Chapter 11

Conservation and Life History of the Striped Newt The Importance of Habitat Connectivity

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Introduction

The striped newt (*Notophthalmus perstriatus*) is an ecologically poorly known species of salamander. Individuals are restricted to xeric upland habitats (primarily sandhill and scrub communities) and breed exclusively in isolated wetlands that lack predaceous fishes (Carr, 1940; Campbell and Christman, 1982; Stout et al., 1988; Christman and Means, 1992; Dodd and LaClaire, 1995; Franz and Smith, 1999; Johnson, 2001; Dodd et al., in press). The upland ecosystems required by striped newts are pyrogenic (Myers, 1990), and fire appears to be crucial for the persistence of the species. Besides having a complex life history involving aquatic and terrestrial stages (Christman and Means, 1992; Dodd, 1993a; Johnson, 2001,2002), individuals commonly exhibit paedomorphosis, the retention of larval traits in sexually mature individuals (Bishop, 1941, 1943; Stevenson et al., 1998; Johnson, 2001; Dodd et al., in press).

Striped newts are endemic to north-central Florida and southern Georgia (Mecham, 1967; Conant and Collins, 1991; Christman and Means, 1992; Dodd and LaClaire, 1995; Franz and Smith, 1999). In peninsular Florida, they range south to Orange and Sumter Counties and west in the panhandle to Wakulla and Leon Counties (Franz and Smith, 1999; Johnson and Dwyer, 2000). In Georgia, striped newts occur from Emanuel, Jenkins, and Screven Counties in the east, to Baker County in the southwest (Dodd and LaClaire, 1995; Stevenson et al., 1998; Stevenson, 2000). Mitochondrial DNA sequence data suggest that striped newts occur in two genetically distinct phylogroups, one in the eastern portion of the range and one in the western portion (Johnson, 2001). Sites within the western group are associated with sandy terraces near rivers that drain into the Gulf of Mexico. The eastern group is composed of sites that are closely associated with relict coastal ridge systems in peninsular Florida and eastern Georgia.

Striped newts have been characterized as "uncommon and enigmatic" (Christman and Means, 1992) and "poorly known" (Dodd, 1993a; Dodd and LaClaire, 1995), and until the 1990s little was known about the species' ecology. Most literature on striped newts is limited to the results of surveys (Dodd and LaClaire, 1995; Hipes and Jackson, 1996; Stevenson et al., 1998; Franz and Smith, 1999; Johnson and Dwyer, 2000) and to species accounts (Carr, 1940; Bishop, 1941, 1943; Mecham, 1967; Ashton and Ashton, 1988b; Carmichael and Williams, 1991; Christman and Means, 1992; Petranka, 1998; Dodd et al., in press). Johnson and Franz (1999) documented the occurrence of albinism in the species. Dodd and Charest (1988) and Dodd (1992) mentioned striped newts as part of the herpetofaunal community of a north Florida sand hills pond, and Dodd (1996) included striped newts in his survey of terrestrial habitat use by amphibians. Prior to my research, studies of striped newt feeding habits (Christman and Franz, 1973), natural history at a breeding pond (Dodd, 1993a), and orientation into and away from a breeding pond (Dodd and Cade, 1998) represented the only published works focusing specifically on striped newt life history. Dodd et al. (in press) and Petranka (1998) provided a summary of the biology of striped newts based mainly on the work of Dodd and coauthors, and Johnson (1999, 2001).

