DISTRIBUTION AND ABUNDANCE OF ANURANS IN SOUTHEAST MISSOURI

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University of Missouri- Columbia

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Master of Science

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by

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled

DISTRIBUTION AND ABUNDANCE OF ANURANS IN SOUTHEAST MISSOURI

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and hereby certify that in their opinion it is worthy of acceptance.

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ABSTRACT

Studies were conducted on 15 1034 ha landscape blocks in 1999 and 2000 to investigate the effects of forest fragmentation and habitat availability on anuran populations in southeast Missouri. To test these landscape level effects, it was first essential to determine the effectiveness of sampling techniques at a large spatial scale. Several techniques including call counts, artificial habitat, visual encounter surveys, visual scan, and larval sampling were tested in 1999. In 2000, a modified night call census road sampling technique was implemented to increase repeated sampling effort of landscape blocks for the presence of anurans. Detections of anurans did not indicate a correlation between the percent of forest on a landscape or habitat types within a landscape and the species richness of the anuran community. Three anuran species (Blanchard's cricket frog, Fowler's toad, and southern leopard frog) were selected to investigate the effects of forest fragmentation and habitat availability on abundance. Detections of Blanchard's cricket frog and southern leopard frog did not indicate a correlation between species abundance and the percent of forest on a landscape or specific habitat types within a landscape block. Detections of Fowler's toad did not indicate a correlation between abundance and the percent of forest on a landscape, but did indicate that there is a correlation between habitats in a landscape and the abundance of Fowler's toads.

Distribution and Abundance of Anurans in Southeast Missouri

CHAPTER I

INTRODUCTION

Reptiles and amphibians represent a large percentage of total diversity globally, despite being overshadowed by more charismatic megafauna. There are 9,220 herptile species (3,266 amphibians and 5,954 reptile) worldwide, and 460 of these occur in the continental United States (Conant and Collins 1998). Missouri alone hosts 107 species or 1.8% of the worldwide diversity. Of these 107 species, 69 exist in southeast Missouri (24 amphibians, 14 turtles, 6 lizards, 25 snakes), but 12 only occur in forested wetlands of the region (Johnson 1997, Appendix A). Although herptiles thrive in forested wetland systems, little is known of their distribution and abundance. Understanding how these animals use forested wetlands throughout the annual cycle is key to developing management strategies of these systems for cold-blooded vertebrates.

The decline of key species across trophic levels often signals the deterioration of an ecosystem (Weiner et al. 1998). Such changes in species abundance are evident in the Mississippi Alluvial Valley (MAV) where cumulative effects of human activities have exceeded ecosystem assimilative capacities to maintain processes (Weiner et al. 1998). One of the dominant causes of amphibian declines in the midwestern United States is habitat loss or alteration associated with agricultural and industrial development (Honegger 1981, Leja 1998, Kuzmen 1999). Unfortunately, little published information is available that measures the effects that deterioration of Mississippi River floodplain forests has had on herptile populations. Thus, developing an understanding of contemporary amphibian populations in this region is critical.

Although numerous studies in the United States have examined the effects of habitat fragmentation on birds and, to a lesser extent, mammals, relevant data for cold-blooded vertebrate taxa generally are lacking (Marsh and Pearman 1997). Despite the lack of landscape studies on these vertebrate taxa, interest in amphibians and their decline has spawned a broader interest on how fragmentation affects amphibian populations.

Past Research Efforts

In the southeast United States, much of the early herptile research focused on general distribution patterns, morphological systematics, and life history observations (Dodd 1997). It was not until the latter half of the 20th century that more in-depth studies for most species were initiated. However, long-term quantitative data are lacking from many of these studies. During the 1970's, studies integrated field and laboratory work to test traditional hypotheses of species interactions (Dodd 1997). Monitoring herptiles on a large scale was initiated during the 1990's; these surveys typically were performed by local or state groups or volunteers associated with state agencies. Information from these surveys contributed greatly to our knowledge of species ranges, emergence/breeding chronologies, and population indices, yet had limited value in understanding the effects of habitat fragmentation on secretive species with low mobility.

To understand larger spatio-temporal patterns, questions regarding the diversity, abundance, and density of amphibian species at a larger scale must be addressed. For example, factors including site fidelity (Holomuziki 1982, Kleeberger and Werner 1982, Sinsch 1990) and limited dispersal (Harris 1975, Beshkov and Jameson 1980, Sinsch 1990) potentially isolate populations and compromise the long-term viability of isolated populations. Metapopulation studies have bridged the gap between traditional research and the need for advanced knowledge of amphibian responses to habitat alteration. However, most studies lack the geographic scale to understand the effect habitat alteration has on amphibian populations at a landscape level.

The MAV is one of the most highly altered ecosystems in the United States, and large river floodplain systems rank among the most altered systems worldwide. Historically the bottomland hardwood forests (BLH) of the MAV contained over 100 species of woody plants that created a diversity of habitat types. Today, 81% of these bottomland forests have been converted to other land uses (Haynes 1988). Limited information is available documenting herptile species abundance, diversity, and richness in the MAV, however, anecdotal information suggests that the MAV teemed with a variety of herptile species historically.

This study identified the distribution of amphibian species within 15 1034 ha study sites of varying forest area within the MAV in southeastern Missouri. Forest cover within the study sites varied from a low of 0.76% of the plot to a high of 58.79%. This range of forest cover encompassed 3 forest cover classes (low <4% forest cover, medium 5-20% forest cover, high >20% forest cover). Within these study sites several common habitat types in the MAV were represented (Fig. 1). I hypothesized that herptile species abundance, density, and richness was dictated by the amount and type of forest, the habitats available in these landscapes, and the juxtaposition of different forest and habitat types on the landscape. Addressing questions about amphibian abundance and richness at a landscape scale ultimately leads to a greater understanding of how amphibian species respond to abiotic and abiotic processes unique to floodplain ecosystems in the MAV.

The objectives of my study were to:

1) Determine species richness and abundance of key herptile species within landscapes of varying amounts and types of forests (low < 2%, medium 3 -10%, high > 11%) in the 100-year floodplain of the Mississippi River in Southeastern Missouri
2) Determine species richness and abundance of key herptile species within specific habitat types in the 100-year floodplain of the Mississippi River in Southeastern Missouri
3) Determine species richness and abundance of key herptile species within agroforestry patches in the 100-year floodplain of the Mississippi River in Southeastern Missouri
4) Determine the effectiveness of several sampling protocols on key herptile species at a landscape scale in the 100-year floodplain of the Mississippi River in Southeastern Missouri.

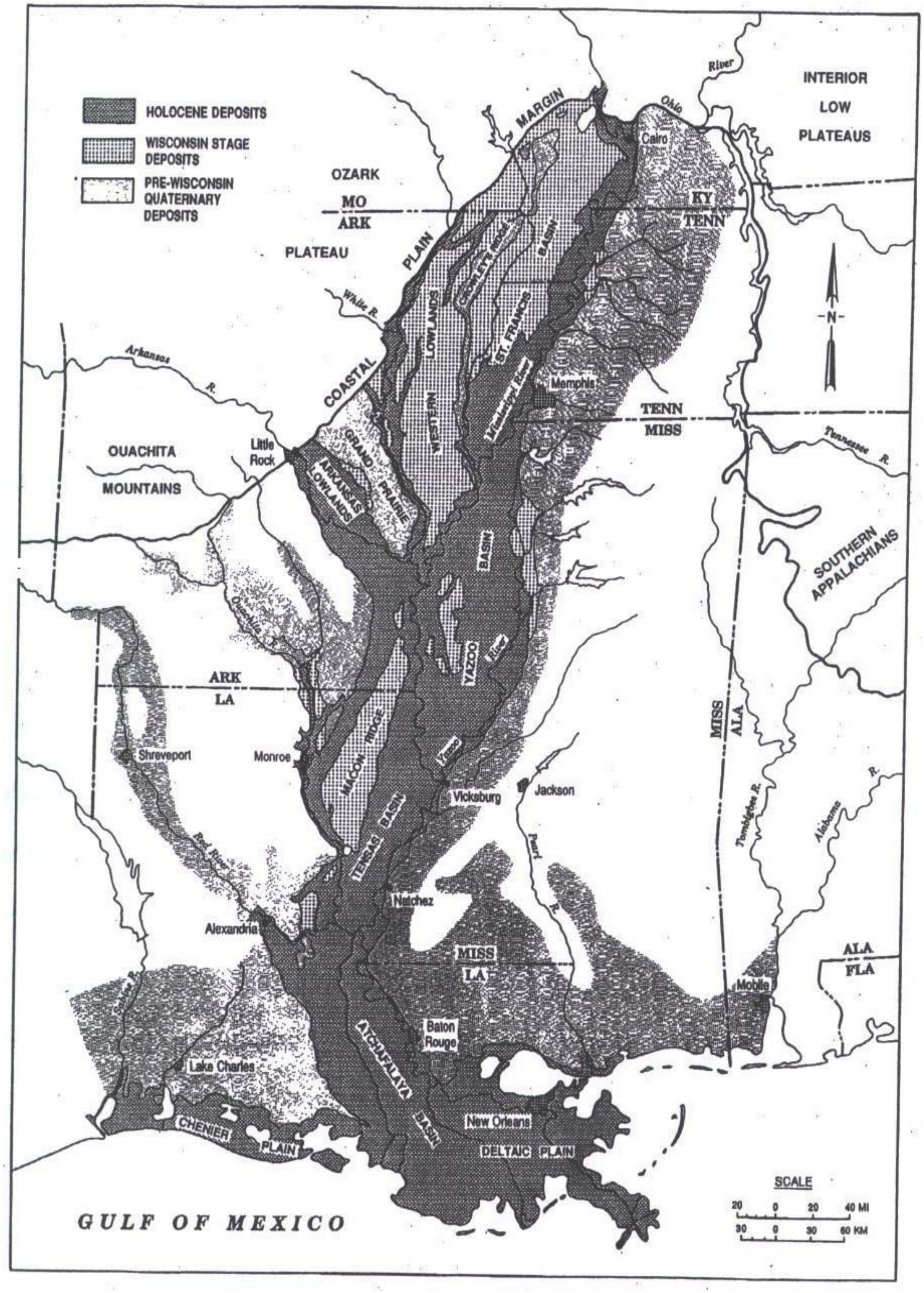

Figure 1. The Mississippi Alluvial Valley, including the six major basins and distribution of Quaternary deposits (Saucier 1994, Papon 2002)

CHAPTER II

HERPTILE USE OF BOTTOMLAND HARDWOOD FORESTS

Amphibians

Amphibians require specific abiotic and biotic conditions widely available in floodplain ecosystems. Examples of these conditions including flooding during the breeding season for species such as the Illinois chorus frog (*Pseudacris strecheri illinoiensis*) and eastern spadefoot toad (*Scaphiopus holbrookii holbrookii*); fishless permanent water for over wintering habitat for the southern leopard frog (*Rana sphenocephala*); and loose soils for hibernation for species like the eastern narrowmouth toad (*Gastrophryne carolinensis*). Unlike other vertebrate taxa, the low mobility of amphibians requires that they complete their life cycle in a relatively small area (Table 1). Amphibians thrive in forested wetland systems but are not dependent on the presence of surface water throughout the annual cycle. However, they are obligate to areas with surface water for reproduction. This dependence on water ties amphibian communities to the hydrologic condition of wetland basins (Table 2). Thus, improved understanding of use is critical for the design of restorations that benefit a larger suite of cold-blooded vertebrates.

Reptiles

Forested wetlands provide diverse hydrologic conditions that create a mosaic of habitat conditions related to forest type, plant density, and understory structure that benefit reptiles. Unlike amphibians, reptiles are not obligate to wetland systems for reproduction, but the dynamic conditions of BLH systems create foraging conditions valued by many reptiles. Temporal and spatial hydrologic variability has important implications for reptilian use because of their life history variability (Fig. 2.3). For example, turtles have high dependence on the presence of water whereas lizards and snakes have a very low dependence (Fig. 2.3). Many species have no direct tie to wetland systems and occur across a suite of habitat types because foraging conditions are ideal for their nutritional needs (Black Rat Snake, Fence Lizard).

Table 1. Bottomland Hardwood Forests Anuran Life History Cycle Needs

Class Salientia	Habitat	Time of breeding	Hatch timing	Transformation	Overwinter
Eastern Spadefoot Toad	Open fields with loose soils	April - August	Few days	< 3 weeks	Animal burrows, loose soils, leaf litter
Dwarf American Toad	Hardwood Forests	March - May	1 week	2 - 3 months	Animal burrows, loose soils, leaf litter
Fowler's Toad	Sandy Lowlands	March - May	1 week	2 - 3 months	Animal burrows, loose soils, leaf litter
Blanchard's Cricket Frog	Open edges along water	April - July	Few days	5 - 10 weeks	Animal burrows, loose soils, leaf litter
Green Treefrog	Vegetated permanent water	May - August	2-3 days	3 - 5 weeks	Animal burrows, loose soils, leaf litter
Northern Spring Peeper	Woodlands	March - May	3-4 days	2 months	Animal burrows, loose soils, leaf litter
Gray Treefrog	Woodlands	April - June	4-5 days	2 months	Animal burrows, loose soils, leaf litter
Illinois Chorus Frog	Flat sandy areas	February - April	3 - 7 days	60 days	Animal burrows, loose soils, leaf litter
Upland Chorus Frog	Damp woods	February - April	3 - 7 days	6-8 weeks	Animal burrows, loose soils, leaf litter
Eastern Narrowmouth Toad	Moist loose soils	May-June	< 2 days	30 - 60 days	Animal burrows, loose soils, leaf litter
Plains Leopard Frog	Grasslands and river floodplains	April-June	2-3 weeks	30+ days (can over winter as tadpoles	Benthic mud
Bull Frog	Permanent water	May - June	4-5 days	11 - 14 months	Benthic mud
Bronze Frog	River sloughs and swamps	April-August	3-10 days	Following summer	Benthic mud
Pickerel Frog	Springs and cool creeks	March-May	10+ days	3 - 4 months	Caves and benthic mud
Southern Leopard Frog	Variety of aquatic habitats	March - April	10-15 days	2 - 2.5 months	Benthic mud

Table 2. Bottomland Hardwood Forests Caudata Life History Cycle Needs

Order Caudata	Habitat	Courtship habitat	Time of breeding	Hatch timing	Nest habitat	Brood habitat	Time to maturity	Overwinter
Western Lesser Siren	Permanent water		Unknown	Unknown	Benthic Mud		2 Years	Permanent water/ benthic Mud
Spotted Salamander	Damp Hardwoods	Shallow fishless ponds	February - March	30 days	Submerged Vegetation	Shallow Fishless ponds	2 Years	Soil
Marbled Salamander	Forested Systems	On land near water	Fall		Leaf Litter / Eggs Submerged Later by Fall Rains	Water	1 Year	Soil
Mole Salamander	Forested Systems	Water	Fall		Submerged Vegetation	Burrows	3-4 Months	Soil
Smallmouth Salamander	Wide Variety	Ponds. Sloughs, Streams, Ditches	February - April	2-4 weeks	Submerged Vegetation, Submerged Rocks	Water	2 Months	Rocks, Litter, Logs, Soil
Eastern Tiger Salamander	Wide Variety	Shallow fishless ponds	February - April	2-4 weeks	Submerged Vegetation	Water	4-5 Months	Soil
Central Newt	Woodland Ponds	Shallow fishless ponds	Spring	3-5 Weeks	Single Eggs on Aquatic Plants	Water as Larvae / Land as sub-Adult	2-3 Years	No Dormant Period
Three-toed Amphiuma	Sloughs and Swamps	Unknown	Late Summer – Early Autumn	Unknown	Leaf Litter / Eggs Submerged Later by Fall Rains	Water	Unknown	Permanent water/ benthic Mud
Mudpuppy	Large Creeks and Rivers	Water	Fall / Lay Eggs following Spring	3-5 weeks	Submerged Rocks	Water	4-6 Years	No Dormant Period

