Management Strategies for Florida's Ephemeral Ponds and Pond-Breeding Amphibians

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ABSTRACT

Studies on the herpetofauna of ephemeral ponds have been conducted across the state. However, existing data on ephemeral pond-breeding amphibians are scattered and are not readily available to land managers, policy makers, scientists, and other interested stakeholders. This project was designed to synthesize existing information for these species in order to develop management strategies for ephemeral ponds, particularly as they pertain to amphibian conservation. Involving stakeholders during this process provided additional input as well as disseminated the information in a manner that facilitated discussion. Other project objectives included developing a geo-referenced database for ephemeral pond-breeding amphibian research and surveying ephemeral ponds. The project focused specifically on 5 Species of Greatest Conservation Need (SGCN): flatwoods salamander (now two species – *Ambystoma bishopi* and *A. cingulatum*), tiger salamander (*A. tigrinum*), striped newt (*Notophthalmus perstriatus*), ornate chorus frog (*Pseudacris ornata*), and gopher frog (*Rana capito*). This final report contains results from a 3-year project.

A comprehensive literature search was conducted and over 800 references were collected and reviewed. This information was synthesized to provide a source of information for ephemeral pond ecology, ephemeral pond-breeding amphibians, greatest threats, and research gaps, as well as to facilitate the development of management strategies.

Biologists, public and private agencies, and universities were contacted to gather information about ephemeral pond research conducted on public and private lands. Ninety-one research projects were incorporated into a geo-referenced database. In addition to locational information for each project, the database provides project objectives, methodology, and dates, amphibian species captured, habitat classification, and reference information. The database fields were developed with input from scientists and other stakeholders. The shapefiles associated with the database are available at www.coastalplains.org.

Fifty ephemeral ponds were selected for dipnet surveys around the state. Species of Greatest Conservation Need were encountered at 24 ponds, including 11 new breeding site records. No flatwoods salamanders or tiger salamanders were encountered. Despite the adequate water levels and the Apalachicola National Forest (ANF) being a former stronghold for the striped newt, newts were only captured at 2 ponds on the ANF. Of greater concern, no striped newt larvae have been encountered in the ANF for 10 years. Drift fences, constructed around 4 ephemeral ponds in the ANF, were activated 40 nights, corresponding with major rain events November-June in 2005, 2006, and 2007. Two SGCN (ornate chorus frog and gopher frog) and 8 other ephemeral pond-breeding amphibians were captured.

Management strategies were developed through literature synthesis, discussions with land managers and biologists, and stakeholder input. Strategies were condensed into a brochure for distribution to land managers and landowners.

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INTRODUCTION

Florida has a large number of ephemeral ponds that serve as breeding sites for at least 28 amphibian species, 14 of which breed exclusively or principally in ephemeral ponds. Studies on the amphibians of temporary wetlands have been conducted across the state (Dodd and Charest 1988, Means and Means 1998*a*, Printiss and Hipes 1999, Enge and Wood 2000, Greenberg et al. 2003) and management strategies have been developed on a species or site specific level (Means et al. 1994, Cox and Kautz 2000, Florida Fish and Wildlife Conservation Commission 2001, Johnson 2001, Printiss and Hipes 2001); however, two problems remain. First, existing information on pond-breeding amphibians is scattered and is not readily available to land managers, scientists, policy makers, and other stakeholders. Second, there are significant gaps in our knowledge of pond breeding amphibians and their use of the Florida landscape. These gaps hinder our ability to develop comprehensive management plans for this species assemblage and their habitats. These amphibians have not received much attention because, with the exception of two, the flatwoods salamander (*Ambystoma cingulatum*) and gopher frog (*Rana capito*), they are not federally or state listed species. However, at least 1 other species is considered to be declining (striped newt, *Notophthalmus perstriatus*) (Moler 1992, Franz and Smith 1999, Dynamic Solutions Group LLC 2004), and the future status of the others may depend on the baseline data gathered now, while they are still considered common.

Species of Greatest Conservation Need

Species of Greatest Conservation Need (SGCN) were identified by biologists and Florida Fish and Wildlife Conservation Commission (FWC) staff during meetings in the summer and fall of 2004 (see Dynamic Solutions Group, LLC 2004). A total of 974 SGCN was identified and included mammals, birds, amphibians, reptiles, fish and invertebrates. Out of the 19 amphibian species identified as SGCN, 5 breed exclusively in ephemeral ponds. These 5 species are the target of this project and include: flatwoods salamander (now two species – *A. bishopi* and *A. cingulatum*), tiger salamander (*A.tigrinum*), striped newt, ornate chorus frog (*Pseudacris ornata*), and gopher frog.

In addition to the SGCN discussed above, there are 8 other species that breed principally or exclusively in ephemeral ponds: oak toad (*Bufo quercicus*), pine woods treefrog (*Hyla femoralis*), barking treefrog (*Hyla gratiosa*), eastern narrowmouth toad (*Gastrophryne carolinensis*), southern chorus frog (*Pseudacris nigrita*), little grass frog (*Pseudacris ocularis*), eastern spadefoot (*Scaphiopus holbrooki*), and mole salamander (*A. talpoideum*). These species are secondary targets for this project as part of the “keeping common species common” theme (Florida Fish and Wildlife Conservation Commission 2005). Because they have specialized habitat requirements (fishless ponds), these species may be more sensitive to landscape changes than are more generalist species.

Objectives

The 4 objectives of this project are to (1) synthesize pre-existing information on ephemeral pond-breeding amphibians, (2) develop a GIS database for ephemeral pond breeding amphibian research, (3) survey ephemeral ponds with special focus on the 5 SGCN and 8 other ephemeral pond obligates, and (4) involve stakeholders in the development of management strategies for Florida’s ephemeral ponds and pond-breeding amphibians.

LITERATURE REVIEW

Over 800 published and non-published papers, journal articles, theses, dissertations, reports, non-technical papers, books, book chapters, and other reference materials pertaining to ephemeral ponds or pond-breeding amphibians were reviewed and compiled into a literature database. The information from these references was synthesized into the following sections below: Ephemeral Pond Ecology, Pond-Breeding Amphibians, Ornate Chorus Frog, Gopher Frog, Flatwoods Salamander, Tiger Salamander, Striped Newt, Threats, and Research Gaps. For more detailed information, Williams (1987, 2006) and LaClaire (1992) provide an excellent discussion of ephemeral pond physiology, biology, and ecology; Lannoo (2005) is an excellent and comprehensive source for distribution, abundance, life history, and conservation information for U.S. amphibian species.

Ephemeral Pond Ecology

Ephemeral ponds are usually small, isolated wetlands with a cyclic nature of drying and re-filling. Termed "hydroperiod," the duration a pond holds water can vary from 1 or 2 weeks to 1 or 2 years, and hydroperiod can vary from year to year and pond to pond. The water-holding capacity of a pond is a function of multiple factors including underlying geology, soil characteristics, rainfall, pond depth and size, evaporation, evapotranspiration, and tree canopy cover (Williams 1987, Hart and Newman 1995, Blood et al. 1997, Tiner et al. 2002). Bands of herbaceous vegetation around the pond periphery, known as the littoral zone, move back and forth depending on the water level of the pond and reflect soil moisture conditions (LaClaire and Franz 1990).

Ephemeral ponds also are known as ephemeral wetlands, isolated wetlands, Carolina bays, seasonal ponds, cypress domes, sinkhole wetlands, seasonal marshes, intermittent ponds, pineland depressions, depressional wetlands, and vernal pools. While ephemeral ponds are geographically and hydrologically isolated from other surface waters, they are not isolated ecologically (Forman and Godron 1986, Tiner et al. 2002). Many amphibians, for example, use ephemeral ponds to breed but then travel widely into the surrounding uplands, transferring biomass from the nutrient-rich ponds into the uplands. The amount of biomass production is substantial as evidenced by the thousands of emigrating metamorphic amphibians captured during drift fence studies (Dodd 1992, Semlitsch et al. 1996, Johnson 2003, Means 2007). In one year, Gibbons et al. (2006) captured over 350,000 juveniles emigrating from an isolated wetland in South Carolina, representing almost 1500 kg of biomass.

In Florida, ephemeral ponds are most commonly embedded within sandhill, scrub, and natural pine habitats such as flatwoods. As these upland habitats are fire maintained, fire is an important component of the ecology of the ponds as well. Historically, fires were ignited in the uplands by lightning during the late spring and early summer. Ponds often are dry during this time and wildfires would have swept through the dry pond basin, reducing organic matter and killing encroaching upland plant species. Fire also encouraged the growth of herbaceous vegetation around the pond edge. This ecological process created a biologically unique system also rich in species diversity.

From an amphibian perspective, the cyclical nature of pond filling and drying is significant because it creates an inhospitable environment for many species of predacious fish and some macroinvertebrates. Some amphibian species lack the defenses to co-exist with predatory fish and require fishless ponds for breeding habitat (Moler and Franz 1987). Therefore, ephemeral ponds support a different assemblage of species than do more permanent waters (Snodgrass et al. 2000*a*). Historically, little value was attributed to ephemeral ponds. They were thought of as subsets of larger wetlands with no unique, intrinsic value. Because they were typically smaller, they were believed to support lower species diversity (Moler and Franz 1987). Studies over the past 20 years have dispelled that notion.

Twenty-seven amphibian species were identified utilizing a 1-ha pond in South Carolina over a 16-year period, resulting in over 200,000 metamorphosing juveniles (Semlitsch 2000). At a 0.16-ha pond in north Florida, Dodd (1992) captured 16 species of amphibians over a 5-year period, representing almost 10,000 individuals. Amphibian species richness from the 4 ponds in the Apalachicola National Forest (ANF) studied as part of this project ranged from 12 to 17 and none of these ponds were larger than 1 ha.

Because of their small size and ephemerality, temporary ponds are essential to the survival of many amphibian species nationwide and 14 species in Florida. The ponds also provide important habitat to a large diversity of plants, invertebrates, reptiles, mammals, and birds (LaClaire 1992, Tiner et al. 2002, Comer et al. 2005, Scheffers et al. 2006, Means 2007). At least 10 federally and state-listed species facultatively or obligately utilize isolated wetlands for some portion of their life cycle (Hart and Newman 1995).

Despite their obvious importance to various species across the country, ephemeral ponds benefit from little federal regulatory protection. The main federal regulatory program protecting wetlands is the Clean Water Act (Section 404), implemented by the U.S. Army Corps of Engineers (U.S. Department of Energy 2003). Section 404 requires a permit for discharging dredge or fill material into “waters of the United States” and “navigable waters” if the degradation or destruction of which could impact interstate commerce. Whether isolated wetlands are included in this protection is unclear as of a 2001 decision by the U.S. Supreme Court in Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers (SWANCC) (531 U.S. 159). The U.S. Supreme Court ruled that isolated wetlands were not necessarily protected under the Clean Water Act by nature of their use as habitat for migratory birds, which are under federal jurisdiction (Bryant and Ervin 2004). Legislation to clarify federal jurisdiction over isolated wetlands, in the form of The Clean Water Authority Restoration Act, has been in Congress since 2003. No decision has been made to date.

At the state level, wetland protection is regulated by the 5 Water Management Districts (WMDs) and the Florida Department of Environmental Protection. All WMDs except Northwest Florida Water Management District (NWFWMD) include isolated wetlands in their Environmental Resource Permit (ERP) process, which means that a permit is required for activities in, on, or over wetlands. The NWFWMD is scheduled to adopt Phase II of their ERP program during summer 2008, which expands the regulation of activities and will include isolated wetlands (NWFWMD 2008). Below a minimum permitting threshold size of 0.2 ha, impacts to fish and wildlife and their habitat are not addressed for mitigation unless a threatened or endangered species is involved, it is located in an area of critical state concern, is connected by standing or flowing surface water at seasonal high water level to 1 or more wetlands and they total greater than 0.2 ha, or the wetland is of more than minimal value to fish and wildlife. Under Chapter 373.406 F.S., agriculture (which includes silviculture) has broad exemptions to alter topography provided it is not for the sole or predominant purpose of impounding or obstructing surface waters.

The cumulative effect of ephemeral pond destruction in Florida has not been measured, but studies by Semlitsch and Bodie (1998) and Gibbs (1993) illuminate the problems associated with the loss of small wetlands. Small wetlands are crucial for maintaining regional biological diversity and are important because they support plants, microcrustaceans, and aquatic insects that would be negatively impacted by their loss. From an amphibian metapopulation standpoint, reducing the number of wetlands reduces the amount of young individuals dispersing into surrounding uplands. Ephemeral pond reduction also increases the dispersal distance among wetlands. While some amphibians can travel up to 2 km (Franz et al. 1988), these dispersal distances appear to be rare. The majority of individuals appear to stay within 1 km of their breeding wetland (Johnson 2003, Rosnik 2007), so increasing dispersal distance could negatively impact amphibian populations. An increase in dispersal distance also may increase the extinction rate of populations of small mammals, turtles, and other less vagile species (Gibbs 1993).

Pond-Breeding Amphibians

In Florida, 14 amphibian species exclusively or principally breed in ephemeral ponds and at least 14 more species utilize the habitat opportunistically (Moler and Franz 1987, Greenberg and Tanner 2005*a*, Means 2007, Means and Meegan 2005) (Table 1). Due to the cyclic nature of drying and filling, ephemeral ponds are unable to support populations of predatory fish. Predation by fish and macroinvertebrates on amphibian larvae is well documented (Caldwell et al. 1980, Hecnar and M'Closkey 1997, Baber and Babbitt 2003). Unlike other amphibian species, pond-breeding amphibians do not have special adaptations to avoid predation (i.e., noxious or unpalatable eggs or larvae, behavioral modifications, large body size), and thus cannot successfully breed in more permanent waters where fish are present (Caldwell et al. 1980, Morin 1983, Hecnar and M'Closksy 1997). It is this lack of predators, rather than ephemerality itself, that seems to be most important to these species.

Table 1. Amphibians in Florida that utilize ephemeral ponds. Obligate refers to those species that exclusively and principally breed in fish-less ponds, in Florida these ponds are typically ephemeral.

Common Name	Scientific Name	Ephemeral Pond Use
Frogs		
Oak toad	*Bufo quercicus*	Obligate
Southern toad	*Bufo terrestris*	Opportunistic
Eastern narrowmouth toad	*Gastrophryne carolinensis*	Obligate
Cope's gray treefrog	*Hyla chrysoscelis*	Opportunistic
Green treefrog	*Hyla cinerea*	Opportunistic
Pine woods treefrog	*Hyla femoralis*	Obligate
Barking treefrog	*Hyla gratiosa*	Obligate
Squirrel treefrog	*Hyla squirella*	Opportunistic
Spring peeper	*Pseudacris crucifer*	Opportunistic
Southern chorus frog	*Pseudacris nigrita*	Obligate
Little grass frog	*Pseudacris ocularis*	Obligate
Ornate chorus frog	*Pseudacris ornata*	Obligate
Gopher frog	*Rana capito*	Obligate
Bull frog	*Rana catesbiana*	Opportunistic
Bronze frog	*Rana clamitans*	Opportunistic
Pig frog	*Rana grylio*	Opportunistic
Southern leopard frog	*Rana sphenocephala*	Opportunistic
Eastern spadefoot	*Scaphiopus holbrookii*	Obligate
Salamanders		
Reticulated flatwoods salamander	*Ambystoma bishopi*	Obligate
Frosted flatwoods salamander	*Ambystoma cingulatum*	Obligate
Mole salamander	*Ambystoma talpoideum*	Obligate
Tiger salamander	*Ambystoma tigrinum*	Obligate
Two-toed amphiuma	*Amphiuma means*	Opportunistic
Dwarf salamander	*Eurycea quadridigitata*	Opportunistic
Striped newt	*Notophthalmus perstriatus*	Obligate
Eastern newt	*Notophthalmus viridescens*	Opportunistic
Southeastern slimy salamander	*Plethodon grobmani*	Opportunistic
Southern dwarf siren	*Pseudobranchus axanthus*	Opportunistic

Larval duration varies per species but also is affected by pond conditions such as food availability, water temperature, and hydroperiod (Semlitsch and Caldwell 1982, Phillips 1995, Ryan and Winne 2001). Because some species take longer to metamorphose than others, the suitability of a pond as a breeding site for an amphibian species depends on the pond's hydroperiod. Eastern spadefoots can fully develop in 2 weeks whereas, other species such as the bullfrog may require more than a year. Therefore, the eastern spadefoot toad can breed in the most ephemeral of ponds, whereas the bullfrog's long larval period restricts them to breed in more permanent waters. Management plans for conserving pond-breeding amphibians should include retention of multiple ponds with differing hydroperiods to account for this variability (Greenberg et al. 2003).

There is a positive correlation between hydroperiod and the number of species that successfully produce juveniles as well as the number of individuals produced (Pechmann et al. 1989). As hydroperiod approaches that of permanent water bodies however, the dynamics change. Ponds with longer hydroperiods harbor insect and salamander larvae that prey on tadpoles, thereby reducing their numbers. Diversity or productivity in communities is generally maximized at intermediate levels of disturbance (Ricklefs 1990). This intermediate disturbance hypothesis is applicable to hydroperiod and amphibian communities as well (Pechmann et al. 1989, Snodgrass et al. 2000*b*). Several species are more likely to breed successfully when a pond dries and subsequently fills during a breeding season (Pechmann et al. 1989). Therefore, timing of inundation matters as well as hydroperiod (Paton and Crouch 2002).

Many biotic and abiotic factors can influence the presence and successful metamorphosis of amphibian species from a pond such as competition, predation, fish presence/absence, fecundity, and hydroperiod. Additionally, the interaction of these factors can be more important in predicting species diversity than a single factor acting alone. Snodgrass et al. (2000*b*) found that hydroperiod length and fish presence are strong structuring forces of amphibian communities. Where fish are absent, hydroperiod becomes the primary source for variation in community structure in an ephemeral wetland (Semlitsch et al. 1996).

Pond-breeding amphibians spend the majority of their lives in the uplands surrounding their breeding pond, utilizing ponds only for short periods to breed. Most are fossorial and bury themselves in friable soils, downed logs, leaf litter, and stumpholes. Many also utilize the burrows of gopher tortoise (*Gopherus polyphemus)*, pocket gopher (*Geomys pinetis*), and other species (Neill 1952, Ashton 1992, Richter et al. 2001, Steen et al. 2006). Terrestrial habitat surrounding ephemeral ponds is critical for the management of ephemeral pond breeders. How much of the uplands are utilized by amphibians depends on the species, habitat quality, and other factors. Radio-telemetry, drift fence, and other studies provide evidence that pond-breeding amphibians are capable of traveling 1 to 2 km (Franz et al. 1988, Ashton and Ashton 2005) and frequently are found hundreds of meters from the nearest breeding pond (Dodd 1996, Johnson 2003, Rosnik 2007).

Breeding populations of most species fluctuate greatly from year to year (Pechmann et al. 1989, Dodd 1996, Semlitsch et al. 1996, Greenberg and Tanner 2005*a*, Means 2007) due to juvenile recruitment during the prior year, movement between ponds, adult survival rates, and weather conditions (Semlitsch et al. 1996, Palis et al. 2006). Temporal variation may favor reproductive success of different species in different years (Semlitsch et al. 1996). These fluctuations become an important management consideration as increased habitat fragmentation further isolates populations, reducing their ability to survive stochastic events such as drought. These high fluctuations also emphasize the necessity of long-term studies. Short-term studies do not allow for the detection of natural fluctuations in community structure and also may miss the presence of multiple species.

Due to high juvenile mortality rates and the difficulties of tracking small-sized individuals, it is unclear what percentage of juveniles and adults return to their natal pond to breed and what percentage travel to other, nearby ponds. Individuals of multiple species have been documented with high breeding site fidelity (Gill 1978, Greenberg et al. 2003, Gibbons et al. 2006), while others readily colonize newly created ponds (Pechmann et al. 1991, R. C. Means, Coastal Plains

Institute, personal communication) or disperse to other ponds (Madison and Ferrand 1998, Johnson 2001, Greenberg et al. 2003, Rosnik 2007). It is clear that extensive movement occurs in the uplands and that some travel between ponds does occur. Therefore, protecting clusters of ponds, properly managing terrestrial habitats, and ensuring that corridors exist between ponds is required for the long-term persistence of pond-breeding amphibian populations (Buhlmann and Mitchell 2000, Semlitsch 2000).