Loss of most of the native longleaf pine-wiregrass (*Pinus palustris-Aristida stricta*) ecosystem (Means, 1996a; Engstrom et al., 2001; Holliday, 2001), fire suppression, and the natural patchy distribution of upland habitats required by striped newts have resulted in fragmentation of striped newt populations. Striped newts have declined throughout their range since the species was first described by Sherman C. Bishop in 1941 (Dodd and LaClaire, 1995; Franz and Smith, 1999). In fact, striped newts apparently no longer occur at the type locality (Dedge Pond, Charlton Co.) on the Trail Ridge in southeastern Georgia (Dodd and LaClaire, 1995; S. Johnson, pers. obs.). A complex life history makes striped newts vulnerable to threats at breeding ponds (e.g., ditching, draining, and filling of temporary ponds) and within the surrounding uplands (e.g., fire suppression, various silviculture practices, and urban and agricultural development). Relative abundance of striped newts is low at most sites where the species persists (S. Johnson, pers. obs.; R. Means, pers. comm., 2001; D. Stevenson, pers. comm., 2001; and see Greenberg and Tanner, Chapter 10). Because of historical declines and low relative abundance at most locations, the striped newt is recognized as a rare species throughout its range (Christman and Means, 1992; Jensen, 1999; Cox and Kautz, 2000). Its biological status is under review by the U.S. Fish and Wildlife Service (L. LaClaire, pers. comm., 2002).

Taking into account the decline of the striped newt throughout its range, and that its biological status is under review by the U.S. Fish and Wildlife Service, it is essential that natural resource managers acquire knowledge of striped newt life history. Such information will be required in order to draft a recovery plan, which would be required by law if the species was federally listed. Knowledge of striped newt life history also will be of immediate use to natural resources managers and may help circumvent the need for federal protection of the species.

To provide recommendations for striped newt conservation and management, I used a multidisciplinary approach to study striped newt life history. The following is a synthesis of several research projects, which appear in detail in my dissertation (Johnson, 2001, 2002, 2003, in press). In addition to summarizing striped newt life history, conservation and management recommendations for the species are provided. Although the recommendations for management target striped newts specifically, they would certainly apply to the numerous other species of amphibians and reptiles that inhabit longleaf pine forests (Stout et al., 1988; Dodd, 1992; Guyer and Bailey, 1993; Johnson, 1999; see Means and Franz, Chapter 3; and Greenberg and Tanner, Chapter 10).

A key element to ensuring the long-term persistence of striped newts and myriad other amphibian species in the southeastern coastal plain is understanding the importance of habitat connectivity between wetland breeding sites and upland retreat sites. The life history of the striped newt provides strong support for the need to preserve native uplands surrounding wetland breeding sites as well as the wetlands themselves. Clearly, an amphibian conservation strategy that focuses exclusively on only one of these habitats will fail if the importance of upland-wetland connectivity is disregarded.

Data Sources

The life history summary and conservation recommendations included in this chapter are based on the results of my dissertation research (Johnson, 2001), surveys that R. B. Owen and I conducted for striped newts throughout their range, and observations of striped newts in the field and laboratory. I also draw from the findings of several herpetologists, especially the work of C. K. Dodd Jr. and his collaborators.

For my doctoral research, I used a multidisciplinary approach that included a fieldwork component, a laboratory experiment, and a molecular genetics study. I conducted a 2-year field study of striped newt life history at a breeding pond (One Shot Pond) during a relatively wet period. One Shot Pond is on the Katharine Ordway Preserve, located in north-central Florida in Putnam County (29°41'N, 82°00'W). Eisenberg and Franz (1995), LaClaire (1995), and Dodd (1996) provided descriptions of the Preserve and its habitats. I used a continuous drift fence with associated pitfall traps to monitor striped newt activity at One Shot Pond from October 1996 through September 1998 (Johnson, 2002). In addition to monitoring newts at the breeding pond, I used drift fences to trap newts at various distances from the pond in the surrounding uplands. Upland fences were placed at 100 m intervals up to 500 m from the pond (Johnson, 2003).

In a laboratory experiment, I tested the hypothesis that expression of alternative life history pathways in the striped newt (i.e., metamorphosis vs. paedomorphosis) is influenced by larval growth rate. To do this, I raised newt larvae individually in plastic containers and randomly assigned each of 10 newts a different food regime. I used four different food treatments in the experiment (Johnson, in press). Experiments on life history expression in salamanders have been conducted almost exclusively with species of mole salamanders (Semlitsch and Gibbons, 1985; Semlitsch, 1987; Harris et al., 1990; Licht, 1992; Whiteman, 1994), and therefore, my experiment with striped newts makes a significant contribution toward our understanding of the evolution and maintenance of this phenomenon in salamanders other than *Ambystoma*.

