A Preliminary Consideration of Highway Impacts on Herpetofauna Inhabiting Small Isolated Wetlands in the Southeastern U. S. Coastal Plain

By:

D. Bruce Means, Ph.D.
President and Executive Director
Coastal Plains Institute and Land Conservancy
1313 N. Duval Street, Tallahassee, FL 32303

A PRELIMINARY CONSIDERATION OF HIGHWAY IMPACTS ON HERPETOFAUNA INHABITING SMALL ISOLATED WETLANDS IN THE SOUTHEASTERN U. S. COASTAL PLAIN

by

D. Bruce Means, Ph.D.
President and Executive Director
Coastal Plains Institute and Land Conservancy
1313 N. Duval Street, Tallahassee, Fl 32303
904-681-6208 pho; 904-681-6123 fax
e-mail: dbm5647@garnet.acns.fsu.edu

Few people would be surprised to learn that, in terms of the number of species of plants and animals, the Southeastern U. S. supports some of the highest biotic diversity in the United States and Canada (Kartesz 1992). On the other hand, most biologists are unaware that over the entire U. S. and Canada, one part of the Southeastern U. S.--the Coastal Plain--is home to the greatest number of trees (Little 1978), the highest species densities of snakes, turtles, and frogs (Kiester 1971, Iverson and Etchburger 1989), and is second only to the southern Appalachian region in number of species of salamanders (Conant and Collins 1991). The Southeastern U. S. Coastal Plain is a distinct geological and biological province of eastern North America composed entirely of sedimentary rocks (thick limestones overlain by shallow terrigenous clastics--silts, sands, clays, and gravels). It is a continent-skirting belt of land of varying width up to about 200 miles, ranging from the Pine Barrens of New Jersey to east Texas, and including all of Florida.

Because most U.S. salamanders and frogs have a complex life cycle involving aquatic larval and terrestrial life stages (Wilbur 1980), and many turtles are aquatic all their lives, the high species richness of salamanders, frogs, and turtles in the low-elevation Coastal Plain is at least partly related to the abundance there of suitable wetlands and aquatic habitats in which to live and breed. Ironically, although the importance to wildlife of the wetlands associated with lakes, rivers, swamps, and streams in the Coastal Plain has long been known and written about (Harris 1984, Means 1991), one category of wetlands that may be more important than all the others has gone unrecognized and unstudied until recently (Moler and Franz 1987, Means 1990, Dodd 1992, Dodd 1993, Burke and Gibbons 1995, and references contained in these papers). These are the small isolated wetlands variously called temporary or ephemeral ponds. In north temperate climates they are also called vernal ponds because they contain water briefly after snowmelt and are used by frogs and salamanders during springtime breeding (see paper by Scott Jackson, this volume). In the warm temperate climate of the Southeastern U.S. Coastal Plain, however, these ponds often maintain water sporadically throughout the year and breeding by different species may take place year-round. In fact, each pond is usually home to a unique suite of winter-breeding and summer-breeding species of frogs and salamanders. "Vernal" is a highly restricted term, therefore, and will not be used here.

Temporary ponds are common in parts of the Coastal Plain especially where limestone lies at or close to ground surface such as in the upper two-thirds of peninsular Florida and adjacent eastern panhandle Florida (Wolfe et al. 1988) or in the case of the Carolina Bays of North and South Carolina. By definition, temporary ponds are water bodies that don't always have water in them, but the hydroperiod of temporary ponds can be highly erratic ranging from those that hold water only a few months in five years (Dodd 1993) to those that hold water for five or more years without drying (personal observation). The species of amphibians and reptiles utilizing temporary ponds are different from those that use permanent ponds and lakes probably partly because animals using temporary ponds must be specially adapted to survive the erratic hydroperiods. Another determinant of which species use temporary or permanent ponds is the presence or absence of predatory fish; larvae of salamanders and frogs are vulnerable to fish predation.