Table 3. Reptilian Dependence on Wetlands

		Breeding	Nest	Development	Forage	Overwinter	Ranking
Common Snapping Turtle	*Chelydra serpentina serpentina*	2	0	2	2	2	8
Alligator Snapping Turtle	*Macroclemys temminkii*	2	0	2	2	2	8
Stinkpot	*Sternotherus odoratus*	2	0	2	2	2	8
Southern Painted Turtle	*Chrysemys picta dorsalis*	2	0	2	2	2	8
Map Turtle	*Graptemys geographica*	2	0	2	2	2	8
Mississippi Map Turtle	*Graptemys kohnii*	2	0	2	2	2	8
False Map Turtle	*Graptemys pseudogeographica pseudogeographica*	2	0	2	2	2	8
Missouri River Cooter	*Pseudemys concinna metteri*	2	0	2	2	2	8
Red-eared Slider	*Trachemys scripta elegans*	2	0	2	2	2	8
Smooth softshell	*Trionyx muticus muticus*	2	0	2	2	2	8
Eastern Spiny Softshell	*Trionyx spiniferspinifer*	2	0	2	2	2	8
Western Chicken Turtle	*Deirchelys reticularia miaria*	2	0	1	1	2	6
Mississippi Mud Turtle	*Kinosternon subrubrum hipporepis*	2	0	1	1	1	5
Western Mud Snake	*Farancia abacura reinwardtii*	1	1	1	1	1	5
Green Water Snake	*Nerodia cyclopion cyclopion*	1	1	1	2	0	5
Yellowbelly Water Snake	*Nerodia erythrogaster flavigaster*	1	1	1	2	0	5
Broad-banded Water Snake	*Nerodia fasciata confluens*	1	1	1	2	0	5
Diamondback Water Snake	*Nerodia rhombifer rhombifer*	1	1	1	2	0	5
Midland Water Snake	*Nerodia sipedon pleuralis*	1	1	1	2	0	5
Graham's Crayfish Snake	*Regina grahamii*	1	1	1	2	0	5
Western Cottonmouth	*Agkistrodon piscivorus leucostoma*	1	1	1	2	0	5
Western Ribbon Snake	*Thamnophis proximus proximus*	0	0	1	1	0	2
Three-toed Box Turtle	*Terrapene carolina triunguis*	0	0	0	0	0	0
Northern Fence Lizard	*Sceloporus Undulatus hyacinthinus*	0	0	0	0	0	0
Five-lined Skink	*Eumeces fasciatus*	0	0	0	0	0	0
Broadhead Skink	*Eumeces laticeps*	0	0	0	0	0	0
Ground Skink	*Scincella lateralis*	0	0	0	0	0	0
Six-Lined Racerunner	*Cnemidophorus sexlineatus*	0	0	0	0	0	0
Western Slender Glass Lizard	*Ophisaurus attenuatus attenuatus*	0	0	0	0	0	0
Western Worm Snake	*Carphophis amoenus vermis*	0	0	0	0	0	0
Southern Black Racer	*Coluber constrictor priapus*	0	0	0	0	0	0
Mississippi Ringneck Snake	*Diadophis punctatus stictogenys*	0	0	0	0	0	0
Black Rat Snake	*Elaphe obsoleta obsoleta*	0	0	0	0	0	0
Dusty Hognose Snake	*Heterodon nasicus gloydi*	0	0	0	0	0	0
Eastern Hognose Snake	*Heterodon platyrhinos*	0	0	0	0	0	0
Prairie Kingsnake	*Lampropeltis calligaster calligaster*	0	0	0	0	0	0
Speckled Kingsnake	*Lampropeltis getulus holbrooki*	0	0	0	0	0	0
Red Milk Snake	*Lampropeltis triangulum syspila*	0	0	0	0	0	0
Rough Green Snake	*Opheodrys aestivus*	0	0	0	0	0	0
Midland Brown Snake	*Storeria dekayi wrightorum*	0	0	0	0	0	0
Northern Redbelly Snake	*Storeria occipitomaculata occipitomaculata*	0	0	0	0	0	0
Eastern Garter Snake	*Thamnophis sirtalis sirtalis*	0	0	0	0	0	0
Western Earth Snake	*Virginia valeriae elegans*	0	0	0	0	0	0
Southern Copperhead	*Agkistrodon contortrix contortrix*	0	0	0	0	0	0
Timber Rattlesnake	*Crotalus horridus*	0	0	0	0	0	0

Color Description	*Numerical Ranking*
No dependence	*0*
Some Dependence	*1*
Strong Dependence	*2*

CHAPTER III

GEOMORPHIC SETTING

The effects of anthropogenic habitat alteration, including fragmentation, can only be addressed entirely by understanding the geomorphic features and how these features influence fragmentation as well as my study design. The Mississippi River is the third longest river, the second largest watershed, and the fifth greatest discharge of the world's rivers (Fig 2). The Mississippi River Basin measures 4.76 million km^2 and covers 40% of the United States, equivalent to one eighth of North America (Weiner et al. 1998). The MAV lies between Cape Girardeau, Missouri and the Gulf of Mexico, a distance of approximately 965 km (600 mi). The MAV falls within seven states, but Arkansas and Louisiana have the largest area of floodplain habitat (Fig. 1). The elevation of the Mississippi River Floodplain between Cape Girardeau, Missouri and the Gulf of Mexico declines from 99 to 12 m above sea level (325 to 40 ft msl) at Baton Rouge, Louisiana creating a valley slope of 1l cm/km (0.6 ft/mi). Floodplain width varies from 48 to 145 km (30 to 90 mi). The total area of the MAV is approximately 86,636 km^2 (33,450 mi^2).

The MAV was formed by a series of climatic and geologic events including continental rifting and downwarping, Pleistocene glacial advancements and retreat, (producing fluctuations in the volumes of melt water and outwash), and cyclical sea level fluctuations (Saucier 1994). Major alluvial floodplains are inextricably connected to major rivers, and owe their existence to upstream soil erosion and subsequent deposition (Messina and Conner 1998). MAV deposits range from 5 to 80 m (16 to 260 ft); (Messina and Conner 1998, Mitsch and Gosselink 2000, Fig. 3,4; Mayhan 2000).

Alluvium comes from as far north as Canada and as far west and east as Montana and Pennsylvania respectively (Messina and Conner 1998). All modern landforms of the MAV result from fluvial, eolian, and marine process of erosion and deposition (Figs. 5-9; Saucier 1994).

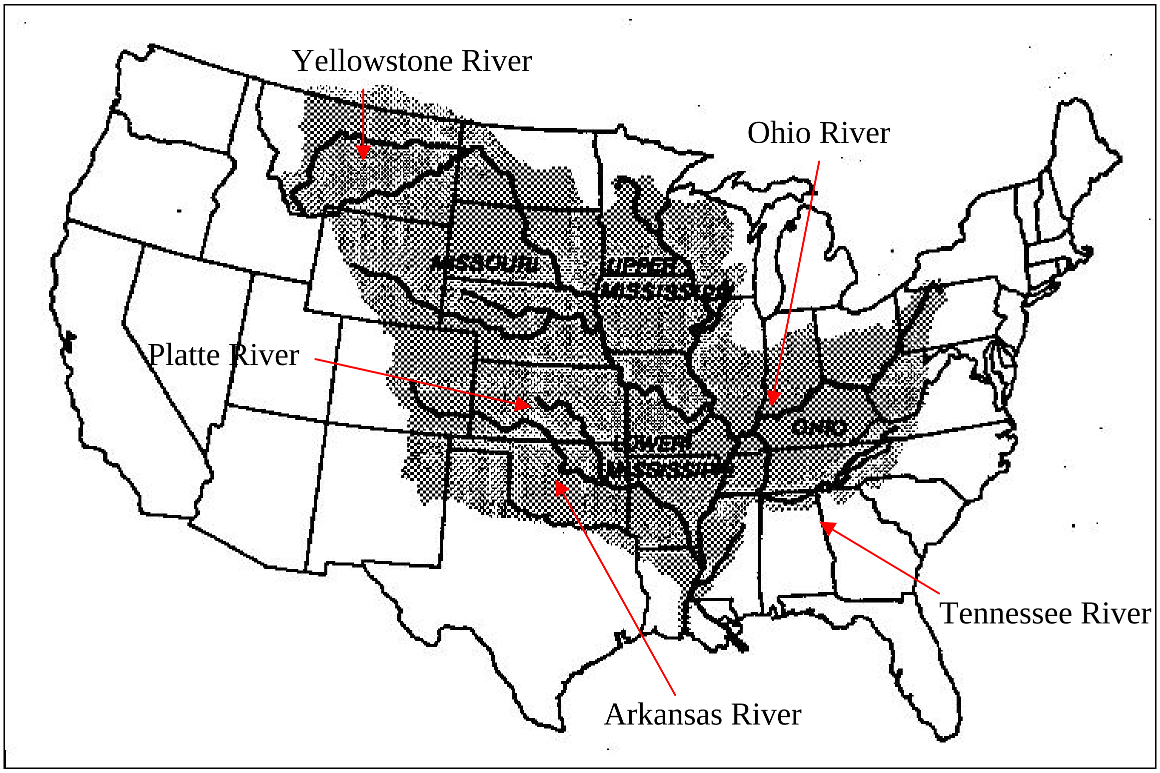

Figure 2. Watershed and major tributaries of the Mississippi River (from Turner and Rabalais 1991)

The Holocene alluvial plain accounts for 39,523 km^2 (46%) of the MAV. The remaining 54% is characterized by braided-stream terraces (valley-trains) of Early and Late Wisconsin Age. Several major geomorphic features occur throughout the MAV floodplain, however the meander belts of the Mississippi River are the primary geomorphic feature associated with wetland dynamics and hydrologic processes (Fig. 7). Meander belts have numerous depositional environments and include natural levees, crevasse splays, distributaries, point bars, abandoned channels, abandoned courses, and back swamps (Saucier 1994, Fig. 8).

Meander belts are the remnants of past river migrations. Sedimentation occurs at a higher rate adjacent to the active river channel, resulting in an alluvial ridge with an elevation higher than the distant floodplain (Saucier 1994). Subsequent drainage is then directed away from the river channel into the lowland areas (Russell 1957). The contemporary floodplain of the MAV contains the present course of the river and as many as five abandoned meander belts (Saucier 1994).

Natural levees are defined as low broad ridges that slope away from the river channel. Natural levees along the Mississippi River are the most obvious landforms because of their topographical presence on the otherwise flat floodplain (Fig. 9). Natural levees are formed where sediments fall out of suspension and are deposited near the channel during high river flow events. These landforms are variable in height and width and typically are comprised of a medium to stiff silty clay, sandy clay, or silty sand (Saucier 1994). The depositional patterns of suspended soil particles are largely driven by bank type. Silts and sands tend to be distributed on migrating bends where crevassing was frequent. Clays and silts are deposited on the opposite banks or laterally downstream from migrating bends. In the alluvial area, most natural levees overlie point bar depositions.

Crevasse splays are often associated with natural levees. They form where a natural levee is breached by high flows. Splays can form during a single flood event but more typically form and grow over time.

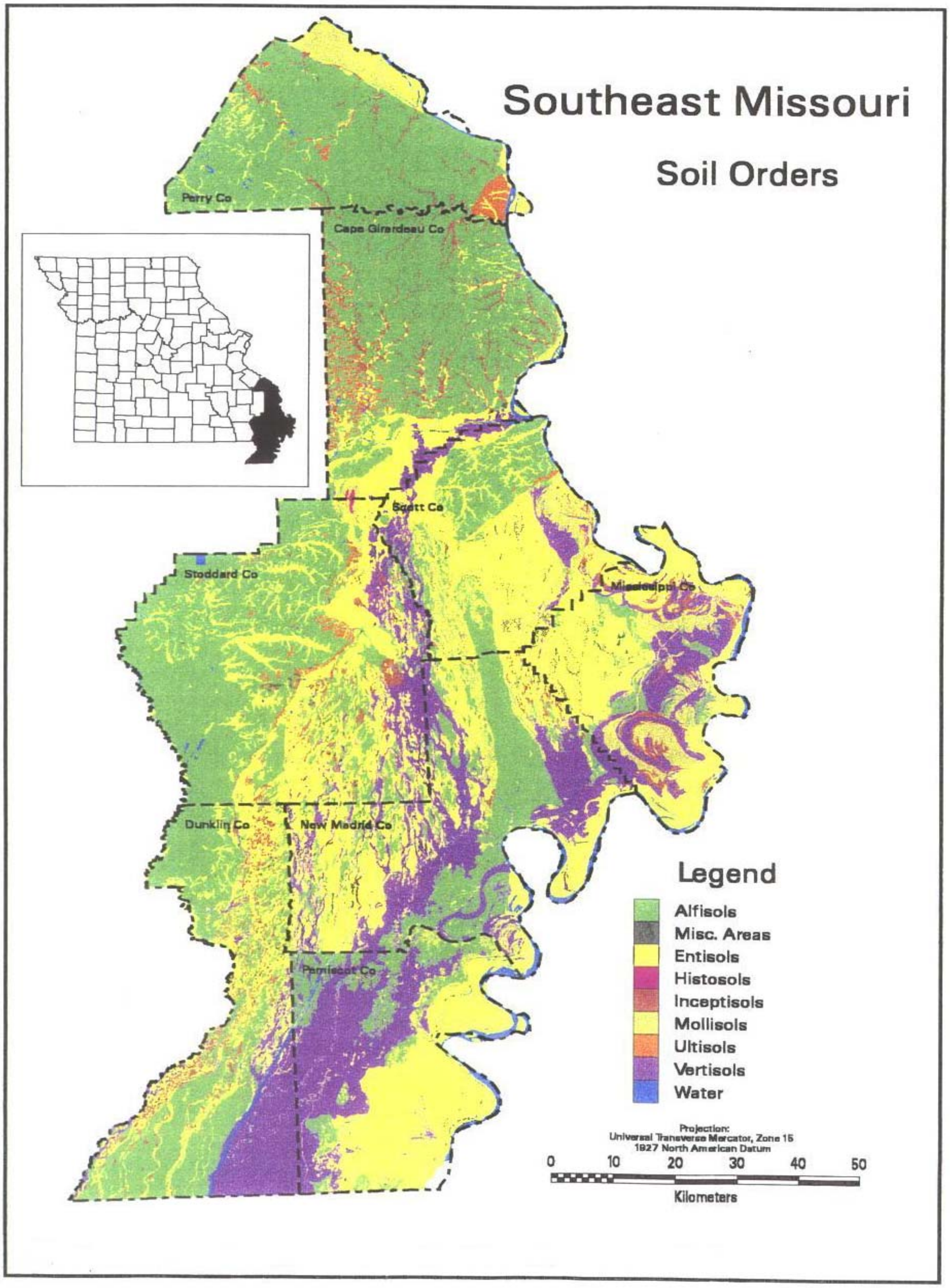

Figure 3. Southeast Missouri soil orders (from Mayhan 2000.)

