, which represent the southern range limits of all target amphibian species except the gopher frog, which is an explosive breeder that ranges into southern Florida. In these climate divisions, the magnitude of recent droughts was similar to those in the past, but recent droughts have lasted significantly longer. Monthly changes in Palmer Hydrological Drought Index showed significant decreases (indicating increasing drought) in the late fall/early winter in the North Central and South Central climate divisions. Significant increases in average, minimum, and maximum temperatures have occurred in all peninsular regions but not the panhandle over the last 120 years. Our analyses of annual average precipitation revealed no changes over time in any part of the state, suggesting that increases in drought in the peninsula are being driven by temperature increases affecting evapotranspiration or evaporation. When we compared past (before 1980) and recent records, we observed a northward shift in the mean latitude and westward shift in the mean longitude of observations for the frosted flatwoods salamander and ornate chorus frog, suggesting that peninsular declines may be related to climate changes.

Threats to amphibian populations are complex, and the species declines we observed may be due to a combination of wetland and upland habitat loss, degradation, and fragmentation; climate change; and disease. Habitat degradation from silviculture and infrequent fire has likely played a major role in the declines of both species of flatwoods salamander. Given the short life span of the ornate chorus frog, prolonged winter droughts could be responsible for local population extinctions, particularly in more fragmented habitats containing few wetlands. Since 1980, significant westward shifts in mean longitude were observed for all species except the striped newt, which showed an eastward shift (approaching statistical significance) due to its apparent recent extirpation in the Munson Sandhills of Apalachicola National Forest. Its disappearance is somewhat enigmatic but may be due to wetland degradation, hydrological changes in wetlands from drought and groundwater withdrawals, and potentially an undocumented disease outbreak. Gopher frogs appear to be thriving in the peninsula; declines in the panhandle are likely primarily due to depleted gopher tortoise populations in this part of the state. Tiger salamanders are likely doing well, despite our lack of success at detecting them during this survey.

INTRODUCTION

Populations of 5 winter-breeding amphibian species that are Species of Greatest Conservation Need (SGCN) are suspected to have declining populations in peninsular Florida: frosted flatwoods salamander (*Ambystoma cingulatum*), tiger salamander (*A. tigrinum*), striped newt (*Notophthalmus perstriatus*), gopher frog (*Lithobates capito*), and ornate chorus frog (*Pseudacris ornata*) (Florida Fish and Wildlife Conservation Commission 2012). These species have distributional information gaps, and most lack current occurrence information. All these species breed in isolated, ephemeral wetlands that lack predatory fish and are situated in either xeric or mesic habitats (primarily sandhill or flatwoods). In the final year of this study, surveys were expanded to include the panhandle, but we did not target the reticulated flatwoods salamander (*Ambystoma bishopi*). The flatwoods salamander was listed as federally threatened in 1999 (U.S. Fish and Wildlife Service 1999), and Florida listed it as a Species of Special Concern in 2001 (Florida Fish and Wildlife Conservation Commission 2001). After Pauly et al. (2007) split the species into 2 species, the frosted flatwoods salamander remained threatened and the reticulated flatwoods salamander was listed as endangered (U.S. Fish and Wildlife Service 2008). The striped newt is a candidate for federal listing as threatened (U.S. Fish and Wildlife Service 2011), and the gopher frog is a state Species of Special Concern that has been petitioned for federal listing as threatened (Adkins Giese et al. 2012). A recent biological status review determined that the gopher frog does not warrant listing as state threatened (Florida Fish and Wildlife Conservation Commission 2011), and the species is expected to be delisted once the species action plan is approved in 2015 (Florida Fish and Wildlife Conservation Commission 2013). However, future changes in gopher frog taxonomy may affect its listing status; Florida apparently has 3 distinct genetic lineages (Richter et al. 2014).

Anecdotal observations and surveys suggest that these target amphibian species have been extirpated from many historical localities; the frosted flatwoods salamander has not been documented in peninsular Florida since 1998. In the 1990s, Florida Natural Areas Inventory (FNAI) staff began surveying for flatwoods salamanders, resulting in the discovery of many new ponds and populations, particularly in Apalachicola National Forest and Eglin Air Force Base (AFB), although most of their dipnet surveys of historical breeding ponds were unsuccessful. Flatwoods salamander surveys conducted in 2001–2005 resulted in the discovery of many new ponds in St. Marks National Wildlife Refuge (NWR) by Florida Fish and Wildlife Conservation Commission (FWC) staff (Palis and Enge 2005) and in Apalachicola National Forest by The Nature Conservancy and U.S. Forest Service staff (Ripley and Printiss 2005). Surveys by Franz and Smith (1999) and FNAI staff for gopher frogs and striped newts in 1994–1998 resulted in the discovery of many new ponds, particularly in Camp Blanding Military Reservation and Jennings State Forest. Bruce Means and Coastal Plains Institute (CPI) staff have been monitoring over 200 ponds in the Munson Sandhills in Leon County since 1995 (Means 2008), some of which were historically used by the striped newt, gopher frog, and ornate chorus frog. Surveys by FNAI staff in the 1990s resulted in the discovery of numerous gopher frog ponds in Eglin AFB (Printiss and Hipes 1999). FWC staff began surveying ponds for striped newts in 2006, resulting in the discovery of many new newt and gopher frog ponds, particularly in Ocala National Forest (Enge 2011). FWC staff at Blackwater River State Forest have been surveying for and monitoring tiger salamander ponds (Showen 2007). The current occurrence of the tiger salamander and ornate chorus frog is unknown in the peninsula, but ornate chorus frog populations are known to have disappeared from many formerly occupied sites in the peninsula.

Habitat destruction and degradation are primarily responsible for declining amphibian populations, but a contributing factor may be prolonged winter droughts (possibly a result of climate change) that have shortened the hydroperiods of ephemeral wetlands used as breeding ponds, reducing juvenile recruitment. In Florida, anthropogenic habitat conversion has destroyed approximately half of historical wetland coverage (Dahl 2005) and modified over 98% of historical longleaf pine (*Pinus palustris*) forests, threatening populations of wetland-dependent fauna (Meshaka and Babbitt 2005). Fire suppression has degraded much of the remaining longleaf pine forest habitat, increasing the amount of slash (*P. elliottii*), loblolly (*P. taeda*), and sand (*P. clausa*) pines on sites, increasing the hardwood understory, and decreasing the herbaceous ground cover (Wolfe et al. 1988).

The number of amphibian species naturally decreases from north to south in the peninsula; this pattern has been attributed to a reduction in topographic and habitat variation and winter rainfall (Means and Simberloff 1987). Florida's humid, subtropical climate is characterized by a cool, dry season and a warm, rainy season that may include tropical storms and hurricanes. The northern peninsula (approximately north of Orlando) and panhandle have cooler weather and relatively high winter precipitation, which is important for the distribution of many amphibian species, particularly salamanders. Rain-bearing cold fronts during the dry season, tropical storms, and hurricanes are important in recharging the aquifer, filling ephemeral wetlands, and stimulating breeding of some amphibian species. Fourteen amphibian species that depend upon winter rains to provide suitable breeding and larval habitat are restricted to the northern peninsula. The ranges of only 2 so-called winter-breeding amphibian species, the gopher frog and southern chorus frog (*Pseudacris nigrita*), extend into southern Florida, where they often breed following summer rains.

Ephemeral ponds are important components of upland habitat in the southeastern United States (LaClaire and Franz 1990) and tend to be small (typically <5 ha) and isolated, with a cyclic nature of drying and refilling known as hydroperiod. Precipitation is the most important water source for ephemeral ponds, and the timing and length of the hydroperiod help determine the suitability of ponds as breeding sites for various amphibian species, many of which exclusively breed in ephemeral ponds (Moler and Franz 1988, LaClaire and Franz 1990). Periodic drying kills fish and aquatic invertebrate populations that represent potential predators on larval amphibians. Arrival of migrating adult amphibians soon after pond filling is advantageous because larvae have more time to develop before pond drying and less initial competition and predation (Semlitsch et al. 1993). Ephemeral ponds are biologically unique, because they support diverse species that are different than species found in larger, more permanent wetlands or ponds (Moler and Franz 1988, Kirkman et al. 1999).

The objectives of this project were to determine 1) population trends of 5 winter-breeding amphibian species that are SGCN, 2) current occurrence of these 5 SGCN on public lands in Florida, and 3) possible reasons for the extirpation or decline of populations of these 5 SGCN. We include information on the current occurrence of a sixth species, the reticulated flatwoods salamander, despite conducting limited surveys for it.

SPECIES INFORMATION

Taxonomy and Description

Flatwoods Salamanders.—Pauly et al. (2007) conducted molecular and morphological analyses and split the flatwoods salamander (*Ambystoma cingulatum*) into the frosted and reticulated species, which are separated by the Apalachicola–Flint rivers. The frosted species has Atlantic Coastal Plain (South Carolina, Georgia, and peninsular Florida) and Eastern Panhandle clades (Pauly et al. 2012). Both species are slender and rarely exceed 130 mm total length (TL) (Conant and Collins 1991, Ashton 1992). Adult dorsal coloration ranges from black to chocolate-black with highly variable, fine, light gray lines forming a netlike or cross-banded pattern across the back (Palis 1996) (Fig. 1). The dorsal and ventral patterns tend to differ between the 2 species, but the main differences are the number of costal grooves, tail length, limb measurements, and head shape (Pauly et al. 2007). Larvae are long and slender with broad heads that have a dark brown stripe passing through the eye from the nostril to the bushy gills, white bellies, and sides with several distinctive tan, black, and cream-colored stripes (Ashton 1992, Palis 1995) (Fig. 2).

Figure 1. Male frosted flatwoods salamander from St. Marks National Wildlife Refuge, Wakulla Co. (photo by Pierson Hill).

Figure 2. Reticulated flatwoods salamander larva from Garcon Point Water Management Area, Santa Rosa Co.

Tiger Salamander.—The tiger salamander was formerly considered a wide-ranging, polytypic species (Jones et al. 1988, Petranka 1998), but the eastern tiger salamander (*A. tigrinum*) and western tiger salamander (*A. mavortium*) are now considered separate species (Shaffer and McKnight 1996, Crother et al. 2012). Analysis of mitochondrial sequence data (mtDNA) suggests that tiger salamanders east and west of the Apalachicola River Basin were separated 0.75–2 million years ago by a migratory event in response to Pleistocene glaciation (Church et al. 2003). It is stocky and large headed, rarely exceeding 260 mm TL (record length of 330 mm TL). Adult dorsal coloration is black or dark brown, and irregularly shaped yellowish or beige spots occur on the head, body, and tail (Fig. 3). Metamorphs typically are black or dark gray without spots. Larvae have large, round heads with blunt snouts and bushy gills (Fig. 4). Large larvae have a light, ragged lateral stripe bordered by dark mottled bands and may exceed 100 mm TL before transforming.

Striped Newt.—The striped newt is more closely related to the black-spotted newt (*Notophthalmus meridionalis*) from southern Texas and Mexico than it is to the sympatric eastern newt (Reilly 1990). The central subspecies of the eastern newt (*N. viridescens louisianensis*) sometimes occurs in the same ponds as the striped newt in Apalachicola National Forest (Means

Figure 3. Adult tiger salamander from Levy Co.

Figure 4. Larval tiger salamander from Hernando Co.

et al. 1994, Means 2001, Means and Means 2005). South and east of northern Alachua County, the central subspecies is replaced by the peninsula subspecies (*piaropicola*), which lacks an eft (terrestrial juvenile) stage and is, therefore, unable to colonize isolated wetlands in xeric landscapes that are used by the striped newt. Prior to this study, striped newt populations near Tallahassee in the Florida panhandle (western region) were thought to be separated by ca. 125 km from those occurring on sand ridges and river terraces in the peninsula (eastern region) (Johnson 2002a). Analysis of mitochondrial DNA showed that newts in eastern and western regions shared no haplotypes, but insufficient genetic divergence had occurred for them to be considered separate cryptic species (Johnson 2002a, May et al. 2011).

Adult striped newts measure 50–105 mm TL. The dorsal coloration of terrestrial adults ranges from light or dark brown to olive green, and 2 red, black-bordered stripes (and sometimes spots) are present (Fig. 5). The venter is yellow with small black spots. Paedomorphs or neotenes (gilled adults) have similar dorsal coloration but often lack red stripes. Efts (terrestrial juveniles) have dull orange dorsal coloration and red stripes, and their skin is rougher and tail less laterally compressed than in adults (Fig. 6). Larvae of striped and eastern newts are similar in having a dark stripe extending from each eye to the bushy gills, light dashes along the lateral line, and a light-colored belly that may have small black spots. Striped newt larvae tend to have a higher tail fin with black mottling, but the amount of mottling is variable, making it difficult to differentiate between the 2 species where they occur in the same wetlands.

Figure 5. Aquatic adult female (top) and male striped newts from Taylor Co.

Figure 6. Striped newt eft that has returned to the pond to breed for the first time in Taylor Co.

Gopher Frog.—Three subspecies of gopher frog were formerly recognized, with 2 subspecies occurring in Florida (Conant and Collins 1991), However, Young and Crother (2001) found no genetic divisions among populations of *Rana capito* east of the Mobile River drainage in Alabama; only a population in southern Mississippi was genetically distinct, and it was elevated to specific status by resurrecting *Rana sevosa*. Frost et al. (2006) removed New World frogs from the genus *Rana* and placed them in *Lithobates*, so the current name for the species occurring in Florida is the gopher frog (*Lithobates capito*). Recent mitochondrial DNA analysis identified 3 distinct lineages: Coastal Plain, northern peninsula, and southern peninsula (Richter et al. 2014). The Coastal Plain lineage, which is the most distinct and diverged from the others about 2 million years ago, extends from North Carolina to Alabama and includes the Florida panhandle (Richter et al. 2014). The location of the genetic break in Florida between the panhandle and peninsula is presumably the low-lying area between the Aucilla and Suwannee rivers ("Suwannee Strait"). The northern and southern peninsula clades diverged about 1 million years ago, with the southern one probably developing on central Florida ridges while isolated during higher sea levels (Richter et al. 2014). The location of this peninsular genetic break is somewhere between Alachua and Hernando counties.

The gopher frog is a heavily spotted, rather stocky, medium-sized ranid frog with a somewhat oversized head and mouth. In Florida, adult males were 61–93 mm snout-urosytle length (SUL) and adult females were 78–112 mm SUL (Palis 1998). The back, head, and legs are covered with irregular brown spots on a pale cream, tan, or gray background (Fig. 7). A pair of bronze-tinted dorsolateral folds runs along the back from behind the eyes to the waist. The belly is typically unmarked posteriorly. The tadpole can be differentiated from that of the leopard frog (*L. sphenocephalus*) by a lack of light-colored facial markings (a mustache and vertical nose stripe or spot), a higher tail fin with larger and fainter spots, a more globular golden-colored body, a light belly, and a translucent snout (Fig. 8). However, coloration of the body and the characteristics of the tail fin can be variable, and the snout becomes more opaque in large tadpoles. Tadpoles may attain 127 mm TL before transforming (Kevin Enge, pers. obs.).

Figure 7. Adult gopher from Hernando Co.

Figure 8. Gopher frog tadpoles from Rock Springs Run State Reserve, Orange Co.

Ornate Chorus Frog.—The ornate chorus frog comprises 3 clades that correspond to geographically distinct regions based on mitochondrial DNA and microsatellites (Degner et al. 2010). All populations in Florida are in the same clade, and the Apalachicola River does not represent a genetic break (Degner et al. 2010). The ornate chorus frog is small with an adult size of 25–40 mm SUL. The dorsal color may be predominantly gray, brown, reddish brown, pinkish, or green, and a population may be predominated by 1 color phase or have a mix of colors. Most populations are polymorphic, with most individuals being various shades of brown or gray and a few individuals being bright green. The proportion of gray to brown morphs in a clutch is strongly influenced by the density and temperature experienced by the tadpoles (Travis and Trexler 1984, Harkey and Semlitsch 1988), whereas the green morph is inherited by 1 dominant allele and is not affected by tadpole density (Blouin 1989). A bold black or chocolate brown stripe extends from the nostril through the eye to the shoulder, where it often becomes broken along the sides of the body (Fig. 9). A dark elongated blotch is present above the groin area, and the concealed portions of the groin and thighs are bright yellow. Faded blotches or stripes may be present on the sides of the back, and the tops of the fore and hind legs may have partial dark bands. Tadpoles attain 43 mm TL and have very high tail fins that begin just behind the eyes (Fig. 10). Two gold or brassy stripes are often present along the sides of the back, and the tail musculature may be strongly bicolored or mottled.

Figure 9. Brown and green morph ornate chorus frogs from Liberty Co.

Figure 10. Ornate chorus frog tadpole from Liberty Co. (photo by Pierson Hill).

Distribution

Flatwoods Salamanders.—The historical range of the frosted flatwoods salamander was the Gulf Coastal Plain east of the Apalachicola–Flint rivers, across northern Florida and north along the Atlantic Coast through coastal Georgia and South Carolina. In Florida, the southernmost record was reported from near Burbank, Marion County (Neill 1954), and several populations occurred around Gainesville, Alachua County (Goin 1950, Ashton and Ashton 2005, Krysko et al. 2011). There is an apparent distributional gap between Jefferson County in the panhandle and Baker and Alachua counties in the peninsula (Krysko et al. 2011). The area between the Aucilla and Suwannee rivers has often been referred to as the “Suwannee Strait,” and various authors have proposed different times when a barrier of sea water might have been present separating peninsular Florida (“Ocala Island”) from the mainland (Webb 1990:84). During periods of highest sea levels, the Apalachicola River basin was a large saltwater embayment that extended north through Alabama and Georgia to the Fall Line, creating a saltwater channel through the coastal plain that acted as a barrier to many species (Cooke 1945, Neill 1957). This saltwater channel probably resulted in genetic differentiation of the flatwoods salamander into 2 species.

Tiger Salamander.—The eastern tiger salamander ranges as far north as Long Island, New York, in the eastern part of its range, and it ranges as far west as Minnesota and eastern Texas but is absent from most of the Appalachian uplands and lower Mississippi delta region (Conant and Collins 1991). In peninsular Florida, tiger salamanders have been found as far south as

Brooksville, Hernando County, but have not been found east of Alachua, Marion, and Sumter counties (Krysko et al. 2011). It occurs in the northern tier of panhandle counties, which tend to have higher clay content in the soil. Apparent gaps in its distribution in the panhandle may be due to its secretive nature and inadequate sampling. Targeting areas for surveys is complicated by its use of a variety of upland and breeding habitats.

Striped Newt.—The striped newt is endemic to southern Georgia and northern Florida, occurring in widely scattered populations. Prior to this survey, its known historical distribution in Florida extended from Leon and Wakulla counties east to Nassau County and south in the peninsula to Citrus, Sumter, and Orange counties (Franz and Smith 1999, Johnson and Owen 2005, this study) (Fig. 1). A distributional gap was thought to occur in the area of the purported Suwannee Strait, and the only record in the peninsula west of the Suwannee River was from eastern Dixie County (Krysko et al. 2011). During this study, we found striped newts at Triple N Ranch WMA, Osceola County, which extends the known range 57 km SSE of records on the University of Central Florida, Orange County (Enge et al. 2014). More significant was the discovery of striped newts in the Spring Creek Unit of Big Bend Wildlife Management Area (WMA), Taylor County, which is ca. 69 km E of the nearest records in St. Marks NWR, Wakulla County, and 84 km W of the nearest record in Gilchrist County (Mays and Enge 2014). Reliable records exist from 18 counties in Florida, excluding erroneous reports from Santa Rosa and Glades counties and a record from Hernando County that should have been Floral City, Citrus County (Franz and Smith 1999, Johnson and Owen 2005). The striped newt occurs on the northern Brooksville Ridge but is apparently absent from large tracts of sandhill habitat farther south in Hernando County, such as the Croom Tract of Withlacoochee State Forest.

Gopher Frog.—The gopher frog occurs in the southeastern Coastal Plain from southern Alabama to North Carolina, with disjunct populations in central Alabama and the Cumberland Plateau in Tennessee (Jensen and Richter 2005). The gopher frog historically occurred throughout Florida except for the Everglades region (Krysko et al. 2011). There are records from 54 counties in Florida (Krysko et al. 2011), including new records from Flagler and Liberty (Enge and Enloe 2014) counties found during this study. An unverified report exists from Jackson County (Cindi Stewart, pers. comm.). Florida represents the largest portion of the total global range of the species, and populations have declined significantly throughout much of its range (Jensen and Richter 2005). It apparently no longer occurs at the southern termini of its historical range along both coasts, likely due to urbanization.

Ornate Chorus Frog.—The ornate chorus frog is restricted to the southeastern Coastal Plain, ranging from North Carolina to extreme eastern Louisiana. Northern peninsular Florida represents the southern terminus of its range, and historically it occurred as far south as northern Lake and southern Flagler counties (Owen 1996, Krysko et al. 2011). Along the Gulf Coast, voucher specimens exist only as far south as Levy County (Krysko et al. 2011), but Richard Bartlett (pers. comm.) heard ornate chorus frogs calling farther south in Hernando, Pasco, and northern Hillsborough counties in the 1960s. Brown and Means (1984) attributed this range terminus to decreased winter rainfall in the southern peninsula and reduced availability of sandy soil. There are records from 29 counties in Florida (Krysko et al. 2011), including a record from Lafayette County found during this study.

Terrestrial Life History

These 6 amphibian species spend most of their adult lives in upland habitats, but relatively little is known regarding this stage of their life history because of their fossorial behavior. The ranges of all species except the tiger salamander coincide with the longleaf pine ecosystem (Guyer and Bailey 1993), where frequent fire is important in maintaining suitable upland habitat with open canopies. Tiger salamanders can occur in fire-dependent habitats but also inhabit fire-suppressed habitats such as xeric and mesic hammocks. Striped newts primarily inhabit xeric upland habitats, but gopher frogs may inhabit open mesic habitats if tortoise burrows are present. As their name indicates, flatwoods salamanders inhabit flatwoods habitats (also pine savannas), whereas ornate chorus frogs may be found in both mesic and xeric habitats. Wiregrass (*Aristida stricta*) and similar clump grasses are probably important to some of these species in xeric habitats or during drought conditions. Brown and Means (1984) identified the following advantages to ornate chorus frogs of the microhabitat provided by grass clumps: (1) soil is probably moister, (2) substrate is cooler because of shading, (3) mass of roots may provide protection from certain predators, (4) tunnels may be less likely to collapse because of supporting root structure, and (5) invertebrate prey may be more common. The moist microhabitat provided by wiregrass clumps may be important to all the target amphibian species during at least part of their life history, such as during migrations to and from breeding ponds.

Flatwoods Salamanders.—Optimal habitat for flatwoods salamanders is open, mesic longleaf and slash pine flatwoods with an herbaceous ground cover typically dominated by wiregrass or dropseed (*Sporobolus* spp.) and a diverse assemblage of forbs (Palis 1996) (Fig. 11). Common shrubs are gallberry (*Ilex glabra*), saw palmetto (*Serenoa repens*), blueberries (*Vaccinium* spp.), and runner oaks (*Quercus pumila* and *Q. minima*) that are low in stature in flatwoods maintained by periodic fires. The soil is typically poorly drained sand or loam that becomes seasonally saturated. Extensive savanna-like wet flatwoods, such as in Apalachicola National Forest, can also provide optimal habitat (Fig. 12). Survival of this fossorial species is apparently dependent upon subsurface conditions (i.e., root channels and burrows). They dig their own burrows or expand crayfish burrows (Neill 1952, Ashton 1992) and have been found in burrows at least 50 cm below the surface (Ashton and Ashton 2005). Captive individuals have been observed digging burrows and resting at night with just the tip of their heads exposed (Goin 1950). Salamanders are occasionally found under fallen logs and pine duff, particularly while migrating (Goin 1950; Ashton and Ashton 2005, Kevin Enge, pers. obs.). Metamorphs and adults have been observed climbing up to 0.5 m off the ground in wiregrass clumps, possibly to forage or escape from predators (Jones et al. 2012). Another possible explanation for this behavior is to ascend above the ground cover to obtain orientation cues in the flat landscape (Pierson Hill, pers. comm.). They presumably prey upon small invertebrates, and earthworms have been recorded from stomachs (Goin 1950). Adults emigrating from a breeding pond have been tracked moving up to 1,700 m (Ashton and Ashton 2005), but the farthest they have been documented from a breeding pond is 1,100 m (Ray Ashton, pers. comm.). Many ambystomatid salamanders live 10 years or longer (Snider and Bowler 1992), but the maximum life span is unknown for the flatwoods salamander. At least 1 salamander has returned to breed for 5 years at Eglin AFB (Tom Gorman, pers. comm.).

Tiger Salamander.—In Florida, tiger salamanders have been found in sandhill, upland pine forest, xeric hammock, mesic hammock, and mixed hardwood-pine forest (Enge 1997a, Enge and Wood 2001, Showen 2007). Optimal habitats have sandy or otherwise friable soils and an abundance of breeding ponds (Petranka 1998). A study in New York found that migrating salamanders avoided grassy fields and agricultural areas (Madison and Farrand 1996), but at a forested site in Georgia, salamanders seemed to prefer wildlife food plots that were annually tilled and had loose soil (Steen et al. 2006). In Florida, they are tolerant of ruderal habitats like pastures

Figure 11. Mesic flatwoods habitat used by flatwoods salamanders in Apalachicola National Forest, Liberty Co.

Figure 12. Grassy wet flatwoods (savanna) habitat used by flatwoods salamanders in Apalachicola National Forest, Liberty Co.

and some types of agricultural fields (Kevin Enge, pers. obs.). Adults emigrating from breeding ponds have been documented moving up to 225 m in the Southeast (Steen et al. 2006) and 286 m in the Northeast (Madison and Farrand 1996). The maximum dispersal distance reported for the species is 600 m (Pechmann et al. 2001), but based upon its large body size and stout limbs compared to other ambystomatid species that have been documented migrating farther, tiger salamanders are probably capable of moving longer distances. Adults leave the pond and migrate into upland habitat from January through April, but some stay around the pond periphery until the next breeding season (Semlitsch 1983b, Steen et al. 2006). A male in South Carolina moved 162 m from the breeding pond on 6 March and then moved distances of only a few meters during the next 5–6 weeks (Semlitsch 1983c). At Chinsegut Nature Center, Hernando County, Enge and Wood (2001) trapped an adult in xeric hammock 230 m from the breeding pond, a 21-ha basin marsh. Tiger salamanders commonly use small mammal burrows, stumps, and logs but can also construct their own tunnels (Gruberg and Stirling 1972, Semlitsch 1983a, Steen et al. 2006). While emigrating from breeding ponds, adults will dig blind tunnels that are used until rainfall allows overland movement to more permanent burrow systems of small mammals such as short-tailed shrews (*Blarina brevicauda*) (Madison and Farrand 1996). Adults eat insects, earthworms, and small vertebrates (Petranka 1998). Terrestrial tiger salamanders have lived up to 16 years in captivity (Nigrelli 1954).

Striped Newt.—Striped newts are primarily found in xeric upland habitat, preferring sandhill habitat but also inhabiting scrub and scrubby flatwoods (Enge 2011) (Fig. 12). Striped newts are rare or absent in sandhills that have been invaded by hardwoods in the absence of fire. It is unknown how striped newts survive in scrub habitats, which usually have sparse herbaceous ground cover and coarse woody debris; most scrub habitat may be a population sink for efts and adults (Enge 2011). Breeding ponds may be situated in mesic flatwoods, if suitable xeric upland habitat occurs in the vicinity (Enge 2011). The striped newt has a complex life history. A larva either changes into an eft, an immature terrestrial stage, and leaves the pond or remains in the pond until it matures into a paedomorph (Johnson 2002b). All larvae that are large enough will metamorphose into efts if the pond dries up. Adult newts typically immigrate from uplands into wetlands during the fall and winter, but some newts may immigrate during spring and summer if environmental conditions are conducive to breeding (Johnson 2005). Even if water remains in the pond, adults emigrate back into uplands after breeding, at which time the tailfin disappears and the skin becomes more granular. Newts migrating from a pond favored the direction leading to sandhill habitat (Dodd and Cade 1998), and 16% of newts migrated > 500 m from ponds (Johnson 2003). Striped newts have been found up to 709 m from the nearest wetland (Dodd and Cade 1998) and probably can disperse even farther. Efts mature into terrestrial adults that return to the pond to breed. Little is known regarding feeding habits of terrestrial adults and efts (Dodd et al. 2005). Newts are long lived (ca. 12–15 years), which allows them to cope with unfavorable stochastic events, such as drought, that adversely affect reproduction (Dodd 1993, Dodd et al. 2005, Wallace et al. 2009). A captive striped newt lived >17 years (Wallace et al. 2009).

Gopher Frog.—Gopher frogs primarily inhabit areas with well-drained sandy soils that support gopher tortoise (*Gopherus polyphemus*) populations (Wright 1932, Franz 1986, Blihovde 2006, Roznik 2007). During the non-breeding season, the gopher frog is generally associated with longleaf pine–xeric oak sandhills but also occurs in upland pine forest, scrub, xeric hammock, mesic and scrubby flatwoods, dry prairie, mixed hardwood-pine communities, and a variety of disturbed habitats (Enge 1997a). Gopher frogs extensively use gopher tortoise burrows for underground retreats (Wright 1932, Carr 1940a, Franz 1986) but also use southeastern pocket gopher (*Geomys pinetis*) burrows, mouse burrows, crayfish burrows, hollow logs, stump holes, root mounds, dead vegetation, and clumps of grass (Wright and Wright 1949, Gentry and Smith 1968, Lee 1968, Godley 1992, Richter et al. 2001, Blihovde 2006, Roznik et al. 2009; Kevin Enge, pers. obs.). Underground retreats in uplands are important for avoiding predation and desiccation, and frogs would be unlikely to survive droughts without them (Blihovde 2006). Gopher frogs in central Florida exhibited strong site fidelity to gopher tortoise and pocket gopher burrows, using 1 to 4 terrestrial shelters and making daily movements of 0–35 m (Blihovde 2006). Frogs were relatively sedentary outside of the breeding season, seldom moving more than 10 m to another burrow, and 1 female did not move from an abandoned pocket gopher burrow for 14 months (Blihovde 2006). Gopher frogs have been documented traveling up to 2 km in Florida (Franz et al. 1988) and up to 4.5 km in North Carolina (Humphries and Sisson 2012) to breeding ponds, typically during heavy winter and spring rains. Underground retreats are essential for the survival of newly metamorphosed gopher frogs, which experience high predation rates when they are above ground and are more vulnerable to desiccation than adults (Roznik and Johnson 2009a). Metamorphs leaving a pond in sandhill habitat in Ocala National Forest moved an average of 173 m (maximum of 691 m) straight-line distance from their natal ponds before finding shelters or being killed by snakes, mammals, or vehicles (Roznik and Johnson 2009a). Metamorphs selected fire-maintained habitat with an open canopy, few hardwood trees, small amounts of leaf litter, and large amounts of wiregrass; this habitat contained more tortoise burrows, which are the primary refuge sites for both juvenile and adult gopher frogs (Roznik and Johnson 2009b, Roznik et al. 2009).

Gopher frogs are generally nocturnal, with individuals often leaving their burrows to forage at night for invertebrates and anurans, including toads (Godley 1992). Occasionally they can be seen foraging on the surface during the day or spotted at the mouths of tortoise burrows, particularly on overcast days. A distinct resting area (“platform”) is often present outside the burrow where the soil has been cleared of vegetation and smoothed by the frog’s constant use (Stevenson and Dyer 2002). Males apparently become reproductively mature at 1.5 years and females at 2 years (Jensen and Richter 2005). Gopher frogs are apparently long lived; a captive frog lived 9 years (Snider and Bowler 1992).

Ornate Chorus Frog.—In Florida, ornate chorus frogs are found in mesic and dry pine flatwoods, sandhills, upland pine forests, oldfield successional mixed pine-hardwood forests, sand pine plantations, and xeric hammocks (Florida Game and Fresh Water Fish Commission 1976, Brown and Means 1984, Enge 1997a, Means and Means 2005). Relatively little is known about adult habitat and microhabitat requirements of this fossorial species (Means and Means 2005). It is frequently found using logs and downed woody debris as refugia (Harper 1937) or burrowed among roots of herbaceous vegetation (Carr 1940a, Neill 1952). Deckert (1915) reported digging them out of sweet potato hills in a garden in the Jacksonville area. Availability of a sandy substrate is important for burrowing, and in areas of inundated flatwoods, frogs may travel far to find suitable substrate in which to burrow (Brown and Means 1984). Adults emigrate from ponds from January through March (Gibbons and Semlitsch 1991). Palis and Aresco (2007) trapped both sexes up to 200 m from the breeding pond in flatwoods habitat, and Brown and Means (1984) found them in uplands over 400 m from the nearest breeding site. During a drift-fence survey in sandhill habitat at Camp Blanding Military Reservation, adults were trapped in an array located ca. 450 m from the nearest wetland (Kevin Enge, pers. obs.). Sexual maturity is reached within the first year. The population turnover is nearly annual; however, females occasionally may postpone reproduction and return to breed the following year when conditions are more favorable (Caldwell 1987). Age at first reproduction is 11.5–14 months (Caldwell 1987). Most frogs breed only their first year, but a few individuals may live for 2 and possibly 3 years (Caldwell 1987).

Aquatic Life History and Reproduction

Predation and competition are the major biotic factors controlling amphibian community composition of ephemeral wetlands (Heyer 1976, Steinwascher 1978, Wilbur 1987, Morin 1988). Interannual turnover in species composition of larval amphibian communities is best predicted by local environmental factors (pond area, hydroperiod, and canopy cover) and pond connectivity on the landscape (Werner et al. 2007). Species composition of a given pond community is highly dynamic, and about half of the potential species are actually present in a particular pond in a given year (Werner et al. 2007). The dry phase in an ephemeral wetland may be seasonal, annual, or greater than annual (LaClaire 1995). The hydroperiod of wetlands varies annually and determines adult use and juvenile recruitment into the population (Greenberg et al. 2003). A wetland's hydroperiod is influenced by underlying geology, soil characteristics, depth, size, amount and timing of rainfall, evaporation rate, and plant transpiration (Sudol et al. 2009). In the Southeast, there is no relationship between amphibian species richness and wetland size, and wetlands with short hydroperiods support a unique group of species (Snodgrass et al. 2000). Annual reproductive success varies widely among amphibians that breed in ephemeral wetlands, but high adult survival often buffers against these fluctuations, particularly for long-lived species like newts and ambystomatid salamanders (Taylor et al. 2006).

Flatwoods salamanders and ornate chorus frogs often breed in the same wetlands in flatwoods habitat (Fig. 13). Striped newts and gopher frogs often breed in the same wetlands in sandhill and scrub habitats (Fig. 14), but gopher frogs are able to use more diverse types of wetlands and ones with shorter hydroperiods. Ornate chorus frogs may breed in the same wetlands in sandhill habitats as the striped newt and gopher frog, particularly in the panhandle, but ornate chorus frogs are able to use shallower wetlands with shorter hydroperiods than the other 2 species. In sandhill and upland pine habitats, gopher frogs, tiger salamanders, and ornate chorus frogs may breed in the same wetlands, although the presence of predatory tiger salamander larvae may affect use by other species. The frequency and duration of inundation in ephemeral ponds create distinct zones of vegetation. Depression and basin marshes in xeric uplands, which are classic breeding sites for the striped newt and gopher frog, typically have maidencane (*Panicum hemitomon*) in portions of the wetland that are usually inundated by shallow water. Persistence of maidencane helps to reduce the oxidation rate of organic matter, soil moisture loss, and growth and establishment of upland plant species (LaClaire 1995). Grassy vegetation along pond edges or in the entire basin provides amphibian larvae with cover from predators. A grassy ecotone is critical for flatwoods salamander reproduction but is not required by the other species, although larvae of all these species may use flooded grassy ecotones (Kevin Enge, pers. obs.).

Figure 13. Dome swamp used by flatwoods salamanders and ornate chorus frogs in Apalachicola National Forest, Liberty Co.

Figure 14. Sinkhole pond (One Shot Pond) used by striped newts and gopher frogs in Ordway-Swisher Biological Station, Putnam Co.

Flatwoods Salamanders.—Flatwoods salamanders typically breed in small (<2 ha, but up to 4 ha), shallow (<50 cm), isolated wetlands that fill during autumn or winter rains and dry in April or May with onset of the growing season (Palis 1996, 1997b). Flooding of flatwoods may permit colonization of breeding ponds by large, predatory fish species such as sunfish (*Enneacanthus* spp.), grass pickerel (*Esox americanus vermiculatus*), and even bowfin (*Amia calva*) (Palis 1997b; Kevin Enge, pers. obs.). Breeding sites include dome swamps, depression marshes, roadside ditches, and shallow borrow pits (Palis 1997b; Kevin Enge, pers. obs.). Dome swamps generally have an overstory dominated by pond cypress, blackgum (*Nyssa biflora*), and slash pine, and depending on closure of the canopy and midstory, the herbaceous ground cover can range from approximately 5% to nearly 100%. Some dome swamps are dominated by myrtle-leaved holly (*Ilex myrtifolia*) (Palis 1996, 1997b). Graminaceous vegetation in the ecotone (and secondarily the basin) is critical as egg deposition sites and to provide shelter for larvae and possibly metamorphs and breeding adults. Adults of both sexes migrate to wetlands from October through December during rain events associated with the passing of a cold front (Anderson and Williamson 1976, Means et al. 1996, Palis 1997a). Pond basins are typically dry when adults arrive, and males actively search for sedentary females to court. Females deposit terrestrially a total of up to 225 eggs (Ashton 1992) in small clumps of 1 to 34 eggs in moist microhabitats at the base of wiregrass clumps, small vegetated depressions, entrances of crayfish burrows, or under sphagnum moss, leaf litter, or dead grass (Anderson and Williamson 1976; Powell et al. 2013; Kelly Jones, pers. comm.). Eggs must be in contact with damp mineral soil to prevent desiccation, and pond basins that develop a duff layer are no longer viable egg-deposition sites (Pierson Hill, pers. obs.). The eggs begin developing immediately after oviposition but do not hatch until inundated by rising pond levels, which is often weeks later and up to 3 months (Anderson and Williamson 1976, Palis 1997b, Bevelhimer et al. 2008). Some eggs laid in moist situations can survive fire (Powell et al. 2013).

The larval period for the flatwoods salamander lasts 3 to 4 months, typically from December or January through March (Palis 1995), although larvae have been found from November 28 through 23 May (Bishop et al. 2006, Bevelhimer et al. 2008). Larvae primarily prey upon crustaceans, mostly isopods (*Caecidotea*), amphipods (*Crangonyx*), and cyclopoid copepods (Whiles et al. 2004). Larvae typically shelter during the day in the inundated graminaceous ecotone but will use other linear-leaved vegetation, such as beakrushes (*Rhynchospora* spp.), panicums (*Panicum* spp.), sedges (*Carex* spp.), and pipeworts in the pond basin if water levels recede (Sekerak 1994, Palis 1996). In ponds with good visibility, larvae are easily detected at night as they float in the water column (Paul Moler, pers. obs.; Pierson Hill, pers. obs.). The substrate of breeding sites is typically relatively firm mud with little or no peat, and burrows of crayfish, primarily *Procambarus*, are usually present (Palis 1997b). Larvae may shelter in crayfish burrows during the day, particularly in ponds with sparse herbaceous cover (Pierson Hill, pers. obs.). Larval pond residency varies among years depending upon the timing of pond filling (Bevelhimer et al. 2008).

Tiger Salamander.—In Florida, tiger salamanders may breed in depression marshes, basin marshes, sinkhole ponds, dome swamps, hardwood swamps, sandhill lakes, farm and retention ponds, and borrow pits (Travis 1992, Enge 1997b) (Fig. 15). Breeding ponds are often large and shallow with abundant herbaceous, emergent vegetation (Travis 1992), but woodland depressions lacking aquatic vegetation are also used (Kevin Enge, pers. obs.). According to Travis (1992), breeding migrations to ponds in Florida occur from December through early February, but migrations were observed in November 2011 and 2014 and in March 2013 (Pierson Hill, pers. obs.). In Blackwater River State Forest in the panhandle, larvae have been found from 9 January to 16 April and eggs as late as 10 April (FWC, unpubl. data). In South Carolina, male tiger salamanders may begin migrating to breeding ponds as early as October during cool temperatures, but peak migration of both sexes is in January and February during and immediately following rains (Semlitsch 1983b). Males typically arrive 2–8 weeks before females, and adults remain in ponds 1–98 days (Semlitsch 1983b). At Rainbow Bay at the Savannah River Site, the number of breeding females varied markedly over a 16-year period depending upon rainfall, with few or no females migrating to ponds during years with low rainfall (Semlitsch et al. 1996). Survival of adults in breeding ponds is generally high except during drought years, when females apparently avoid mortality by not attempting to breed (Church et al. 2007). Adults may return to the same pond to breed every year (Church et al. 2007) but will breed in other ponds when displaced (Madison and Ferrand 1998). Tiger salamanders exhibit the boom and bust fluctuations that are typical of pond breeders (Semlitsch 1983b). During a 4-year study, Semlitsch (1983b) reported that annual juvenile production of tiger salamanders varied from 1 per year to over 1,000.

Tiger salamander larvae are faster growing than other ambystomatid species and require a minimum of 10 weeks for metamorphosis (Lannoo and Phillips 2005). Growth rates depend upon water temperature, food supply, and population density. Due to their predacious nature, communities with and without tiger salamander larvae are very different with respect to the species of tadpole, insect, and zooplankton present, and relative abundances of different species in the community (Travis 1992, Petranka 1998). Larvae feed upon nematodes, insects, snails, clams, cladocerans, copepods, ostracods, fairy shrimp, crayfish, and amphibian eggs and larvae (Petranka 1998). At Blackwater River State Forest, larvae of the following species were present in some tiger salamander breeding ponds: southern toad (*Anaxyrus terrestris*), eastern spadefoot (*Scaphiopus holbrookii*), eastern narrow-mouthed toad (*Gastrophryne carolinensis*), southern cricket frog (*Acris gryllus*), squirrel treefrog (*Hyla squirella*), southern chorus frog, ornate chorus frog, green frog (*Lithobates clamitans*), southern leopard frog, and central newt (Showen 2007).

Figure 15. Tiger salamander pond (Seed Orchard Pond) in Blackwater River State Forest, Santa Rosa Co.

Striped Newt.—Striped newts breed in sinkhole ponds (lime sinks), depression or basin marshes, wet prairies, dome swamps, and borrow pits that are typically vegetated with emergent grasses, sedges, and forbs (Enge 2011). Maidencane is often the predominant vegetation throughout shallow wetlands and along the periphery of deeper wetlands, which often have floating-leaved plants in the middle. Sexually mature, terrestrial adults typically migrate to breeding ponds during rains in fall and winter (some newts may migrate in spring or summer), and courtship, copulation, and oviposition occur in the water (Johnson 2002b). A female may take several months to lay all her eggs, which are singly attached to aquatic vegetation or other objects (Johnson 2002b). When a larva is ca. 6 months old, it either changes into an eft or remains in the pond until it matures ca. 6 months later into a paedomorph (Johnson 2002b). At a breeding pond in northern Florida, larvae required a minimum hydroperiod of 139 days to metamorphose (Dodd 1993). In a pond in sandhill habitat at the Ordway-Swisher Biological Station, ca. 25% of larvae became paedomorphs, which bred only once before transforming into terrestrial adults (Johnson 2002b). In order for larvae to mature into paedomorphs, a pond must hold water for at least a year, and an additional 6 months would be needed for successful reproduction and metamorphosis of larvae produced by paedomorphs (Johnson 2005). Adults are sometimes found in extremely small wetlands that are probably unsuitable for reproduction (Kevin Enge, pers. obs.); they might enter these wetlands to hydrate or forage. Extended breeding periods allow striped newts to adapt to temporary breeding habitats whose conditions fluctuate within seasons (Johnson 2002b, U.S. Fish and Wildlife Service 2011). In scrub habitat that is presumably unsuitable for survival of efts and terrestrial adults, breeding ponds are typically permanent and continuously inhabited by paedomorphs and/or larvae (Fig. 16), or ponds are depressions situated in large wet prairie systems dominated by blue maidencane (*Amphicarpum muehlenbergianum*) that are typically dry and may provide suitable upland habitat (Fig. 17). Striped newts are found in prairie wetlands in scrub habitat in the Long Pond wetland complex and in Juniper Prairie Wilderness Area in Ocala National Forest. Aquatic adults opportunistically feed upon frog eggs, fairy shrimp, spiders, and larval and adult insects (Christman and Franz 1973, Dodd et al. 2005).

Figure 16. Permanent striped newt pond (Telford Pond) in scrub habitat in Ocala National Forest, Putnam Co.

Figure 17. Striped newt prairie wetland in scrub habitat in Juniper Prairie Wilderness Area, Ocala National Forest, Marion Co.

Gopher Frog.—Gopher frogs typically breed in temporary or semipermanent shallow ponds that lack predatory fish and have an open canopy and emergent vegetation, including depression marshes, basin marshes, wet prairies, dome swamps, upland sandhill lakes, sinkhole ponds, borrow pits, and ditches (Godley 1992; Enge 1997a; Jensen and Richter 2005; this study). Many breeding ponds used by gopher frogs are completely encircled by a dense stand of saw palmetto, which apparently is not a deterrent to gopher frog movements. The breeding season is usually September–April (Palis 1998, Branch and Hokit 2000, Blihovde 2006), but frogs potentially can breed during any month of the year following heavy rains. Summer breeding is probably more common in southern Florida because winter frontal systems are weaker there (Godley 1992, Jackson 2004). Steve Morrison (pers. comm.) has recorded calling in every month of the year except May and August along the southern end of the Lake Wales Ridge (Polk and Highlands counties), and calling has been reported during May and August elsewhere in southern Florida (Jackson 2004; Betsie Rothermel, pers. comm.). Relative calling intensities suggest that winter is the primary breeding season in south-central Florida (Branch and Hokit 2005; Steve Morrison, pers. comm.). The call of the gopher frog is a loud snore that may last up to 2 seconds.

A female gopher frog attaches only a single egg mass (Fig. 18) containing a mean of 1,200–2,200 eggs to vegetation (Jensen and Richter 2005). Tadpoles transform in 87–225 days (Phillips 1995, Semlitsch et al. 1995, Palis 1998) at a size of 28–37 mm SVL (Franz 1986, Palis 1998, Semlitsch et al. 1995) (Fig. 19). Cooler water temperatures may inhibit growth (Phillips 1995). Tadpoles are grazing herbivores that use dense emergent and submergent vegetation for cover (Jensen and Richter 2005). Snakes, turtles, fish, dragonfly naiads, and backswimmers prey upon tadpoles (Travis et al. 1985, Cronin and Travis 1986, Phillips 1995, Aresco and Reed 1998, Jensen and Richter 2005), and eastern newts and trichopteran larvae feed upon eggs (Bailey 1989). High annual variability in juvenile recruitment success and in body size of metamorphs probably result from a variety of factors, including rainfall, pond hydrology, and competition and predation within ponds (Greenberg 2001). Although adult pond use was low but relatively constant among years and did not differ between ponds in frequently burned versus hardwood-invaded sandhill habitat in Ocala National Forest, juvenile recruitment was significantly higher in ponds in frequently burned habitat (Greenberg 2001). In a laboratory experiment, gopher frog tadpoles hid from fish more often than did leopard frog tadpoles but still sustained higher predation rates by warmouth (*Lepomis gulosus*) and eastern mosquitofish (*Gambusia holbrooki*); the latter species injured tail fins instead of consuming tadpoles whole (Gregoire and Gunzburger 2008). Another study found that dusky gopher frog tadpoles did not respond to the presence of green sunfish (*Lepomis cyanellus*), whereas leopard frog tadpoles reduced their activity and hid (Thurgate 2006). In an experiment, all dusky gopher frog tadpoles were depredated by green sunfish within 3 weeks (Braid et al. 1994).

Figure 18. Gopher frog egg mass in Ocala National Forest, Marion Co., on 26 December 2013.

Figure 19. Metamorphosing gopher frog tadpole in Ross Prairie State Forest, Marion Co., on 7 June 2010.

Ornate Chorus Frog.—Ornate chorus frogs breed in seasonally inundated ponds that lack predatory fish (Eason and Fauth 2001). Breeding sites include dome swamps, basin swamps, depression marshes, sinkhole ponds, borrow pits, flooded fields, and roadside ditches (Harper 1937, Martof et al. 1980, Caldwell 1987, Enge 1997a, Jensen 2005). According to Snodgrass et al. (2000), breeding ponds up to 5 ha in size may be used, but we found larvae in wetlands up to 14 ha in size. Migration to breeding sites is weather dependent and begins as early as November, with males arriving before females, and there are often 2 distinct migration events (Caldwell 1987). In northern Florida, ornate chorus frogs normally breed from late November through March but have been heard calling as early as October 23 after a heavy rain (Carr 1940b). Breeding males suffer higher mortality rates than breeding females, partly because they spend more time in the pond (up to 18 weeks) and expend more energy. Males may use several breeding ponds during a season (Ashton and Ashton 1988), and a tracked male visited and bred in 2 ponds during the same night (Ray Ashton, pers. comm.). In a 16-year study of a pond in South Carolina, Semlitsch et al. (1996) found longer hydroperiods were associated with decreased recruitment, but a 4-month hydroperiod is needed to ensure complete metamorphosis of tadpoles. Ornate chorus frog tadpoles transform in 90–120 days (Dundee and Rossman 1989, Caldwell 1987). Metamorphs typically emerge from ponds from mid-April through mid-May at ca. 20 mm SUL, and synchronous emergence is presumably triggered by periods of rainfall (Caldwell 1987). If ponds fill early before the breeding season, ornate chorus frog tadpoles may be exposed to greater levels of competition and predation from ambystomatid and invertebrate larvae (Snodgrass et al. 2000). Frogs apparently will not breed in ponds that have not experienced a drydown that year (Caldwell 1987; William Barichivich, pers. comm.). Tadpoles usually inhabit water <20 cm deep with "linear" vegetation (grass-like) for cover but can be found in open water with a detrital substrate (Sekerak et al. 1996). During an 8-year study at a South Carolina wetland, about ⅔ of juveniles were produced during only 2 of those years, and the number of breeding females, not hydroperiod, was a significant predictor of the number of metamorphosing juveniles (Pechmann et al. 1989).