For the molecular genetics component, I analyzed mitochondrial DNA from newts that were collected at 10 locations throughout most of the striped newt's range. I analyzed a 593 base-pair fragment of the Cytochrome *b* gene for 86 samples (Johnson, 2001). Genetic data can be useful for conservation planning because they allow natural resource stewards to define the appropriate scale for management efforts. Detailed descriptions of the methods and statistical analyses I used for each of these projects can be found in Johnson (2001, 2002, 2003, in press).

Striped Newt Life History and Life History State Terminology

To better understand the rest of this chapter, it would help to have a basic understanding of striped newt life history and terminology describing the various life history stages. The life history stages are complex, and no published source adequately defines these stages as they relate to this species.

Throughout the life of an individual, both aquatic and terrestrial stages occur, and an individual may move several times between aquatic and terrestrial habitats (Figure 11.1). Reproduction occurs primarily in isolated, seasonally ponded wetlands that lack predaceous fishes because the ponds dry relatively often. Courtship and oviposition occur in the ponds and females lay eggs one at a time over a protracted period of several months. Eggs are often attached to aquatic vegetation. Eggs hatch into larvae that feed and grow in the pond.

Larvae - A larva is a sexually immature aquatic stage newt. Larvae have bushy external gills, a membranous tail fin, and a conspicuous lateral line, which is visible as a series of dorsolateral dashes on each side of the animal. Larvae do not posses the namesake lateral stripe and they do not have swollen vents. After a period of growth, but before sexual maturation, a larva may metamorphose and leave the pond as an immature eft (i.e., metamorphic pathway; Figure 11.1). On the other hand, a larva may remain in the pond, continue to grow, and mature while retaining the larval morphology (i.e., paedomorphic pathway; Figure 11.1).

Efts - An eft is a sexually immature terrestrial stage newt. Efts lack gills and do not have a tail fin or lateral line. Efts have conspicuous, dorsolateral stripes, which are reddish to orange. The stripes appear during metamorphosis. Because efts are immature they do not have swollen vents. After larvae metamorphose into efts, they disperse into the uplands surrounding the breeding pond (Figure 11.1). Efts mature in the uplands, at which point they are referred to as terrestrial adults.

Paedomorphs - A paedomorph is a sexually mature, aquatic stage newt. Paedomorphs are larger than immature larvae, have bushy external gills, a membranous tail fin, and a conspicuous lateral line. Paedomorphs do not usually possess the namesake stripes but they do have swollen vents. Paedomorphs reproduce in the breeding pond, then metamorphose and disperse into the surrounding uplands (Figure 11.1). Once a paedomorph transforms and leaves the pond it is referred to as a terrestrial adult. On rare occasions, a paedomorph may transform directly into an aquatic adult (i.e., dashed line in Figure 11.1).

Adults - An adult is a sexually mature terrestrial or aquatic stage newt. Adults lack gills and do not have a visible lateral line. Adults possess dorsolateral stripes and have swollen vents. They are sexually dimorphic, and males have a light colored gland that is visible at