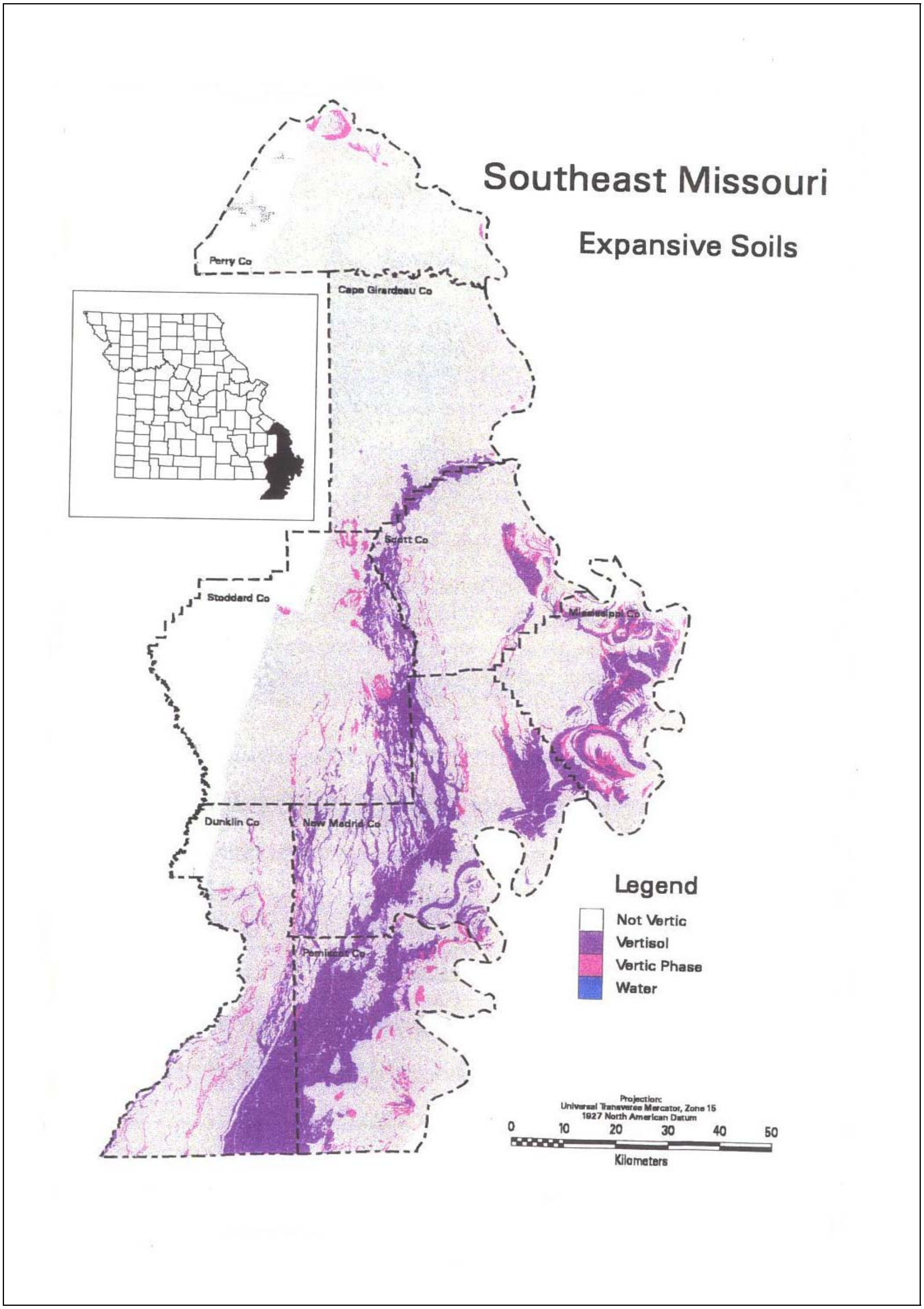

Figure 4. Expansive soils of southeast Missouri (from Mayhan 2000.)

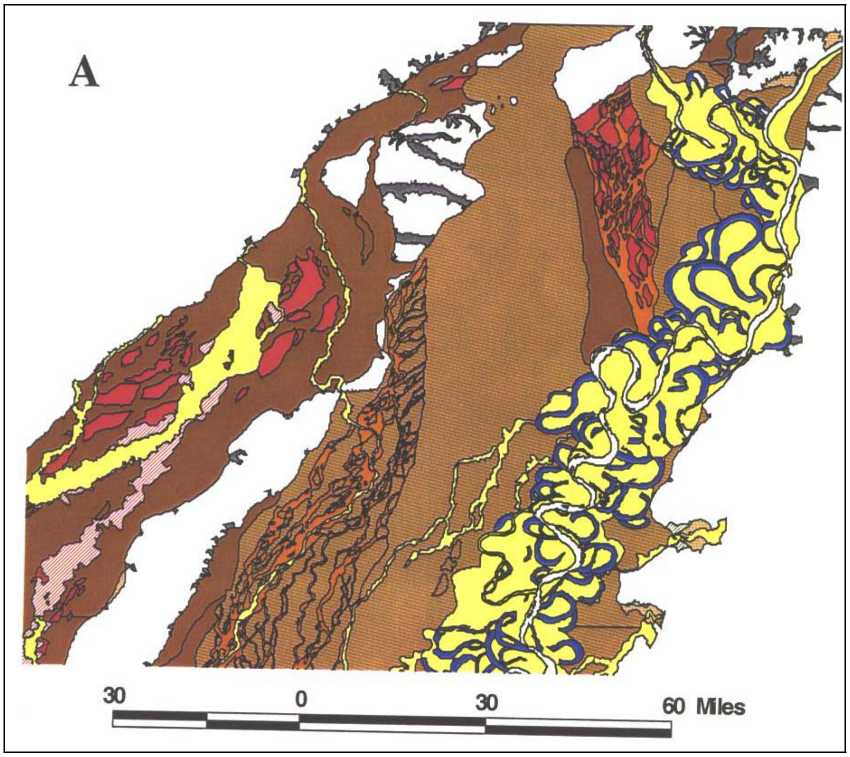

Figure 5. Quaternary geomorphology of southeast Missouri. Blue indicates abandoned channels of the Mississippi River; yellow indicates point bar deposits; and brown, red, and orange indicate valley trains of different ages (from Saucier 1994).

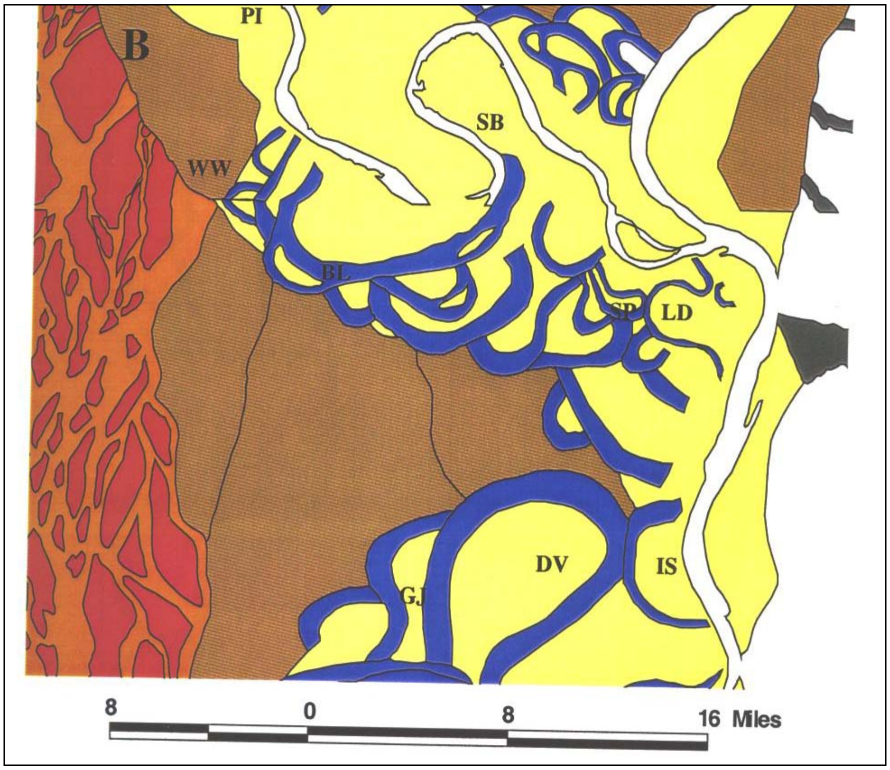

Figure 6. Geomorphic features near the confluence of the Mississippi and Ohio Rivers. Blue indicates abandoned channels of the Mississippi River; yellow indicates point bar deposits; and brown, red, and orange indicate valley trains of different ages (from Saucier 1994). Two letter abbreviations (e.g. "BL") indicate locations of 9 of the 17 study plots in this project relative to geomorphic features. (from Papon 2002)

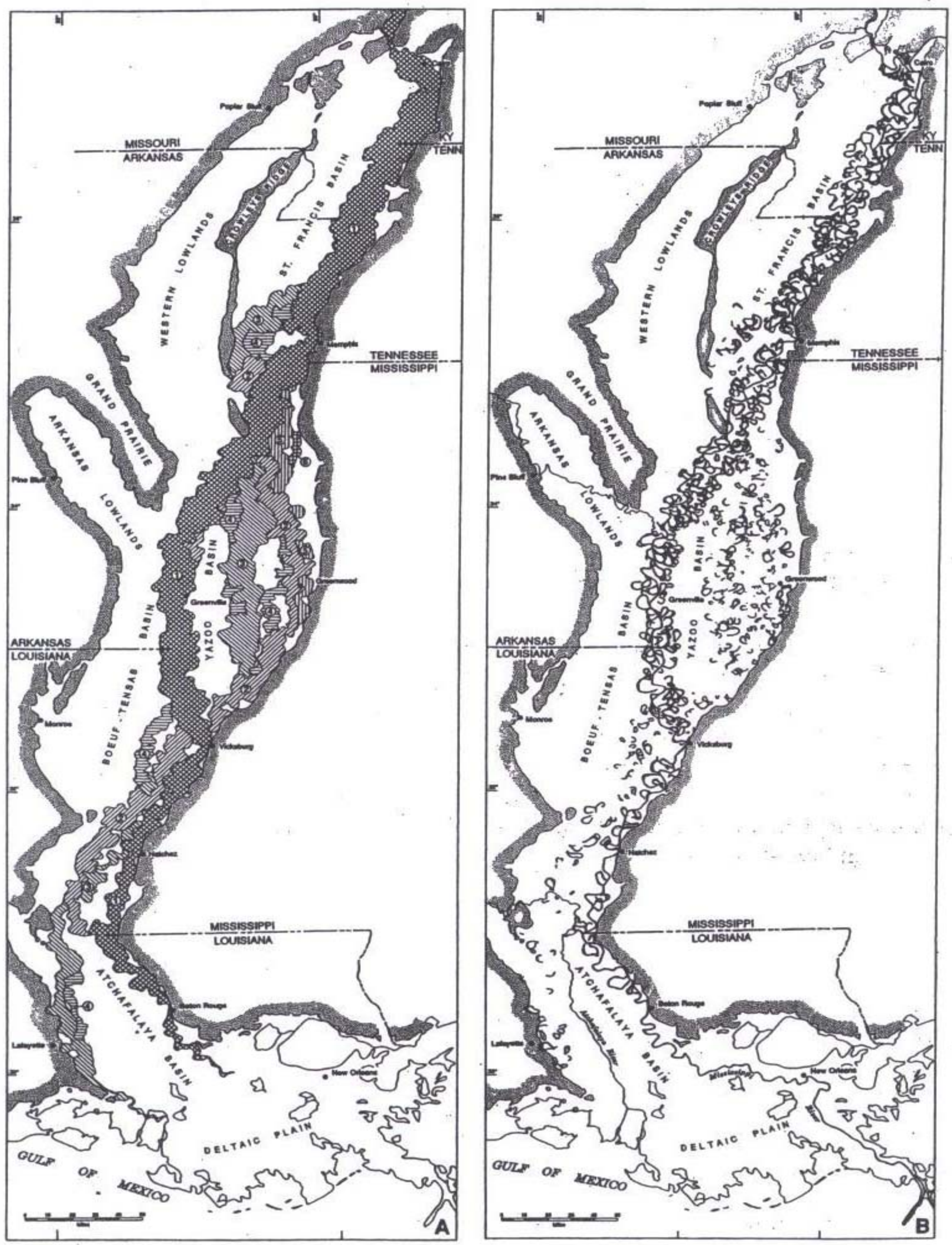

Figure 7. (A) Meander belts of the Mississippi River; number 1 refers to the most recent meander belt and number 6 refers to the oldest meander belt, and (B) the distribution of neck and chute cutoff abandoned channels (from Saucier 1994).

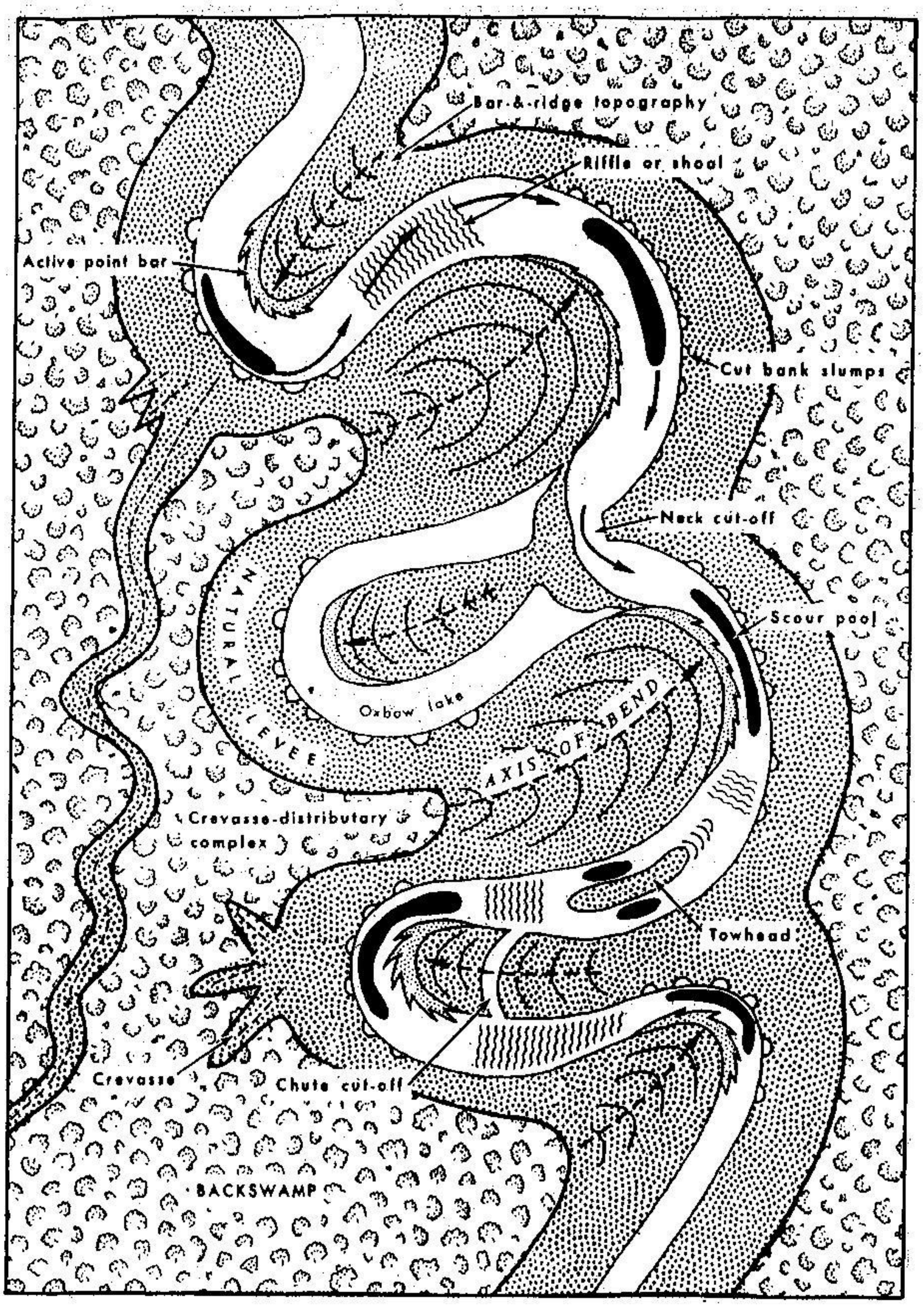

Figure 8. Common geomorphic features of the Mississippi Alluvial Valley (from Saucier 1994)

