DEMOGRAPHIC RESPONSES OF AMPHIBIANS TO WETLAND RESTORATION IN CAROLINA BAYS ON THE SAVANNAH RIVER SITE

A Dissertation

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Zoology

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by

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To the Graduate School:

This dissertation entitled "Demographic Responses of Amphibians to Wetland Restoration in Carolina Bays on the Savannah River Site" and written by Karen E. Kinkead is presented to the Graduate School of Clemson University. I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy with a major in Zoology.

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We have reviewed this dissertation and recommend its acceptance:

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ABSTRACT

This project studied the effects of wetland restoration on amphibian populations. These wetlands were Carolina bays located on the Savannah River Site, located near Aiken, S.C. The Savannah River Site is a National Environmental Research Park owned and operated by the U.S. Department of Energy. The study sites included three reference bays (functionally intact), three control bays (with active drainage ditches), six treatment bays (restored during 2001), and four bays near two of the treatment bays (in effect creating two metapopulations).

Amphibians at each bay were captured, marked, and released between January and July, 2000-2003. 2000 was a pre-restoration year, the bays were restored prior to the trapping season in 2001, and 2002 and 2003 being post-restoration years. Each bay was partially encircled with drift fences and pitfall traps. Amphibians were given batch marks that designated the year and bay of capture.

A total of 43,432 amphibians of 24 species were captured during the study. While I documented a decrease in salamander populations during this study, the restoration appears to have provided additional breeding habitat for several anuran species.

In addition, I present survival estimates for 2 salamander species, ***Ambystoma maculatum***, and ***A. talpoideum***. These estimates were lower than previously reported for these species, however two years of this study were conducted during drought conditions which may have impacted these results.

In addition, we present information on environmental variables and responses of *A. opacum*, and *A. talpoideum*, as well as 2 species of anurans, *Bufo terrestris*, and *Scaphiopus holbrooki*.

Ambystoma species are believed to be highly philopatric, returning to the natal pond to breed. I examined the genetic structure of two species, *A. talpoideum* (mole salamanders) and *A. opacum* (marbled salamanders) in 16 Carolina bays. Amplified fragment length polymorphisms (AFLP) were used to determine genetic variation within and among populations of salamanders separated by distances of 150 m to 25 km. Although this technique was capable of verifying variation between the species, we were unable to document genetic structure at the population level for either of these species.

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CHAPTER 1

EFFECTS OF HYDROLOGY RESTORATION ON AMPHIBIANS IN CAROLINA BAYS

Introduction

By the mid 1980s the United States had lost more than one-half (46.9 of 87 million hectares) of the original (pre-European settlement) wetlands (Mitsch and Gosselink 2000). Fifty percent (18.8 million hectares) of the remaining acreage is located in the southeastern US. Nationwide, wetlands comprise 5 % of the surface area, but in the Southeast, wetlands account for 15 % of the surface area (Hefner and Brown 1985). Nationwide, 81 % of the original bottomland hardwoods had been lost by the mid-1980s. In the southeastern US, 92 % of all lost bottomlands were harvested between 1950 and the mid-1970s (Haynes and Moore 1988).

Following disturbance by farming or other land use practices, an area can partially revert back into a wetland through natural processes (Patchett 1990). Restored sites may often function as if they were disturbed wetlands (Odum 1988). To restore a site is to intervene in the natural recovery process, and move the recovery rate forward (Haskisaki 1996), although some believe that restoration is an "attempt to imitate succession in order to control it" (Ashby 1987). Restored sites may begin to function as a wetland, with respect to animal habitat, more quickly than new, artificially created wetlands. Wetland restoration and creation projects often fail because of a "general lack of understanding of ecosystem development in wetlands" (Odum 1988).

Many authors have recognized the need for improved methods to quantify the successful function of regenerated and restored sites (Parker 1997, Michner 1997), but comprehensive long term monitoring programs that evaluate wetland functions have rarely been conducted (Hammer 1992). Commonly, guidelines set forth by the U.S. Army Corps of Engineers for the assessment of success in created or mitigated wetlands in the southeastern US require only the estimation of the survival of the planted trees and herbaceous wetland species. However, survivorship and growth of vegetation is a measure of structure, not function, and therefore does not necessarily indicate successful function of the site in providing habitat suitable for wetland wildlife species (Berger 1991, Perry et al. 1996). Therefore, more meaningful protocols are needed to define and evaluate success in restored wetland areas. The function of the site in the landscape and the effect of structure and function of the site on the vertebrate communities in the restored site as well as the surrounding landscape should be considered (Kentula 1997), but few restoration studies have attempted to measure the response of the wildlife communities to the restoration efforts. Almost all restoration projects monitor hydrology with respect to ground water levels (Perry et al. 1996) as well as planted vegetation (Perry et al 1996, Odum 1988, Brown 1999). The majority of wildlife community studies have focused on birds, (Zedler and Callaway 1999, Perry et al. 1996, Weller 1995), although a few recent studies have examined amphibians (Pauley and Barron 1995, Lehtiner and Galatowitsch 2001, Perry et al. 1996, and Petranka et al. 2003). Semlitsch (2002) suggested that a restored site should not be considered successful as amphibian habitat until the second generation of the species of interest successfully breeds. He defined initial success as the emergence of metamorphs; intermediate success as the metamorphs returning as adults for the first breeding; and complete success as 5 years of continuous breeding. Site failure is defined as no adults returning to breed in 5 to 10 years (Semlitsch 2002). However, the entire population of any amphibian species will not migrate to the pond to breed in a given year (Semlitsch et al. 1996), and large population size fluctuations among amphibians are common, in response to environmental conditions such as flooding or drought (Gibbons et al. 1997).