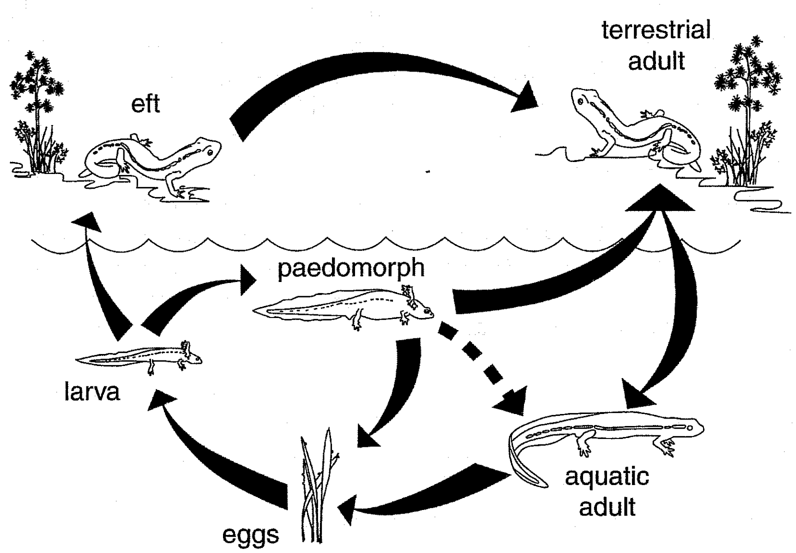

Figure 11.1 Life history schematic for the striped newt (*Notophthalmus perstriatus*). Life history stages include aquatic and terrestrial phases. During the life of an individual, it will move between aquatic and terrestrial habitats. Lines and arrows indicate direction of movement. The dashed line infers that this developmental path is possible, but uncommon.

the posterior end of the vent. Adults occur in the uplands around breeding ponds (i.e., terrestrial adults) as well as in the ponds (i.e., aquatic adults), and there is movement between these habitats during the life of an adult. Aquatic adults develop a membranous tail fin similar to the tail fin of larvae and paedomorphs. They do not regrow external gills, however. Terrestrial adults lack a tail fin. They differ from efts in that the vent of a terrestrial adult is swollen, whereas the vent of an eft is not swollen.

Striped Newt Life History

Based on life history data collected at ponds within the Katharine Ordway Preserve, monthly dipnet sampling of striped newts in several ponds, and observations on laboratory reared striped newts, it is apparent that striped newts have a complex life history. The life cycle of an individual includes terrestrial and aquatic stages (Figure 11.1).

Breeding occurs exclusively in fishless ponds that are small and have variable hydroperiods (hydroperiod is the number of days a pond holds water between periods when it is dry). Based on observations of captive striped newts, courtship is similar to that described for the red-spotted newt (*Notophthalmus viridescens*) (Pope, 1924; Duellman and Trueb, 1986; Petranka, 1998). After internal egg fertilization, striped newt females lay eggs one at a time and attach them to aquatic vegetation or some object, such as a decaying leaf, in the breeding pond. Eggs are laid singly or in small clusters. The egg-laying period is protracted, and a single female may lay eggs for several months during a breeding season. In general, reproduction occurs during the "winter" half of a year. I observed mature newts in One Shot Pond from October through June. Eggs hatch into small, nonfeeding larvae. Once they reach the feeding stage, small larvae readily consume zooplankton, at least in captivity. When they have attained the minimum size required for metamorphosis (ca. 18 to 20 mm SVL), larvae may take one of two developmental pathways. An individual may undergo metamorphosis and exit the pond as an immature eft, or it may remain in the pond and grow, eventually maturing as a paedomorph (Figure 11.1).

Hydroperiod has a major impact on success of reproductive effort and life history pathway expression. If pond hydroperiod is too short, larvae will not have enough time to reach the minimum size needed to initiate metamorphosis and will perish when the pond dries. A minimum hydroperiod of 139 days was required for larvae to reach metamorphosis at one breeding pond (Dodd, 1993a). At One Shot Pond, larvae appeared to metamorphose into efts after a developmental period of about 6 months. For a larva to mature as a paedomorph, a breeding pond must hold water for at least a year. For a paedomorphic individual to successfully reproduce the pond must hold water for at least 6 more months to allow its offspring time to initiate metamorphosis.

Immature larvae transform into efts at a wide range of body sizes, indicating that in many individuals, growth continues after they reach the minimum size required to initiate metamorphosis. Immature newts transformed and dispersed from One Shot Pond during all months except January and February. Efts dispersed far into the uplands around One Shot Pond. Based on captures at upland drift fences, I estimated that 16% of the individuals of a single breeding event dispersed more than 500 m from the pond. Efts mature in the uplands and when conditions are appropriate (e.g., adequate rainfall) they return to the pond to reproduce.