Ornate Chorus Frog (*Pseudacris ornata*)

The ornate chorus frog (Figure 1) is restricted to the southeastern Coastal Plain and in Florida is found throughout the Panhandle and south down the Peninsula to Lake County. Brown and Means (1984) attribute this range terminus to a combination of decreased winter rains in the southern Peninsula and the reduced availability of sandy soil. This species is a specialist of the longleaf pine savanna (D. B. Means 2006) but also can be found in the following habitat types: cypress swamps, freshwater marsh/wet prairie, grassland/improved pasture, hydric hammock, mixed hardwood-pine forest, natural lake, and scrub (Florida Fish and Wildlife Conservation Commission 2005). Although no significant changes in ornate chorus frog distribution have been documented (Jensen 2005), anecdotal evidence indicates populations in the Florida Peninsula may be declining (K. Enge, Florida Fish and Wildlife Conservation Commission, personal communication), and the continual elimination of its upland longleaf pine habitat will probably increase the likelihood of future declines.

Figure 1. Ornate Chorus Frog

The ornate chorus frog is a fossorial species and is frequently found using logs and downed woody debris as refugia (Harper 1937) or burrowed among roots of herbaceous vegetation (Carr 1940, Neill 1952). They are known to vocalize underground, though the functional significance of the subterranean calls is unknown (Brown and Means 1984). Availability of a sandy substrate is important for burrowing and in areas of inundated flatwoods, the ornate chorus frog may travel far to find suitable substrate to burrow (Brown and Means 1984). They have been documented utilizing uplands up to 480 m away from the nearest breeding site (Brown and Means 1984), but very little is known about the adult habitat and microhabitat requirements of this species (Means and Means 2005).

The frogs breed in seasonally inundated ponds that lack predatory fish and invertebrates (Eason and Fauth 2001) and usually breed soon after ponds fill with the beginning of the winter rainy season. This timing allows their larvae to develop before larger salamander and invertebrate larvae (predators) become present. If ponds are filled early, before their breeding season, the tadpoles may be exposed to greater levels of competition and predation. In a 16-year study of a pond in South Carolina, Semlitsch et al. (1996) found longer hydroperiods were associated with decreased recruitment of ornate chorus frogs. Alternatively, pond hydroperiod must be longer than the chorus frog's 4-month larval duration in order to ensure complete metamorphosis.

Sexual maturity is reached in 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). Variation of breeding population size among years can be quite high. Pechmann et al. (1989) found that during an 8-year study, ornate chorus frog juveniles were only produced during two of those years.

Little research has been conducted specifically on the ornate chorus frog, though this species has been documented in many drift fence and dipnet surveys (Enge and Wood 1998, Warner and Dunson 1998, Ripley and Printiss 2002, Means and Means 2005, Means 2007). A recent analysis used genotypic and phenotypic geographic variation to study migration, genetic drift, and natural selection in the ornate chorus frog (Degner 2006).

Gopher Frog (*Rana capito*)

Historically, gopher frogs (Figure 2) ranged throughout the southeastern Coastal Plain, from North Carolina south and west to Louisiana. Two subspecies are present in Florida, the dusky gopher frog (*R. capito sevosa*) and the Florida gopher frog (*R. c. aesopus*). The dusky gopher frog inhabits the western portion of the Florida Panhandle west through Alabama. Only 10 extant populations of this rare subspecies are known (Bailey 1991). The Florida gopher frog is more common but is a state-listed Species of Special Concern. Today, this species is found in patches of remnant sandhills and scrub but also can be found in the following habitat types: agriculture, cypress swamps, dry prairie, freshwater marsh/wet prairie, grassland/improved pasture, industrial/commercial pineland, hydric hammock, mixed hardwood-pine forest, natural lake, and natural pinelands (Florida Fish and Wildlife Conservation Commission 2005).

Figure 2. Gopher frog

The presence of gopher tortoises and their associated burrows appears to be an important habitat variable for gopher frogs (Wright 1932, Franz 1986, Blihovde 2006, Rosnik 2007). Gopher frogs extensively use the tortoise burrows for underground retreats (Wright 1932, Carr

1940, Franz 1986) but also utilize burrows excavated by small mammals and other refugia such as broken limbs, crevices, hollow logs, and stump holes (Lee 1968, Godley 1992, Nickerson and Celino 2003, Blihovde 2006, K. Enge, Florida Fish and Wildlife Conservation Commission, personal communication). Gopher frogs exhibit strong burrow fidelity and will move back to their original burrow if displaced (Blihovde 2006). They exhibit a unique defensive behavior, called the unken reflex, which involves raising their hands over the head with the back flexed upwards and the head bent down. This behavior may be an adaptation of co-habitating with gopher tortoises and might protect the frog's eyes and dorsum from abrasion and sharp toenails within the gopher tortoise burrow (Means 2004).

During heavy winter and spring rains, gopher frogs will travel up to 2 km from their terrestrial habitat to a breeding pond (Franz et al. 1988). They breed in temporary or semi-permanent, shallow, fishless ponds with an open canopy and emergent vegetation (Bailey 1991). Egg masses are attached to vegetation and tadpoles transform in 3 to 5 months (Godley 1992). Newly metamorphosed frogs leave their natal pond and spend the majority of their life in the surrounding uplands. The frogs become reproductively mature in their second year (Godley 1992).

Maintenance of native upland habitat is important to the persistence of gopher frog populations. Gopher frog larvae were found in only 1 of 85 ponds sampled in a sand pine plantation but were found in significantly more ponds embedded in an adjacent longleaf pine forest (Means and Means 2005). Wigley et al. (1999) sampled 444 ponds on forest industry lands and identified gopher frogs in only 17 (<4%). In a study comparing fire-suppressed uplands to those regularly burned, Greenberg et al. (2003) identified gopher frogs as one of the species sensitive to hardwood invasion as a result of the upland fire suppression. Whether gopher frogs are responding directly to changes in their upland habitat or indirectly to the decline in gopher tortoises, which are sensitive to habitat changes associated with long-term fire suppression, is unknown (Cox et al. 1987, Greenberg et al. 2003). The most cited management concerns for gopher frogs are infrequent fire regimes, resulting in the encroachment of hardwoods and shrubs in the upland habitat, and the loss of gopher tortoise or pocket gopher populations that provide the primary source of upland shelters (Moler 1992, Hipes et al. 2001, Jensen and Richter 2005, Blihovde 2006, Rosnik 2007).

Within the past 10-15 years, studies involving gopher frogs have focused on a wide range of topics including terrestrial ecology, pond creation, and spatio-temporal dynamics. Blihovde (2006) and Rosnik (2007) used radio-telemetry to study the terrestrial ecology of adult and juvenile gopher frogs. In North Carolina, Braswell (1995) conducted a 5-year study designing, constructing, and monitoring breeding ponds for the gopher frog. Experiments on reclaimed phosphate-mined lands have involved translocation of gopher frogs to newly created breeding areas (Concoby 2007). Other studies conducted include gopher tortoise burrow and upland fence surveys on public lands (Jackson et al. 1999, Printiss and Hipes 1999, Enge and Douglas 2000, Jackson 2004) and breeding pond surveys on forest industry and public lands (Means and Means 1998*a, b*; Wigley et al. 1999; Means 2007; this study).

Flatwoods Salamander (*Ambystoma bishopi* and *A. cingulatum*)

Based on molecular and morphological analyses, Pauly et al. (2007) proposed the separation of the flatwoods salamander (Figure 3) into two species. The division lies along the Apalachicola-Flint Rivers with reticulated flatwoods salamanders, *A. bishopi*, inhabiting areas to the west and frosted flatwoods salamanders, *A. cingulatum*, ranging to the east of the Rivers. As these findings are new, little work has been done to separate the ecology of these two species. For purposes of this report, the flatwoods salamander complex will be treated as 1 species.

Figure 3. Flatwoods salamander

The flatwoods salamander is restricted to the lower southeastern Coastal Plain of the U.S., ranging from southern South Carolina west to Mobile County, Alabama and south to Marion County, Florida (Moler 1992). Many historical sites are no longer occupied and others have not been sampled in over a decade. In Florida, an estimated 38 populations remain (Florida Fish and Wildlife Conservation Commission 2001). The species was federally listed by the USFWS as threatened in 1999 (U.S. Fish and Wildlife Service 1999) and the state of Florida listed the flatwoods salamander as a Species of Special Concern in 2001 (Florida Fish and Wildlife Conservation Commission 2001).

Flatwoods salamanders now exist in disjunct populations in South Carolina, Georgia, and Florida. As with many other species, habitat loss is the principal cause for the decline of this species. Optimal flatwoods salamander habitat is open, mesic longleaf and slash pine flatwoods with an herbaceous ground cover typically dominated by wiregrass (Palis 1996, Ripley and Printiss 2005). Flatwoods salamanders also can be found in cypress swamps, freshwater marsh/wet prairie, hydric hammock, mixed hardwood-pine forest, and shrub swamp (Florida Fish and Wildlife Conservation Commission 2005).

How much of the terrestrial uplands flatwoods salamanders use is unknown. Although flatwoods salamanders movements have been tracked up to 1700 m (Ashton and Ashton 2005), the farthest they have been documented from their breeding pond is 1100 m (R. Ashton, unpublished data). Flatwoods salamanders are fossorial, digging burrows or expanding crayfish burrows (Neill 1952, Ashton 1992) but also burying in pine duff (Ashton and Ashton 2005). During the winter breeding season, adults become more active and migrate to breeding ponds, typically from October through January, during rain events associated with the passing of a cold front (Means et al. 1996, Palis 1997).

Due to their ephemeral nature, breeding ponds are typically fishless though some breeding ponds harbor a suite of small fishes such as the pygmy sunfish (*Elassoma* sp.) and the mosquitofish (*Gambusia holbrooki*) (Palis 1997). Although the percent canopy cover varies among ponds used by flatwoods salamanders, the presence of herbaceous vegetation appears to be an important factor (Sekerak 1994, Palis 1997). Larvae inhabit pipewort, sedges, and other herbaceous vegetation that grows along the shallow water edges (Sekerak 1994). Metamorphosis occurs after 3 to 5 months and the majority of juveniles leave the pond in March and April (Ashton 1992).

As a result of federal listing, Davis et al. (2002) developed a habitat evaluation model to identify and evaluate quality of potential flatwoods salamander habitat. An FWC-led investigation surveyed over 2100 ponds on public and private lands over a 3-year period beginning in 2002 (K. Enge, Florida Fish and Wildlife Conservation Commission, unpublished data). Salamanders were found at a total of 54 ponds on the following public lands: ANF, Eglin Air Force Base, Flint Rock Wildlife Management Area, Garcon Point Water Management Area, Holley Outlying Landing Field, and St Marks National Wildlife Refuge. No salamanders were encountered on private lands. In conjunction with the FWC-led investigation, The Nature Conservancy surveyed ponds in the Apalachicola and Osceola National Forests and developed a management plan for flatwoods salamander populations on National Forests in Florida (Ripley and Printiss 2005).

Tiger Salamander (*Ambystoma tigrinum*)

Figure 4. Tiger Salamander

Tiger salamanders (Figure 4) are the most widespread salamander species in North America, ranging from Canada to Mexico and the state of Washington to Florida. While remaining locally abundant in some areas, many populations in its historic distribution are declining, have been extirpated, or are found only in isolated colonies (Lannoo and Phillips 2005, D. B. Means, Coastal Plains Institute, personal communication). Of the 6 subspecies recognized, the eastern tiger salamander (*A. t. tigrinum*) is the only one found in Florida. Very little data are available on tiger salamanders in Florida, but they are believed to be declining (Florida Fish and Wildlife Conservation Commission 2005).

Eastern tiger salamanders are endemic to the longleaf pine ecosystem (Means 2005) but can be found in a variety of habitats including agriculture, cypress swamps, freshwater marsh/wet prairie, grassland/improved pasture, hydric hammock, mixed hardwood-pine forest, natural lake, natural pinelands, sandhill, shrub swamp (Florida Fish and Wildlife Conservation Commission 2005, Steen et al. 2006, D. Bruce Means, Coastal Plains Institute, unpublished data). Optimal habitats have sandy or otherwise friable soils and an abundance of breeding ponds (Petranka 1998). Eastern tiger salamanders commonly use small mammal burrows, stumps, and logs but can also construct their own tunnels (Gruberg and Stirling 1972, Semlitsch 1983*b*, Lee 2006, Steen et al. 2006). Adult upland movement varies per individual; distances of up to 225 m have been identified in the Southeast (Steen et al. 2006).

Adults migrate to breeding ponds October through February, corresponding with rain events (Morin 1983, Semlitsch 1983*a*). Breeding ponds are fishless and vary from depressions in flatwoods to farm ponds in pastures (Travis 1992, Conant and Collins 1998). They prefer shallow ponds with large surface area and a significant amount of herbaceous, emergent vegetation on which eggs are deposited (Travis 1992). A minimum of 10 weeks is required for metamorphosis (Lannoo and Phillips 2005). 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 the relative abundances of the members of the community (Travis 1992, Petranka 1998).

Adults leave the pond and migrate to their upland habitat January through April, though some stay around the pond periphery until the next breeding season (Semlitsch 1983*a*, Steen et al. 2006). Adults may return to the same pond to breed every year 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. During a 4-year study, Semlitsch (1983*a*) reported that annual juvenile production of tiger salamanders varied from 1 per year to over 1,000. Breeding age is between 2 and 6 years (Buhlmann and Mitchell 2000), though tiger salamanders in captivity can live over 20 years (Snider and Bowler 1992).

Steen et al. (2006) conducted a small radio-telemetry study on Joseph W. Jones Ecological Center in Georgia to study post-breeding movements of tiger salamanders. Tiger salamander larvae have been captured at 6 wetlands on the property since 2002 and over 1300 individuals have been captured at a drift fence (L. L. Smith, Joseph W. Jones Ecological Center, personal communication). Recent surveys on the Savanna River Site in South Carolina have documented tiger salamanders at 22 wetlands (D. Scott, Savanna River Ecological Laboratory, personal communication). At one location, tiger salamanders were a dominant salamander species in 1978-1981 (Semlitsch et al. 1996) but now appear to be locally extinct due to a shortened hydroperiod and repeated consecutive reproductive failures (Daszak et al. 2005).

The only study conducted in Florida that targeted tiger salamanders is a survey on Blackwater River State Forest (M. Wilson, Florida Fish and Wildlife Conservation Commission, unpublished data, Showen 2007). Dipnet surveys at potential breeding ponds and drift fences were used to identify populations of tiger salamanders on the state forest. Tiger salamanders were found on a small subset of survey ponds and not captured in the drift fence study. Tiger salamander larvae were not encountered during comprehensive flatwoods salamander and striped newt surveys conducted by FWC at almost 2000 ponds around the state (Kevin Enge, Florida Fish and Wildlife Conservation Commission, unpublished data). Extensive surveys for tiger salamanders are needed to identify the status and distribution of this species in Florida.

Striped Newt (*Notophthalmus perstriatus*)

Striped newts (Figure 5) are endemic to southern Georgia and northern Florida and exist as local populations that are widely scattered (Conant and Collins 1998, Petranka 1998). In Florida, they are found in Leon and Wakulla counties of the

Figure 5. Striped Newt

Panhandle (in the Munson Sandhills/Woodville Karst Plain) and in the central northern part of the Peninsula south to Orange and Sumter counties (Franz and Smith 1999). Mitochondrial DNA data suggest that striped newts occur in 2 genetically distinct phylogroups, one in the eastern portion of the range and one in the western portion (Johnson 2001). The eastern group is closely associated with relict coastal ridge systems in peninsular Florida and eastern Georgia and the western group is associated with sandy terraces near rivers that drain into the Gulf of Mexico (Johnson and Owen 2005). Striped newts can be found in the following habitat types: cypress swamps, disturbed/transitional (but see discussion below), freshwater marsh/wet prairie, hydric hammock, mixed hardwood-pine forest, natural lake, natural pinelands, sandhill, and scrub (Florida Fish and Wildlife Conservation Commission 2005).

Populations of striped newts in their historic range appear to be declining. Many known, historic breeding sites in the Florida Peninsula have been either degraded or destroyed (Franz and Smith 1999, Johnson and Owen 2005). Striped newt decline in the western part of its range may have been underway for decades (Means 2007). Despite multiple sampling efforts, no striped newt larvae have been found in the ANF for 10 years. This area used to support one of the largest populations of striped newts in Florida (Means 2007, Bruce Means, Coastal Plains Institute, unpublished data).

As with other pond-breeding amphibians, striped newts spend the majority of their life in the pine uplands that surround their breeding ponds. Terrestrial adults can move 500 to 700 m from ponds after breeding (Dodd 1996, Johnson 2003). Johnson (2003) found at least 16% of individuals breeding at a single pond migrated in excess of 500 m from the pond. Striped newts appear to be sensitive to disturbance of upland soils and replacement of native longleaf pine vegetation surrounding breeding ponds. In a study of the effects of sand pine silviculture on pond-breeding amphibians, Means and Means (2005) found striped newts completely absent from lands converted to pine plantation. Research by Dodd and LaClaire (1995), Franz and Smith (1999) and Johnson and Owen (2005) also attribute the loss of striped newts to the conversion of native forests to pine plantations, agriculture, or urban development. Greenberg et al. (2003) identified striped newts as one of the species sensitive to hardwood invasion as a result of upland fire suppression.

Striped newts breed exclusively in small, ephemeral ponds that lack fish (Johnson 2003, Petranka 1998, Christman and Means 1992). These breeding ponds are typically sinkhole ponds in sandhills and cypress and bay ponds in the pine flatwoods communities (Christman and Means 1992). Newts exhibit phenotypic plasticity in the timing of breeding migrations. This characteristic may allow them to take advantage of temporary breeding habitats and is likely an adaptation to living in an unpredictable environment (Dodd 1993, Johnson 2002).

In north-central Florida, striped newts are active in breeding ponds year round, though they exhibit peak activities associated with immigration into and emigration out of the breeding pond. In general, adult newts move to breeding ponds associated with heavy rain events from November through March (Dodd 1993). Newts have protracted courtship and oviposition with females laying eggs 1 at a time over the course of several months (Johnson 2005). The larval period lasts anywhere from 2 to 6 months (Dodd 1993, Petranka 1998, Johnson 2005). Once larvae reach metamorphosis size, larvae may either undergo metamorphosis and exit the pond as immature terrestrial efts or remain in the pond and grow, eventually maturing as gilled aquatic adults (paedomorphs) (Petranka 1998, Johnson 2005).

As with most pond-breeding amphibians, research on striped newt ecology has been limited to breeding sites. Dodd (1993) conducted a 5-year study of striped newt ecology at a single pond in north-central Florida. Johnson (2002) conducted a 2-year study at a pond in central Florida that included seasonal breeding, migration distances, and orientation. Means (2007) and Greenberg and Tanner (2005*a*) both conducted long-term drift fence studies at ponds where striped newts bred. All these studies occurred during drought years, so “normal” newt activity was not observed.

Other recent studies have focused on surveys for breeding pond locations. During the mid-1990s, Florida Natural Areas Inventory (FNAI) conducted surveys on various public lands throughout Florida (Jackson 1998, Hipes and Jackson 1998, Hipes and Jackson 1996). From 1990 to 1995, Franz and Smith (1999) surveyed for striped newts in historic and known breeding ponds in the Florida Peninsula. Johnson and Owen (2005) returned to ponds surveyed by Franz and Smith (1999) 10 years later to determine their present-day breeding suitability for. In the Florida Panhandle, Means and Means (1998*a*) surveyed for newts in 57 ponds in the Tallahassee Red Hills of Florida and Tifton Upland of Georgia. Coastal Plains Institute (CPI) continues to monitor striped newts in the Munson Sandhills of the ANF and has been regularly surveying over 100 ponds since 1994.