Because of the ephemeral presence of water in temporary ponds, vertebrates that utilize such ponds migrate into the adjacent uplands and survive there during varying periods of time until water returns to the pond or live in the uplands until specific times in their life cycles when they must return to water to breed. The environmental quality of adjacent uplands, therefore, is very important in the local survival of temporary pond populations. For vertebrate species that are dependent upon temporary ponds, the quality of native upland habitats adjacent to temporary ponds is just as important as the quality of the pond environment, itself. Adjacent upland habitats that have been altered by human activities into agricultural fields, pastures, densely planted silvicultural stands, asphalt parking lots, or suburban lawns may not be suitable for the long-term maintenance of viable populations of salamanders, frogs, turtles, and other vertebrates that utilize temporary ponds. A buffer zone of native habitat surrounding temporary ponds is crucial, therefore, to the survival of temporary pond fauna (Burke and Gibbons 1995).

One large problem facing animals inhabiting temporary ponds is the presence in the upland buffer zone of roads and highways. These often impose on populations additional and heavy mortality involving direct road-kills by automobiles, desiccation of small, moist-bodied animals on dry and sometimes hot asphalt and concrete, and increased exposure of small animals to aerial predation. Some other effects of roads on small species are habitat fragmentation and unwillingness on behalf of the animals to move across broad expanses of hostile habitat.

In 1967 I began a 30-year long period of observations on the herpetofauna that utilizes several small temporary ponds (with maximum areas from 0.1 - 3.0 ha) in Leon County, Florida, on property of the Apalachicola National Forest. One pond (hereafter called Study Pond 1) is particularly relevant to this symposium because it lies in a limesink depression immediately adjacent to U. S. Highway 319 about 4.0 km south of the city limits of Tallahassee. Through 1992 my observations were sporadic and limited to generating data on the presence in the ponds of breeding adults, eggs, larvae, and neotenes of the striped newt, *Notophthalmus perstriatus*, recently considered a C2 candidate for federal listing.

In the spring of 1992, more intensive studies of the entire fauna using these temporary ponds were initiated in conjunction with a survey of the use by vertebrates of approximately 150 temporary ponds within a 10-km radius of Study Pond 1 (Means et al. 1994a, b). In September 1995 we constructed a 300-m drift fence with 66 five-gallon drop buckets entirely around Study Pond 1 to monitor all the vertebrates moving in and out of it. Table 1 lists 45 species of amphibians and reptiles known to utilize temporary ponds in the Southeastern U. S. Coastal Plain, including 27 species so far determined to utilize Study Pond 1. The results of this multifaceted and long-term research project are still coming in, but some tentative conclusions can be made about potential impacts of U. S. Highway 319 on the vertebrate fauna of Study Pond 1.

Four species of salamanders breed in Study Pond 1, including the rare striped newt (Christman and Means 1992) which has one of the most complex life cycles of any amphibian. Sexually mature adults migrate from the surrounding uplands to the pond for breeding purposes in mid-winter, November-February. Courtship, copulation, and oviposition take place, presumably, January-April and eggs hatch beginning about mid-April. Externally gilled larvae grow in the temporary pond environment for several months until the pond dries in midsummer. We have evidence that small larvae can metamorphose at least by three months of age, at which time they lose their external gills, develop lungs for air-breathing, and become a relatively dry-skinned animal called an eft. The eft stage is adapted for life in the longleaf pine/wiregrass forest of the adjacent hot and dry sandhills.

After life as an eft, individuals undergo a second metamorphosis when they return to the pond to breed. There they develop fins on their tail and hind limbs to assist in swimming and courtship and take up a life in the water again, but this time they must come to the water's surface to gulp air into their lungs. The life cycle is completed when they court and produce viable eggs. This is not the complete life story, however. In times when Study Pond 1 has retained water all year, the larvae bypass the eft stage and remain in the pond until the next breeding season when some individuals become sexually mature--as gilled larvae. Retention of larval characteristics when sexually mature in salamanders is known as neoteny. The neotenes, as they are called, complete the life cycle without ever leaving the pond. It is assumed that the post-breeding neotenes and post-breeding lunged adults return to the uplands again to live through additional breeding cycles, but is not known whether they metamorphose back into the eft morphology again. The striped newt has survived in captivity for 12-15 years (Grogan and Bystrak 1973). A young striped newt runs the gauntlet of potential highway mortality three times as it grows to sexual maturity: once when it migrates into the uplands as an eft; a second time when it returns to the pond to breed; and a third time when it exits the pond for another bout of terrestrial life.