Male ornate chorus frogs typically call from the water's edge or on emergent vegetation <10 cm above the surface (Gerhardt 1973). Calls are a rapid succession of whistled single notes (*kik-kik-kik-kik*) up to 91 calls long (Gerhardt 1973) that from a distance sound like a hammer striking a steel chisel (Deckert 1915). Calling usually commences about sunset, but on unusually warm days or after rain, calling may occur during the day (Harper 1937). Gerhardt (1973) reported sporadic calling during the daytime at temperatures as high as 23ºC. Males call most frequently for several nights after rainfall and when temperatures are 3–18ºC (Gerhardt 1973), but they may call at temperatures as low as -2.8ºC (Harper 1937). Under the right conditions, calls can be heard up to 640 m away (Harper 1937). Frogs are known to vocalize underground, though the functional significance of subterranean calling is unknown (Brown and Means 1984). Gravid females may not deposit their eggs after arriving at a pond, but the stimulus stimulus for egg deposition is unknown (Caldwell 1987). Gravid females typically carry ca. 400 eggs (range 200−800) that are deposited in masses of 20−40 eggs (range 10−100) (Martof et al. 1980, Seyle and Trauth 1982). Egg masses are attached to submerged grass and sedge stems in shallow water exposed to full sunlight (Seyle and Trauth 1982). During typical summer drydowns, various annual grasses invade pond basins, and the presence of grassy calling sites for males may constitute a proximate cue indicating a relatively predator-free larval environment (Caldwell 1987).

METHODS

Compilation of Records

All records from various databases, museums, reports, scientific literature, other surveys, and this survey were entered into an Excel database totaling 1,596 records. Databases consulted included those of FNAI, FWC (Wildobs and dipnet or drift-fence surveys), and CPI. Prior to surveys conducted during this study, the Excel database contained 864 records of the 5 target species (records of the reticulated flatwoods salamander were added later). Many records were from roads, captures in traps, or observations of gopher frogs in tortoise burrows by biologists, environmental consultants, and the general public. Locations of breeding ponds associated with these incidental observations were usually unknown. The first and last year the species was observed at a location was recorded in the Excel database, along with the observer and/or source of the information. We also received reports of calling frogs from knowledgeable persons. Presumably extant breeding ponds were mapped for future surveys. Locations of breeding ponds found prior to the common use of GPS sometimes could not be accurately identified from the information provided, which was often distance from a city or the township, range, and section number. We attempted to delete historical records from the database that likely represented specimens from the same population.

Pond Selection for Surveys

The most recently available Google Earth satellite imagery was primarily used to identify potential breeding ponds for the gopher frog and striped newt. Palis (2014) also used Google Earth imagery to successfully identify potential crawfish frog (*Lithobates areolatus*) ponds in southern Illinois. Early in our study, a striped newt potential habitat GIS layer was used to identify suitable xeric habitats for the striped newt and gopher frog. Later in the study, we used ArcGIS and the Florida Cooperative Land Cover (CLC) version 2.3 layer to map the following suitable upland habitats: sandhill, scrub, scrubby flatwoods, and upland pine forest. Suitable wetlands lacking a tree canopy (depression marsh, basin marsh, wet prairie, sinkhole pond, sandhill upland lake) were easy to identify using Google Earth imagery, and the timeline feature was sometimes used to determine suitable hydroperiods and land-use changes. During drought periods, this timeline feature was particularly important in identifying ponds with longer hydroperiods that were most likely to contain water. Google Earth imagery was usually adequate at identifying dome swamps, particularly ones with relatively open canopies. However, the extent of grassy vegetation in dome swamps was difficult to determine, although wide grassy ecotones suitable for flatwoods salamander reproduction could occasionally be detected. The timeline feature was useful for detecting cypress-dominated dome swamps, because they appeared gray in winter when cypress trees are leafless. Potential breeding ponds for tiger salamanders in hardwood forests were sometimes undetectable using Google Earth, because the pond and surrounding upland canopies were indistinguishable.

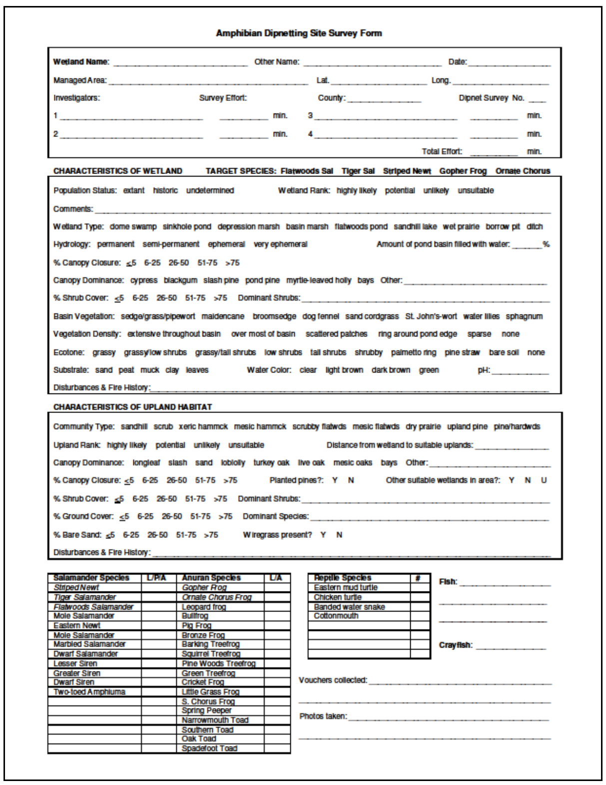
Using Google Earth, each conservation land to be surveyed had an individual folder in which ponds were named and coordinates were provided. Each pond name consisted of a unique acronym of the conservation land followed by a 3-digit number (e.g., JSF010 = pond 10 in Jennings State Forest). Ponds on private property were identified by the first 4 letters of the county followed by a 3-digit number (e.g., SUWA001 = pond on private property in Suwannee County). Printed color maps of aerial images with the ponds labeled with their names and coordinates were taken into the field; when needed, pond coordinates were entered into a GPS unit to help locate ponds. Whenever possible, we were accompanied on public lands by area staff, which helped with navigation and sometimes with identifying additional potentially suitable ponds for surveys. Because these are sensitive species, maps of ponds provided in this report do not provide sufficient detail to readily identify exact pond locations.

Dipnet Surveys

Amphibian reproduction is highly influenced by climatic conditions and varies among years and sites. Adults of these amphibian species typically migrate to breeding ponds during rains in October−December, but dipnet surveys intended to detect larvae are usually initiated at least a month after hatching to allow larvae time to grow, so they do not slip through the mesh of nets. Bishop et al. (2006) recommended that dipnet surveys for flatwoods salamander larvae be conducted in February−early April. Johnson (2002b) recommended that dipnet surveys for striped newts be conducted in April−June when all 3 aquatic life stages may be present, including larvae, which typically are easiest to detect because of their higher densities. Because the gopher frog is an explosive breeder that responds to large rainfall events, we tracked precipitation at Florida Forest Service weather stations to determine when gopher frog larvae might be present at a site, waiting at least 90 days after large rainfall events. We dipnetted most (87%) ponds in January–June, with 66% of dipnet surveys in January−April.

Because of the large number of potential breeding sites, most ponds could only be surveyed once by dipnetting. We typically visited a known breeding pond only once in a breeding season, even if the pond was dry during the first visit. Low-density populations of larvae (or adults, in the case of striped newts) may not have been detected during a site visit, particularly if the wetland and upland habitat conditions appeared unsuitable or sampling conditions were difficult (e.g., dense vegetation precluded effective dipnetting). We typically spent less time sampling a wetland under these conditions, particularly if only a single surveyor was present. In general, we tried to spend at least 30 person-minutes sampling a wetland during a visit, unless the wetland contained little water or habitat conditions were poor. We did not try to determine detection probability. A mean of 16 minutes of dipnetting is required to detect flatwoods salamander larvae in a pond (Bishop et al. 2006). We usually terminated dipnetting once the target species was detected (unless multiple target species were potentially present) or predatory fish species were found. The entire perimeter of a pond was typically dipnetted, unless the wetland was too large to accomplish this in the allotted time period. Suitable microhabitats for larvae (based upon water depth and type and density of vegetation) were targeted for intensive dipnetting.

During each pond visit, we recorded the following information: names of surveyors, the number of minutes each person spent dipnetting, the number and life stage (adult, paedomorph, larva) of specimens of target species captured, the life stage of other amphibian species detected, reptile and fish species found, presence of crayfish, and the percent of the pond basin filled with water (Fig. 20). We characterized the upland and wetland habitats at each site by collecting a variety of descriptive variables (Fig. 20). These data were entered into a Microsoft Access database, with 1 record for each pond that contained the habitat descriptors. A record was entered for each pond visit and linked to the pond description record by the wetland name. Identification guides were developed for salamander larvae (Fig. 21) and for fishes that are often found in isolated wetlands. Separate identification guides were developed for tadpoles typically found in isolated wetlands in winter (Fig. 22) versus in summer (Fig. 23). A guide for differentiating between gopher and leopard frog tadpoles was also created. These guides were supplied to field personnel and distributed via email to anyone interested in conducting dipnet surveys.



Amphibian Dipnetting Site Survey Form

Wetland Name: ______ Other Name: ______ Date: ______
Managed Area: ______ Lat. ______ Long. ______
Investigators: Survey Effort: County: ______ Dipnet Survey No. ___
1 ______ ______ min. 3 ______ ______ min.
2 ______ ______ min. 4 ______ ______ min.
Total Effort: ______ min.

CHARACTERISTICS OF WETLAND **TARGET SPECIES: Flatwoods Sal Tiger Sal Striped Newt Gopher Frog Ornate Chorus**

Population Status: extant historic undetermined Wetland Rank: highly likely potential unlikely unsuitable
Comments: ______
Wetland Type: dome swamp sinkhole pond depression marsh basin marsh flatwoods pond sandhill lake wet prairie borrow pit ditch
Hydrology: permanent semi-permanent ephemeral very ephemeral Amount of pond basin filled with water: ______%
% Canopy Closure: ≤5 6-25 26-50 51-75 >75
Canopy Dominance: cypress blackgum slash pine pond pine myrtle-leaved holly bays Other: ______
% Shrub Cover: ≤5 6-25 26-50 51-75 >75 Dominant Shrubs: ______
Basin Vegetation: sedge/grass/pipewort maidencane broomsedge dog fennel sand cordgrass St. John's-wort water lilies sphagnum
Vegetation Density: extensive throughout basin over most of basin scattered patches ring around pond edge sparse none
Ecotone: grassy grassy/low shrubs grassy/tall shrubs low shrubs tall shrubs shrubby palmetto ring pine straw bare soil none
Substrate: sand peat muck clay leaves Water Color: clear light brown dark brown green pH: ______
Disturbances & Fire History: ______

CHARACTERISTICS OF UPLAND HABITAT

Community Type: sandhill scrub xeric hammck mesic hammck scrubby flatwds mesic flatwds dry prairie upland pine pine/hardwds
Upland Rank: highly likely potential unlikely unsuitable Distance from wetland to suitable uplands: ______
Canopy Dominance: longleaf slash sand loblolly turkey oak live oak mesic oaks bays Other: ______
% Canopy Closure: ≤5 6-25 26-50 51-75 >75 Planted pines?: Y N Other suitable wetlands in area?: Y N U
% Shrub Cover: ≤5 6-25 26-50 51-75 >75 Dominant Shrubs: ______
% Ground Cover: ≤5 6-25 26-50 51-75 >75 Dominant Species: ______
% Bare Sand: ≤5 6-25 26-50 51-75 >75 Wiregrass present? Y N
Disturbances & Fire History: ______

Salamander Species	L/P/A	Anuran Species	L/A
Striped Newt		*Gopher Frog*	
Tiger Salamander		*Ornate Chorus Frog*	
Flatwoods Salamander		Leopard frog	
Mole Salamander		Bullfrog	
Eastern Newt		Pig Frog	
Mole Salamander		Bronze Frog	
Marbled Salamander		Barking Treefrog	
Dwarf Salamander		Squirrel Treefrog	
Lesser Siren		Pine Woods Treefrog	
Greater Siren		Green Treefrog	
Dwarf Siren		Cricket Frog	
Two-toed Amphiuma		Little Grass Frog	
		S. Chorus Frog	
		Spring Peeper	
		Narrowmouth Toad	
		Southern Toad	
		Oak Toad	
		Spadefoot Toad	

Reptile Species	#
Eastern mud turtle	
Chicken turtle	
Banded water snake	
Cottonmouth	

Fish: ______
______
______

Crayfish: ______

Vouchers collected: ______
______
Photos taken: ______
______

Figure 20. Data sheet for recording habitat and capture information from dipnet surveys.

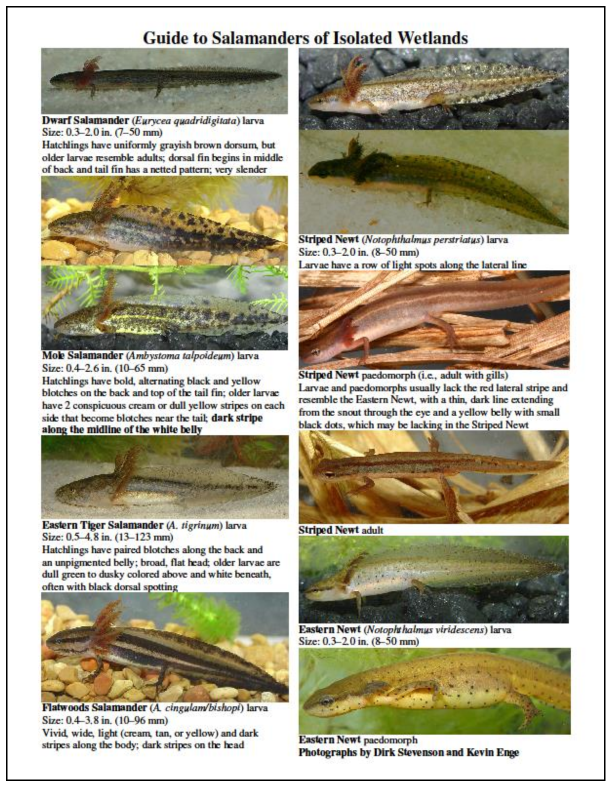


Figure 21. Identification guide to salamanders found in isolated wetlands.

Figure 22. Identification guide to tadpoles found in isolated wetlands in xeric uplands in winter.

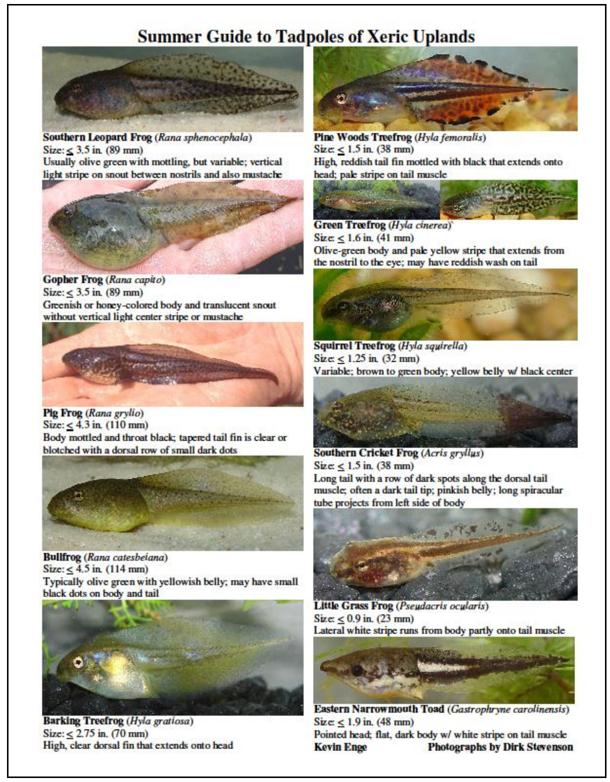


Figure 23. Identification guide to tadpoles found in Isolated wetlands in xeric uplands in summer.

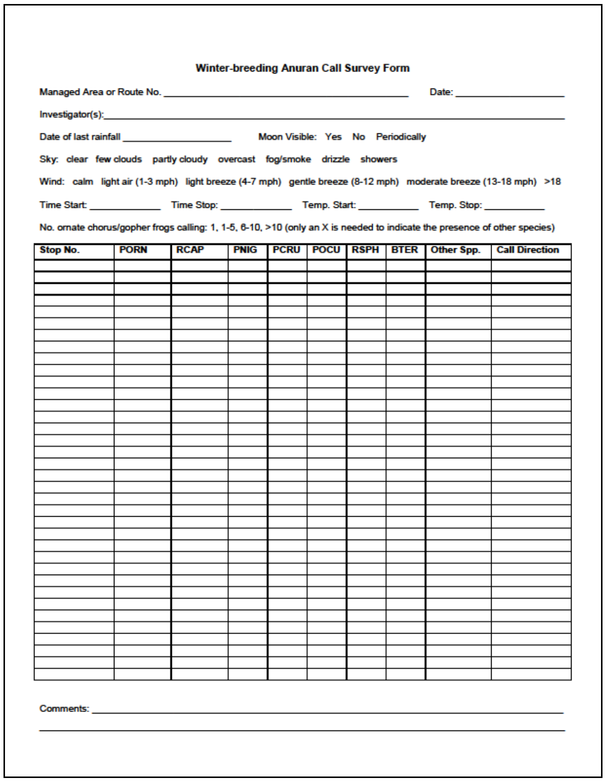
Call Surveys

Gopher frogs heard calling in ponds accounted for most records of ponds in preexisting databases, and Franz and Smith (1999) used call surveys to document ponds because they were unsuccessful at identifying tadpoles. In order to detect gopher frogs and ornate chorus frogs on public and private lands in the northern peninsula, Kevin Enge or Paul Moler drove 11 survey routes at night in January−March 2010, 6 routes in January–February 2011, 2 routes in December 2012, and 3 routes in January 2013 in Alachua, Baker, Clay, Duval, Levy, Marion, Nassau, Putnam, Taylor, and Union counties to listen for calling frogs. These routes totaled 582 km. A route had an average of 33 pre-selected stops (range 16−89) near wetlands along the road. At each stop, the observer turned off the vehicle's engine and listened for at least 1 minute, recording all species heard calling (Fig. 24). If ornate chorus or gopher frogs were heard calling, an estimate was made of the number of animals (1, 2–5, 6–10, and >10) and direction (Fig. 24). An additional 95-km route was driven on 12 December 2012 in Alachua, Bradford, Union, and Baker counties at ca. 50 km per hour with the windows open listening for calling ornate chorus frogs. While driving to and from routes, observers often drove with the windows open listening for calling frogs.

In the winters of 2013 and 2014, we collaborated with staff of the U.S. Geological Survey's (USGS) Southeast Amphibian Research Monitoring Initiative and deployed automated recording units (ARUs or frogloggers) at ponds on public lands to detect calling ornate chorus frogs (Fig. 25). We used Wildlife Acoustics Song Meter SM2 and SM2+ units to digitally record calls, and Song Scope™ Bioacoustics Monitoring Software (Ver. 4 Wildlife Acoustics Inc., Concord, Massachusetts, USA) was later used to identify the calls. In December 2012, we deployed 30 ARUS on 10 public lands in the northern peninsula: Camp Blanding Military Reservation; Guana River WMA; Jennings State Forest; Longleaf Flatwoods Reserve; Newnans Lake Conservation Area; Osceola National Forest; Raiford WMA; and the Jena, Spring Creek, and Tide Swamp units of Big Bend WMA. In December 2013, we deployed 33 ARUS on 11 conservation lands in the peninsula: Balu Forest, Caravelle Ranch WMA, Cary State Forest, Etoniah Creek State Forest, Goethe State Forest, Lafayette Forest Mitigation Park Wildlife and Environmental Area (WEA), Osceola National Forest, Phifer Flatwoods, Pumpkin Hill Creek Preserve State Park, Raiford WMA, and the Spring Creek Unit of Big Bend WMA. We also deployed 30 ARUs on 10 public lands in the panhandle: Aucilla WMA, Apalachicola River WEA, Box-R WMA, Eglin AFB, Flint Rock WMA, Garcon Point Water Management Area, Joe Budd WMA, Nokuse Plantation (privately owned), Tarkiln Bayou Preserve State Park, and Tate's Hell State Forest. We tried to select grassy ephemeral wetlands primarily in mesic flatwoods habitat, because we suspected populations would have more likely persisted in more mesic habitats than in sandhill habitat during droughts in the peninsula. In the peninsula, we selected lands that we deemed most likely to support populations or that had historical records. In the panhandle, where ornate chorus frogs are still widely distributed, we selected smaller conservation lands, lands with degraded upland habitat (former commercial forest land being restored), or lands without recent records of ornate chorus frogs instead of large lands with robust populations in well-managed habitats, such as Apalachicola National Forest, Blackwater River State Forest, Pine Log State Forest, Point Washington State Forest, and St. Marks NWR. The ARUs were attached to trees in or near wetland basins and programmed to record the first 5 minutes of every hour between 1800 and 0600 hr. The ARUs were in place between January and April, and USGS staff later analyzed the digital recordings for ornate chorus frogs using digital recognizers (files created from local recordings of a species) that allow the Song Scope software to scan through recordings and recognize the call signature of a particular species. All recording intervals identified by the software were verified by experts listening to the original recordings. Any gopher frogs heard calling during this verification process were noted as incidental observations.

Road Surveys

Road surveys on rainy nights can be successful at detecting winter-breeding amphibian species, particularly relatively large species migrating to breeding ponds. The direction of movement can sometimes be used to identify likely breeding ponds, but that is complicated if several potential ponds are in close proximity. Some road surveys were conducted on rainy nights in November and December 2014 in Alachua, Marion, Levy, and Citrus counties to detect migrating tiger salamanders. Road surveys have been successful at detecting flatwoods salamanders (Means et al. 1996), and the only records from Aucilla WMA, Jefferson County, came from 2 adults found crossing a paved highway (Means 1998). Gopher frogs can also be found on roads at night, but the small size of striped newts make them difficult to detect, although an eft was found on a road in Wakulla County in 1976 (Franz and Smith 1999). Ornate chorus frogs are occasionally seen on roads during mass migrations to nearby breeding ponds.



Winter-breeding Anuran Call Survey Form

Managed Area or Route No. ______________________ Date: ____________

Investigator(s):______________________________

Date of last rainfall ____________ Moon Visible: Yes No Periodically

Sky: clear few clouds partly cloudy overcast fog/smoke drizzle showers

Wind: calm light air (1-3 mph) light breeze (4-7 mph) gentle breeze (8-12 mph) moderate breeze (13-18 mph) >18

Time Start: ________ Time Stop: ________ Temp. Start: ________ Temp. Stop: ________

No. ornate chorus/gopher frogs calling: 1, 1-5, 6-10, >10 (only an X is needed to indicate the presence of other species)

Stop No.	PORN	RCAP	PNIG	PCRU	POCU	RSPH	BTER	Other Spp.	Call Direction

Comments: ______________________________

Figure 24. Data sheet for recording anuran calls while driving road routes to detect ornate chorus frogs.

Figure 25. Installing an automated recording unit (froglogger) for ornate chorus frogs.

Pond Delineation and Characterization

ArcGIS was used to digitize pond margins and calculate size of breeding ponds used by the gopher frog, striped newt, tiger salamander, and ornate chorus frog. In general, a pond was delineated at its upland habitat boundary, as determined by visual interpretation of aerial photographs and its CLC classification. However, deeper depressions imbedded in wet prairie, wet flatwoods, or other wetland types that do not provide suitable breeding habitat for the target species were delineated as distinct breeding ponds, even though the surrounding habitat is technically another wetland type. In contrast, deeper holes in basin marshes or sandhill lakes were usually not considered separate ponds, because these wetlands would provide suitable breeding habitat even when totally inundated. However, ponds in a wetland complex were delineated separately if they were separated by higher elevation areas that precluded connection except during extreme high-water events, even though intervening habitats were technically wetlands. Ponds were also delineated separately if they were only connected by narrow, grassy “channels” that seldom flooded. For example, striped newts have been found in 4 “ponds” (slightly deeper basins) that were delineated as separate ponds within the Watermelon Pond complex in Alachua and Levy counties, much of which rarely floods. Wetlands that are separated by roads or levees and apparently lack culverts were considered separate ponds.

For all 6 amphibian species, we calculated the percentage of various landcover classes (CLC 3.0) within 300 m of a point in each pond basin. We selected 300 m (an area of ca. 28 ha) because Semlitsch and Bodie (2003) found that the core upland habitat used by 32 amphibian species generally extended 159 to 290 m from the wetland edge. Landcover types were grouped into 8 broad landcover classes: sandhill, scrub, upland pine forest, flatwoods, mixed or hardwood (i.e., mixed pine-hardwood or hardwood forests), pine plantation, disturbed habitats, and wetlands. Scrubby flatwoods was not identified by GIS as land cover for any species, although field observers identified scrubby flatwoods around several gopher frog and striped newt ponds. These variables were used to describe ponds used by the different species and to examine differences between ponds in the panhandle and peninsula. In addition, we compared land cover between records for extant versus presumably extinct populations, again using 300-m buffers around the points, including incidental and road observations (pond locations of many extinct and some extant populations are unknown). We also used historical aerial photographs to describe land-use changes around ponds that no longer support populations of the striped newt or gopher frog.

Development of Potential Habitat Maps

Cox and Kautz (2000) developed rules-based GIS models of potential habitat for the gopher frog, striped newt, flatwoods salamander, and tiger salamander, and they determined whether existing and proposed conservation lands provided future security for survival of the species. Endries et al. (2009) also developed potential habitat models for the striped newt (Fig. 26) and flatwoods salamanders (Fig. 27). Because relatively few new locality records have been found for flatwoods salamanders since the Endries et al. (2009) map, we decided a new potential map was unnecessary. Potential habitat models for flatwoods salamanders have limited utility because mesic flatwoods is the most common habitat in northern Florida, and the critical graminaceous wetland ecotone cannot be detected using available GIS layers. For the gopher frog, we developed a rules-based model, with assistance from Brian Beneke, based upon our knowledge of its habitat requirements and natural history. Computer-generated potential habitat models (Maxent or Resource Selection Function), where computers determined what variables were important for species presence/absence, were developed by staff from FWC's Fish and Wildlife Research Institute's Center for Spatial Analysis based upon locations of presumably extant populations of the striped newt (Mark Barrett), tiger salamander (Jennifer Bock), gopher frog (James Beerens), and ornate chorus frog (Jennifer Bock). Populations were usually considered presumably extant if records existed since around 1995, and if aerial imagery indicated that suitable-looking upland and wetland habitats were present.

The rules-based GIS model for gopher frog potential habitat considered suitable breeding sites to be the following CLC 2.3 wetland types $\leq$20 ha in size: freshwater marsh, coastal interdunal swale, isolated freshwater swamp, artificial/farm pond, and dome swamp. Other suitable breeding sites were the following wetland types $\leq$40 ha in size: sandhill lake, flatwoods/prairie marsh lake, isolated freshwater marsh, depression marsh, and basin marsh. All upland habitats within 2 or 5 km (these 2 different models used distances that represent maximum movements from ponds recorded for the species in Florida and North Carolina, respectively) of suitable breeding sites were mapped as potential habitat if they intersected the 2011 gopher tortoise habitat map, after excluding habitats not used by gopher frogs: pine rockland, rockland hammock, beach dune, coastal berm, shell mound, and sand beach. The final map classified remaining habitats into either primary or secondary habitat. Primary habitats were scrub, oak scrub, sand pine scrub, sandhill, and scrubby flatwoods. Secondary habitats were coastal scrub, upland pine, mesic flatwoods, dry prairie, coastal grassland, coastal strand, and maritime hammock. Other secondary habitats were used as a mask in the 2011 gopher tortoise model (i.e., restricted to xeric soils): upland mixed woodland, upland coniferous, mixed hardwood-coniferous, shrub and brushland, rural open, reclaimed lands, bare soil/clear cut, rural open forested, rural open pine, parks, improved pasture, unimproved/ woodland pasture, and coniferous plantations.

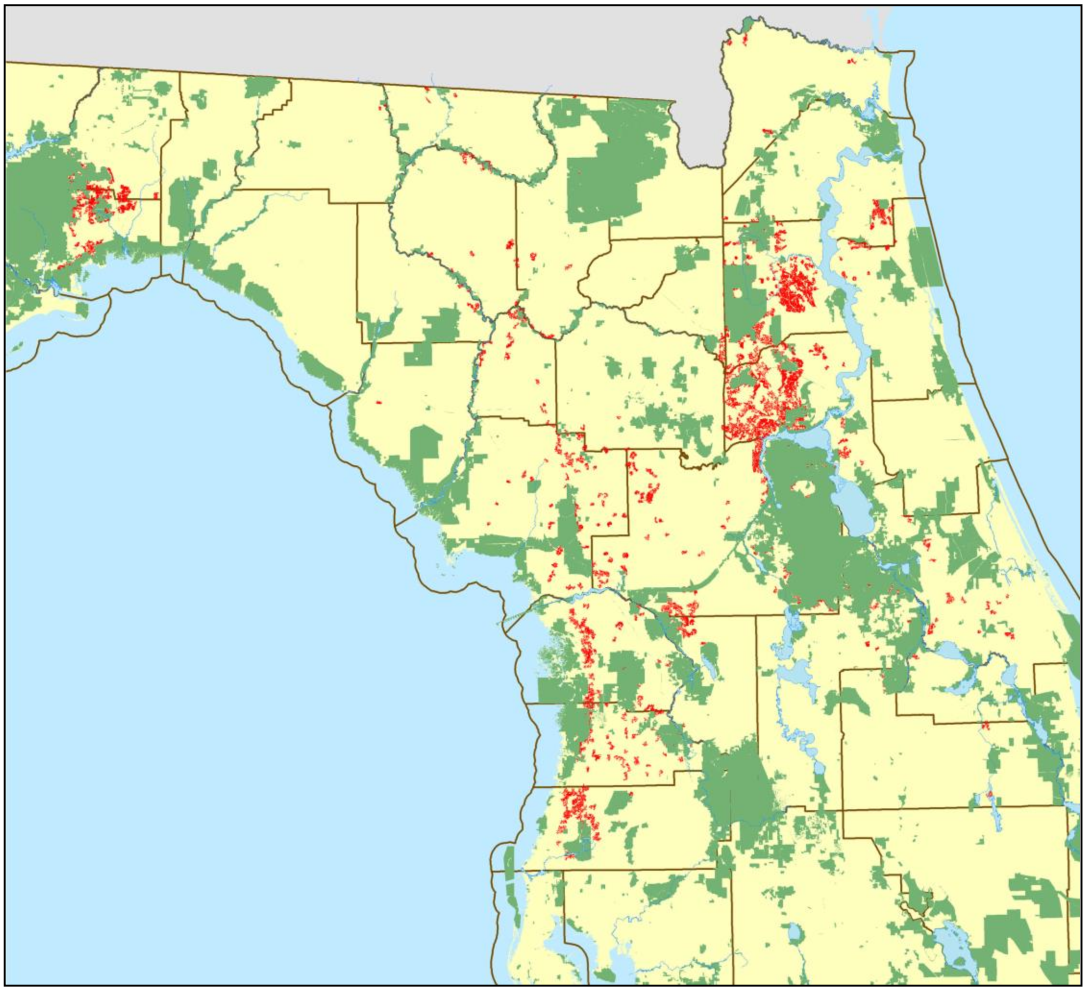


Figure 26. Potential habitat map for the striped newt developed by Endries et al. (2009), with red indicating potential habitat and green areas representing Strategic Habitat Conservation Areas.

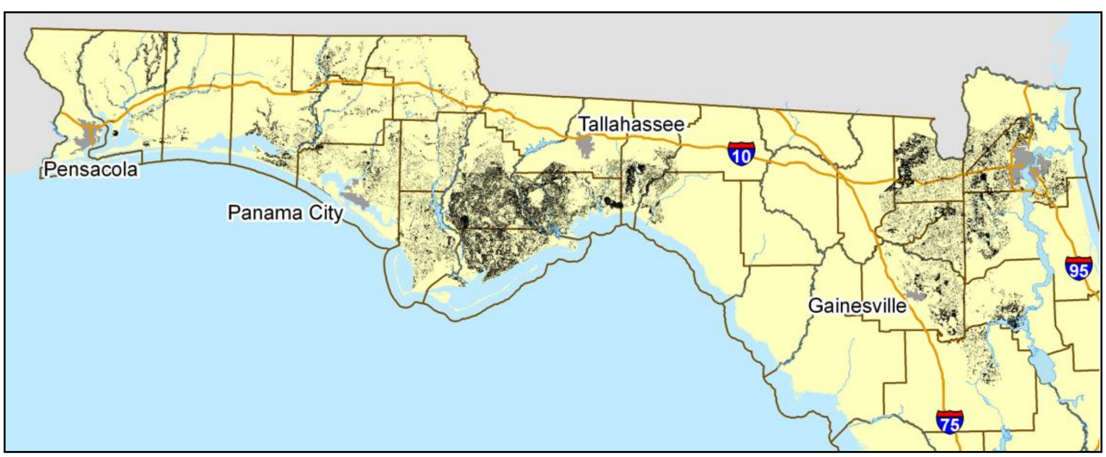


Figure 27. Potential habitat map for flatwoods salamanders developed by Endries et al. (2009), with black indicating potential habitat.

Computer-generated potential habitat models were created for most species using the maximum entropy algorithm (Maxent), which estimates the likelihood of potential habitat based on environmental constraints (Phillips et al. 2006). Maxent requires only species presence data (not absence) and environmental variable (continuous or categorical) layers, and it may be effective despite small sample sizes (Wisz et al. 2008). A fixed threshold (10 percentile) was applied to create a binary output of potential habitat that rejected only the lowest 10% of possible predicted values at presence locations (Pearson et al. 2007). On potential habitat maps, areas above the threshold are indicated in green, with higher likelihood areas indicated sequentially from yellow to red. Maxent was run using default parameters and a 10-fold cross validation, which breaks up occurrence locations into 10 subgroups and runs the model 10 times, creating an averaged (and standard deviation) output from the 10 model runs.

Maxent was used to estimate potential habitat for the striped newt using 89 points representing known occurrences from 1998 through 2014 and the following variables at 30-m resolution: CLC 2.3 (generalized to 20 classes), distance to sandhill, distance to scrub or scrubby flatwoods, distance to xeric soils, elevation (digital elevation model), canopy cover, and land form (Topographical Position Index). The Maxent model for tiger salamander used 55 points of known occupancy from 2000 through 2014 and the following variables at 15-m resolution: CLC 2.3, Soil Survey Geographic (SSURGO 2012) layer (hydric or not hydric and percent clay), and distance to 2-ha, 4-ha, or any size wetland taken from the National Wetlands Inventory (NWI 2013), National Hydrography Dataset (NHD 2013), and CLC 2.3 coverages. Another variable was derived from the climate mapping system Parameter-elevation Regressions on Independent Slopes Model (PRISM) using average precipitation and minimum, maximum, and mean temperature in November–April. The Maxent model for the ornate chorus frog used 248 occupancy points from 2000 through 2014 and the following variables at 15-m resolution: CLC 3.0; SSURGO 2012 drainage class, hydrological rating and hydrological group; percent sand; slope; and distance to wetlands of 1, 5, 10, and 14 ha, as well as dissolved wetlands (i.e., all categories of wetland considered as 1 polygon) of 1, 5, 10, and 14 ha.

To develop the computer-generated potential habitat map for the gopher frog, habitat selection was estimated using the Resource Selection Function (RSF; Manly et al. 2002) with occurrence data from 1996 through 2014 to calculate habitat use versus availability. A total of 3,400 random locations was generated within the range of the species and compared to 338 occupancy locations using logistic regression. The data layers used were CLC 2.3 classes, distance to freshwater marshes <20 ha in size, distance to xeric soils, land form (e.g., canyons and valleys), and percent forest canopy cover. A non-habitat mask was applied to exclude NHD 2013 water bodies >20 ha in size, including a 200-m buffer around lakes, ponds, and reservoirs and along NHD major flow ways (e.g., streams, rivers, and canals).

Identification of Number of Gopher Frog and Striped Newt Metapopulations

Many pond-breeding amphibian species are thought to form metapopulations (i.e., neighboring local populations close enough to one another that dispersing individuals could be exchanged [gene flow] at least once per generation) in the vicinity of relatively few breeding ponds because of their limited dispersal abilities, strong site fidelity, and spatially disjunct breeding habitat (Smith and Green 2005). Four conditions are necessary to demonstrate the existence of a metapopulation: 1) habitat patches support local breeding populations, 2) no single population is large enough to ensure long-term survival, 3) patches are not too isolated to prevent recolonization, and 4) local dynamics are sufficiently asynchronous to make simultaneous extinction of all local populations unlikely (Hanski 1999). However, Smith and Green (2005) questioned whether the dispersal abilities of some pond-breeding amphibian species are sufficiently limited to meet the metapopulation definition. They conducted a literature review of the maximum movement distance of 90 amphibian species and found that 5% were capable of movements >10 km, with 44% of anuran species moving >1 km and 7% moving >10 km (Smith and Green 2005). Thus, populations that are isolated by distances approaching 10 km are perhaps more likely to form metapopulations than less isolated populations (Smith and Green 2005). In sandhill habitat in peninsular Florida, 83% of 12 amphibian species were captured 600 m from the nearest wetland, and only 28% were captured <400 m from the wetland (Dodd 1996). Because of their larger body sizes, the tiger salamander, flatwoods salamander, and gopher frog probably have greater dispersal potential than the striped newt, which has been found >700 m from the nearest pond (Dodd and Cade 1998). The flatwoods salamander can disperse 1 km from a breeding pond, and the gopher frog can disperse at least 4.5 km (Humphries and Sisson 2012). Ornate chorus frogs have been trapped in sandhill habitat >400 m from the nearest wetland (Kevin Enge, pers. obs.).

All records of gopher frogs and striped newts that were thought to represent extant sites were assigned to metapopulations. Although we do not know maximum dispersal distances, we decided to define metapopulations using a dispersal distance of 1 km for striped newts and 5 km for gopher frogs. Incidental observations not associated with an identified breeding pond were included when counting metapopulations. All records since 1990 were included unless aerial imagery showed that suitable upland or breeding habitat no longer existed in the area or extensive surveys of the breeding pond(s) indicated the metapopulation was probably extinct. Breeding ponds were included in the same metapopulation if potentially suitable upland habitat was present between ponds and no major barrier to movements was present (e.g., high-traffic divided highway, large stream, railroad track for newts). Breeding ponds separated by a greater distance were included in the same metapopulation if intervening potential breeding ponds were present.

Climate Data Analyses

To look for differences in long-term climate patterns among different regions of the state, we examined the divisional climate indices data from the NOAA National Climate Data Center. These data consist of quality-controlled daily weather station data (precipitation; average, minimum, and maximum temperature) that have been corrected for any bias in the time of data collection and averaged into monthly values for each climate division, as well as 5 drought indices that are calculated monthly for each climate division using climate and hydrological data: Palmer Drought Severity Index (PDSI), Palmer Hydrological Drought Index (PHDI), Palmer "Z" Index (ZNDX), Modified Palmer Drought Severity Index (PMDI), and a Standardized Precipitation Index (SPI) calculated over different time scales. These different drought indices measure different aspects of drought at different time scales. The climate data are divided into 7 climate divisions in Florida based on climate similarity: Northwest (panhandle west of the Aucilla River), North, North Central, South Central, Everglades and Southwest Coast, Lower East Coast, and Florida Keys (Fig. 22). To examine long-term climate trends, the monthly climate indices were averaged for each year over the period of record (1895–2014) for each Florida division and fitted with a linear regression trendline across years. For climate indices with a significant change across years, we performed linear regression analyses across years for each month to determine if the trend in the annual data reflected changes during specific months over time. P-values for multiple tests were adjusted using a sequential Bonferroni correction (Holm 1979, Rice 1989). To determine if recent droughts were longer than historical droughts, we compared the mean number of dry years (years with a negative drought index) per drought period (sequence of years with a negative drought index) for the period 1980–2014 to the mean from 1895–1979 with a Mann-Whitney rank sum test. To determine if the number of wet years between droughts had gotten shorter during recent droughts, we used a Mann-Whitney rank sum test to compare the mean number of wet years between each drought period before 1980 and in 1980–2014. We used Mann Whitney rank sum tests because our data failed to meet the assumptions of normality or equal variances required for a t-test.

To look for northward range shifts in amphibian distributions over time consistent with a climate-change hypothesis, we calculated the minimum, maximum, and mean latitude and longitude for each species for all records before 1980 and all records from 1980 through 2014. Anecdotal evidence suggests that amphibian declines and extirpations have occurred since the 1980s. Mean values for each time period were compared for each species using a t-test. All analyses were performed in SAS version 9.3 (Cary, NC.)

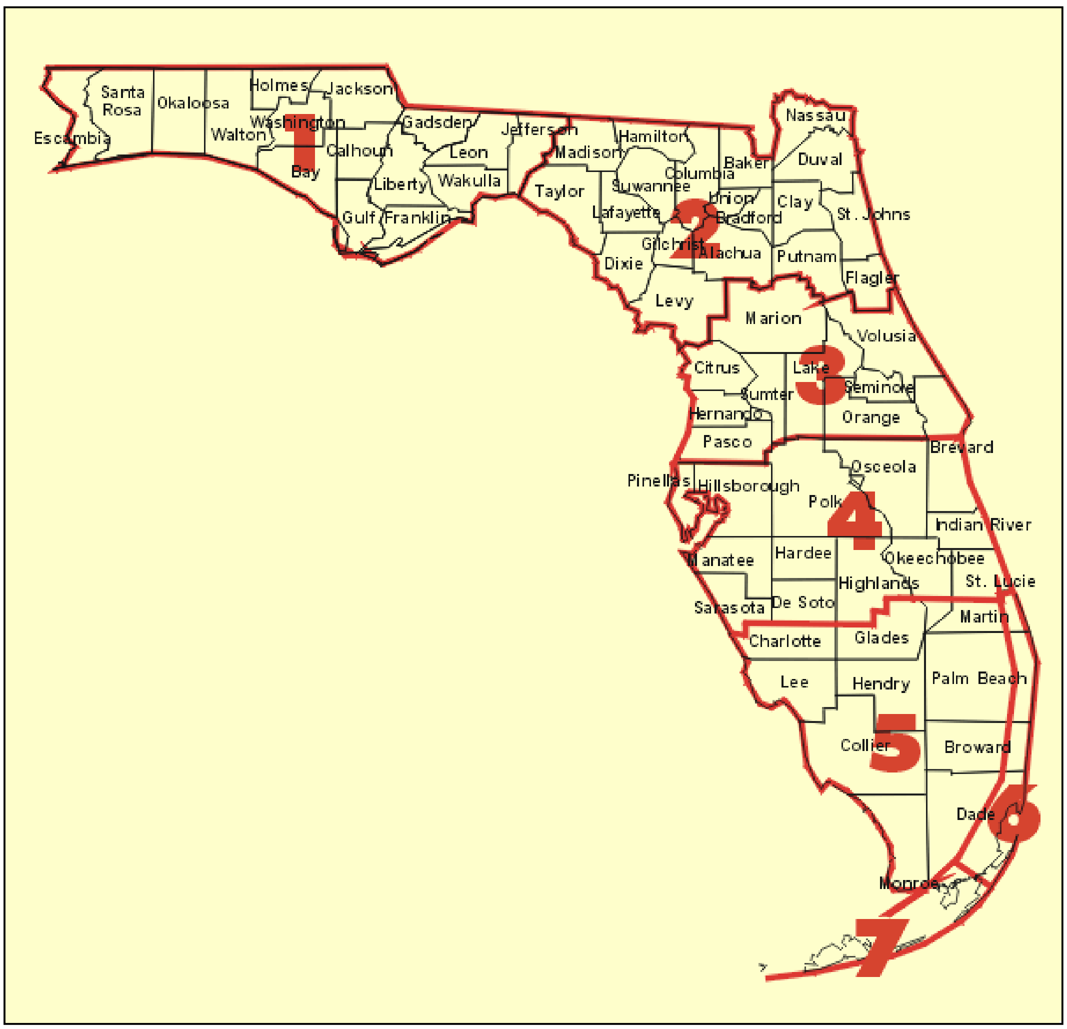


Figure 28. Map showing NOAA climate divisions in Florida: 1 = Northwest, 2 = North, 3 = North Central, 4 = South Central, 5 = Everglades/SW Coast, 6 = Lower East Coast, and 7 = Florida Keys.

RESULTS

Dipnet Surveys

During this project, we spent most of our effort dipnetting potential ponds for the gopher frog, followed by the striped newt, frosted flatwoods salamander, ornate chorus frog, tiger salamander, and reticulated flatwoods salamander. We dipnetted 419 ponds on 39 conservation lands in 2010, 157 ponds on 19 conservation lands in 2011, 150 ponds on 31 conservation lands in 2012, 157 ponds on 44 conservation lands in 2013, and 586 ponds on 60 conservation lands in 2014. In 2010‒2014, we visited 1,188 unique ponds on 121 conservation lands, but 45 ponds were dry and not dipnetted (Appendix 1). We also dipnetted 36 ponds on private lands in Alachua, Calhoun, Gilchrist, Hardee, Hernando, Highlands, Jackson, Manatee, Marion, Pasco, Suwannee, and Taylor counties. These totals include surveying some ponds multiple times. In 2010‒2013, dipnet surveys primarily targeted gopher frogs and striped newts in the peninsula. Surveys were primarily confined to the northern peninsula in 2010 and 2011 but were expanded into the southern peninsula in 2012 because many ephemeral wetlands dried in the northern peninsula. Heavy rains in October 2011 in parts of southern Florida stimulated gopher frog reproduction. In 2013, drought conditions remained in much of the northern peninsula, and gopher frog surveys were expanded into the panhandle. Heavy rainfall in fall 2013 and winter 2014 in the panhandle and parts of the northern peninsula produced good survey conditions, and many known breeding ponds of striped newts and gopher frogs were surveyed in the northern peninsula in 2014. Most known ponds of the frosted flatwoods salamander were surveyed in 2014 in Apalachicola National Forest and St. Marks NWR as part of a multi-agency effort to determine the species' status. We dipnetted the 3 known breeding ponds of the frosted flatwoods salamander in Osceola National Forest in 2010, 2011, 2013, and 2014, but lack of fire contributed to degraded habitat conditions, and low water levels sometimes precluded effective dipnetting. We also visited at night in 2012 and 2014 the last pond where flatwoods salamanders were found in Osceola National Forest, but again we were unsuccessful. We surveyed ponds in the Hatchet Creek Tract of Newnans Lake Conservation Area twice, but habitat conditions were poor. At this site, UF zoology classes collected numerous adult and metamorph flatwoods salamanders under fallen logs in the 1950s and deposited them in museum collections. We surveyed 11 ponds on Nokuske Plantation and Garcon Point Water Management Area in 2014 for the reticulated flatwoods salamander.