During 2005 and 2006, FWC collaborated with land managers around the state to comprehensively sample for striped newts, with an emphasis on finding new sites on public land (K. Enge, Florida Fish and Wildlife Conservation Commission, personal communication). While in no way exhaustive, this survey represented the first large-scale survey for striped newts in Florida that focused on known and potential breeding sites on public lands. The striped newt has 5 stronghold areas in Florida: Jennings State Forest, Camp Blanding Training Site, Ocala National Forest, Katharine Ordway Preserve, and the ANF (Johnson and Owen 2005).

The striped newt is an imperiled species that needs to be considered for state and federal listing. Surveys conducted over the past fifteen years have demonstrated the loss of known breeding sites in both Florida and Georgia (Dodd and LaClaire 1995, Franz and Smith 1999, Johnson and Owen 2005). Although conducted during low rainfall years, the recent FWC-led survey found striped newts at only 28 locations statewide. The isolation of extant populations makes them vulnerable to stochastic events such as drought. Of particular concern is the lack of breeding that has occurred at one of the striped newt's strongholds, the ANF. No larvae have been encountered in 10 years despite adequate pond levels and extensive survey efforts (Means and Means 1998, Means 2007). Protection should be given to striped newts before the loss of additional populations goes unnoticed.

Threats

Without question, habitat loss is the single greatest threat to pond-breeding amphibians in Florida. In the past 50 years, Florida's population has grown from 2.8 million to 18 million and in that same time period, over 24% of Florida's forest and wetland habitats have been cleared to accommodate this expanding population (Cox et al. 1994). The longleaf pine ecosystem that once covered most of Florida has been reduced to a mere fraction of its original extent and, from a larger perspective, less than 3% of the original longleaf pine ecosystem in North America remains (Frost 1993). Loss of wetland habitat means there are fewer sites in which amphibians can breed and recruit juveniles into the population. Loss of upland habitat is even more detrimental because pond-breeding amphibians spend the majority of their life in the uplands.

Coastal Plains Institute hosted a workshop on 5 March 2007 in cooperation with the USGS Florida Integrated Science Center, Gainesville Florida. Eighteen amphibian experts were invited to identify and prioritize the threats and research gaps to ephemeral pond-breeding amphibians.

Eight scientists attended the meeting and an additional 8 participated via email (Appendix A). Threats were divided into six categories: invasive species, water quality, disease, incompatible management, habitat, and other issues. The group identified and prioritized 65 threats (Table 2). The greatest threats to ephemeral pond-breeding amphibian conservation identified were habitat loss, upland habitat alteration, urban sprawl, habitat fragmentation, loss of metapopulation function, fire suppression, industrial silviculture (upland monoculture), and pond ditching.

Habitat Loss

The first 5 threats identified during the meeting all relate to the concept of habitat loss. Alteration of upland habitat from development (urban sprawl) and other incompatible land uses results in habitat fragmentation and loss of metapopulation function. As populations become more and more isolated, their population sizes are reduced and so is the ability to recover from stochastic events such as drought. The striped newt provides an example of how this process can potentially result in the extirpation of a population.

Striped newts have a small range from southern Georgia south to the central Florida Peninsula. The historic range was probably similar, but because of extensive habitat loss, many populations have been lost (Dodd et al. 2005). Two distinct groups exist, a western group inhabiting the Florida Panhandle near Tallahassee and the Georgia Dougherty Plain and an eastern group associated with sand ridges and river terraces on the Coastal Plain (Johnson 2003).

Based on genetic data, we know gene flow occurred relatively recently between the ANF population in the Florida Panhandle and a site in southern Georgia (Johnson 2001). As land use changes continued to eliminate the sandhill and scrub habitat of the striped newt, these populations became more isolated. No striped newts have been found in the Florida Panhandle

Table 2. Threats to amphibian conservation identified and prioritized by 16 amphibian experts. Average threat rating of 5 corresponds to the greatest threat; value of 1 is the least threatening.

Threat	Average Threat Rating	Threat	Average Threat Rating
Invasive Species		**Water Quality**	
Armadillos	2	Contaminant transfer to uplands (bioaccumulation)	2
Brown hoplo	2	Conductivity	2
Cane toad	2	Pharmaceuticals	2
Swamp eel	2	Caffeine	2
Cuban treefrog interference competition	3	Other contaminants	2
Cuban treefrog predation	3	Insecticides	3
Fire ants	3	Herbicides	3
Fish stocking (disease, tadpole introduction)	3	Surfactants	3
Invasive plants	3	Fertilizer	3
Feral pigs	4	Run-off (contamination)	3
Fish stocking (predation)	4	Run-off (sedimentation)	3
Predatory fish (refugia)	4	pH	3
		Heavy metals	3
Disease			
Microsporidia	2	**Habitat Destruction**	
Myxidium (mesozoa)	2	Pond isolation	4
Saprolegnia	2	Habitat isolation	4
Ranavirus?	2	Roads	4
Amphibian Chytrid (BD)	3	Inadequate wetland regulations	4
Perkinsus-like	3	Recreation vehicles	4
Biocontrol	3	Wildfire suppression techniques	4
		Habitat loss	5
Incompatible Management		Habitat fragmentation	5
Grazing Issues	2	Urban Sprawl	5
Cows in wetlands (drainage changes, habitat destruction)	3	Loss of metapopulation function	5
Fire season	4		
Fire periodicity	4	**Other Issues**	
Upland bedding	4	Scientific take	1
Blading/chopping	4	Pet-trade take	2
Groundwater withdrawal	4	Sea level change	3
Agriculture	4	Lack of ecological legal wording (fire, water use)	3
Researcher/Manager/Regulator Disconnect	4	Lack of Public Education	3
Recreation vehicles	4	Law Enforcement Education	3
Fire suppression	5	Lack of collaborative mgt statewide	3
Ditching (ponds)	5	Climate Change (temperature)	4
Industrial silviculture	5	Rainfall pattern change	4
Upland habitat	5	Drought	4

north of the ANF since 1971 despite survey efforts by Means and Means (1998*a*). Populations to the east of the ANF have been eliminated due to intensive sand pine silviculture (Means and Means 1998*b*) and striped newts haven't been located south of the ANF since the 1970s. The current ANF population is likely completely isolated from other striped newt populations.

Historically, newts bred in at least 20 ponds in the ANF (Means 2001). Extensive surveys of close to 200 ANF ponds from 1994 to 1998 revealed striped newts in 17 ponds. Repeated surveys in 2004-2007 captured striped newts in only 4 ponds. Even more alarming, no striped newt larvae have been found in ANF ponds since 1998.

Striped newts persist as metapopulations at most locations (Johnson 2001). Ponds act as focal points for subpopulations and there are periods of extirpation and recolonization over time. The ANF striped newt population is separated from the nearest known population by 100 km (Dodd et al. 2005). Habitat loss has eliminated any opportunity for striped newts from other locations to augment the ANF population. Severe drought has further compromised the striped newt population in the ANF (Means 2007). Habitat loss and its associated impacts may be responsible for the isolation and subsequent extirpation of the striped newt in the ANF.

<u>Fire Suppression</u>

Many communities in Florida have evolved with fire and hence require periodic fires to maintain the conditions that support the native flora and fauna (Main and Tanner 1999, Means and Campbell 1981). In the absence of fire, southern pine forests are replaced by fire-intolerant associations dominated by hardwoods. These forests differ compositionally and structurally from the pine ecosystem and lack the herbaceous understory and other associated factors required by many pond-breeding amphibians.

Historically, fires were ignited by lightning in late spring and early summer and with high frequency (Platt 1999). This fire regime resulted in the longleaf pine savanna system sometimes described as “park-like” because of its widely spaced trees and herbaceous understory. After decades of fire suppression policy, many uplands and wetlands in Florida are so heavily encroached by hardwoods that impenetrable thickets are formed and no herbaceous vegetation can grow. The resulting habitat is unsuitable for many species that they have evolved and adapted to the native fire-maintained communities. Some species that appear particularly sensitive to fire suppression include fox squirrel (*Sciurus niger)*, northern bobwhite quail (*Colinus virginianus*), red-cockaded woodpecker (*Picoides borealis)*, gopher tortoise, eastern indigo snake (*Drymarchon corais*), flatwoods salamander, striped newt, and gopher frog (Brennan et al. 1998, Greenberg et al. 2003, Bishop and Haas 2005).

Besides the inhospitable habitat fire suppression creates, other factors make fire suppression a threat to pond-breeding amphibians. The physical act of plowing firelines around wetlands can alter pond hydroperiod and create ruts. These ruts can serve as population sinks because they provide a breeding site for amphibians that is subject to more rapid drying and may have a shorter hydroperiod than required for full metamorphosis to be completed (Bishop and Haas 2005). Firelines also can provide an unnatural means of dispersal for predatory fish species to move from nearby, more permanent waters (Ripley and Printiss 2005). Additionally, the increase in organic matter that results from fires not burning through the pond basin may contribute to successional change within the wetland and shorten the pond hydroperiod (Russell et al. 1999, Ripley and Printiss 2005).

<u>Industrial Silviculture</u>

Ecological concerns with silvicultural activities primarily are associated with intensive forestry practices (i.e., plantation forestry) but also involve the loss of spatial, temporal, and vertical heterogeneity associated with less intensive practices. Pine plantations are managed for the maximum amount of cellulose production, which results in a densely stocked, single-species stand with little understory or ground cover except pine needles and twigs. This condition is far removed from the open canopy and diverse herbaceous ground cover found in the native longleaf pine savanna. The list of flora and fauna known to be negatively impacted by this type of land use is long and diverse and includes wiregrasses (*Aristida spp*.) (Means 2005), gopher tortoises (Auffenberg and Franz 1982), red-cockaded woodpeckers (U.S. Department of the Interior 1985), flatwoods salamanders (Means et al. 1996, Means 2005), striped newts (Means 2005, Means and Means 2005), and gopher frogs (Means 2005, Means and Means 2005).

Factors associated with industrial silviculture that negatively impact amphibians include bedding, mechanical site preparation, soil compaction, reduction of vertical and horizontal heterogeneity, short-term rotation, stocking densities, pond ditching, and fertilizer and herbicide use. These activities can interfere with migration, successful hatching, larval behavior, growth, and survival; eliminate refugia such as borrows and coarse woody debris essential for adults and migrating juveniles; and eliminate herbaceous ground cover important for food webs (Means et al. 1996, Means and Means 2005, Rothermel and Luhring 2005, Bailey et al. 2006).

While studies have shown that amphibians can inhabit industrial lands (Enge and Marion 1986, Wigley et al. 1999, Means and Means 2005), the composition of these communities often differs from those found in native systems. Generalist species, species that can live in many different habitat types including urban areas, tend to be numerous. However, few or no species that are specifically adapted to the native ecosystem are present. These species are the ones that are of most concern from a conservation perspective. For example, out of 444 ponds sampled on industry lands, southern leopard frogs and southern cricket frogs were found in over 300 ponds whereas flatwoods salamanders, tiger salamanders, striped newts, and gopher frogs were found in less than 20 ponds (Wigley et al. 1999). Means and Means (1998*b*) surveyed 85 ponds in a sand pine plantation and found no striped newts and found gopher frogs at only 1 pond despite the fact that they were common several decades ago when the landscape was known to have been a longleaf pine forest. Additionally, some species present may not be sustainable populations, but rather remnants from populations before the habitat was altered.

Pond Ditching

Ditching around ponds is a common practice in flatwoods systems where hydric soils create less than ideal conditions for silvicultural operations. Ditches are used to increase wet season surface water runoff from pinelands by creating a series of connected ponds (Vickers et al. 1985). Similar to firebreaks, ditching is detrimental to pond-breeding amphibians for 2 main reasons: alteration of the pond hydroperiod and facilitation of predatory fish movement into otherwise fishless ponds.

Ditching draws water from the pond thereby shortening the pond hydroperiod (Vickers et al. 1985). Shortened hydroperiod impacts species richness and abundance of metamorphosing amphibians (Pechmann et al. 1989) and can alter the hydroperiod sufficiently enough to cause reproductive failure for some species (Semlitsch 1983*a*). Ditches may be the first water that amphibians encounter on their migration to a breeding site. Approaching females may lay eggs in the deep furrows of the ditch and, if these structures have a shorter hydroperiod than the adjacent pond, the ditch could serve as a population sink.

Ditches that facilitate the movement of fish species between ponds can introduce predators of amphibian larvae to a system that is typically fishless. As most pond-breeding amphibians do not have sufficient defenses against predatory fish, the presence of fish can prevent amphibian species from successfully breeding in a pond. Furthermore, if ditches hold water longer than adjacent ponds, they can provide a refuge for fish when the adjacent pond dries.

Other Threats

Other important threats to pond-breeding amphibians are related to invasive species, incompatible management practices, habitat destruction, and other issues. The threat of invasive species includes direct predation, competition for resources, habitat destruction and possible vectors of disease. In Florida, the primary concerns for pond-breeding amphibians are predatory fish, feral pigs (*Sus scrofa*), and red imported fire ants (*Solenopsis invicta*). Important threats associated with incompatible management practices include improper fire regime, upland bedding, blading and chopping, groundwater withdrawal, agriculture, and disconnect between researchers, managers, and regulators. Additional threats identified associated with habitat destruction are roads, pond and habitat isolation, inadequate wetland regulations, destruction by recreational vehicles, and fire suppression techniques. Other issues that are important threats to pond-breeding amphibians include climate change, changing rainfall pattern, and drought.

Research Gaps

At the 5 March 2007 meeting CPI hosted in cooperation with the USGS Florida Integrated Science Center, Gainesville Florida, the group of experts identified and prioritized 84 research gaps (Table 3). The gaps were divided into 8 categories: invasive species, disease, water quality, habitat effects, incompatible management, life history, distribution/surveys, and other gaps. When results were summarized, no research gaps were identified as having the highest priority

Table 3. Research gaps identified and prioritized by amphibian experts. Gaps were rated 1-5 with 5 having the highest research priority and 1 the lowest.

Research Gap	Research Priority Rating
Invasive Species	
Effects of microhabitat on amphibian larvae-invasive fish interaction	2
How extensive is pond alteration to create a more suitable environment for stocking ponds	2
Distribution, status, and persistence of cane toads	2
Cuban treefrog tadpole effects on native tadpoles (natural conditions)	3
Armadillo indirect effects on microhabitat in specific habitats	3
Armadillo direct effects as predator	3
Effects of various fish species on various amphibian species	3
What mechanisms do amphibian species use to detect fish presence	3
Test amphibian response to the presence of fish in field conditions	3
How does feral pig damage compare to OHV damage in terms of tadpole survivorship, water quality, species richness, microhabitat, trophic interactions, hydroperiod	3
Feral pig direct effects as predator	3
Swamp eel method of dispersal and ability to colonize temporary ponds	3
Direct and indirect effects of native invasive plants on microhabitats and impacts on their amphibians	3
Direct and indirect effects of alien invasive plants on microhabitats and impacts on their amphibians	3
How extensive a problem are invasive plants in ephemeral ponds	3
Cuban treefrog ability to disperse	3
Cuban treefrog survey and monitoring to determine distribution extent and persistence	3
More information about where and what species are stocked in ephemeral ponds	3
Fire ants and their interaction with wetlands and wetland species	3
Feral pig indirect effects on microhabitat in specific habitats	4
Disease	
Central clearinghouse for disease information for land managers	3
Long term effects of diseases at affected sites	3
Effects of stressors on susceptibility to different diseases	3
Comprehensive survey and monitoring of amphibian diseases	4
Water Quality	
How does dry-up effect contaminant concentration and affects	2
How low or high of pH can various species persist and tolerate	2
Do amphibians show specificity or adaptation to local conditions (pH, conductivity)	2
Survey ephemeral ponds for presence of various contaminants and pathways	3
Assembling a literature review appropriate to ephemeral ponds	3
Negative impacts of amphibians using retention ponds (contaminants, sinks, roads)	3
What contaminants bioaccumulate in amphibians and if so, what effects does it have	3
Water quality of groundwater augmentation of ephemeral ponds	3
Baseline assessment for background heavy metal contamination	3
Better understanding of how sedimentation effects ephemeral ponds (turbidity, chlorophyll)	3
Effects of endocrine disrupters on local population status and persistence	3

Table 3. (*cont'd*)

Habitat Effects	
Assess importance of retention ponds for amphibian reproduction	3
Importance of urban/suburban wetlands, what role do they serve	3
What is natural intraspecific genetic variation especially for rare and declining species	3
How much is habitat isolation effecting genetic diversity especially for rare and declining species	4
Extent of terrestrial habitat use for different species	4
Incompatible Management	
Impacts of noise pollution on amphibian species	2
Impacts of light pollution on amphibian species	2
Survey of land managers to learn their perception of wetland burning (difficulties, ecological knowledge)	3
Long-term monitoring on wellfield properties to identify changes in amphibian communities	3
Do ditches alter pond hydrology	3
Do ditches act as corridors for fish dispersal	3
Direct mortality effects on amphibians in transportation corridors	3
How prevalent and what are the effects of grazing on ephemeral ponds and amphibian populations	3
Longer term studies looking at fire return intervals and season	4
Long term effects of winter burning versus summer burning	4
Can unburned wetlands be restored and what methodologies are needed	4
Does altered fire regime in the pond basin effect species richness, abundance	4
What species persist or disappear with intense or long-term site preparation, why and for various habitats	4
Methods of reducing impacts of roads	4
Long term effectiveness of wildlife underpasses	4
What impacts on amphibian populations occur as a result of ditching and other mechanical disruptions	4
Long term effects of various silvicultural treatments on amphibian populations	4
Life History	
Identify the necessary characteristics of an ephemeral pond for individual species	3
Population estimates for various species	3
Specific life history information for spring peepers	3
Specific life history information for pine woods treefrog	3
Specific life history information for central newts	3
Specific life history information for barking treefrog	3
Specific life history information for dwarf salamander	3
Definitive assessment of the specific status of the leopard frog	3
Definitive assessment of the specific status of the bullfrog	3
Other amphibians that are not directly tied to ephemeral ponds, taxonomic status	3
Can we restore striped newts to historic ponds and what methods will be needed	4
Specific life history information for ornate chorus frog	4
Specific life history information for tiger salamander	4

Table 3. (*cont'd*)

Distribution/Surveys	
Distributional surveys for mole salamanders	2
Distributional surveys for dwarf salamanders	2
Distributional surveys for ornate chorus frogs	3
Striped newt surveys on private lands	4
Distributional surveys for tiger salamanders	4
Where are the ephemeral ponds, quality assessment, restoration potential	4
Other Gaps	
How do amphibian populations respond to storm surge	2
Do seed banks persist or will appropriate plant species need to reintroduced	3
Better understanding of how the public and land managers perceive amphibian conservation issues	3
Which species exhibit metapopulation structure	3
Model the effects of climate change on amphibian populations (sea level rise, changes in weather, etc)	3
Assessing educators in Florida school systems and their knowledge of amphibians and ephemeral ponds	3
Techniques for restoring ephemeral ponds in terms of fire, vegetation removal, revegetation, hydrologic restoration	4
Long-term monitoring of all amphibian species in Florida	4

with respect to ephemeral pond-breeding amphibian conservation. Twenty-one gaps were ranked second highest priority and were associated with fire, invasive species, restoration, life history, monitoring and distributional surveys, and silviculture. After reviewing the literature and communicating with other researchers through meetings, panel discussions, and private conversations, 2 main research gaps appear to be the most urgent: amphibian use of the uplands and long-term studies.