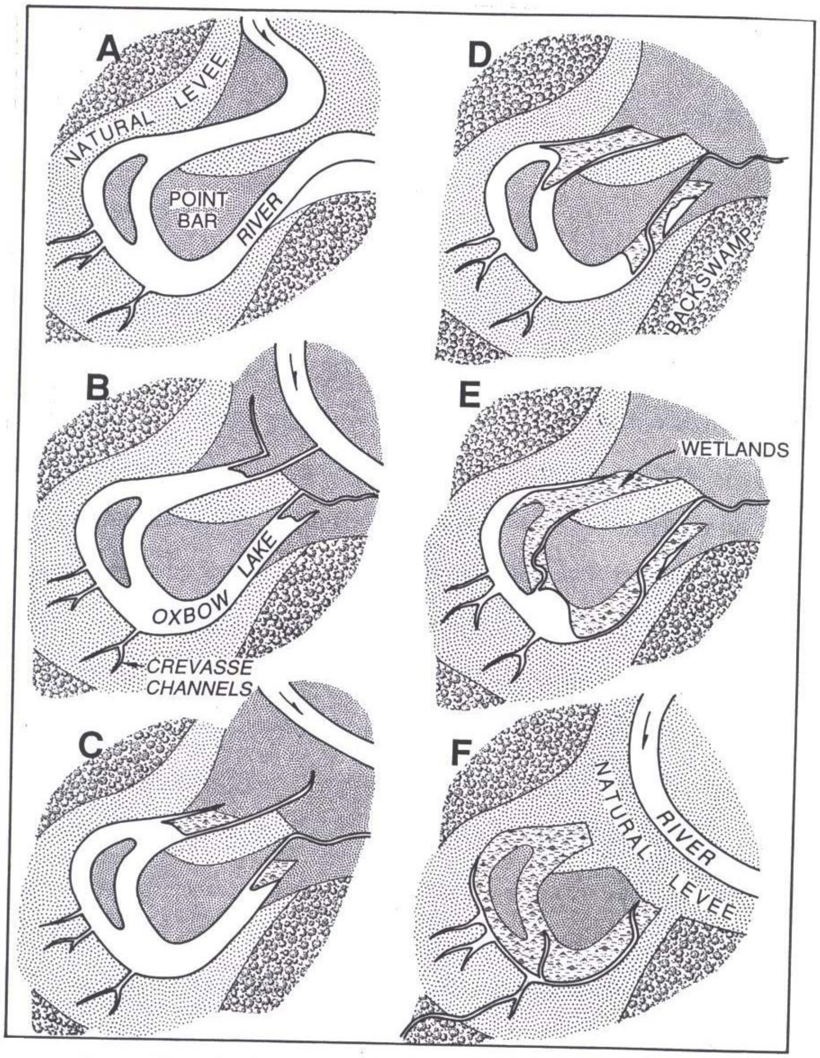

Figure 9. The life cycle of a typical neck cutoff in the Mississippi Alluvial Valley (from Saucier 1994). (A and B) Sand bars quickly form after a neck cutoff takes place, (C) batture channels develop which connect the abandoned channel to the active channel, thus aiding in deposition of sediment, and (D-F) the abandoned channel is eventually filled with sedimentation and converted to a hardwood swamp (from Saucier 1994).

These landforms tend to have a coarser texture than natural levees and tend to be relatively short-lived geomorphic features. Crevasses in levees can potentially develop into distributaries when flood flow is sufficient to carve a channel capable of carrying low to moderate flows (Saucier 1994). Over time, these smaller channels become abandoned or disconnected.

Point bar accretions are the deposition of coarse-grained soils on the bank opposite the river cut bank. Deposition of these coarse particles creates a series of rolling undulations commonly referred to as ridge and swale topography. The dynamic nature of these subtle rolling landscape features creates very localized variation in hydrology thus creating diverse vegetative communities in a relatively small area.

Abandoned channels result from meandering by the river channel as it attempted to shorten its course; these occur as either neck cutoffs or chute cutoffs (Fig. 9). Neck cutoffs occur when two bends of a river migrate in such a way that they intersect each other; these cutoffs result in the formation of an oxbow lake. Chute cutoffs occur when river flows occupy a swale and scour a major channel. Strong hydrologic links often exist between abandoned channels and the river, creating very dynamic hydrologic regimes in the abandoned channel. These hydrologic links typically lead to sedimentation and early succession into a hardwood swamp. When little hydrologic connection exists between the active channel and the abandoned channel an open water lake may form.

St Francis Basin

The MAV is divided into six lowland areas bounded by upland remnants, terraces, and ridges (Fig. 1). For this study, I concentrated on the northern reaches of the MAV, specifically the St. Francis Basin. The St. Francis Basin extends south from Cape Girardeau, Missouri along the Mississippi River to Memphis, Tennessee about 306 km (190 miles). All study sites were within the southeastern Missouri counties of Scott, Mississippi, New Madrid, and Pemiscot. The St. Francis Basin is bounded on the west by Crowley's Ridge (an upland remnant that once separated the main valley of the Mississippi River from the main valley of the Ohio River) and the Commerce Hills and on the east by the present meander belt of the Mississippi River (Saucier, 1994). Throughout the St. Francis Basin the Mississippi River floodplain has a relatively constant width of 64 km (40 miles). The northwestern two thirds of the St Francis Basin are characterized by Wisconsin-Age glacial outwash while the remaining third (southeastern) is characterized by Holocene Mississippi River meander belts (Saucier 1994). The main tributaries include Little River, Pemiscot Bayou, and the Tyronza River. Major geologic features of the St. Francis Basin are the Sikeston Ridge and the Charleston Fan. The Sikeston Ridge is a 48 km (30 mi) long remnant of Early-Wisconsin glacial outwash surrounded by Late Wisconsin Mississippi River glacial outwash (Saucier 1994). The Charleston Fan is a 259 km^2 (100 mi^2) unit of Late Wisconsin glacial outwash believed to have resulted from a pulse of melt water, that flowed through Thebes Gap (Saucier 1994).

Hydrology

Geomorphic features influence wetland soil processes, and hydrologic regimes define how water enters and moves through a system. An understanding of these hydrologic and geomorphic conditions is integral to developing management and restoration efforts.

Riparian forests and deepwater swamps constitute the most extensive wetland class in the United States (Dahl and Johnson 1991). The most extensive riparian ecosystem in the United States is the mesic BLH of the broad flat floodplain of the Mississippi River (Mitsch and Gosselink 1993). Bottomland hardwood forests are characterized by the following features (Huffman and Forsyth 1981):

1. Habitat that is inundated or saturated by surface or groundwater periodically during the growing season

2. Soils within the root zone become saturated periodically during the growing season.

3. Prevalent woody plant species associated with a given habitat have demonstrated characteristics, because of morphological and/or physiological adaptation(s), to survive, achieve maturity, and reproduce in a habitat where within the root zone may become anaerobic for various periods during the growing season. Continental climate determines precipitation patterns.

Precipitation in the major alluvial floodplains of the southeastern United States ranges from 120 cm (48 in) to 160 cm (64 in) / year and is generally highest in the months of March, April, and May. Precipitation alone is not a reliable indicator of flood duration or magnitude (Messina and Conner 1998). Precipitation drives the duration and extent of flooding but the character of a watershed influences river flooding. Thus localized flooding is determined by the elevation of the watershed, size of the watershed, and its slope (Table 4, Bedinger 1981, Mitch and Gosselink 2000).

In the MAV, both on and off-site precipitation influences the spatial and temporal patterns of wetland flooding. Flooding regimes in BLH forests are highly dynamic, variable within and among years, dependent upon elevation relative to the river, driven by floodwater from a variety of on-site and off-site sources, influenced by soils and vegetation, and affected by anthropogenic alterations such as levees and ditches (Heitmeyer et al. 1989). Soil saturation is variable annually and seasonally with winter and spring months typically representing the wettest period. Evapotraspiration (ET) is highest when temperatures are high during the growing season, but minimal during the dormant season. When ET is high, precipitation is less likely to accumulate on the surface. ET directly affects soil saturation, as ET rates decrease less water is removed from the system through evaporation and plant respiration reduces removal of water. Soils become increasingly saturated with precipitation and water begins to form pools in small depressions. The combination of precipitation and decreased ET influence the degree of surface flooding. Surface flooding occurs where precipitation is high and ET is low during the dormant season. Soil moisture also varies across topography. Low-lying areas experience longer more frequent flood periods. In contrast higher elevations experience greater temporal variation in flood frequency and duration.

Table 4. Relationship of Drainage Basin Size to Duration of Flooding of Bottomland Forests in Arkansas

Drainage basin area, km^2	Annual flooding duration (percent of time)
777	5 – 7
1,295 – 1,813	10 – 18
Several tens of thousands	18 - 40
Bedinger 1981, Mitch and Gosselink 2000	

Anthropogenic Alteration

Before European settlement, the MAV consisted of approximately 8.5 million ha of BLH and was the largest continuous wetland system in North America (The Nature Conservancy 1992, Wierner et al. 1998). The vegetative community of the area was historically a mixed BLH comprised of over 100 species of woody plants (Haynes 1988; Fig. 10). In its natural state the MAV was a hydric system with soils completely inundated with water for a portion of each year (Fig. 11). Vegetation distribution in this system is determined primarily by physiological adaptations that allow different plants to survive different hydrologic regimes. MAV wetlands are identified by a dominance of hardwood forest species however some gymnosperms are present, primarily the bald cypress (*Taxodium distichum*), that occupies the lowest and wettest areas. Forest stand structure is highly variable. The presence and density of understory species are determined by the frequency and type of disturbance. Old growth BLH stands are typified by sparse understory vegetation because of low light penetration. Early successional species, including dogwood (*Cornus spp.*), poison ivy (*Toxicondendron radicans*), trumpet creeper (*Campsis radicans*), and hawthorn (*Crataegus spp.*) occur within gaps created by natural or man induced disturbance. On wetter sites where flooding is more frequent and of longer duration buttonbush is prevalent.

Floodplain systems rank among the most altered systems worldwide. Arguably, the MAV is one of the most highly altered systems in the United States. Today 81 percent of MAV bottomland forests have been converted to other land uses (Haynes 1988). In southeastern Missouri, loss of BLH exceeds 95% (Korte and Fredrickson

1977). Because of high soil fertilities, floodplains were among the first areas to be converted to crop production despite the threat of flooding and crop loss (Dahl and Johnson 1991). Despite man's desire to farm fertile floodplains, the MAV was one of the last regions of the United States to be converted to row crops.

By the early 1800's the first agricultural development in southeast Missouri began on the highest elevations in the floodplain. In 1811 and 1812, two separate earthquakes shook southeast Missouri, and many left the region, temporarily slowing human encroachment. Historian Thad Snow (1954) described the "Delta" region of southeast Missouri as "America's last agricultural frontier" because of the impenetrable swamps, clouds of biting insects, poisonous snakes, and seemingly endless forests.

When Missouri became a state in 1821, the desire to farm the great swamp of southeast Missouri was revitalized and drainage of the "Bootheel" became a priority (United States Department of Agriculture Soil Conservation Service 1981). To remove floodwaters extensive networks of ditches and canals were dug. Early drainage attempts proved successful. By 1901 six drainage districts were developed in Mississippi County alone. Special agent John Nolen in his report to the forty-seventh Missouri General Assembly dated January 1913 captured the emotion of the time: "The men who are pushing forward the movement to have the four million acres of swamp and overflowed lands in Missouri reclaimed are laying the foundation for the most beneficent and enduring monument ever erected. Long after the hand of time has erased from view the other monuments this one will stand, and so long as man kind shall inhabit that state each succeeding generation will reverence the names of those who were instrumental in bringing about the reclamation of these precious lands." (Nolen 1913). In 1913 283,400 ha (700,000 acres) of Missouri's BLH had been modified by drainage or levees (Figs. 12 - 14). By 1928 development of the floodplain resulted in 1,410 km (875 mi) of drainage ditches, which opened opportunities to convert over 202,429 ha (500,000 ac) of forestland to agriculture (United States Department of Agriculture Soil Conservation Service 1981). Today, 9,121 km (5,668 miles) of ditches have been dredged to drain wetlands in southeastern Missouri (Figs. 12 - 13).

Harvest of forest resources followed the receding swamp, claiming the ancient stands of bald cypress, tupelo (*Nyssa aquatica*), sweet gum (*Liquidambar styraciflua*), and oak (*Quercus spp*.). Draining and deforestation were not confined to the lowlands of south Missouri, in the 1930's logging reduced the 8.5 million ha (21 million ac) of forest in the MAV to 4.8 million ha (11.9 million ac), and by the 1980's BLH in the MAV had been reduced to 1.7 million ha (4.2 million ac) (Allen and Kennedy 1989).

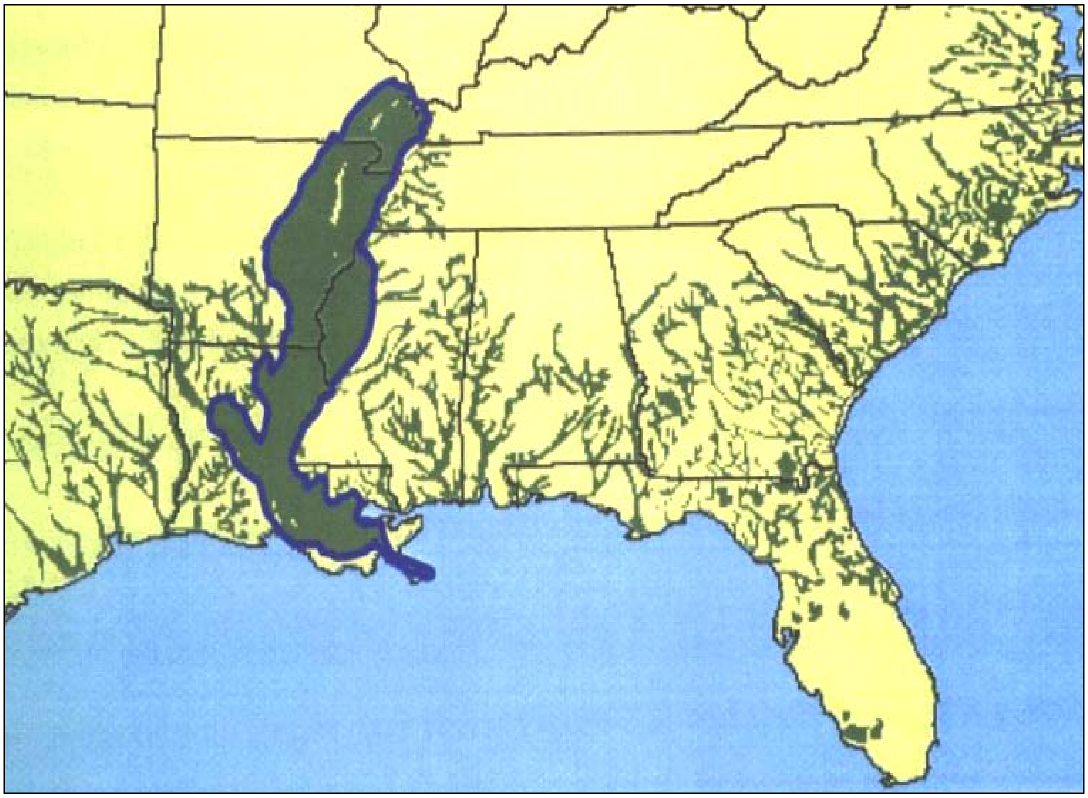

Figure 10. Historical bottomland hardwood forest of the Mississippi Alluvial Valley (outlined in blue) – the most extensive class of wetlands in the United States (from Putnam et al. 1960).