Study Pond 1 is very important in the global survival of the striped newt. It is one of less than 32 known breeding ponds in the entire geographic range of the species (Franz and Smith 1994). About 10 breeding ponds--one-third of the known total--occur within a 5-km radius of Study Pond 1, representing what we believe is three or four metapopulations. There is evidence that dispersal away from a breeding pond can take place over at least 0.5 km. A road construction borrow pit 1.5 km SW of Study Pond 1 and also adjacent to U. S. Highway 319 supports a breeding population of the striped newt. This artificial borrow pit pond is about 0.5 km SE of the closest natural striped newt breeding pond.

In its first seven months of operation (09/08/95-04/07/96), the drift fence surrounding Study Pond 1 produced 116 captures of out-migrating metamorphs of the striped newt, and 392 and 4,531, respectively, of the common newt and the mole salamander. Over the same time period 41 striped newts (35%), 51 common newts (13%), and only 256 mole salamanders (6%) returned to the pond, but about one-half of these returning individuals of all three species were juveniles that were captured more than once as they dispersed. Only the other half were sexually mature adults returning to the pond to breed. These data reflect the intense mortality experienced by these species between the time they migrate into the uplands and when they return to breed. Road-kill mortality would seem to have the most influential impact on populations of all three species, therefore, during the time when sexually mature adults migrate back to the pond to breed.

We are impressed with the contribution of biomass of the mole salamander to the adjacent upland ecosystem. As an adult it is several times more massive than the two species of newts. The mole salamander must play a very important role in the upland vertebrate food web.

An amazingly large number of frogs--15 species--live and breed in Study Pond 1. Four of these species (*Rana utricularia, R. catesbeiana, Hyla cinerea, Acris gryllus*) live at the pond's edge or in shrubs growing in the pond as adults, but all the rest take up a terrestrial life away from the pond after metamorphosis. Even the four, however, must be capable of dispersing away from the pond when it dries. Study Pond 1 is especially important to the gopher frog, *Rana capito*, a rare species (Franz and Smith 1994) that was a C2 candidate until Congress put a ban on federal listing recently.

Like the striped newt, the gopher frog is also a long-lived animal (5-10 years) but has a broader geographic distribution than the striped newt in the Atlantic and Gulf coastal plains. It has a complex amphibian life cycle involving a tadpole larval stage in temporary breeding ponds and a terrestrial stage as a frog in the dry upland habitats of sandhills. Its upland habitat preferences are reasonably well known as longleaf pine/wiregrass/turkey oak forest (Godley 1992). It utilizes burrows of the gopher tortoise for daytime retreat from predators and desiccation, and also other animal burrows and stumpholes (Means 1996c).

The gopher frog breeds in temporary ponds when these fill with heavy rains in winter, December-March. Tadpoles are found in ponds through late spring when they metamorphose and disperse from ponds in May and June. Individuals are capable of moving over relatively long distances because marked gopher frogs were recovered up to two kilometers away from breeding ponds in north central Florida (Franz et al. 1988), but nothing is known about breeding site fidelity in this species. Habitat quality and fragmentation, and impacts from roads all potentially affect successful dispersal in this species because of the long distances involved.

To date five species of aquatic turtles have been recorded utilizing Study Pond 1 (Table 1). These all migrate out from the pond during nesting season when the females of each species must lay eggs in the terrestrial environment. Later, hatchlings must make their way overland to the pond. Additionally, when the pond dries, all these species migrate through the adjacent uplands looking for water.