Movement distances of certain species have been reported, but we do not know the densities of amphibian populations at various distances from the pond, what microhabitat variables are most important, how frequently movement between ponds occurs and how important this movement is to the persistence of the population. This information is vital to land managers to assist in the designation of core terrestrial habitat areas that are sufficient for maintaining amphibian populations yet are not too big to be impractical for land managers. This information is also important for knowing the impact various land management activities may have on pond-breeding amphibian populations.

Funding for long-term studies is rare and difficult to acquire. Furthermore, many research projects are conducted by university graduate students who are limited to 1-2 years of data gathering. Very little of our information about pond-breeding amphibians in the Coastal Plain comes from studies longer than 5 years. Because these species do not always breed every year and their movements and reproduction are highly dependent on weather conditions, short-term studies cannot accurately portray amphibian communities. In particular, we need studies examining the long-term effects of burn season and frequency and of various silvicultural techniques on the amphibian community, and longer-term monitoring and distributional surveys.

Dormant season burning is a common practice now among land managers for various reasons. We have some data on the long-term effects of dormant season burning on various plant species (Platt et al. 1988, Waldrop and Lloyd 1991, White et al. 1991, Streng et al. 1993), but the long-term impacts to amphibian communities are unknown. Similarly, the response of amphibian communities and wetland ecology to annual or bi-annual burns versus longer fire frequencies has not been tested over a long period and is still debated (Schurbon and Fauth 2003, Means et al. 2004, Robertson and Ostertag 2004, Schurbon and Fauth 2004).

Evidence regarding the effects of various silvicultural techniques on amphibians in the Southeast is slim and contradictory and most research has been short term or comparative in nature (Russell et al. 2004). In fact, only 1 of the 18 studies conducted in the southeastern Coastal Plain relating to silvicultural impacts lasted more than 3 years, and that single study was not experimental. Short-term declines in amphibian populations following clear cutting and site preparation have been reported (Enge and Marion 1986, deMaynadier and Hunter 1995, Phelps and Lancia 1995), but research studying long-term responses in the Southeast is absent. The lack of long-term data is significant to our ability to determine the silviculture management strategies most effective for ephemeral ponds and pond-breeding amphibians.

Three consecutive, long-term monitoring projects have been conducted in Florida (Dodd 1996, Greenberg and Tanner 2005*a*, Means 2007). While these studies have provided very important life history information, they were focused at only 10 individual ponds and therefore could not provide information about the health of amphibian populations on a landscape scale. The USGS has begun a long-term amphibian monitoring program nationwide and is monitoring populations at St. Marks NWR and Lower Suwannee NWR (U.S. Geological Survey 2006). A few large-scale distributional surveys have occurred (Franz and Smith 1999, Means 2007, Showen 2007, K. Enge, Florida Fish and Wildlife Conservation Commission, unpublished data). Most surveys were limited to a single pond visit and therefore only provide a “snapshot in time” view of the amphibian community. Annual, multi-visit monitoring of amphibians in ephemeral ponds is essential, especially where species or populations are believed to be declining, such as the case with the striped newt in the ANF.

GEO-REFERENCED DATABASE

A geo-referenced database was created with assistance from FWC Herp Taxa Coordinator Kevin Enge, FWC GIS Analyst Mark Endries, and with input from other biologists. The database was introduced at a joint meeting of the Society of Wetland Scientists and the Florida Chapter of The Wildlife Society on 5 October 2006, “Conservation and Management Issues Affecting Amphibians in the Southeast.” I gave a presentation entitled “Synthesizing Amphibian Research in Florida: a Preliminary Summary” to approximately 65 participants. The 15-minute presentation was followed by a 15-minute facilitated discussion during which feedback and suggestions regarding the database were obtained.

Methods

The database was designed for use in ArcGIS but also will be useable for Microsoft Excel and Access programs. Mapping methods ranged from GPS locations supplied by researchers to estimating research locations based on basic maps and descriptions. Where shapefiles or GPS data were supplied, reprojection was achieved using the Projector! extension in ArcView. Attribute data were manually entered based on reports or information supplied by the researcher.

Results and Discussion

The database was designed with input from the FWC herpetofauna coordinator, FWC GIS Analyst, and other researchers and contains 26 fields. The database is geo-referenced, meaning there is locational information (latitude/longitude) associated with each research project. Additional information (fields) provided per research location includes objectives, project dates, methods, individual species encountered including first and last year recorded for 13 ephemeral pond obligates, Florida Vegetation and Land Cover 2003, FNAI habitat classification, land ownership, mapping method, source, and comments. The shapefiles associated with the database are available at www.coastalplains.org.

Coordination with state park, state forest, wildlife management areas, water management districts, U.S. military, national forest, national park, and national wildlife refuge systems occurred to gather information about unpublished ephemeral pond research conducted by these entities or on their lands. Private organizations, land conservancies, and independent researchers also were contacted. Ninety-one research projects have been incorporated into the database (Appendix B). I had difficulties obtaining complete location or other data associated with many research projects, a result of either inaccessible data due to loss or some other complication or to a lack of cooperation from the researcher.

The database can be used to provide information and create maps for many purposes. If a project is proposed for a certain area that is potentially detrimental to pond-breeding amphibians, the database can be used to identify known locations of specific species or target areas where surveys have not occurred and therefore should be concentrated. Land managers can then redirect proposed activities to other areas. For example, the U.S. Forest Service was interested in the location of striped newt and gopher frog breeding ponds in a certain area to aid in the proposed designation of off-road vehicle trails. Using the database, CPI was able to provide the locations where these species historically were encountered, how many research projects involving these species were conducted in the area and during what years, and the last year these species were encountered (Figure 6).

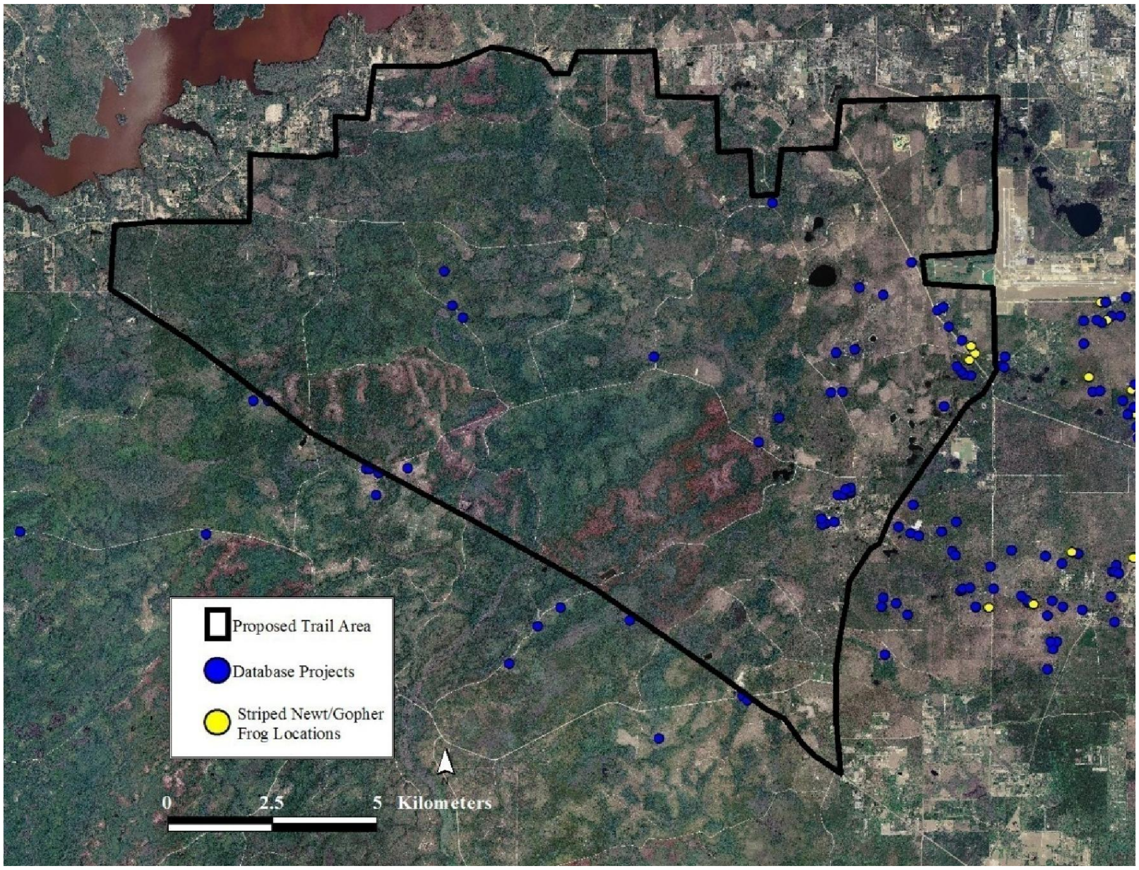

Figure 6. Example of database use. The database was used to provide information about the location of striped newt and gopher frog breeding ponds (yellow circles) in an area proposed for off-road vehicle trails (black outline). Using the database, CPI was able to inform the USFS that three breeding ponds were located within 2 km of the proposed area, that 5 research projects had been conducted in that area from 1969 to 2006, and the last time one of those species was encountered was in 2006.

The database also can be used to assist researchers in targeting areas where historical surveys have taken place or conversely, where research previously has not been conducted (Figures 6 and 7). For example, if a student wants to conduct research at a particular location, the database can be used to find what projects have already been conducted there, during which years, and the amphibian species that were encountered (Figure 6). Additional uses of the database include finding out when the last year a particular species was encountered and identifying where the majority of research occurred for a particular species, where research gaps occur in the State, successful methodologies for encountering a particular species, duration of projects, and researchers with the most experience researching a particular species.

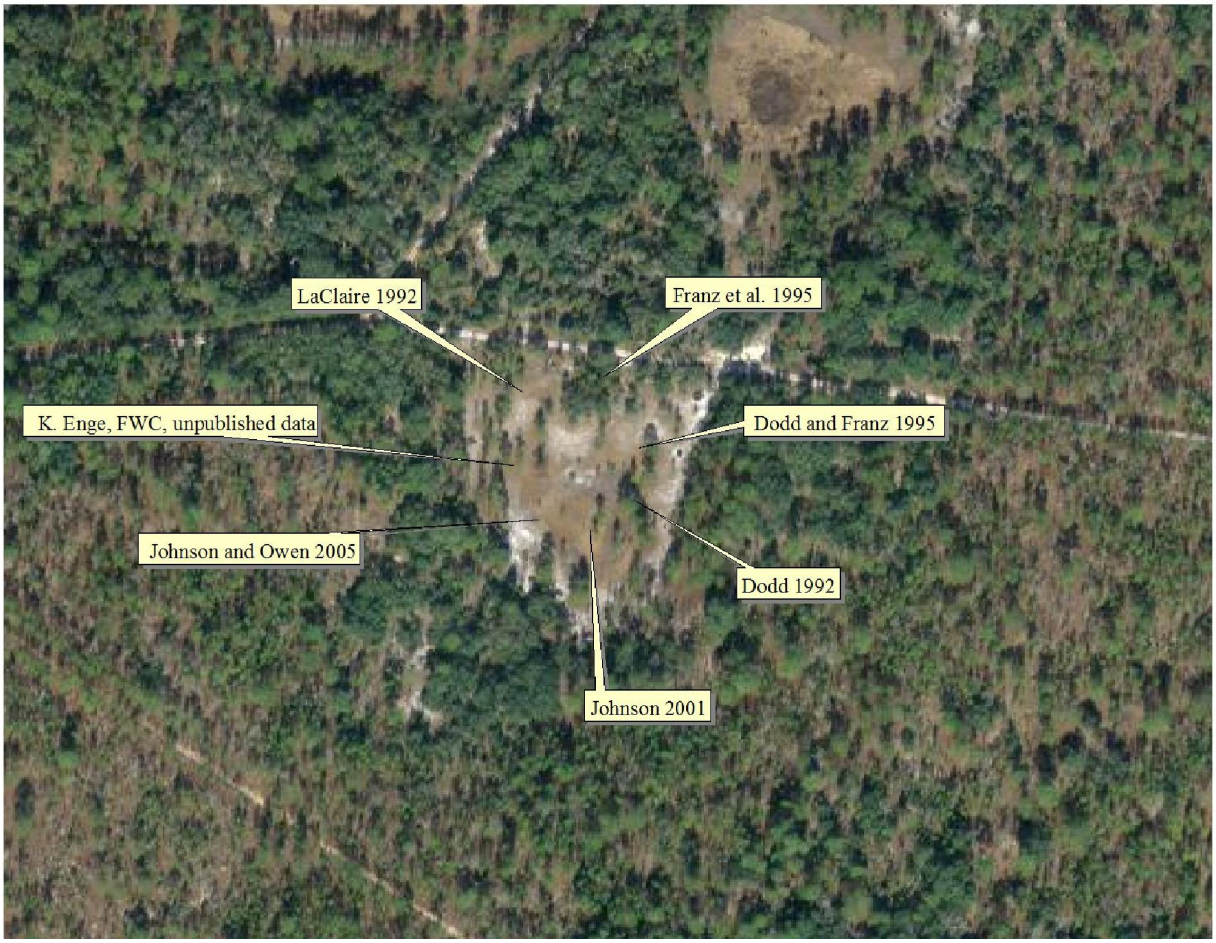

Figure 7. Example of database -- Breezeway Pond. Based on database results, 7 research projects involving amphibians have been conducted within the vicinity of this pond over 19 years. Eight species that breed exclusively or principally in ephemeral ponds were encountered, including 2 SGCN: gopher frog and striped newt.

Before analyzing or summarizing data contained in the database, it is imperative that the comment field of the database be reviewed. For some projects, species information for individual locations was not available and species data were summarized for all locations of the individual project. Some researchers only recorded data for target species and therefore the absence of data for other species at a survey location does not mean the species was absent, just that it was not recorded. A metadata file was created to accompany the database, providing descriptions of each field.

EPHEMERAL POND SURVEYS

An ephemeral pond survey was initiated to ascertain the current condition of ephemeral ponds, improve distribution and status data, and increase our knowledge of breeding site locations. Special focus was given to the 5 SGCN. Several methods were used to conduct pond surveys including dipnetting, drift fencing, and road cruising.

Methods

Ponds were selected based on historical records, lack of existing data, SGCN ranges, upland habitat factors, and advice from resident biologists. Surveys were conducted in ephemeral ponds in sandhill, scrub, and flatwoods habitat types using standard amphibian survey methods as described in Enge (1997) and Heyer et al. (1994). Ponds were located on state park, state forest, national forest, and private lands.

Dip Net Surveys

Fifty ephemeral ponds were sampled for amphibian larvae twice per year using a heavy duty dip net (Memphis Net and Twine Co. HDD-2 model) or a smaller framed net (Forestry Suppliers, Inc baitwell/fingerling net), both with 3/16” mesh. The number of dip net sweeps per pond varied depending on pond size. The entire pond periphery of smaller ponds was swept and a minimum of 50 sweeps was used for larger ponds. Total length of the first 10 larvae per species was recorded to the nearest mm.

Drift Fence Survey

Drift fences were constructed around 4 ephemeral ponds in the Munson Sandhills region of the ANF. The drift fences were constructed using 10-m-long segments and encircled 50% of each pond (Figure 8). Each drift fence had 2 single-ended funnel traps at each end (4 traps per fence) to enable analysis of amphibian movement into and out of the pond. In addition, 12 fences had double-ended funnels on each side for the purpose of comparing capture rates of fences with 6 traps to those with 4 traps. A total of 160 single-ended and double-ended screen funnel traps was employed at the 4 ponds.

Eleven species were individually marked (toeclipping) per pond and represent 3 SPGN (striped newt, ornate chorus frog, and gopher frog) and 8 other species that breed exclusively or principally in ephemeral ponds. Additional traps were placed in uplands between the 4 ponds in an effort to capture dispersal or migration movement between ponds. Traps were placed along logs, downed trees, or other natural obstacles using methodology employed by Dodd and Franz (1995). Dipnet and aural surveys also were conducted at these ponds.

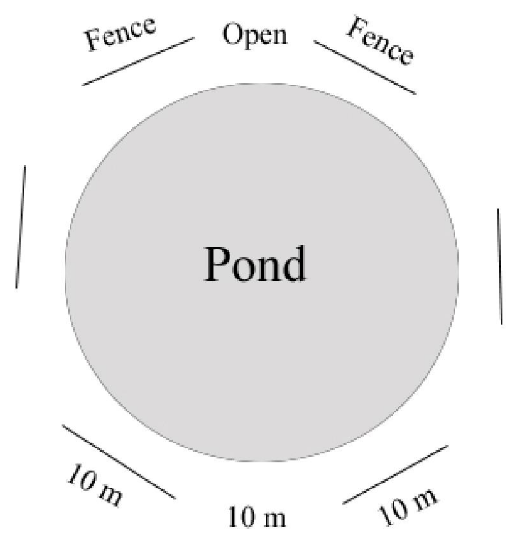

Figure 8. Diagram of the drift fence used in this study. Drift fences encircled 50% of the pond; each segment was 10m in length.

Fences were activated just before a major rain event and closed at the onset of the dry weather following the front. This sample timing is similar to methods used by the Florida

Natural Areas Inventory (Hipes and Printiss 2002, Palis et al. 1995) and was employed to reduce mortality rates.

Road Cruise Surveys

Road cruise surveys were designed to target 2 winter-breeding SGCN (flatwoods salamander and tiger salamander). Surveys were conducted during rainy nights in the winter months (Nov-Apr). Routes were chosen based on habitat and for the purpose of retracing historical surveys (Means et al. 1996, D.B. Means, Coastal Plains Institute, unpublished data).

Results and Discussion

Dipnet Surveys

Fifty ephemeral ponds were selected for dipnet and aural surveys. These ponds were located on private conservation (Nokuse Plantation, 8 ponds), national forest (ANF, 22 ponds), state forest (Goethe State Forest, 10 ponds), and state park (Wekiva River Basin State Parks, 10 ponds) lands. Ponds were distributed around the state and represent a wide range of habitat types (Figure 9). Surveys were timed to document the breeding events of the 5 SGCN targeted for this study. As these species are all winter breeders, dipnet surveys occurred between January and June. Ponds were scheduled to be surveyed twice per year for the 2-year sampling period, but drought conditions and access issues reduced the amount of sampling that actually occurred. This project's sampling period overlapped with a comprehensive statewide survey for striped newts organized by K. Enge of FWC and some of the data collected were also recorded in that database. Dipnet survey locations are provided in Appendix C.

Dipnet surveys at Nokuse Plantation were conducted in collaboration with Margaret Gunzburger, Ecologist, and Matt Aresco, Director. Target SGCN include flatwoods salamanders, tiger salamanders and ornate chorus frogs. Seven of the 8 ponds selected at Nokuse were identified during an FWC flatwoods salamander survey as potential flatwoods salamander breeding sites (K. Enge, Florida Fish and Wildlife Conservation Commission, personal communication). Dipnetting was not conducted during the first year of this project (2006) due to staff changeover at the Plantation and access issues. Extreme dry conditions during winter and spring 2007 prevented most ponds from filling and only 1 pond was sampled. Only larvae of the southern leopard frogs (*R. sphenocephala*) were found. Ornate chorus frogs and southern chorus frogs were heard calling during several winter months, but no tadpoles were encountered. Dipnet survey locations for Nokuse Plantation are provided in Appendix C.