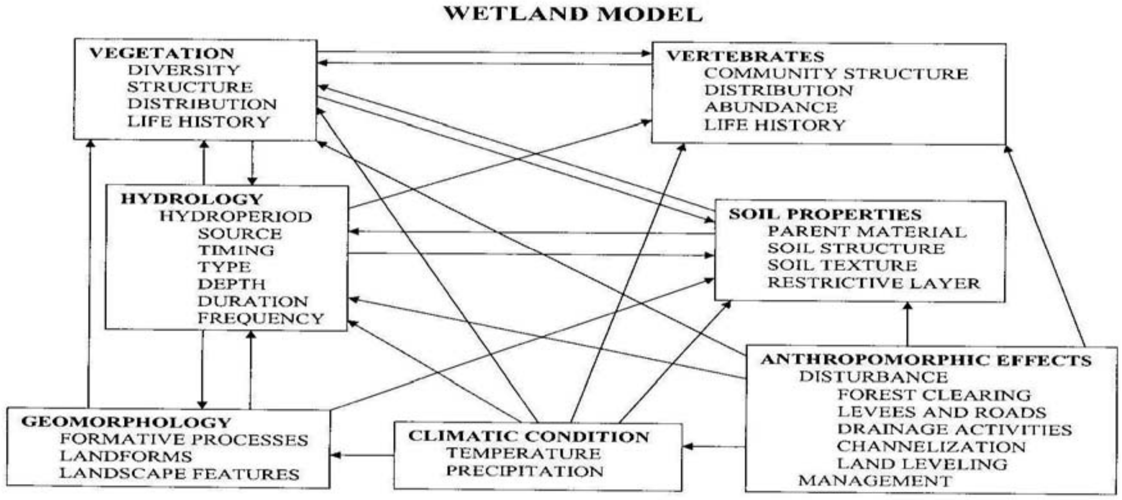

Figure 11. Abiotic and biotic factors of big-river floodplain systems important in structuring vegetation and vertertebrate communities.

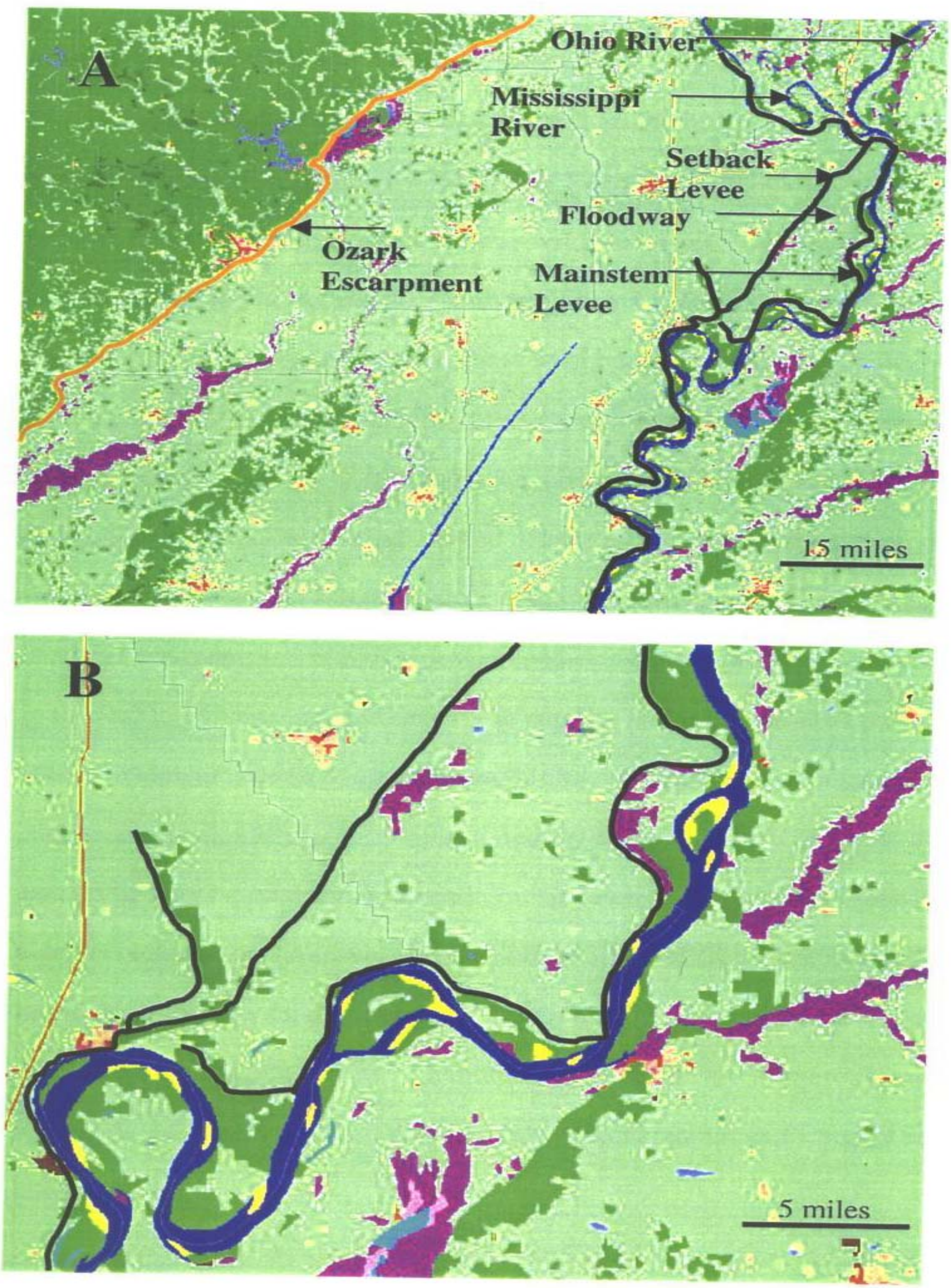

Figure 12. (A) Extent of BLH forest in relation to the mainstem levee system in southeastern Missouri (purple and dark green indicate forest; black indicates levees), and (B) habitat fragmentation near New Madrid, MO (from CARES and USGS 2001).

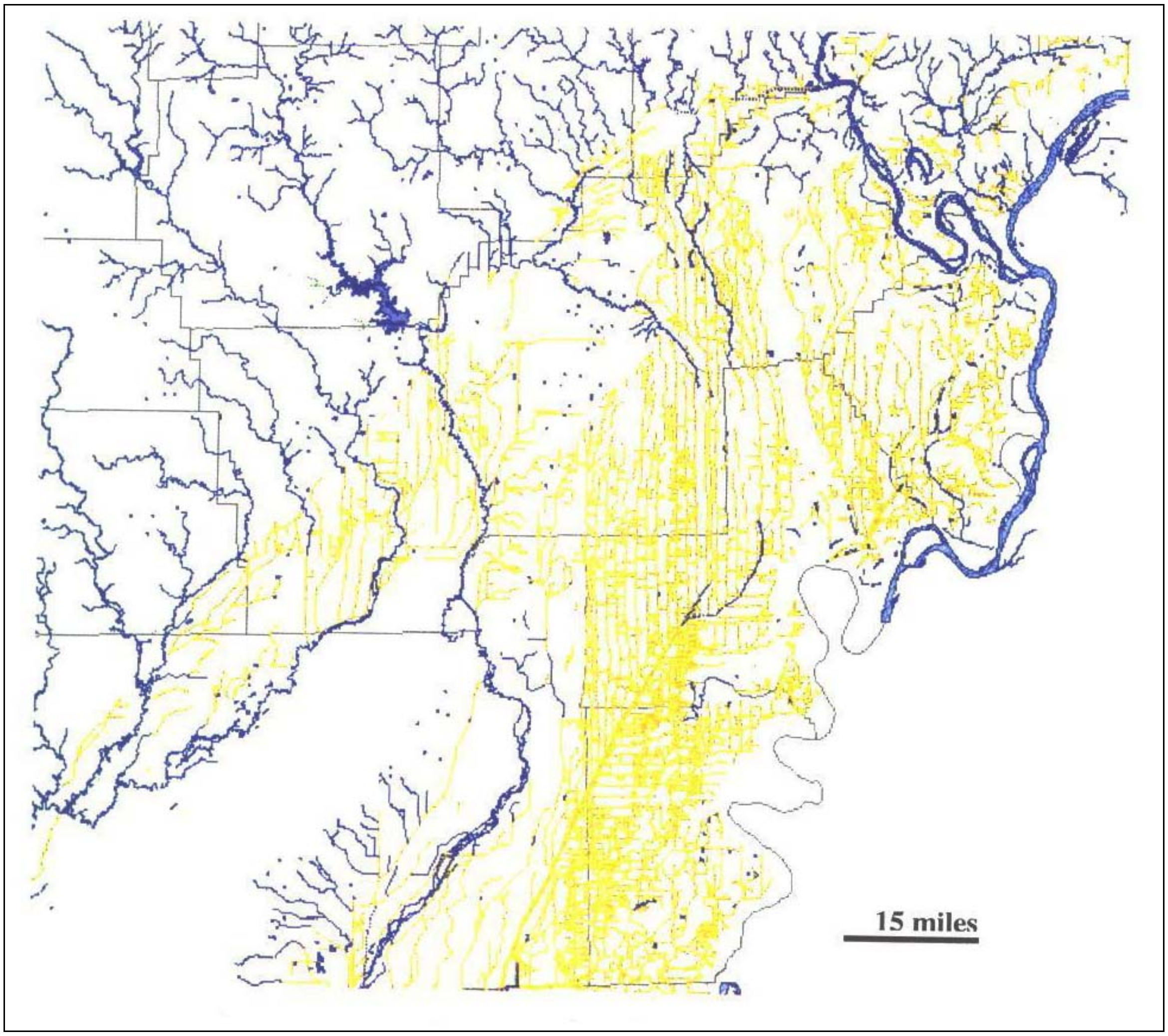

Figure 13. Ditch and canal network in southeast Missouri. A total of 9,834 km (6,107 mi) of ditches and canals (yellow lines) were developed in southeast Missouri during the early 1900's to facilitate drainage (from CARES et al. 1999).

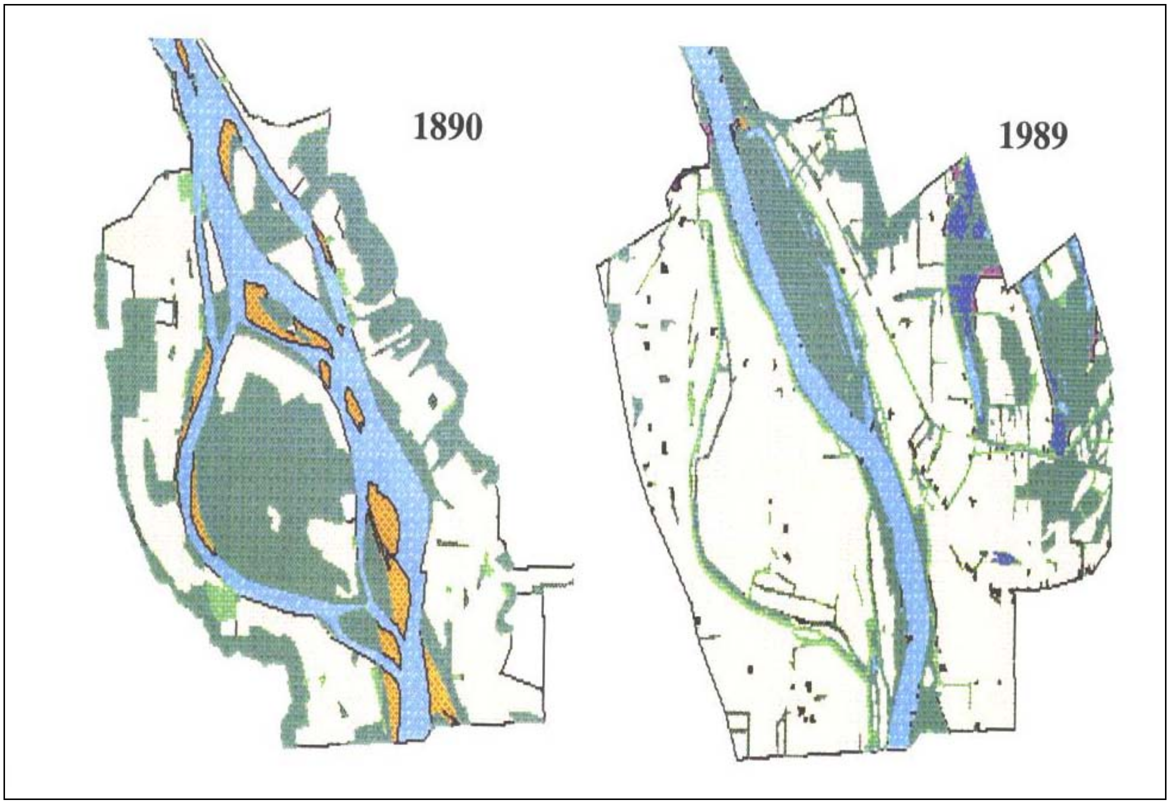

Figure 14. The effects of channelization on the Lower Mississippi River at Powers Island (near Commerce, Missouri), One of the study plots in this project (from Wiener et al. 1998, Papon 2002). Blue indicates active river channel, yellow indicates sand bars, green indicates BLH forest, and white indicates open areas of cropland.

CHAPTER IV

METHODS

STUDY AREA AND DESIGN

Satellite imagery of the MAV and study area in southeast Missouri were obtained from 1993 LANDSAT 4 TM images (Twedt and Loesch 1999). Using these data, 250 4-square mile landscape blocks within the Holocene active meander belt of the Mississippi River (Fig. 6) between Cape Girardeau, Missouri and the Arkansas state line were identified. A stratified random sample of 15, 1034 ha (2560 ac, 4 mi) plots from this pool were selected and used to sample herptiles. Site distribution throughout counties in southeast Missouri included Scott (2 sites), Mississippi (6 sites), New Madrid (6 sites), and Pemiscott (1 site) (Fig. 15). Elevations ranged from 100 m (330 ft) msl at the Powers Island (PI) plot (Scott County) to 85 m (280 ft) msl at the Girvin (GV) plot (Pemiscott County) (Fig. 15; Saucier 1994). Criteria for the selection of the landscape study sites included:

- Within the 100 year floodplain of the Mississippi River in southeastern Missouri
- 4-square mile (1034 ha) landscape blocks
- Sites both outside and within mainstem levees of the Mississippi River
- Sites if possible should be privately owned to avoid those areas undergoing active habitat enhancement or management
- Portions of sites that included public land did not have active water or timber management
- Sites were under normal agricultural crops and farming practices (i.e., no unusual or specialty crops)

- There should be only limited tree harvest in forest patches

The extent of forest loss, the distribution of habitat fragments, the matrix of surrounding forest fragments, and the juxtaposition of habitats were determined for each study plot (Fig. 15, Table 5). Landscape plots were ranked according to percent forest and divided into three corresponding forested categories: low (< 4% total forest), medium (5 to 20 percent total forest), high (> 20% total forest) (Appendix B).

Landownership of each plot was determined using Farm Service Administration (FSA) farm compliance maps and county plat maps. All landowners and contract farmers were contacted in person before the initiation of the study and given information packets detailing research activities and contact numbers for all investigators. Support within the local farming community for this research effort was mixed. Concerns stemmed from localized fears that increased regulation on their farming activities might result from the research findings. Regional cautiousness toward government agencies and research required positive interactions with landowners. All landowner requests were addressed as sampling procedures were developed. Primary concerns of most landowners included:

- Driving on farm access roads and levees during inclement weather conditions and potentially causing damage
- Walking in fields after crops had been planted
- Research activities interfering with farm operations.

Where sampling procedure could potentially compromise landowner relationships sampling was not conducted or techniques were modified to satisfy landowner concerns. Researcher presence on each site was limited to no more than 3 visits each month.