The ensemble of vertebrate species in Study Pond 1 is rather typical of temporary ponds in the sand hills of the Coastal Plain. Another group of frogs and salamanders (*Ambystoma cingulatum, A. mabeei, A. texanum*) utilizes temporary ponds in flatwoods, often in accompaniment with many of the same species of frogs and turtles in sand hills. Throughout the Coastal Plain the critical upland habitats of the temporary pond-inhabiting vertebrates have been severely diminished by logging, agriculture, silviculture, and urbanization (Means 1996a,b), so that many species of temporary pond breeders have become threatened species because their upland habitats are destroyed. Now, every additional impact to the adjacent uplands--and any direct impacts on temporary ponds--are having an increasingly devastating toll on the large suite of vertebrate animals that are dependent upon temporary ponds. It in imperative that biologists be aware of the impacts of road construction on animals using temporary ponds in the Coastal Plain. The time has arrived when building and improving our nation's highways and roads that these animals and their critical breeding ponds--as well as their adjacent upland habitats--are carefully taken into consideration in the construction design.

Five or more years in advance of the need to expand U. S. 319 into a four-lane highway there exists a great opportunity for gathering the basic knowledge necessary in designing remedies for future impacts on the striped newt, gopher frog, and all the other salamanders, frogs, and turtles that inhabit Study Pond 1 and other ponds along the right-of-way. The following are some of the important studies that I and my coworkers presently are seeking funds for.

Project 1. Continue monitoring the population status of the wildlife using Study Pond 1 by means of the drift fence and dipnetting regimen presently in operation. At least two more years are required to characterize the life history phenology and important parts of the life cycle of all the species, for instance: the season of oviposition; season of development of eggs; season of hatching; length of larval life; brevity of larval life in the event of spring drought; season of metamorphosis; season of return of adults to breeding pond to mate; length of time required for development of neoteny if the pond remains wet. In the case of the striped newt, monitoring is required to answer important questions such as, do neotenes mate with returning sexually mature adults or is the season of neotenic maturity different from that of returning terrestrial animals? And do terrestrial adults that have mated metamorphose again into efts and return to the uplands? After the life history study is completed, a monthly or quarterly monitoring program should be conducted in Study Pond 1 until the time that US 319 is slated to be improved in order to be cognizant of the population status of the two species at construction time.

Project 2. A study of dispersal of individual newts and gopher frogs moving away from the breeding pond into the adjacent uplands. The cheapest and most effective way to do this is to erect drift fences with drop buckets at incremental distances away from the ponds and check them regularly. Frogs and newts leaving the pond should be marked for later identification. The study should include two breeding ponds close together so that possible colonization of each pond by newts born in the other pond could be tested. This should be done at Study Pond 1 as well as with another set of ponds elsewhere and not near a major highway.

Project 3. Run experiments during out-migration periods of metamorphosing newts, gopher frogs, and the entire pond fauna to determine if they will migrate through culverts of different sizes, design, and internal substrates. This will help evaluate the efficacy of amphibian underpass culverts as a mechanism aiding dispersal away from breeding ponds and avoiding excessive road-kill mortality.

Project 4. Conduct a genetic study (electrophoresis, mitochondrial DNA, etc.) of newts and gopher frogs to determine the genetic status of breeding populations. This study will examine the genetic variability and allellic differences among local breeding populations to determine if gene exchange is occurring.

Project 5. Study whether competition among the striped newt and the common newt exists. From my observations of the population levels of each species in different ponds over the years it seems plausible that a long series of wet years favors the common newt. It is entirely possible that competition among the two species, over a sufficiently long period of time, might result in the local extirpation of the striped newt. Experimental research with different densities of the common newt in the presence of the striped newt are appropriate. Newt densities will be manipulated in experimental enclosures in breeding ponds and in laboratory aquaria.

Project 6. Experiment by digging shallow pits with different hydroperiods to determine if stormwater runoff retention ponds might serve a useful role in providing breeding ponds for the temporary pond biota.

Project 7. Monitor hydroperiod in all the known ponds in which breed the striped newt and gopher frog and compare with an equal number of ponds not having these species. It is vitally important that we learn what physical environmental characteristics make up the critical breeding habitat of these species.