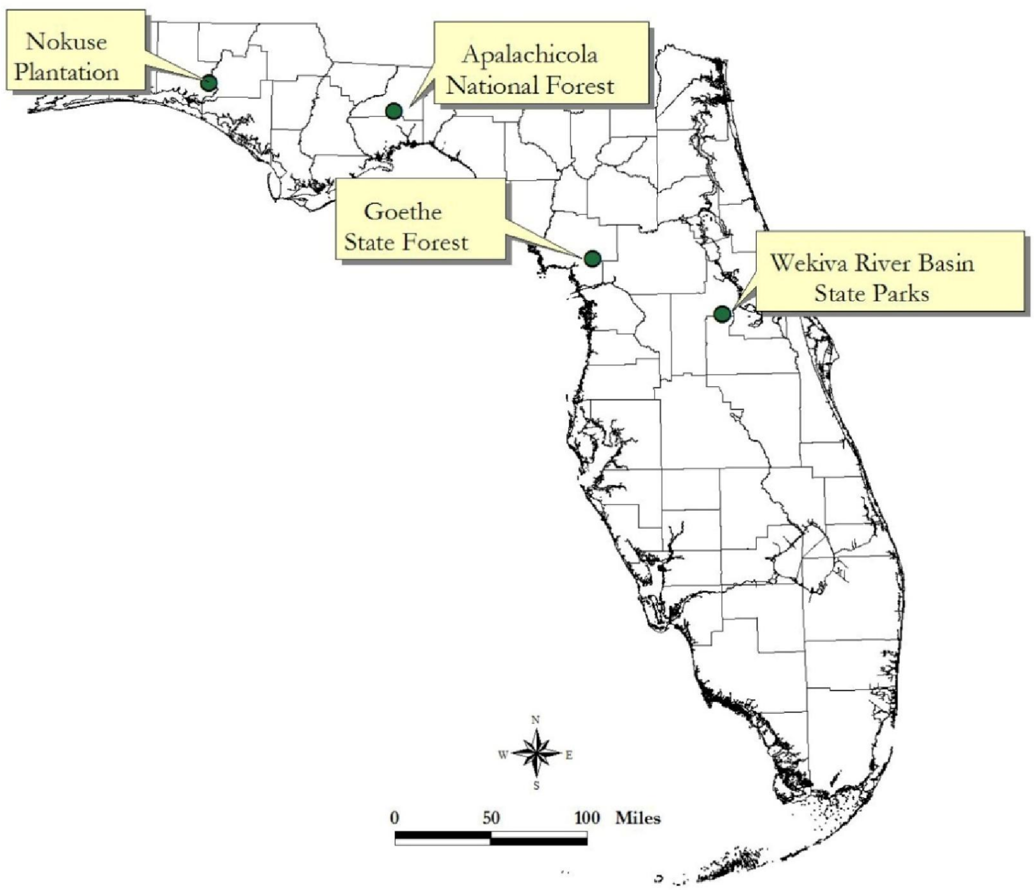

Figure 9. Map of dipnet survey locations. Four survey locations were chosen representing federal, state, and privately owned lands. The locations included Nokuse Plantation, Apalachicola National Forest, Goethe State Forest, and Wekiva River Basin State Parks.

The Munson Sandhills region of the ANF provides habitat for 3 of the 5 SGCN targeted for this study: striped newt, ornate chorus frog, and gopher frog. The decline of striped newt populations in this area is a major concern, so the 22 ponds selected represent 19 historical striped newt ponds and the 4 ponds around which drift fences were placed (one of which is an historical striped newt pond). Six ponds remained dry throughout the project period; all other ponds were dipped at least twice.

All 3 targeted SGCN were encountered, though striped newts were captured in very small numbers. Three female striped newts were captured at Pond 6, 2 in March 2006 and 1 in January 2007. One striped newt was captured at Pond 37. All captures were adults; no larvae were encountered. Gopher frog larvae were encountered at 12 ponds (55%) in the ANF and ornate chorus frog larvae were captured at 16 ponds (73%). One pond was a new record breeding location for ornate chorus frogs.

Dipnet surveys are an effective method for determining if breeding occurred, though they do not provide proof of breeding success, unless metamorphosing larvae are captured. In 2007, most ANF ponds dried before gopher frogs had a chance to metamorphose completely. Gopher frogs require at least 3 months to metamorphose (Phillips 1995, Palis 1998) and the majority of ponds did not retain water for that long. With shorter larval stage duration, ornate chorus frogs were probably more successful. Additionally, metamorphic ornate chorus frogs were captured as part of the drift fence survey at all 4 ponds, but no metamorphic gopher frogs were captured. Other species that breed exclusively or principally in ephemeral ponds that were encountered in the ANF include the mole salamander, oak toad, eastern narrowmouth toad, pine woods treefrog, barking treefrog, southern chorus frog, little grass frog, and eastern spadefoot. No new species records were recorded for the Munson Sandhills.

Dipnet surveys at Goethe State Forest were conducted in collaboration with the state forest biologist, Libby Stuart, and other state forest staff. The 10 ponds associated with this project are a subset of a larger group of ponds irregularly monitored by Goethe staff. The striped newt, gopher frog, and ornate chorus frog were the targeted SGCN. Due to lack of water in the ponds, dipnetting occurred only once in 2006 and was limited to 4 ponds in 2007. Striped newts were captured at 3 ponds representing 3 new pond records. Gopher frogs were encountered at 1 pond, also a new record. During 2007, most ponds remained dry or held water for too short a period for amphibians to successfully breed.

Dipnet surveys at the Wekiva River Basin State Parks were conducted in collaboration with the park biologists, Rick Owen and Gregg Walker. The striped newt, ornate chorus frog, and gopher frog were the targeted SGCN. Three of the 10 ponds selected were known breeding sites for the gopher frog and 2 were known striped newt breeding sites. The striped newt was encountered at 2 ponds, representing 2 new records. New records for gopher frogs were obtained at 5 ponds. Pine woods treefrogs and barking treefrogs were also encountered. Due to lack of water in the ponds, no dipnetting occurred in 2007.

Drift Fence Survey

The drift fence survey was designed to target 3 SGCN (striped newt, ornate chorus frog, gopher frog) and 7 other ephemeral pond breeders (mole salamander, oak toad, pine woods treefrog, barking treefrog, little grass frog, southern chorus frog, and eastern spadefoot toad). Drift fences were constructed around 4 ephemeral ponds in the Munson Sandhills of the ANF in October 2005. The ponds vary in size, character, and hydroperiod (Figure 8) and are located within a 3.7-ha area. Drift fence pond locations are provided in Appendix D. These ponds were surveyed to monitor SGCN breeding success and presence, detect movements between the ponds, and obtain information on the diversity of Florida Panhandle ponds with varying sizes and hydroperiods.

Figure 10. Four drift fence survey ponds in the Apalachicola National Forest. Ponds vary in size, character, and hydroperiod and are in close proximity to one another. Drift fences were operated from November to June for 2 years.

Pond 53, the smallest pond, was approximately 0.01 ha in size with an oak leaf liter floor and a hydroperiod of 1-4 months. Pond 54 was approximately 0.06 ha in size with a deep center, herbaceous aquatic vegetation throughout, and a hydroperiod of 6 months to 1 year. Pond 55, the largest pond, was approximately 1.0 ha in size with herbaceous aquatic vegetation around the periphery and can hold water for several years. Pond 56 was 0.03 ha in size, predominately sand bottomed with a thin amount of herbaceous vegetation around the periphery, and a hydroperiod of about 4 months.

The fences were operated during rain events November through June, 2005-2007. These months correspond to the majority of migration movement by the targeted species (Means 2007). Over the 2-year period, traps were opened a total of 40 nights. Rainfall was 22-30% below average during the 2005/2006 and 2006/2007 sampling seasons. According to the National Oceanic and Atmospheric Administration (2008), the study area ran a monthly precipitation deficit for virtually the entire year, both years. This low precipitation rate corresponded to shorter than usual hydroperiods for each pond.

A total of 3,321 individuals representing 18 species was captured as part of the drift fence survey (Table 4). Two SGCN were captured: the gopher frog (34 individuals) and the ornate chorus frog (408 individuals). Gopher frogs were captured at 3 of the 4 ponds and ornate chorus frogs were captured at all 4 ponds. Gopher frogs did not successfully breed either sampling year. No metamorphic gopher frogs were captured and only 1 tadpole was found in the only pond that still held water at the end of June 2007. Pond 55 had about 4 cm of muddy water in which 1 gopher frog tadpole was found during a late June dipnet event. That tadpole did not have its hind legs erupted and therefore is unlikely to have metamorphosed before the pond dried completely. Ornate chorus frogs, however, successfully bred in all 4 ponds as demonstrated by the metamorphic froglets captured (92% of total captures for the species). The third targeted SGCN, the striped newt, did not breed in any of the 4 ponds during the 2-year sample period, as evidenced by zero captures via both drift fence and dipnet survey methods.

Table 4. Drift fence total captures from 4 ponds in the Apalachicola National Forest. Drift fences were operated during major rain events from November through June for 2 years.

	Pond 53			**Pond 54**			**Pond 55**			**Pond 56**			**Total**		
	Year 1	Year 2	Total	Year 1	Year 2	Total	Year 1	Year 2	Total	Year 1	Year 2	Total	Year 1	Year 2	Total
Cricket frog	84	15	99	246	34	280	1247	162	1409	74	11	85	1651	222	1873
Oak toad	3	0	3	8	0	8	3	0	3	11	1	12	25	1	26
Southern toad	0	1	1	10	0	10	13	4	17	4	0	4	27	5	32
Eastern narrowmouth toad	3	0	3	1	2	3	6	6	12	0	1	1	10	9	19
Barking treefrog	8	1	9	9	2	11	35	4	39	1	0	1	53	7	60
Pine woods treefrog	18	3	21	28	1	29	138	4	142	4	0	4	188	8	196
Squirrel treefrog	2	0	2	0	0	0	1	1	2	0	0	0	3	1	4
Spring peeper	0	0	0	0	3	3	0	0	0	2	82	84	2	85	87
Little grass frog	1	1	2	3	0	3	18	5	23	1	0	1	23	6	29
Ornate chorus frog	0	61	61	2	221	223	1	98	99	3	22	25	6	402	408
Southern chorus frog	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
Gopher frog	0	1	1	1	2	3	10	20	30	0	0	0	11	23	34
Bull frog	0	0	0	1	0	1	1	0	1	0	0	0	2	0	2
Pig frog	4	0	4	28	2	30	76	0	76	11	0	11	119	2	121
Southern leopard frog	19	0	19	41	7	48	159	10	169	10	0	10	229	17	246
Eastern spadefoot toad	1	2	3	0	0	0	0	1	1	0	0	0	1	3	4
Mole salamander	10	5	15	1	18	19	61	68	129	4	12	16	76	103	179
Central newt	0	0	0	0	1	1	1	0	1	0	0	0	1	1	2
Totals	153	90	243	379	293	672	1771	383	2154	125	129	254	2428	895	3323
Species	11	9	14	13	11	15	16	12	17	11	6	12	18	16	18

Pond species richness varied between ponds and ranged from 12 to 17 species. These numbers are similar to the species richness reported at other locations in the state (Dodd 1992, Greenberg and Tanner 2005*a*). The pond with the lowest species richness, Pond 56, had an intermediate hydroperiod compared with the other 3 ponds. More amphibian species were captured at Pond 53, which held water for a maximum of 2 months at a time, than were captured at the larger Pond 56. It is possible that captures made at Pond 53 are a result of movement from nearby Pond 54, though no recaptures verify this statement. These data support assertions from other researchers that a larger pond with longer hydroperiod does not directly correspond to higher species richness (Pechmann et al. 1989, Snodgrass et al. 2000*a*).

A great deal of variation occurred between sampling years at all ponds. Most species were captured in much greater numbers during the first sampling year compared to the second. During the first sampling year, 2,428 individuals were captured at the 4 ponds combined and during the second sampling year, captures totaled 893. Species richness at each pond also was greater during the first year. Differences in rainfall patterns and pond hydroperiod affect amphibian movement. Rainfall in 2006 was 9 cm greater than rainfall in 2007. Additionally, pond hydroperiod was longer during the first sampling year than the second (Table 5). At any given pond, at least 5 species were found during only 1 of the 2 sampling years. The presence of some species would have been missed at all ponds if sampling had only occurred in the first year. This high variation is common among ephemeral pond-breeding amphibians (Dodd 1992, Gibbons et al. 1997, Johnson 2002, Greenberg and Tanner 2005*a*, Means 2007) and emphasizes the need for multi-year studies.

Only 9 recaptures were positively identified, 2 of which represented movement between ponds. A female mole salamander was first documented at Pond 54 and later recaptured moving into Pond 55, a distance of 100 m. A female ornate chorus frog was first documented at Pond 54 and later recaptured moving out of Pond 56, a distance of 160 m. It is likely that more inter-pond movement occurred but was not documented because the fences were intermittent and did not completely encircle the ponds. No inter-pond movement was detected from the upland funnel traps.

Table 5. Hydroperiod of 4 ponds studied as part of the drift fence survey. Shading represents months when water was in the pond.

	Pond 53	Pond 54	Pond 55	Pond 56
Nov 05				
Dec 05				
Jan 06				
Feb 06				
Mar 06				
Apr 06				
May 06				
Jun 06				
Jul 06				
Aug 06				
Sep 06				
Oct 06				
Nov 06				
Dec 06				
Jan 07				
Feb 07				
Mar 07				
Apr 07				
May 07				
Jun 07				

The number of traps along a 10-m drift fence resulted in significantly different numbers of amphibian captures ($t_{384} = 2.265$, $P = .024$). Mean captures at fences with 4 single-funnel traps placed on the ends of fences ($M = 1.92$, $SD = 3.93$) were less than fences with additional double-funnel traps placed in the midpoint of the fences ($M = 2.37$, $SD = 4.18$). Based on these results, I recommend if fences are at least 10 m in length, capture rates will improve by using double-funnel traps in the center in addition to single-funnel traps used on the ends. Note: a single extreme outlier was deleted from the data. On one day, 92 metamorphic froglets were captured at 1 fence, the range of captures for all other fences on all days was 0-42. Although all fences captured more individuals on this day due to increased rainfall, this fence caught more than twice the number of any other. Also of note, SD's are somewhat high due to high fluctuations in number of captures, which was a result of varying movement activity in response to rainfall and was a pattern that was consistent across fence type (6-trap or 4-trap).

Road Cruise Survey

Three survey routes were selected to target flatwoods and tiger salamanders based on presence of historical breeding populations. One route was located along SR 12 in the western ANF and was approximately 21 km long. This route was an historical road-cruise route for flatwoods salamanders and the population was believed to be extirpated (Means et al. 1996). The second route was located along SR 59 in between Tram Road and US 98 and was an area with historic flatwoods salamander records. The third route was located NW of Tallahassee along Centerville, Crump, and Miccosukee Roads and was an historic tiger salamander breeding area.

Few substantial nocturnal cold fronts (heavy rains) occurred during the winter and spring of 2005/2006 and 2006/2007 when the salamanders migrate between their wetland breeding and their upland habitats. Seven road-cruise surveys were conducted. No SGCN or other ephemeral pond obligates were encountered.

MANAGEMENT STRATEGIES

This section introduces management strategies for ephemeral ponds, particularly as they relate to amphibian conservation. The majority of Florida's ephemeral ponds are embedded within the longleaf pine ecosystem (includes Natural Pineland and Sandhill as described by FWC (2005)) and therefore strategies discussed here will pertain to this ecosystem. Most strategies will be applicable to the scrub habitat as well but, because of its different fire regime and other factors, strategies specific to scrub are addressed in a separate section of this chapter. Several references provide excellent management strategy discussions and were used extensively during this synthesis, including Semlitsch (2000), Calhoun and deMaynadier (2004) and Bailey et al. (2006).

Management strategies were developed based on the synthesis of published literature and discussions with other scientists. Input from timber industry, small private landowners, policy makers, land managers, urban developers, government agencies, and other interested stakeholders was obtained during meetings designed to obtain feedback.

A meeting entitled "Management Strategies for Ephemeral Ponds" was held at Tall Timbers Research Station on 23 October 2007. Sixty people registered for the meeting (maximum capacity) representing private landowners and consultants, water management districts, developers, non-profit organizations, land conservancies, research centers, timber industry, colleges and universities, and county, state, and federal governments. Sponsors in addition to the Florida Legacy Initiative and CPI included Tall Timbers Research Station, National Wild Turkey Federation, Forest Stewardship Council, Florida Division of Forestry, University of Florida IFAS Extension, and Society of Wetland Scientists.

The author presented a summary of management strategies from an amphibian perspective in order to obtain feedback and input from various stakeholders and scientists. Other presentations included management strategies from various perspectives, landowner assistance programs, and issues in restoration. Three panel discussions were conducted in the afternoon; topics included Ephemeral Ponds and Silviculture: Impacts and Strategies; Issues in Wildlife and Land Management; and Restoration of Upland and Wetland Systems. A court reporter transcribed the panel discussions, the transcript was edited, and the proceedings were made available in January 2008 at www.coastalplains.org/ttrsmeeting.htm.

An ephemeral wetland advisory committee was formed as a result of this meeting. The committee was solicited to review, comment, and contribute to the management strategies developed as part of this project. The drafted management strategies also were sent out to amphibian and wetland ecologists for review.

A final meeting was scheduled 8 April 2008 in conjunction with the Florida Division of Forestry at the Welaka Training Center. The purpose of this meeting was to specifically obtain input from land managers regarding practical experience managing ephemeral ponds and the surrounding uplands, and the drafted management strategies. Email announcements were sent directly to 38 contacts, 100s of private landowners and natural resource managers were reached via Florida Forest Stewardship Coordinator Chris Demers' email list-serve and other contacts, and the meeting was advertised on The Society of Wetland Scientists, Partners in Amphibian and Reptiles Conservation (PARC), FWC, and CPI websites. Less than 10 land managers registered and the meeting was cancelled. Drafted management strategies were sent to registrants for review, comment, and discussion.

In addition to this report, these strategies will be condensed in a brochure to be distributed to landowners and land managers across the state. A sample of the brochure will be provided with the final report.

Landscape Context

An essential concept for managing ephemeral ponds and associated amphibian populations is that the ponds must be viewed within the context of the surrounding uplands (Gibbs 1993, Semlitsch 2000, Baldwin et al. 2006, D. B. Means 2006). Amphibians spend the majority of their life cycle in the uplands; therefore, these uplands are as vital to the survival of pond-breeding amphibian populations as the aquatic breeding habitat (Dodd 1996, Marsh and Trenham 2001, Gibbons 2003, D. B. Means 2006). Managing only for the aquatic habitat is of little conservation value if the adjacent uplands are not also protected and managed properly.

How much of these uplands are essential is still unknown. Data from radio-telemetry, radioactive tagging, and drift fence studies provide information about distances individuals can travel from a breeding pond, ranging from 100 m to 1100 m (Table 6). However, the density of these populations at varying distances from a pond edge is still unknown. Until such research is conducted, management recommendations must be based on the best available science and adapted accordingly when new data are available. Judging from available data, it appears that pond-breeding amphibians use a much greater proportion of the landscape then their small size would suggest.

Semlitsch and Bodie (2003) suggested that amphibians need a radius of approximately 339 m of terrestrial habitat surrounding a wetland. This recommendation was based on a summary of terrestrial migration distances for amphibian species from all over the world. Summarizing migration distances of ambystomatid salamanders from several U.S. geographic locations, Semlitsch (1998) recommended a 164-m zone surrounding a wetland. He includes the caveat that this zone may be an underestimate for some species and does not incorporate metapopulation dynamics and landscape-level processes.

Table 4. Farthest distance from a breeding pond recorded for 12 ephemeral pond-breeding amphibian species.