Ultimately, permission for access to private land on the study plots was high with approximately 90% of the landowners cooperating throughout the study. Landowner reluctance and concern for research on properties required the removal of 2 of the original 15 sites; these sites in Mississippi County were North Ten Mile (NTM) and Brewer Land Company (BLC). When such problems arose, alternative sites were drawn from the original landscape block pool. Girvin (GV) Replaced NTM and Sunburst (SB) replaced BLC in Mississippi County. Brewer Land Company was removed early in the study development process; North Ten Mile however was pulled during the spring 1999 season. These changes in study plots resulted in a postponement in the timing of data collection on the Girven and Sunburst sites during the 1999 field season.

Table 5. Habitat types (ha) within each 1,034 ha study plot located within the 100-year floodplain of the Mississippi River in southeastern Missouri. TF=Total Forest+Sum of NF,AF, and ST. (From Papon 2002)

PLOT	NF	AF	ST	AG	SS	OW	TF	% FOREST	GROUP
BL	131.13	0	12.18	803.5	65.62	23.57	143.31	13.833%	Medium
DO	24.57	0	1.49	1001.97	0	7.97	26.06	2.515%	Low
DP	592.08	16.52	0	324.7	0	102.7	608.6	58.745%	High
DV	0	0	15.33	1015.73	0	4.94	15.33	1.480%	Low
EN	126.44	0	49.82	805.73	27.29	26.72	176.26	17.014%	Medium
GJ	111.44	0	16.7	864.13	28.82	14.91	128.14	12.369%	Medium
GV	271.99	36.09	3.69	689.05	5.59	16.34	325.02	31.373%	High
HM	8.07	0	48.29	1017.38	0	6.86	11.76	1.135%	Low
LD	3.423	0	37.88	964.907	0	29.79	41.303	3.987%	Low
PI	0	0	16.48	995.3	0	24.22	16.48	1.591%	Low
PP	18.29	0	75.89	929.62	0	12.2	94.18	9.091%	Medium
SB	174.81	0	37.03	615.6	0	208.6	211.84	20.448%	High
SP	9.64	0	4.59	1017.52	0	4.25	14.23	1.374%	Low
WC	116.59	55.78	38.97	753.26	0	71.4	211.34	20.400%	High
WL	171.99	111.5	80.02	637.05	0	35.41	363.54	35.091%	High
WW	191.82	0	22.5	804.25	5.7	11.73	214.32	20.687%	High
TOTAL	1952.3	219.9	460.9	13239.7	133.0	601.6	2601.7	15.70%	

NF = Natural Forest; AF = Agroforestry; ST = Strip Cover;
AG = Agricultural Fields; SS = Shrub/Scrub Swamp; OW = Open Water

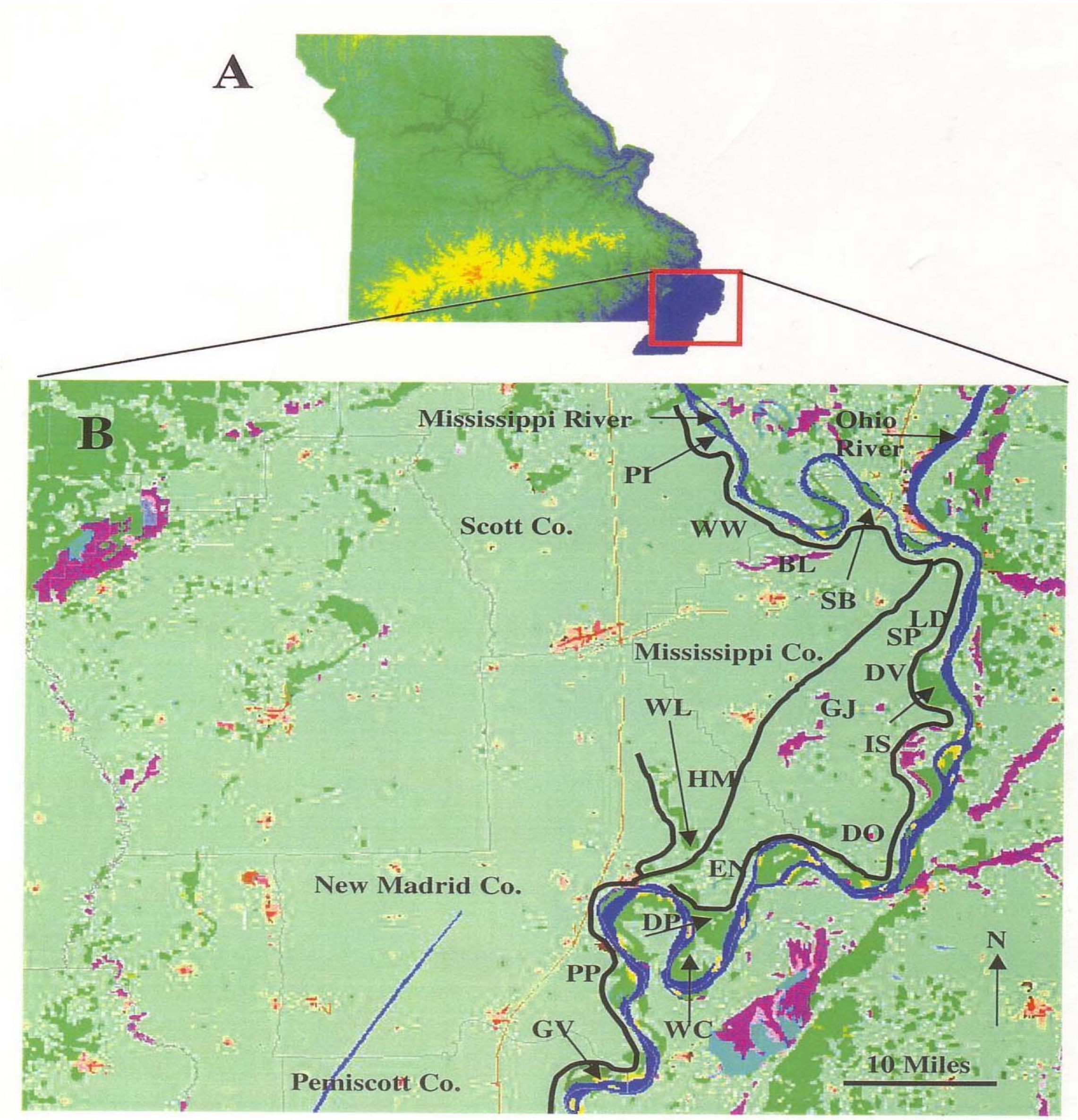

Figure 15. (A) Location of study area in the state of Missouri, and (B) location of 17 plots (e.g., PI) in relation to the Mississippi and Ohio rivers, forest cover, levees, and counties. Dark green and purple areas indicate remnant forest and black lines indicate levees. (Papon, 2002)

HERPTILE SAMPLING PROCEDURES 1999

This study was designed to identify the presence and abundance of members of the Orders Caudata, Salientia, Testudines, and Squamata that occur in southeastern Missouri (Appendix A; Johnson 1997). Call counts, larval sampling, cover boards, and visual scans were utilized to assess distribution of the herptile community. Sampling techniques for herptiles were guided by Foster et al. (1994) and Karns (1986) (Table 6).

Table 6. Sampling techniques for Herptiles (Foster et al. 1994, Karns 1986)

Technique	Information gained	Time	Cost	Personnel
1. Complete species inventories	Species richness	High	Low	Low
2. Visual encounter surveys	Relative abundance	Low	Low	Low
3. Audio strip transects	Relative abundance	Medium	Medium	Low
4. Quadrat sampling	Density	High	Low	Medium
5. Transect sampling	Density	High	Low	Medium
6. Patch sampling	Density	High	Low	Medium
7. Straight-line drift fences and pitfall traps	Relative abundance	High	High	High
8. Surveys at breeding sites	Relative abundance	Medium	Low	Low
9. Drift fences at breeding sites	Relative abundance	High	High	High
10. Quantitative sampling of amphibian larvae	Density or relative abundance	Medium	Medium	Medium

Selection of target species for this study was based on historical distribution and occurrence for herptiles in Missouri (Johnson 1997, Table 7). Target species included obligate floodplain species and those with a cosmopolitan distribution throughout Missouri. I hypothesized that species more obligate to BLH ecosystems likely would be affected by habitat loss more than those found throughout the state. Although a suite of target species was selected, all herptiles encountered were documented. The diversity of the contemporary herptile community in southeast Missouri dictated that sampling techniques include a cross section of approaches to identify representative herptile population. Because the effectiveness and logistics associated with sampling techniques were unknown in 1999, techniques were tested during the first field season.

Table 7. Species of interest, expected timing and technique for sampling.

Species of interest	**Sampling technique**	**Sampling month**
Illinois chorus frog*	Call counts	February
Western chorus frog	Call counts	February
Northern spring peeper	Call counts	February
Eastern tiger salamander	Visual encounter surveys**	March
Smallmouth salamander	Visual encounter surveys**	March
Spotted salamander	Visual encounter surveys**	March
Eastern American toad	Call counts	March
Pickerel frog	Call counts	March
Green frog	Call counts	April
Gray treefrog	Call counts	April
Eastern spadefoot toad*	Call counts	April
Bullfrog	Call counts	May
Green treefrog*	Call counts	May
Eastern narrowmouth toad*	Call counts	May
Southern painted turtle*	Aquatic sampling (Scan surveys)	May
Mississippi mud turtle*	Aquatic sampling (Scan surveys)	May
Western chicken turtle*	Aquatic sampling (Scan surveys)	May
Red-eared slider	Aquatic sampling (Scan surveys)	May
Central newt	Aquatic sampling (seining/dip net)	May
Western mud snake*	Visual encounter surveys**	May
Green water snake*	Visual encounter surveys**	May
Broad-banded water snake*	Visual encounter surveys**	May
Midland brown snake*	Visual encounter surveys**	May
Western ribbon snake*	Visual encounter surveys**	May
Western cottonmouth*	Visual encounter surveys**	May
Black rat snake	Visual encounter surveys**	May
Eastern hognose snake	Visual encounter surveys**	May
Speckled king snake	Visual encounter surveys**	May
Three-toed box turtle	Visual encounter surveys**	May
Marbled salamander	Visual encounter surveys**	October
Mole Salamander*	Visual encounter surveys**	October

* Species found primarily in southeastern Missouri

** Cover boards used in conjunction with visual encounter surveys

Call Censuses

In spring, male frogs vocalize to signal their location and availability to prospective females. Calling is either by individuals or from gatherings (choruses) at breeding sites. Calling activity for most species is greatest between sunset and midnight on warm calm nights. Vocalizing frogs and toads are surveyed at night during the reproductive period thus this behavior provides one of the most effective ways to sample anuran populations (Zimmerman 1994). Furthermore, mapping distributions and estimating relative abundance of calling males using call counts is comprehensive and powerful (Zimmerman 1991). Call censuses allow the surveyor to sample all habitats, micro-habitats, and forest strata equally; arboreal and fossorial species can be counted as easily as ground dwellers, and concealed species are included as easily as unconcealed species (Zimmerman 1994).

Call surveys were the primary technique used to monitor anuran populations in both 1999 and 2000. I randomly selected 42 call stations within each 1034 ha study plot, each station was stratified according to habitats and spaced far enough apart to ensure independence (Engel-Wilson et al. 1981 and Hanowski et al.1990). Call censuses were performed during spring (April – May, 1999 and 2000); each station was visited at least once each month. Call surveys began after sunset and continued until midnight. Surveys were not conducted when wind speeds were greater than 17 km/hour (approximately 10 mi/hr) or if temperatures dropped below 0 ^{o}C (32 ^{o}F). At each station vocalizing species were identified and abundance estimated based on a scale of 1 individual, 2-5 individuals, or >5 individuals calling. For each census location, habitat type, vegetative community, and presence of surface water was documented. Weather conditions and moon phase also were recorded.

Visual Encounter Surveys and Artificial Cover

Several research efforts indicated that artificial cover provides an index to populations of terrestrial herptiles that normally use surface cover for refugia (Fellers and Drost 1994). Visual encounter surveys (VES) are useful for rapid evaluation of herptile populations in structurally uniform habitats where visibility is good (Crump and Scott 1994). While surveying amphibian communities in Florida, Campbell and Christman (1982) compared results of VES with three other techniques (road cruising, quadrat searches, and pitfall arrays). They found that VES accounted for 68% (15) of the 22 total amphibian species surveyed. Visual encounter surveys are particularly useful on rainy or foggy nights when animals travel from underground retreats (Hairston 1980; Pough et al. 1987, Nishikawa 1990).

Because the southeast Missouri study area was large, sampling time was limited to survey landscape blocks. Thus VES seemed to provide a feasible method to quickly assess herptile populations. Visual surveys were conducted the day following the nocturnal aural census on individual plots. To increase sampling efficiency, VES surveys were used in combination with artificial habitat (cover boards). Traditionally VES are conducted using either randomized walk or transect study design (Crump and Scott 1994). Traditional VES techniques were modified to include the distance between artificial habitat points as the VES area. The surveyor searched by moving systematically among cover board locations documenting individuals as they were encountered. At the cover board location, a thorough search of the surrounding area was conducted for 10 minutes. Although the technique is fairly new, it has been used successfully in California, Georgia, and British Columbia (Fellers and Drost 1994). Several advantages of using this technique to index population sizes include standardization of samples, reduction in observer variability, limited disturbance to cover, minimal financial and time investment, and easy maintenance.

Twenty-four random locations were selected for permanent cover board stations in study plots, however, agricultural habitat was not sampled using cover boards to avoid interfering with cropping practices. Thus sample locations were limited to 18. A cover board station was an untreated 80 x 120 x 1.25 cm plywood board. Cover board stations were stratified according to habitat type. Each station was checked once each month during the day. The vegetative community, and the presence or absence of water was recorded at each cover board location. This microhabitat information was important in understanding if the cover boards were supplying potential habitat. If boards were overtopped with water they only were usable by the most aquatic species. On drier sites cover boards provided potential shelter for a different suite of species. Cover board sampling to determine presence and abundance of target species was conducted during spring (April and May) and fall (September) 1999 and 2000 (Table 5).

Aquatic Larval Sampling

Sampling aquatic environments for larval amphibians is a fast and relatively thorough quantitative indication of the presence of amphibian populations. However, there is not equal catchability of individuals (Shaffer et al. 1994). Given the large size of the study plots, detailed sampling of specific aquatic habitats was important. Thus all wetland habitats were sampled for larval amphibians to determine their distributions (Alford 1986). Frog call census stations were visited during the day following the evening call census. All aquatic habitats near these stations were sampled to capture aquatic adults as well as larval forms. Larval forms were sampled with 2, 1 m long sweeps using a 1 m wide dip net at 2 sample points in each selected wetland. Larval presence also was sampled with VES and artificial habitats. As the surveyor walked between cover board stations all aquatic habitats encountered were sampled. Small water areas including tree holes, blowovers, and puddles were sampled using a small hand held dip net. Where possible, 20 larval samples were taken within each 1034 ha plot. Larval amphibians were fixed in a 10% formalin solution upon capture (McDiarmid 1994) and identified with keys (Altig 1970, Altig and Ireland 1984). Larval sampling was conducted during spring (April and May) and fall (September) 1999 and 2000.

Scan Surveys

Numerous sloughs, backwaters, creeks, and bayous provide ideal habitat for turtles and aquatic snakes. Because turtles and aquatic snakes make up a large portion of the herptile community in southeast Missouri, information on the distribution and abundance of these populations was collected. Sampling different habitats for turtles require several techniques including hoop nets, mudding, and self contained underwater breathing apparatus (SCUBA). Because of the large size of the study area, new approaches were required to obtain data on the diversity and abundance of the aquatic reptile community. Ground survey techniques similar to those used to census bird communities allow the surveyor to scan basking turtles (Karns 1986). Where possible 10 wetland sites were randomly selected for scan samples in each 1034 ha study area. A pair of observers scanned all basking habitat within sight of a predetermined observation point using a window mounted Baush and Lomb (15 x 45) spotting scope. Each observation site was visited once each month in April and May to identify the presence and abundance of species.