Gopher Frog.—Dipnet surveys were most successful at finding gopher frog tadpoles, although some new ponds were found by call surveys (driving routes and ARUs). In 2010–2014, we found gopher frog tadpoles in 30.2% of 666 unique ponds ranked by surveyors as potential or highly likely for the species and in 3.1% of 192 ponds ranked as unlikely or unsuitable. We detected tadpoles in 63 ponds in 2010, 17 ponds in 2011, 37 ponds in 2012, 36 ponds in 2013, and 71 ponds in 2014. Twenty-seven of these 223 ponds were surveyed more than once in 2010–2014. Of the 202 unique ponds with gopher frog tadpoles, 147 were previously unknown breeding sites on 51 conservation lands and on private lands in Calhoun, Gilchrist, Highlands, Marion, and Pasco counties (Appendix 1). The most productive conservation land was Ocala National Forest, where we found gopher frog tadpoles in 17 known and 18 new ponds (Fig. 29, Appendix 1). Dipnet surveys detected gopher frogs for the first time on the following conservation lands: Annutteliga Hammock (2 ponds), Buck Lake Conservation Area (2 ponds), Bull Creek WMA (1 pond), Cary State Forest (2 ponds), Conner Preserve (1 pond), Halpata Tastanaki Preserve (8 ponds), Hesperides (2 ponds) and Walk-in-the-Water (5 ponds) tracts of Lake Wales Ridge State Forest (2 ponds), Lake Kissimmee State Park (1 pond), Little Big Econ State Forest (1 pond), and

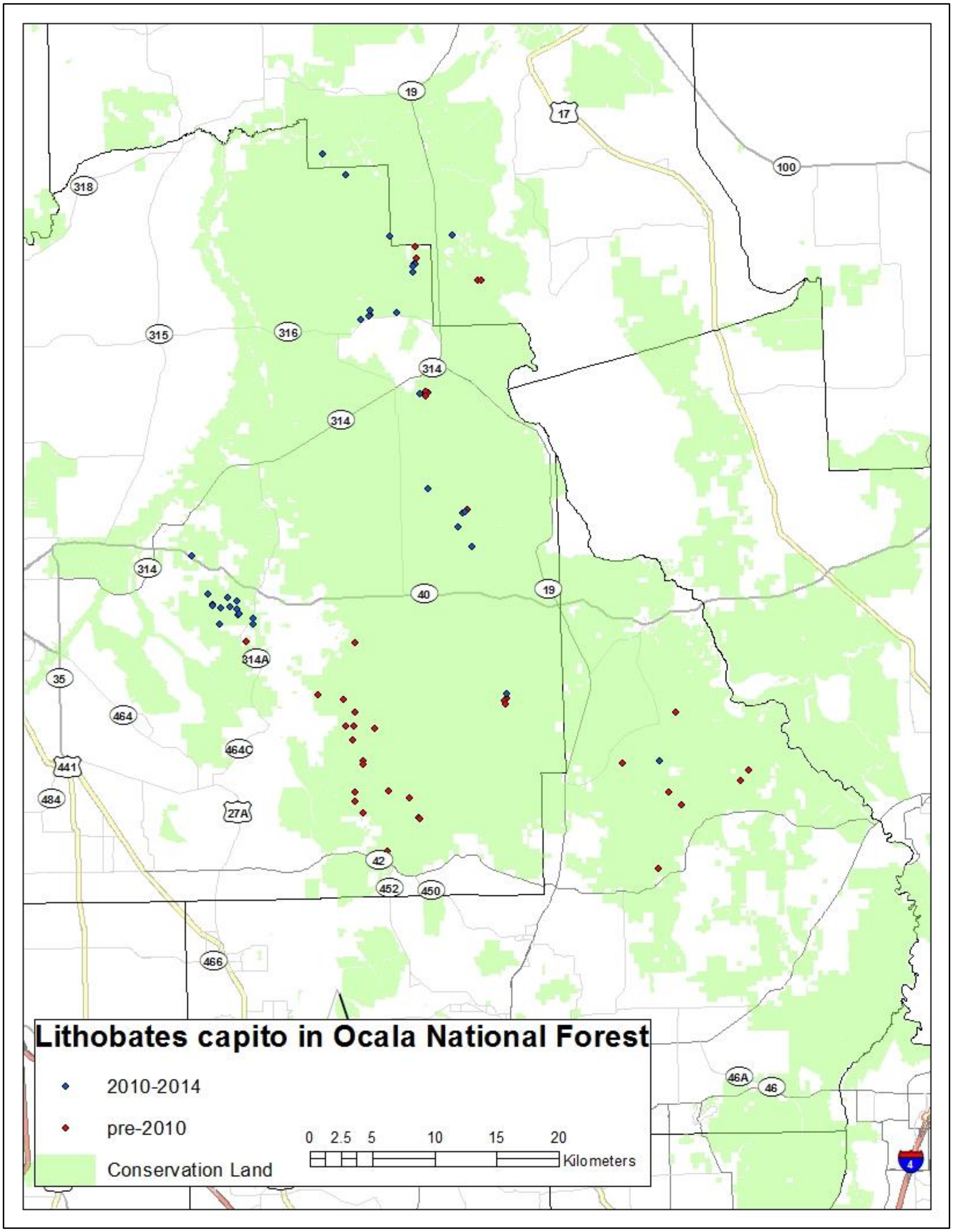


Figure 29. Gopher frog ponds in Ocala National Forest, Lake, Marion and Putnam counties.

Mosaic Fertilizer's Wellfield (1 pond) (Appendix 1). In addition, we found the first breeding ponds on conservation lands where gopher frogs had been previously documented using other methods: Arbuckle Tract of Lake Wales Ridge State Forest (1 pond), Disney Wilderness Preserve (2 ponds), Half Moon WMA (2 ponds), Lake Panasoffkee WMA (2 ponds), Ross Prairie State Forest (2 ponds), St. Sebastian River Preserve State Park (9 ponds), Triple N Ranch WMA (1 pond), and the Carter Creek (1 pond), Lake Placid Scrub (1 pond), and Sun n Lakes Sebring (1 pond) units of Lake Wales Ridge WEA (Appendix 1). Three ponds discovered in the Liberty County portion of Apalachicola National Forest represented a new county record (Fig. 30, 31). One new gopher frog pond each was discovered on private lands in Calhoun County (Fig. 32), Gilchrist County (adjacent to Fort White Mitigation Park WEA), and Highlands County (near Highlands Hammock State Park). A metamorphosing tadpole found in a pond on private land in Suwannee County (Fig. 33) represented the first voucher specimen (photograph) for the county, although gopher frogs were heard calling there in the 1970s (Paul Moler, pers. comm.).

Figure 30. Bonnet Pond (dry) when first visited in April 2012, Apalachicola National Forest, Liberty Co.

Figure 31. Bonnet Pond in April 2013 when gopher frog tadpoles were first found in Liberty Co.

Figure 32. Gopher frog pond discovered on private property in Calhoun Co.

Figure 33. Gopher frog pond on private property in Suwannee Co.

Using all methods, we documented gopher frogs from 237 ponds in 30 counties, including 2 new counties (Flagler and Liberty). Most ponds were in the peninsula, particularly Marion, Clay, Lake, Hernando, and Polk counties. Populations are widely distributed throughout much of the peninsula, particularly on the Trail, Brooksville, and Lake Wales ridges. On these ridges, populations occur on both public and private properties, but because of development, populations along the Atlantic Coast are primarily restricted to public lands, particularly in southeastern Florida. The gopher frog apparently no longer occurs at the southern extent of its range because of urbanization in Palm Beach, Broward, and Collier counties. Ocala and Apalachicola national forests represent strongholds for the species, with 76 known breeding ponds in the former (Fig. 29) and 38 known ponds in the latter (Fig. 34). Prior to this survey, the species was known only from the Leon County portion of Apalachicola National Forest (Munson Sandhills), but we also discovered it in the Liberty County portion near Camel Lake. Other public lands such as Eglin AFB (Fig. 35) and Withlacoochee State Forest contain extensive sandhill habitat but relatively few breeding ponds. Populations in the panhandle may not be faring as well as in many parts of the peninsula.

Striped Newt.—Dipnet surveys were less successful at finding striped newts. We surveyed but failed to document striped newts in 62 known ponds, including 18 in Apalachicola National Forest (Fig. 36), 12 in Ocala National Forest, 9 in Ordway-Swisher Biological Station, 8 in Camp Blanding Military Reservation (Fig. 37), and 5 in Jennings State Forest (Fig. 38). Precipitation in 2010 refilled many of the ponds in the Munson Sandhills of Apalachicola National Forest, and gopher frog, ornate chorus frog, and mole salamander (*Ambystoma talpoideum*) larvae were present in many ponds but apparently no striped newts. Heavy rainfall in 2013 and 2014 in the Munson Sandhills resulted in extremely high pond water levels in 2014, but separate surveys of historical striped newt breeding ponds by us and CPI staff failed to detect striped newts. We did not survey the 3 historical ponds where a striped newt repatriation project is underway.

During this study, we found striped newts in 22 historical and 24 new ponds in 8 counties, but survey conditions were poor in most areas. Multiple breeding ponds are still present in Camp Blanding Military Reservation, Jennings State Forest, and Ordway-Swisher Biological Station, although pond occupancy varies among years, and some ponds are rarely used. Pond-water levels in Clay County were good for dipnet surveys in 2014, and we found striped newts in 2 historical and 4 new ponds in Camp Blanding (Fig. 37) and 6 historical and 7 new ponds in Jennings State Forest (Fig. 38). Three known breeding ponds in Ordway-Swisher were dry during 2014 surveys, and we found newts in only 2 of 10 known ponds that contained water. We found striped newts in only 14 breeding ponds in Ocala National Forest (Fig. 39), but we did not re-survey many known ponds that were surveyed in 2006–2009 by Enge (2011). Beginning in 2012, many Ocala ponds dried down, resulting in poor survey conditions. Striped newts have been recorded since 2005 from most known ponds in Ocala National Forest, but 3 metapopulations may now be extinct: Penner Ponds (recorded in 1970), 10 km west of Astor Park (recorded in 1969), and Mill Dam Health Camp (recorded in 1948). We unsuccessfully surveyed for newts in several ponds near the first 2 sites.

There were fewer potential striped newt ponds than gopher frog ponds, despite both species having similar breeding pond requirements, because the striped newt has a more restricted distribution and more selective upland habitat requirements. Striped newt larvae and paedomorphs are present in ponds for longer periods of time than gopher frog tadpoles, but they tend to be more difficult to detect. Gopher frog tadpoles were present in 37.7% of ponds containing striped newts, whereas striped newts were found in 8.8% of ponds containing gopher frog tadpoles. We found striped newts in 10.2% of 410 unique ponds that were ranked as potential or highly likely for the species, and in 1.4% of 142 ponds that were ranked as unlikely or

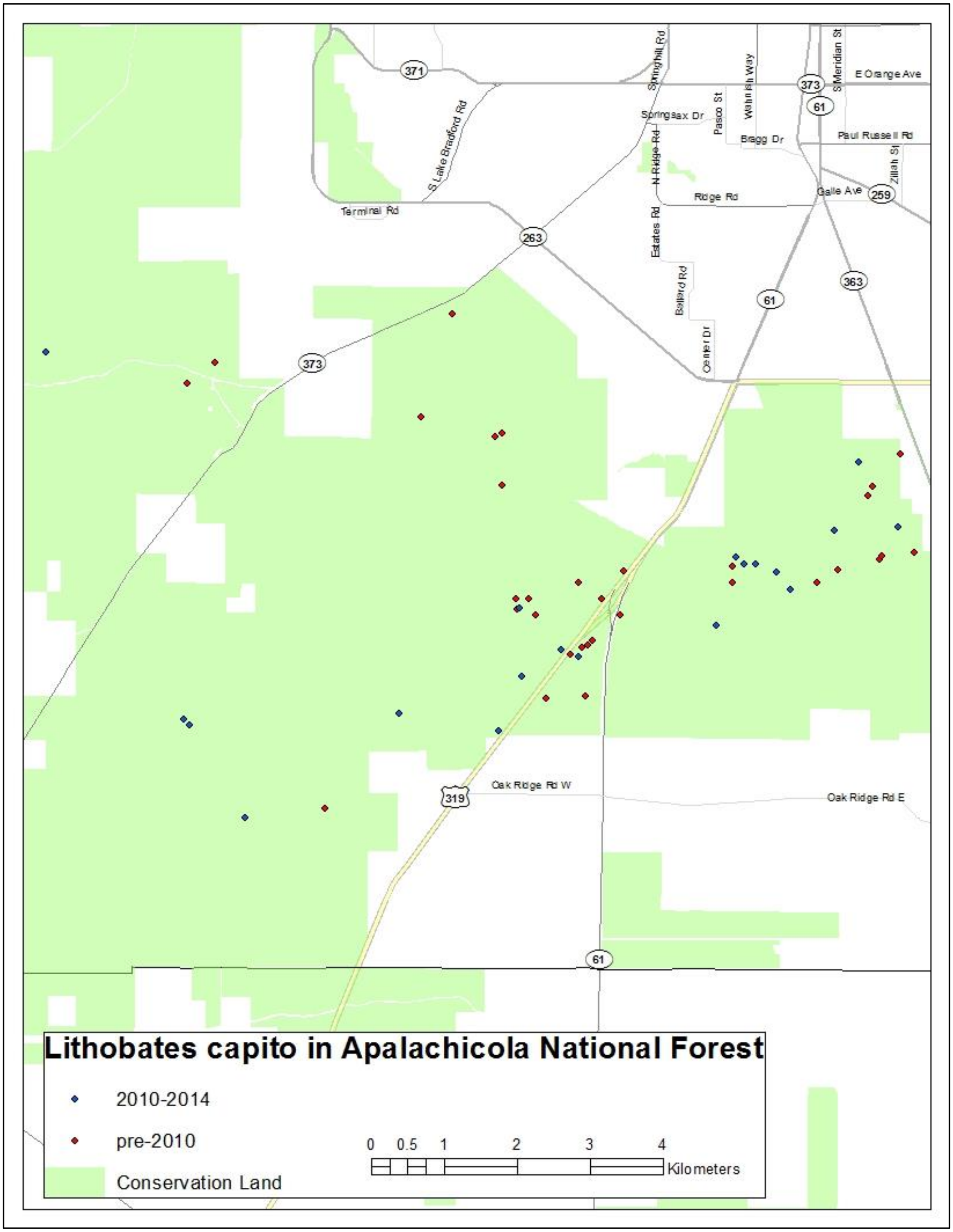


Figure 34. Gopher frog ponds in the Munson Sandhills of Apalachicola National Forest, Leon Co.

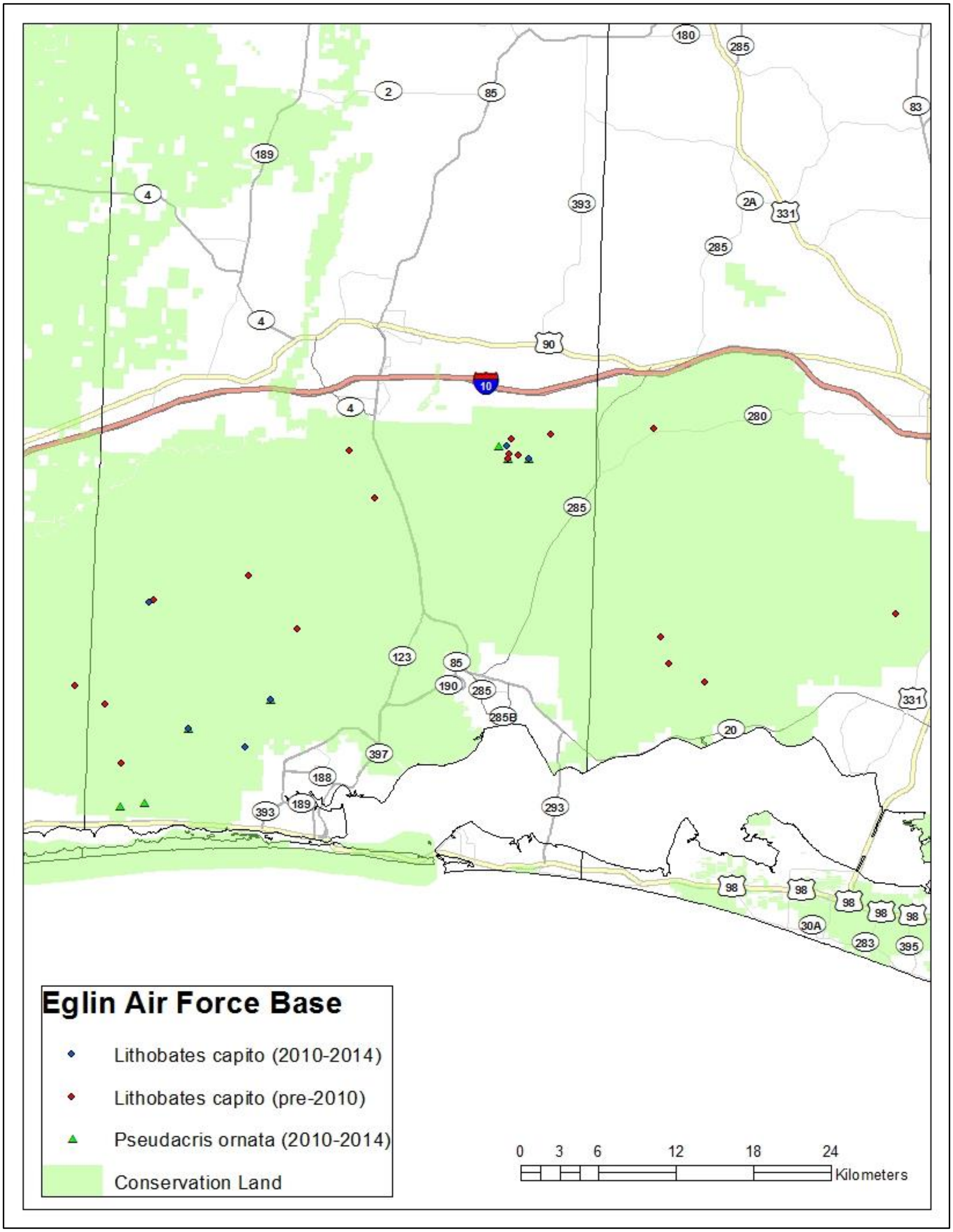


Figure 35. Gopher frog and ornate chorus frog ponds on Eglin Air Force Base, Okaloosa, Santa Rosa, and Walton counties.

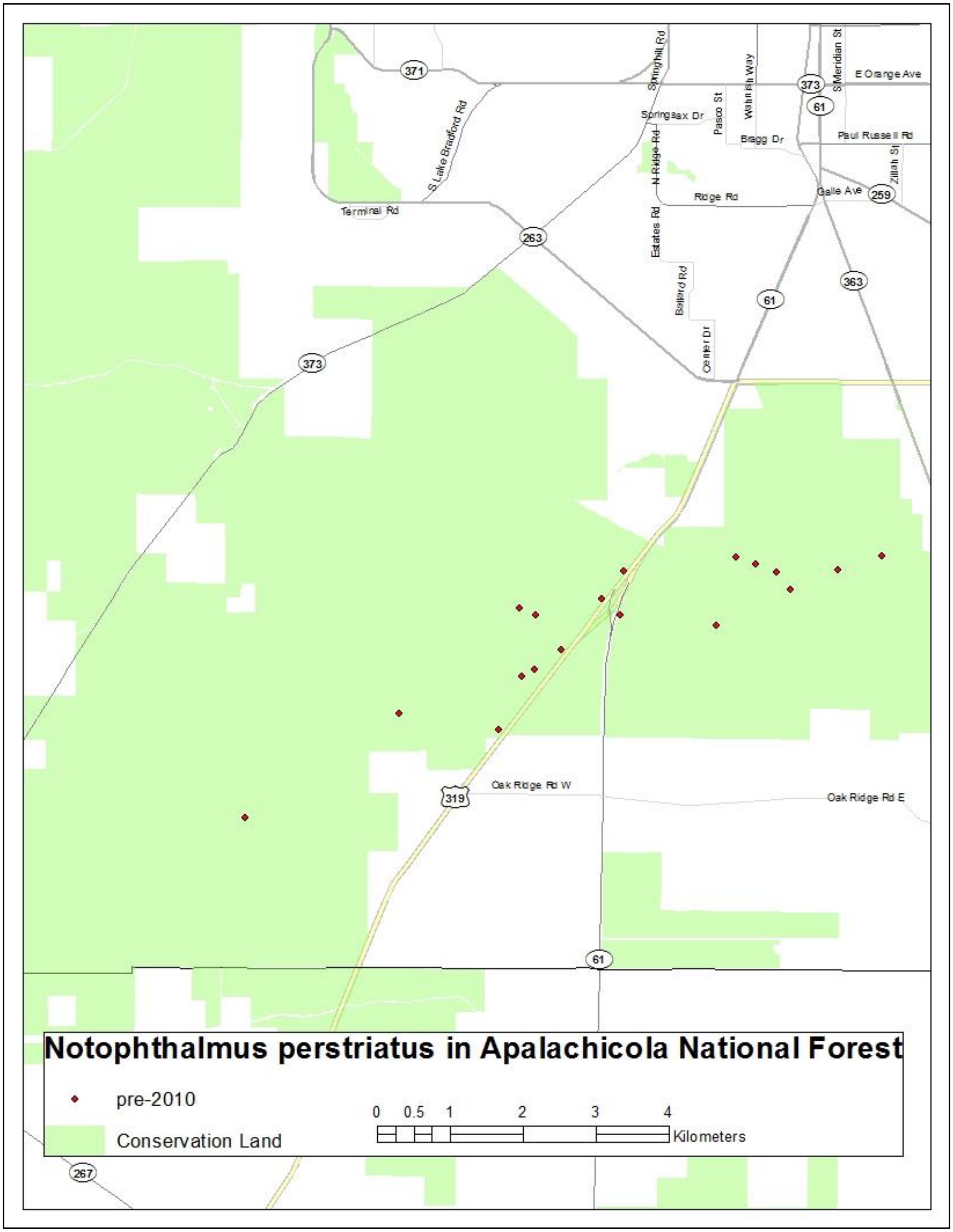


Figure 36. Striped newt ponds in the Munson Sandhills of Apalachicola National Forest, Leon Co., where extensive surveys last documented striped newts in 2007.

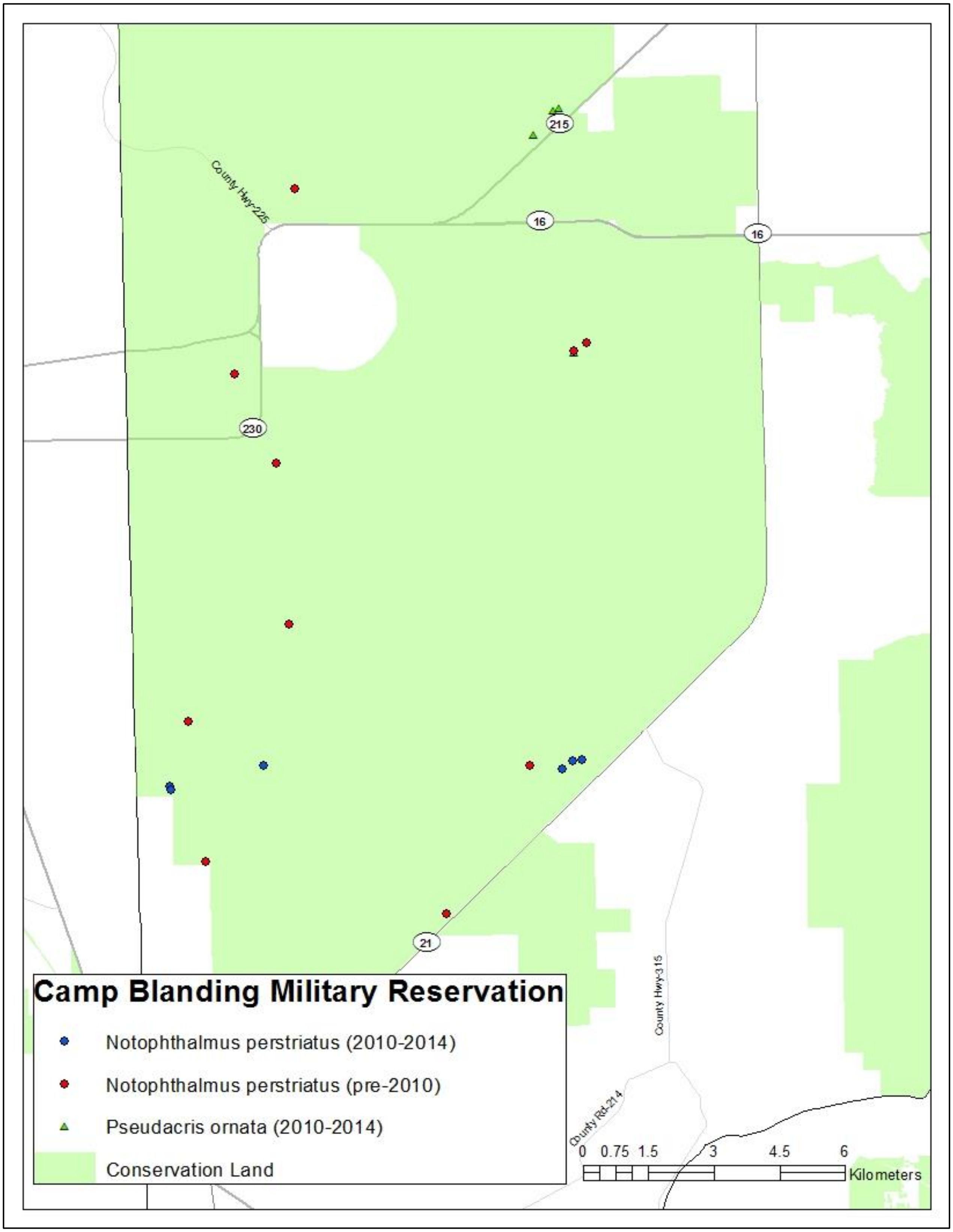


Figure 37. Striped newt and ornate chorus frog ponds on Camp Blanding Military Reservation, Clay Co.

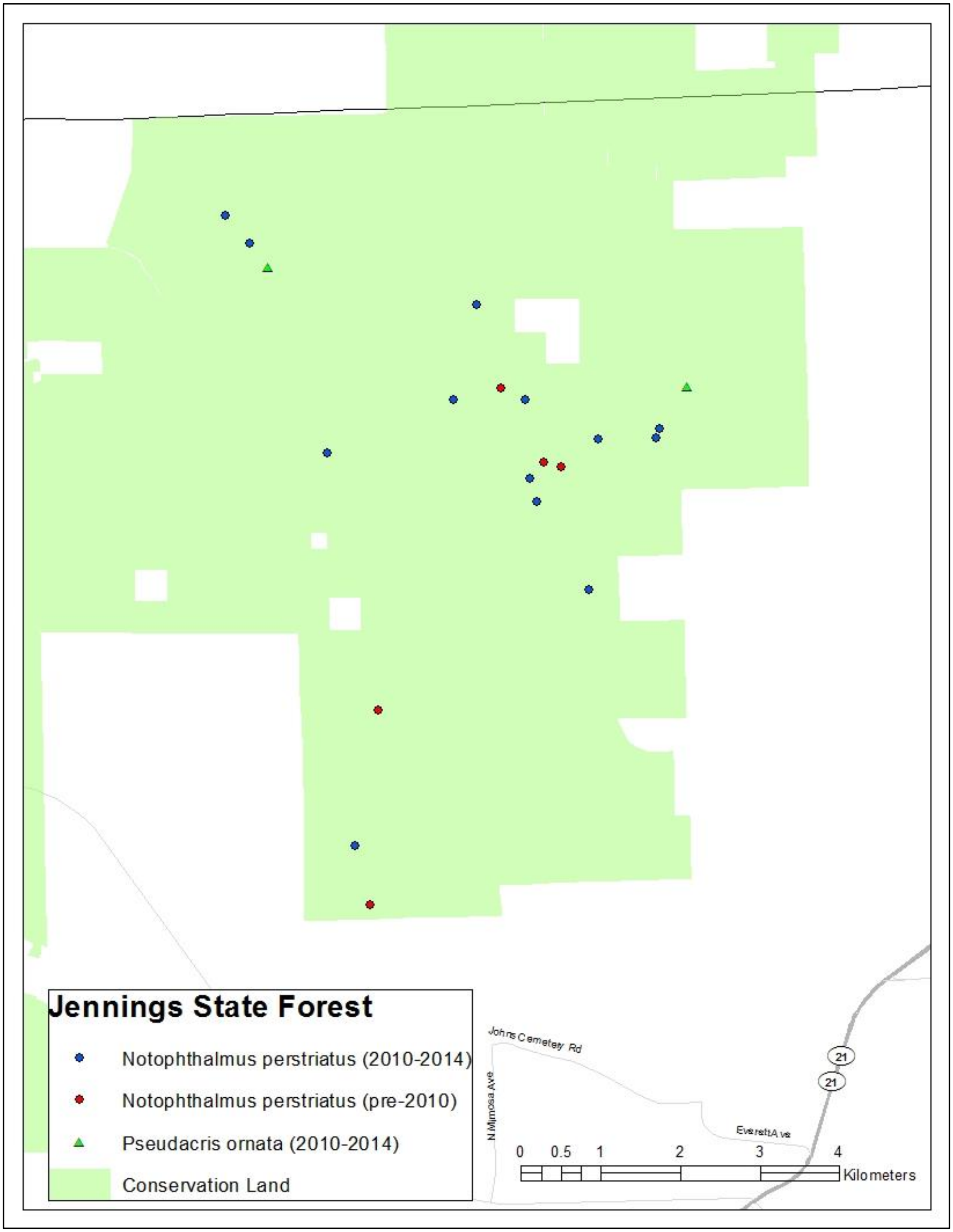


Figure 38. Striped newt and ornate chorus frog ponds in Jennings State Forest, Clay Co.

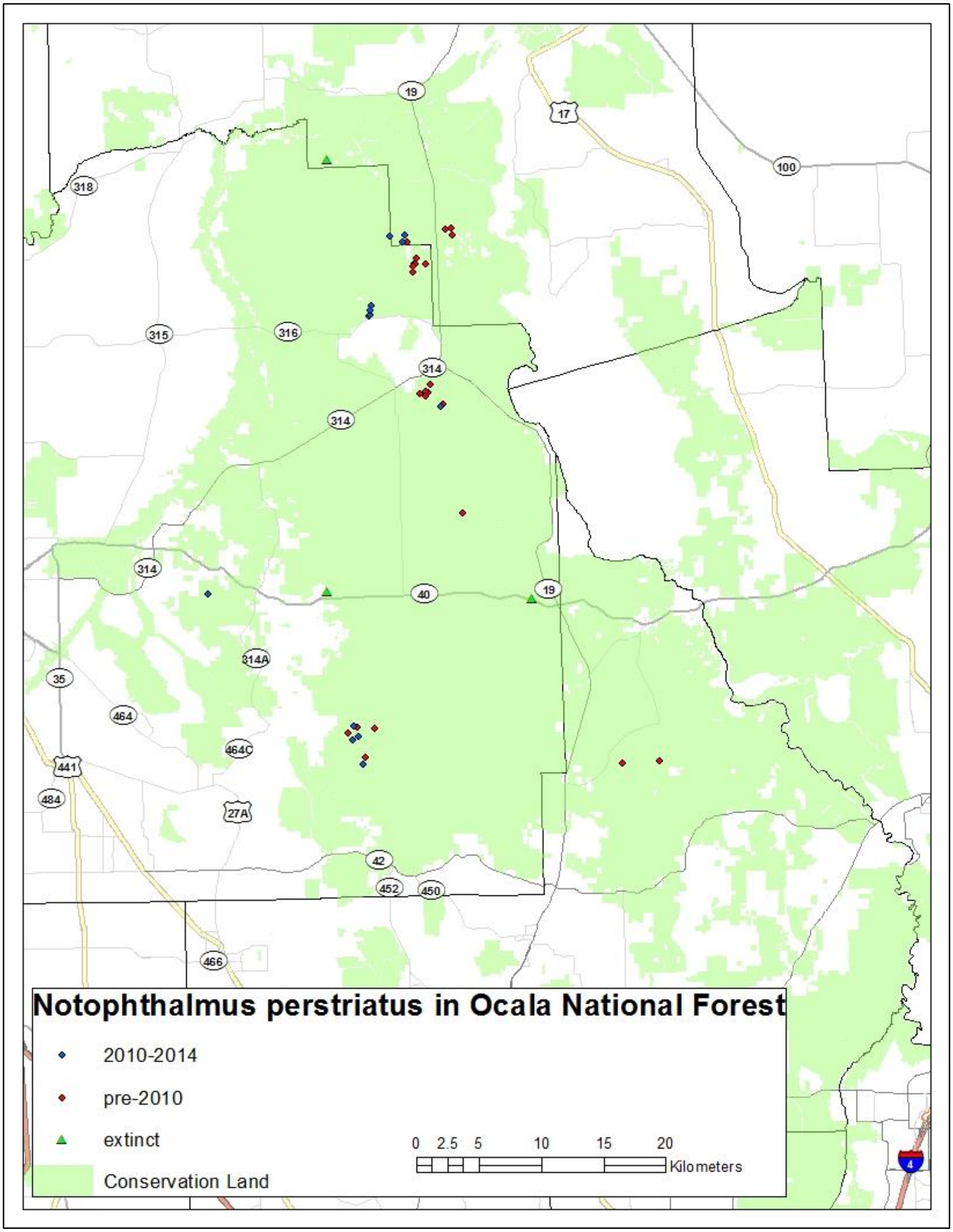


Figure 39. Striped newt ponds in Ocala National Forest, Lake, Marion, and Putnam counties.

unsuitable. We found striped newts in 10 ponds in 2010, 9 ponds in 2011, 0 ponds in 2012, 5 ponds in 2013, and 28 ponds in 2014. Twenty-four of the 46 ponds were previously unknown breeding sites: Camp Blanding Military Reservation (4 ponds), Faver-Dykes State Park (1 pond), Goethe State Forest (1 pond), Guana River WMA (2 ponds), Jennings State Forest (7 ponds), Ocala National Forest (3 ponds), Ordway-Swisher Biological Station (1 pond), Rock Springs Run State Reserve (1 pond), Spring Creek Unit of Big Bend WMA (2 ponds), and Triple N Ranch WMA (1 pond) (Appendix 1). The latter 2 sites represented new county records; both were outside the previously known range of the species.

Our discovery of a striped newt population in western Taylor County vastly expands its potential range in Florida. The record is located in the purported 125-km-wide distributional gap between genetically distinct eastern and western populations. It is located ca. 69 km east of the nearest records in Wakulla Co. (UF 45398–45409) and 84 km west of the nearest record in Gilchrist County (UF 93125). The 2 ponds on the Spring Creek Unit are depression marshes (Fig. 40) in a slash pine plantation in sandhill habitat (Fig. 41) surrounded by dense sand pine plantations or former sand pine plantations that have been clear cut. The slash pines were thinned in the latter half of 2011, and the area was burned in April 2013. In addition, woody vegetation was removed from 1 of the ponds in 2012 as part of wetland restoration. It is surprising that a population was able to persist in this degraded habitat; the patch of suitable upland habitat is only 67 ha in size and contains 2 wetlands used by striped newts, 2 wetlands used by gopher frogs, and 4 wetlands used by ornate chorus frogs (another breeding site is farther north in a clear cut). The record from Triple N Ranch WMA in Osceola County represents a range extension of 57 km from the previous southernmost record from the University of Central Florida, Orange County. The pond on Triple N Ranch WMA is a depression marsh (Fig. 42) in mesic flatwoods habitat adjacent to oak scrub and scrubby flatwoods habitats (Fig. 43). Similar patches of potentially suitable habitat occur elsewhere on this WMA and adjacent properties, Bull Creek WMA and Three Lakes WMA (Fig. 44), but dipnet surveys of other ponds were unsuccessful.

Some of the other new striped newt ponds were near known ponds, but other ponds were more significant. The new pond at Rock Springs Run State Reserve represents a new population >3.5 km from the closest known newt pond. The 3 previously known ponds in Rock Springs Run are situated in scrub habitat that is marginally suitable for newts. The new pond is in high-quality

Figure 40. Largest striped newt pond discovered in the Spring Creek Unit of Big Bend WMA, Taylor Co.

Figure 41. Thinned slash pine plantation in sandhill habitat near striped newt ponds in Big Bend WMA, Taylor Co. (log landing in foreground).

Figure 42. Striped newt pond discovered in Triple N Ranch WMA, Osceola Co.

Figure 43. Xeric upland habitat near the striped newt pond on Triple N Ranch WMA, Osceola Co.

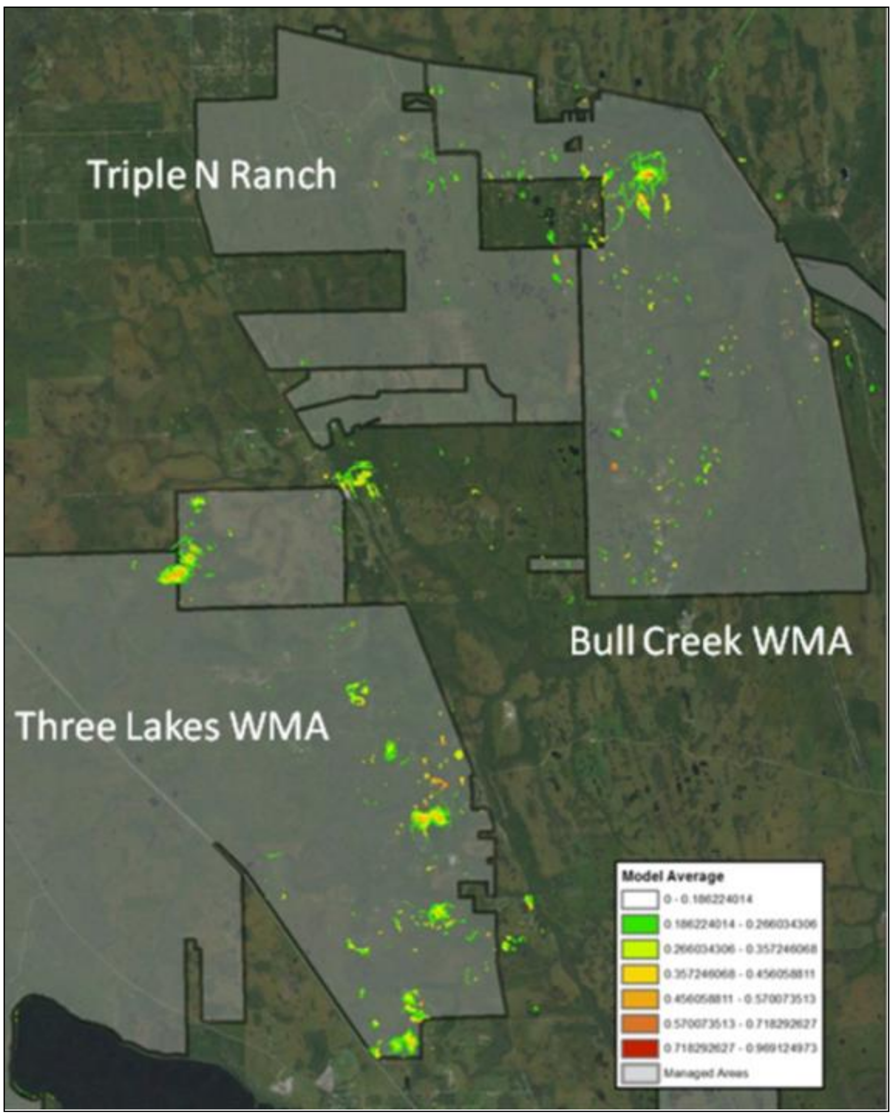


Figure 44. Potential striped newt habitat on 3 conservation lands in Osceola Co.

sandhill habitat, and the wetland is a 3.69-ha semi-permanent basin marsh (Fig. 45) with other potential breeding ponds nearby. In Guana River WMA, the new pond, which is a 0.64-ha depression marsh adjacent to scrub habitat (Fig. 46), represents a second population on the area. The other 2 ponds there are located at least 3 km away and are separated by presumably unsuitable upland habitat. A new pond in Ocala National Forest represents a new population in high-quality sandhill habitat south of Church Lake that has a suite of other potential breeding ponds (Fig. 47). The new pond in Ordway-Swisher Biological Station is a 40.5-ha, irregular-shaped sandhill lake (Dark Brantley Lake) whose northernmost arms are ca. 500 m south of known newt ponds. When Dark Brantley Lake was surveyed on 27 February, it had dried down to 7 pools of water, and the larval newt was found in the southernmost pool ca. 1.2 km from the nearest known newt pond (Fig. 48). In 2014, more newt larvae were found in this pool and in the next pool to the north in Dark Brantley Lake. We found 7 new ponds in Jennings State Forest (Fig. 38) and 4 new ponds in Camp Blanding Military Reservation (Fig. 37), but none represented a new population. One of the new ponds in Camp Blanding is a deep, 0.50-ha borrow pit (Fig. 49) adjacent to a shallow, 0.04-ha borrow pit that is probably a population sink most years because of its short hydroperiod (Fig. 50).

Figure 45. Striped newt pond discovered in Rock Springs Run State Reserve, Lake Co.

Figure 46. Striped newt pond discovered in Guana River WMA, St. Johns Co.

Figure 47. Striped newt pond discovered south of Church Lake in Ocala National Forest, Marion Co.

Figure 48. Pool of Dark Brantley Lake where striped newts were found at Ordway-Swisher Biological Station, Putnam Co.

Tiger Salamander.—Locations are known for only a few tiger salamander breeding ponds in the peninsula. In 2010–2014, we documented it from 7 counties and discovered 16 new populations or ponds, although we personally found few records because dipnetting was mostly ineffective at detecting the species. We dipnetted a known pond at San Felasco Hammock Preserve State Park, Alachua County, numerous times during the study but found larvae only once. In 2010, surveys of this pond were unsuccessful on 23 January and 1 March. However, a third visit on 29 March found numerous larvae measuring 30−35 mm TL in the drying pond, which consisted of 2 pools <15 cm deep (Fig. 51). The Principal Investigator (PI) collected 7 tail tips for genetic analysis and informed DEP staff, which visited the pond on 31 March and translocated ca. 110 larvae to another pond (not a known breeding pond) with a longer hydroperiod on the opposite side of I-75. Approximately 40 larvae were reared in captivity for later release as metamorphs at the breeding pond. The PI organized a rescue operation consisting of ca. 20 people for 3 April to remove more larvae for rearing in captivity and future release, but the pond had completely dried, killing all the larvae. A January 2013 survey of a known pond in Yellow Jacket Conservation Area, Dixie County, was unsuccessful. We were unsuccessful at finding larvae in wetlands near 2 road locations of tiger salamanders in Hernando County. On 16 March 2010, we found large tiger salamander larvae in a retention pond in a subdivision in Brooksville, Hernando County (Fig. 52), and salamanders bred there again in 2011 (Phillip Frank, pers. comm.) and December 2014 (Garrett Craft, pers. comm.). Dipnet surveys were unsuccessful at other potential ponds in San Felasco Hammock Preserve State Park and on Suwannee River Water Management District lands in Lafayette and Suwannee counties. Detection of new breeding ponds was difficult because the specific characteristics of suitable upland and breeding habitat are unknown. A commercial collector regularly finds tiger salamanders at a pond near Citrus Springs, Citrus County (Bill Kellner, pers. comm.). Tiger salamanders were found in 1 known pond in Blackwater River State Forest on 16 April 2014 while collaborating with WMA staff on surveys.

Flatwoods Salamanders.—We dipnetted 244 unique ponds primarily in mesic flatwoods on 27 conservation lands but failed to find frosted flatwoods salamander larvae in the peninsula (Appendix 1). We were successful at finding frosted flatwoods salamanders in Apalachicola National Forest, St. Marks NWR, and Flint Rock WMA in the panhandle (Appendix 1). We found larvae in only 1 pond in St. Marks NWR on 31 March 2010 while trying to collect genetic samples, but most larvae had probably already metamorphosed. A trip on 9 March 2011 to known breeding ponds in Apalachicola National Forest for disease sampling found larvae in only 1 pond.

Figure 48. Large, deep borrow pit with striped newts in Camp Blanding Military Reservation, Clay Co.

Figure 49. Small borrow pit with striped newts in Camp Blanding Military Reservation, Clay Co.

Figure 51. Drying pond containing tiger salamander larvae on 29 March 2010 in San Felasco Hammock Preserve State Park, Alachua Co.

Figure 52. Retention pond containing tiger salamander larvae on 16 March 2010 in a subdivision in Brooksville, Hernando Co.

In 2014, dipnet surveys of 25 known breeding ponds in St. Marks NWR documented larvae in only 3 ponds, but USGS staff document larvae in 2 other ponds using minnow traps (Fig. 53). Dipnet surveys of 5 known breeding ponds in Flint Rock WMA documented larvae in only 1 pond (Fig. 53). No larvae were found in the westernmost population at St. Marks NWR (Fig. 53). Dipnet surveys in 2014 of 72 ponds in Apalachicola National Forest documented larvae in 15 of 56 known ponds and 5 new ponds (Appendix 1, Fig. 54).

Ornate Chorus Frog.—Ornate chorus frog tadpoles were not found in the peninsula during dipnet surveys in 2010–2013. Heavy winter rains in 2014 filled shallow, grassy wetlands favored by ornate chorus frogs for breeding, and we targeted these types of wetlands for dipnet surveys (often in conjunction with ARU installation). In 2014 in the peninsula, we dipnetted ornate chorus frog tadpoles from 5 ponds in the Spring Creek Unit of Big Bend WMA, 2 ponds in Lafayette Forest Mitigation Park WEA (new county record), 1 pond in Jennings State Forest (Fig. 38), and 3 ponds in Camp Blanding Military Reservation (Fig. 37, Appendix 1). In the panhandle, ornate chorus frog tadpoles were found in 42 ponds in Apalachicola National Forest during flatwoods salamander surveys in 2014 (Appendix 1). Also in 2014, tadpoles were found in the panhandle in 2 ponds in Apalachicola River WEA that had undergone recent mechanical restoration, 1 pond in Blackwater River State Forest, 6 ponds in Dixie Plantation in Jefferson County, 4 ponds in Eglin AFB (Fig. 35), 2 ponds in Joe Budd WMA, 2 ponds in Tate's Hell State Forest, and 1 pond on private property in Jackson County (Appendix 1).

Automated Recording Units

In 2013 and 2014, we installed 93 ARUs on conservation lands. No historical records of ornate chorus frogs existed for some sites, but suitable upland and breeding habitats were present. One ARU in 2013 and 2 ARUs in 2014 failed to record data. In 2013, 29 ARUs in the northern peninsula recorded calling ornate chorus frogs at only 1 wetland in Jennings State Forest. In 2014, calling ornate chorus frogs were detected at 7 (21.2%) of 33 ARU ponds in the peninsula and 9 (32.1%) of 28 ponds in the panhandle. In 2014 in the peninsula, ornate chorus frogs were detected by ARUs in Etoniah Creek State Forest (3 ponds), Lafayette Forest Mitigation Park WEA (3 ponds), and Phifer Flatwoods (1 pond). The ornate chorus frog detected in Phifer Flatwoods, Alachua County, called for only 1 night. In 2014 in the panhandle, ornate chorus frogs were detected by ARUs in Apalachicola River WEA (2 ponds), Eglin AFB (2 ponds), Joe Budd WMA (1 pond), Nokuse Plantation (1 pond), and Tate's Hell State Forest (3 ponds). In the peninsula, ornate chorus frogs were also heard calling in Camp Blanding Military Reservation and the Spring Creek Unit of Big Bend WMA during dipnet surveys or nocturnal visits.

Automated recording units detected a gopher frog calling in 2013 at a known breeding pond in Jennings State Forest. In 2014, ARUs detected calling gopher frogs in the peninsula in 1 pond in Cary State Forest, 2 ponds in Etoniah Creek State Forest, 2 ponds in Goethe State Forest, 1 pond in Phifer Flatwoods, and 1 pond in the Spring Creek Unit of Big Bend WMA. Most of these were previously unknown breeding ponds, and at the time, these represented the first records of the species from Cary State Forest and Phifer Flatwoods. More gopher frog recordings could have been present, but we did not have a call recognizer that would have allowed us to scan digitally for this species. Gopher frog calls were detected incidentally while verifying ornate chorus frog hits from its recognizer.

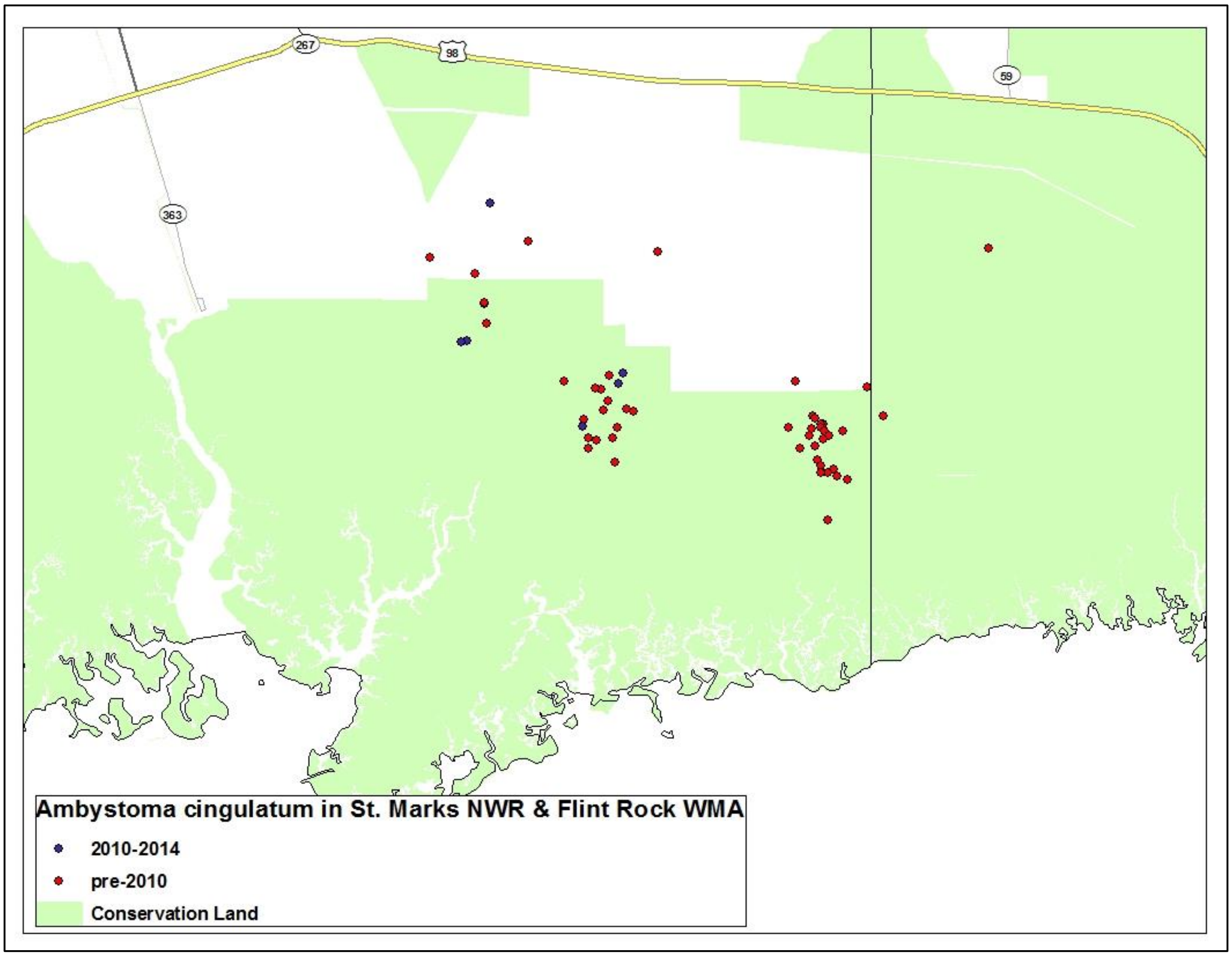


Figure 53. Frosted flatwoods salamander ponds in St. Marks National Wildlife Refuge and Flint Rock WMA, Jefferson and Wakulla counties. Flint Rock ponds are the 7 ponds in the white area in Wakulla Co. and 2 ponds in the green area in Jefferson Co.