An alternative to the metamorphic life history pathway, which results when a larvae transforms into an immature eft, is the paedomorphic life history pathway. I estimated that about 25% of striped newt larvae of several cohorts expressed the paedomorphic life history pathway in One Shot Pond. Paedomorphosis appears to be common and has been observed at many ponds throughout the range of the species (S. Johnson, pers. obs.; R. Means, pers. comm., 2001; D. Stevenson, pers. comm., 2001). Paedomorphs postpone metamorphosis until after they have matured and reproduced. Paedomorphs reproduce at about one year old, then metamorphose and migrate into the uplands around the pond. Transformation of aquatic paedomorphs into the terrestrial adult stage occurs even if the breeding pond holds substantial water. The life history pathway "decision" of an individual appears to be controlled by expression of genes that may be influenced by environmental factors.

Once a paedomorph has transformed and left the pond it is referred to as a terrestrial adult. While in the uplands, efts also mature into terrestrial adults. Under appropriate environmental conditions (e.g., adequate rainfall), terrestrial adults move back to breeding ponds to court and reproduce. Once they enter the pond they are referred to as aquatic adults. Male and female aquatic adults develop a membranous tail fin and flanges that extend slightly from their rear limbs. The flanges and the tail fin become more developed in male aquatic adults than in females. Males also develop cornifications on their toe tips as well as nuptial excrescences on the rear legs. I captured adults immigrating to One Shot Pond during all months except August and September. Within a year, there was a bimodal distribution of adult immigration. Distinct periods of movements of adults into One Shot Pond occurred in the spring/summer months and again during the fall/winter months. After reproduction, adults emigrated from the pond back into the surrounding uplands even when the pond held water.

In summary, striped newts move between terrestrial and aquatic habitats numerous times during their life. Breeding (i.e., courtship and oviposition) occurs in the pond over a protracted period, primarily during the fall and winter, but some newts immigrate to breed during spring and summer. The timing of migration to the breeding pond is influenced by rainfall. However, the absolute amount of rainfall is a poor predictor of the magnitude of a breeding migration. Eggs are laid in the water and develop into larvae. Once a larva reaches the minimum size for metamorphosis, it may remain in the pond and continue to grow, or metamorphose into an immature terrestrial stage—the eft stage. Efts migrate into the uplands where they mature into terrestrial adults. Some larvae postpone metamorphosis, mature in the pond while maintaining the larval morphology, and then reproduce—this is the paedomorph stage. Once reproduction is complete, paedomorphs transform and migrate into the surrounding uplands, at which point they are termed terrestrial adults. Terrestrial adults partition their lives between aquatic breeding habitats and upland retreat sites.

Metapopulation Structure and the Importance of Wetland-Upland Connectivity

Striped newts have a biphasic life history and spend portions of their lives in both aquatic and upland habitats. Based on mark-recapture studies at the Ordway Preserve and analysis of mitochondrial DNA sequences from samples throughout the range of the species, I propose that striped newts form metapopulations (Hanski and Simberloff, 1997). I suggest that within a metapopulation ponds function as focal points for demes (i.e., local breeding populations) and that demes experience periods of extirpation and recolonization through time. A pond may act as a source at one point and a sink at another. A pond at which newts arrive to breed but where they are unsuccessful because of a short hydroperiod or high predation level could act as a sink. Over time, a specific deme of newts may decline (Dodd, 1993a), and possibly become extinct. Recolonization of a deme within a metapopulation is possible by dispersal through contiguous upland habitat. Direct evidence of this was shown by mark-recapture of striped newts at the Katharine Ordway Preserve. A newt that was marked leaving One Shot Pond in November 1996 was recaptured in February 1998 as it colonized neighboring Fox Pond, a dispersal distance of ca. 685 m (Johnson, 2001, 2003, in press). Prior to the capture of several striped newts immigrating to Fox Pond during the winter of 1997/98 (Johnson, 1999), the species had not been documented at the pond despite repeated sampling during the previous decade (R. Franz, pers. comm., 2000).

Striped newts presently persist in isolated fragments (i.e., metapopulations) of the longleaf pine-wiregrass ecosystem. Because of the current patchy distribution of localities where striped newts persist, as a result of anthropogenic and natural causes, remaining striped newt populations are effectively isolated. Cytochrome *b* sequence data from samples collected throughout the range of striped newts show that contemporary gene flow between habitat fragments is severely restricted. On a local scale, gene flow occurs among some breeding ponds. Taken together these data suggest that striped newts form metapopulations and that the long-term survival of the species may depend on preserving existing metapopulations.