Species	Farthest Distance from Breeding Pond (m)	Source
Oak Toad	914	Dodd (1996)
Eastern Narrowmouth Toad	914	Dodd (1996)
Pine Woods Treefrog	815	Dodd (1996)
Barking Treefrog	100	Murphy et al. (1993)
Little Grass Frog	434	Dodd (1996)
Ornate Chorus Frog	425	Brown and Means (1984)
Gopher Frog	2000	Franz et al. (1988)
Eastern Spadefoot Toad	914	Dodd (1996)
Flatwoods Salamander	1100	R. Ashton (personal communication)
Mole Salamander	300	Semlitsch (1981)
Tiger Salamander	225	Steen et al. (2006)
Striped Newt	709	Dodd (1996)
Average	738	
Median	762	
Range	286-2000	

More relevant to the development of management strategies in Florida is the use of the uplands by amphibians native to the Southeast. A 1000-m upland habitat buffer was recommended for the dark gopher frog based on post-breeding movements, in order to incorporate neighboring ponds and reduce edge effects of clearcuts and development (Richter et al. 2001). During an upland survey, Dodd (1996) found that 83% of amphibian captures were within 600 m of the nearest breeding pond, though due to sampling biases he could not say whether this distance would be effective at protecting the local amphibian community. Roznik (2007) used radio-telemetry to track juvenile and adult gopher frogs. She found adults typically moved from 63 m to 396 m into the surrounding uplands, though 1 was located 862 m from the nearest breeding pond. Juveniles generally moved greater distances, 100-691 m away from natal ponds. Similarly, Blihovde (2006) tracked adult gopher frogs captured in gopher tortoise burrows 100-460 m from the frogs' breeding pond. Based on upland drift fence captures adjacent to a pond in North Florida, Johnson (2003) suggested a 1000 m radius would be needed to preserve the area used by the vast majority of striped newts at that breeding pond.

The shape of the terrestrial habitat incorporated into management plans is a factor as well as the radial distance. Amphibians breeding in vernal pools in the northeastern U.S. travel to forested wetlands to overwinter. Conservation planning for these species involves a cone-shaped terrestrial habitat core that originates at the breeding site and expands out to the forested wetlands (Baldwin et al. 2006). This approach can reduce the amount of land potentially requiring protection by more than 65% (Baldwin et al. 2006). Though sometimes nonrandom, amphibians in the Southeast travel in various directions from a pond into the uplands (Dodd and Cade 1998, Johnson 2003, Greenberg and Tanner 2005*b*) and therefore this cone shape is not applicable.

As a starting point, I recommend land managers incorporate 500 m of uplands surrounding an ephemeral wetland into their management plans as *core terrestrial habitat*. Once that radius is delineated, other factors should be considered to determine the size and shape of this core terrestrial habitat. The zone should be expanded where rare or sensitive species are present that may require more terrestrial habitat, as in the case of the striped newt mentioned above. The zone also should be expanded to incorporate adjacent ponds within 1 km and good or restorable habitat, thereby preserving landscape connectivity for dispersal and metapopulation function. The zone can be reduced to avoid high-intensity land uses such as major roads, industrial silviculture, and urban areas. If a limited number of ponds can be incorporated into a management plan, prioritize:

- Pond clusters
- Ponds with known populations of specialized or target species
- Ponds with varying hydroperiods
- Ponds within 1 km of other ponds
- Ponds surrounded by native or restorable habitat

It should be noted that reducing the number of ponds not only reduces the number and density of sites where amphibians can reproduce and recruit juveniles into the population, but also increases the distances between ponds, diminishing the capacity to maintain local and regional species populations (Gill 1978, Gibbs 1993, Semlitsch and Bodie 1998, Skelly et al. 1999, Semlitsch 2000).

The first step to managing ephemeral ponds is to know where they are located on the landscape. Ponds can be identified using aerial photography, topographic maps, or satellite imagery and then ground truthed to verify their location. Some small or shallow ponds may not be evident using remote technology and the importance of on-the-ground visits cannot be overemphasized.

The best time to identify ponds is during the wet season when they likely hold water. In the Coastal Plain of Florida, there are 2 wet seasons. The winter wet season is from December through March and the summer wet season is from May through September. In South Florida, there is only 1 wet season, from May to September. Multiple annual and seasonal droughts might keep ponds dry even in a “normally” wet season. The most ephemeral of ponds may not hold water unless it is a very wet year. These small ponds should not be discounted, as they are still important to pond-breeding amphibians (Semlitsch 2000). Some plant species that may be helpful in determining the pond boundaries include *Andropogon glomeratus, Dicanthelium* sp., *Eriocaulon compression, E. decangulare, Hypericum fasiculatum, Ilex glabra, Nyssa sylvatica, Panicum hemitomon, Rhexia mariana, Rhynchospora* sp., and *Taxodium ascendens* (Franz and Smith 1999, LaClaire 1995, Sekerak et al. 1996)

Management of Ephemeral Pond Basin

The ephemeral pond basin consists of the depressional area that holds water and the outer edge of aquatic vegetation (littoral zone) and/or the wetland overstory canopy in the case of cypress and black gum ponds. The location of the littoral zone fluctuates greatly depending on the water level of the pond and bands of vegetation move back and forth reflecting soil moisture conditions (LaClaire and Franz 1990). This littoral zone is usually denoted by the presence of herbaceous vegetation or the stalks of senescent plants and is vital for amphibian reproduction as it serves as oviposition sites as well as food and cover for amphibian larvae.

The use of heavy machinery or vehicles of any kind in and around the pond basin should be avoided as they can compact soil or break the hard pan within the pond basin. Ruts formed by vehicles can disrupt the natural spread of fire; act as obstacles to migrating amphibians, particularly salamanders; channel or intercept water, disrupting the natural sheet flow of the flatwoods systems; and provide a vector for the dispersal of predatory fish (Ripley and Printiss 2005). Gates, fencing, and road closures may be needed to reduce access and have been used successfully in some areas (C. Petrick, U.S. Forest Service, personal communication).

Ditching and draining of ephemeral ponds should be avoided and, where possible, existing ditches should be filled. Ditches and drains can connect ponds to other, more permanent water sources, providing a corridor for the migration of predatory fish. Ditches also alter the hydroperiod of ponds, impact natural sheetflow in flatwoods systems, and can present a physical barrier to migrating amphibians. Restoration of the natural sheet flow in parts of Tate's Hell State Forest was accomplished by the removal of road systems and the filling of ditches (D. Morse, personal communication).

The diversion of surface water from roads into ephemeral ponds should be avoided as it can cause sedimentation, nutrient loading, and affect the water quality of the pond. Avoid stocking ponds with predatory fish that prey on amphibian larvae. If permanent ponds are desired on the property, do not alter existing ephemeral ponds; instead, create a separate pond away from ephemeral ponds.

Fencing of ephemeral ponds or sections containing pond clusters may be necessary to control damage caused by feral pigs. Rooting and subsequent habitat alteration can destroy breeding habitat as well as upland refugia (Printiss and Hipes 2001). The direct effects of predation are another concern. Selective foraging by feral pigs during amphibian breeding events has been observed and could result in the consumption of significant number of breeding adults when they are most vulnerable (Jolley 2007). Due to the importance of fire across Florida landscapes, specific management strategies relating to fire in the pond basin are discussed in a separate section. Likewise, strategies relating to silvicultural activities in the pond basin also are treated in a separate section.

Management of Core Terrestrial Habitat

Simply setting aside and preserving land within the core terrestrial habitat alone is not sufficient. Proper, long-term management is essential for the survival of pond-breeding amphibian populations. Improper management of the uplands can extirpate species or reduce their numbers considerably (Means et al. 1996, Means 2007). The most important strategy for managing uplands surrounding ephemeral ponds is to burn regularly, varying the frequency between 1 and 4 years. A more detailed description of fire management strategies is discussed in a separate section below. Strategies specifically relating to silvicultural activities in the core terrestrial habitat are also discussed in a separate section below.

Roads, including unpaved roads, that traverse the core terrestrial habitat should be limited. Roads affect amphibian dispersal (Reh and Seitz 1990, Gibbs 1998), cause direct mortality (Fahrig et al. 1995, Smith and Dodd 2003, Rosnik 2007), increase habitat fragmentation, and facilitate further development and access. Run-off from roads can degrade the quality of both aquatic and terrestrial habitats (Calhoun and Klemens 2002). Beginning in 2007, road closures were used as a management technique in the national forests of Florida to protect the integrity of ephemeral ponds and pond-breeding amphibians (U.S. Forest Service 2007*a*, *b*, *c*).

Standing dead trees, tree stumps, logs, and other coarse woody debris should be left on site because these features serve as important refugia for amphibians (Dodd 1996, Means, D. B. 2006, Rothermel and Luhring 2005, Rosnik 2007). Some research indicates that the presence of these refugia may ameliorate the negative impacts of intensive land use (Rothermel and Luhring 2005). The importance of these habitat features to all wildlife was recognized by the federal government during a conference entitled “Biodiversity and Coarse Woody Debris in Southern Forests” (McMinn and Crossley 1993).

As a restoration technique, direct application of herbicides may be one of the only options available and should not be eliminated as a land management tool (Meegan 2008). However, recent studies suggest that exposure to various pesticides causes detrimental effects at some level of concentration. Effects range from reduced swimming and feeding activity of larvae (Berrill et al. 1994, Semlitsch et al. 1995) to interference with metamorphosis (Cheek et al. 1999, Boone and James 2003) and direct mortality (Bridges and Semlitsch 2000, Boone and James 2003, Relyea 2005). *In situ* experiments testing the effects of the practical application of these chemicals are scarce, as most studies have tested various concentrations in laboratory or mesocosm experiments. A thorough understanding of the impact of pesticides and other water quality issues is complicated by their synergistic effects and the variation in response both within and between species. Furthermore, most experiments have been conducted on larvae and the impacts of these pesticides at the adult population level have not been studied. Until these impacts are understood, the use of pesticides in the uplands surrounding ponds should be used with extreme caution.

Fire

The most important management strategy for ephemeral ponds and pond-breeding amphibians is to identify and actively maintain or restore historic fire regimes. Fire suppression was identified as one of the top 8 threats to amphibian conservation (see pg 23) and frequently is cited as a cause for decline in pond-breeding amphibian populations (Palis 1997, Franz and Smith 1999, Hipes 2003, Jensen and Richter 2005, Means 2007) as well as other taxa (Stoddard 1931, Mushinsky 1985, Brennan et al. 1998, USFWS 2003). The Florida Comprehensive Wildlife Conservation Strategy ranked “incompatible fire” as one of the highest overall threats across all Florida’s terrestrial habitat (FWC 2005). Most land managers recognize the necessity of fire to maintain the longleaf pine ecosystem, but there is debate regarding the importance of fire season versus fire frequency (Bishop and Haas 2005) and as to the appropriate fire frequency (Schurbon and Fauth 2003, Means et al. 2004, Robertson and Ostertag 2004).

Historically, fires were ignited by lightning during the spring and early summer and had the potential to burn across large portions of the landscape (Robbins and Myers 1992). Ponds were sometimes dry during this time and fires often burned through the pond basin, reducing hardwood encroachment and organic matter. Fires also served to encourage growth of the herbaceous vegetation around the pond edge or littoral zone.

Due to the fragmented nature of today's landscape, prescribed fires are needed to maintain the native longleaf ecosystem. These fires frequently are conducted during the cool, dormant season when the number of allowable burn days is higher, thus enabling managers to burn more acreage than possible during the warmer growing season. The long-term impacts of dormant-season burning on amphibian populations are unknown. The impacts on vegetative structure differ in the ephemeral pond basin compared to the uplands.

Fire in the Wetlands

As mentioned above, the majority of prescribed fires occur during the dormant season when allowable burn days are greatest. Ephemeral pond basins typically contain water during this time and fires are unable to carry across the wetland. The absence of fire in some ponds may result in a rapid accumulation of organic material, reducing pond hydroperiod to such a degree as to make it unsuitable for amphibian reproduction (Ripley and Printiss 2005). Encroaching hardwoods can change the ecology of the pond, potentially making it unsuitable for pond-breeding amphibians by eliminating the herbaceous littoral zone needed for oviposition sites and larval food and cover habitat (Franz and Smith 1999, Ripley and Printiss 2005, Means 2007).

Management strategies that ensure that prescribed fires burn through the wetland are essential to maintaining appropriate pond-breeding amphibian habitat. Firelines should not be constructed around wetlands and, where present, should be restored. These plowlines can increase wetland hydroperiod by channeling excess water into the pond or decrease the hydroperiod by siphoning water out of the pond (Ripley and Printiss 2005). Firelines can facilitate the introduction of predatory fish, if they are connected to more permanent water bodies. Furthermore, firelines may provide an artificial breeding area that likely has a shorter hydroperiod than the nearby wetland, thus potentially stranding the resultant larvae (Means et al. 1994, Printiss and Hipes 2000).

Another strategy to ensure that prescribed fires are carried through the wetland is to burn when the wetlands are dry, typically during the early growing season. Managers should ensure the ephemeral pond basin is burned at least every 1-4 years (Printiss and Hipes 2000, Ripley and Printiss 2005, Means 2007). Because some wetlands may be severely fire suppressed, several years of annual or biannual burns may be necessary to initially suppress the hardwoods (Printiss and Hipes 2000), and for best results, burn annually during the early growing season (Streng et al. 1993).

The U.S. Forest Service (USFS), in cooperation with Florida State University (FSU), recently began an experiment to test whether dormant season upland burns combined with growing season wetland burns will improve conditions for flatwoods salamander populations in the ANF (C. Hess, U.S. Forest Service and Florida State University, personal communication). The uplands surrounding the pond were burned during the USFS's normal winter burning season, but the researchers will return several months later when the pond basin is dry and conduct a burn through the pond basin. The results of this experiment will test whether growing-season burns through the pond basin are capable of restoring ephemeral pond systems to suitable conditions for pond-breeding amphibians, when uplands are burned during the dormant season. If successful, this method could be implemented to improve the ecological condition of the ephemeral pond basin in those areas where growing-season burns are not possible or probable.

Fire in the Uplands

As reviewed by Streng et al. (1993), results from studies examining the effects of season of burn on longleaf pine forests are confounded by many variables, including time between burning and sampling, fire intensity, short-term records, study site conditions, and incorrect data analysis. Robbins and Myers (1992) also conducted a comprehensive review of seasonal effects of prescribed burning in Florida. These reviews along with research on the Santee Fire Plots in South Carolina (included in Robbins and Myers (1992) review) (Waldrop and Lloyd. 1991, White et al. 1991), on sandhill and flatwoods systems on the St. Marks National Wildlife Refuge in north Florida (Streng et al. 1993), and on flatwoods in Georgia (Brockway and Lewis 1997) comprise the bulk of our knowledge on the long-term effects of prescribed fire. Impacts associated with overstory vegetation, understory hardwoods and shrubs, and the herbaceous understory are summarized below.

The effect of season of burn on pine growth is unclear, but growth may be enhanced by early growing-season burns in young longleaf pines (Robbins and Myers 1992). Mortality of overstory pine is usually greater following late growing-season fire than early growing-season fire (Robbins and Myers 1992). Low-intensity prescribed fires in mature stands could probably be conducted in any month, even in the growing season, without injuring pine overstory (Waldrop and Lloyd 1991, Robbins and Myers 1992, Streng et al. 1993).

Growing-season fires are more damaging to hardwoods than dormant-season fires (Waldrop and Lloyd 1991, Streng et al. 1993, Brockway and Lewis 1997). Streng et al. (1993) also found that spring fires, rather than all growing-season fires, were more effective at eliminating oaks.

During a 43-year study on an even-aged loblolly pine stand in South Carolina known as the Santee Fire Plot Study, treatment plots were burned in the winter or summer at 1, 3 and 7-year intervals and changes in vegetation were analyzed. All treatments killed above-ground hardwoods, but only annual summer burning completely eliminated hardwood sprouting (Waldrop and Lloyd 1991). Grasses and forbs dominated the understory of plots that were winter burned annually, though numerous hardwoods sprouts survived (Waldrop et al. 1992). Brockway and Lewis (1997) studied the effects of 40 years of periodic dormant-season burning on a flatwoods longleaf pine wiregrass system in Georgia. They concluded that although growing-season fires afford better control of woody plants, periodic winter burning significantly reduced the shrub layer.

Most long-term studies failed to find a significant effect of season of burn on herbaceous species composition despite studies demonstrating increased flowering of grasses following growing-season burning (Platt et al. 1988). Brockway and Lewis (1997) found that periodic winter burning (every 2 years) reduced litter cover and increased wiregrass, forbs, and other herbaceous vegetation. On the Santee Fire Plots, burning annually in the winter reduced hardwood sprouts over time and supported the grasses and forbs typical of open pine communities (Komarek 1974, White et al. 1991). Streng et al. (1993) found that groundcover biomass and species composition did not significantly change in response to the seasonal burning treatments over an 8-year period.

These studies provide some evidence that, in terms of vegetation, fire frequency may be more important than season for upland communities. However, until we know the long-term effects of dormant-season burning on amphibians and other faunal species, the best fire management strategy should be to use prescribed fires in the season when lightning-ignited fires burned naturally (May-June) (D. B. Means 2006). Dormant-season fires can be employed in areas where heavy fuels have built up and followed by growing-season burns in subsequent years. Where hardwood encroachment is severe, annual, growing-season burns early in the season may be necessary to eliminate sprouting. In areas where growing-season burns are not an option due to drought, management objectives, smoke management issues, or some other reason, burning should be implemented during whatever time of year is feasible (Cox et al. 1987).

The historical fire regime varied across the landscape as a result of differing weather conditions, topography, vegetation type, and fuel loads, thus creating a range of microhabitats and stand conditions that shifted spatially and temporally across the landscape (Campbell and Christman 1982, Myers 1990, Greenberg et al. 1994, Platt 1999). Additionally, fires were sufficiently patchy, infrequent, and/or cool to permit the establishment and survival of some hardwoods (Greenberg and Simmons 1999). In order to mimic historic conditions, patches that vary in fire frequency (1-4 years) may be important for providing a range of appropriate habitats.

Silvicultural Activities

While it is important to maintain a core terrestrial habitat around ponds to prevent physical and chemical degradation of the wetland itself, a 500 m core would be needed to ensure the integrity of the upland habitat used by amphibians (see pg 57). As the size of this terrestrial habitat core is not practical for commercial forestry operations, some suggestions are provided in this section to minimize the impact of silvicultural activities on ephemeral ponds and pond-breeding amphibians. Silviculture Best Management Practices (BMPs) were developed by the Florida Department of Forestry and associated Technical Advisory Committee and are a good resource for general silviculture practices (Florida Division of Forestry 2004). However, these

BMPs are not sufficient to protect ephemeral ponds and pond-breeding amphibians. Calhoun and deMaynadier (2004) and Bailey et al. (2006) provide more biologically centric strategies and are a good resource for land managers. Management considerations for scrub are addressed in a separate section.

Activities associated with timber harvesting have varying impacts on the soil, microclimate, and vegetative structure, potentially rendering it unsuitable for moisture- and temperature-sensitive amphibians (Russell et al. 2004). Impacts vary depending on intensity of harvesting technique, size of disturbance, habitat type, and species, but most declines in amphibian richness and abundance are attributed to the loss of overstory shade and alteration of forest floor microhabitats (i.e., coarse woody debris, leaf litter, soil moisture) after harvest and site preparation (deMaynadier and Hunter 1995). While plantations are notorious for their paucity of biodiversity, Hartley (2002) presents evidence that by altering factors such as species composition, site preparation, stand management, and harvesting techniques, managers can create plantations beneficial to wildlife without a significant reduction in yield.

Activities in Ephemeral Ponds

The first step to managing ephemeral ponds is to know their location on the property. Ponds can be remotely identified using aerial photography then ground truthed and documented during timber cruising or other on-the-ground activities. The periphery of the pond (high-water mark) itself should be flagged for easy identification during harvest activities. Pond boundaries can be identified, even when dry, by changes in herbaceous and woody vegetation.

The pond depression should be left completely undisturbed. The use of heavy equipment in and around a pond should be avoided as should the location landing and skidding sites near a pond. The pond should be kept free of forestry operation sediment, slash, and tree-tops.

Ditching and draining wetlands should be avoided and surface water should not be diverted from roads or facilities into wetlands.

Activities in Core Terrestrial Habitat

The uplands adjacent to an ephemeral pond are equally as important to amphibian conservation as the aquatic breeding habitat. Pond-breeding amphibians regularly use the uplands at least 500 m from their breeding site and can travel even farther distances (Dodd 1996, Johnson 2003, Blihovde 2006, Roznik 2007). Some upland habitat factors important to pond-breeding amphibians include the presence of burrows or other refugia, a more open canopy structure, herbaceous vegetation such as wiregrass, and the presence of coarse woody debris.