Temporary ponds, including Carolina bay wetlands, are used by many species of amphibians for mating, oviposition, and larval growth. During the non-breeding season most amphibians associated with these wetlands live in the surrounding terrestrial habitat. After hatching, larvae stay in the pond until they metamorphose into juveniles (Beiswenger 1988). Hydroperiod (the length of time an area is flooded by water), food, temperature, predator density, and the length of the larval stage, all influence the success and mortality of offspring.

Philopatry (returning to the natal site to breed) is thought to occur because an individual will be more successful at a site with which it has previous experience (Semlitsch and Ryan 1998). Many amphibians are philopatric and move less than two hundred meters from the breeding area (Semlitsch and Bodie 1998). Due to the higher risks of desiccation and predation associated with looking for additional habitats, natural selection is thought to act against this behavior. However, studies have shown that amphibians can quickly colonize new sites, especially if a new site is between the upland, non-breeding habitat and the natal breeding site (Petranka et al. 2003 a and b, Semlitsch and Ryan 1998). Rainfall is used as a cue by amphibians as to hydroperiod. Temporal time variations in hydroperiod allow different species to be successful in different years

(Semlitsch et al. 1996). The longer the hydroperiod, the more juveniles are produced (Paton and Crouch 2002). If a site dries before the juveniles are capable of leaving, the larvae either desiccate or become more vulnerable to predation. Because many amphibian species return to the same breeding site year after year, the colonization of artificially created sites may be slow (Pechmann et al. 1989) or fast (Semlitsch and Ryan 1998) depending on the location of the new site.

Ephemerally flooded sites often produce more amphibians than permanent water sources because fewer predators, such as fish and invertebrates, are present in the ephemeral ponds (Pechmann et al. 1989). Ephemeral ponds with longer hydroperiods, however, often support a larger number of species (Paton and Crouch 2002, Snodgrass et al. 2000). Some states have wetland protection laws based on the size of a wetland. The hypothesis is that a larger wetland would have the same species present in a smaller wetland as well as additional species. However, hydroperiod is not necessarily correlated with the size of a Carolina bay. Even short hydroperiod wetlands are important as these systems support species adapted for fast metamorphosis which may not be competitive in longer hydroperiod wetlands (Snodgrass et al. 2000). Hydroperiod can directly control the water depth, water volume and water area, but also indirectly influence mean larval densities, and food resources (Pechmann et al 1989). Hydrological variables, genotype, predation, and competition combine to influence nest success in amphibians, along with nest placement and parental care in some species. Eggs may perish due to freezing, predation, and desiccation (Jackson et al. 1989).

Amphibians are the most plentiful vertebrate group in many forests. In the southern Appalachians, salamander biomass can be larger than all other vertebrates combined (Hairston 1987). Due to several amphibian characteristics (poikilothermy, aquatic/terrestrial phases of the life cycle, small home range, philopatry, moist, permeable eggs and skin) amphibians are more likely to be impacted by changes to the environment before those changes impact other organisms. Many studies have shown that clearcut areas support fewer amphibians than forested areas and that some species are more affected by clearcutting than others (deMaynadier and Hunter 1995, Ash 1988, Johnston and Frid 2002, Bury 1982). Salamanders appear to be impacted to a greater extent than do anurans, possibly due to the ability of anurans to conserve more water and tolerate higher temperatures (Petranka 1994). One large remaining question from these earlier studies is: what happens to the salamanders? Do they die, migrate elsewhere, or move underground for more extended periods where they cannot be captured? Petranka (1994) argues that they die, because even if they migrate elsewhere, they would not be able to competitively establish new home ranges. It is also unknown how amphibians are affected by forest succession. Slimy salamanders are more susceptible to forest management practices than other more migratory species (Grant et al. 1994). Woody debris and litter depth may directly influence the number of all salamander species present in a stand. Young forests and old forests tend to have higher amounts of woody debris than intermediate aged forests. Pine plantations tend to have a lower soil pH, reduced hardwood litter depth, reduced herbaceous and shrub layers resulting in less vertical structure, and less coarse woody debris (deMaynadier and Hunter 1995).

Habitat degradation has been proposed as the primary cause of amphibian declines (deMaynadier and Hunter 1995, Semlitsch 2002). Metapopulations are important for sustainable densities of amphibians because breeding populations can vary in size among sites and years, and have extreme variation in juvenile recruitment, which make them vulnerable to extinction and reliant upon recolonization (Semlitsch 2002). Metapopulations are dependent upon habitat quality, both of the breeding pond and the terrestrial environment, and the dispersal and survival rates of the animals. Larval periods vary from as low as 12 days for eastern spadefoot toads (*Scaphiopus holbrookii*) to up to 2 years for bullfrogs (*Rana catesbeiana*). Growth and development is affected by food, temperature, hydroperiod, density, predators, disease and chemical contamination. Variation and timing of rainfall affects the production of metamorphs. Some species including southern cricket frogs (*Acris gryllus*), green treefrogs (*Hyla cinerea*), bullfrogs, and green frogs (*R. clamitans*), will breed in ponds with fish. Amphibians are capable of maintaining high biodiversity because each species is periodically favored with a productive year. The metamorphic juveniles may represent the primary dispersal stage as most adults are believed to return to the same pond each year. Open areas such as roads and powerlines may prevent movement (Semlitsch 2002).

The primary objective of this study is to examine the effects of wetland restoration of Carolina bays on amphibian communities at the Savannah River Site, near Aiken, South Carolina. The study employed a pre- and post-treatment/control/reference experimental design, and I used amphibian species and community parameters as response variables. A secondary objective of the study was to evaluate the feasibility of using amphibians as a metric for the successful function of restored wetlands. The specific questions include: Did the Carolina bay restoration provide suitable habitat for breeding amphibians overall? Was there a relative increase in the post-treatment