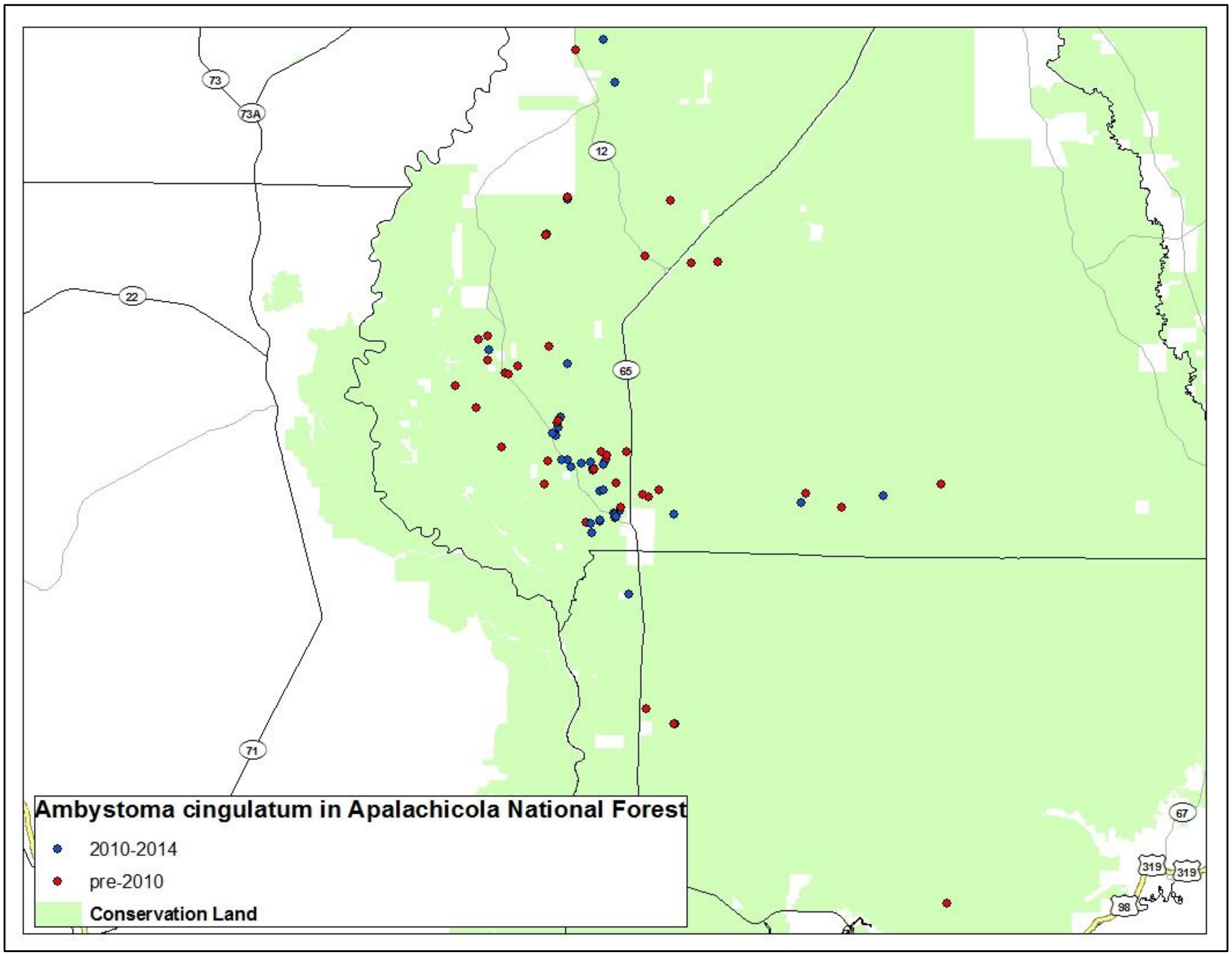


Figure 54. Frosted flatwoods salamander ponds in Apalachicola National Forest, Franklin and Liberty counties.

Call Surveys

We heard ornate chorus frogs calling on only 1 of 23 survey routes, despite driving 677 km. On 4 February 2010, ornate chorus frogs were calling at 17 of 89 stops on the route west of Otter Creek, Levy County. They called along CR 336 and State Road 24 on private land containing primarily flatwoods habitat (sandhill habitat on the northern end) with numerous dome swamps in pine plantations. They also called from flooded roadside ditches and yards. Ornate chorus frogs also called here in 2011, 2013, and 2014. They did not call in 2012 because of drought conditions. These additional visits to the site were not counted as call surveys. One frog was incidentally heard calling in the afternoon along the Gainesville-Hawthorne Bike Trail, Alachua County, but a visit to the site at night failed to detect any calling frogs (Jonathan Mays, pers. obs.). In past decades, ornate chorus frogs were commonly heard calling from ponds and roadside ditches in and around Alachua County. Failure to detect calling ornate chorus frogs at these historical sites is cause for concern.

During call surveys, we detected only 2 gopher frog breeding ponds in Goethe State Forest, Levy County (1 pond was already known), and 1 new pond along State Road 40 on private land adjacent to Ocala National Forest, Marion County. Gopher frogs are often sporadic callers and typically remain in ponds for <2 weeks, so it is not too surprising that this method was relatively ineffective at detecting the presence of gopher frogs. At the Marion County pond, a single frog responded to an imitated call. While dipnetting a pond in Ocala National Forest, a calling frog was used to document this as a new breeding pond. Phillip Frank, a resident of Citrus County, provided the locations of 6 ponds on private land in Citrus County based upon calling gopher frogs. Biologists reported calling frogs from 1 pond in Lake Panasoffkee WMA, 1 pond in the Citrus Tract of Withlacoochee State Forest, and 3 ponds in Camp Blanding Military Reservation during this survey period (all were previously unknown breeding ponds).

We heard the following nontarget species calling on ornate chorus frog survey routes: spring peeper (*Pseudacris crucifer*; 133 stops), southern chorus frog (106 stops), southern leopard frog (96 stops), little grass frog (*P. ocularis*; 58 stops), southern cricket frog (6 stops), and Cope's gray treefrog (*Hyla chrysoscelis*; 1 stop). The latter 2 species are common but are not considered winter breeders. The high-frequency calls of the little grass frog cannot be detected by some people, including 1 of the 2 surveyors, so its occurrence was under represented on the call routes. Habitat differences accounted for the presence or absence of the southern chorus frog and spring peeper on various routes. For example, on the Otter Creek route where we heard ornate chorus frogs in 2010, we heard southern chorus frogs calling at 50.6% of the 89 stops but no spring peepers. In contrast, on a route in 2010 near Lochloosa, Alachua County, we heard spring peepers calling at 92% of 25 stops but no southern chorus frogs. Up until the 1980s, ornate chorus frogs were commonly heard calling on the Lochloosa route, and 1 frog was heard in 2010 during an ancillary survey (Paul Moler, pers. obs.). Call routes may be effective at detecting robust populations of the ornate chorus frog but are probably ineffective at detecting marginal populations. Froglogger data indicated that ornate chorus frogs sometimes called for only a few days per breeding season and often called early in the morning after our call-route surveys had ended (William Barichivich, pers. comm.).

Road Surveys

We received several reports of gopher frogs on roads on rainy nights in Levy, Marion, and Sumter counties. Road surveys on rainy nights proved to be the most successful method for finding new tiger salamander locations, but follow-up dipnet surveys would be required to confirm the location of some breeding ponds, which were all located on private property. The locations of most ponds were inferred based upon salamander locations and direction of movement. Phillip Frank provided locations of 4 sites in Hernando County where tigers have been found on roads, but only 1 breeding site was subsequently confirmed. Daniel Parker found an adult tiger salamander crossing a road at night on 9 January 2012 south of Bushnell, Sumter County. Since 2007, adult tiger salamanders have been observed crossing roads through quail plantation land in northern Leon and Jefferson counties (Pierson Hill, pers. obs.). Volunteers (Glenn Bartolotti, Garrett Craft, Dan Rieck, and Jordan Schmitt) drove roads during rainy nights in 2013–2014 and found tiger salamanders at 2 new sites in Hernando County, 1 new site in Levy County, and 3 new sites in Marion County. Tiger salamanders were found moving on 26 November 2013, 14 December 2013, and 1 January 2014. Jonathan Mays failed to find salamanders migrating to the known pond in San Felasco Hammock Preserve State Park during this same period, but the pond remained dry despite substantial rainfall. Tiger salamanders were found on roads at several sites in Levy County during rains on 26 November 2014 (Paul Moler, pers. obs.; Cody Godwin, pers. comm.) and in Hernando and Marion counties during rains on 21 December 2014 (Garrett Craft, pers. comm.).

Typically, ornate chorus frogs are observed crossing roads at night during breeding migrations. However, in June 2013 during Tropical Storm Andrea, an ornate chorus frog was found crossing CR 346 headed toward Horse Prairie, Alachua County, among thousands of squirrel treefrogs (Bruce Morgan, pers. comm.). Hundreds of ornate chorus frogs could be heard calling from Horse Prairie in the early 1990s, but none has been heard since then (Paul Moler, pers. comm.).

Incidental Observations

Some preexisting gopher frog records we compiled at the beginning of this project were of frogs observed in gopher tortoise burrows, on the surface (sometime during prescribed burns), or captured in drift-fence or Sherman live traps. In 2014, a gopher frog was caught in a drift fence at a flatwoods salamander pond at Eglin AFB, Santa Rosa County (Kelly Jones, pers. comm.). Our observation of a gopher frog in a tortoise burrow accounted for the first record from Charles H. Bronson State Forest, Orange County. The PI photographed a juvenile gopher frog in a tortoise burrow in Pellicer Creek Conservation Area, Flagler County, which represented a new county record. On the Lake Wales Ridge, we have recent reports of juvenile frogs found under artificial cover objects.

There are a few historical records of striped newts found under logs near ponds in Alachua County. The only records of striped newts from Half Moon WMA (Johnson and Dwyer 2000) and Rainbow Springs State Park represent drift-fence captures in the 1990s; subsequent dipnet surveys have failed to find breeding ponds. Similarly, the only records of striped newt and gopher frogs in the Panacea Unit of St. Marks NWR, Wakulla County, came from drift-fence captures in the late 1970s (U.S. Fish and Wildlife Service 1980). Recent drift-fence and dipnet surveys have failed to detect the species at St. Marks NWR, despite the presence of suitable-looking habitat (Dodd et al. 2007). There are several historical records of flatwoods salamanders found under logs, particularly in Alachua County, and some individuals in the panhandle were found during the period of this survey under logs adjacent to known breeding ponds.

Most records of tiger salamanders represent incidental observations of individuals crossing roads at night or found under cover objects. A metamorphic tiger salamander was found on private property near Williston, Alachua County, in 2010 (Anthony Flanagan, pers. comm.). A student found a tiger salamander at a high school in Bushnell, Sumter County. Dale Jackson discovered a new breeding pond in a subdivision in Leon County, where he counted 634 metamorphs during a 2-hour period on 29 May 2013. He estimated that at least 2,000 metamorphs exited the pond in 26 May–1 June; long-time residents of the subdivision had never seen tiger salamanders previously. On 2 January 2014, we found 2 tiger salamanders in a roadside ditch NW of Otter Creek, Levy County, while photographing calling anurans.

In 2012, we received a photograph of a frog observed during the daytime in 2012 on private property west of Rice Creek Conservation Area, Putnam County. In April–June 2014, 9 adult ornate chorus frogs were trapped in drift-fence arrays in sandhill habitat at 2 sites in Camp Blanding Military Reservation during a snake survey.

Status of Populations

Care must be taken when using the number of records by decade as an index of the status of a species. Most records prior to the 1990s represent museum vouchers, so relatively few localities are represented. The exact locations of many historical breeding ponds are unknown, and many records represent individuals found crossing roads at night. It is often difficult to determine whether historical records from ponds represent the same pond or multiple ponds because of inexact locality information based upon directions or township, range, and section number. The accuracy of many record locations increased after 1995 with the availability of GPS. Most records after 1990 represent pond locations found during targeted surveys. In describing the status of populations, we use the terms presumably extinct, possibly extinct, presumably extant, and probably extant. These terms are subjective and indicative of the PI's level of certainty regarding a population's continued existence at a site. A species' detectability and tolerance for disturbed habitats helped determine which status category was applicable. Other determining factors were the year the species was last observed at a site, the amount of survey effort expended since the last record, and the continued presence of suitable upland and wetland habitats at a site.

Gopher Frog.—Gopher frogs have been recorded from 54 Florida counties historically and from 37 counties since 2000 (Table 1). We determined that at least 140 gopher frog metapopulations are probably extant in Florida based upon our surveys and other data. Based upon our criteria for defining metapopulations, Ocala National Forest has only 3 metapopulations because of the abundance of ponds in relatively close proximity (Fig. 29). In contrast, Eglin AFB, where ponds are widely scattered, has 24 known breeding ponds (Fig. 35) but 11 metapopulations (4 metapopulations contain only 1 pond).

Table 1. The last decade gopher frogs were recorded from sites in a county, including survey data from this study. The number of records refers to breeding ponds or to populations when the breeding pond is unknown.

County	<1970	1970s	1980s	1990s	2000s	2010s
Alachua	7	3	1	5	3	9
Baker	1	0	0	0	2	0
Bradford	0	1	0	0	0	0
Brevard	1	0	0	2	0	7
Calhoun	1	1	0	1	0	1
Charlotte	0	0	0	1	0	0
Citrus	2	0	1	3	4	7
Clay	0	0	0	13	0	31
Collier	1	0	0	0	0	0
Columbia	0	0	1	0	1	0
DeSoto	2	0	0	0	0	0
Duval	6	1	0	0	0	3
Flagler	0	0	0	0	0	1
Franklin	1	0	0	0	0	0
Gilchrist	0	0	0	0	0	6
Glades	0	0	1	1	1	0
Gulf	1	0	0	0	0	0
Hamilton	0	0	0	1	0	0
Hardee	0	0	0	0	12	0
Hernando	0	0	0	9	10	16
Highlands	2	0	0	12	7	14
Hillsborough	2	0	1	0	0	0
Indian River	1	0	0	0	0	5
Jackson	0	0	0	0	1	0
Lake	5	0	0	1	15	12
Leon	0	0	1	23	15	12
Levy	3	1	1	1	5	7

Liberty	0	0	0	1	0	3
Madison	0	0	0	0	1	0
Manatee	2	0	0	0	2	1
Marion	9	9	2	1	35	49
Martin	0	0	0	0	1	4
Nassau	2	0	0	1	0	0
Okaloosa	0	0	0	13	0	6
Okeechobee	2	0	0	0	0	0
Orange	1	1	0	1	1	2
Osceola	0	0	0	0	2	5
Palm Beach	4	0	1	2	0	0
Pasco	1	0	0	0	2	4
Pinellas	3	0	0	1	0	0
Polk	3	1	1	6	1	23
Putnam	3	2	1	5	7	8
St. Johns	0	0	0	0	1	1
St. Lucie	0	0	0	1	2	1
Santa Rosa	0	0	1	3	0	0
Sarasota	3	0	1	0	1	0
Seminole	1	1	0	0	1	1
Sumter	0	0	0	2	1	5
Suwannee	0	1	0	0	0	1
Taylor	0	0	1	1	2	5
Volusia	0	0	0	1	1	0
Wakulla	0	1	0	1	0	0
Walton	0	0	0	5	0	0
Washington	0	0	0	1	0	0
Total	**70**	**23**	**15**	**119**	**137**	**250**

Striped Newt.—The striped newt is historically known from 18 Florida counties, and we discovered it in 2 additional counties (Table 2). Records since 2000 exist from only 11 of the 20 counties (Table 2). There are no records since at least the 1980s from Citrus, Columbia, Dixie, Duval, Gilchrist, Orange, and Seminole counties (Table 2). We determined that at least 44 of 76 identified striped newt metapopulations are probably extant in Florida based upon our surveys, other data, and continued existence of suitable habitat. Eleven other metapopulations are possibly extinct, including panhandle metapopulations in Leon and Wakulla counties. The upland habitat in these panhandle sites appears to be in better condition than many sites in the peninsula where the species still occurs, so the reason for these population declines are unknown. We calculated that there are 12 extant and 3 possibly extinct metapopulations (40 ponds, including 2 unknown ponds in 2 possibly extinct populations) in Ocala National Forest, 10 probably extant metapopulations (16 ponds) in Camp Blanding Military Reservation, 5 extant metapopulations (18 ponds) in Jennings State Forest, 5 possibly extinct metapopulations (18 ponds) in Apalachicola National Forest, and 4 probably extant metapopulations (18 ponds) in Ordway-Swisher Biological Station (Appendix 2). Our discovery of striped newts in Osceola and Taylor counties expands the range of the species in the peninsula and provides hope that additional populations are present in intervening areas or in counties with no recent records. This species is often difficult to detect when populations are low, even during intensive surveys.

We know the locations of only a few ponds where striped newt populations are apparently extinct, except for the ponds in Apalachicola National Forest (Fig. 36). Excluding the Apalachicola National Forest and St. Marks NWR locations, we used Google Earth to examine land use in the vicinity of extinct populations to determine the most likely reasons for extirpation. Of 33 localities where populations are presumably extinct, the probable causes are residential development (57.6%), silviculture (24.2%), ecological succession (9.1%), and agriculture (9.1%). From 1922 through 1952, striped newts were collected at 10 locations in the Gainesville area. Populations in Gainesville (5 km north of downtown and Bivans Arm) were extirpated by development. Populations 8−11 km east of Gainesville and southwest of Gainesville (Sugarfoot Prairie, Haile's Siding) were probably extirpated by development, silviculture, and/or ecological succession. The only unaltered historical pond that can be identified is Twin Oaks Pond 5 km east of Gainesville, where striped newts were collected from 1931 through 1952. An aerial photograph from 1949 shows this pond surrounded by sandhill habitat succeeding to xeric hammock (Fig. 55). There is now a housing development to the west and a correctional facility to the northeast (Fig. 56). The PI visited this pond in 2014, and the dense, fire-excluded mesic hammock surrounding the pond is unsuitable for striped newts. Planted pines in oldfield habitat farther north could be used by gopher frogs but not striped newts. Still Hunt Ponds in Lochloosa Conservation Area, Alachua County, still had newts in 1985, but Google Earth imagery indicates the site was harvested and replanted in pines ca. 1999. Vegetation there is controlled by herbicide treatment instead of prescribed fire (Rob Hicks, pers. comm.). The wetland is still grassy and looks suitable for newts, but there is too much canopy closure and groundcover vegetation is sparse or disturbed. Four historical striped newt locations (some could be the same site) from the Jacksonville area, Duval County, from 1922 through 1961 have been lost to residential development. The same fate happened to the Rose's Bluff location in Nassau County. The dome swamp at the University of Central Florida campus is still present, as well as some sandhill habitat to the east, but the upland patch is probably too small to support a newt population (last documented in 1989).

Table 2. The last decade striped newts were recorded from sites in a county, including survey data from this study. The number of records refers to breeding ponds or to populations when the breeding pond is unknown.

County	**<1970**	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**
Alachua	8	0	2	0	2	0
Citrus	1	0	0	0	0	0
Clay	0	0	0	11	5	18
Columbia	0	1	0	0	0	0
Dixie	0	1	0	0	0	0
Duval	0	1	0	0	1	0
Gilchrist	0	2	0	0	0	0
Lake	0	0	0	0	4	2
Leon	2	0	0	13	5	0
Levy	0	0	0	0	2	1
Marion	2	2	0	1	19	12
Nassau	1	0	0	0	0	0
Orange	0	0	1	1	0	0
Osceola	0	0	0	0	0	1
Putnam	0	3	1	10	8	4
St. Johns	0	0	0	1	2	2
Seminole	1	0	0	0	0	0
Sumter	0	0	0	2	0	0
Taylor	0	0	0	0	0	2
Wakulla	0	2	0	0	0	0
Total	**19**	**11**	**4**	**39**	**48**	**42**

Figure 55. Aerial photo from 1949 of Twin Oaks Pond, Alachua Co., a historical striped newt and gopher frog breeding pond.

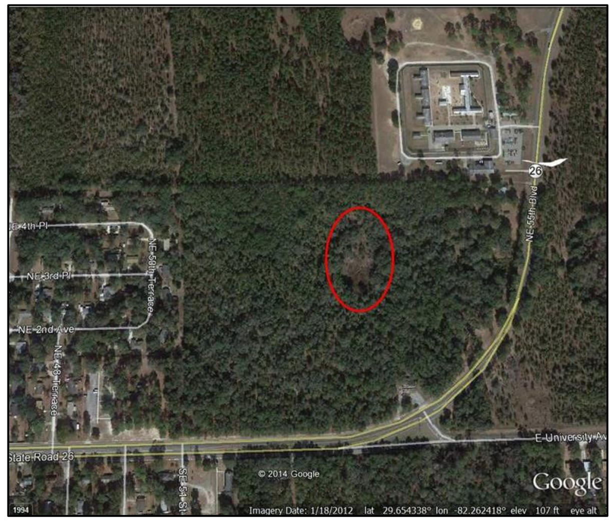


Figure 56. Google Earth image from 2012 of Twin Oaks Pond, Alachua Co., a historical striped newt and gopher frog breeding pond.

Tiger Salamander.—The tiger salamander is historically known from 20 Florida counties (Table 3), but there are records since 2000 from only 13 counties. However, the species probably still occurs in all these counties because of its tolerance of habitat alteration and its ability to live undetected in an area for decades. The tiger salamander is the most difficult of the target species to survey, and most records represent incidental observations crossing roads, except for targeted dipnet surveys conducted by FWC staff in Blackwater River State Forest that began in 2005. On 24 November 2014, Pierson Hill observed 20–30 adult male tiger salamanders in a pond on Tall Timbers Research Station, Leon County; this record is included in Table 4 but not in calculations of pond area and surrounding habitats. In January 2007, 3 adults were found under logs in this pond when it was almost dry, and an egg mass was found in a soggy depression beneath a log (Pierson Hill, pers. obs.). A tiger salamander found crossing a road in Jefferson County on 23 November 2014 is recorded in Table 4 but not included in calculations.

Flatwoods Salamanders.—The frosted flatwoods salamander is historically known from 4 counties in peninsular Florida but may now be extinct there (Table 4). Surveys during the present study concentrated on areas in the peninsula where the species was historically present and that contain the most suitable habitat, particularly Osceola National Forest and Raiford WMA. During this study, we collaborated with other agencies in 2014 to re-survey most known breeding ponds in St. Marks NWR and Apalachicola National Forest. We found reduced levels of pond occupancy in St. Marks NWR compared to the early 2000s, suggesting substantial population declines, particularly in the easternmost population, where the habitat was most degraded. The reticulated flatwoods salamander is historically known from 9 Florida counties but is apparently now present in just Okaloosa, Santa Rosa, and possibly Washington counties (Table 5). The stronghold for the species is southern Okaloosa and Santa Rosa counties, primarily the East Bay flatwoods in Eglin AFB and adjacent Hurlburt Field (Fig. 57). Eglin AFB contains 25 known ponds, and Hurlburt Field contains 13 ponds (Tom Gorman, pers. comm.). The winter of 2014 was exceptionally wet, and Virginia Tech staff found larvae in 7 known ponds and 4 new ponds in Eglin AFB and 1 known pond in Hurlburt Field (Tom Gorman, pers. comm.). Six of the 7 known Eglin AFB ponds with larvae in 2014 also contained larvae in 2013, but larvae were last found in the other pond in 1994. Extant breeding ponds are now clustered (Fig. 57). In addition, larvae were found in 2014 in a wetland adjacent to a housing development at a known site owned by Santa Rosa County (Tom Gorman, pers. comm.), where larvae were last found in 1993. Only 28.3 ha of undeveloped habitat remain at this site, which might represent the least amount of upland habitat available for any extant population. In 2010, larvae were found at 2 of 3 known ponds in Holley Naval Outlying Landing Field, Santa Rosa County (Ron Cherry, pers. comm.).

Table 3. The last decade tiger salamanders were recorded from sites in a county, including survey data from this study. The number of records refers to breeding ponds or to populations when the breeding pond is unknown.

County	**<1970**	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**
Alachua	5	0	2	0	0	1
Calhoun	2	0	0	1	0	0
Citrus	0	0	0	0	2	1
Columbia	1	0	0	0	0	0
Dixie	0	1	0	0	1	0
Gadsden	0	0	0	0	2	0
Hernando	2	0	0	1	2	4
Gadsden	1	0	0	0	0	2
Gilchrist	0	0	1	0	0	0
Jackson	1	0	0	0	0	0
Jefferson	0	1	0	0	0	1
Leon	10	6	2	4	0	4
Levy	2	0	1	0	1	3
Madison	1	0	1	2	0	0
Marion	5	0	0	0	0	4
Okaloosa	0	0	2	1	5	7
Santa Rosa	0	0	3	0	5	8
Sumter	2	0	0	0	0	2
Suwannee	1	0	0	0	0	0
Taylor	0	1	0	0	0	0
Total	**38**	**9**	**15**	**9**	**19**	**37**

Table 4. The last decade frosted flatwoods salamanders were recorded from sites in a county, including survey data from this study. The number of records refers to breeding ponds or to populations when the breeding pond is unknown.

County	**<1970**	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**
Alachua	1	2	0	0	0	0
Baker	0	0	1	4	0	0
Duval	0	0	1	0	0	0
Franklin	0	0	1	2	2	0
Jefferson	0	0	0	1	2	0
Liberty	0	0	0	19	22	28
Marion	1	0	0	0	0	0
Wakulla	0	0	0	0	47	6
Total	**2**	**2**	**3**	**26**	**73**	**34**

Table 5. The last decade reticulated flatwoods salamanders were recorded from sites in a county. The number of records refers to breeding ponds or to populations when the breeding pond is unknown.

County	<1970	1970s	1980s	1990s	2000s	2010s
Calhoun	4	5	0	4	0	0
Escambia	2	0	0	0	0	0
Gulf	1	1	0	0	0	0
Holmes	0	0	0	1	0	0
Jackson	6	2	1	2	0	0
Okaloosa	0	0	0	9	11	17
Santa Rosa	1	0	0	6	2	4
Walton	0	0	0	1	0	0
Washington	1	0	0	2	1	0
Total	**15**	**8**	**1**	**25**	**14**	**21**

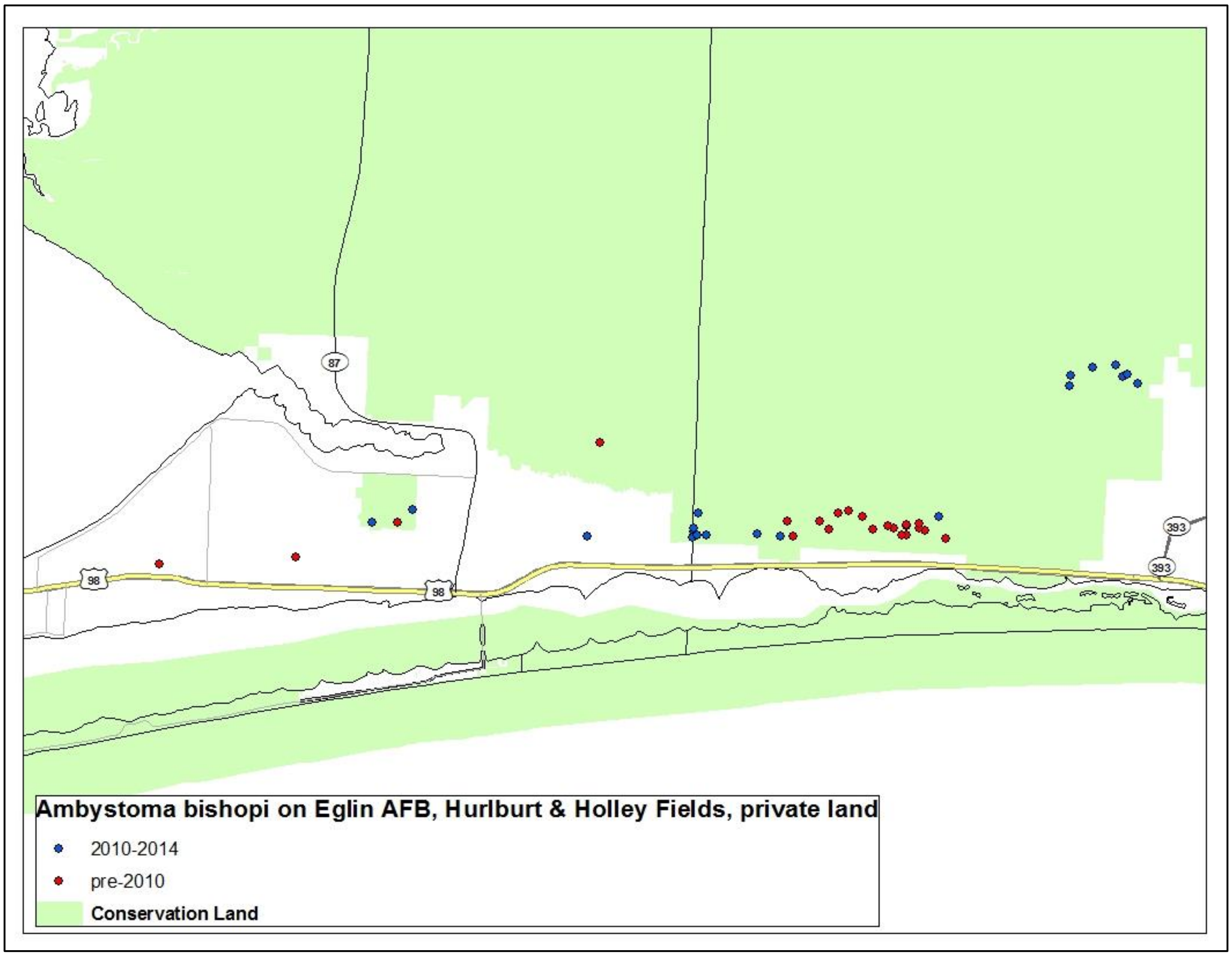


Figure 57. Reticulated flatwoods salamander ponds in southern Okaloosa and Santa Rosa counties, including Eglin AFB, Hurlburt Field, Holley Naval Outlying Landing Field, and private lands.

Ornate Chorus Frog.—The ornate chorus frog is historically known from 28 Florida counties and have been recorded from 21 counties since 2000 (Table 6). Historical ornate chorus frog records are spotty, and the presence of this species was typically not reported during surveys for other amphibians in the 1990s and 2000s. Most records from the 2010s were compiled during this project. We were able to find records of ornate chorus frogs from FWC annual amphibian survey reports prepared for Pine Log, Point Washington, and Blackwater River state forests, resulting in a large number of recent pond records from these sites. The species was once relatively common in mesic and xeric habitats in the northern peninsula, but populations have seriously declined in the past 2 decades. Most peninsular populations are now found in the low-lying Big Bend region, but small populations remain elsewhere, such as Camp Blanding Military Reservation, Jennings State Forest, and Etoniah Creek State Forest. The species is still common in much of the panhandle in both mesic and xeric habitats. After surveys ended, we received reports from Scott Davis (USFWS) of calling frogs on 24–25 November 2014 from 5 new sites in Wakulla County (mostly along a powerline easement), including the first record from the St. Marks Unit of St. Marks NWR. Pierson Hill heard calling frogs and observed amplectant pairs on 24 November 2014 in a pond on Tall Timbers Research Station, Leon County, the first record from the site. We included these Leon and Wakulla County records in Table 6, but they were not included in calculations of pond areas and surrounding habitats.

Table 6. The last decade ornate chorus frogs were recorded from sites in a county, including survey data from this study. The number of records refers to breeding ponds or to populations when the breeding pond is unknown.

County	**<1970**	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**
Alachua	10	0	2	2	1	2
Bay	0	0	0	0	2	2
Bradford	0	0	1	0	1	0
Clay	0	0	0	0	0	6
Columbia	1	0	0	1	1	0
Dixie	0	0	0	0	1	0
Duval	4	0	1	0	0	0
Flagler	0	0	0	1	0	0
Gadsden	1	0	0	1	0	2
Gulf	0	0	0	0	1	0
Holmes	0	1	0	0	0	0
Jackson	1	0	0	0	0	1
Jefferson	0	0	0	0	2	6
Lafayette	0	0	0	0	0	3
Lake	1	0	0	0	0	0
Leon	1	1	1	12	20	3
Levy	0	0	0	0	0	>10
Liberty	2	0	0	0	0	43
Marion	3	0	0	0	0	0
Nassau	2	0	0	0	0	0
Okaloosa	0	0	2	1	5	7
Putnam	1	0	0	0	0	4
St. Johns	3	1	0	0	0	0
Santa Rosa	0	0	6	1	31	1
Taylor	0	0	0	2	11	6
Wakulla	0	1	0	0	0	21
Walton	0	1	0	0	15	41
Washington	0	0	0	0	1	6
Total	**30**	**5**	**13**	**21**	**92**	**>164**

Breeding Pond Characteristics

Size.—Known gopher frog breeding ponds (n =396) ranged in size from 0.01 to 42.27 ha, with a mean size of 1.92 ± 4.10 ha (SD) and a median size of 0.70 ha. Known striped newt breeding ponds (n =124) ranged in size from 0.02 to 12.22 ha, with a mean size of 1.01 ± 1.55 ha and a median size of 0.48 ha. The mean size of breeding ponds for the gopher frog was larger than for the striped newt (P = 0.00029; Student's two-tailed T-test for unequal variance). The mean size of striped newt ponds in the panhandle (n =18) was 0.37 ± 0.50 ha and in the peninsula was 1.12 ± 1.64 ha (n =116). Panhandle newt ponds, where populations may be extinct, were smaller than peninsula newt ponds (P = 0.00031; Student's two-tailed T-test for unequal variance). Known tiger salamander ponds (n =28) ranged in size from 0.04 to 20.65 ha, with a mean size of 1.69 ± 3.84 ha (SD) and a median size of 0.87 ha. Known ornate chorus frog ponds (n =232) ranged in size from 0.01 to 13.65 ha, with a mean size of 0.78 ± 1.45 ha (SD) and a median size of 0.39 ha. These calculations do not include roadside ditches.

Type.—Depression marsh was the most common wetland habitat used by breeding gopher frogs (59.9%) and striped newts (50.4%). Other wetland habitats used by breeding gopher frogs were basin marsh (14.1%), sinkhole pond (11.2%), dome swamp (8.4%), borrow pit (4.2%), sandhill lake (2.5%), and wet prairie (1.4%). Other wetland habitats used by striped newts were sinkhole pond (18.9%), dome swamp (18.0%), basin marsh (9.0%), borrow pit (1.8%), and sandhill lake (1.8%). These wetland types were determined by surveyors and may not agree with landcover classifications (e.g., sandhill lakes may have been called basin marshes). Gopher frogs were more likely to use breeding ponds surrounded by disturbed upland habitats within 300 m of the pond margin, whereas striped newt breeding ponds were usually surrounded by natural xeric habitats.

Surrounding Land Cover.—We conducted landcover analyses within 300 m of amphibian locations (Table 8). On average, sandhill comprised 31% of the land cover surrounding extant gopher frog ponds, with a higher proportion in the panhandle (57%) than in the peninsula (24%). Other predominant land cover classes were pine plantation (17%) and disturbed habitats (9%) in the panhandle, and flatwoods (19%), wetlands (15%), and scrub (14%) in the peninsula (Table 7). Sandhill was the predominant land cover around striped newt ponds, including 76% of historically occupied ponds in the panhandle and 38% in the peninsula. For some comparisons, the 18 known ponds in Apalachicola National Forest were considered as extant instead of possibly extinct. The next most common landcover classes for the striped newt were pine plantations (12%) and disturbed habitats (7%) in the panhandle, with none being surrounded by flatwoods. In the peninsula, the next most common classes were scrub (13%), wetlands (13%), flatwoods (12%), and pine plantations (11%) (Table 7). Compared to extant striped newt populations, presumably extinct populations had reduced coverage by natural habitats (14% as much sandhill, 50% as much flatwoods, and no scrub) and increased coverage by anthropogenically altered habitats, including 6 times more disturbed habitat and 4 times more mixed or hardwood forest (result of fire suppression).

Predominant landcover classes within 300 m of extant tiger salamander ponds were upland pine (40%), disturbed habitats (29%), and pine plantations (13%) (Table 7). There were differences in land cover around extant ponds in the panhandle versus the peninsula. Panhandle ponds had almost 10 times more upland pine forest coverage, and peninsula ponds had 7 times more mixed or hardwood forest coverage and 2 times more disturbed habitat and wetland coverage (Table 7). Overall, records from recorded locations of presumably extinct populations had 2 times more disturbed habitat coverage than extant populations and substantial reductions in upland pine forest, mixed or hardwood forest, and pine plantation coverage (Table 7), indicating that development may be primarily responsible for population declines.

Predominant landcover classes within 300 m of extant frosted flatwoods salamander ponds were flatwoods (35%), wetlands (29%), upland pine forest (13%), pine plantations (11%), and disturbed habitats (11%) (Table 7). Because flatwoods salamanders have selective wetland habitat requirements and conditions can degrade quickly in the absence of fire, we used more stringent criteria for defining presumably extant versus extinct populations than for other species. We considered a pond to have an extant population if a record of the species existed from the pond since 1999, and we considered a record of an adult specimen that was not found in a pond to represent an extant population if a pond with suitable conditions was nearby. Some of the presumably extinct populations might be extant; thus, landcover differences between extinct and extant populations might not be as great as for other species. Compared to extinct ponds, extant ponds had 50% less pine plantation coverage and 1.3 times more flatwoods coverage, suggesting that silviculture may be the primary contributing factor to population declines. Extinct records had 60% less flatwoods, 1.7 times as much pine plantation, and 2.6 times as much disturbed habitat coverage as extant records (Table 7). Land cover around extant reticulated flatwoods salamander ponds differed from that around extant frosted flatwoods salamander ponds in having 1.8 times as much flatwoods (62%), 50% less wetland habitat (15%), only 1% upland pine forest, and no mixed or hardwood forest (Table 7).

Predominant landcover classes within 300 m of extant ornate chorus frog ponds were sandhill (23%), flatwoods (18%), wetlands (18%), upland pine forest (17%), and pine plantations (12%) in the panhandle and pine plantations (52%) wetlands (13%), flatwoods (12%), and disturbed habitats (10%) in the peninsula (Table 7). Sandhill comprised only an average of 7% of the land cover around ornate chorus frog ponds in the peninsula. For all ornate chorus frog records in the peninsula, presumably extinct populations had about 50% less pine plantation coverage and 3.5 times as much disturbed habitat as extant populations (Table 7), suggesting that development of upland habitat, including pine plantations, may be a contributing factor to population declines.

Amphibian and Fish Communities.—When gopher frog tadpoles were present in ponds (n =238), the most common additional amphibian larvae present were southern leopard frog (76.9%), barking treefrog (42.9%), southern cricket frog (38.7%), and pine woods treefrog (32.4%) (Table 8). Larvae of 15 anuran and 4 caudate species were recorded from gopher frog breeding ponds (Table 8). When striped newts were present in ponds (n =61), the most common additional amphibian larvae present were southern leopard frog (73.8%), barking treefrog (57.4%), pine woods treefrog (50.8%), and southern cricket frog (49.2%) (Table 8). Larvae of 13 anuran and 2 caudate species were recorded from striped newt breeding ponds (Table 8). Adult southern cricket frogs were observed or heard calling at most gopher frog and striped newt ponds. Although tadpoles of 4 other ranid species potentially can be present in gopher frog ponds, pig frog (*Lithobates grylio*) and American bullfrog (*L. catesbeianus*) tadpoles are more likely to be present in striped newt ponds, indicating that striped newt ponds may have longer hydroperiods than gopher frog ponds. In 2 ponds, tadpoles of 3 other ranid species were present with gopher frog tadpoles. Crayfishes were present in 38.2% of gopher frog and 39.3% of striped newt ponds. Fishes were present in 17.2% of gopher frog and 11.5 % of striped newt ponds. Eastern mosquitofish was present in all 7 striped newt ponds containing fish, and 1 additional fish species was present in 3 ponds: pygmy sunfish (*Elassoma* spp.), least killifish (*Heterandria formosa*), or

Table 7. Mean proportion (± SD) of landcover classes within 300 m of location points for the target amphibian species. Extant and extinct records include all observations, not just pond locations.

Species	No.	Sandhill	Scrub	Flatwoods	Upland pine	Mixed or hardwood	Pine Plantation	Disturbed habitats	Wetland habitats
Gopher frog									
Extant ponds	427	0.31 ± 0.36	0.11 ± 0.25	0.17 ± 0.27	0.02 ± 0.08	0.03 ± 0.11	0.11 ± 0.23	0.11 ± 0.19	0.14 ± 0.15
Panhandle	89	0.57 ± 0.35	0.0 0± 0.02	0.07 ± 0.14	0.01 ± 0.03	0.00 ± 0.01	0.17 ± 0/26	0.09 ± 0.17	0.08 ± 0.08
Peninsula	338	0.24 ± 0.32	0.14 ± 0.27	0.19 ± 0.29	0.02 ± 0.09	0.04 ± 0.13	0.09 ± 0.22	0.12 ± 0.20	0.15 ± 0.16
Striped newt									
Extant ponds	124	0.44 ± 0.37	0.11 ± 0.26	0.10 ± 0.22	0.03 ± 0.10	0.02 ± 0.08	0.11 ± 0.21	0.07 ± 0.19	0.12 ± 0.14
Panhandle	18	0.76 ± 0.21	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.03	0.00 ± 0.00	0.12 ± 0.18	0.07 ± 0.17	0.04 ± 0.04
Peninsula	106	0.38 ± 0.36	0.13 ± 0.27	0.12 ± 0.23	0.04 ± 0.11	0.02 ± 0.09	0.11 ± 0.22	0.07 ± 0.20	0.13 ± 0.15
Extant records	137	0.42 ± 0.37	0.11 ± 0.25	0.10 ± 0.22	0.03 ± 0.10	0.01 ± 0.08	0.10 ± 0.21	0.08 ± 0.12	0.13 ± 0.15
Extinct records	29	0.06 ± 0.19	0.00 ± 0.01	0.05 ± 0.12	0.07 ± 0.14	0.04 ± 0.14	0.18 ± 0.28	0.34 ± 0.29	0.26 ± 0.29
Tiger Salamander									
Extant ponds	33	0.03 ± 0.14	0.00 ± 0.00	0.01 ± 0.02	0.40 ± 0.37	0.06 ± 0.14	0.13 ± 0.23	0.29 ± 0.30	0.09 ± 0.13
Panhandle	27	0.03 ± 0.15	0.00 ± 0.00	0.01 ± 0.02	0.48 ± 0.36	0.03 ± 0.10	0.13 ± 0.22	0.25 ± 0.27	0.07 ± 0.12
Peninsula	6	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.13	0.21 ± 0.21	0.13 ± 0.32	0.49 ± 0.38	0.14 ± 0.18
Extant records	90	0.03 ± 0.08	0.00 ± 0.00	0.00 ± 0.02	0.22 ± 0.31	0.09 ± 0.16	0.12 ± 0.22	0.41 ± 0.33	0.11 ± 0.20
Extinct records	13	0.01 ± 0.02	0.00 ± 0.00	0.01 ± 0.02	0.06 ± 0.08	0.01 ± 0.03	0.01 ± 0.05	0.81 ± 0.19	0.04 ± 0.06
Frosted flatwoods									
Extant ponds	107	0.00 ± 0.00	0.00 ± 0.00	0.35 ± 0.31	0.13 ± 0.22	0.05 ± 0.09	0.11 ± 0.19	0.11 ± 0.07	0.29 ± 0.19
Extinct ponds	24	0.00 ± 0.00	0.00 ± 0.00	0.27 ± 0.32	0.14 ± 0.23	0.00 ± 0.00	0.22 ± 0.27	0.11 ± 0.10	0.27 ± 0.24
Extant records	113	0.01 ± 0.03	0.00 ± 0.00	0.34 ± 0.31	0.14 ± 0.22	0.05 ± 0.10	0.13 ± 0.21	0.07 ± 0.11	0.28 ± 0.19
Extinct records	46	0.00 ± 0.00	0.00 ± 0.00	0.20 ± 0.27	0.14 ± 0.22	0.00 ± 0.01	0.22 ± 0.19	0.18 ± 0.23	0.26 ± 0.22
Reticulated flatwoods									
Extant ponds	43	0.01 ± 0.006	0.01 ± 0.04	0.62 ± 0.30	0.01 ± 0.07	0.00 ± 0.00	0.07 ± 0.14	0.12 ± 0.17	0.15 ± 0.16
Ornate chorus frog									
Extant ponds	240	0.21 ± 0.32	0.01 ± 0.05	0.18 ± 0.26	0.15 ± 0.30	0.01 ± 0.05	0.17 ± 0.26	0.10 ± 0.17	0.18 ± 0.21
Panhandle	211	0.23 ± 0.33	0.01 ± 0.05	0.18 ± 0.26	0.17 ± 0.31	0.01 ± 0.03	0.12 ± 0.21	0.10 ± 0.18	0.18 ± 0.21
Peninsula	29	0.07 ± 0.13	0.00 ± 0.00	0.12 ± 0.21	0.01 ± 0.04	0.05 ± 0.09	0.52 ± 0.27	0.10 ± 0.09	0.13 ± 0.14
Extant records from peninsula	46	0.04 ± 0.10	0.00 ± 0.00	0.08 ± 0.18	0.01 ± 0.04	0.04 ± 0.09	0.53 ± 0.25	0.11 ± 0.09	0.19 ± 0.18
Extinct records from peninsula	17	0.00 ± 0.02	0.00 ± 0.00	0.12 ± 0.29	0.04 ± 0.07	0.05 ± 0.10	0.24 ± 0.28	0.38 ± 0.30	0.16 ± 0.17

Table 8. Species found in ponds along with target amphibian species. Numbers represent the number of ponds; a pond may be counted more than once if at least 6 months separated visits. Only amphibian larvae are included, but adult southern cricket frogs were observed or heard calling at most ponds. Amphibian names follow Crother et al. (2012).

Species	**Gopher Frog**	**Striped Newt**	**Flatwoods Salamander**	**Ornate Chorus Frog**
Anurans				
Southern Cricket Frog (*Acris gryllus*)	92	30	1	6
Oak/Southern Toad (*Anaxyrus quercicus/terrestris*)	14	6	0	4
E. Narrow-mouthed Toad (*Gastrophryne carolinensis*)	1	0	0	1
Pine Woods Treefrog (*Hyla femoralis*)	77	31	0	2
Barking Treefrog (*Hyla gratiosa*)	102	35	0	5
Squirrel Treefrog (*Hyla squirella*)	3	1	0	0
Gopher Frog (*Lithobates capito*)	238	34	0	3
American Bullfrog (*Lithobates catesbeianus*)	15	10	0	0
Green Frog (*Lithobates clamitans*)	3	5	0	0
Pig Frog (*Lithobates grylio*)	31	20	0	1
Southern Leopard Frog (*Lithobates sphenocephalus*)	183	45	9	40
Spring Peeper (*Pseudacris crucifer*)	2	0	0	1
Southern Chorus Frog (*Pseudacris nigrita*)	0	0	4	16
Little Grass Frog (*Pseudacris ocularis*)	9	1	0	7
Ornate Chorus Frog (*Pseudacris ornata*)	3	1	12	77
Eastern Spadefoot (*Scaphiopus holbrookii*)	3	0	0	4
Caudates				
Frosted Flatwoods Salamander (*Ambystoma cingulatum*)	0	0	19	12
Mole Salamander (*Ambystoma talpoideum*)	13	1	0	3
Dwarf Salamander (*Eurycea quadridigitata*)	0	0	11	33
Striped Newt (*Notophthalmus perstriatus*)	21	61	0	0
Eastern Newt (*Notophthalmus viridescens*)	3	0	1	1
Dwarf Siren (*Pseudobranchus* spp.)	3	0	0	0
Fishes				
Pygmy Sunfish (*Elassoma* spp.)	15	1	11	33
Bluespotted Sunfish (*Enneacanthus gloriosus*)	0	0	2	3
Swamp Darter (*Etheostoma fusiforme*)	1	0	0	0
Grass Pickerel (*Esox americanus*)	0	0	3	2
Golden Topminnow (*Fundulus chrysotus*)	0	0	2	0
Banded Topminnow (*Fundulus cingulatus*)	2	0	0	0
Eastern Mosquitofish (*Gambusia holbrooki*)	30	7	11	12
African Jewelfish (*Hemichromis letourneuxi*)	1	0	0	0
Least Killifish (*Heterandria formosa*)	1	1	3	0
Brown Hoplo (*Hoplosternum littorale*)	1	0	0	0
American Flagfish (*Jordanella floridae*)	0	0	4	0
Pygmy Killifish (*Leptolucania ommata*)	0	0	4	0
Sailfin Molly (*Poecilia latipinna*)	0	1	0	0
None	197	54	4	41
Crayfishes	91	24	18	54
None	147	37	1	23

sailfin molly (*Poecilia latipinna*). Seven different fish species were present in gopher frog ponds, with mosquitofish (58.8%) and pygmy sunfish (29.4%) being the most common.