HERPTILE SAMPLING PROCEDURES - 2000

The goal of this study was to determine the distribution of herptiles among different habitats throughout forested landscapes of varying forest cover. Thus I evaluated the results from the 1999 sampling techniques before initiating work in 2000. Results from 1999 indicated the best data were derived from call counts, however calling response and hydrologic condition changed the time required to sample all 15 study plots with the 1999 sampling strategy. These changes in hydrologic conditions in combination with the intensity of selected behavior compromised understanding calling chronologies and the effects that forest cover and habitat might have on populations. Especially problematic was the ineffective results from sampling techniques in determining faunal and habitat interactions. The inadequacies of the sampling techniques were related to the secretive nature of many herptile species as well as their patchy distribution in this highly modified system. After testing the selected techniques used in 1999, it was clear that implementation of a detailed sampling design to gain an understanding of herptile populations at this large scale would require more personnel than available funding could support. Furthermore, landowner conflicts would likely result if sampling intensity were increased because more time would be required on each property.

A road survey sample technique was used to determine the relative abundance of Illinois Chorus Frogs in southeast Missouri (Johnson 1997). I modified this sampling design to develop a protocol for sampling anurans on my study plots in 2000.
This change in sampling design narrowed data collection to Anuran species. Thus the total number of sample days per site was increased, while the number of points per plot and habitat type decreased.

In 2000, a minimum of 6 sampling point census stations were randomly selected within each 1034 ha study site, stratified according to habitats, and spaced far enough apart to ensure independence. All call stations were near roadways allowing observers to move quickly between call stations. The study area was divided into sample units (North and South) with one unit surveyed night one and the second unit sampled night two. Surveys were initiated at sunset and continued until 12:00 AM or until the sample route was completed whichever came first. Surveys were not conducted when wind speeds exceeded 17 km/hr or the temperature dropped below 0^{o}C (32^{o}F). At each call station, vocalizing species were identified and abundance estimated, in addition, habitat type, and the presence or absence of water was documented. Sampling was conducted bi-weekly from March through June (3/3/2000 – 6/2/2000).

Early spring (March 3 – March 17) sampling focused on Illinois chorus frog (*Psuedacris streckeri illinoensis*) and the upland chorus frog (*Psuedacris triseriata feriarium*). Mid-spring (March 24 – April 14) sampling matched the expected calling periods for the eastern American toad (*Bufo americanus americanus*). Late spring (April

21 – May 12) sampling focused on Fowler's toad (*Bufo fowleri*), bronze frog (*Rana clamitans clamitans*), Cope's gray treefrog (*Hyla chrysoscelis*), and eastern spadefoot toad (*Scaphiopus holbrookii holbrookii*). Sampling in early summer (May 19 – June 2) identified the presence and abundance of bullfrog, (*Rana catesbeiana*), green treefrog (*Hyla cinerea*), and eastern narrowmouth toad (*Gastrophryne carolinensis*).

Analysis

Data analysis was conducted using a split-block and time analysis of variance. All landscape study sites were stratified by land cover and use. A 1-factor analysis of variance on %-forested cover was used to test each of the stated objectives with an P-value of 0.05.

CHAPTER V

HYDROLOGIC CONDITIONS DURING THE STUDY PERIOD

The distribution and duration of water on a landscape dictates how and when an organism uses a system. In the case of herptiles, water availability dictates the abundance of prey, where animals can over winter, where they can reproduce, where young can grow and mature, and the types and effectiveness of predators. Dependence on water throughout the life cycle varies greatly across the diversity of herptile species (Table 1 - 3).

New Madrid, Missouri is centrally located in my study area and provides a reasonable model of the regional climatic conditions within the area of investigation. Climatic data were summarized by the High Plains Regional Climate Center (HPRCC) (Figure 16) over a 30-year period (1970-2000). These data illustrate the long-term average climate for the region. Averages are useful in understanding climatic variation throughout an annual cycle, however they fail to capture yearly and monthly variation. Based on the 30-year average, spring precipitation was highest in late April and early May (7.59 cm – 10.13 cm). The 30-year average low temperature for April was 13°C and the average high temperature was 33°C. The 30-year average low temperature for May was 23°C and the average high temperature was 43°C.

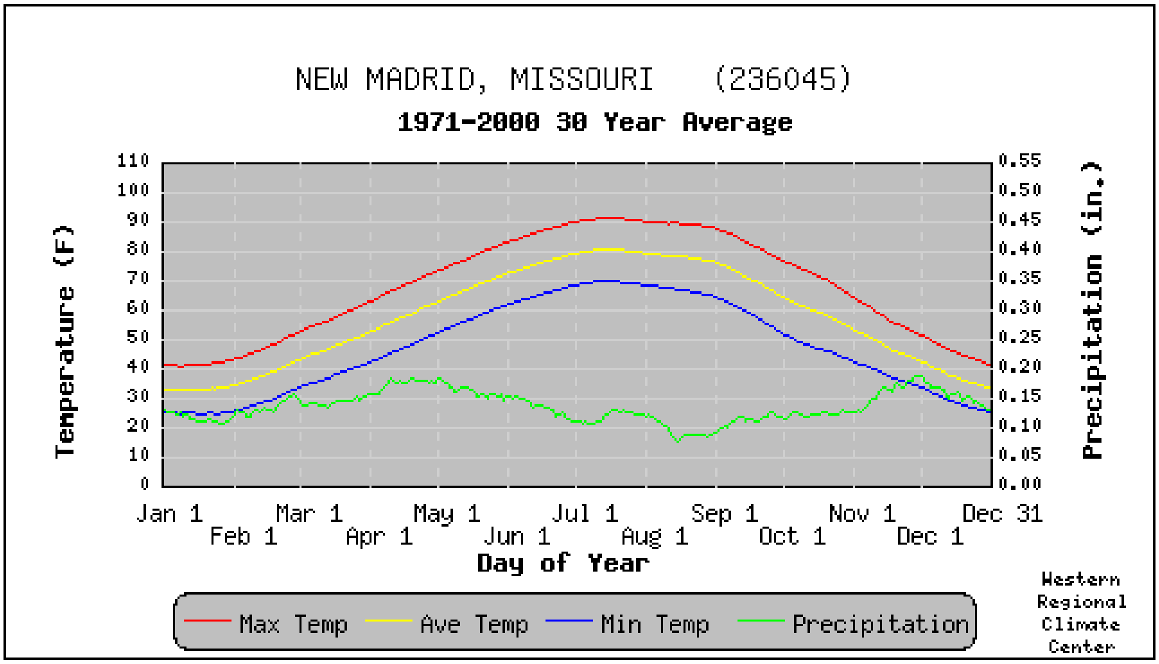

Figure 16. 30-Year daily climate average for New Madrid Missouri

Hydrologic conditions in 1999

In 1999 sampling was conducted during sample periods in April and in May. During each sample period the current habitat condition was described including the presence of surface water at each of the 42-point count stations within each of the 15 study plots. The presence or absence of water was used as the basis for developing a hydrograph for each sample period that identified the presence of water in each habitat type. These hydrographs illustrated the temporal and spatial diversity of water availability throughout the study area (Fig. 17).

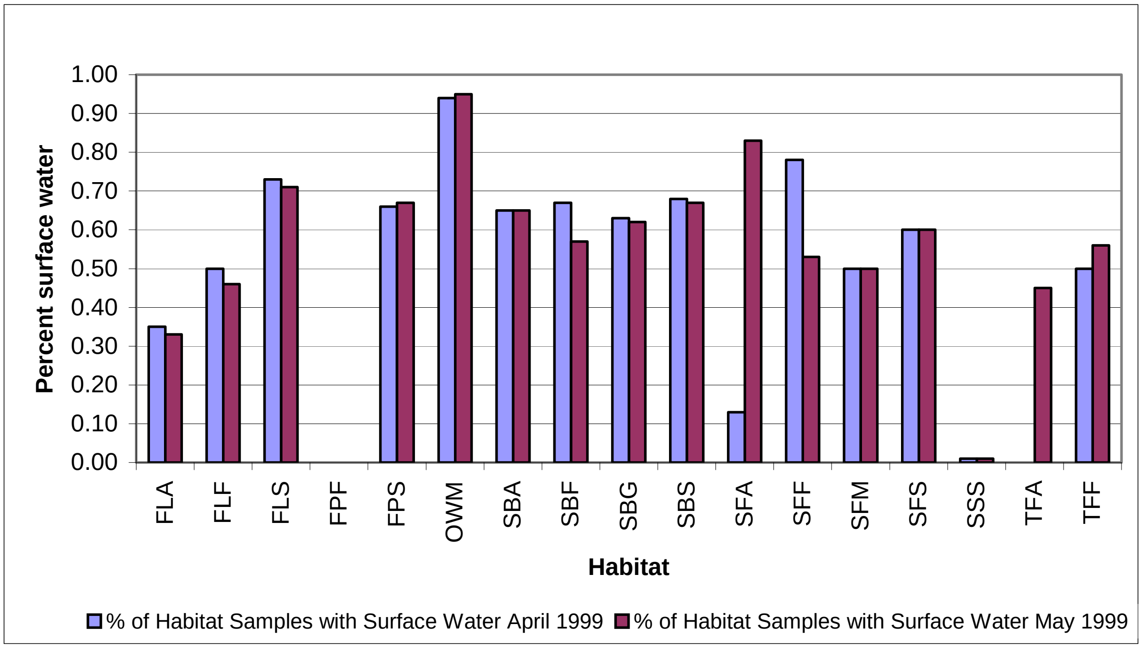

Figure 17. Comparison of the presence of water on habitat types between the April and May sample periods 1999.

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

The hydrographs developed during the 1999 field season indicated little variation in the presence of surface water among habitat types and between April and May when monthly precipitation is highest. The variation in surface flooding was greatest in seasonally flooded agriculture (SFA) and seasonally flooded forests (SFF) (Fig. 17). Less variable water levels influence the richness and abundance of the herptile population in these habitat types. These surface water flooding conditions also influence the type and abundance of predators that forage on herptiles.

Hydrologic conditions in 2000

Changes in sampling protocol for 2000, provided the opportunity to gather spatial and temporal hydrologic data for spring (Table 16). Increasing the frequency of data collection allowed the development of a more precise hydrograph of each habitat type within each forest category. Hydrographs in 2000 were more dynamic and identified some of the temporal and spatial variation in the region (Figs. 18, 19).

Table 8. Percent of sample points with surface water, 2000

Sampling period	Percent of sampling points with water
March 3, 2000	86
March 22 and 23, 2000	75
April 6, 2000	69
April 9 and 10, 2000	37
April 24 and 25, 2000	43
May 9 and 10, 2000	43
May 20 and 21, 2000	35
June 5 and 6, 2000	34

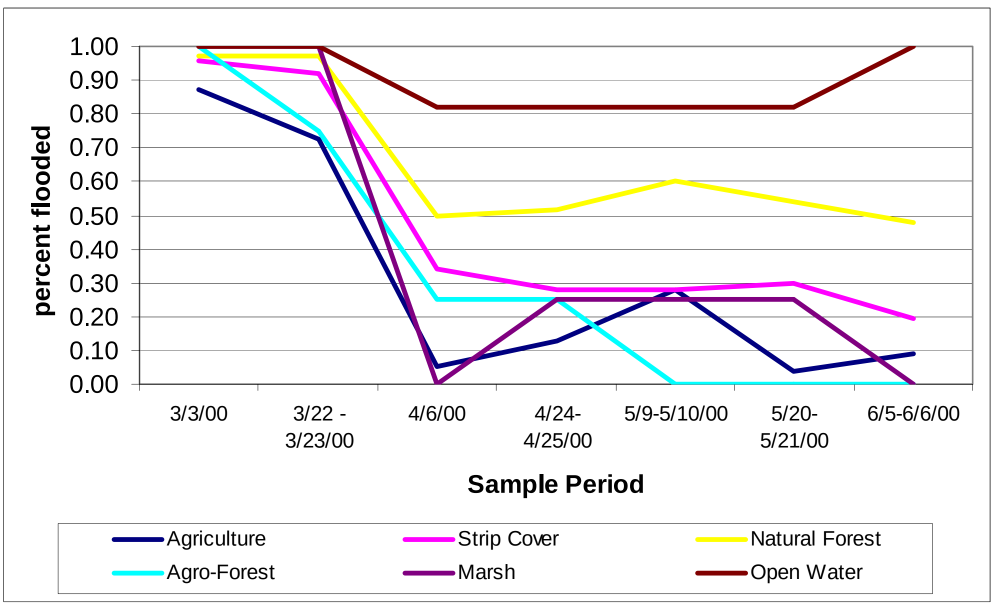

Figure 18. Spring 2000 hydrograph based on habitat type

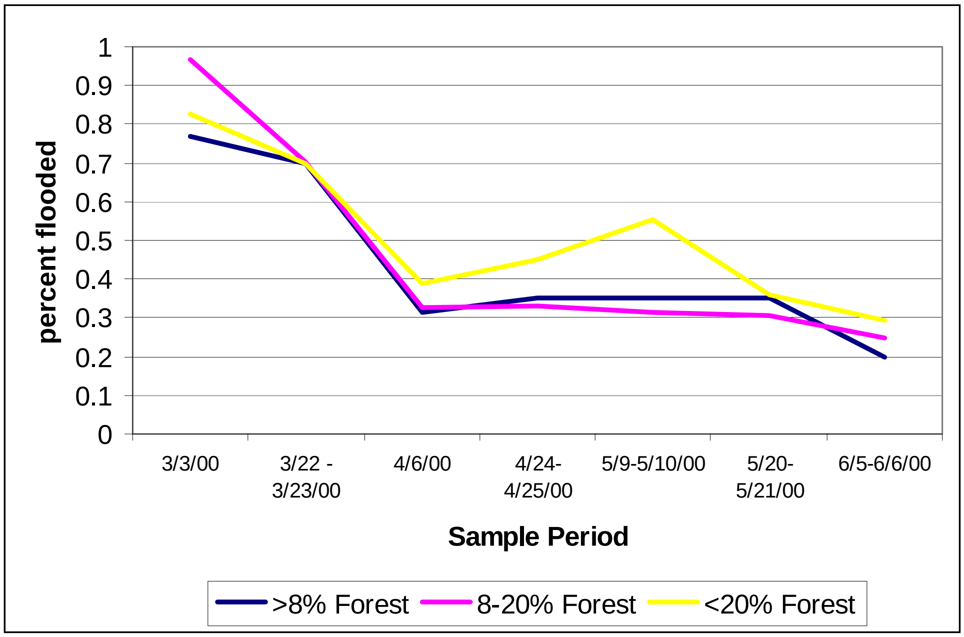

Figure 19. Spring 2000 hydrograph based on percent forest cover

Unlike 1999, surface water conditions in 2000 were variable throughout the sample period from March through May. The presence of surface water from rainfall and controlled flooding varied at the local (habitat) and landscape (forest cover) scale. Surface water was present on 86% of sampling points during the first survey, but only 34% of the sampling points retaining surface water by the conclusion of the field season (Table 8). Of greater significance was the manner in which landscapes with different percentages of forest cover retained surface water. Early spring surveys indicated that 75% to 95% of the points across the study area had surface water present. The greatest percentage of flooded land occurred within the mid-forested landscapes. Through the spring, sample points with high forest cover retained surface water on a greater proportion of the landscape than mid to low-forested landscapes (Fig. 19). General patterns of hydrologic conditions are apparent in relation to the percent of habitat types on a landscape (Fig. 19). Hydroperiods were dynamic regardless of whether sites had low (0.76%) or high (58.79%) forest cover. However plots with 58.79% forested area had the least variable hydroperiod. Interestingly, the landscape with the second highest percentage of forested area (34.83%) showed the most dramatic decline in surface water from a high of 100% in period 2 to 0% in period 3. Plots with 15% to 19% forest area had hydroperiods with high water early in the spring and then experienced a gradual drawdown from March until May. Landscapes with less forest (<15%) had hydrographs marked by sharp declines in surface water early to stable water between March and April, but were stable from April through June.