Maintaining the connectivity between upland retreat sites and wetland breeding sites is crucial for metapopulations to function. I believe that long-term persistence of the species is most probable in areas where metapopulations exist. Few such areas remain and presently striped newts persist at only a few "stronghold" locations (areas where, according to recent surveys, newts are known to occur) throughout the range of the species. Stronghold locations have multiple breeding ponds with appropriate upland habitat that allows dispersal to occur among the ponds. In Florida, these include Apalachicola National Forest, Ocala National Forest, Jennings State Forest, Katharine Ordway Preserve, and Camp Blanding Training Site (Franz and Smith, 1999; S. Johnson, unpubl. data; see Means and Means, Chapter 7; and Greenberg and Tanner, Chapter, 10). In Georgia, "strongholds" appear to be limited to the Joseph Jones Ecological Research Center property and Fort Stewart Military Instillation (Stevenson, 2000). Metapopulations likely persist at all of these sites and they hold the most promise for the long-term preservation of the striped newt. For metapopulations to function, habitat connectivity must be maintained between uplands and wetlands. This is crucial for striped newts as well as many other amphibian species in the Southeast (Semlitsch and Bodie, 1998; Semlitsch, 2000b).

Conservation, Management, and Research Prospectus for Striped Newts

Current knowledge of striped newt life history, status and distribution, and population genetic structure can be used to make recommendations for the conservation and management of the species. In general, presence of newts at a location (Dodd and LaClaire, 1995; Franz and Smith, 1999) might suggest that land managers are managing the habitat effectively. Nevertheless, present management practices may not ensure the long-term persistence of newts where they are currently found. Land managers should consider the following recommendations carefully. Some of the suggestions are not novel; for example, see recommendations in Christman and Means (1992), Dodd (1993a), Dodd and LaClaire (1995), and Franz and Smith (1999). The recommendations that follow are based on the results of my studies, or they reinforce ideas previously presented. Managing upland habitats to reestablish historical ecosystem function is the most effective approach for achieving the conservation of striped newts. Such an approach will rely on a prescribed burn program. Managing upland and pond habitats as a unified landscape (i.e., preserving habitat connectivity) should prove an effective conservation strategy. Protecting and managing small, seasonally ponded wetlands where striped newts breed, as well as the adjacent uplands, also will enhance populations of the numerous other species that rely on these habitats (Moler and Franz, 1987; Dodd and Charest, 1988; Dodd, 1992; Guyer and Bailey, 1993; Johnson, 1999). Semlitsch (2000b) presented an excellent template for land managers concerned with aquatic breeding amphibians. My recommendations lend support for his protocols. The order in which the following recommendations are listed does not imply any hierarchy of importance. Suggestions for additional research on striped newts follow most recommendations.

Manage Striped Newt Metapopulations as Independent Demographic Units - Remaining metapopulations in both Florida and Georgia are confined to isolated areas because of the natural patchy distribution of appropriate upland habitats, as well as habitat loss and degradation caused by anthropogenic factors. Genetic data show strong partitioning of striped newt metapopulations, and there is essentially no contemporary gene flow among metapopulations. These data imply that if a local extinction of a metapopulation occurs, it will not be recolonized naturally from other metapopulations on a contemporary time scale. Based on analysis of mitochondrial DNA sequences, the locations I sampled meet the requirements of Management Units (Moritz, 1994a, b).

Although samples were analyzed from throughout the range of the striped newt, one region of interest in Georgia was not sampled. Consequently, the genetic affinities of striped newts that persist in apparent isolation within the Tifton Uplands in Irwin County (Dodd and LaClaire, 1995) are unknown. Based on the biogeographic scenario proposed by Dodd and LaClaire (1995), these newts are probably allied with the western phylogroup. Tissue samples of newts from this location should be analyzed to determine the genetic relationship of newts in this area.