It is particularly appealing that with a lead time of 5-7 years or more until the four-laning of U. S. 319 is imminent, ample opportunity exists for interagency cooperation and involvement in the researches I propose so that the appropriate environmental issues will have been addressed far in advance of road design and construction. I look forward to making progress reports on this research in the years ahead.

LITERATURE CITED

Burke, V. J. and J. W. Gibbons. 1995. Terrestrial buffer zones and wetland conservation: A case study of freshwater turtles in a Carolina Bay. Conservation Biology 9(6):1365-1369.

Christman, S. P. and D. B. Means. 1992. Rare Striped Newt. Pages 62-65 *in* Paul E. Moler, ed. Rare and endangered biota of Florida. Volume III. Amphibians and Reptiles. University Presses of Florida, Gainesville.

Conant, R. and J. T. Collins. 1991. A field guide to reptiles and amphibians, eastern and central North America. 3rd. ed. Houghton Mifflin Co., Boston.

Dodd, C. K., Jr. 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. Biodiversity and Conservation 1:125-142.

Dodd, C. K., Jr. 1993. The cost of living in an unpredictable environment: the ecology of striped newts *Notophthalmus perstriatus* during a prolonged drought. Copeia 1993(3):605-614.

Franz, Richard, C. Kenneth Dodd, Jr., and C. Jones. 1988. Life history notes: *Rana areolata aesopus* (Florida gopher frog). Movement. Herpetol. Rev. 19:33.

Franz, Richard and Lora L. Smith. 1994. Distribution and status of the striped newt and Florida gopher frog in peninsular Florida. Final Report of Project NG90-035 submitted to the Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program.

Godley, J. S. 1992. Threatened gopher frog. Pages 15-19 *in* Paul E. Moler, ed. Rare and endangered biota of Florida. Volume III. Amphibians and Reptiles. University Presses of Florida, Gainesville.

Grogan, W. L., Jr. and D. Bystrak. 1973. Longevity and size records for the newts *Notophthalmus perstriatus* and *Notophthalmus v. viridescens*. Hiss News-Journal 1(2):54.

Harris, L. D. 1984. Bottomland hardwoods: Valuable, vanishing, vulnerable. Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Iverson, J. B. and C. R. Etchburger. 1989. The distributions of the turtles of Florida. Florida Scientist, Biological Sciences 52(2):119-144.

Kartesz, J. T. 1992. Preliminary counts for native vascular plant species of U. S. states and Canadian Provinces. Biodiversity Network News 5(3):6. The Nature Conservancy.

Kiester, A. R. 1971. Species density of North American amphibians and reptiles. Systematic Zoology 20:127-137.

Little, E. L., Jr. 1978. Atlas of United States trees, Vol. 5. Florida. United States Department of Agriculture Forest Service Miscellaneous Publication No. 1361.

Means, D. B. 1990. Temporary ponds. Florida Wildlife 44(6):12-16.

Means, D. B. 1991. River bottomlands. Florida Wildlife 45(1):11-16.

Means, D. B. 1996a. Chapter 15. Longleaf pine forest, going, going.... Pages 210--229 *in* M. B. Davis, ed. Eastern old-growth forest: Prospects for rediscovery and recovery. Island Press, Washington, D. C.

Means, D. B., J. G. Palis, and M. Baggett. 1996b. Effects of slash pine silviculture on a Florida population of flatwoods salamander. Conservation Biology 10(2):1-13.

Means, D. B. 1996c. The importance of tree bases to wildlife. (In preparation.)

Means, D. B., T. E. Ostertag, and D. Printiss. 1994a. Florida populations of the striped newt, *Notophthalmus perstriatus*, west of the Suwannee River. Contributions to life history, ecology, and distribution. I. Report under contract with the U. S. Fish and Wildlife Service, Jackson, MS, 57 pages. 1994.