One of the most significant strategies for forestry operations is to stagger activities in space and time, creating a mosaic of forest patches of varying ages and densities on the landscape. Amphibians are resistant to some degree of disturbance. They leave altered habitats and move in to more suitable habitat (Semlitsch et al. *in press*) as well as re-colonize an area once suitable habitat becomes available (Ash 1997, Russell et al. 2002, Morris and Maret 2007). However, if disturbances are too large, they may exceed the resilience capacity of amphibian populations. For example, many forestry companies in the Southeast limit their maximum clearcut size to 60-90 ha (Boston and Bettinger 2001). A clearcut this size surrounding an ephemeral pond would impact the entire core terrestrial habitat of pond-breeding amphibians. If such large clearcuts are necessary, they could be designed to encompass only part of the core terrestrial habitat, leaving more suitable upland habitat intact and, if possible, maintain connections between adjacent ponds.

Some amphibians have shown the ability to navigate through their landscape, avoiding certain habitats in favor of others (Madison and Farrand 1998, Malmgren 2002, Blihovde 2006, Roznik 2007), and therefore should be able to withstand localized disturbances. In a 3-year study in the Southeast Coastal Plain, clearcuts with and without site preparation were applied to 2/3 of the landscape surrounding isolated wetlands. Two years after the treatment, Russell et al. (2002) found little impact from disturbance of this proportion of the uplands in terms of amphibian abundance and richness. Whereas other studies have reported a negative effect resulting from partial upland disturbances (Raymond and Hardy 1991), Russell et al. (2002) provide some evidence to the short-term resiliency of some amphibian species. Long-term, large-scale disturbances may extirpate entire species from the landscape (Means et al. 1996, Means and Means 2005). Management strategies that create a mosaic of small-scale disturbances across the landscape would enable the survival of source populations and maintain or restore species diversity and community composition (Cromer et al. 2002, LeGrand 2005).

The impact of canopy removal may be mediated by the presence of burrows and other microhabitat refugia (Rothermel and Luhring 2005). Research has shown that the probability of survival for juvenile, migrating amphibians greatly increases with the presence of microhabitat refugia (Rothermel and Luhring 2005, Roznik 2007). Additionally, evacuation from disturbed habitat is reduced by the presence of high amounts of coarse down wood (Semlitsch et al., *in press*). Therefore, activities that reduce impacts to soil, such as compaction, or increase microhabitat refugia may be an extremely important factor to amphibian survival in silvicultural areas. Such activities include harvesting during dry seasons, using techniques such as controlled yarding, minimizing sharp turns, using brush to help increase the bearing capacity of soils, and avoiding mechanical site preparation techniques such as roller chopping, web plowing, root raking, and disking that can damage the soil structure and destroy microhabitat refugia (Tanner and Terry 1981, American Pulpwood Association 1997). Limbs and tops should be left where they fall and leave snags, stumps, and coarse woody debris as refugia for amphibians.

A third management strategy that is particularly important in flatwoods systems is to avoid bedding. This silvicultural technique is particularly detrimental to pond-breeding amphibians because it can impact migration and alter the hydrology of the pond and upland flatwoods system by interrupting sheet flow and draining or funneling water into or away from wetlands. Where bedding already exists, regular burning (1-2 years) can be employed to expose the native seed bank and allow the ground cover to return over time (Meegan 2008). Mechanical removal of beds may be more damaging than beneficial, and studies are in progress to test the effects of bed removal (Meegan 2008).

A final strategy that can be employed to ameliorate the impacts of silviculture on ephemeral ponds and pond-breeding amphibians is the use of fire. Discussed in more detail in the Fire section, fire can be used to expose the mineral soil, preparing the seedbed for natural regeneration, and reduce hardwood competition in pine stands while at the same time encouraging native herbaceous vegetation. Longleaf and slash pines are highly resistant to fire damage and loblolly pines are resistant to fire damage after they've reached a diameter of 2" (Ware et al. 1993).

Scrub Habitat

Scrub habitat is found on coastal and ancient dunes in small, disjunct patches throughout Florida (Cox et al. 1994). This system was maintained by high-intensity fires that burned at lower frequencies than the longleaf pine systems (anywhere from 10 to 100 years) and created small localized, micro-disturbances rather than widespread species composition (Myers 1990). Sand pine scrub, oak scrub, rosemary scrub, scrubby flatwoods, coastal scrub, and slash pine scrub are all variants of the scrub ecosystem. Many species are endemic to scrub including the bluetail mole skink (*Eumeces egregous lividus*), Florida scrub-jay (*Aphelocoma coerulescens coerulescens*), Florida mouse (*Podomys floridanus*), scrub oak (*Quercus inopina*), and scrub plum (*Prunus geniculata*) (Myers 1990).

While most management strategies mentioned in the previous sections apply to scrub habitat, exceptions exist relating to fire frequency and silviculture. Historically, scrub burned less frequently and at higher intensity than the longleaf pine ecosystem and therefore, a fire frequency of 1-4 years is not appropriate. Fire dynamics in scrub vary depending on location and type of scrub. The “catastrophic” nature of these fires makes prescribed fire management a difficult task. Land managers may benefit from creating a task force or clearinghouse for sharing information regarding prescribed fire techniques.

The scrub habitat may be more resilient to silviculture techniques such as clear-cutting. Some research shows that clear-cutting mimics the disturbance regime and consequent habitat structure to which many scrub organisms are adapted and thus may be a suitable tool for maintaining scrub (Campbell and Christman 1982, Greenberg 1993). Greenberg (1993) suggested that where natural disturbance (i.e., fire) is incompatible with forestry objectives, clear-cutting on 30-50 year rotations is suitable ecosystem management. However, the long-term effects of this silvicultural method on fauna and flora are unknown and should be identified before this strategy is widely adopted.

Inventorying and Monitoring

An inventory and quality assessment of ephemeral ponds is a necessary step to understanding management needs on a property. Secondly, a biological inventory is necessary to give land managers an idea of the amphibian community composition. The presence of sensitive species, such as the 5 SGCN discussed in this report, should alert the manager to take more precautions during management activities. In addition, the amphibian community should be monitored on a regular basis to ensure the implemented management strategies are effective.

Dipnetting for larvae is the most efficient and cost-effective methodology for sampling the amphibian community. The results provide information about breeding occurrence, breeding success (if metamorphosing larvae are present), and density of breeding population. If the dipnet methodology is to be implemented, considerable thought must go into the sampling schedule. As discussed in the Literature Review chapter, amphibian species breed during different seasons and the duration of time that larvae are present varies considerably based on species, pond hydroperiod, and food availability. Sampling 1 or 2 times per year likely will result in an incomplete assessment of the amphibian community. Managers must also keep in mind that lack of detection does not mean species absence. See MacKenzie et al. (2002), Bailey et al. (2004), Dodd and Dorazio (2004) and Gu and Swihart (2004) for a more thorough review of detection probabilities.

I recommend dipnet surveys monthly, if possible, but a minimum of every 3 months is necessary to provide an accurate assessment of the amphibian community. Additionally, dipnet surveys must occur over a period of several years as amphibian reproduction is highly dependent on weather conditions and some species will not breed every year (Dodd 1993, Sekerak et al. 1996, Palis et al. 2006, Means 2007, this study). Typical dipnet survey methodology is time constrained or based on a certain number of sweeps and will vary depending on pond size (Shaffer et al. 1994). Nocturnal dipping may increase detection of some larval species (Branch and Altig 1981).

A more effective method of determining the community composition is through the use of drift fences. A drift fence that completely encircles a pond, while time intensive to operate, will provide the most accurate assessment of species and number of individuals utilizing the pond, breeding success (the number of metamorphosing individuals leaving the pond), and seasonality. Both pitfall and funnel traps have been used successfully and by combining the 2, the number of individuals and species that can trespass over, under, or around the fence will be reduced (Greenberg et al. 1994, this study, but see also Dodd 1991). If incomplete drift fences are used and will not be operated continuously, it is more effective to operate fences during rain events rather than during a set number of days per month. Amphibians primarily move nocturnally and during rain events; therefore, concentrating efforts during these times will yield more effective results and reduce mortality of amphibians as well as reptiles and mammals. Similar to dip net surveys, drift fences should be operated for longer than 1 year due to the high variability of amphibian populations. Drift fences can be used in the uplands as well.

PVC pipe refugia can be used as an inventory tool for hylid treefrogs (Boughton et al. 2000, R. C. Means 2006), a common trespasser of drift fences (Dodd 1991, this study). However, due to a number of capture biases, this method is not an ideal technique for monitoring population trends (Zacharow et al. 2003).

Aural surveys are a popular method of inventory but are not as effective as drift fence and dipnet surveys, primarily because they are biased towards anurans. The types of calls can be classified but this method does not give a quantitative assessment of the population. Interspecific temporal variation in anuran calling activity, observer bias, and other factors can further complicate the applicability of aural results (Bridges and Dorcas 2000).

The best methodology to employ will vary depending on species, objectives, and whether the sampling is for inventory (presence data) or for monitoring purposes when abundance data may be important. For best total results, a combination of methods should be employed.

CONCLUSIONS

The geo-referenced database contains 90 research projects, representing almost 5700 records. The database will be available on the CPI website as a downloadable shapefile. It will be updated regularly as more data are available. The data associated with many research projects have been lost or are otherwise unavailable. The aim of this database is to preserve historical data where possible and ensure no further data loss occurs.

Pond surveys identified new breeding site locations for gopher frogs, striped newts, and ornate chorus frogs. Dipnet surveys in the ANF demonstrated the severity of striped newt decline in this former stronghold. Only 3 individuals were encountered after sampling 20 known breeding sites at least 4 times. No striped newt larvae have been documented in the ANF for 10 years despite adequate water levels and survey efforts. Tiger salamanders appear to be rare now in Florida. Based on the 90 research projects currently in the database, tiger salamanders have been documented in 9 locations, only 4 of which have been in the last 10 years. Except for at Blackwater River State Forest, little effort has been given to tiger salamander surveys. An extensive, range-wide survey is imperative to assess the distribution and status of this species in Florida.

The greatest threats to amphibian conservation in Florida are loss of general habitat, loss of upland habitat, urban sprawl, habitat fragmentation, loss of metapopulation function, industrial silviculture, fire suppression, and ditching of ponds. Highest priority research needs are associated with fire, invasive species, restoration, life history, monitoring and distributional surveys, and silviculture. After reviewing the literature and communicating with other researchers through meetings, panel discussions, and private conversations, 2 main research gaps appear to be the most urgent: amphibian use of the uplands and long-term studies.

To successfully manage for Florida's ephemeral ponds and pond-breeding amphibians, ponds must be viewed within a landscape context. At least 500 m of upland habitat surrounding a pond should be incorporated into any management plan in order to account for essential non-breeding habitat for amphibians. Priority should be given to pond clusters, ponds with known populations of specialized or target species, ponds with varying hydroperiods, ponds within 1 km of other ponds, and ponds surrounded by native or restorable habitat. Management strategies were condensed into a brochure for distribution to land managers, landowners, and other interested stakeholders.

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APPENDIX A. Invitees and Participants for 8 April 2007 Amphibian Biologist Meeting.

Name	Affiliation	Attended	Participated via Email
Jamie Barichivich	US Geological Society, Florida Integrated Science Center	X	
Todd Campbell	University of Tampa		
Kenneth Dodd	US Geological Society, Florida Integrated Science Center	X	
Kevin Enge	Florida Fish and Wildlife Conservation Commission		X
John Fauth	University of Central Florida		
Richard Franz	University of Florida, Retired	X	
Catherine Greenberg	US Forest Service		X
Margaret Gunzburger	Nokuse Plantation		X
John Jensen	Georgia Department of Natural Resources		X
Steve Johnson	University of Florida	X	
Bruce Means	Coastal Plains Institute		X
Ryan Means	Coastal Plains Institute	X	
Paul Moler	Florida Fish and Wildlife Conservation Commission, Retired	X	
Henry Mushinsky	University of South Florida		X
John Palis	No affiliation		X
David Printiss	The Nature Conservancy	X	
Lora Smith	Joseph W. Jones Ecological Research Center		X
Jennifer Staiger	US Geological Society, Florida Integrated Science Center	X	

APPENDIX B. Research Projects Included in the Database. Ninety-one projects have been incorporated into the database as of April 2008. They are listed below in alphabetical order according to the principal researcher on the project.

Target Species	Research Dates	Source
Amphibian larvae	1979-1981	Alford, R.A. 1981. Community organization and behavior of anuran larvae in a northern Florida temporary pond. UF Thesis, Gainesville, FL.
Herpetofauna	2003-2004	Ashton, K, unpublished data
Amphibian larvae	1994-1995	Babbitt, K.J., and G.W. Tanner. 2000. Use of temporary wetlands by anurans in a hydrologically modified landscape. Wetlands 20(2):313-322.
Amphibians	2001-2002	Blihovde, B. 2001. Monitoring amphibian movements during mechanical treatment of scrub. Proceedings of the Florida Scrub Symposium, Orlando. Pp 25-26.
Herpetofauna	2001-2002	Blihovde, B. Florida Park Service, unpublished data.
Gopher frog	1999-2000	Blihovde, B.W. 2006. Terrestrial movements and upland habitat use of gopher frogs in central Florida. Southeastern Naturalist 5(2):265-276.
Treefrogs	1995-1996	Boughton, R. 1997. The use of PVC pipe refugia as a trapping technique for Hylid treefrogs. Thesis, University of Florida, Gainesville.
Herpetofauna	1994-1998	Branch, L.C., and D.G. Hokit. 2000. A comparison of scrub herpetofauna on two central Florida sand ridges. Florida Scientist 63(2):108-117.
Herpetofauna	1998-2003	Brascacin C., and S. Scott. Seminole County unpublished data
Herpetofauna	1991-1994	Charest, B., and other park staff, Florida Park Service, unpublished data.
Striped newt	1971-1972	Christman, S.P. 1973. Feeding habits of the striped newt. Journal of Herpetology 7(2):122-125.
Striped newt, gopher frog	1969-2007	Coastal Plains Institute field notes and various reports
General fauna	1940-1942	Dickinson, J.C., Jr. 1948. An ecological reconnaissance of the biota of some ponds and ditches in Northern Florida. Quart. J. Fl. Acad. Sc. 2:51-28
Barking treefrog and pine woods treefrog	1996-1998	Delis, P.R. 2001. *Hyla gratiosa* and *H. femoralis* (Anura: Hylidae) in West Central Florida: a comparative study of rarity and commoness. Dissertation, University of South Florida, Tampa, FL.
Amphibians	1985-1990	Dodd, C.K., Jr. 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. Biodiversity and Conservation 1: 125-142.
Snakes	1989 and 1990	Dodd, C.K., Jr., and R. Franz. 1995. Seasonal abundance and habitat use of selected snakes. Bull. Fl Mus. Nat. Hist. 38, Pt 1(2):43-67 and Dodd.1996. Use of terrestrial habitats by amphibians in the sandhill uplands of north-central Florida. Alytes 14(1):42-52

APPENDIX B. *cont'd.*

Target Species	Research Dates	Source
Herpetofauna	1997-1998	Donnelly, M.A., M.J. Baber, C. J. Farrell. 2001. The amphibians and reptiles of the Kissimmee River. II. Patterns of abundance and occurrence in hammocks and pastures. Herpetological Natural History 8(2):171-179.
Herpetofauna	1953-1954	Duellman, W.E. and A. Schwartz. 1958. Amphibians and reptiles of southern Florida. Bulletin of the Florida Museum of Natural History 3:181-324
Herpetofauna	1998	Dwyer, N. Half Moon Wildlife Management Area, unpublished data.
Flatwoods salamander	2002-2005	Enge, K., Florida Fish and Wildlife Conservation Commission, unpublished data.
Striped newt	2005-2007	Enge, K., Florida Fish and Wildlife Conservation Commission, unpublished data.
Herpetofauna	1996-1997	Enge, K., and D. Francis, Florida Fish and Wildlife Conservation Commission, unpublished data.
Herpetofauna	1989-1990	Enge, K., and D. Runde, Florida Fish and Wildlife Conservation Commission, unpublished data.
Herpetofauna	1988-1990	Enge, K., and P. Southall, Florida Fish and Wildlife Conservation Commission, unpublished data.
Herpetofauna	1981-1982	Enge, K., and W. Marion. 1986. Effects of clearcutting and site preparation on herpetofauna of a north Florida flatwoods. Forest Ecology and Management 14:177-192.
Herpetofauna	1992-1993	Enge, K.M., and K.N. Wood. 1998. Herpetofaunal surveys of the Big Bend Wildlife Management Area, Taylor County, Florida. Florida Scientist 61(2): 61-87.
Herpetofauna	1995-1996	Enge, K.M., and K.N. Wood. 2000. A herpetofaunal survey of Chassahowitzka Wildlife Management Area, Hernando County, Fl. Herpetological Natural History 7(2):117-144.
Herpetofauna	1995-1998	Enge, K.M., and K.N. Wood. 2001. Herpetofauna of Chinsegut Nature Center, Hernando County, Florida. Florida Scientist 64(4): 283-305.
Herpetofauna	2000	Enge, K.M., and N.J. Douglas. 2000. Easement Documentation Report (Volume II: Vertebrate Surveys) for Fisheating Creek Ecosystem - Phase I Glades County, Florida. Report to Conservation and Recreational Lands Program and the Division of State Lands, Fl.
Herpetofauna	2001, 2006	Folk, M., The Nature Conservancy, unpublished data
Gopher frogs and striped newts		Franz, R., and L.L. Smith. 1999. Distribution and status of the striped newt and Florida gopher frog in peninsular Florida. Final Report to Florida Fish and Wildlife Conservation Commission.
Herpetofauna	1987-1989	Franz, R., R.E. Ashton, and W.W. Timmerman. 1995. Behavior and Movements of Certain Small Sandhill Amphibians and Reptiles in Response to Drift Fences. Project Report to the GFC, Nongame Wildlife Program.
Herpetofauna	1992-1993	Florida Fish and Wildlife Conservation Commission, unpublished data. Locations obtained from D. Pearson, data from K. Enge

Anurans	2001-2002	Gonzalez, S. 2004. Biological indicators of wetland health: comparing qualitative and quantitative vegetation measures with anuran measures. University of South Florida Thesis.

APPENDIX B. *cont'd.*

Target Species	Research Dates	Source
Biotic communities	1991-1992	Greenberg, C.H. 1993. Effect of high-intensity wildfire and silvicultural treatments on biotic communities of sand pine scrub. University of Florida Dissertation.
Amphibians	1994-present	Greenberg, K., and G. Tanner. 2005. Chaos and continuity: the role of isolated ephemeral wetlands on amphibian populations in xeric sand hills. In Meshaka and Babbitt (ends) Amphibians and Reptiles: Status and Conservation in Fl, pp 79-90. And other sources.
Gopher frog, flatwoods salamander, striped newt	2000-2001	Gregory, C.J., R.R. Carthy, and L.G. Pearlstine. 2006. Survey and monitoring of species at risk at Camp Blanding Training Site, Northeastern Florida. Southeastern Naturalist 5(3):473-498
Flatwoods salamander	2002-2003	Hipes, D., 2003. Field surveys for flatwoods salamander on under-surveyed publicly owned lands in Florida. Final Report, FNAI.
Flatwoods salamander	2002-2003	Hipes, D.L., and H. Noreen. 2003. Rare Plant and Animal Inventory of Air Force Special Operations Command, Hurlburt Field, Florida. Final Report, FNAI.
Flatwoods salamander and striped newt	1998	Hipes, D.L., and D.R. Jackson. 1998. A survey for flatwoods salamanders and striped newts on Jennings State Forest, Clay County, Florida: Final Report, FNAI
Gopher frog and striped newt	1993-1994	Hipes, D.L., and D. Jackson. 1994. Rare Vertebrate Survey of Camp Blanding Training Site. Florida Natural Areas Inventory, Tallahassee, FL.
Gopher frogs	2003	Jackson, D. 2004. Occurrence of the Gopher Frog, Rana capito, on Conservation Lands in Southern Florida. FNAI Report, Tallahassee, FL.
Rare amphibian larvae	1998	Jackson, D.R. 1998. Survey for two rare salamanders on Goethe State Forest, Levy County, Florida: and FNAI Ecological Survey. FNAI, Tallahassee, FL.
Amphibians	1974-1976	Jetter, W., and L.D. Harris. 1976. The effects of perturbation on the cypress dome animal communities. Center for Wetlands Third Annual Report to the National Science Foundation and the Rockefeller Foundation. Pp 577-652.
Striped newt	2001	Johnson, S.A. 2001. Life history, ecology, and conservation genetics of the striped newt (*Notophthalmus perstriatus*). Dissertation, University of Florida, Gainesville, FL.
Striped newt	2001	Johnson, S.A., and R.D. Owen. 2005. Status of historical striped newt (Notophthalmus perstriatus) locations in peninsular Fl. Final Report to USFWS.
General fauna	1991	Joiner, N.D., and J. Godwin. 1992. Aquatic and terrestrial wildlife surveys for the Lake Panasoffkee Watershed. Report prepared for the SWIM Department of SWFWMD.