Fish populations are dynamic; ponds containing fish during 1 survey sometimes lacked fish during other surveys. Because of the dynamic nature of faunal populations in ephemeral wetlands, we only included species that were present when the target species were found; additional species may have been found during other pond visits. For example, a pond on Triple N Ranch WMA contained mosquitofish, pygmy sunfish, and brown hoplos (*Hoplosternum littorale*) when gopher frog tadpoles were discovered in February 2012. These fishes probably colonized the pond when a nearby stream flooded. This pond dried the following winter, and no fishes were present in January 2014 when striped newts were discovered in the pond. The most productive striped newt pond in Faver-Dykes State Park contained mosquitofish in 2010 but not in 2013 and 2014. Predatory fish species were not present in any ponds used by gopher frogs or striped newts, but surveys were terminated once predatory centrarchid species – bluegill (*Lepomis macrochirus*), warmouth, largemouth bass (*Micropterus salmoides*) − were detected. The African jewelfish (*Hemichromis letourneuxi*) was found in a gopher frog pond in Manatee County, and this nonnative species has invaded ponds at Archbold Biological Station, Highlands County (Betsie Rothermel, pers. comm.). Fish densities may also be a factor in determining whether ponds are suitable for larval survival. Mosquitofish can be present at very high densities, particularly in the shallowest portions of ponds. In some ponds with striped newts or gopher frog tadpoles, only a few mosquitofish were dipnetted, indicating low population densities.

When flatwoods salamander larvae were present in ponds (n =19), the most common additional amphibian larvae present were ornate chorus frog (63.2%), dwarf salamander (57.9%), and southern leopard frog (47.4%) (Table 8). Dwarf salamanders were probably more common than indicated, but larvae sometimes escaped through the mesh of dipnets before being detected. Only 4 anuran and 3 caudate species were found in flatwoods salamander ponds (Table 8), partly because flatwoods salamander larvae were present before the spring/summer breeding season of many amphibian species. Eight fish species were present in breeding ponds, with mosquitofish (28.2%) and pygmy sunfish (28.2%) being the most common (Table 8). Fishes were present in 78.9% of ponds, and crayfishes were present in 94.7%. Five fish species were found in 2 ponds, and 2 ponds contained grass pickerel.

When ornate chorus frog tadpoles were present in ponds (n =76), the most common additional amphibian larvae present were southern leopard frog (52.6%), dwarf salamander (40.8%), southern chorus frog (21.0%), and frosted flatwoods salamander (15.8%) (Table 8). Thirteen anuran, 4 caudate, and 4 fish species were found in ornate chorus frog ponds (Table 8). Only 1 of 22 ornate chorus frog ponds embedded in sandhill or upland pine habitats contained fish, whereas fishes were more common in ponds situated in mesic flatwoods, such as in Apalachicola National Forest, which contained 56.6% of the breeding ponds dipnetted. Overall, fishes were present in 46.0% of ponds, and crayfishes were present in 69.7% of ponds (Table 8). Amphibian species richness in ornate chorus frog ponds in flatwoods habitat was much lower than in ponds in sandhill habitats. At least 2 different breeding events occurred in some ponds in 2014; the prolonged period of time when larvae were present resulted in temporal overlap with larvae of spring/summer breeding amphibian species.

Potential Habitat Models

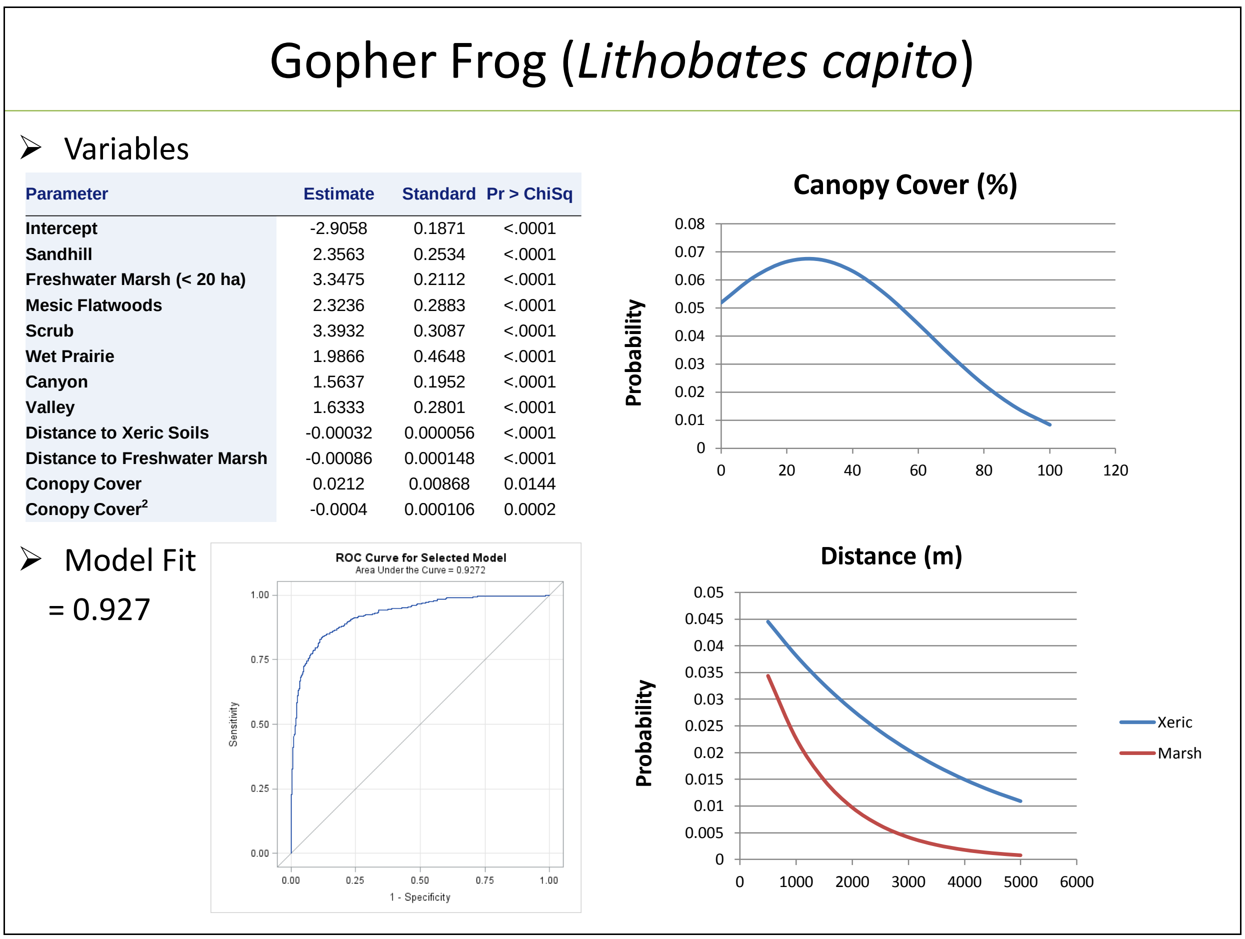
Gopher Frog.—Potential habitat models were developed for the gopher frog, striped newt, tiger salamander, and ornate chorus frog. The model fit (Area Under the Curve [AUC]) is 0.927 for the RSF potential habitat map developed for the gopher frog (Fig. 58). Of the 338 gopher frog locations used, 49.4% are in freshwater marshes, 12.1% in sandhill, 8.6% in scrub, and 6.8% in mesic flatwoods. The RSF model identifies a total of 258,722 ha of potential habitat, 85.7% of which is considered good habitat (Figs. 59, 61, 63). Conservation lands contain 41.4% of the total habitat and 42.6% of the good habitat. One hundred eighty-two conservation lands contain at least 50 ha of potential habitat. Ocala National Forest has 3.6 times more potential habitat than Eglin AFB, the conservation land with the next greatest amount of habitat (Table 9). Among the top 10 conservation lands in terms of habitat (Table 9), we failed to find gopher frogs during 1 survey of Avon Park Air Force Range and Duette Preserve, although the species has previously been recorded from these sites (only 1 record from a burrow in Duette Preserve). There are also records from Merritt Island NWR, but the interdunal swales used as breeding sites never filled with water in 2013−2014 when our survey permit was valid.

Table 9. Top 10 conservation lands in total amount of identified potential habitat (ha) for each amphibian species. Figures in parentheses are ha of potential habitat on lower-ranked lands that are in the 10 for at least 1 other species. For the gopher frog, results of the Resource Selection Function and rules-based GIS habitat models are provided. For the other species, Maxent models were used.

Conservation Land	Gopher Frog RSF Model	Gopher Frog GIS Model	Striped Newt	Tiger Salamander	Ornate Chorus Frog
Apalachicola National Forest	2,220	29,163	3,332	6,468	78,106
Avon Park Air Force Range	1,991	15,825	(658)	(0)	(0)
Blackwater River State Forest	(373)	31,106	(0)	47,865	47,561
Camp Blanding Military Reservation	(940)	(10,194)	4,127	(<50)	(4,372)
Chassahowitzka Wildlife Management Area	1,045	(2,675)	2,804	(1,275)	(821)
Duette Preserve	1,719	(5,383)	(0)	(0)	(0)
Eglin Air Force Base	9,498	71,301	(0)	7,105	17,731
Fred C. Babcock-Cecil M. Webb WMA	(369)	19,224	(0)	(0)	(0)
Flying Eagle Ranch	(349)	(738)	(1,093)	3,385	(3,209)
Goethe State Forest	(1,126)	(11,058)	2,299	5,760	13,609
Green Swamp	1,456	19,501	(1,032)	3,426	8,719
Lake Wales Ridge State Forest	2,357	(5,877)	1,626	(0)	(0)
Marjorie Harris Carr Cross Fla. Greenway	(815)	(5,338)	1,683	5,964	(2,795)
Merritt Island National Wildlife Refuge	3,629	(12,438)	(654)	(0)	(235)
Ocala National Forest	34,531	96,960	22,644	12,028	5,425
Osceola National Forest	(<50)	(12,322)	(<50)	5,741	19,010
St. Marks National Wildlife Refuge	(938)	(9,129)	3,943	(148)	10,352
Seminole State Forest	1,776	(5,925)	1,455	(1,447)	(3,047)
Tate's Hell State Forest	(549)	(963)	(0)	(569)	27,352
Three Lakes WMA	(295)	15,857	(193)	(0)	(0)
Withlacoochee State Forest	5,310	27,729	7,054	10,981	10,032

The rules-based GIS model that includes 2 km of suitable upland habitat around potential breeding ponds identifies 1,549,034 ha of potential habitat (Figs. 60, 62, 64), which is 6 times more habitat than the RSF model identified. Conservation lands contain 49.6% of potential habitat identified. Only 6 conservation lands are on the top 10 list for both models (Table 9); these lands contain primarily sandhill habitat. The rules-based model has Big Cypress National Preserve and Fred C. Babcock-Cecil M. Webb WMA on the top 10 list (Table 9), but gopher frogs have never been documented on these lands, and Big Cypress is outside the known range of the species. Identification of mesic flatwoods and dry prairie as secondary upland habitats helps account for the large discrepancy between the 2 models and for inclusion in the top 10 of Big Cypress

National Preserve, Fred C. Babcock-Cecil M. Webb WMA, Osceola National Forest, and Three Lakes WMA (Table 9). Only 1 breeding pond is known from Osceola National Forest and 2 possible breeding ponds from Three Lakes WMA. Blackwater River State Forest is identified as having the third greatest amount of potential habitat because upland pine forest is considered secondary upland habitat. Only 1 breeding pond has been found in Blackwater River State few gopher frog records exist from upland pine forest, which has similar vegetative species and structure to sandhill habitat but higher clay content in the soil. The rules-based model that includes a 5-km instead of 2-km buffer around ponds identifies an additional 216,797 ha of potential habitat. The RSF model is much more selective at identifying potential habitat than the rules-based GIS model and should potentially be considered the preferred model, although further analyses are needed to determine accuracy of the 2 models regarding the number of gopher frog locations that fall within identified potential habitat. Modifications of the 2-km rules-based GIS model could make it more selective at identifying potential habitat, and combining the revised model with the RSF model might produce an even more accurate model. A previous rules-based GIS model identified ca. 899,200 ha of potential habitat (Florida Fish and Wildlife Conservation Commission 2011), which is halfway between the amount of habitat identified by the RSF and the 2-km rules-based GIS model.



Parameter	Estimate	Standard	Pr > ChiSq
Intercept	-2.9058	0.1871	<.0001
Sandhill	2.3563	0.2534	<.0001
Freshwater Marsh (< 20 ha)	3.3475	0.2112	<.0001
Mesic Flatwoods	2.3236	0.2883	<.0001
Scrub	3.3932	0.3087	<.0001
Wet Prairie	1.9866	0.4648	<.0001
Canyon	1.5637	0.1952	<.0001
Valley	1.6333	0.2801	<.0001
Distance to Xeric Soils	-0.00032	0.000056	<.0001
Distance to Freshwater Marsh	-0.00086	0.000148	<.0001
Conopy Cover	0.0212	0.00868	0.0144
Conopy Cover^2	-0.0004	0.000106	0.0002

Figure 58. Results of Resource Selection Function model of potential habitat for the gopher frog.

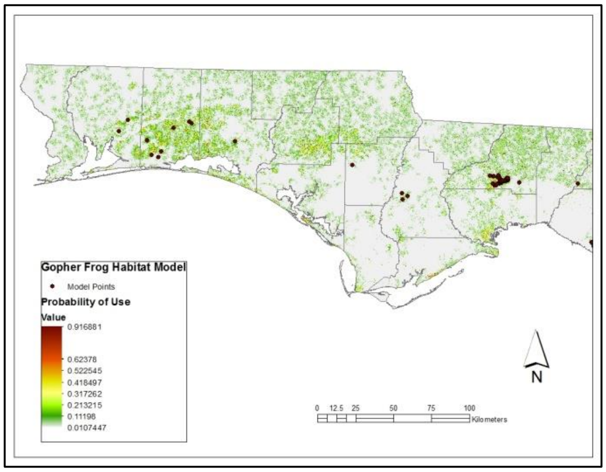


Figure 59. Gopher frog potential habitat identified in the panhandle using the Resource Selection Function model. Dots are 1996–2014 locations.

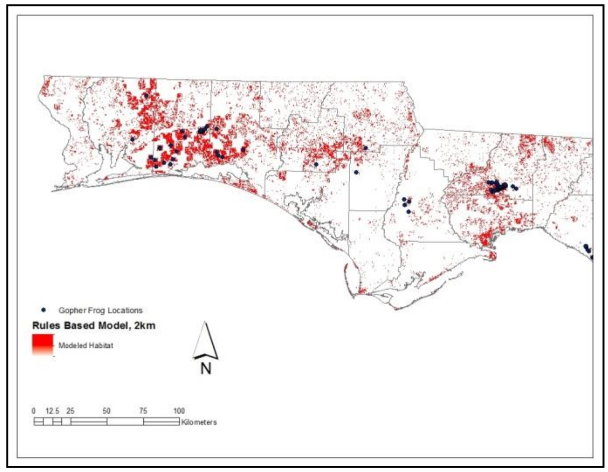


Figure 60. Gopher frog potential habitat (red) identified in the panhandle using the rules-based GIS model. Dots represent presumably extant pond locations.

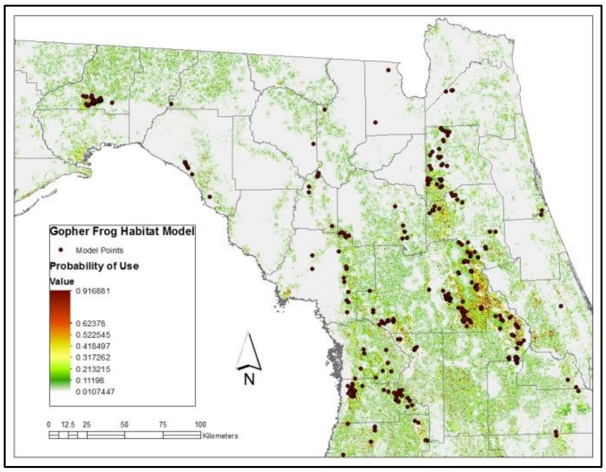


Figure 61. Gopher frog potential habitat identified in the northern peninsula using the Resource Selection Function model. Dots are 1996–2014 locations.

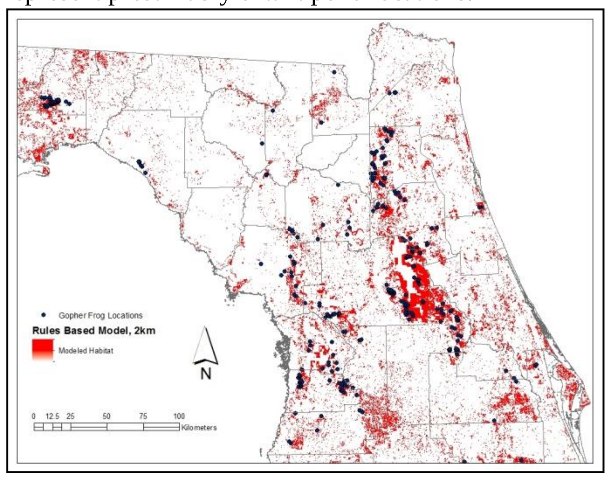


Figure 62. Gopher frog potential habitat (red) identified in the northern peninsula using the rules-based GIS model. Dots represent presumably extant ponds.

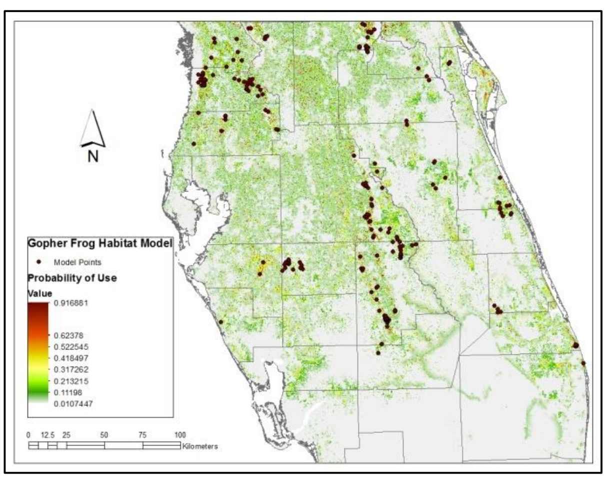


Figure 63. Gopher frog potential habitat identified in the southern peninsula using the Resource Selection Function model. Dots are 1996–2014 locations.

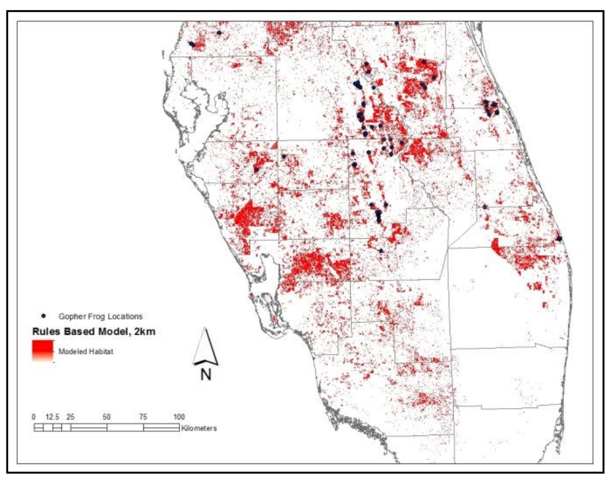


Figure 64. Gopher frog potential habitat (red) identified in the southern peninsula using the rules-based GIS model. Dots represent presumably extant ponds.

Striped Newt.—The Maxent model fit (AUC) for striped newt potential habitat is 0.970 (Fig. 65). The variables land cover and distance to sandhill had the strongest positive influence on the model, whereas elevation and canopy cover had the least influence. Of the 89 locations used, 40.5% are in freshwater marshes, 24.7% in sandhill, and 7.9% in wet prairie. A total of 158,706 ha of potential habitat was identified (Fig. 66), 88.4% of which is considered good. Conservation lands contain 50.2% of the total habitat and 49.4% of the good habitat. One hundred four conservation lands contain at least 50 ha of potential habitat. Ocala National Forest has 3.2 times more potential habitat (Fig. 67) than Withlacoochee State Forest, the conservation land having the second greatest amount of habitat (Table 9), but where striped newts have not been found. Of the 4 other strongholds for the species, Camp Blanding Military Reservation has the most habitat (Table 9), and Jennings State Forest (1,128 ha) and Ordway-Swisher Biological Station (819 ha) have the least (Fig. 68).

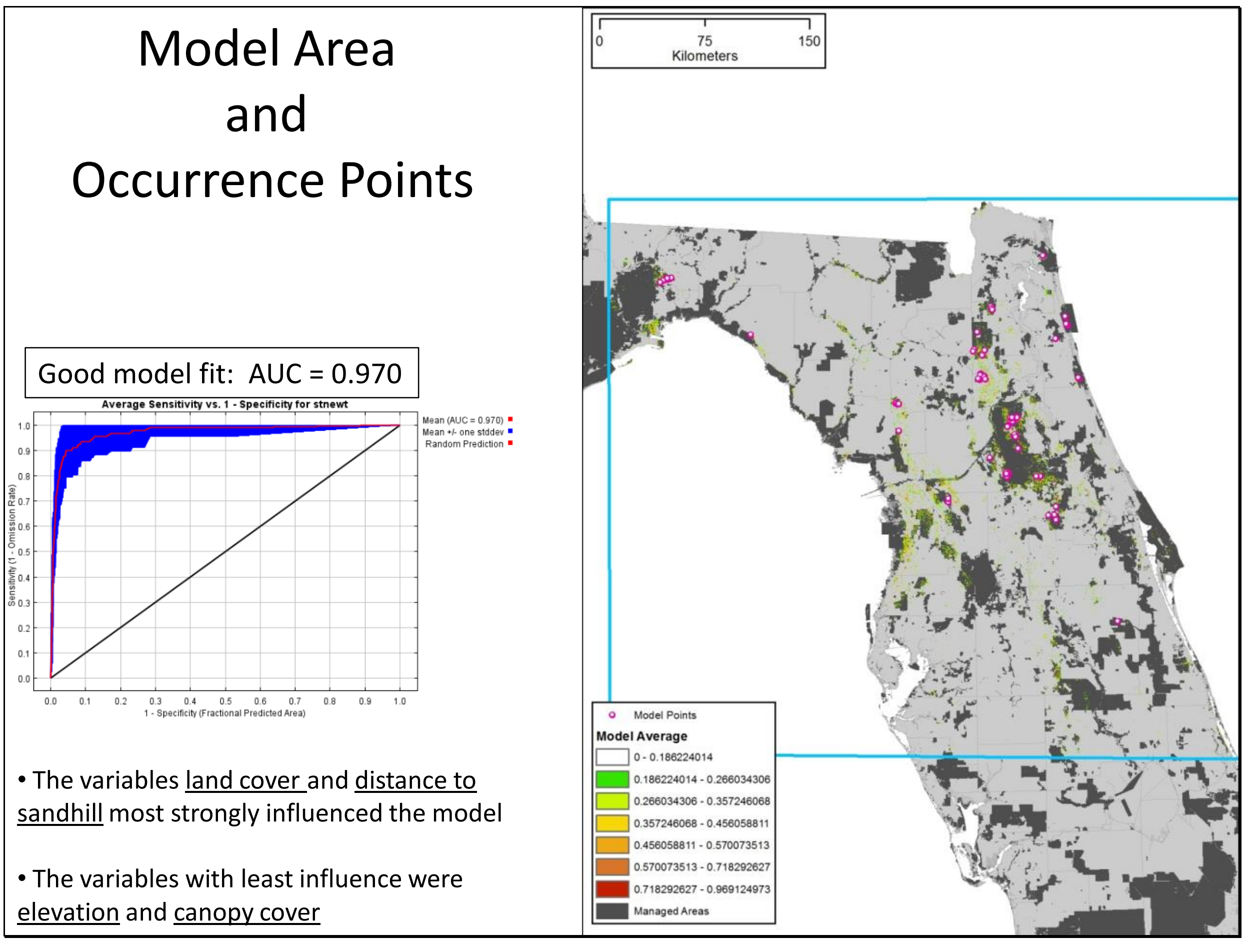


Figure 65. Results of Maxent model of potential habitat for the striped newt. On the map, green or yellow colors indicate potential habitat, and dark gray areas are conservation lands.

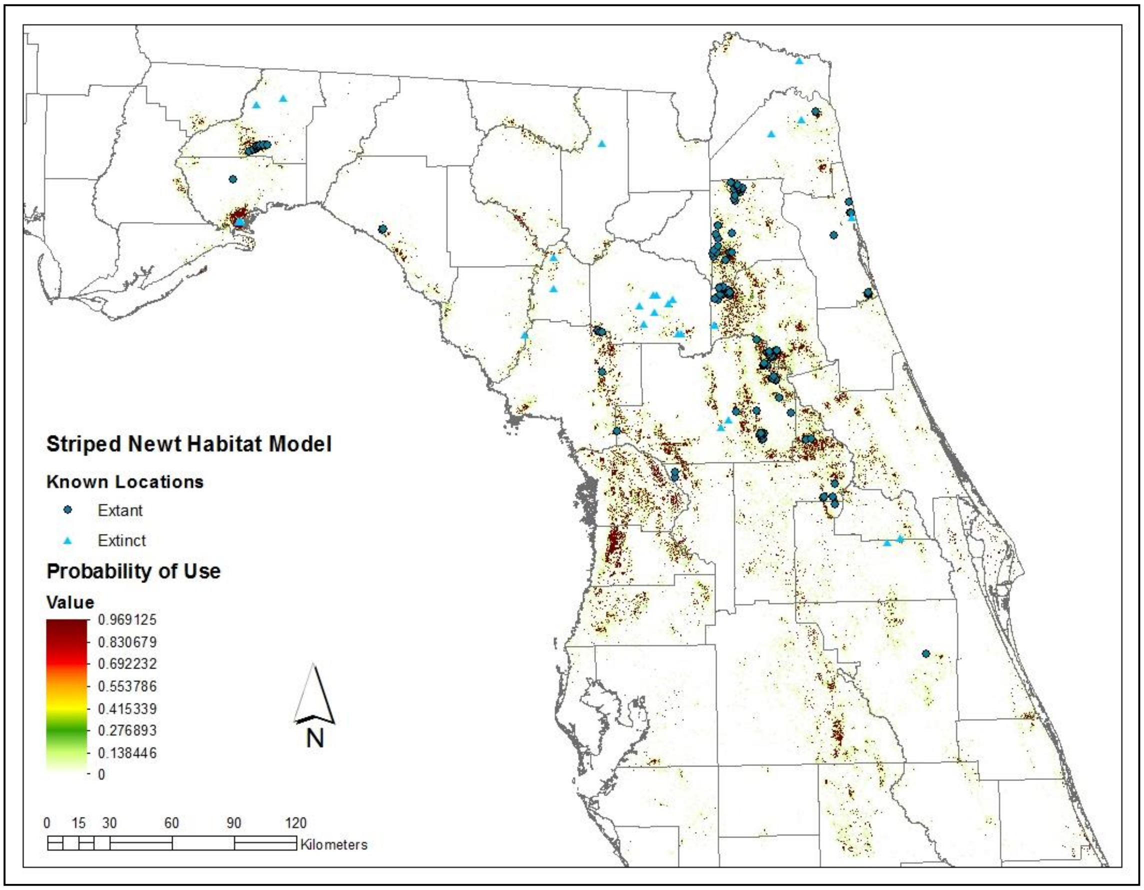


Figure 66. Striped newt potential habitat identified by the Maxent model. Dots represent presumably extant pond locations, including those in Apalachicola National Forest, and triangles presumably extinct pond locations.

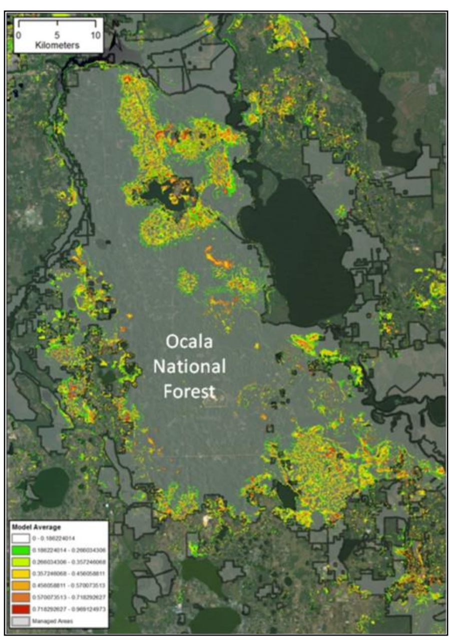


Figure 67. Striped newt potential habitat in Ocala National Forest, which contains the most habitat and at least 38 extant ponds.

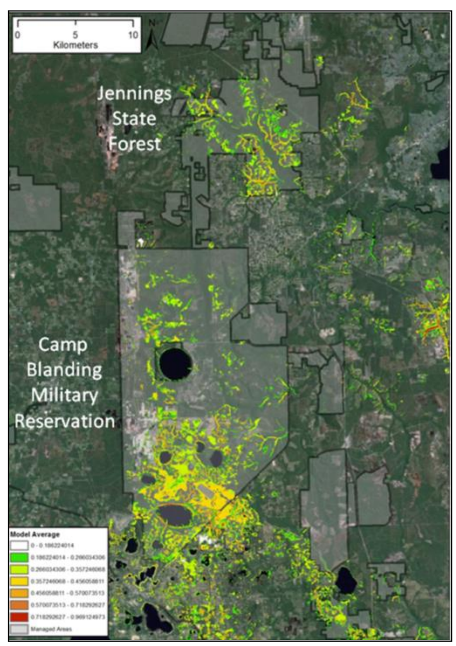


Figure 68. Striped newt potential habitat in Clay Co. where robust populations remain in Camp Blanding Military Reservation and Jennings State Forest.

Tiger Salamander.—The Maxent model fit (AUC) for tiger salamander potential habitat is 0.875 (Fig. 69). The variables distance to 2-ha wetland and land cover had the most influence on the model, whereas mean and minimum temperatures in November−April had the least influence (Fig. 69). The model indicates that tiger salamanders are most likely to be found within 1 km of an ephemeral wetland ≤2 ha in size on clay sands. Of the 55 locations used, 23.6% are in cypress/tupelo, 20.0% in freshwater marshes, 14.5% in upland pine, and 10.9% in mixed hardwood-coniferous forests. A total of 842,564 ha of potential habitat was identified (Figs. 70, 71), 90.7% of which is considered good. Conservation lands contain only 20.9% of the total habitat and 20.2% of the good habitat. Two hundred four conservation lands contain at least 50 ha of potential habitat. Of the top 10 conservation lands with potential habitat (Table 9), tiger salamanders have only been reported from Blackwater River State Forest, Ocala National Forest, and Goethe State Forest. Blackwater River State Forest contains 4 times more potential habitat (Fig. 72) than Ocala National Forest, the conservation land with the second greatest amount of habitat. Inclusion of Ocala National Forest is based on the assumption that a spotted salamander (*Ambystoma maculatum*) reported from Hughes Island (Funderburg et al. 1970) was actually a tiger salamander; we dipnetted the only pond in Hughes Island several times without success. Withlacoochee State Forest has the third greatest amount of potential habitat (Fig. 73). Tiger salamanders have not been reportedfrom there, but records exist from subdivisions and farmlands to the west in Citrus and Hernando counties. The lack of records from Withlacoochee State Forest may be an artifact of insufficient sampling of sandhill wetlands or its occurrence in xeric and mesic hammocks that have never been surveyed. We suspect that the species does not occur in Eglin AFB and Apalachicola National Forest because no records exist south of the Cody Scarp in the panhandle, where sandy instead of clay sand soils predominate.

Ornate Chorus Frog.—The Maxent model fit (AUC) for ornate chorus frog potential habitat is 0.905 (Fig. 74). The variables land cover and hydric rating influenced the model most, whereas distances to 5-ha and 14-ha wetlands had the least influence. A total of 1,231,746 ha of potential habitat was identified (Figs. 75, 76), 86.5% of which is considered good. Conservation lands contain 31.8% of the total habitat and 30.1% of the good habitat. Three hundred thirty-eight conservation lands contain at least 50 ha of potential habitat. Apalachicola National Forest has 1.6 times more potential habitat than Blackwater River State Forest (Fig. 77), the conservation land with the second greatest amount of habitat (Table 9). Ornate chorus frogs have not been reported from areas at the southern extent of their range, including 3 among the top 10 conservation lands with the greatest amount of potential habitat: Withlacoochee State Forest, Green Swamp, and Ocala National Forest (Table 9). Museum records exist from the 1950s and 1960s from an area near Silver Springs, Marion County, so ornate chorus frogs might have historically occurred in the western portion of Ocala National Forest. According to Richard Bartlett (pers. comm.), ornate chorus frogs occurred in Hernando and Pasco counties in the 1960s, which means that they could have also historically occurred in Withlacoochee State Forest and Green Swamp. Extant populations remain in Camp Blanding Military Reservation (4,372 ha of habitat), Jennings State Forest (3,769 ha), and Etoniah Creek State Forest (1,787 ha) (Fig. 78).

Conservation Lands.—For these 4 amphibian species, only 21–50% of the potential habitat identified by the computer-generated models occurs on conservation lands, and there is not much difference in the proportion of good and marginal habitats on conservation versus private lands. The following conservation lands provide at least 300 ha of potential habitat for all 4 species: Apalachicola National Forest (the only panhandle site), Chassahowitzka WMA, Flying Eagle

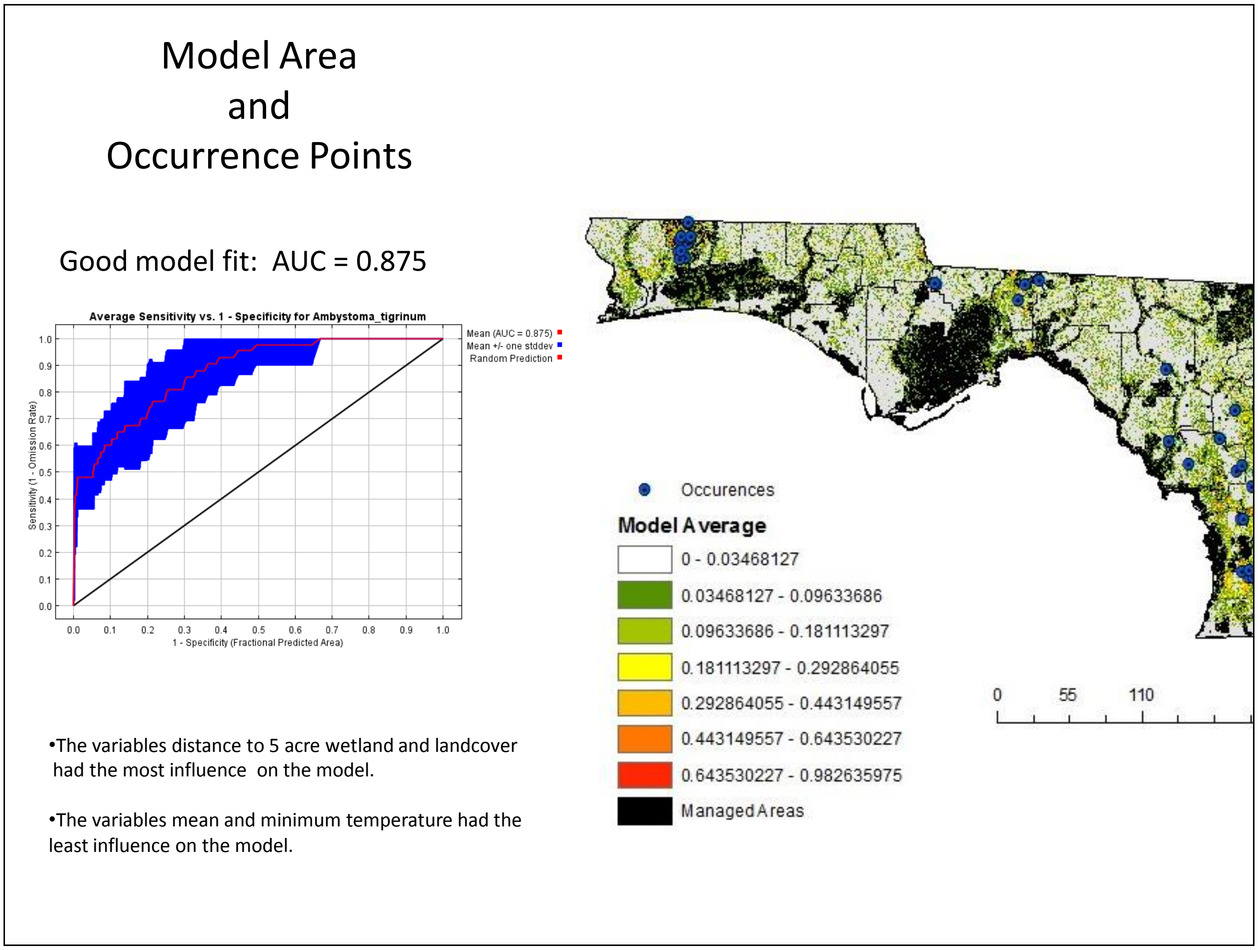


Figure 69. Results of Maxent model of potential habitat for the tiger salamander. On the map, green, yellow , or orange colors indicate potential habitat, and black areas are conservation lands.

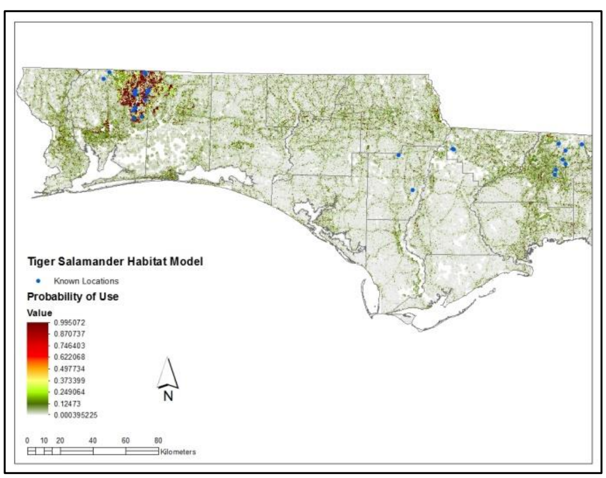


Figure 70. Tiger salamander potential habitat identified by the Maxent model in the panhandle. Dots represent presumably extant locations (pond and other records).

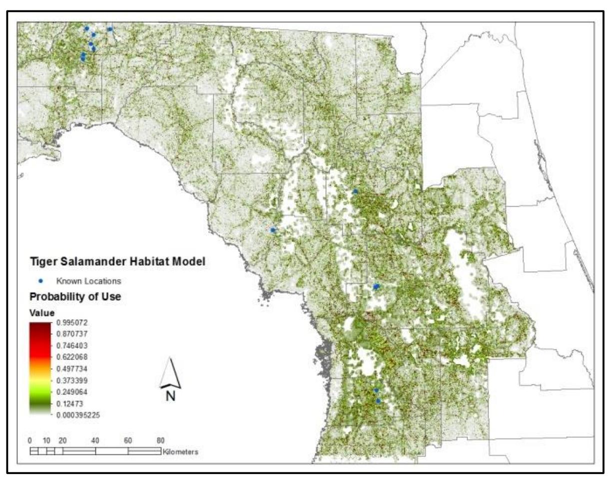


Figure 71. Tiger salamander potential habitat identified by the Maxent model in the peninsula. Dots represent presumably extant locations (ponds and other records).

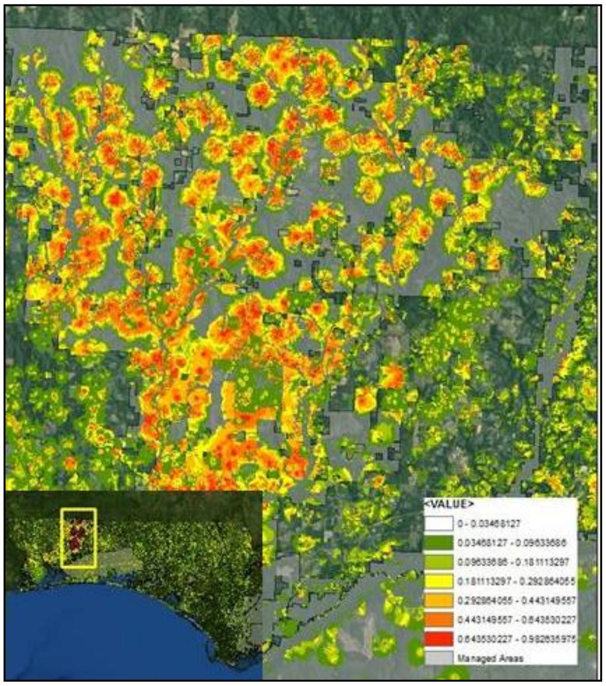


Figure 72. Tiger salamander potential habitat in Blackwater River State Forest, which has the greatest number of known breeding ponds.

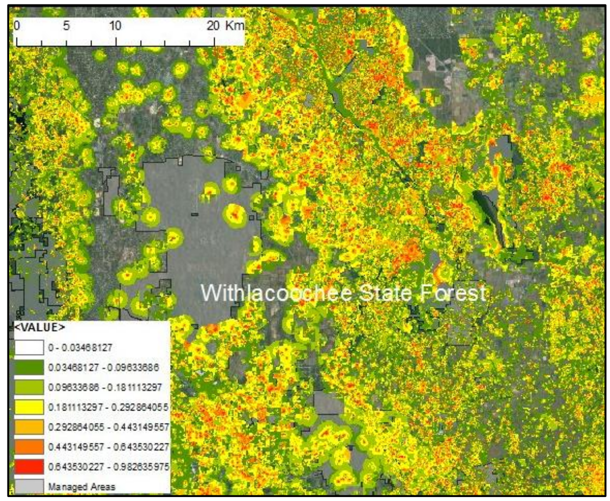


Figure 73. Tiger salamander potential habitat in Withlacoochee State Forest near the southern extent of the species' range.

Ranch, Goethe State Forest, Green Swamp, Half Moon WMA, Marjorie Harris Carr Cross Florida Greenway State Recreation Area, Ocala National Forest, Seminole State Forest, and Withlacoochee State Forest (Table 9). Only Apalachicola National Forest, Ocala National Forest, and Withlacoochee State Forest rank in the top 10 in terms of potential habitat for all 4 species. Of these 10 sites, ornate chorus frogs are known only from Apalachicola National Forest and Goethe State Forest. Striped newts are known from 5 of the 9 peninsular sites, but populations may be extinct in Apalachicola National Forest. In contrast, gopher frogs are known from 9 of the 10 sites and are probably also present on Flying Eagle Ranch in Sumter County, which we did not survey. Only 6,084 ha (0.3%) of the total 2,035,883 ha of potential habitat for all 4 species are shared by all species; 51.0% of this habitat overlap is on conservation lands. Ocala National Forest (871 ha), Seminole State Forest (228 ha), Withlacoochee State Forest (192 ha), and Green Swamp (190 ha) have the most potential habitat overlap for all 4 species.

Climate Change

All drought indices except the Standardized Precipitation Index (SPI), which is based on precipitation data, displayed significant ($P < 0.05$) negative trends over the period of record (indicating increasing drought over time) for all of Florida's climate divisions except the Northwest and North. The trend towards increasing drought was greatest in the North Central and South Central climate divisions. The Palmer Hydrological Drought Index (PHDI) was the drought index that displayed the strongest relationship with time for these divisions. PHDI is a measure of long-term hydrological drought based on precipitation, evapotranspiration, soil moisture, and runoff that incorporates a lag time for environmental recovery from drought (Palmer 1965). For those climate divisions with significant trends in PHDI over time, estimates of the x-intercept

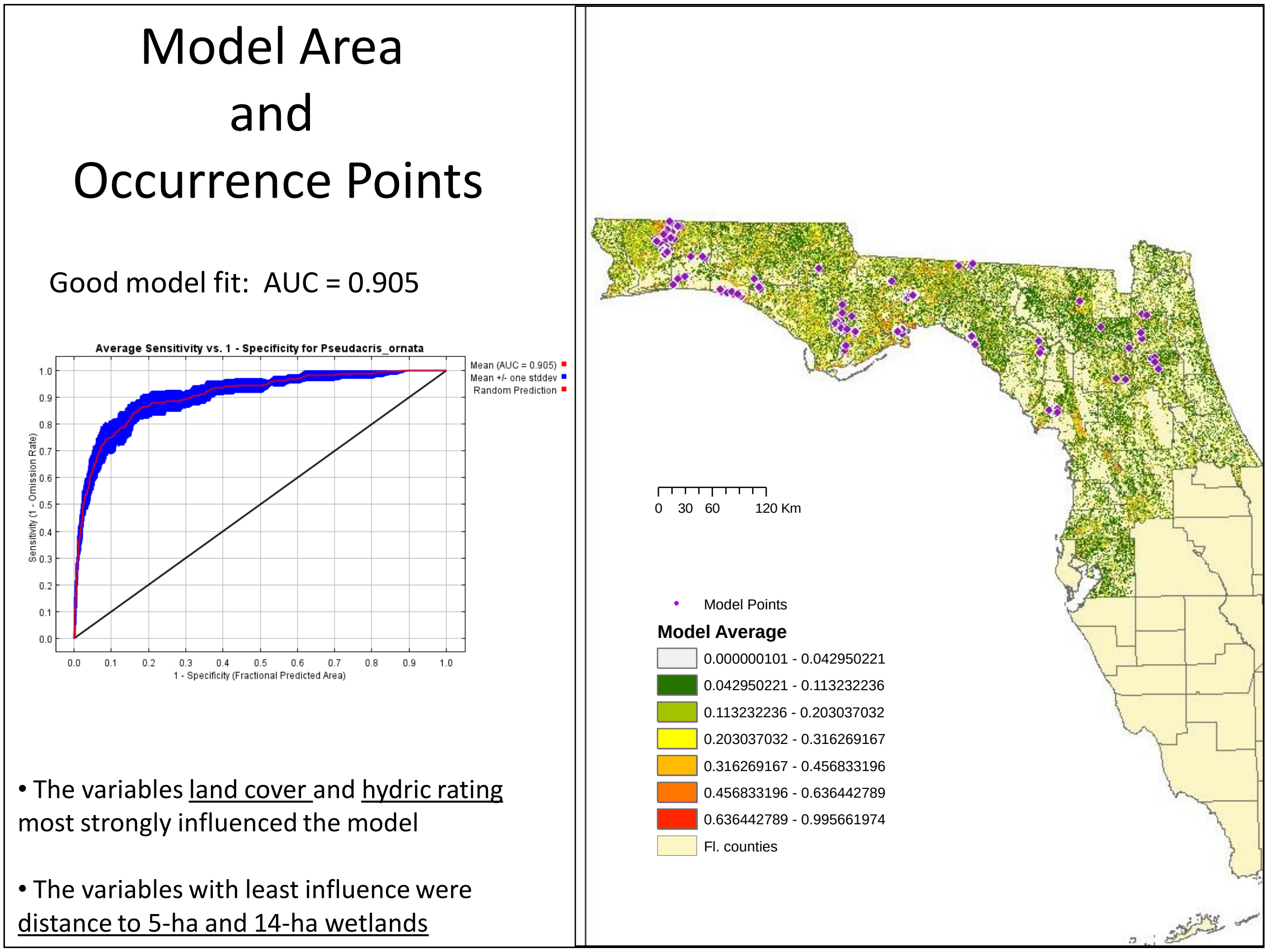


Figure 74. Results of Maxent model of potential habitat for the ornate chorus frog.

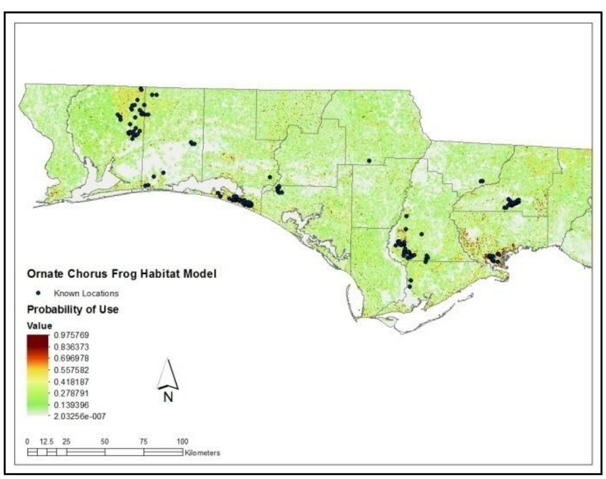


Figure 75. Ornate chorus frog potential habitat identified by the Maxent model in the panhandle. Dots represent presumably extant pond locations.

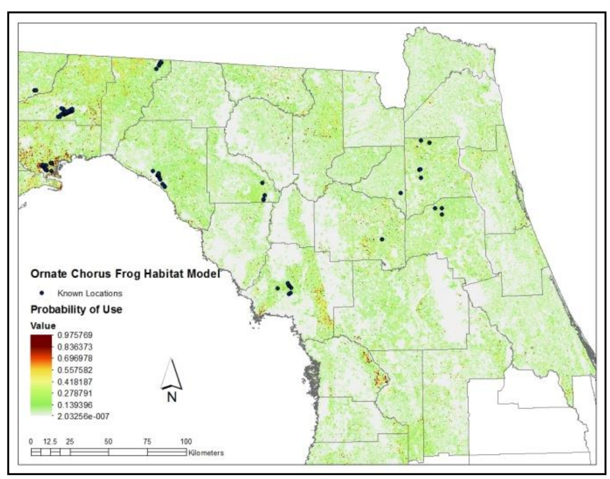


Figure 76. Ornate chorus frog potential habitat identified by the Maxent model in the peninsula. Dots represent presumably extant pond locations.