Protect Small, Isolated Wetlands Where Striped Newts Are Known to Occur or May Potentially Occur - Striped newts breed exclusively in ponds that are devoid of predatory fishes. Such ponds are isolated and usually dry frequently; they are often less than 1 ha in extent (Means et al., 1994a; LaClaire, 1995). Small, isolated wetlands receive little protection at local or federal levels (Kirkman et al., 1999; Semlitsch, 2000b). If striped newts are to be conserved, small, isolated wetlands must be afforded protection. Furthermore, as initially suggested by Christman and Means (1992), stocking of fish in known or suspected breeding ponds should never be allowed. Natural hydroperiods of breeding ponds must be maintained, and indirect effects on pond hydroperiods, such as groundwater removal (Means and Franz, Chapter 3), must be considered in management planning.

Research on striped newt breeding ponds is needed. Dodd and LaClaire (1995) reported biotic and abiotic characteristics of striped newt ponds in Georgia, and LaClaire (1995) presented vegetative and soil characteristics of dry pond basins for several known newt ponds in Florida. Hydroperiods of striped newt breeding ponds vary considerably (S. Johnson, pers. obs.; R. Means, pers. comm., 2001; Greenberg and Tanner, Chapter 10). A very short hydroperiod will preclude or negate reproduction, but a long hydroperiod may result in colonization by predatory fishes (Semlitsch, 2000b). The window of hydroperiod lengths that allows local persistence of striped newts is unknown and needs to be established. Such data would be useful to identify potential breeding sites. In addition, wildlife managers need to know which microhabitat features of a breeding pond affect metamorphosis of striped newt larvae (e.g., types of predators, density of larvae, food availability). In captivity, larval striped newts eat zooplankton, but the diet of larvae in natural ponds is unknown. Knowledge of food requirements of larvae could help identify potential breeding ponds.

Initiate or Continue Prescribed Burn Programs in Upland Sites Near Striped Newt Breeding Ponds - Although there has never been an empirical test of the effect of fire suppression on striped newts, surveys conducted by several researchers have suggested that local extinction has occurred at sites where fire has been suppressed (Franz and Smith, 1999; R.

Means, pers. comm., 2001; S. Johnson, unpubl. data). However, fire suppression at some of these sites has been concurrent with conversion of uplands to pine plantations, so interpreting the direct impact of fire suppression is confounded by silviculture. Fire probably plays a crucial role in maintaining productive breeding ponds for striped newts and other pond-breeding amphibians in the southeastern coastal plain (Kirkman et al., 1999). Periodic burning of dry pond basins may be necessary to maintain the quality of breeding ponds. Fires, as evidenced by charring on the stems of shrubs and trees, frequently occur within the basins of many striped newt breeding ponds. Land management practices that discourage fire in small, isolated wetlands should be abandoned. Studies of the influence of prescribed fire in breeding ponds are crucial to effective conservation planning for striped newts and other pond-breeding amphibians.

Although regular burning of upland habitat may be essential for the persistence of striped newts, the optimal frequency of prescribed fire is unknown, as is the most appropriate season(s) to burn and the optimal fire intensity. It would be valuable to analyze prescribed burn records from locations that support the highest densities of striped newts, such as the Katharine Ordway Preserve and Ocala National Forest, to determine if there is any correlation between burning regime and striped newt relative abundance at breeding ponds. Experiments that manipulate fire frequency, intensity, and burn season would prove informative for managing striped newts, but will be difficult to undertake because of sample size considerations. Research needs to address the fundamental issue of why striped newts appear to persist only at sites that burn regularly. Research should also determine the direct impact of fire suppression in the absence of confounding factors, especially silviculture.