Means, D. B., T. E. Ostertag, and D. Printiss. 1994b. Distribution, habitat ecology, and management of the striped newt, *Notophthalmus perstriatus*, in the Apalachicola National Forest, Florida. Report under contract with the U. S. Forest Service, National Forests in Florida, Tallahassee, FL, 30 pages. 1994.

Moler, P. E. and R. Franz. 1987. Wildlife values of small, isolated wetlands in the Southeastern Coastal Plain. Pages 234-241 *in* R. R. Odum, K. A. Riddleberger, and J. C. Dozier (eds.). Proceedings of the 3rd S. E. Nongame and Endangered Wildlife Symposium. Georgia Department of Natural Resources, Atlanta, GA.

Wilbur, H. M. 1980. Complex life cycles. Annual Review of Ecology and Systematics 1980:67-93.

Wolfe, S. H., J. A. Reidenauer, and D. B. Means. 1988. An ecological characterization of the Florida panhandle. U. S. Fish & Wildlife Service Biological Report 88(12):1-277.

Table 1. Temporary pond-inhabiting amphibians and reptiles in the Southeastern U. S. Coastal Plain. x = uses temporary ponds exclusively; + = uses temporary ponds but also other types of wetlands; o = using study pond along US Hwy 319.

Species	Category
SALAMANDERS	
Flatwoods salamander (*Ambystoma cingulatum*)	x
Mabee's salamander (*Ambystoma mabeei*)	x
Small-mouthed salamander (*Ambystoma texanum*)	x
Striped newt (*Notophthalmus perstriatus*)	x, o
Spotted salamander (*Ambystoma maculatum*)	+
Marbled salamander (*Ambystoma opacum*)	+
Mole salamander (*Ambystoma talpoideum*)	+, o
Tiger salamander (*Ambystoma tigrinum*)	+
Eastern newt (*Notophthalmus viridescens*)	+, o
Lesser siren (*Siren intermedia*)	+
Dwarf siren (*Pseudobranchus striatus*)	+
Two-toed amphiuma (*Amphiuma means*)	+
Dwarf salamander (*Eurycea quadridigitata*)	+, o
Undescribed species (*Eurycea* n. sp.)	+?
FROGS	
Eastern spadefoot (*Scaphiopus holbrooki*)	x, o
Oak toad (*Bufo quercicus*)	x, o
Barking treefrog (*Hyla gratiosa*)	x, o
Squirrel treefrog (*Hyla squirella*)	x, o
Pinewoods treefrog (*Hyla femoralis*)	x, o
Little grass frog (*Limnaoedus ocularis*)	x, o
Ornate chorus frog (*Pseudacris ornata*)	x, o
Gopher frog (*Rana areolata*)	x, o
Southern chorus frog (*Pseudacris nigrita*)	x
Eastern narrowmouth toad (*Gastrophryne carolinensis*)	+, o
Spring peeper (*Hyla crucifer*)	+, o
Southern toad (*Bufo terrestris*)	+, o
Green treefrog (*Hyla cinerea*)	+, o
Gray treefrog (*Hyla chrysoscelis*)	+, o
Southern cricket frog (*Acris gryllus*)	+, o
Bronze frog (*Rana clamitans*)	+
Pig frog (*Rana grylio*)	+
Bullfrog (*Rana catesbeiana*)	+, o
Southern leopard frog (*Rana utricularia*)	+, o
Carpenter frog (*Rana virgatipes*)	+
Upland chorus frog (*Pseudacris triseriata*)	+
River swamp frog (*Rana heckscheri*)	+

TURTLES	
Chicken turtle (*Dierochelys reticularia*)	x, o
Mud turtle (*Kinosternon subrubrum*)	+, o
Stinkpot (*Sternotherus odoratus*)	+, o
Pond slider (*Pseudemys scripta*)	+, o
Eastern softshell turtle (*Apalone ferox*)	+, o
Snapping turtle (*Chelydra serpentina*)	+
SNAKES	
Banded water snake (*Nerodia fasciata*)	+, o
Garter snake (*Thamnophis sirtalis*)	+, o
Swamp snake (*Seminatrix pygaea*)	+