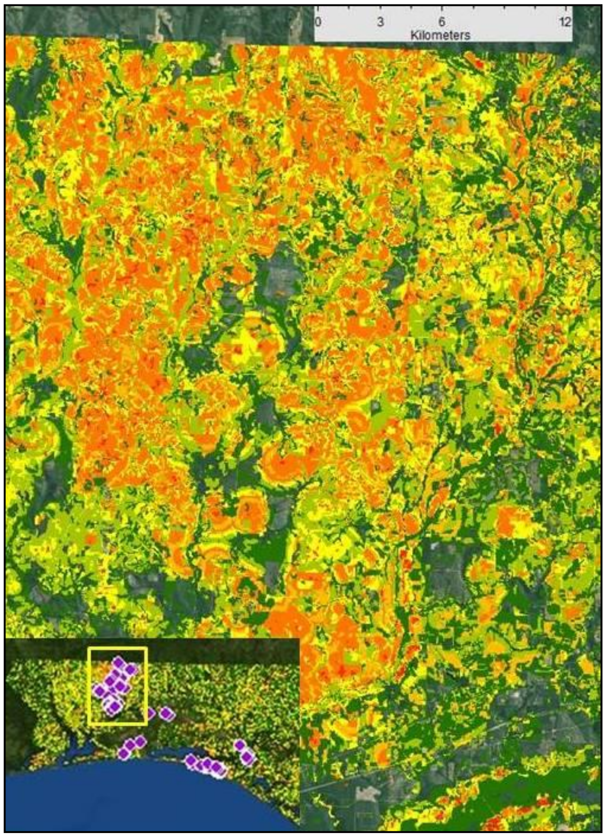


Figure 77. Ornate chorus frog potential habitat in Blackwater River State Forest, the conservation land identified as having the second most habitat.

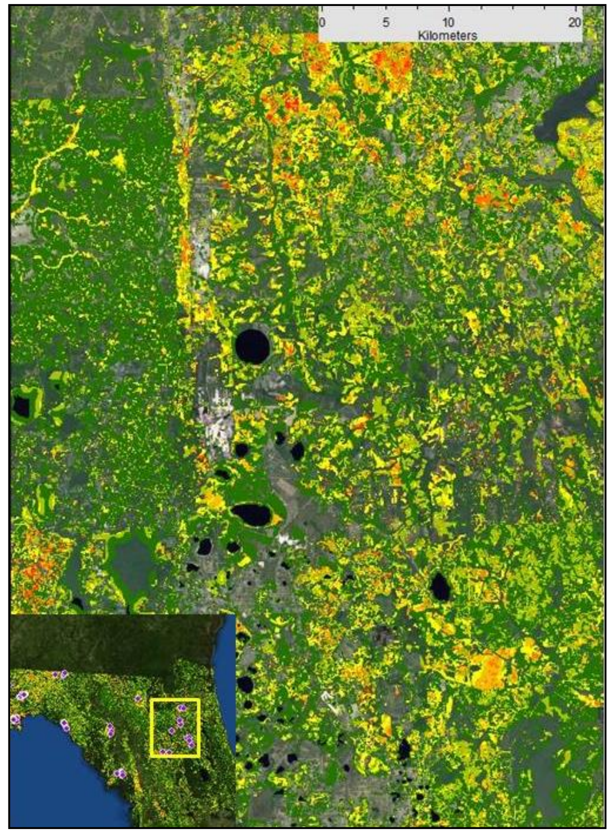


Figure 78. Ornate chorus frog potential habitat in Clay Co., where populations still remain in Camp Blanding Military Reservation and Jennings State Forest.

from linear regression equations indicated that a shift to predominantly drought conditions occurs over various time periods after 1950 (North Central = 1953, South Central = 1961, Everglades/ SW Coast = 1963, Lower East Coast = 1971). The minimum PHDI values before and after these tipping points for each division were similar, indicating that the magnitude of recent droughts is similar to those in the past. On average, however, recent droughts in most of the peninsular divisions (all except the North and Lower East Coast divisions) were less frequent and longer in duration with fewer wet years in the interval between droughts (Fig. 79). When these differences were compared, only drought length in the North Central and South Central divisions was significantly different. The median number of drought years per drought (drought length) was greater ($U = 11.0$, $n_1 = 20$, $n_2 = 6$, $P = 0.008$ 2-tailed) in 1980–2013 (median = 6 years, mean = 5 years) than it was in 1895–1979 (median = 2 years, mean = 1.9 years) in the North Central climate division. The number of drought years per drought was also greater ($U = 20.5$, $n_1 = 16$, $n_2 = 6$, $P = 0.03$ 2-tailed) in 1980–2013 (mean = 3.7 years) than before 1980 (mean = 1.8 years) in the South Central climate division. When monthly changes in PHDI were examined over time, significant decreases ($P < 0.05$) in PHDI were found to occur in the late fall/early winter in the North Central and South Central climate divisions (Fig. 80).

In addition to a long-term trend of increasing drought, linear regressions also revealed significant ($P < 0.05$) increases in average, minimum, and maximum air temperatures in peninsular climate divisions over the last 120 years. These temperature changes follow a gradient

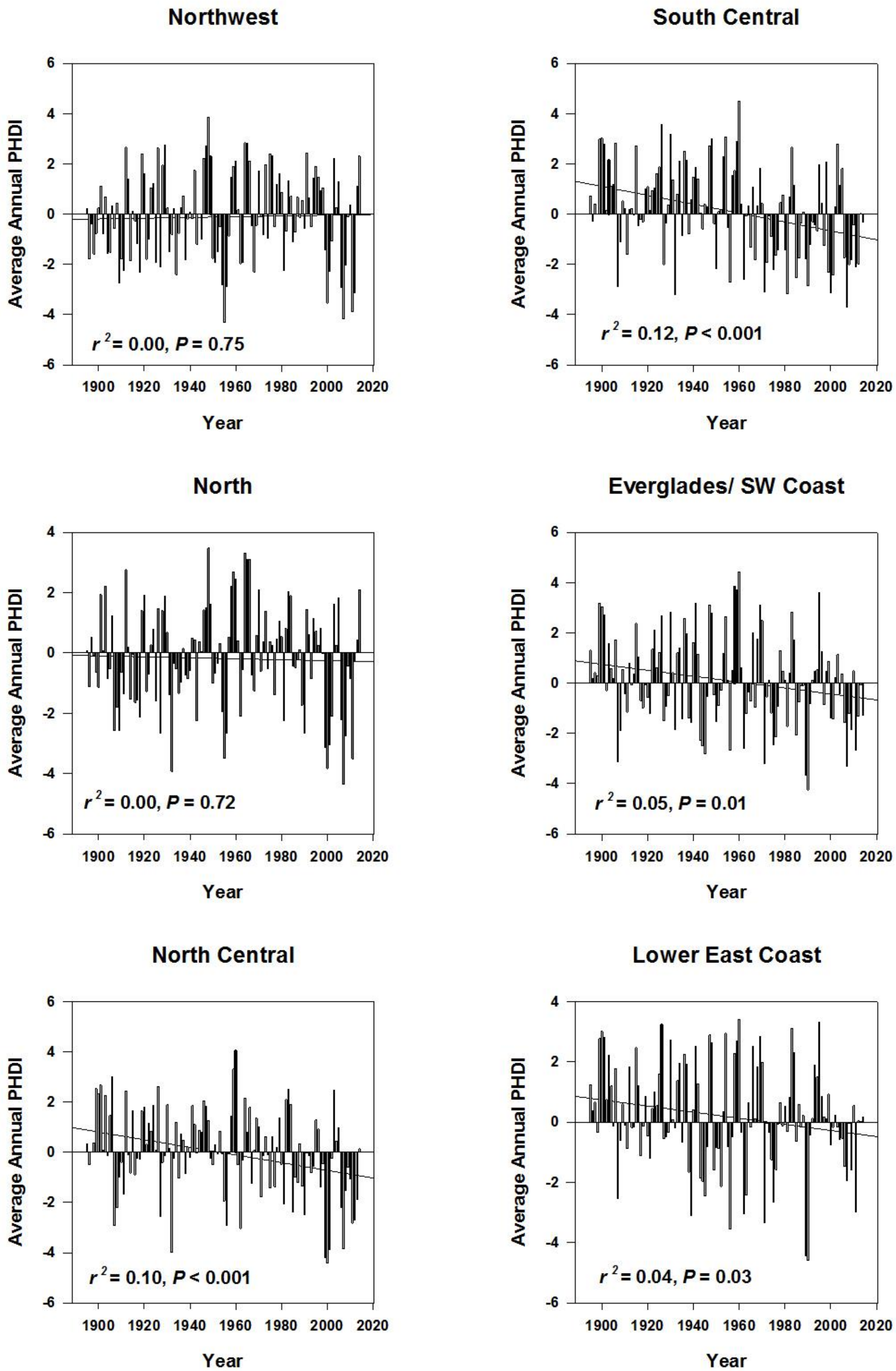


Figure 79. Long-term trend in annual PHDI 1895–2014 in Florida's mainland climate divisions. Negative values denote dry years, and positive values indicate wet years. PHDI values 0 to -0.5 = normal; -0.5 to -1.0 = incipient drought; -1.0 to - 2.0 = mild drought; -2.0 to -3.0 = moderate drought; -3.0 to -4.0 = severe drought; and greater than -4.0 = extreme drought.

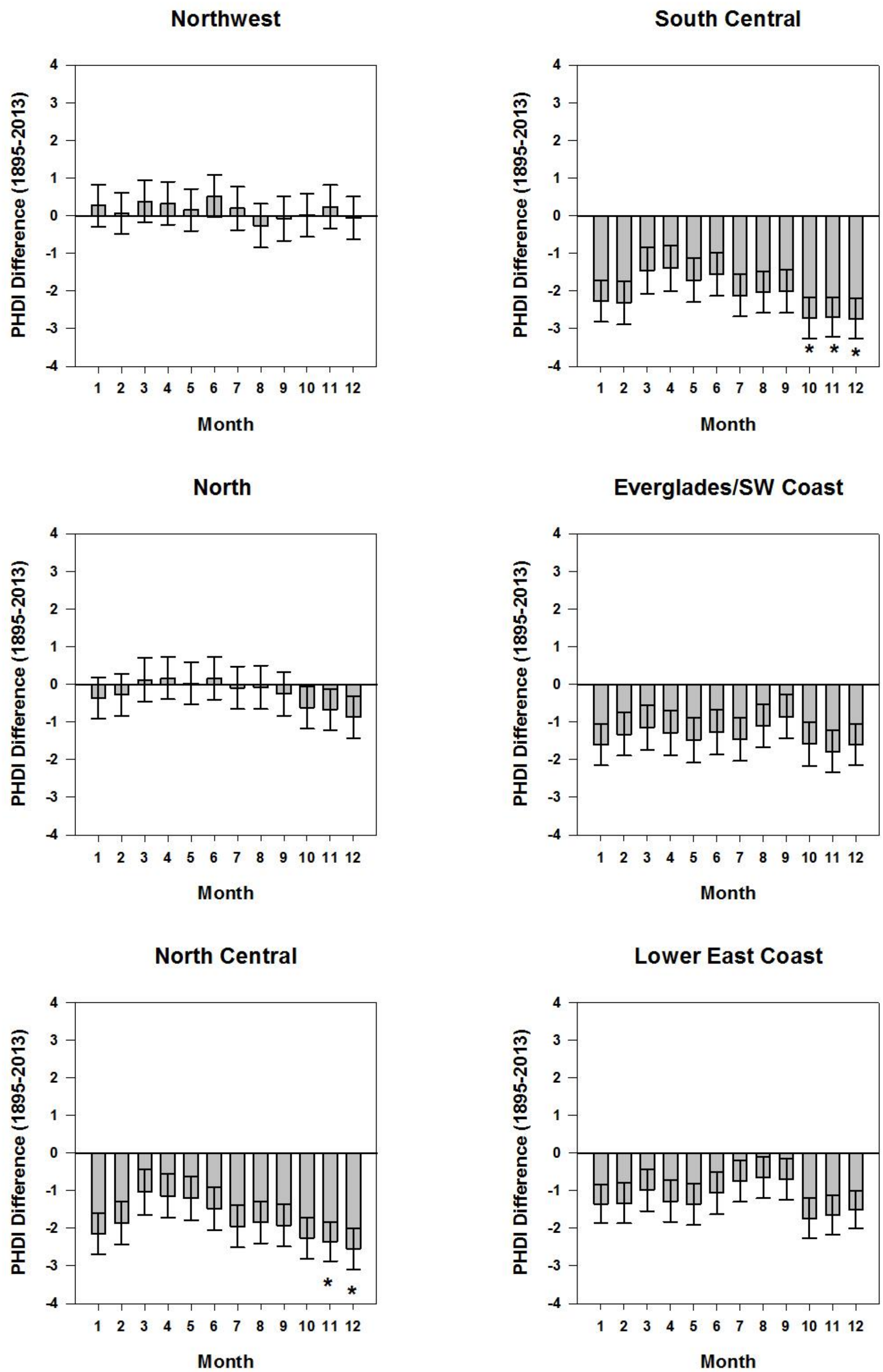


Figure 80. Difference in monthly PHDI 1895–2013 ± SE for Florida's 6 mainland climate divisions. Asterisks denote months with significant (α = 0.05, $P < 0.05$ after sequential Bonferroni correction) changes in PHDI over time based on linear regression.

of increasing magnitude from north to south in the peninsula, ranging from an increase in average air temperature of 0.52°C in North Florida to 1.4°C in the Lower East Coast. In Northwest Florida, there was no significant change in any measure of temperature over time (Fig. 81). When monthly changes in average temperature were examined over time, significant increases ($P < 0.05$) in average temperature were found to occur in various months in different divisions (Fig. 82). The number of months with significant increases in average temperature increased from north to south in the peninsula, and significant temperature increases ranged from a 0.72°C increase in July in North Florida to a 2.0°C increase in December in the Lower East Coast. No significant changes in air temperature were found in any month in the Northwest division. No long-term trend in annual or monthly precipitation was evident in any of Florida's climate divisions, although considerable year-to-year variation in precipitation existed in all divisions (Fig. 83).

A comparison of observations before and after 1980 revealed a significant increase in mean latitude for the ornate chorus frog and frosted flatwoods salamander, and a significant decrease in mean latitude for the reticulated flatwoods salamander (Fig. 84). Significant westward shifts in mean longitude were observed for all species except the striped newt. The mean longitude of striped newt observations slightly increased after 1980, suggesting an eastward shift; however, this difference was not quite statistically significant ($P = 0.07$) (Fig. 84).

Potential Areas for Future Surveys

We used potential habitat maps to identify areas for future surveys for 4 amphibian species. We either did not survey these areas or did not survey them sufficiently in terms of intensity or timing (i.e., during conditions when larvae should be present). These potential habitat maps could also be used to identify key private lands for conservation efforts; most of the potential habitat for all species except the striped newt occurs on private lands. We surveyed the top 10 public conservation lands with the greatest amount of potential habitat for striped newts, gopher frogs (except Merritt Island NWR), tiger salamanders (except Flying Eagle Ranch), and ornate chorus frogs, but we primarily concentrated our dipnet survey efforts on potential wetlands for the first 2 species (in some cases, wetlands could be used by at least 3 species). We sometimes detected ornate chorus frogs while dipnetting for flatwoods salamanders. We did not have habitat models for the tiger salamander and ornate chorus frog until after surveys were completed, and the wide variety of upland and wetland habitats potentially used by these species complicated identification of particular areas for surveys. We concentrated our survey efforts on public lands because their habitats, particularly sandhill, are often in better condition than on private lands. Also, it was easier to get permission to access public than private lands, particularly when surveying for listed species. The large number of public lands with potential habitat negated the need to pursue surveys of private lands, although we did survey some private lands in parts of the state where public conservation lands were limited. Hodges Conservation Easements along San Pablo Creek, Duval County, is an area with a large amount of potential habitat for the striped newt (222 ha) and gopher frog (196 ha) in a part of the state with relatively few records (Fig. 85). When we contacted the lead managing agency, the St. Johns River Water Management District, regarding access to this property, we were told that the landowner would not be receptive to surveys.

Conservation areas not surveyed that have large amounts of potential habitat for striped newts are Flying Eagle Ranch (1,093 ha), Potts Preserve (852 ha), and Al Bar Ranch (387 ha). We failed to find striped newts in Withlacoochee State Forest, which ranks third in amount of potential habitat (Table 9). The Citrus and Croom tracts contain extensive sandhill habitat in good condition and suitable ephemeral wetlands, although many of them are widely separated (Fig. 86).

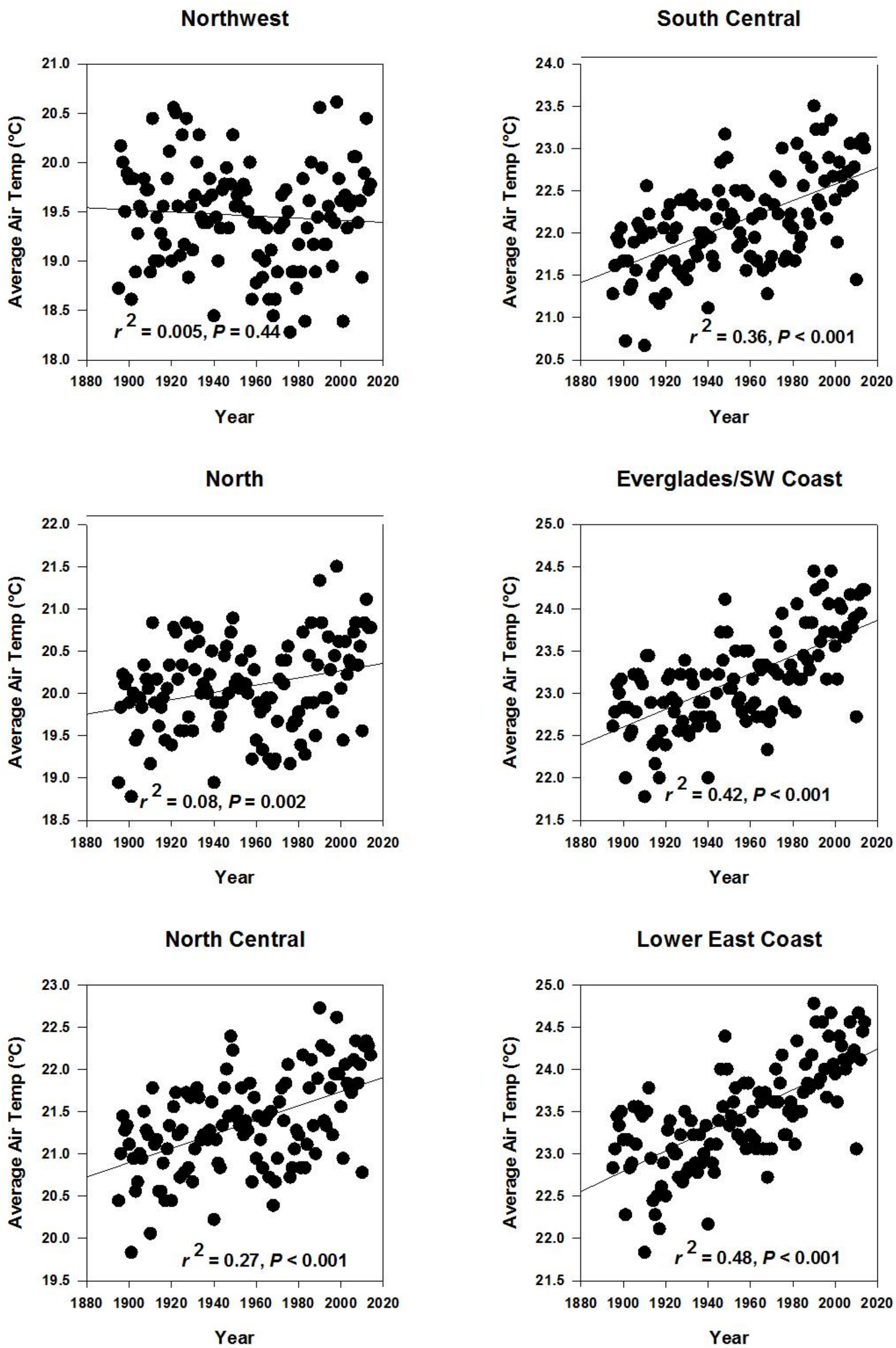


Figure 81. Long-term trends in annual average air temperature 1895–2014 in Florida's 6 mainland climate divisions.

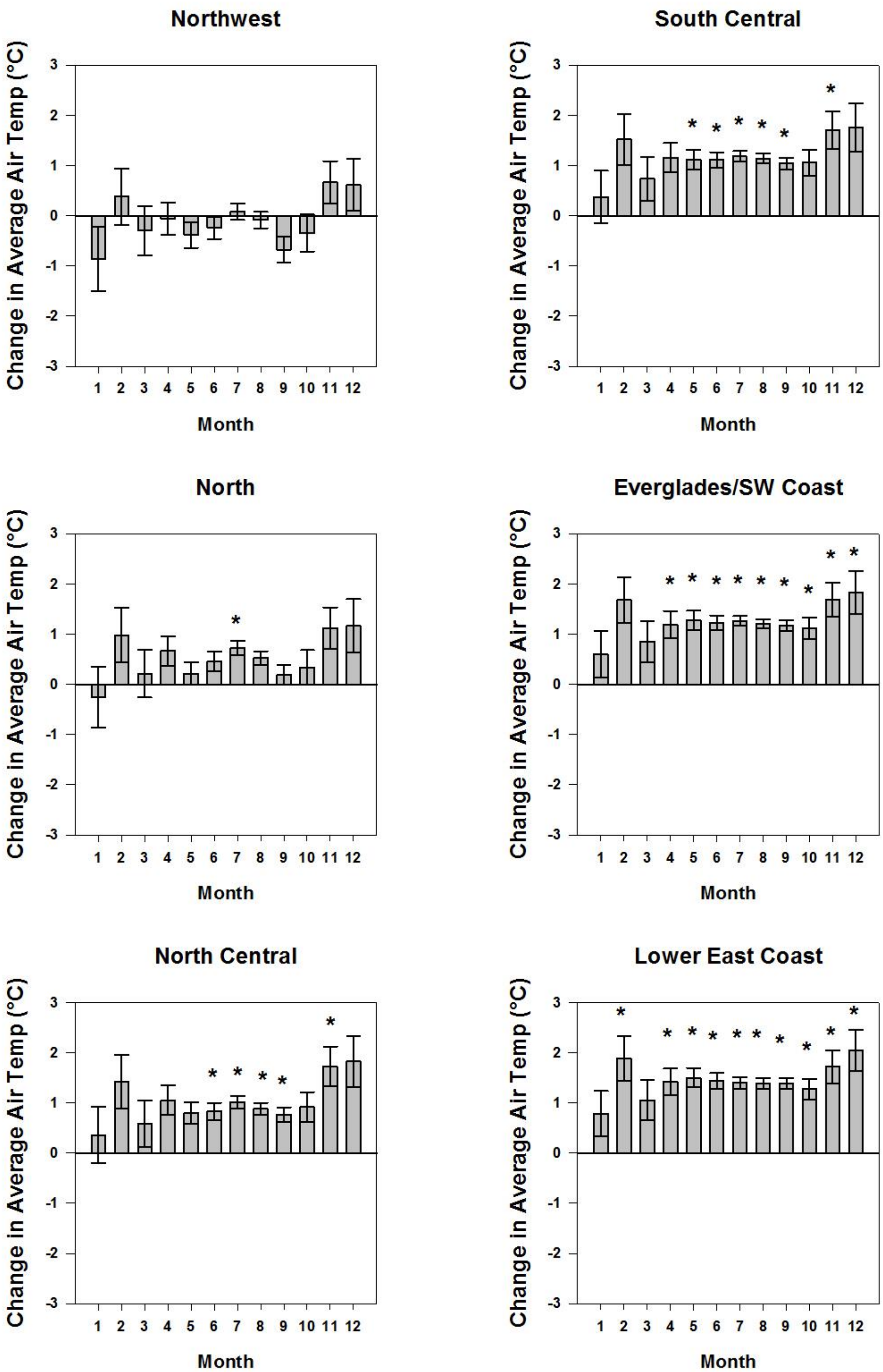


Figure 82. Difference in monthly average air temperature 1895–2013 ± SE for Florida's 6 mainland climate divisions. Asterisks denote months with significant ($\alpha = 0.05$, $P < 0.05$ after sequential Bonferroni correction) changes in PHDI over time based on linear regression.

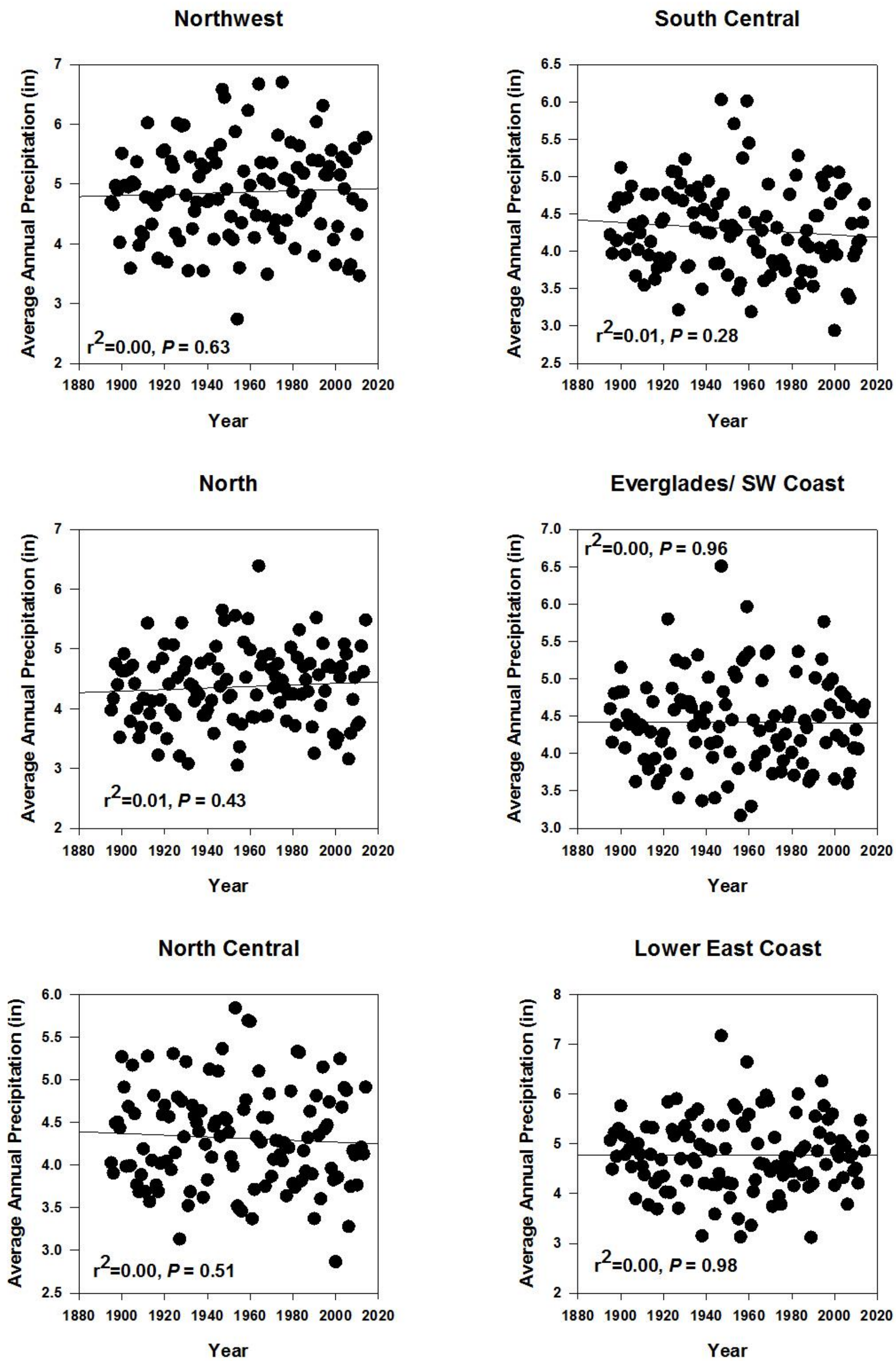


Figure 83. Lack of long-term trends in average annual precipitation 1895–2014 in Florida's 6 mainland climate divisions.

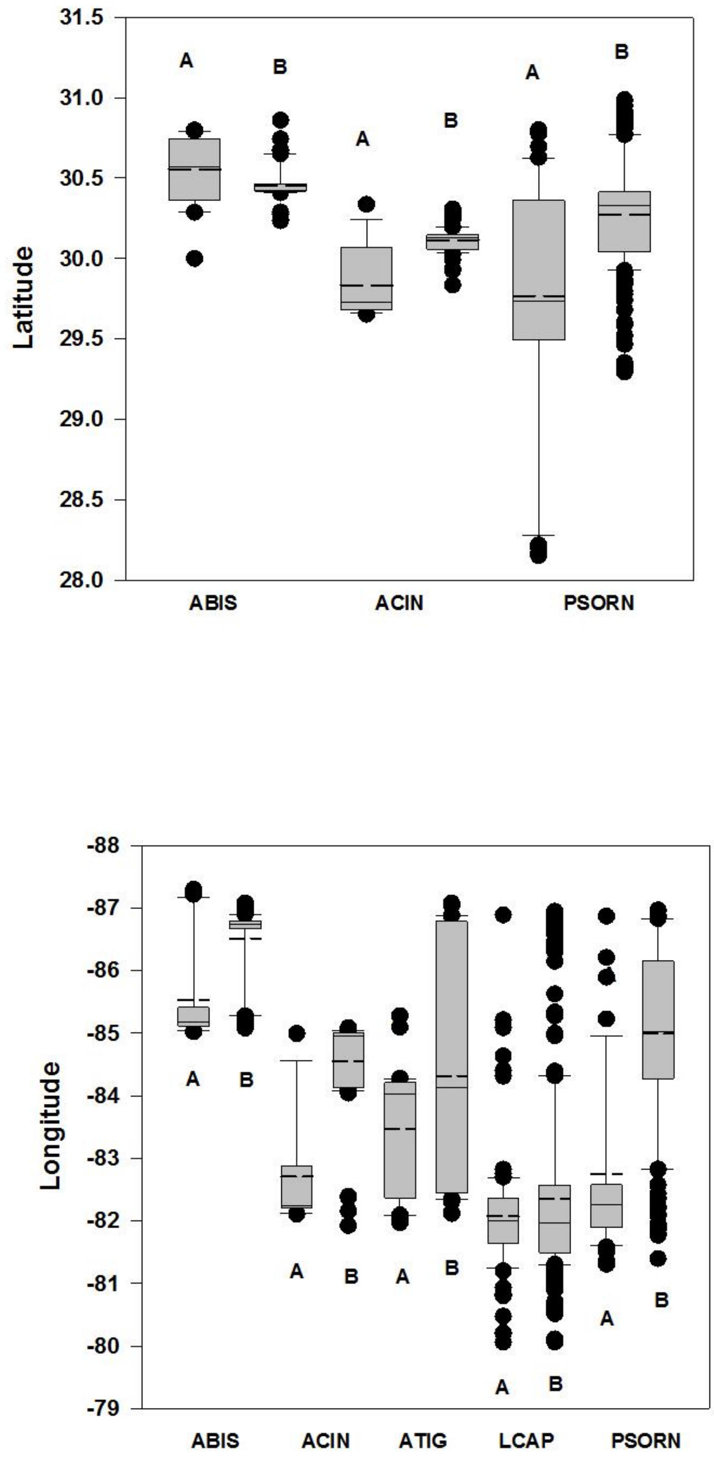


Figure 84. Box plots of change in median latitude and longitude before 1980 (A) and 1980–2014 (B) by species. The central line is the median, dashed line is the mean, box is the interquartile range, whiskers are the 10th and 90th percentiles, and black dots are outliers. Only species with significant differences ($P < 0.05$) are shown. ABIS = reticulated flatwoods salamander, ACIN = frosted flatwoods salamander, ATIG = tiger salamander, LCAP = gopher frog, PSORN= ornate chorus frog

We do not know whether our failure was due to insufficient survey effort or lack of populations. The species occurs farther north on the Brooksville Ridge, and there is a record from the 1930s from Floral City, Citrus County. All 4 of these sites are near or beyond the southern extent of the species' known range in the western peninsula. Suitable sandhill habitat occurs in Lake Wales Ridge State Forest in Polk County (Table 9), but there is no evidence that striped newts ever colonized the Lake Wales Ridge, and we did not detect them during dipnet surveys. We found striped newts in a pond on Triple N Ranch WMA in Osceola County, which contains <50 ha of identified habitat, so additional surveys of nearby Bull Creek WMA (119 ha of habitat) and Three Lakes WMA (193 ha) might prove productive. Surveys of plantation lands managed for quail in the Tallahassee Red Hills may detect new populations. The first record of the species in Florida was from Lake Jackson north of Tallahassee in 1922 (UMMZ 74434), and a pond was discovered north of Tallahassee in 1969.

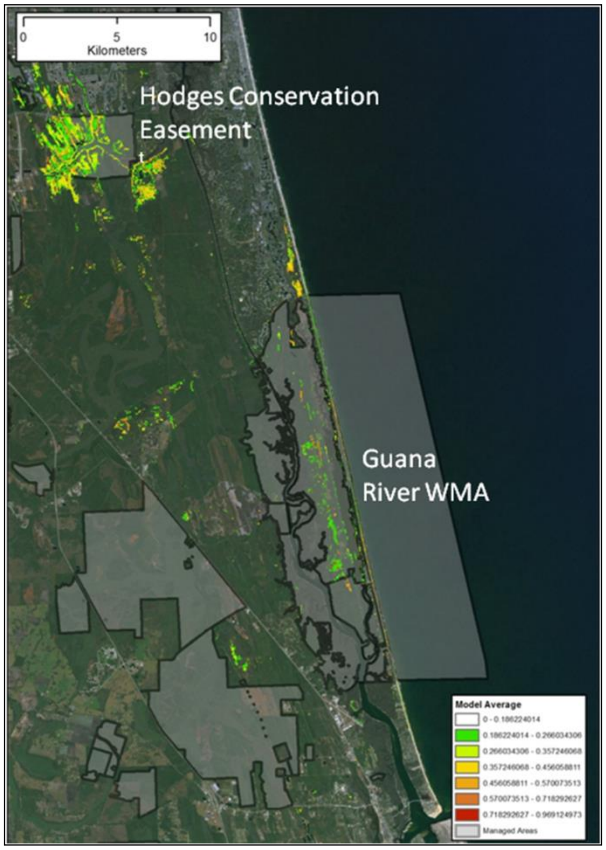


Figure 85. Extensive striped newt potential habitat in Hodges Conservation Easement, Duval Co., compared to Guana River WMA, which has striped newts.

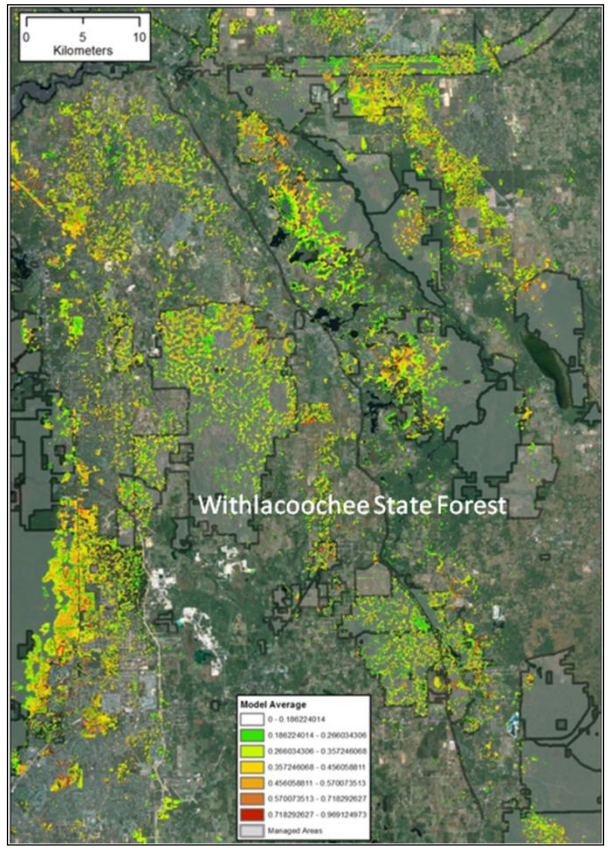


Figure 86. Striped newt habitat in Citrus and Hernando counties, where the species has not been documented.

Based upon the RSF potential habitat map, potential areas for future gopher frog surveys are Duette Preserve (1,719 ha), Tyndall AFB (919 ha), Loxahatchee Slough Natural Area (680 ha), Myakka River State Park (473 ha), J. W. Corbett WMA (418 ha), Potts Preserve (375 ha), and Fred C. Babcock-Cecil M. Webb WMA (369 ha). There are single records in 1983 from Myakka River State Park and in 2005 from Duette Preserve, which we surveyed once. Most of these properties are in the southern peninsula, which was not the primary focus of our survey efforts. We considered surveying the 2 WMAs and even identified potential ponds, but conversations with area biologists regarding upland and wetland habitat conditions discouraged us from following through.

We suspect it would be unproductive dipnetting for tiger salamander larvae in many of the conservation lands that the model identified as having the greatest amount of potential habitat. It is difficult to identify particular ponds for survey efforts because of the wide variety of wetland and upland habitats potentially used. Extensive herpetofaunal surveys have been conducted in Ocala National Forest, Osceola National Forest, Eglin AFB, and St. Marks NWR without detecting the species, and we suspect it does not occur in these areas, with the possible exception of Ocala National Forest.

The large amount of potential habitat identified for the ornate chorus frogs makes selecting future survey areas difficult. Most of the top-ranked areas in terms of potential habitat already have records or are near the southern extent of the species' range, where we suspect populations never occurred or have disappeared. Call surveys may prove more effective than dipnet surveys, particularly on lands with a lot of potential habitat and breeding ponds.

Participants

During this project, 226 individuals participated in dipnet surveys from 1 to 50 times each for a total of 600 person-days, excluding the PI (Fig. 87). This total does not include 20 participants on a field trip to the Juniper Prairie Wilderness Area, Ocala National Forest, organized by the PI for the 2010 Southeastern Partners in Amphibian and Reptile Conservation (SEPARC) Conference. The total also does not include 19 participants on a gopher frog survey field trip to Allen David Broussard Catfish Creek Preserve State Park as part of the Lake Wales Ridge Ecosystem Working Group Meeting in August 2010, 38 people who attended training in Ocala National Forest for NewtFest 2011, and ca. 30 University of Florida students attending a Wildlife Techniques class at Ordway-Swisher Biological Station in 2011. Affiliations of the 225 participants were FWC (78), Florida Department of Environmental Protection (DEP; 20), University of Florida (19), Sierra Club (15), U.S. Forest Service (USFS; 9), 3 water management districts (9), Florida Forest Service (FFS; 6), Central Florida Zoo (5), University of Central Florida (4), U.S. Fish and Wildlife Service (USFWS; 4), U.S. Air Force (3), Zoo Miami (3), Coastal Plains Institute (2), Hillsborough County (2), The Nature Conservancy (TNC; 2), Virginia Tech (2), Atlanta Zoo (1), Cardno ENTRIX (1), Florida Department of Transportation (1), Florida State University (1), Louisiana State University (1), Mosaic Fertilizer (1), Palm Beach County (1), Santa Fe College (1), Seminole County Natural Lands (1), Tall Timbers Land Conservancy (1), University of South Florida (1), and U.S. Geological Survey (1). Thirty-one participants were volunteers with no affiliations.

Education and Outreach

During the entire study, the PI regularly updated ca. 150 persons ("newtists") on results of amphibian surveys and notified them of upcoming surveys. Some of these updates were via multi-page "newtletters" with photographs. These updates were more frequent during the first 2 years of the grant when outside participation in surveys was emphasized.

The PI provided technical assistance regarding these amphibian species. Using data collected previously and during this project, he prepared a 15-page information response in May 2010 from the FWC to the USFWS for the 90-day finding on the petition to list the striped newt as threatened. In August 2011, he reviewed a document from Carrie Sekerak (USFS) entitled

"Project Design Criteria for Striped Newts" that outlines preferred silvicultural practices to minimize impact on the species in sandhill and scrub habitats in Ocala National Forest. He helped identify candidate ponds of importance to striped newts and gopher frogs and the best times of year for treatments to minimize impacts to these species. In September 2011, he met with Patrick McCord (FWC) to discuss his Aquatic Habitat Restoration and Enhancement Subsection proposal to restore ephemeral sandhill ponds that have been impacted by ORV use in Ocala National Forest. Several experimental treatments will be used to replant barren sand with grassy vegetation, primarily maidencane. In 2014, he reviewed and commented on the USFWS Species Assessment and Listing Priority Assignment Form for the striped newt. Locality information collected on the gopher frog was used for FWC's biological status review to determine whether the gopher frog should be state listed as threatened (Florida Fish and Wildlife Conservation Commission 2011). In September 2014, he met with Carrie Sekerak and Jay Garcia (USFS) to discuss proposed changes by the USFS in scrub management in the Long Pond wetland complex in the southwestern portion of Ocala National Forest. In November 2014, he provided the USFS with a letter supporting an Aquatic Habitat Restoration/Enhancement (AHRE) proposal being submitted to restore the ecological integrity of Long Pond wetland complex, including relocating a road that presently bisects Big Prairie. The 8 striped newt ponds in this area represent the largest cluster of known breeding ponds in Ocala National Forest (6 known gopher frog ponds also occur here). He also commented on a proposal to the USFS from CPI to repatriate striped newts in Apalachicola National Forest. The PI met with Rob Hicks of Plum Creek Timberlands, the largest private landowner in Florida, to discuss striped newt and gopher frog sites on its lands.

The PI participated in numerous educational and public outreach events regarding winter-breeding amphibian species during the period of the grant. In 2010, he presented a poster about this grant, along with live specimens, for Marine Quest at the Fish and Wildlife Research Institute office in St. Petersburg. On 17 August 2010, he gave a presentation on gopher frog surveying to ca. 70 people at the Lake Wales Ridge Ecosystem Working Group Meeting at Bok Tower Gardens and afterwards led a field trip to the Walk-in-the-Water tract of Lake Wales Ridge State Forest to demonstrate techniques. On 2 September 2010, he gave a presentation entitled "Sandhill Herps and Their Habitat Needs," including gopher frogs and striped newts, to ca. 90 people at the West Central Florida Upland Working Group Meeting in Brooksville. In February 2011, he presented a poster on the results of striped newt surveys at the SEPARC meeting in Louisville, Mississippi. In March 2011, he provided a half-day training session for 37 people in Ocala National Forest as part of "NewtFest 2011" (Fig. 88). In February 2012, he presented the results of gopher frog surveys to the Crawfish/Gopher Frog Group at the SEPARC meeting in Tennessee to help determine the current status of the species throughout its range. In August 2012, FWC staff met with USFWS staff to discuss conservation strategies for the striped newt. In September 2013, he gave a presentation entitled "FWC Flatwoods Salamander Surveys in Florida" the Flatwoods Salamander Working Group Meeting at St. Marks NWR. In February 2014, he was co-author of a presentation entitled "Roadblocks to recovery: flatwoods salamanders as a case study" by Tom Gorman at the SEPARC meeting.

Pierson Hill, who was hired for the project in December 2013, gave a presentation on suitable habitat management for flatwoods salamanders to St. Marks NWR staff and salamander researchers in March 2014. The same month, he gave a presentation on the natural history and conservation of the flatwoods salamander to the Florida Reptile and Amphibian Working Group (zoo professionals) at Busch Gardens, Tampa.

Figure 87. Volunteers (mostly UF students) standing by a striped newt pond discovered in Ocala National Forest.

Figure 88. Participants of a survey training session during "Newtfest 2011" in Ocala National Forest.

DISCUSSION

Population Status and Trends

Prior to initiation of this survey, anecdotal evidence and previous surveys suggested that ornate chorus frog and frosted flatwoods salamander populations in the peninsula had experienced population declines, whereas striped newt populations in the panhandle were possibly extinct (Means et al. 2008). The results of this study paint a dire picture for these species in parts of Florida. Surveys of 52 wetlands on 6 conservation lands in the peninsula failed to find flatwoods salamanders. We were unable to detect striped newts in the panhandle despite surveying 59 suitable ponds on Apalachicola National Forest and St. Marks NWR, which previously supported the species. Striped newts may still be present in Apalachicola National Forest, but detecting newts at low population densities can be difficult. For example, dipnetting for 18 minutes on 22 April 2010 found the first striped newt (a paedomorph) in a pond south of Church Lake in Ocala National Forest (Fig. 47). However, no newts were found during 9 other visits to this pond, including 2 other visits in 2010, totaling 482 person-minutes of dipnetting. Gopher frogs were detected in many historical and new breeding ponds in peninsular Florida but were detected in only 1 pond in the panhandle aside from those ponds in Apalachicola National Forest and Eglin AFB. Our surveys suggest that ornate chorus frog populations are still robust in much of the panhandle but have declined in the peninsula. Despite using a variety of survey methods, we detected ornate chorus frogs in only 18 wetlands in the peninsula, not counting an area west of Otter Creek, Levy County, that has numerous breeding sites on private lands.

Gopher Frog.—Florida represents the largest portion of the total global range of the gopher frog, which has experienced significant population declines throughout much of its range (Jensen and Richter 2005). Gopher frog populations are presumably extant on 95 Florida conservation lands, where 388 breeding ponds have been identified (Appendix 2). This total includes all records since 1990 as long as suitable upland and wetland habitats remain. Breeding ponds have not been identified on 26 of these conservation lands (Appendix 2). Gopher frogs are still widely distributed in the peninsula, where we documented 186 breeding ponds during surveys (Appendix 1). However, only 2 strongholds exist in the panhandle, Apalachicola National Forest and Eglin AFB. Despite suitable habitat and wetlands, gopher frog populations are apparently extinct in the

Panacea Unit of St. Marks NWR, where the population may never have been large (Dodd et al. 2007). We surveyed 97 ponds elsewhere in the panhandle and found tadpoles in only 1 pond on private property in Calhoun County. We surveyed potential ponds that had the best upland habitat up to 3 times.

Our surveys suggest a further decline of this species in the panhandle, although we did not sample all known breeding ponds, and most known breeding ponds were sampled only once. In 1993−1994, Palis and Jensen (1995) found 26 gopher frog breeding ponds on Eglin AFB, whereas we found gopher frogs in only 5 known ponds. In 1994−1997, Means and Means (2005) found 26 gopher frog breeding ponds in the Munson Sandhills of Apalachicola National Forest. We found gopher frogs in 12 ponds (1 new pond) in the Munson Sandhills, but we did not survey all the known ponds. In addition, we found 3 new ponds in the Liberty County portion of Apalachicola National Forest, where the species was not known to occur. Although more extensive surveys are needed to determine the occupancy of this species at historical and new sites in the panhandle, our study suggests that conservation measures may be needed to prevent this species from further declines in the panhandle.

Our surveys indicate that healthy populations still exist in the peninsula, particularly in Ocala National Forest and Camp Blanding Military Reservation, which have the most known breeding ponds in the peninsula. These findings are consistent with Franz and Smith (1999), who considered the species to be common on protected lands along the central spine of the peninsula north of Lake Okeechobee based on surveys of 146 ponds in the peninsula. During surveys for striped newts in 2008–2011, Enge (2011) found 110 gopher frog breeding ponds, 96 of which were previously unknown. Our detection of 19 occupied breeding ponds on Camp Blanding Military Reservation are similar to the results of Hipes and Jackson (1996), who heard gopher frogs calling from 21 of 35 ponds visited in 1993−1994. Based on the lack of recent activity at many historical breeding sites, Franz and Smith (1999) concluded that gopher frog populations had declined east of the Apalachicola River in the last 20 years (1975–1995), particularly in coastal counties and in South Florida where most of the human population is concentrated. Franz and Smith (1999) compiled records from 258 localities in 45 counties in the peninsula. During surveys in 1990–1995, they found gopher frogs at only 3 of 63 historical sites visited but found 83 new sites in 19 counties, including 4 new county records. Disturbed habitats often continue to support gopher frog populations. Substantial populations utilize open pastures with tortoise burrows at sites such as Green Swamp West, Lake Panasofkee WMA, Starkey Wilderness Park, and All-Bar Ranch, but less disturbed upland habitats are adjacent to these pastures (Jackson 2004). A survey of 227 ephemeral ponds on commercial forest lands in northern Florida in 1996−1998 found gopher frogs in 14 ponds in Clay, Leon, Nassau, Putnam, Volusia, and Wakulla counties (Wigley et al. 1999).

Striped Newt.—Striped newt populations are presumably extant on 15 Florida conservation land, where 128 breeding ponds have been identified (Appendix 2). Populations are considered presumably extant if records exist since 1990 and suitable upland and wetland habitats remain (elsewhere in the report, Apalachicola National Forest populations are referred to as possibly extinct because recent survey efforts have failed to find the species). The current stronghold for the striped newt is Ocala National Forest, where striped newts have been found in 38 ponds since 2006 (Appendix 2). During this study, we were unsuccessful at finding newts in some known ponds, and we found only 3 new breeding ponds in Ocala National Forest because many ephemeral wetlands in the Marion and Putnam County portions of the forest dried completely or partially starting in 2012. When semipermanent wetlands dry down to the interior where floating-leaved plants are present, habitat conditions apparently become unsuitable for striped newts, which typically use the grassy portions of ponds. Also, dipnet surveys of pond interiors are usually unfeasible during drydowns because of the muck substrate. However, we suspect that the 29 ponds detected by Enge (2011) will be used again by this species once appropriate hydrological conditions return. Interestingly, precipitation was above normal in other parts of northern Florida in 2014, and striped newts were found in 5 ponds (3 new ponds) in Camp Blanding and 12 ponds (6 new ponds) in Jennings State Forest. Despite favorable survey conditions, we failed to find newts in 8 ponds in Camp Blanding and 5 ponds in Jennings where they were found in the 1990s. We found newts in only 3 of the 12 known ponds that contained water at Ordway-Swisher Biological Station.