Preserve Core Areas and Buffer Zones of Protected Upland Habitat Around Breeding Ponds - Striped newts spend most of their lives in upland habitats. A large percentage of striped newts at One Shot Pond, located in a sandhill longleaf pine habitat, dispersed hundreds of meters and many newts (an estimated 16% of the breeding population) exceeded 500 m (Johnson, 2001). Striped newts have been found as far as 709 m from the closest breeding pond (Dodd, 1996). Protecting adequate upland habitat is crucial for persistence of striped newts. Core areas and their associated buffer zones should be as large as possible, but managers should strive to preserve upland sandhill habitat that extends at least 1000 m from the pond edge. Data from One Shot Pond show that protected areas of this amount of habitat will encompass most of the newts that use the pond. Dispersal distances of striped newts in other upland habitat types (e.g., scrub) and at other breeding ponds needs to be studied. In any case, the extent of upland used by striped newts appears to be much greater than that used by pond-breeding salamanders of the genus *Ambystoma* (Semlitsch, 1998). Therefore, extrapolating data across amphibian genera or species may not be justified.

Avoid Mechanical Disturbance of Native Vegetation in Upland Habitats, Especially Near Breeding Ponds - Silvicultural practices that disturb the herbaceous ground layer and disrupt the soil (e.g., extensive mechanical site preparation) should be avoided because they appear to lead to local extirpation of striped newts (Dodd and LaClaire, 1995). Protecting the ground cover and subsurface soil structure in established core areas and buffer zones is crucial for the persistence of striped newt populations.

Maintain Corridors of Managed Habitat at Sites Where There are Striped Newt Breeding Ponds - Genetic and field data demonstrated that striped newts disperse among breeding ponds. One individual captured as an eft dispersing from One Shot Pond was later captured at a neighboring pond (Fox Pond). The genetic data from the Katharine Ordway Preserve indicate that newts disperse between ponds often enough to homogenize the metapopulation at mitochondrial loci. Throughout their range, striped newts appear to persist mainly at locations where multiple breeding ponds have been identified. In concert with dispersal records from One Shot Pond and genetic data, this supports the hypothesis that striped newts occur in metapopulations and likely require a functional metapopulation for long-term persistence. Maintaining connectivity among ponds via upland habitat will facilitate metapopulation function and provide a buffer against local extirpation. Where connectivity among ponds is maintained with habitat corridors, it is important to determine if newts will use the corridors and what corridor characteristics influence newt dispersal among breeding ponds.

Surveys Should Be Conducted to Locate Additional Striped Newt Populations - Striped newts have declined throughout their range during the last few decades. Therefore, all remaining populations are vital to the long-term persistence of the species. Striped newts may persist in some areas and have not been detected because of low population density or lack of survey effort. Given the imperiled status of the species, it is important to identify all remaining sites that support striped newts so that they can be managed properly. Sites found on private land should be purchased or protected through a conservation easement. Permission to manage the property for striped newts should be guaranteed. Based on a habitat model, the Florida Fish and Wildlife Conservation Commission identified areas that should contain suitable habitat and could serve as target areas for future surveys (Cox and Kautz, 2000). Dodd and LaClaire (1995) identified areas in Georgia that should be surveyed.

Striped Newts Should Be Regularly Monitored at Sites Where They Occur - Regularly monitoring striped newts will enable biologists to determine natural levels of population fluctuation and possibly identify the cause(s) if a decline or local extinction occurs. With this information, declines might be mitigated or prevented at other sites. It is crucial to understand population dynamics so that natural fluctuation can be recognized as distinct from declines caused by human impacts (Pechmann et al., 1991).

Conclusion

Striped newts have a complex life cycle that includes aquatic and terrestrial phases. As a result of this biphasic life history, striped newts are vulnerable to threats at breeding ponds and in the surrounding uplands. Although reproduction and larval growth occur in isolated, ephemeral wetlands, striped newts spend much of their lives in xeric upland habitats. They migrate hundreds of meters from their natal pond and occasionally disperse to a non-natal pond to breed. Striped newts have declined throughout their range and apparently persist at fewer than a dozen metapopulation sites that are isolated from each other. For metapopulations to function there must be connectivity among breeding ponds and their associated uplands. An effective conservation strategy for striped newts requires a landscape approach. Large tracts of upland habitats containing multiple breeding ponds of varying hydroperiods must be preserved. These areas should be managed to facilitate natural ecosystem processes—fire in the landscape is crucial.

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