Herpetofauna	1996-1997	Enge, K., and K. Wood, Florida Fish and Wildlife Conservation Commission, unpublished data

APPENDIX B. *cont'd.*

Target Species	Research Dates	Source
Herpetofauna	1997-1999	Koebel, J.W., J.L. Lawrence, and R.H. Carroll, IV. 2005. Amphibian and reptile communities of the lower Kissimmee River basin prior to restoration: baseline and reference conditions and expectations for restoration. Chapter 12 in S.G. Bousquin, D.H. Anderson, G.E. Williams, and D.J. Colangelo, editors. Establishing a baseline: pre-restoration studies of the channelized Kissimmee River. South Florida Water Management District, West Palm Beach, Florida.
Herpetofauna	1980-81	Labisky, R.F., and J.A. Hovis. 1987. Comparison of vertebrate wildlife communities in longleaf pine and slash pine habitats in north Florida. Pg 210-228 in Ecological Physical and Socioeconomic relationships within southern national forest.
Amphibians	1990-1991	LaClaire, L. 1992. Ecology of temporary pond in north-central Florida. Thesis, University of Florida, Gainesville, Fl.
Herpetofauna	1997 and 1998	Litt, A.R. 1999. Herpetofaunal Responses to Longleaf Pine Sandhill Restoration Treatments on Eglin Air Force Base, Florida. M.S. Thesis, University of Florida. And related references
Herpetofauna	1998-2000	Wilson, M. Blackwater River State Forest, unpublished data
Flatwoods salamander, Gopher frog, Striped Newt	1969-1997	Means, B., and R. Means. 1997. Red Hills Survey for Breeding Pond Habitat of the Flatwoods Salamander, Gopher Frog, and Striped Newt in the Tallahassee Red Hills and the Tifton Uplands. CPI Report.
Amphibians	1995-2005	Means, D.B. 2007. Life Cycles, Dispersal, and Critical Habitat Utilization of Vertebrates Dependent upon Small Isolated Water Bodies in the Munson Sandhills and Woodville Karst Plain, Leon County, Florida. CPI Final Report to the Florida Department of Transportation.
Herpetofauna	1994-1995	Means, D.B., and K.R. Studenroth, Jr. 1995. Amphibians and Reptiles of Torreya State Park. Report to Torreya State Park.
Flatwoods salamander	1970-72, 1980-89, 1990-92	Means, D.B, J.G. Palis, and M. Baggett. 1996. Effects of slash pine silviculture on a Florida Panhandle population of flatwoods salamander. Conservation Biology 10:426-437
Amphibians	1999-2008	Means, R. 2007. Assessment of Amphibian Response to Wetlands Augmentation. Annual Reports to SJRWMD 2003-2007. Also Means, R. 2001. Herpetofauna of impacted wetlands in East Florida: a pre-augmentation assessment. UF Thesis.
Amphibians	2005-2007	Meegan, R. 2008. Management strategies for Florida's ephemeral ponds and pond-breeding amphibians. Coastal Plains Institute, Tallahassee, Florida.
Herpetofauna	1979-1988, 1994	Meshaka, W., and J. Layne. 2002. Herpetofauna of a long-unburned sandhill habitat in south-central Florida. Fl Scientist 65:35-49. K. Ashton personal communication
Herpetofauna	2003-2004	Morin, K.C. 2005. Herpetofaunal responses to prescribed fire in upland pine communities of Northeast Florida. UF thesis, Gainesville, FL.

APPENDIX B. *cont'd.*

Target Species	Research Dates	Source
Barking treefrog	1990	Murphy, C.G., S.T. Emlen, and P.W. Sherman. 1993. Reproductive strategies of the treefrog Hyla gratiosa: implications for management. Final Report to the Florida Game and Fresh Water Fish Commission Nongame Wildlife Program, Tallahassee.
Vertebrates	1989-1990	Mushinsky, H.R., and E.D. McCoy. 1995. Vertebrate species composition of selected scrub islands on the Lake Wales Ridge of Central Florida. Final report to the Florida Game and Freshwater Fish Commission.
Herpetofauna	1976-1977	National Fish and Wildlife Laboratory. 1979. Osceola National Forest Phosphate Extraction and Processing: Impacts on Federally Listed and Threatened or Endangered or Other Species of Special Concern. Prepared for the US Fish and Wildlife Service.
Cuban treefrogs	2005-2006	Nusinov, T.M. 2006. Limnological and landscape factors affecting use of manufactured ponds by the invasive Cuban treefrog (Osteopilus septentrionalis). University of Central Florida Thesis. Orlando, FL.
Herpetofauna	1993-1994	O'Neill, E.D. 1995. Amphibian and reptile communities of temporary ponds in a managed pine flatwoods. University of Florida Thesis.
Amphibian larvae	2004-2006	Owen, R. Florida Park Service, unpublished data
Flatwoods salamander	1991-2004	Palis, J.G. 1995. Larval growth, development, and metamorphosis of Ambystoma cingulatum on the Gulf Coastal Plain of Florida. Florida Scientist 58(4):352-35. Also J. Palis, personal communication
Flatwoods salamander	1993	Palis, J.G., and R.N. Walker. 1993. Distribution and Status of the Flatwoods Salamander, Ambystoma cingulatum, on the Osceola National Forest, Florida. FNAI Report.
Flatwoods salamander	1999-2002	Palis, J.G., M.J. Aresco, and S. Kilpatrick. 2006. Breeding biology of a Florida population of Ambystoma cingulatum (flatwoods salamander) during a drought. Southeastern Naturalist 5(1):1-8
Flatwoods salamander and gopher frog	1993-1995	Palis, J.G., J.B. Jensen, and D.R. Jackson. 1995. Distribution and breeding biology of the flatwoods salamander and gopher frog on Eglin AFB. FNAI Final Report.
Flatwoods salamander	2002-2005	Printiss, D. 2002. Flatwoods salamander survey of the Apalachicola National Forest, Year One. The Nature Conservancy Final Report to the USFS and unpublished data.
Flatwoods salamander	1999	Printiss, D., and D. Hipes. 2000. Flatwoods salamander survey and habitat evaluation of Eglin Air Force Base, Hurlburt Field, and Tyndall Air Force Base, Florida. Florida Natural Areas Final Report
Flatwoods salamander	2000-2001	Printiss, D., and D. Hipes. 2001. Flatwoods salamander survey of St. Marks National Wildlife Refuge, Florida. Final Report to U.S. Department of Interior, Fish and Wildlife Service. Florida Natural Areas Inventory, Tallahassee, FL.
Herpetofauna	2001	Printiss, D., and D. Hipes. 2001. Inventory and management considerations of amphibians and reptiles on the Sumatra tract, Tate's Hell State Forest, Florida. FNAI Final Report to FL Dept. of Agriculture and Consumer Services, Division of Forestry.

APPENDIX B. *cont'd.*

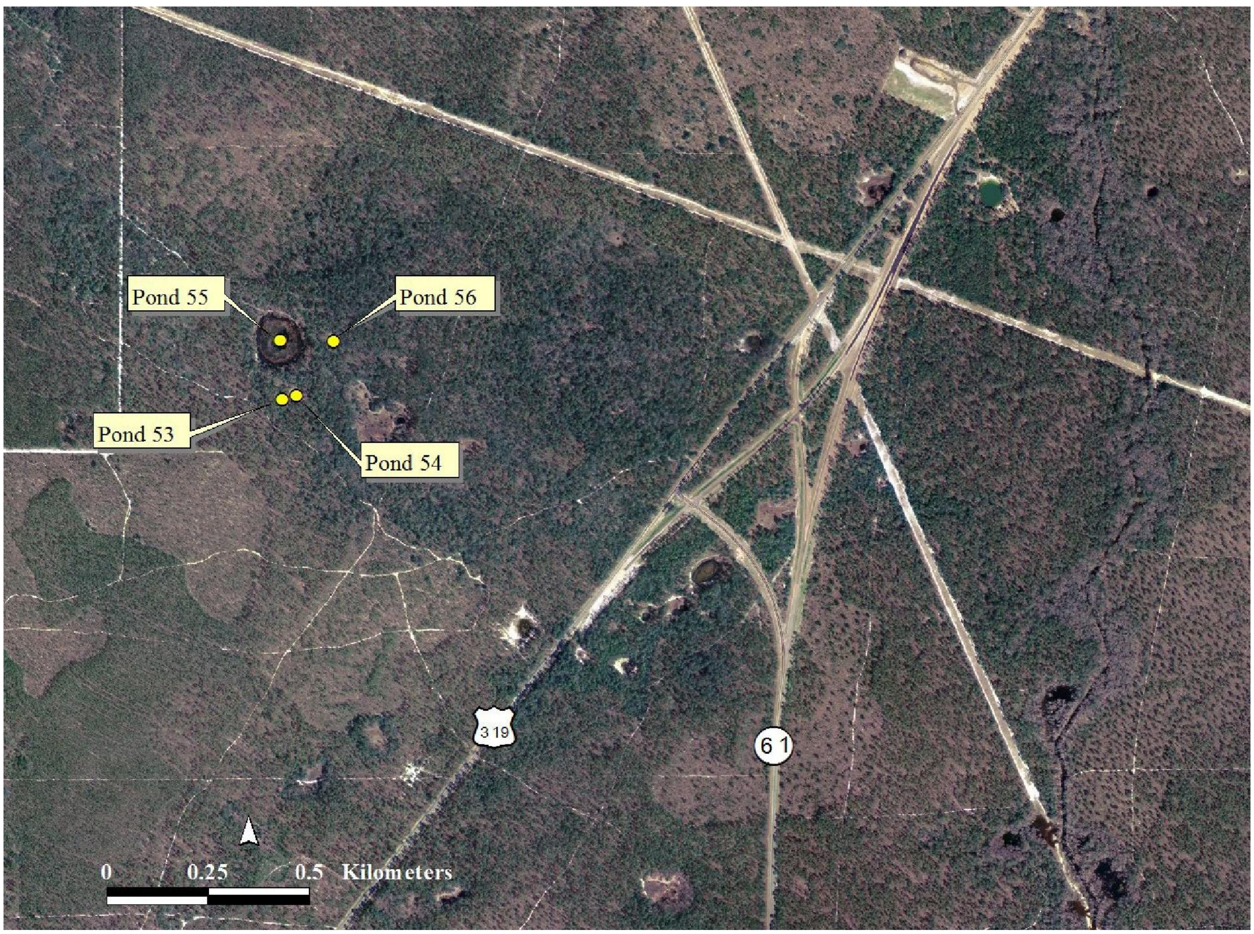
Target Species	**Research Dates**	**Source**
Flatwoods salamander	1996	Printiss, D., and D.B. Means. 1996. Distribution of the Flatwoods Salamander, Ambystoma cingulatum, on the Osceola National Forest, Florida. Coastal Plains Institute, Tallahassee, Fl.
Flatwoods salamander	2001-2005	Ripley, R., and D. Printiss. 2005. Management Plan for Flatwoods Salamander Populations on National Forests in Florida. TNC Final Report to Florida Fish and Wildlife Conservation Commission.
Amphibians	2007	Showen, L.L. 2007. Survey of the amphibian breeding ponds on the Blackwater Wildlife Management Area: with a special investigative focus on the distribution of the tiger salamander. Florida Fish and Wildlife Conservation Commission Report.
Amphibians	2000-present	Southeast Amphibian Research and Monitoring Initiative. Annual Reports 2003, 2004, 2005. USGS Florida Integrated Science Centers, Gainesville, FL.
Wildlife	1986-1988	Stout, I.J., and D.T. Corey. 1995. Effects of patch-corridor configurations on nongame birds, mammals and herptiles in longleaf pine-turkey oak sandhill communities. Final report to Florida Game and Fresh Water Fish Commission, Tallahassee, FL.
Herpetofauna	1991-1992	Studenroth, K. 1993. A herpetofaunal survey of the Econfina River region, Taylor County, Florida. Report to the Florida Department of Natural Resources.
Herpetofauna	1989-1999	Sullivan, D. 1999. Tate's Hell Wildlife Management Area 1998/99 herpetolgical survey summary. Unpublished agency report.
Gopher frog and striped newt	1993	Telford, S.R., Jr. 1993. Breeding sites for the gopher frog and the striped newt in Ocala National Forest. Unpublished report to the U.S. Forest Service, Ocala National Forest.
Herpetofauna	1991-1993	Timmerman, W.W., J.B. Miller, and C.V. Tamborski. The Herpetofauna of Jonathan Dickinson State Park, Martin County, Florida. FDEP Final Report to Florida Game and Fresh Water Fish Commission.
Herpetofauna	1977-1979	USFWS. 1980. St. Marks National Wildlife Refuge: Forestry Management and Non-Game Wildlife. Final Report to SMNWR. USFWS National Fish and Wildlife Laboratory.
Amphibians	1986-1989	Warner, S.C. and W.A. Dunson. 1998. The Effect of Low pH on Amphibians Breeding in Temporary Ponds in North Florida. Final Report to the GFC.
Amphibian larvae	1996-1998	Wigley, T., S. Sweeney, and J. Sweeney. 1999. Southeast Coastal Plain Amphibian Survey. Final Report. National Fish and Wildlife Foundation Project #97-074. National Council for Air and Stream Improvement. Research Triangle Park, NC.
Flora and fauna survey	2004-present	Wilde, D. Florida Department of Forestry, unpublished data

APPENDIX C. Dipnet and drift fence survey locations on Nokuse Plantation, Apalachicola National Forest, Goethe State Forest, and Wekiva River Basin State Parks.

Site ID	Ownership	Latitude	Longitude	Notes
ANF 001	Apalachicola National Forest	30°21'8.63"N	84°18'30.39"W	
ANF 002	Apalachicola National Forest	30°20'56.48"N	84°18'42.25"W	
ANF 003	Apalachicola National Forest	30°20'33.71"N	84°19'2.89"W	
ANF 006	Apalachicola National Forest	30°19'18.92"N	84°21'44.65"W	
ANF 016	Apalachicola National Forest	30°21'16.36"N	84°16'17.08"W	
ANF 018	Apalachicola National Forest	30°21'0.46"N	84°17'5.24"W	Dry, was not sampled
ANF 020	Apalachicola National Forest	30°21'8.71"N	84°17'11.52"W	
ANF 026	Apalachicola National Forest	30°21'9.11"N	84°16'40.06"W	
ANF 033	Apalachicola National Forest	30°19'57.80"N	84°19'34.92"W	
ANF 037	Apalachicola National Forest	30°20'1.86"N	84°20'30.14"W	
ANF 041	Apalachicola National Forest	30°20'25.07"N	84°19'16.73"W	Dry, was not sampled
ANF 042	Apalachicola National Forest	30°20'21.51"N	84°19'22.64"W	Dry, was not sampled
ANF 048	Apalachicola National Forest	30°21'11.60"N	84°17'22.71"W	Dry, was not sampled
ANF 050	Apalachicola National Forest	30°20'49.92"N	84°19'14.67"W	
ANF 053	Apalachicola National Forest	30°20'51.86"N	84°19'25.70"W	Drift fence pond
ANF 054	Apalachicola National Forest	30°20'51.93"N	84°19'24.34"W	Drift fence pond
ANF 055	Apalachicola National Forest	30°20'56.31"N	84°19'25.82"W	Drift fence pond
ANF 056	Apalachicola National Forest	30°20'56.34"N	84°19'20.89"W	Drift fence pond
ANF 060	Apalachicola National Forest	30°20'47.86"N	84°18'32.02"W	
ANF 071	Apalachicola National Forest	30°20'44.88"N	84°17'42.83"W	Dry, was not sampled
ANF 073	Apalachicola National Forest	30°21'5.46"N	84°17'35.81"W	
ANF 075	Apalachicola National Forest	30°21'15.16"N	84°17'32.55"W	Dry, was not sampled
GSF 01	Goethe State Forest	29°33'9.51"N	82°37'53.36"W	
GSF Hog Pond	Goethe State Forest	29°21'40.89"N	82°35'56.63"W	
GSF WP00	Goethe State Forest	29°32'1.98"N	82°36'20.54"W	
GSF WP02	Goethe State Forest	29°31'39.08"N	82°36'2.78"W	
GSF WP12	Goethe State Forest	29°32'8.71"N	82°35'56.16"W	
GSF WP17	Goethe State Forest	29°32'30.95"N	82°37'8.96"W	
GSF WP20	Goethe State Forest	29°32'12.51"N	82°37'5.98"W	
GSF WP24	Goethe State Forest	29°32'13.74"N	82°36'50.92"W	
GSF WP26	Goethe State Forest	29°33'51.38"N	82°38'5.73"W	
GSF WP30	Goethe State Forest	29°33'32.81"N	82°37'55.31"W	
NP 01	Nokuse Plantation	30°27'15.55"N	85°56'54.12"W	
NP 02	Nokuse Plantation	30°29'8.03"N	85°56'18.38"W	Dry, was not sampled
NP 03	Nokuse Plantation	30°31'10.74"N	86° 1'32.56"W	Dry, was not sampled
NP 04	Nokuse Plantation	30°31'5.01"N	86° 1'45.87"W	Dry, was not sampled
NP 05	Nokuse Plantation	30°29'1.00"N	85°54'30.70"W	Dry, was not sampled
NP 06	Nokuse Plantation	30°28'1.10"N	85°59'21.40"W	Dry, was not sampled
NP 07	Nokuse Plantation	30°26'56.60"N	85°59'27.10"W	Dry, was not sampled
NP 08	Nokuse Plantation	30°26'47.83"N	85°59'34.13"W	Dry, was not sampled

APPENDIX C. *cont'd.*

Site ID	Ownership	Latitude	Longitude	Notes
LWRPSP 03	Wekiva River Basin State Park	28°49'35.95"N	81°24'29.11"W	
MWT 06	Wekiva River Basin State Park	28°47'14.75"N	81°23'50.56"W	
RSRSR 09	Wekiva River Basin State Park	28°47'51.84"N	81°26'59.62"W	
RSRSR 10	Wekiva River Basin State Park	28°48'19.00"N	81°27'47.68"W	
RSRSR 11	Wekiva River Basin State Park	28°46'19.83"N	81°27'12.13"W	
RSRSR 36	Wekiva River Basin State Park	28°48'26.01"N	81°27'30.00"W	
WBMKT 31	Wekiva River Basin State Park	28°48'11.33"N	81°30'25.63"W	
WBMKT 33	Wekiva River Basin State Park	28°48'19.76"N	81°30'13.52"W	
WBMKT 35	Wekiva River Basin State Park	28°48'3.08"N	81°30'29.05"W	
WSSP 016	Wekiva River Basin State Park	28°44'30.08"N	81°30'0.43"W	



Map of 4 drift fence ponds. Ponds are located in the Apalachicola National Forest 9 km south of Tallahassee.