Previous surveys indicated that populations of striped newts in parts of their historical range were declining (Dodd and LaClaire 1995, Franz and Smith 1999, Means et al. 2008, Enge 2011). A 1990–1995 baseline survey by Franz and Smith (1999) found striped newts at 38 (12.8%) of 297 ponds sampled in Florida, but newts were present at only 4 of 30 historical sites that could be located (28 historical sites could not be located). In 1993–1994, Hipes and Jackson (1996) discovered striped newts in 10 of 28 ephemeral wetlands surveyed; striped newts have not been found in 5 of these ponds since then. A survey of 227 ephemeral ponds on commercial forest lands in northern Florida in 1996−1998 found striped newts in only 4 ponds in Clay and Putnam counties (Wigley et al. 1999). In 2006−2011, Enge (2011) found striped newts in 57 (58.8%) of the 97 known striped newt ponds surveyed. Since 1990, newts have been found in 83 of the 100 known ponds in the peninsula, but breeding ponds could not be located in Half Moon WMA and Rainbow Springs State Park, where newts were trapped during drift-fence surveys in the 1990s (Enge 2011).

The 5 former strongholds for the striped newt in Florida were Apalachicola National Forest, Ocala National Forest, Camp Blanding Military Reservation, Jennings State Forest, and Ordway-Swisher Biological Station (Johnson 2005, Johnson and Owen 2005, Means et al. 2008), all of which contained at least 12 breeding ponds (Enge 2011). However, multiple surveys since 1997 in the Munson Sandhills of Apalachicola National Forest indicate that populations have seriously declined or disappeared (Means et al. 2008). Newts have not been found on private property in the eastern portion of the sandhills since the 1980s when it was converted to a dense sand pine plantation (Means and Means 1998a). Surveys of 265 ephemeral ponds in the Munson Sandhills of Apalachicola National Forest in 1995–2007 located 18 breeding ponds (Means and Means 1998a), but during surveys in 2001–2008, no larvae and only 3 adults were found in 2 ponds (Means and Means 2008, U.S. Fish and Wildlife Service 2011). We were unable to detect striped newts in the panhandle, despite surveying 33 suitable ponds (not counting 7 historical ponds ranked as unlikely) in Apalachicola National Forest and 26 suitable ponds in St. Marks NWR.

The striped newt is listed as threatened in Georgia, where it has been recorded from ca. 30 wetlands on 15 properties (Means et al. 2010). Since 1990, however, it has been documented from only 7 populations (Stevenson et al. 2007). Presently, the only conservation lands thought to support viable populations are the Joseph W. Jones Ecological Research Center at Ichauway, Fort Stewart Military Reservation, and the Fall Line Sandhills Natural Area. Intensive annual surveys since 2002 have found newts in only 3 of 5 known breeding ponds at the first site 1 of 10 known breeding ponds at the second site, and the only known pond at the third site (Stevenson et al. 2007, Means et al. 2010, U.S. Fish and Wildlife Service 2011). Our study suggests that this species has also suffered dramatic declines in Florida and that the western clade may be extinct in Florida and close to global extinction. In an effort to repatriate Apalachicola National Forest with striped newts, captive-bred offspring from larvae collected in 2011 and 2013 from a large pond in the Fall Line Sandhills Natural Area, Taylor County, Georgia, were experimentally reintroduced into 1 pond in Apalachicola National Forest in 2013 and 4 ponds in 2014, resulting in successful exodus of efts (Means et al. 2013; Ryan Means, pers. comm.). Pond liners were installed in the interiors of 3 ponds to increase their hydroperiods.

Tiger Salamander.—Populations of the long-lived tiger salamander are apparently doing well in Florida, even at the southern extent of its range in Hernando and Sumter counties. Tiger salamanders appear to be locally common in some areas, but relatively few breeding ponds have been identified, except in Blackwater River State Forest (Showen 2007, Pepe and Mahoney 2009), where 18 ponds are known (Appendix 2). Many records consist of a single animal found terrestrially, and because of the fossorial nature of the species, a population assessment is impossible. The variety of wetlands and upland habitats potentially suitable for tiger salamanders makes identification of particular areas for dipnet surveys difficult, and annual variation in use of breeding ponds also complicates survey efforts. Our relative lack of success at finding breeding ponds during dipnet surveys should not be construed as meaning that the tiger salamander is rare or experiencing population declines. Urbanization in some areas, such as along I-75 on the west side of Gainesville, has undoubtedly impacted populations. However, populations appear to be able to survive in low-density residential areas and in agricultural areas, as evidenced by their use of breeding ponds in pastures, orchards, and subdivisions. Population strongholds are apparently Blackwater River State Forest, the Tallahassee Red Hills region, and portions of the Brooksville Ridge and western Marion County. However, only 17 breeding ponds have been identified on 4 conservation lands (Appendix 2)

Flatwoods Salamanders.—Populations of frosted flatwoods salamander are presumably extant on 4 Florida conservation lands, where 128 breeding ponds have been identified (Appendix 2). This study and extensive dipnet surveys of 485 ponds in 2002–2005 failed to detect frosted flatwoods salamander larvae in the peninsula (FWC, unpubl. data). Palis (1997b) detected larvae in 3 ponds in Osceola National Forest, Baker County, during surveys in 1990–1995, and the species was last recorded in the peninsula in 1998 from 1 of these ponds. The only designated critical habitat in the peninsula is 449 ha in Osceola National Forest around these ponds and 66 ha of private land in Baker County that contained 1 breeding pond (U.S. Fish and Wildlife Service 2007), which has subsequently been obliterated by mining (John Palis, pers. comm.). This species has experienced declines throughout the eastern portion of its range, threatening its long-term survival. Reproductive activity in the Atlantic Coastal Plain Clade (the genetically distinct eastern portion of the species' range) has been observed at only 1 population in South Carolina and 2 populations in Georgia in over a decade (Pauly et al. 2012).

Remaining strongholds for the frosted flatwoods salamander (Eastern Panhandle Clade) are St. Marks NWR and Apalachicola National Forest. Dipnet surveys in 2002–2005 indicated that populations remained robust around many breeding ponds. During these surveys, larvae were found in 44 ponds (3 metapopulations) in St. Marks NWR and 9 ponds (4 metapopulations) in adjacent Flint Rock WMA (Palis and Enge 2005). Surveys of 771 ponds in Apalachicola National Forest found 28 new ponds in 9 metapopulations (Ripley and Printiss 2005). In 2002, surveys of 35 known breeding ponds in Apalachicola National Forest found larvae in 6 ponds (FWC, unpubl. data). Palis (1997b) found larvae in 30 ponds in Liberty County and 1 pond in Franklin County during surveys in 1990–1995. Our survey results suggest marked declines of this species in St. Marks NWR, where it was detected in only 5 of 25 known wetlands surveyed in 2014, despite good sampling conditions. The clumped nature of extant ponds in Apalachicola National Forest (Fig. 54) and St. Marks NWR (Fig. 53) may indicate extinction of some metapopulations, but additional surveys of known breeding ponds will be needed before any conclusions can be drawn.

Reticulated flatwoods salamander populations may be extant only in Eglin AFB, Hurlburt Field, Holley Naval Outlying Landing Field, Garcon Point Water Management Area, and a few other properties in Santa Rosa County. Only the first 2 conservation lands have more than 3 known breeding ponds, and the lack of recent records from 20 ponds along the coast in the western part of Hurlburt Field and adjacent Eglin AFB (Fig. 57) may indicate local population extinction. The species was last detected in Pine Log State Forest, Washington County, in 2005. During surveys in 1990–1995, Palis (1997b) found larvae in 1 pond in Holmes, Jackson, and Walton counties, 3 ponds in Calhoun and Washington counties; 4 ponds in Santa Rosa County; and 24 ponds in Okaloosa County.

Ornate Chorus Frog.—Recent surveys have documented ornate chorus frogs in 254 ponds on 28 Florida conservation lands (Appendix 2). Our study provides additional confirmation of anecdotal reports that ornate chorus frog populations have declined in the peninsula. The Florida Game and Fresh Water Fish Commission (1976) reported that "available evidence seems to indicate that this rare species is on the decline" in peninsular Florida. According to Richard Franz (pers. comm.), Archie Carr told him in the late 1970s that he felt the ornate chorus frog was in serious trouble and should be monitored based on its disappearance from many breeding ponds all over northern Florida, particularly areas around Gainesville. Many museum vouchers came from the Gainesville area, particularly east of Gainesville near Newnan's Lake and south of Gainesville near Micanopy and Lake Lochloosa, where frogs could be commonly found calling from grassy ponds and roadside ditches in the 1980s (Alford 1986; Kevin Enge, pers. obs.). These roadside ditches typically no longer contain water in winter, and small populations apparently persist only in a few areas south of Gainesville, where 1 or 2 males have been heard calling at widely scattered localities (Richard Bartlett, pers. comm.; Jonathan Mays, pers. obs.; Paul Moler, pers. obs.; Kevin Enge, pers. obs.). According to Richard Franz, (pers. comm.), the severe drought that began in the late 1980s affected ornate chorus frog populations, which disappeared from many sites in Putnam and Clay counties. Populations rebounded in the late 1990s–2000s in the Camp Blanding area but collapsed again during the 2006–2008 drought, which was even more severe than the previous one (Richard Franz, pers. comm.). According to the literature and climate databases, recent droughts in the northern peninsula have been most pronounced in 1988–1990, 1998–2002, 2006–2008, and 2010–May 2012.

At the beginning of this study, we hypothesized that ornate chorus frog population declines in the peninsula may primarily be due to winter droughts resulting in local extinctions. Unlike the other target species, ornate chorus frogs are short lived, living a maximum of 3 years in the wild and exhibiting almost annual population turnover (Caldwell 1987). We suspected that peninsular populations would most likely persist in more poorly drained habitats (e.g., mesic flatwoods instead of sandhill), where wetlands would probably be less affected by droughts, and in relatively unfragmented upland habitats containing numerous wetlands. According to Caldwell (1987), total reproductive failure within a limited geographic area during any given year is very unlikely because ponds are abundant and close together, prolonged regional winter droughts could potentially eliminate populations in areas with few ponds.

Using a variety of survey methods over a 5-year period, we were only able to locate this species in 18 wetlands in the peninsula and along 1 call survey route in Levy County. In contrast, we detected this species in 64 wetlands in the panhandle during 1 year of surveying. To some degree, our lack of success in the peninsula in 2010–2013 may be related to drier weather conditions. The winter of 2013‒2014 was wetter than average from Gainesville northward, and we found ornate chorus frogs at several peninsular sites, including in sandhill habitat in Jennings State Forest, Camp Blanding Military Reservation, and Etoniah Creek State Forest. Most of the other sites (Spring Creek Unit of Big Bend WMA, Lafayette Forest Mitigation Park WEA, and west of Otter Creek in Levy County) were in the low-lying Big Bend area, where water tables are probably higher and impacts of drought less severe. These public lands are mostly unfragmented and contain numerous ephemeral wetlands with varying hydroperiods, which has probably allowed continued metapopulation persistence. In Alachua County, ornate chorus frog populations are scarce, and all recent records are of singletons. The ornate chorus frog detected by a frog logger in Phifer Flatwoods, Alachua County, called only 1 night.

Possible Reasons for Population Declines

The most likely reasons for observed population declines in these species are habitat loss, degradation, and fragmentation and climatic changes (e.g., prolonged droughts). We suspect that disease and harvest have had minimal population impacts.

Upland Habitat Loss and Alteration.—The target species in this study spend most of their life in upland habitats, typically returning to wetlands only to breed. The condition of both upland and wetland habitats are important to the survival of these amphibian populations. The characteristics of breeding habitat that are apparently important to long-term persistence of populations are relatively easy to quantify, but few studies have quantified the relevant importance of upland habitat variables to amphibian populations (Moseley et al. 2004, Semlitsch et al. 2009). Upland habitat connectivity in the form of continuous natural forests is important for dispersal of juveniles to new areas and recolonization of areas after local extinctions. Many amphibian species are either unable to cross large expanses of deforested habitat due to desiccation or avoid such habitats (deMaynadier and Hunter 1999, Rothermel and Semlitsch 2002).

Upland habitat loss has undoubtedly played a role in population declines of some of these species. Historically, terrestrial habitat surrounding isolated wetlands in Florida was predominately longleaf pine savanna characterized by an open canopy that supported a high diversity of herbaceous vegetation and arthropod prey for amphibians (Lannoo 2005). Subcanopy vegetative diversity in these forests was high (Earley 2004) and likely provided key shelter and foraging requirements for amphibians (Stephens and Wagner 2007). Longleaf pine savanna occupied over 30 million ha in the Southeast at the time of European discovery, but only ca. 1.2 million ha remain today, mostly in isolated fragments (Van Lear et al. 2005). In Florida, logging, agriculture, urbanization, silviculture (tree farming), and fire suppression have reduced old growth, longleaf savanna to <1–2% of its former range (Lannoo 2005). The full effect of habitat degradation in longleaf pine on amphibians is not fully known despite recent evidence that one-third of amphibian species that are habitat specialists in longleaf pine may be declining (Lannoo 2005, van Lear et al. 2005, Means 2008). Between 1936 and 1989, longleaf pine forests within the range of the striped newt in Florida decreased from more than 3 million ha to only 384,500 ha, an 88% decrease (Dodd 1995). Losses of xerophytic uplands used by gopher frogs have been severe, especially along the highly developed coastal ridges of both southeastern and southwestern

Florida, as well as the central ridges that have been mined, converted to agriculture, and developed (Jackson 2004).

Degradation of upland habitat surrounding breeding ponds can result from interruption of natural fire regimes, silvicultural practices, and invasive plant species. Frequency and seasonality of fire in the Southeast are important in determining the vegetative community and its quality. Frequent, low- to moderate-intensity surface fires ignited by lightning and Native Americans sustained open diverse stands in a fire climax and prevented succession of longleaf pine savannas to mixed hardwood forests dominated by fire-intolerant hardwood species (Battle and Golladay 2003, van Lear et al. 2005). Ecologists consider fire suppression to be the primary reason for the degradation of remaining longleaf pine forest. Wear and Greis (2002) found that 3.9 million ha of natural pine forest throughout the Southeast were reclassified to hardwood and natural oak-pine forests because of lack of fire. Of the remaining longleaf pine habitat in the Southeast, only 0.2% is managed with fire and can support native species of plants and animals typical of longleaf pine habitats (Frost 2006). Disruption of the natural fire cycle has increased slash and loblolly pine coverage on sites formerly dominated by longleaf pine, increased hardwood understory, and decreased herbaceous ground cover (Wolfe et al. 1988). The succession of natural pine forest to more shade-tolerant species, such as oaks and hickories (*Carya* spp.), can result in the loss of ground cover, such as wiregrass, that is presumably important to amphibian species like the flatwoods salamander, striped newt, and ornate chorus frog for shelter and foraging (Means 2001).

The most cited management concerns for gopher frogs are infrequent fire regimes, resulting in the encroachment of hardwoods and shrubs in upland habitat, and the loss of gopher tortoise burrows or pocket gopher burrows that are the primary sources of upland shelters (Hipes et al. 2001, Jensen and Richter 2005, Blihovde 2006, Roznik 2007). Gopher frog larvae were found in only 1 of 85 ponds sampled in sand pine plantations but were found in significantly more ponds in adjacent longleaf pine forests in Apalachicola National Forest (Means and Means 2005). Wigley et al. (1999) sampled 444 ponds on forest industry lands in 1996–1998 and identified gopher frogs in only 17 (<4%). In a study comparing fire-suppressed to regularly burned uplands, Greenberg et al. (2003) identified the gopher frog among the species most sensitive to hardwood invasion resulting from fire suppression. Prescribed burns in sandhill habitat need to take place in a 1- to 3-year cycle to provide ideal habitat for striped newts and gopher frogs (Johnson and Gjerstad 2006), but less frequent fires are needed for scrubby flatwoods and scrub. It is unknown whether gopher frogs are responding directly to changes in their upland habitat or indirectly to the decline in gopher tortoises, which are also sensitive to habitat changes associated with long-term fire suppression (Cox et al. 1987, Greenberg et al. 2003). Gopher tortoise populations do best under an open canopy and with an herbaceous ground cover that provides food (Enge et al. 2006). The relative scarcity of gopher frog populations in the panhandle, which has extensive suitable upland habitat, may be due to the scarcity of gopher tortoise burrows, which has also been identified as the primary reason for declines in eastern indigo snake (*Drymarchon couperi*) populations (Enge et al. 2013). Panhandle gopher tortoise populations have not recovered from past human depredation (Enge et al. 2006), and survival of dispersing gopher frog metamorphs depends upon them finding suitable burrows within a few days (Roznik and Johnson 2009a). A threshold density of burrows in proximity to a breeding pond may be necessary to support a viable gopher frog population. Other types of burrows can serve as refugia, but the silvicultural practices of stumping and short-term rotation of pines reduce the availability of stumpholes.

Striped newt declines are most likely due to conversion of longleaf pine forests to unsuitable habitats, fire suppression, and loss of ephemeral wetlands. Striped newts are apparently sensitive to hardwood invasion of sandhill habitat due to fire suppression (Greenberg et al. 2003). Fire suppression is probably the primary reason striped newts have not been found at known breeding ponds in Osceola National Forest, Lochloosa Wildlife Conservation Area, or the University of Central Florida campus since 1985 (Enge 2011), although silviculture may also be responsible at the first 2 sites. In 2000–2003, Johnson and Owen (2005) visited 51 historical sites (64 ponds) in 11 counties in the Florida peninsula and ranked the habitat quality of the wetland and surrounding uplands in terms of their potential to support newts (excellent, good, moderate, poor, none). Upland and wetland habitats at 26 sites in Clay, Marion, and Putnam counties merited a ranking of excellent, but 22 sites in 9 counties were ranked as moderate to no potential to support newts. A survey of 227 ephemeral ponds on commercial forest lands in northern Florida in 1996−1998 found striped newts in only 4 ponds in Clay and Putnam counties (Wigley et al. 1999), suggesting that some aspect of commercial forestry is incompatible with this species. Striped newts are thought to form metapopulations that persist in isolated fragments of longleaf pine-wiregrass ecosystems (Johnson 2001, 2005). Striped newts probably have limited dispersal ability, so protecting connectivity between uplands and breeding ponds of diverse hydroperiods is crucial for maintaining metapopulations (Gibbs 1993, Johnson 2005, Compton et al. 2007, Dodd and Johnson 2007). In the eastern portion of the Munson Sandhills, the native second-growth longleaf pine forest was clear cut, roller chopped, and planted in sand pine that now has a closed canopy with little native ground cover, and striped newts have disappeared (Means and Means 1998a, Means and Means 2005).

In contrast to striped newts, gopher frog and tiger salamander populations may persist in disturbed habitats. Substantial gopher frog populations utilize open pastures with tortoise burrows at sites such as Green Swamp West, Lake Panasofkee WMA, Starkey Wilderness Park, and All-Bar Ranch, but less disturbed upland habitats are adjacent to these pastures (Jackson 2004). The tiger salamander, which is not a longleaf pine specialist, appears adapted to hardwood forests, including mesic hammocks. Urbanization in some areas, such as along I-75 on the west side of Gainesville, has undoubtedly impacted tiger salamander populations. However, populations appear to be able to survive in low-density residential areas and in agricultural areas, as evidenced by their use of breeding ponds in pastures, orchards, and subdivisions.

Both flatwoods salamander species were probably once widely distributed in extensive flatwoods habitat, but habitat degradation primarily related to silviculture and fire suppression has severely curtailed their ranges to a few of the better-managed public and private lands. Although frosted flatwoods salamanders have been found at fire-suppressed sites where disruption of the natural fire cycle has resulted in increased coverage by loblolly or slash pine rather than longleaf pine, the long-term viability of populations at these sites is unknown. Closed-canopy pine plantations typically provide unsuitable habitat for the flatwoods salamander, but populations may persist in plantations where the original hydrology, ground cover, and soil structure have been less severely altered (U.S. Fish and Wildlife Service 2007). A 22-year decline in a flatwoods salamander population in the Florida panhandle was attributed to mechanical alteration of terrestrial habitat from slash pine silviculture (Means et al. 1996). Silviculture has probably been responsible for the decline or extinction of flatwoods salamander populations in the peninsula and from most private lands in Florida; the last salamander records were in the 1990s. Many populations apparently persisted after the first rotation of planted pines, but destruction of ground cover and pond ecotones by harvest, bedding, ditching, and planting during the second rotation probably extirpated most populations (CITE). However, relatively few historical ponds on private lands have been surveyed since the species was federally listed in 1999 because of problems with getting landowner permission. Improper frequency or season of prescribed burns has degraded the quality of upland and ecotonal habitats at St. Marks NWR for the frosted flatwoods salamander. Because of a long history of predominantly dormant-season (winter and early spring) fires at St. Marks NWR, the uplands are dominated by saw palmetto and appear to be of marginal quality to support flatwoods salamander populations. Much of the uplands around breeding ponds have not burned in 7 or 8 years, exacerbating the situation and resulting in even higher and denser saw palmettos and diminished wiregrass ground cover.

The ornate chorus frog is a specialist of the longleaf pine savanna (Means 2006), and the continual elimination of its upland longleaf pine habitat will probably increase the likelihood of future declines. However, we suspect habitat loss and degradation are not the primary factors responsible for population declines in the peninsula. Populations can persist in or recolonize disturbed habitats, including abandoned agricultural land (Brown and Means 1984). Population declines have been documented in areas with high-intensity forestry practices that disturb the soil or alter breeding sites, and alteration of natural fire regimes resulting from development of industrial forest plantations may cause substantial loss of populations in many areas (Dorcas and Gibbons 2008). However, populations often persist in ruderal situations, and frogs breed in flooded areas in center-pivot agriculture fields in Georgia (Lora Smith, pers. comm.). Ornate chorus frogs appeared to use a longleaf pine savanna and a slash pine plantation equally (Palis and Aresco 2007), and they did not differ significantly in use of ponds embedded in longleaf pine sandhill versus planted sand pine in the Woodville Karst Plain (Means and Means 2005). We also found an ornate chorus frog breeding pond in a clear cut sand pine plantation in Taylor County, and Gerhardt (1973) found 20 breeding sites in the area around Savannah, Georgia, situated in well-drained, sandy, and relatively open areas, typically in fields and pine flatwoods.

There are presently about 11 million ha of managed pine plantations where natural longleaf pines were once found (Frost 2006). From 1952 through 1999, a large increase in planted pine occurred simultaneously with a significant loss of native longleaf uplands. The Southeast produces approximately 60% of the domestic timber supply and, as timber prices rise, the area managed for pine silviculture is projected to increase 67% from 1995 through 2040 (Prestemon and Abt 2002). Upland conversion to pine monocultures is a disturbance spanning several decades that modifies an entire landscape. Reduction in habitat heterogeneity during post-harvest silviculture likely interferes with life histories of some species and may play a large role in species declines (Means et al. 1996). Amphibian abundance may decline following timber harvest because of direct mortality, evacuation to nearby habitat, or retreat to refugia until suitable conditions return via vegetative succession (Semlitsch et al. 2008, 2009). However, pond-breeding ambystomatid salamanders still used most breeding ponds even when the surrounding core terrestrial habitat had been logged (Scheffers et al. 2013). Determining the physiological stress and dispersal constraints posed by a habitat can provide direct evidence for reduced site occupancy (Rothermel 2004). Unlike other land uses, silviculture is common on public lands containing the last occurrences of rare amphibians.

Pine silviculture reduces vegetative diversity to a densely stocked monoculture of slash, loblolly, or sand pine, with a diminished ground cover of mostly pine needles and twigs (Means 2008). Stands are typically harvested every 15–30 years using methods that generally maximize timber yield, which may eliminate groundcover vegetation used by amphibians for foraging and shelter (Lannoo 2005). Small-scale experimental clearcuts surrounding isolated wetlands indicate timber harvest influences amphibian species composition (Bennett et al. 1980, Enge and Marion 1986, Raymond and Hardy 1991), desiccation rates, and movements (deMaynadier and Hunter 1995, Semlitsch et al. 2009). Studies have shown reduced amphibian diversity in pine plantations in the Southeast (Labisky and Hovis 1987, Russell et al. 2002, Means and Means 2005, Means 2008), but additional studies are need to identify what conditions in the uplands are most responsible for reductions in amphibian diversity (Jones et al. 2010). Canopy removal increases surface temperature and decreases soil-litter moisture, which usually has a negative effect on survival of juvenile and adult amphibians in the uplands but may have a positive effect on larval survival in ponds (Semlitsch et al. 2009).

Bedding, which is typically used in flatwoods and other poorly drained habitats, creates a small ridge of elevated soil to prepare sites before replanting pine seedlings. Bedding alters the surface soil layers, disrupts the site hydrology, and often eliminates the native herbaceous ground cover, such as wiregrass (U.S. Fish and Wildlife Service 2008). This can reduce the invertebrate community fed upon by juvenile and adult amphibians in the uplands (U.S. Fish and Wildlife Service 2008). The hills and valleys produced by bedding may also affect amphibian migrations to breeding ponds by making them expend more energy or even directing them away from ponds as they follow paths of least resistance along furrows. Bedding might be particularly detrimental to amphibians living in areas of low topography, such as flatwoods salamanders, because it disrupts elevational cues that indicate breeding pond locations. Postlarval and adult flatwoods salamanders occupy upland flatwoods sites where they live underground in crayfish burrows, root channels, or burrows of their own making (Goin 1950, Neill 1951, Mount 1975, Ashton and Ashton 2005). The occurrence of these underground habitats is dependent upon protection of the soil structure. Intensive site preparation such as bedding and roller chopping destroys the subterranean voids and may result in entombing, injuring, or crushing individuals (U.S. Fish and Wildlife Service 2008). Windrowing, the practice of piling logging slash, can reduce the risk of desiccation of amphibians in clearcuts (Rittenhouse et al. 2008), but long, linear windrows may block amphibians from their breeding ponds and metamorphs from dispersing into suitable upland habitats. Amphibian metamorphs often moved along linear windrows in clearcuts (Enge and Marion 1986). On drier soils, site preparation may include bedding but typically consists of roller chopping and sometimes scraping the surface with a blade. The latter practice eliminates ground cover and woody debris besides potentially killing amphibians on the surface.

Road construction associated with land development contributes to habitat fragmentation by isolating blocks of remaining contiguous habitat. Roads may impact amphibians by disrupting dispersal to and from breeding sites or by killing individual via vehicles, desiccation on dry asphalt, or increased exposure to aerial predation (Means 1996). Amphibians are often the most common road-killed vertebrates (Fahrig et al. 1995, Smith and Dodd 2003, Glista et al. 2007). During a study in Apalachicola National Forest south of Tallahassee, most striped newts and gopher frogs were forced to cross a major highway to reach their breeding pond (Means 1999), and gopher frogs were frequently killed crossing a highway in Marion County (Smith 2006). One hundred thirty flatwoods salamanders were observed crossing a road in Liberty County in 1970–1972, but none was seen after 1992 (Means et al. 1996). During this study in 2013 and 2014, road-killed tiger salamanders were observed on roads at night in Hernando, Levy, and Marion counties during breeding migrations.

Invasive plant species, such as cogongrass (*Imperata cylindrica*), threaten to further degrade pinelands. Pyrogenic cogongrass, a perennial grass native to Southeast Asia, is one of the leading threats to the ecological integrity of native herbaceous flora, including that in the longleaf pine ecosystem in the southern United States (Jose et al. 2002). Cogongrass can outcompete wiregrass, altering the soil chemistry, nutrient cycling, and hydrology of an infested site (Jose et al. 2002). Furthermore, cogongrass fires are typically 15–20% hotter and more intense than natural fires in southern pinelands (MacDonald 2007), killing most aboveground vegetation except trees and limiting natural secondary succession (Lippincott 2000). These hot fires might result in increased mortality of amphibians, including ones sheltering underground.

Wetland Loss and Alteration.—From the 1780s to 1980s, Florida lost more wetland acreage (3.8 million ha) than any state (Dahl 1990), but how much of this loss represented isolated wetlands potentially used by the target amphibian species is unknown. Isolated, ephemeral wetlands lack federal protection (Pittman and Waite 2009), but these are the wetlands used by many amphibian species that are absent from large wetlands (Snodgrass et al. 2000). Ten anuran and 5 salamander species in Florida, including our 6 study species, breed principally or exclusively in small isolated wetlands, and an additional 12 anuran and 7 salamander species may use small isolated wetlands (Moler and Franz 1988). Most amphibian species, including the six target species in this study, are suspected to occur in metapopulations in which local extirpations or poor recruitment from individual ponds are offset by colonizations of individuals from nearby ponds (Marsh and Trenham 2001). Within these metapopulations, the spatial arrangement of ponds and local habitat quality can determine population extirpation and colonization rates (Marsh and Trenham 2001). Loss of small, ephemeral wetlands changes the metapopulation dynamics of a species by reducing the number of individuals that can disperse and reproduce successfully, and by increasing the distance among wetlands (Semlitsch and Bodie 1998). Amphibian populations that no longer have access to a variety of wetlands with different hydroperiods may become extinct if unsuitable hydrologic conditions persist for multiple years during prolonged droughts, particularly for short-lived species (e.g., ornate chorus frog). Studies have shown that local extinction of fragmented populations is common, and recolonization is critical for their regional survival (Fahrig and Merriam 1994, Burkey 1995). Amphibian populations may be unable to recolonize areas after local extirpations due to their physiological constraints, relatively low mobility, and site fidelity (Blaustein et al. 1994).

Isolated, ephemeral wetlands are important because they lack large predatory fish species and may have relatively few other predators, such as smaller fish species and aquatic invertebrates (Moler and Franz 1988). Predator populations are eliminated when temporary wetlands dry periodically, and when isolated wetlands refill, they are less likely to be recolonized by predators, although some may hatch from existing eggs. Aquatic insects are major predators of amphibian larvae in temporary wetlands (Brockelman 1969, Caldwell et al. 1980, Formanowicz and Brodie 1982), and the most isolated wetlands are less likely to be colonized by dispersing adult phases of aquatic insects (Wilkerson 2001). The most isolated wetlands are presumably less likely to be colonized by fish, although topography is critical. Wetlands in more poorly-drained habitats, such as wet and mesic flatwoods, are more susceptible to colonization by fish species. Large predatory fish species may be introduced into isolated ponds by flooding; sheet flow through the uplands is a natural phenomenon during hurricanes and tropical storms. Sheet flow is more common in poorly-drained habitats, such as pine flatwoods and dry prairie, but occasionally occurs in xeric habitats. For example, flooding from Tropical Storm Debby in June 2012 resulted in the colonization by fish of many isolated wetlands in sandhill habitat in the Panacea Unit of St. Marks

NWR. Over 50% of the 60 ponds being monitored in the Panacea Unit were fishless prior to Debby, but only 5 ponds remained fishless after Debby (William Barichivich, pers. comm.). Hydrological alteration can facilitate fish colonization by connecting isolated wetlands in xeric habitats using ditches to more permanent bodies of water. Creation of nearby roadside ditches, canals, borrow pits, or fish ponds can also serve as sources of fish introductions.

Stocking of sport fish in isolated permanent and semipermanent wetlands makes them unsuitable breeding sites for amphibian species requiring fish-free wetlands. Potholes were blasted into ephemeral wetlands in Ocala National Forest and stocked with game fish to provide fishing holes (Christman and Means 1992). In December 2013, gopher frogs bred in the main basin of Watermelon Pond because it had dried earlier, eliminating predatory fish species. In 2014, FWC stocked bluegills and other forage species in Watermelon Pond in preparation for later stocking of bass, likely resulting in direct mortality of gopher frog tadpoles. In 2006 and 2010, striped newts were found in 4 small, isolated basins south of Watermelon Pond in Alachua and Levy counties. Gopher frogs and striped newts will be prevented from breeding in the main pond basin until hydrological drydowns extirpate the introduced game fish. Human prolongation of hydroperiods can also result in persistence of predator populations, such as deepening wetlands for livestock watering. A breeding pond north of Tallahassee in the Tallahassee Red Hills once contained striped newts, but this site was dredged, deepened, and stocked with game fish in the 1980s and no longer supports newts (Means and Means 1998b). However, cattle dugouts can benefit amphibian populations by allowing successful metamorphosis of larvae during dry conditions. We sometimes found gopher frog tadpoles in dry wetland basins only in these dugout areas, which functioned as alligator holes. Some mosquito control districts stock isolated wetlands with mosquitofish to control mosquito populations. Although the eastern mosquitofish is native to the Southeast and amphibian species requiring fish-free wetlands often tolerate its presence, larval survival is undoubtedly higher in ponds without mosquitofish. Mosquitofish are primarily planktivorous at low population densities, but at high densities, their diet may change to include animal matter (Blanco et al. 2004). Mosquitofish can consume amphibian eggs (Grubb 1972) and small larvae (Gamradt and Kats 1996, Goodsell and Kats 1999, Stanback 2010), and they nibble on tail fins, bellies, and external gills of larvae of all sizes, often resulting in mortality (Pyke and White 2000, Baber and Babbitt 2004, Gregorie and Gunzburger 2008). Mosquitofish can occur at high densities (Baber et al. 2002) and are able to forage in shallow, vegetated habitats that would otherwise serve as refuge from larger predators (Baber and Babbitt 2004). Large predatory centrarchid fish and smaller fish like mosquitofish can significantly alter the behavior and survival of tadpoles unaccustomed to their presence (Gregoire and Gunzburger 2008).

Groundwater withdrawal has impacted the hydroperiods of ephemeral wetlands in parts of Florida. Some ephemeral wetlands are mostly unaffected by groundwater withdrawal because they have almost impermeable sediments and are solely dependent upon rainfall and surface runoff for filling. Water levels of other ephemeral wetlands are associated with groundwater levels. A study on the effects of reducing groundwater withdrawal in west-central Florida showed that hydrological recovery of wetlands was most influenced by the presence of recent karst activity (i.e., sinkholes) below or near the wetlands and the depth of the potentiometric surface of the Upper Floridan aquifer below the wetlands (Metz 2011). Breaches in the underlying sediments of the wetlands due to recent karst subsidence activity connected some wetlands to the underlying aquifer, and downward leakage potential decreased when the distance between the potentiometric surface of the aquifer and the wetland-bottom elevation decreased. Hydroperiods of most wetlands increased in response to a reduction in groundwater withdrawal. Ephemeral wetlands in the Munson Sandhills south of Tallahassee are associated with a 5–10 m layer of clean sands containing thin lenses of clay that rest upon limestone units comprising the regional aquifer system (Kish and Means 2012). Approximately 85% of ponds are within 2 m of the groundwater surface, and ponds fill when the groundwater surface is very near to the base elevation of the ponds and high seasonal rainfall provides additional water to the surface sand aquifer, producing a local "cap" resting on top of the main groundwater surface (Kish and Means 2012). Groundwater withdrawal in conjunction with a severe drought in 1999−2000 may have contributed to striped newt declines in Apalachicola National Forest (Means and Means 2008).

Prescribed fire plays an important role in maintaining productive breeding ponds for all the target amphibian species (Kirkman et al. 1999). Fire exclusion may impact vegetative composition, solar radiation, water temperature, water chemistry, hydrology, nutrient cycling, and productivity of wetlands (Kirkman 1995, Battle and Golladay 2003, Pilliod et al. 2003). Historically, fires that naturally ignited in the uplands during the late spring and early summer would sweep through the dry pond basins, reducing organic matter and killing encroaching upland plant species (Myer 1990, Bishop and Haas 2005, Means 2008). However, most prescribed burning in the Southeast is conducted in winter and early spring when wetlands are typically filled with water; thus, fires cannot burn through pond basins, particularly large ones (Bishop and Haas 2005). Burning in dry pond basins is necessary to maintain the quality of vegetation needed for laying eggs, cover, or foraging. In the absence of fire, a peat layer starts developing and woody vegetation invades, eliminating much of the herbaceous vegetation. Accumulation of plant detritus decreases the hydroperiod and eventually fills in ephemeral wetlands. Lack of fire in maidencane-dominated ponds can lead to such a thick mat of vegetation, particularly during low water levels, that amphibian larvae cannot readily maneuver. We seldom found gopher frog tadpoles in ponds with extremely dense vegetation, but difficulty in effectively dipnetting these ponds might have been a factor. Most wetlands used by the target amphibian species either lack a canopy or have an open canopy that allows grassy vegetation to be present around the perimeter or in the basin. Compared to closed canopy ponds, open canopy ponds have higher water temperatures, higher dissolved oxygen levels, and higher algal productivity and more periphyton (tadpole food), resulting in increased tadpole growth (Skelly et al. 2002, Thurgate 2006). Flatwoods salamanders require moist mineral soil upon which to lay their eggs. When pond basins fail to burn and develop a duff layer, salamanders are forced to lay their eggs in the ecotone where they will not hatch if ponds do not sufficiently fill with water. These ecotonal areas will also become unsuitable egg-deposition sites when shrubs invade in the absence of fire, shading out herbaceous vegetation and producing leaf litter. Fires that only burn as far as the pond ecotone likely benefit larval flatwoods salamanders by increasing herbaceous growth, water temperatures, and dissolved oxygen levels (Bishop and Haas 2005).

Improperly timed fires may kill or produce unfavorable environmental conditions for eggs, larvae, metamorphs, or migrating adult flatwoods salamanders. During growing-season fires, flatwoods salamanders and the other target amphibian species are underground in the uplands. Burns in October–December may directly kill adults migrating to and from breeding ponds or result in increased mortality from predation or desiccation because of the lack of protective cover. Migrating gopher frogs sheltering on the surface were killed by prescribed burns in North Carolina (Humphries and Sisson 2012). Winter fires also can kill eggs of flatwoods salamanders (Pierson Hill, pers. obs.) and reduce protective vegetative cover for eggs and larvae. Growing-season prescribed burns in April, which are before the May–August peak lightning season (Bishop and Haas 2005), may affect dispersing metamorphs by direct mortality, reducing protective vegetative cover and coarse woody debris, and producing harsh environmental conditions.

Wetland degradation from fire suppression is at least partially to blame for some of the observed population declines in these amphibian species. For instance, multiple surveys have failed to detect the frosted flatwoods salamander in the 3 known breeding ponds in Osceola National Forest since 1998. Habitat conditions in these ponds are suboptimal, partly because of insufficient growing-season burns, which are complicated by the proximity of I-10 and potential smoke issues. At St. Marks, a lack of growing-season fire has resulted in sawgrass (*Cladium jamaicense*) and shrubs encroaching and obliterating the graminaceous ecotones around many known flatwoods salamander ponds, rendering them unsuitable as breeding sites. Shrub encroachment of pond ecotones in flatwoods habitat is observed throughout the peninsula and much of the panhandle.

Silvicultural practices, including mechanical site preparation, pond ditching, soil disturbance, and the use of fertilizer and herbicides, can interfere with migration and successful reproduction of amphibians (Dodd and LaClaire 1995, Means and Means 2005, Means 2008). Pond ditching, which is used to drain ponds to create ideal conditions for silvicultural operations, is often detrimental because it alters pond hydrology and facilitates predatory fish movement into otherwise fishless ponds (Means 2008). Ditching creates a shortened hydroperiod, reducing the amount of time larvae have to metamorphose, eventually decreasing the number of reproducing adults (Means 2008). Flatwoods salamanders sometimes deposit eggs in plowlines around wetlands; these plowlines may provide suitable conditions for larval survival but may dry before the pond basin, killing the larvae (Bishop and Haas 2005). However, ditches or plowlines sometimes contain the only water with emergent vegetation and allow larval survival when pond basin conditions are unfavorable and the grassy ecotone is dry (Kevin Enge, pers. obs.).

Off-road vehicle use, which is locally referred to as “mud bogging” or “mudding,” within breeding ponds and their margins severely degrades wetland habitat. In the Southeast, ORV use impacts upland and wetland habitats and has the potential to cause direct mortality of individual amphibians on both public and private lands. Even a single afternoon of individuals riding their ORVs in a pond can completely destroy the integrity of breeding sites by damaging or killing the herbaceous vegetation and rutting the substrate (Ripley and Printiss 2005). In 1994, 27 of 100 ponds at ANF were found to be damaged by ORV use, including 3 of 18 striped newt ponds (Means et al. 1994). By 2006, ORV impacts were documented at nearly every pond at ANF (Means et al. 2008). The littoral zone of ephemeral ponds provide shallow, warm water and abundant vegetation that provides cover for larval amphibians and food in the form of animals for salamander larvae and newts and algae, vegetation, and detritus for tadpoles. Excessive ORV use eliminates the grassy vegetation around ponds, creating barren sandy beaches that provide no food or protection from predators, such as wading birds (Means et al. 2008). By 2010, the USFS closed the Munson Sandhills to ORV use to protect the striped newt ponds (U.S. Fish and Wildlife Service 2011). Off-road vehicle use of wetlands is also prevalent in areas of Ocala National Forest (Figs. 89, 90), and many areas and trails have been closed. However, these restrictions are difficult to enforce. In some years, the presence of deep ruts in wetland basins may benefit amphibians by retaining water when the rest of the wetland has dried, allowing some larvae time to successfully metamorphose, if food remains available. Large numbers of gopher frog tadpoles can sometimes persist in vehicle ruts in drying ponds (Kevin Enge, pers. obs.).

Figure 89. Off-road vehicle trail disturbance in the middle of a historical striped newt and extant gopher frog pond in Salt Springs Island, Ocala National Forest.

Figure 90. Off-road vehicle destruction of the littoral zone of a gopher frog breeding pond ("Racetrack Pond") south of Church Lake, Ocala National Forest.

Rooting by feral hogs also can alter wetlands by affecting vegetation, microtopography of the bottom, nutrient levels (inorganic nitrogen and phosphorous are released), and water turbidity. Rooting primarily occurs when the pond basin is moist but not inundated (Fig. 91). Rooting of pond margins and ecotones is probably the most detrimental to amphibian communities, because grassy vegetation in shallow water is often used by larval amphibians. In the case of flatwoods salamanders, grassy ecotones are egg deposition sites. At St. Marks NWR, hog rooting of graminaceous ecotones has favored sawgrass and other vegetation that thrives on disturbance, which are unfavorable for egg deposition and larval cover. Redroot (*Lachnanthes caroliniana*) typically flourishes in hog-rooted areas (Boughton and Boughton 2014; Kevin Enge, pers. obs.) (Fig. 92), but the suitability of redroot monocultures for amphibian larvae is unknown. Redroot probably provides less cover from predators than grasses, and the reduction in grassy vegetation prevents fire from readily carrying into pond basins. Hogs also target redroot-dominated areas, presumably feeding upon the rhizomes; redroot vigorously re-sprouts from rhizome fragments, further increasing redroot density (Boughton and Boughton 2014). Gopher frog tadpoles are sometimes found in wetlands that have experienced heavy disturbance by hogs; hog wallows may retain the only water in drying wetlands (Kevin Enge, pers. obs.). Changes or reduction in vegetation can reduce egg attachment sites, larval cover, perching sites, and food. Changes in microtopography from rooting can affect hydroperiod, create small pools that dry and trap larvae, create deep holes that don't dry down and kill predatory invertebrates and fishes, alter the pond margin or ecotone and cues for breeding amphibians, disrupt the ability of fires to carry into basins and prevent peat buildup and shrub invasion, and interrupt dispersal of metamorphs. Rooting and hog feces may affect nutrient levels, food supply for larvae (algae, phytoplankton, and zooplankton), predator populations, dissolved oxygen levels, water chemistry, and water turbidity. Feral hogs also opportunistically prey on amphibians or inadvertently kill amphibians during rooting activities both in wetlands and uplands. Feral hogs opportunistically consumed large numbers of spadefoot toads (*Scaphiopus holbrookii*) in Georgia (Jolley et al. 2010), and 2 adult frosted flatwoods salamanders were observed killed by rooting hogs at St. Marks NWR (Scott Davis, pers. comm.).

Figure 91. Extensive hog rooting of the entire basin of a dry dome swamp in Green Swamp West, Pasco Co.

Figure 92. Red root dominance in a hog-rooted portion of a gopher frog breeding pond in Chassahowitzka WMA, Hernando Co.

Drought and Climate Change.—Potential direct and indirect effects of climate change may affect amphibian survival, growth, reproduction, dispersal capabilities, habitats (vegetation, soil, and hydrology), food availability, predator-prey relationships, and pathogen-host dynamics (Blaustein et al. 2010). Ranges of amphibian species are predicted to change as a result of climate change (Blaustein et al. 2010), and poleward and elevational shifts of amphibians and other species in response to recent climate changes have been documented elsewhere (Parmesan and Yohe 2003). These range shifts result from migrations and extirpations of species at the edges of their range as species respond to long-term climate shifts, short-term climate extremes, and range shifts of other species and ecosystems (Walther et al. 2002). Florida represents the southern terminus of the ranges of the target amphibian species, and some populations in Florida may have been the first to be impacted by climate change. In addition, climate-driven effects on species distributions should be magnified in Florida, because of a peninsula effect (decreasing biodiversity towards the tip of the peninsula) and the presence of multiple climate zones (subtropical and tropical with a transition zone in between) that have their own unique biomes.

Our analyses of long-term regional climate patterns show a marked difference between the panhandle and the peninsula. Minimum, maximum, and average annual air temperatures have increased steadily over the last 120 years throughout the peninsula, while temperatures have remained steady in the panhandle. These temperature increases increase in magnitude along a gradient from north to south in the peninsula, although there are months with significant increases in every peninsular climate division. Because of these temperature increases, the length of droughts has increased in the north central and south central parts of the peninsula, and the severity of droughts has significantly increased in late fall/early winter months in these regions. Increases in temperature result in increased evapotranspiration of wetlands, shortening their hydroperiods unless the water loss is offset by increased precipitation.

Although southeastern amphibian species are adapted to periodic droughts, prolonged droughts can worsen threats to already small amphibian populations and exacerbate the already present degradation and fragmentation of upland and wetland habitats, leading to extinction in many areas (U.S. Fish and Wildlife Service 2011). During multi-year droughts, continued lack of juvenile recruitment can cause extirpation of a local population if adults cannot survive long enough in adjacent upland habitat until rains return to fill ponds (Biek et al. 2002, Baldwin et al. 2006, Taylor et al. 2006). The USGS has documented multiple drought periods in the southeastern United States since the 1890s (USGS Open File Report 00-380). Significant drought periods in the last 3 decades were 1980–1982, 1984–1988, 1998–2000 (USGS Water Supply Paper 2375), and 2006–2008. Droughts normally occur in cycles, and amphibian populations fluctuate with drought conditions, but droughts lasting >4 years affect reproductive success of long-lived amphibian species (e.g., flatwoods salamander, tiger salamander, striped newt) to the extent that populations decline because of decreased recruitment? (Dodd 1992, Petranka 1998, Buhlmann and Mitchell 2000, Palis et al. 2006, Dodd and Johnson 2007). Our analyses of regional climate data revealed that recent droughts (since 1980) in the north central and south central peninsula were 4−5 years long and 2−3 years longer on average than droughts in the past. This increase in drought duration likely had devastating consequences for the ornate chorus frog due to its short (1−3 years) lifespan. Increased drought severity in the late fall/early winter is also potentially significant, because this is the time period when the target amphibian species are migrating to wetlands and ephemeral ponds are filling. During and immediately following a 4-year drought (1999−2002) in the panhandle, the number of adult flatwoods salamanders immigrating to a breeding pond steadily declined, and there was no evidence of population recruitment (Palis et al. 2006). A severe drought in Apalachicola National Forest in 1999−2000 (less severe drought conditions persisted until 2006) probably contributed to declines in newt populations (Means and Means 2008).

Mark Barrett compared the attributes of occurrences in Apalachicola National Forest and St. Marks NWR, where striped newt populations may be extinct, versus those in northern and southern Ocala National Forest, where populations are extant (Fig. 93). These areas with extinct versus extant populations are separated by similar latitudinal distances (Fig. 94). Panhandle areas with possibly extinct populations apparently have more annual and winter/fall precipitation, more disturbed areas, and closer proximity to major roads than areas with extant populations (Fig. 95).

Climate changes will likely result in loss and degradation of habitats in Florida and affect the reproductive phenology and success of some amphibian species. Temperature and rainfall are critical to amphibian physiology and behavior because of their role in gametogenesis and reproductive migrations (Semlitsch 1985, Beebee 1995, Todd and Winne 2006).The threat of amphibian population extinctions from long-term droughts is expected to continue or escalate in the future; droughts are predicted to be more severe and longer in duration in the coming years throughout the entire range of all 5 target species except the tiger salamander (U.S. Fish and Wildlife Service 2011). Climate change may increase the incidence and severity of both drought and major storm events. This extreme variation in precipitation and the pattern and timing of rainfall events are likely to become more influential on seasonal reproduction of amphibians, affecting competitive and predatory interactions of larvae (Walls et al. 2013). Climate models project continued warming across the southeastern United States, with an increasing rate of warming towards the end of the century (Karl et al. 2009). Using downscaled climate data downloaded from Climate Wizard (Zganjar et al. 2009), mid-century projections suggest average annual temperature increases of 1.7−2.2°C across the state of Florida, with the greatest increase in the panhandle (Dubois et al. 2011). Precipitation projections are more variable, with some models projecting increases and others projecting decreases in annual precipitation. However, even if increases in precipitation occur, these will be offset by increased evaporation and water loss resulting from higher temperatures.

Attributes for each area:

N = Number of occurrence points
Model Value = Maxent output at occurrence points
Precipitation (ppt) = Annual mean (& Stdev) over a 30-year period (1981-2010)
= Winter/Fall (Oct-Feb) mean (& Stdev) over a 30-year period (1981-2010)
Distance to = Distance (km) from occurrence point to Hwy (major highway) and Major Rd
Disturbed area = Amount (ha) of disturbed area within a 500-m buffer around occurrence points
Disturbed classes - High/low intensity urban, extractive, rural lands, transportation, utilities, tree plantations
NHD pond size – Size of pond (ac) for the occurrence points

Summary (means) among the areas, with the lower portion of the table being the combined means of the two areas per population status type (possibly extinct or extant).

			Precipitation (ppt)							
		Model	Annual		Winter/Fall		Distance to		Disturbed	NHD pond
Area	N	Value	Mean	Stdev	Mean	Stdev	Hwy (km)	Major Rd (km)	area (ha)	size (ac)
Apalachicola	23	0.55	126.2	42.1	100.5	17.0	1.1	0.8	13.7	3.7
St. Marks	3	0.37	128.4	45.0	98.9	11.0	1.4	0.7	6.8	1.1
ONF_North	12	0.65	109.4	49.1	73.1	12.0	17.4	1.8	1.6	0.7
ONF_South	4	0.58	109.5	52.7	69.5	11.7	11.6	3.2	0.0	6.0
		Mean values								
Possibly extinct	26	0.46	127.3	43.5	99.7	14.0	1.2	0.7	10.2	2.4
Extant	16	0.62	109.5	50.9	71.3	11.9	14.5	2.5	0.8	3.4

Figure 93. Analysis of attributes of occurrence points of extant (Ocala National Forest North and South) and possibly extinct (St. Marks NWR and Apalachicola National Forest) striped newt populations. Extant ponds included had at least 3 years of occurrences.

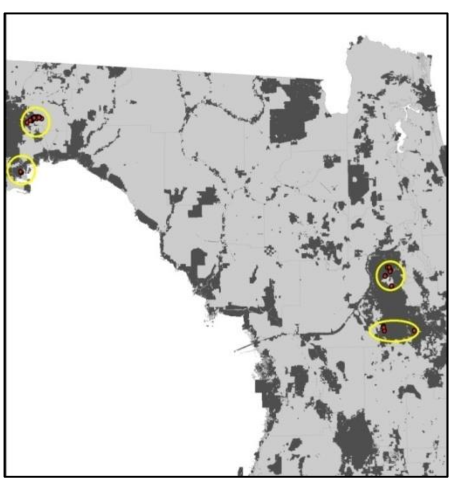


Figure 94. Locations of 2 areas with possibly extinct and extant populations of striped newts that were

Figure 95. Historical striped newt breeding pond in Apalachicola National Forest, Leon Co., that is

used to analyze attributes of occurrence points. immediately adjacent to Highway 319 (background).

We have no information on changes in the timing of reproduction of amphibian species in Florida, but changes in reproductive phenology in other areas have resulted in decreased reproductive success. A 30-year study of the phenology of reproductive migrations of 10 amphibian species using a temporary wetland in South Carolina showed that 2 autumn-breeding species (mole salamander and dwarf salamander) are breeding increasingly later in recent years, whereas 2 winter-breeding amphibian species (tiger salamander and ornate chorus frog) are breeding increasingly earlier (Todd et al. 2011). The median arrival date at the breeding pond has changed 23.5 days per decade for the tiger salamander and 37.2 days per decade for the ornate chorus frog. These changes in reproductive phenology are apparently in response to an estimated 1.2°C increase in local overnight air temperatures during the September–February pre-breeding and breeding periods. However, the trend of earlier arrival in recent years for the tiger salamander was not significant after factoring in rainfall, which might account for most of the observed annual variation in phenology. Several other studies have shown earlier breeding in temporary pond-breeding amphibians in North America, Europe, and Japan (Beebee 1995, Gibbs and Breisch 2001, Beebee 2002, Chadwick et al. 2006, Kusano and Inoue 2008). Increases in temperature may have a greater effect on the timing of early-breeding amphibian species (Todd et al. 2011). Changes in reproductive timing of amphibian species may affect population trends and long-term persistence of populations because of larval interactions influencing juvenile recruitment into the population (Wilbur 1997). Changes in the timing of breeding can result in an altered composition of the larval amphibian community in terms of species, densities, and body sizes, which can affect competitive interactions, resource availability, and predator–prey dynamics (Alford 1989, Lawler and Morin 1993, Boone et al. 2002). For example, the presence of tiger salamander larvae in a pond containing amphibian larvae that are not adapted to the presence of a large, voracious predator would be deleterious to juvenile recruitment into populations of the other species. Further study is needed to determine if climate-driven phenological changes are affecting amphibian populations in Florida, particularly for winter breeding species with distinct breeding periods like the ornate chorus frog.

Our comparison of recent (since 1980) with older (before 1980) records of the target species showed that the ornate chorus frog and flatwoods salamander species have experienced northward latitudinal shifts at the southern limit of their range that would be consistent with a climate-change effect. The direction and magnitude of the northward latitudinal shifts are consistent with range shifts observed in other locations that have been attributed to climate change (Parmesan and Yohe 2003). Significant westward shifts of 5 of our 6 target species may also be related to long-term regional differences in temperature and drought between the peninsula and panhandle. The western range boundary of the striped newt shifted eastward due to the recent apparent extirpation of populations in Apalachicola National Forest. Although caution should be used in interpreting these data, as we must assume that survey efforts were adequate in both time periods, these results suggest that climate changes may have had at least a partial role in observed species declines. It is interesting to note that the boundary between NOAA’s North and North Central climate divisions corresponds closely with the historical southern extent of the range of the frosted flatwoods salamander and current southern extent of the range of the ornate chorus frog (Fig. 22).

Climate change is not solely responsible for the latitudinal shift in the range of the frosted flatwoods salamander in Florida. Extirpation of the southernmost peninsular populations in

Alachua County and the southernmost panhandle populations in Tate's Hell State Forest are probably also due to silvicultural practices and improper fire regimes. The significant decrease in mean latitude for the reticulated flatwoods salamander (Fig. 86) is likely related to extirpation of populations on private lands in Calhoun and Jackson counties due to silviculture and agriculture. No significant change in mean latitude is observed for any other species due to recent records from the panhandle.

Disease.—The threat of disease to Florida populations of these 6 amphibian species is unknown. Few amphibian mortality events have been documented in Florida; major events thus far have been due to alveolate parasites (Rothermel et al. 2008). A die-off of hundreds of ranid tadpoles, including gopher frogs, in 2 ponds in Withlacoochee State Forest, Hernando County, was apparently caused by alveolate parasites (Davis et al. 2007, Rothermel et al. 2008). The alveolate protistan parasite responsible for amphibian die-offs in the United States has been referred to as *Dermomycoides* sp., *Perkinsus*-like, and *Anuraperkinsus* (Green et al. 2002, Davis et al. 2007, Cook 2009). A newly identified mesomycetozoan pathogen, *Anuraperkinsus emelandra*, was the cause of massive ranid tadpole mortalities in 10 states, including a 2003 die-off of almost all tadpoles at the only known breeding pond of the federally endangered dusky gopher frog (Cook 2008. 2009). A striped newt in captivity was found to be infected with a protistan parasite (Cook 2008). Another recently described disease caused by a fungus-like protist (*Amphibiocystidium viridescens*), has been reported in eastern newt populations (Raffel et al. 2008).

Chytridiomycosis, a disease caused by the fungus *Batrachochytrium dendrobatidis* or *Bd*, has been implicated or documented as a causative agent in amphibian population declines in many parts of the world (Blaustein and Johnson 2003). Although *Bd* has been found at low prevalence levels in several amphibian species in Florida (Rizkalla 2009, 2010; Chatfield et al. 2012; Reintjes-Tolen 2012), it has apparently not been responsible for any acute mortality events in Florida or elsewhere in the Southeast (Rothermel et al. 2008, Gray et al. 2009b). Daszak et al. (2005) found that the impact of *Bd* on amphibians can vary among species, and factors such as climate (i.e., drought) and life-history traits can affect a species' response to the disease. *Bd* was not responsible for observed declines in amphibian species in South Carolina, including those of the tiger salamander and ornate chorus frog (Daszak et al. 2005). Zero of 18 gopher frog tadpoles examined from Florida and Georgia tested positive for *Bd* (Rothermel et al. 2008). *Bd* is present in eastern newts in North America (Ouellet et al. 2005). Recently, a chytrid fungus *B. salamandrivorans* (*Bs*) of Asian origin has emerged and decimated European fire salamander (*Salamandra salamandra*) populations (Martel et al. 2014). It was probably introduced into Europe via the pet trade, and there is concern that *Bs* may be introduced into the United States via importation of newts. Experiments have shown that native salamanders are highly vulnerable, particularly newts (Martel et al. 2014).

A group of viruses belonging to the genus *Ranavirus* has been shown to affect some local populations and to cause localized die-offs of amphibians (Gray et al. 2009a). Green et al. (2002) found that *Ranavirus* was the most frequent cause of amphibian mortality in at least 10 species, including the spotted salamander and eastern newt, so this virus potentially could impact the flatwoods salamander, tiger salamander, and striped newt. However, *Ranavirus* is difficult to detect in less abundant species (Gray et al. 2009a). The emergence of *Ranavirus* in amphibian populations can be attributed to reduced amphibian immunity associated with increased occurrence of anthropogenic stressors (e.g., drought) and introduction of *Ranavirus* strains into amphibian populations by humans (Gray et al. 2009b).

During this study, a few healthy-looking striped newts from Round Pond in Ocala National Forest tested positive for *Bd* or *Ranavirus* (Jen Stabile, pers. comm.). In 2011, the PI discovered a die-off of bullfrog and southern leopard frog tadpoles in Pebble Lake in Mike Roess Gold Head Branch State Park, Clay County. Tadpoles, including that of 1 gopher frog, were found to be infected by alveolate parasites and a ranavirus (FV3-like), but the extent to which the virus played a primary role in the die-off remains uncertain (Landsberg et al. 2013). Some gopher frog tadpoles in Pebble Lake successfully metamorphosed. In a survey of 32 ponds in Florida, *Bd* was detected in asymptomatic southern cricket frogs in 1 pond in Camp Blanding Military Reservation and 1 pond in Osceola National Forest, and *Ranavirus* was detected in American bullfrogs and southern leopard frogs only in Pebble Lake (Reintjes-Tolen 2012). The extirpation of striped newts from the Munson Sandhills of Apalachicola National Forest is somewhat enigmatic and was possibly the result of a disease outbreak (Means et al. 2008).

Harvest.—Serious amphibian keepers will occasionally pay high prices for species with restricted distributions and specialized care requirements. With the advent of the internet, more commercial collectors or dealers have access to these potentially lucrative outlets for rare species, which are often European or Southeast Asian countries. Captive breeding of all target species except the striped newt is difficult and typically requires hormone injections. Harvest of the protected flatwoods salamander species and the gopher frog is illegal and presumably an insignificant threat to their populations. Larvae of these species are relatively easy to collect compared to adults, particularly in regards to flatwoods salamanders. The only area where flatwoods salamanders might be vulnerable to collection is Apalachicola National Forest because of unrestricted public access and an extensive road network. Scientists collected 141 frosted flatwoods salamanders from Franklin and Liberty counties in 1970−2002. One scientist collected 65 adults from Apalachicola National Forest on roads in 1970−1972. Gopher frogs could be collected from many areas, including private lands, but a market apparently does not exist for this species. We found most gopher frog breeding ponds by dipnetting for tadpoles, which are relatively delicate for a ranid and often do not survive transport from the field. Large numbers of tadpoles could be collected from some ponds, but they would have to be successfully identified and then raised until metamorphosis, which would likely not be very lucrative.

Tiger salamanders are commonly sold as pets, but most specimens are collected in states where they are more numerous. In Florida, none was reported collected for the pet trade in 1990–1994 (Enge 2005), but there is some commercial collection of migrating adults or dispersing metamorphs from a few populations in Citrus and Hernando counties (Bill Kellner, pers. comm.; Phillip Frank, pers. comm.). Tiger salamanders from the peninsula tend to be more brightly patterned and attractive than those from the panhandle and consequently may be more desirable in the pet trade. Eastern tiger salamanders can be collected in much greater numbers in other states, and there is no particular demand for Florida specimens. The more brightly colored barred tiger salamander (*Ambystoma mavortium mavortium*) is probably the most commonly sold tiger salamander in the pet trade. Tiger salamander larvae (often called waterdogs) are sometimes sold as fish bait in certain states, which has resulted in introduction of the species outside its natural range, particularly in the southwestern United States (Petranka 1998). We are unaware of using larvae for bait in Florida, but in 2014, FWC was contacted regarding the legality of importing from Minnesota eastern tiger salamander larvae (Kelly Gestring, pers. comm.), which if released, could compromise the genetic integrity of Florida populations.

The striped newt is a candidate for federal listing but is currently unprotected. Striped newts are occasionally collected and offered for sale on the internet. The source of these newts is probably Ocala National Forest because of unrestricted public access and an abundance of occupied ponds. The trade in striped newts appears to be small, but removal of even a few adults from declining populations may have a significant impact. Because of its restricted distribution and attractive appearance, the striped newt may be desirable and reasonably valuable to select clientele. Striped newts have been successfully bred in captivity by zoos and private citizens, and they do well in captivity like most other newt species. Scientists may have overcollected some populations, particularly when these collections occurred during a short period of time. For example, 229 striped newts were collected from Still Hunt Ponds, Lochloosa Wildlife Conservation Area, in 1970–1971; this population is now extinct. Ninety-nine newts were collected by scientists from Apalachicola National Forest, but the collections occurred from 1969 through 1997. Other large scientific collections have come from Ordway-Swisher Biological Station (319 newts in 1985–2005, including 212 from 1 pond) and Ocala National Forest (195 newts in 1994–2009).

Harvest is probably not a significant threat to ornate chorus frog populations, although 901 were reported collected in the panhandle for the pet trade in 1990–1994 (Enge 2005). The ornate chorus frog is an attractive species and appears to do reasonably well in captivity (Brown and Means 1984), but its short life span and fossorial habits make it more of a specialty pet for the serious enthusiast. Because of its relatively low monetary value, it would be economically worthwhile to collect only when large numbers migrate across roads at night to breeding ponds, which happens in some areas of the panhandle. Calling ornate chorus frogs are difficult to locate and collect in large numbers, unlike many treefrog (*Hyla*) species.

Recommendations for Land Managers

Here we provide a brief overview of suitable habitat management for the target amphibian species, but Means (2008) provides more details on management strategies for ephemeral pond-breeding amphibians. Managing upland amphibian species requires consideration of both the breeding pond and surrounding terrestrial habitat. Means (2008) recommended that land managers consider 500 m of uplands surrounding an ephemeral wetland as core terrestrial habitat for amphibians. Ideally, roads should be restricted in the core terrestrial habitat for continuity of habitat and reduction of road mortality?. In a management plan, priority should be given to ponds that occur in clusters, have known populations of target species, have varying hydroperiods, occur within 1 km of other ponds, and are surrounded by native or restorable habitat (Means 2008). Most wetlands used by the target species are 0.01 to 10 ha in size (median size <1 ha) and lack populations of large predatory fish species. The use of heavy machinery or vehicles in and around the pond basin should be avoided so as not to compact soil or break the hard pan (Means 2008). Vehicle ruts, plowlines, and ditches can disrupt fire and natural sheet flow, alter hydroperiods, present obstacles to migrating amphibians, and facilitate invasion of predatory fish (Ripley and Printiss 2005, Means 2008).

The flatwoods salamander and striped newt have the most exacting habitat requirements, and their populations are the most difficult to retain on the landscape. Gopher frog, ornate chorus frog, and tiger salamander populations can persist in degraded habitats and still occupy much of their historical distribution in Florida except in urbanized areas (ornate chorus frog population reductions in the peninsula are probably related more to climate than habitat). Reduced gopher frog populations in parts of the panhandle are probably due to depleted gopher tortoise populations, and remnant frog populations would benefit from activities that restore tortoise populations, including translocation efforts. All these species do best in open-canopy habitats with grassy wetlands that are maintained by frequent fire, although the tiger salamander can occur in fire-suppressed forests. In sandhill and upland pine habitats, striped newts, gopher frogs, and ornate chorus frogs do best in areas with wiregrass ground cover maintained by fire every 1–3 years. In wet and mesic pine flatwoods in good condition, flatwoods salamanders and ornate chorus frogs benefit from prescribed fire every 2 to 4 years, preferably during the growing season (April−September) and optimally during the natural lightning season (May−July) when pond basins are most likely to be dry. When shrubs and hardwoods dominate the uplands or invade breeding ponds and ecotones, a more aggressive burning schedule needs to be implemented. Several consecutive growing-season fires (1–2 years apart) may be necessary to suppress shrubby/woody vegetation and enhance herbaceous vegetation. In cases where excessive shrub cover, such as saw palmetto, persists even after multiple growing-season fires, it may be necessary to precede growing-season prescribed fire with light roller chopping during dry conditions to prevent soil compaction and rutting. If heavy fuel loads have built up because of infrequent fire, a dormant-season fire may be necessary before growing-season fires can be employed. Spot-burning dry wetlands during the early growing season following dormant-season burning of uplands has been used to restore degraded flatwoods salamander breeding ponds in Apalachicola National Forest (Means 2008). Gopher frogs and striped newts sometimes inhabit scrubby flatwoods, which should be burned every 5−15 years (Florida Natural Areas Inventory 2010). In very disturbed uplands such as old fields, intensive management practices may be needed, including thinning the pine overstory, decreasing shrub coverage, and restoring the native ground cover, particularly wiregrass, through seeding or planting (Means 2008).

The importance of season of fire versus frequency of fire is open to debate (Bishop and Haas 2005). Dormant-season fires are better than no fire, but may result in direct mortality of adults and metamorphs leaving ponds or increased predation because of reduced ground cover. Historically, longleaf pine uplands experienced low-intensity fires every 1 to 4 years (Platt et al. 1988, Martin and Kirkman 2009), whereas embedded ephemeral wetlands burned at least every 4 to 10 years (Frost 1995, Kirkman 1995). It has been suggested that managers burn ephemeral pond basins every 1−4 years (Printiss and Hipes 2000, Ripley and Printiss 2005). Flatwoods salamanders typically breed in wetlands with high herbaceous vegetation cover and open canopy cover (Gorman et al. 2009), and these attributes are favored by the other target amphibian species. In the absence of fire, ephemeral wetlands become shrub encroached and accumulate organic material. Ideal breeding ponds for these amphibian species have a firm bottom (typically sand or clay) and are vegetated with a variety of herbs, grasses and sedges. Ephemeral wetlands are typically dry in late spring or early summer when lightning-ignited fires were prevalent prior to human intervention, whereas ponds are typically wet during dormant-season fires. In addition, plowlines that often encircle wetlands in pine plantations prevent fires from carrying into pond basins. Peat eventually develops in unburned ponds, and land managers are often reluctant to burn these ponds when dry because of slow-burning, smoky muck fires. However, peat-filled ponds, particularly ones with a closed canopy, are seldom suitable breeding sites for these amphibian species. A graminaceous pond ecotone, preferably one at least 5 m wide, is critical for successful reproduction of flatwoods salamanders. Other amphibian species also benefit from grassy ecotones and littoral zones because they provide easier passage into and out of ponds and provide food and cover to larvae when flooded.

In the absence of frequent fire, wetland ecotones in flatwoods are invaded by shrubs, such as titi or fetterbush, that shade out herbaceous vegetation and create leaf litter. Fire alone is often inadequate to eliminate these dense stands of shrubs, which either do not burn or vigorously resprout. Mechanical removal of shrubs or trees from wetlands may be necessary. This has been done to restore flatwoods salamander ponds, sometimes along with the judicious application of herbicides, making sure to keep chemicals out of the soil and water. Experimental mechanical removal of the woody midstory canopy from fire-suppressed ephemeral wetlands reduced the canopy cover but did not increase the herbaceous ground cover, which did respond to burning (Gorman et al. 2013). A Gyro Trac can be used to cut shrubs without compacting the soil, but the resulting mulch can be deleterious to herbaceous vegetation and bury the mineral soil used for ovipositing by flatwoods salamanders. However, a pond that has become degraded to the extent that a Gyro Trac is needed is probably not being used by breeding flatwoods salamanders, so this is a viable restoration tool. Careful mechanical scraping of dome-swamp ecotones with dense shrubs and deep plowlines in Aucilla WMA and Apalachicola Rive WEA restored the microtopography of ecotones and stimulated regrowth by herbaceous vegetation. Ponds in scrub, sandhill, flatwoods, and dry prairie may be ringed by dense saw palmetto that would appear to inhibit amphibian movements, although gopher frogs breed in such ponds. Roller chopping, preferably when larvae are in the pond, may be the only method of reducing this palmetto ring.

Commercial forestry using silvicultural Best Management Practices (Florida Forest Service 2012) will likely extirpate flatwoods salamander and striped newt populations over time but possibly not populations of the other 3 target species. More favorable practices for ephemeral pond-breeding amphibians are provided by Calhoun and deMaynadier (2004) and Bailey et al. (2006). Impacts of timber harvesting on the soil, microclimate, and vegetative structure can be deleterious to moisture- and temperature-sensitive amphibians (Russell et al. 2004), but altering species composition, site preparation, stand management, and harvesting techniques can create pine plantations beneficial to wildlife without a significant reduction in yield (Hartley 2002, Means 2008). After clear cutting, the least intensive site preparation practices, particularly burning, prior to replanting of pine seedlings would be more beneficial to amphibian populations than intensive site preparation practices: roller chopping, web plowing, root raking, disking, and bedding (Enge and Marion 1976). Bedding is particularly detrimental because it destroys subterranean refugia and can alter the hydrology of ponds and uplands, impacting amphibian migration. Retention of coarse woody debris can ameliorate the impacts of harvesting by providing moisture-conserving refugia for amphibians (Rothermel and Luhring 2005). All these targets species are occasionally found using coarse woody debris (Kevin Enge, pers. obs.), and the potential benefits of debris are numerous (Whiles and Grubaugh 1996), but coarse woody debris may not be as important to burrowing amphibians in humid southeastern pine forests with short fire-return intervals as in other areas (Owens et al. 2008). Selective harvesting is preferable to clear cutting. Smaller clearcuts are better than large clearcuts, and a mosaic of forest stands of different ages and densities near ponds provide amphibians with the option of finding suitable habitat conditions. If the maximum clearcut size (60–90 ha) of many forestry companies in the Southeast (Boston and Bettinger 2001) is used, the clearcut should be located so it does not encompass the entirety of the core terrestrial habitat around a pond and does not isolate ponds from other ponds by intervening habitat that is unsuitable for amphibians (Means 2008). During harvesting, pond margins and basins should be protected from heavy equipment, location of log landing or skidder sites, logging slash, and sediment runoff.

Scrub management to benefit gopher frogs and striped newts differs from longleaf pine uplands management because scrubs naturally burn every 10 to 80 years (Florida Natural Areas Inventory 2010), although scrub habitat dominated by saw palmetto may burn more frequently. Earlier successional scrubs with herbaceous ground cover provide better habitat than mature scrubs with closed canopies and sparse ground cover. Clear cutting followed by light roller chopping and fire may be more feasible to create these young scrubs than burning mature scrub in many landscapes because of the harsh environmental conditions typically needed to ignite scrub fires, which are then difficult to control (Campbell and Christman 1982, Greenberg 1993). Good scrub management for gopher tortoises benefits the commensal gopher frog. Striped newts typically occur in prairie wetland complexes in scrub habitat, and these maidencane-dominated habitats need to be burned frequently when dry to maintain their open condition and prevent peat development.

Because all these amphibian species typically shelter underground, subsurface soil structure is important. Heavy equipment that compacts the soil and causes substantial groundcover disturbance is detrimental to the survival of these species. The gopher frog is probably the least affected because it typically occupies deep burrows. Stump removal is detrimental, because stumpholes and hollowed root channels may be used as refugia. Gopher frog metamorphs migrating from natal ponds must find a burrow within a few days to survive, and stumpholes and small mammal burrows are used in lieu of tortoise burrows (Roznik and Johnson 2009a). Ornate chorus frogs, tiger salamanders, and presumably flatwoods salamanders may dig their own burrows; tiger salamanders also use small mammal burrows, and flatwoods salamanders frequently use crayfish burrows. Almost nothing is known regarding the subterranean life of striped newts.

Creation of artificial wetlands could be considered on tracts of land with only a single suitable breeding pond, or if surrounding land use does not allow burning of the pond to maintain favorable habitat conditions. Populations are more likely to survive if several wetlands are available with different hydroperiods to allow successful reproduction during years with different rainfall patterns. Gopher frogs are more apt to breed in borrow pits than striped newts. Ornate chorus frogs frequently breed in shallow, grassy borrow pits and large roadside ditches, and flatwoods and tiger salamanders occasionally breed in similar borrow pits. On grazed lands, dugouts for watering livestock in natural wetlands may provide the only suitable breeding sites for gopher frogs during dry conditions. These cattle dugouts mimic the deep “potholes” in otherwise dry wet prairies or basin marshes that are used by gopher frogs and striped newts. Augmentation of drying ponds with ground water until larvae had a chance to metamorphose proved successful at a dusky gopher frog pond, but the pH was substantially changed (Seigel et al. 2006). It is important to retain the isolated nature of wetlands; ditches that allow colonization by predatory fish should be plugged or filled. Land managers and the public should not introduce game fish into isolated wetlands, and introduction of mosquitofish to control mosquito populations should be discouraged. Feral hog control or pond exclosures may be necessary on lands in which substantial rooting of wetlands occurs, particularly if only a few suitable wetlands are present.

Colonization of restored habitats by nearby amphibian populations may occur if no barriers to movements exist, particularly for vagile species like the gopher frog. However, if source populations for recolonization are absent, translocation is necessary to restore the species to the landscape. Upland amphibian reintroductions are complicated because suitable upland and wetland habitats are needed, and amphibians have to be able to locate the breeding pond. Translocation of larvae into a pond has the greatest chance of success, but there have been relatively few successful amphibian reintroductions (Germano and Bishop 2009). There is no evidence that multiple gopher frog translocations onto reclaimed mine sites in west-central Florida were successful, but reintroduction of gopher frogs has been successful at ponds in Mississippi and Georgia (Lavender 2013). A striped newt repatriation project is underway in Apalachicola National Forest, but successful reproduction has not yet occurred (Means et al. 2013). There have been discussions on reintroducing flatwoods salamanders to restored habitats in Florida, but no attempt has been made yet.

Periodic monitoring of populations should be conducted on public lands, particularly in parts of the state where populations have declined. For example, ornate chorus frog populations should be monitored in the peninsula, and gopher frog and striped newt populations in the panhandle. Frosted and reticulated flatwoods salamander populations should be monitored everywhere. Small or disjunct populations, particularly on the edge of a species' range, should also be targeted for monitoring, because these populations are most likely to respond to climate change, habitat degradation, or other stressors. For example, the 1 striped newt pond in Osceola County and 2 ponds in Taylor County should be monitored, and habitat management around these ponds should be tailored to this species. Monitoring these amphibian populations on a property could be accomplished by dipnetting for larvae during the proper time of the year and pond conditions. We found that dipnetting was an effective survey technique for all species except the tiger salamander, but Blackwater WMA staff has used dipnetting to monitor tiger salamander populations (Showen 2007, Pepe and Mahoney 2009). There is a reasonable chance of detecting all these species during dipnet surveys due to the long period of time that larvae are present in ponds, and methodology has been developed for flatwoods salamanders (Bishop et al. 2006). The distinctive flatwoods salamander and ornate chorus frog larvae are easy to identify, and it is not difficult to distinguish between tiger and mole salamander larvae. However, distinguishing between striped and eastern newt larvae can be challenging because the red dorsolateral stripes are usually present only on efts and adults. Many researchers have had trouble distinguishing between gopher and leopard frog tadpoles (Franz and Smith 1999, Hipes and Jackson 2006), but the PI has developed a 1-page identification guide and succeeded in training people in the field. Call surveys at night could be used to monitor gopher frog and ornate chorus frog populations, but the limited time that gopher frogs call from ponds and the sometimes sporadic calling of ornate chorus frogs make this method unreliable. Instead, ARUs could be deployed at known breeding ponds.

Significant gaps in data on ephemeral pond-breeding amphibians and their use of the Florida landscape exist, and the future status of other species may depend on baseline data gathered now while they are still reasonably common (Meshaka and Babbitt 2005, Means 2008). Conservation actions have been identified in the species action plan for the gopher frog (Florida Fish and Wildlife Conservation Commission 2013). If local microhabitats or natural habitat patches are retained and maintained within the pine silviculture landscape, forest managers and private land owners may be able to conserve diverse amphibian communities. Extensive surveys are badly needed, as many historical populations of rare amphibian species appear to have been extirpated in the last 10 years, leaving extent of occurrence unclear (U.S. Fish and Wildlife Service 2011).

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Appendix 1. Number of unique ponds dipnetted in 2010–2014 on 121 conservation lands and 21 private lands, and the number of ponds in which gopher frogs, striped newts, tiger salamanders, flatwoods salamanders, or ornate chorus frogs were found (the number of previously known ponds is followed in parentheses by the number of newly discovered ponds). Forty-five ponds that were always dry when visited are not counted, but the conservation land is included.

Conservation Land	No. Ponds	Gopher Frog Ponds	Striped Newt Ponds	Tiger Salaman. Ponds	Flatwoods Salaman. Ponds	Ornate Chorus Ponds	Counties
Annutteliga Hammock	3	0(2)	0	0	0	0	Hernando
Apalachee WMA	2	0	0	0	0	0	Jackson
Apalachicola National Forest	130	11(4)	0	0	8(4)	40	Leon/Liberty/ Wakulla
Apalachicola River WEA	3	0	0		0	0(2)	Franklin
Archbold Biological Station	15	1	0	0	0	0	Highlands
Aucilla WMA	3	0	0	0	0	0	Jefferson
Avon Park Air Force Range	4	0	0	0	0	0	Highlands/Polk
Balm Scrub	0	0	0	0	0	0	Hillsborough
Balu Forest	5	0	0	0	0	0	Alachua
Bell Creek Preserve	1	0	0	0	0	0	Hillsborough
Big Bend WMA – Spring Creek Unit	15	0(4)	0(2)	0	0	0(5)	Taylor
Big Bend WMA – Tide Swamp Unit	4	0	0	0	0	0	Taylor
Blackwater River State Forest	10	0	0	1	0	1	Santa Rosa
Bluefield Ranch Preserve	7	0(1)	0	0	0	0	St. Lucie
Box-R WMA	3	0	0	0	0	0	Franklin
Brooker Creek Preserve	2	0	0	0	0	0	Pinellas
Buck Lake Conservation Area	4	0(2)	0	0	0	0	Brevard
Bull Creek WMA	12	0(1)	0	0	0	0	Osceola
Bullfrog Creek Mitigation Park WEA	1	0	0	0	0	0	Hillsborough
Camp Blanding Military Reservation	41	11(8)	2(4)	0	0	1(3)	Clay
Caravelle Ranch WMA	8	0	0	0	0	0	Putnam
Cary State Forest	11	0(3)	0	0	0	0	Duval
Catfish Creek Preserve State Park	17	0(9)	0	0	0	0	Polk
Cedar Key Scrub Preserve State Park	7	0	0	0	0	0	Levy
Charles H. Bronson State Forest	0	0(1)	0	0	0	0	Orange
Chassahowitzka WMA	11	0(7)	0	0	0	0	Hernando
Chuluota Wilderness Area	2	0	0	0	0	0	Seminole
Conner Preserve	7	0(1)	0	0	0	0	Pasco
Crooked Lake Prairie	1	0	0	0	0	0	Polk
Cross Florida Greenway	4	0(2)	0	0	0	0	Marion/Putnam
Disney Wilderness Preserve	8	0(2)	0	0	0	0	Osceola/Polk
Dixie Plantation	9	0	0	0	0	0(5)	Jefferson
Duette Preserve	3	0	0	0	0	0	Manatee
Dunns Creek State Park	9	0(2)	0	0	0	0	Putnam
Econfina Creek Water Management Area	10	0	0	0	0	0	Bay/Washington
Eglin Air Force Base	17	5	0	0	0	5(2)	Walton/Okaloosa/ Santa Rosa
Etoniah Creek State Forest	16	1(2)	0	0	0	1(1)	Putnam
Faver-Dykes State Park	13	0(1)	1(2)	0	0	0	St. Johns
Fisheating Creek Conserv. Easement	2	0	0	0	0	0	Glades
Flint Rock WMA	11	0	0	0	1	0	Jefferson/Wakulla
Fort White Mitigation Park WEA	9	1	0	0	0	0	Gilchrist

Conservation Land	No. Ponds	Gopher Frog Ponds	Striped Newt Ponds	Tiger Salaman. Ponds	Flatwoods Salaman. Ponds	Ornate Chorus Ponds	Counties
Garcon Point Water Management Area	6	0	0	0	1	0	Santa Rosa
Geneva Wilderness Area	1	0	0	0	0	0	Seminole
Goethe State Forest	19	0(3)	0(1)	0	0	0	Alachua/Levy
Gold Head Branch State Park	2	1	0	0	0	0	Clay
Golden Aster Scrub	1	0	0	0	0	0	Hillsborough
Green Swamp West	12	0(2)	0	0	0	0	Pasco
Guana River WMA	14	0	1(2)	0	0	0	St. Johns
Half Moon WMA	19	0(2)	0	0	0	0	Sumter
Halpata Tastanaki Preserve	13	0(7)	0	0	0	0	Marion
Hilochee WMA	9	0	0	0	0	0	Lake
Holton Creek Conservation Area	1	0	0	0	0	0	Hamilton
Indian Lake State Forest	4	0	0	0	0	0	Marion
Jennings State Forest	30	2(4)	6(6)	0	0	0(1)	Clay
Joe Budd WMA	4	0	0	0	0	0(2)	Gadsden
Jonathan Dickinson State Park	7	0(3)	0	0	0	0	Martin
Julington-Durbin Preserve	3	0	0	0	0	0	Duval
Kissimmee Prairie Preserve SP	5	0	0	0	0	0	Okeechobee
Lafayette Forest Mitigation Park WEA	4	0	0	0	0	0(2)	Lafayette
Lake Kissimmee State Park	5	0(1)	0	0	0	0	Polk
Lake Louisa State Park	9	0	0	0	0	0	Lake
Lake Panasoffkee WMA	6	0(1)	0	0	0	0	Sumter
Lake Proctor Wilderness Area	7	0	0	0	0	0	Seminole
Lake Wales Ridge State Forest	3	0	0	0	0	0	Polk
Lake Wales Ridge State Forest – Arbuckle Tract	9	0(3)	0	0	0	0	Polk
Lake Wales Ridge State Forest – Hesperides Tract	3	0(2)	0	0	0	0	Polk
Lake Wales Ridge State Forest – Walk-in-the-Water Tract	20	0(5)	0	0	0	0	Polk
Lake Wales Ridge WEA – Carter Creek Unit	3	0(1)	0	0	0	0	Highlands
Lake Wales Ridge WEA - Clements Unit	0	0	0	0	0	0	Highlands
Lake Wales Ridge WEA - Henscratch Unit	1	0	0	0	0	0	Highlands
Lake Wales Ridge WEA – Lake Placid Scrub	4	0(1)	0	0	0	0	Highlands
Lake Wales Ridge WEA– McJunkin Unit	1	0	0	0	0	0	Highlands
Lake Wales Ridge WEA - Royce Unit	2	0	0	0	0	0	Highlands
Lake Wales Ridge WEA – Silver Lake Unit	2	0	0	0	0	0	Highlands
Lake Wales Ridge WEA – Sun N Lakes Sebring	2	0(1)	0	0	0	0	Highlands
Lake Wales Ridge WEA – Sunray Unit	2	0	0	0	0	0	Polk
Lake Wales Ridge WEA – Tubbs Unit	1	0	0	0	0	0	Highlands

Conservation Land	No. Ponds	Gopher Frog Ponds	Striped Newt Ponds	Tiger Salaman. Ponds	Flatwoods Salaman. Ponds	Ornate Chorus Ponds	Counties
Little Big Econ State Forest	5	0(1)	0	0	0	0	Seminole
Little River Conservation Area	2	0	0	0	0	0	Suwannee
Lochloosa Wildlife Conservation Area	9	0	0	0	0	0	Alachua
Longleaf Flatwoods Reserve	4	0(1)	0	0	0	0	Alachua
Lower Suwannee NWR	2	0	0	0	0	0	Dixie
Moody Branch Mitigation Park WEA	1	0	0	0	0	0	Manatee
Mosaic Fertilizer's Wellfield	1	0(1)	0	0	0	0	Manatee
Newnan's Lake Conservation Area	14	0	0	0	0	0	Alachua
Nokuse Plantation	5	0	0	0	0	0	Walton
Ocala National Forest	149	17(18)	4(3)	0	0	0	Lake/Marion/ Putnam
Ordway-Swisher Biological Station	17	0(1)	1(2)	0	0	0	Putnam
Osceola National Forest	22	0	0	0	0	0	Columbia
Pellicer Creek Conservation Area	2	0	0	0	0	0	Flagler
Phifer Flatwoods	5	0	0	0	0	0	Alachua
Pine Log State Forest	5	0	0	0	0	0	Bay/Washington
Platt Branch Mitigation Park WEA	4	0	0	0	0	0	Highlands
Point Washington State Forest	1	0	0	0	0	0	Walton
Pumpkin Hill Creek Preserve SP	13	0	0	0	0	0	Duval
Raiford WMA	12	0	0	0	0	0	Bradford
Rainbow Springs State Park	3	1	0	0	0	0	Marion
Rhodine Scrub	2	0	0	0	0	0	Hillsborough
Rock Springs Run State Reserve	17	1(4)	0(1)	0	0	0	Lake/Orange
Ross Prairie State Forest	3	0(2)	0	0	0	0	Marion
St. Marks National Wildlife Refuge	73	0	0	0	4	0	Wakulla/Jefferson
St. Sebastian River Preserve State Park	19	0(10)	0	0	0	0	Brevard/Indian River
San Felasco Hammock Preserve SP	4	0	0	1	0	0	Alachua
Seminole State Forest	20	0(7)	1	0	0	0	Lake
Split Oak Forest WEA	2	0	0	0	0	0	Orange/Osceola
Starkey Wilderness Park	7	1	0	0	0	0	Pasco
SUMICA	4	0	0	0	0	0	Polk
Suwannee Ridge Mitigation Park WEA	2	0	0	0	0	0	Hamilton
Tarkiln Bayou Preserve State Park	3	0	0	0	0	0	Escambia
Tate's Hell State Forest	7	0	0	0	0	0(2)	Franklin
Three Lakes WMA	13	0(2)	0	0	0	0	Osceola
Triple N Ranch WMA	8	0(1)	0(1)	0	0	0	Osceola
Troy Springs Conservation Area	1	0	0	0	0	0	Lafayette
Watermelon Pond – Gladman Tract	2	0(1)	0	0	0	0	Alachua
Watermelon Pond – Metzger Tract	1	0(1)	0	0	0	0	Alachua
Wekiwa Springs State Park	3	0	0	0	0	0	Orange
Welaka State Forest	6	0	0	0	0	0	Putnam
Withlacoochee State Forest – Citrus Tract	4	0	0	0	0	0	Citrus
Withlacoochee State Forest – Croom Tract	8	1(4)	0	0	0	0	Hernando/Sumter
Woods Ferry Conservation Area	1	0	0	0	0	0	Suwannee
Yellow Jacket Conservation Area	1	0	0	0	0	0	Dixie
Private land	2	0	0	0	0	0	Alachua

Conservation Land	No. Ponds	Gopher Frog Ponds	Striped Newt Ponds	Tiger Salaman. Ponds	Flatwoods Salaman. Ponds	Ornate Chorus Ponds	Counties
Private land	2	0(1)	0	0	0	0	Calhoun
Private land	1	0(1)	0	0	0	0	Gilchrist
Private land	1	0	0	0	0	0	Hardee
Private land	3	0	0	(1)	0	0	Hernando
Private land	2	0(2)	0	0	0	0	Highlands
Private land	1	0	0	0	0	0(1)	Jackson
Private land	1	0	0	0	0	0	Leon
Private land	2	0	0	0	0	0	Manatee
Private land	3	0(1)	0	0	0	0	Marion
Private land	2	1	0	0	0	0	Suwannee
Private land	1	0	0	0	0	0	Washington
Total	**1,179**	**55(147)**	**16(24)**	**2(1)**	**14(4)**	**48(26)**	

Appendix 2. Public or conservation lands with presumably extant populations of gopher frogs, striped newts, tiger salamanders, flatwoods salamanders, and ornatc chorus frogs based on the presence of suitable upland and wetland habitats, with the number of known breeding ponds (X indicates the species has been found on the property, but breeding ponds have not been identified).

Conservation Land	Gopher Frog	Striped Newt	Tiger Salam.	Flatwoods Salam.	Ornate Chorus	Counties
Alachua County Fairgrounds	X	0	0	0	0	Alachua
All-Bar Ranch	X	0	0	0	0	Pasco
Annutteliga Hammock	2	0	0	0	0	Hernando
Apalachicola National Forest	54	18	0	72	74	Leon/Liberty/ Wakulla
Apalachicola River WEA	0	0	0	0	3	Franklin/Gulf
Archbold Biological Station	9	0	0	0	0	Highlands
Aucilla WMA	0	0	0	X	X	Jefferson/Taylor
Avon Park Air Force Range	8	0	0	0	0	Highlands/Polk
Beker, Wingate Creek Parcel	X	0	0	0	0	Manatee
Big Bend WMA – Hickory Mound Unit	0	0	0	0	1	Taylor
Big Bend WMA – Jena Unit	0	0	0	0	1	Dixie
Big Bend WMA – Spring Creek Unit	6	2	0	0	14	Taylor
Big Bend WMA – Tide Swamp Unit	X	0	0	0	2	Taylor
Blackwater River State Forest	1	0	18	0	35	Okaloosa/Santa Rosa
Bluefield Ranch Preserve	1	0	0	0	0	St. Lucie
Brooker Creek Preserve	X	0	0	0	0	Pinellas
Buck Lake Conservation Area	2	0	0	0	0	Brevard
Bull Creek WMA	1	0	0	0	0	Osceola
Camp Blanding Military Reservation	36	16	0	0	4	Clay
Cary State Forest	3	0	0	0	0	Duval
Catfish Creek Preserve SP	9	0	0	0	0	Polk
Charles H. Bronson State Forest	1	0	0	0	0	Orange
Chassahowitzka WMA	14	0	0	0	0	Hernando
Chinsegut Nature Center	1	0	1	0	0	Hernando
Chuluota Wilderness Area	1	0	0	0	0	Seminole
Conner Preserve	1	0	0	0	0	Pasco
Cypress Lakes Preserve	X	0	0	0	0	Hernando
Disney Wilderness Preserve	2	0	0	0	0	Osceola/Polk
Dixie Plantation	0	0	0	0	6	Jefferson
Duette Preserve	X	0	0	0	0	Manatee
Dunns Creek State Park	2	0	0	0	0	Putnam
Econfina Creek Water Manage. Area	1	0	0	0	1	Bay/Washington
Eglin Air Force Base	25	0	0	25	7	Walton/Okaloosa/ Santa Rosa
Etoniah Creek State Forest	6	0	0	0	3	Putnam
Faver-Dykes State Park	2	3	0	0	0	St. Johns
Fisheating Creek Conserv. Easement	1	0	0	0	0	Glades
Flaming Arrow Boy Scout Camp	X	0	0	0	0	Polk
Flint Rock WMA	0	0	0	10	1	Jefferson/Wakulla
Fort White Mitigation Park WEA	2	0	0	0	0	Gilchrist
Garcon Point Water Manage. Area	0	0	0	1	1	Santa Rosa
Goethe State Forest	9	5	X	0	1	Alachua/Levy
Gold Head Branch State Park	1	0	0	0	0	Clay
Green Swamp West	2	0	0	0	0	Pasco

Conservation Land	Gopher Frog	Striped Newt	Tiger Salam.	Flatwoods Salam.	Ornate Chorus	Counties
Guana River WMA	0	3	0	0	0	St. Johns
Half Moon WMA	2	X	0	0	0	Sumter
Halpata Tastanaki Preserve	7	0	0	0	0	Marion
Harold Outlying Landing Field	X	0	0	0	0	Santa Rosa
Highlands Hammock State Park	1	0	0	0	0	Highlands
Holley Naval Outlying Landing Field	0	0	0	3	0	Santa Rosa
Horse Creek Scrub	X	0	0	0	0	Polk
Hurlburt Field	0	0	0	11	0	Okaloosa
Itchetucknee Springs State Park	X	0	X	0	0	Columbia
Jack Creek	X	0	0	0	0	Polk
Jennings State Forest	11	18	0	0	2	Clay
Joe Budd WMA	0	0	0	0	2	Gadsden
John Bethea State Forest	1	0	0	0	0	Baker
Jonathan Dickinson State Park	4	0	0	0	0	Martin
Lafayette Forest Mitigat. Park WEA	0	0	0	0	4	Lafayette
Lake Kissimmee State Park	1	0	0	0	0	Polk
Lake Manatee Lower Watershed	X	0	0	0	0	Manatee
Lake Panasoffkee WMA	2	0	X	0	0	Sumter
Lake Wales Ridge NWR – Flamingo Villas	X	0	0	0	0	Highlands
Lake Wales Ridge State Forest – Arbuckle Tract	3	0	0	0	0	Polk
Lake Wales Ridge State Forest – Hesperides Tract	2	0	0	0	0	Polk
Lake Wales Ridge State Forest – Walk-in-the-Water Tract	5	0	0	0	0	Polk
Lake Wales Ridge WEA – Carter Creek Unit	1	0	0	0	0	Highlands
Lake Wales Ridge WEA – Henscratch 27	X	0	0	0	0	Highlands
Lake Wales Ridge WEA - Henscratch Unit	X	0	0	0	0	Highlands
Lake Wales Ridge WEA – Lake Placid Scrub	1	0	0	0	0	Highlands
Lake Wales Ridge WEA – McJunkin Unit	X	0	0	0	0	Highlands
Lake Wales Ridge WEA - Royce Unit	X	0	0	0	0	Highlands
Lake Wales Ridge WEA – Sun N Lakes Sebring	1	0	0	0	0	Highlands
Little Big Econ State Forest	1	0	0	0	0	Seminole
Lochloosa Wildlife Conservation Area	1	0	0	0	0	Alachua
Longleaf Flatwoods Reserve	1	0	0	0	0	Alachua
Marjorie Harris Carr Cross Florida Greenway State Recreation Area	2	X	0	0	0	Marion/Putnam
Lower Wekiva River Preserve SP	X	0	0	0	0	Lake
Mosaic Fertilizer's Wellfield	1	0	0	0	0	Manatee
Myakka River State Park	X	0	0	0	0	Sarasota
Nokuse Plantation	0	0	0	0	1	Walton
Ocala National Forest	69	38	0	0	0	Lake/Marion/Putnam
Ordway-Swisher Biological Station	7	18	0	0	0	Putnam
Oscar Scherer State Park	X	0	0	0	0	Sarasota
Osceola National Forest	1	0	0	0	3	Columbia

Conservation Land	Gopher Frog	Striped Newt	Tiger Salam.	Flatwoods Salam.	Ornate Chorus	Counties
Pellicer Creek Conservation Area	X	0	0	0	0	Flagler
Perry Oldenburg Mitigat. Park WEA	X	0	0	0	0	Hernando
Phifer Flatwoods	1	0	0	0	1	Alachua
Pine Log State Forest	0	0	0	1	8	Bay/Washington
Platt Branch Mitigation Park WEA	1	0	0	0	0	Highlands
Point Washington State Forest	0	0	0	0	55	Walton
Port Orange Well Field	1	0	0	0	0	Volusia
Pumpkin Hill Creek Preserve SP	0	1	0	0	0	Duval
Raiford WMA	0	0	0	0	2	Bradford
Rainbow Springs State Park	1	X	0	0	0	Marion
Rock Springs Run State Reserve	11	4	0	0	0	Lake/Orange
Rodman Bomb Target	2	0	0	0	0	Putnam
Ross Prairie State Forest	2	0	0	0	0	Marion
St. Marks NWR	0	0	0	44	17	Wakulla
St. Sebastian River Preserve SP	10	0	0	0	0	Brevard/Indian River
San Felasco Hammock Preserve SP	X	0	1	0	0	Alachua
Santa Rosa Outlying Landing Field	1	0	0	0	0	Santa Rosa
Seminole State Forest	9	1	0	0	0	Lake
Split Oak Forest Mitigat. Park WEA	1	0	0	0	0	Orange/Osceola
Starkey Wilderness Park	2	0	0	0	0	Pasco
Tall Timbers Research Station	0	0	0	1	1	Leon
Tate’s Hell State Forest	0	0	0	0	4	Franklin/Liberty
Three Lakes WMA	2	0	0	0	0	Osceola
Tiger Creek Preserve	X	0	0	0	0	Polk
Triple N Ranch WMA	1	1	0	0	0	Osceola
Watermelon Pond – Gladman Tract	1	0	0	0	0	Alachua
Watermelon Pond – Metzger Tract	1	0	0	0	0	Alachua
Watermelon Pond Mitigat. Park WEA	1	0	0	0	0	Alachua
Welaka State Forest	2	0	0	0	0	Putnam
Withlacoochee State Forest – Citrus Tract	1	0	0	0	0	Citrus
Withlacoochee State Forest – Croom Tract	9	0	0	0	0	Hernando/Sumter
Woodfield Springs Plantation Conservation Easement	0	0	X	0	0	Leon
Woods Ferry Conservation Area	X	0	0	0	0	Suwannee
Yellow Jacket Conservation Area	0	0	1	0	0	Dixie
Total	**388**	**128**	**21**	**169**	**254**	