Natural forests had more area flooded with a longer duration than other habitats except for open water. Flood duration was less where the diversity and area was less. For example, agroforestry plots were characterized by a short hydroperiod and ranked third behind ephemeral marsh and agriculture.

The heterogeneity of surface water conditions within the geomorphic and hydrologic habitat classifications throughout spring varied widely within and between years (Fig. 20.). For example floodplain agriculture (FLA) showed only a small change between sample periods in 1999. In contrast FLA fluctuated during 2000 from a high of near 70% of the points flooded in period 1 to a low of 15% of the sites flooded in period 6. In 2000 floodplain forests (FLF) had similar surface water conditions throughout the sample period, whereas other habitat types had greater variability in hydroperiods. Floodplain strip cover (FLS) had a gradual but steady reduction in surface water. In contrast seasonally flooded strip cover (SFS) had a dramatic decline in surface water from 100% of the sites flooded in periods 1 and 2 to 0% flooded in period 3.

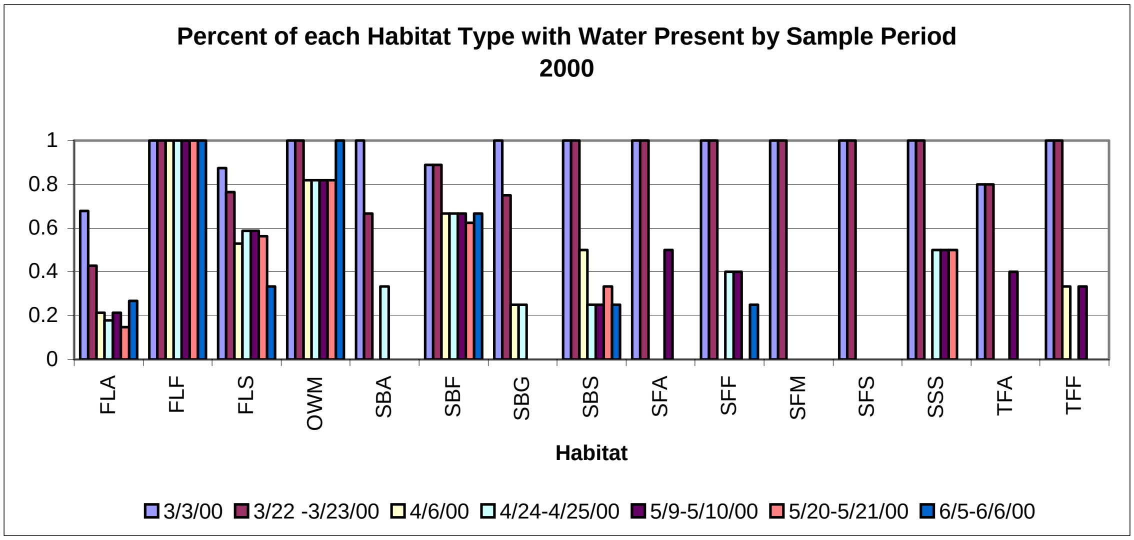

Figure 20. Percent of each forest category with water present by sample period 2000

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

The high degree of hydrologic variability in BLH systems makes it difficult to develop generalities about the processes in this system. Soil type, geomorphology, and connectivity to the river (surface and subsurface) and biotic factors including the vegetation determine on-site hydrology. Landscapes with more forest tend to have prolonged hydroperiods whereas landscapes with little forest cover have flashy hydroperiods.

CHAPTER VI

RESULTS

Call Sampling

All call counts were cancelled during March 1999 because unseasonable weather including snow and nighttime temperatures below 0 ^{o}C did not meet sampling protocol. Later in the 1999 field season, 1191 point counts were conducted in April (566) and May (625) (Fig 21). Variation in the number of point counts between April and May resulted from the need to replace plots on sites where landowners had withdrawn permission for access. Calling anurans were encountered during 485 (40%) of the point counts, whereas 706 (60%) counts had no vocalizing anurans (Table 9). Nine anuran species were encountered during April and 12 during May. Spring peepers were encountered only during April (Table 9) whereas the narrowmouth toad, bronze frog, bullfrog, and eastern spadefoot toad were encountered only during May (Table 9).

Availability of water during spring courtship and larval development determines the reproductive status and success of many anuran species, thus presence of surface water was documented to describe the timing and duration of flooding on study sites. During April water was present on 345 of 566 (61%) sampling points. In May only 354 (57%) of points had surface water (Fig. 20). Although the number of sample points with surface water was similar during the two sample periods, different wetland types were flooded. In April, water remained on waterfowl leases (artificial flooding), agricultural land (natural and artificial flooding), and greentree reservoirs (natural and artificial flooding). During May heavy rainfall filled low-lying areas that resulted in surface flooding in depressions with seasonal and ephemeral wetland characteristics.

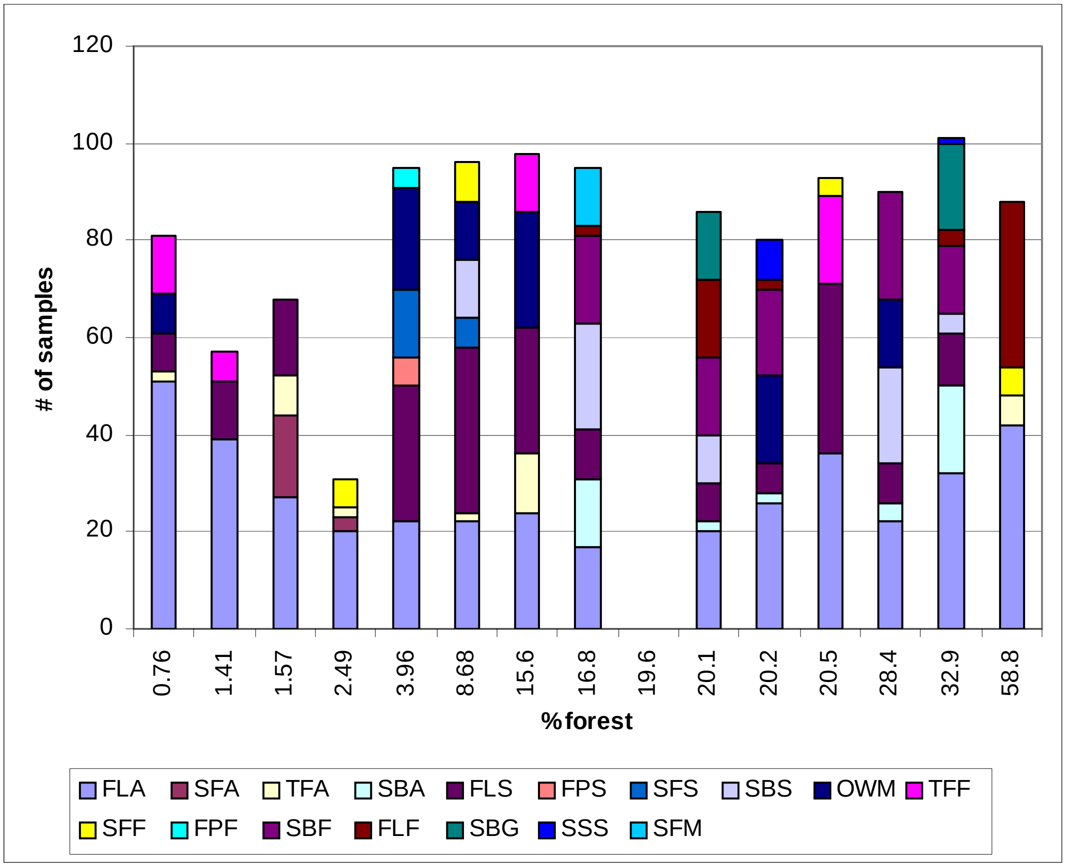

Figure 21. Distribution of point counts by percent forest and habitat Spring 1999.

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

Table 9. The occurrence of 13 anuran species during April and May 1999

Species	Percentage occurrence April 1999 N = 566	Percentage occurrence May 1999 N = 625	Percentage occurrence Spring 1999 N = 1191
Upland Chorus Frog	10.4	0.3	5.1
Illinois Chorus Frog	0.4	1.3	0.8
Blanchard's Cricket Frog	3.2	13.3	8.5
Gray Treefrog	6.4	4.3	5.3
Green Treefrog	0.2	2.9	1.6
Spring Peeper	0.4	0.0	0.2
Southern Leopard Frog	11.5	2.6	6.8
Bronze Frog	0.0	0.3	0.2
Bullfrog	0.0	4.6	2.4
American Toad	2.5	0.2	1.3
Fowler's Toad	7.6	8.2	7.9
Eastern Spadefoot Toad	0.0	0.2	0.1
Narrowmouth Toad	0.0	0.5	0.3
TOTAL	42.4	38.6	40.4

Artificial Habitat

Initially I believed that woody debris on each site could be searched and used to assess herptile populations (see methods chapter IV). Because, debris distribution was not uniform on study plots or among habitat types, equal sampling was not possible. Thus cover boards were randomly placed on each study site (18/site) and throughout each habitat type (6 boards in strip cover, 6 boards along ditches, 6 boards in forest; agricultural habitats were omitted to avoid interfering with farming operations). Only 17 encounters of herptiles associated with cover boards occurred even though boards were in place for 120 days. Encounters occurred in all forest cover categories and all were in strip cover habitat. These encounters included 13 snakes, 2 lizards, 1 toad, and 1 frog. Artificial habitat offered a potential index of herptile population on the site but only presence/absence data were acquired. However, presence/absence information did not meet the goal to understand the effect of habitat loss on the herptile community throughout the bottomland ecosystem (Table 10).

Table 10. Occurrences of herptiles under artificial cover, spring 1999

	Number of cover boards	Number of encounters
April	360	9
May	360	8
Total	720	17

Scan Surveys

During 120 scans in April, 268 individual herptiles were encountered whereas 194 individuals were encountered in May (150 scans) (Table 11). Water availability not only affected spring courtship and the reproductive status of many anuran species, but these conditions also affected the distribution of aquatic reptiles as well. With increased surface water availability, aquatic reptiles spread out across the landscape to take advantage of flooded habitat while reductions in water availability forced them into the remaining bodies of water. Though I tried to scan all aquatic habitats, open-water habitat including ditches and lakes (natural and man made) were the easiest to scan because basking animals were highly visible. Scan samples provided an index of the potential aquatic herptile composition at open-water habitat, but the information only identified presence/absence. Unfortunately, presence/absence information did not meet the goal to understand how habitat loss affected the herptile community throughout the bottomland ecosystem.

Table 11. Occurrences of aquatic herptiles using scan surveys, spring 1999. N = 270

	Snakes	Turtles	Number of species
April	9	259	12
May	19	175	12
Total	28	434	13

Larval Sampling

The rapid drying of temporary wetlands created conditions unsuitable for sampling larval forms. Less than 100 individuals were captured during the spring of 1999. The majority of larval forms captured were southern leopard frog and bullfrog, however several (>10) larval spotted salamanders (*Ambystoma maculatum*) were captured at one location. The limited captures of larval forms only indicted presence/absence of a few species but did not provide estimates of population size. Although this technique resulted in the successful capture of salamanders, presence/absence information did not meet the goal to understand how habitat loss affected the amphibian community throughout the bottomland ecosystem.

1999 Results

During the 1999 season several traditional herptile sampling methods were tested to determine their effectiveness in collecting useful information at the scale necessary to meet study objectives. Species richness was documented for all herptiles, but the presence of anurans offered the best information on the effects of fragmentation on species richness and abundance related to forest cover and the composition of habitat within a bottomland system.

During April herptile detections were 10 in landscapes where forest cover was <4% of a landscape. Within these landscapes 10 herptiles were detected in strip cover (tree line and ditch), 4 in agricultural, and 1 in forest. Where forest cover was 5-20% of a landscape there were 16 species of herptiles detected during April. These detections were distributed as follows 14 in strip cover, 11 in forest, and 8 in agriculture. During April, herptile detections were 21 where forest cover was greater than 20%. In these sites with the highest forest cover, detections were 17 in forest habitat, 14 in strip cover, and 6 in agriculture. Agro-forestry habitat had the lowest herptile detections where only 1 species was encountered.

During May cumulative herptile species detections in landscapes with <4% of forested habitat was 19 species. Strip cover habitat had 18 species, agriculture 7 species, and forest habitat 4 species. Where forest cover was 5-20%, the cumulative herptile species detected was 18. Strip cover had 11 species, agricultural habitat 7 species, and forested habitat had 10 species. Cumulative herptile species detections were lowest in landscapes with >20% forested where only 17 species were encountered. In these landscapes with more forest habitat 14 species were encountered; 12 were in strip cover, and 7 were in agricultural habitat. Only 3 species were detected in Agro-forestry.

The cumulative number of herptile species detected in April and May 1999, was 35. The cumulative number of herptile species detections was 21 in landscapes with <%4 forested habitat. There were 7 detections in agricultural habitat and 5 in forested habitat. The cumulative number of herptile species detections was 21 in landscapes with 5-20% forest cover. The cumulative number of herptile species detected was 18 in forest patches, 17 in strip cover, and 11 in agricultural habitat. Five herptiles (bronze frog, eastern spade-foot toad, three-toed box turtle, five-lined skink, and rough green snake) were encountered only in landscapes with 5-20% forested habitat. The cumulative number of herptile species detections in landscapes with >20% forest cover during spring was 26. Forest patches had 22 species, strip cover had 20 species, and agricultural land had 9 species. Five species were documented only in heavily forested habitats (spring peeper, Illinois chorus frog, map turtle, prairie king snake, southern painted turtle). Agro-forestry habitat had only 3 species.

The number of anuran species detected during 1999 was 13 (Table 12). In landscapes with <4% forested habitat, 9 anuran species were detected. The number of anuran species detected was 9 in strip cover, 6 in open-water habitat, and 6 in agriculture. When forest cover increased to 5-20%, anurans detected decreased by 1. The bronze frog was only documented in medium forested landscapes. The number of anuran detections was 8 in strip cover, 6 in forest habitat, 5 in open-water habitat, 3 in agricultural habitat, and 3 in agro-forestry. In landscapes where forest cover was greater than 20% of the landscape cumulative anuran detections was 13 species. The number of species detected was 11 in strip cover, 10 in agriculture, 8 in forest, 5 in open-water, 3 in agro-forest, and 1 in scrub swamp. Only two anurans (spring peeper and Illinois chorus frog) were encountered in landscapes >20% forested. I performed ANOVA on anuran species detections to determine if richness was affected by the amount of forest cover. The variability of encounters throughout the season resulted in inclusive results and no effects were identified with a $P \leq$ of 0.05.

ANOVA revealed no effects when the number of herptile species or anuran species detected was compared to the amount of forest cover and habitat types. I then tested the abundance of selected species to investigate whether forest cover and habitat type were influencing species abundance. I chose 3 representative anuran species of bottomland habitats including Blanchard’s cricket frog, a habitat generalist (Fig. 22); Fowler’s toad, a well drained soils specialist (Fig. 23); and southern leopard frog, a forest generalist (Fig. 24), to examine the effects of habitat and percent of forest cover on species abundance.

Table 12. Spring 1999 anuran species richness by habitat and percent forest cover (X represents habitats not within landscape plot)

	Agriculture				Strip cover					Forest					Agro-forest	Swamp		
Percent forest	FLA	SFA	TFA	SBA	FLS	FPS	SFS	SBS	OWM	TFF	SFF	FPF	SBF	FLF	SBG	SSS	SFM	Forest richness
0.76	2	X	0	X	2	X	X	X	2	0	X	X	X	X	X	X	X	3
1.41	3	X	X	X	1	X	X	X	X	2	X	X	X	X	X	X	X	6
1.57	4	5	3	X	9	X	X	X	X	X	X	X	X	X	X	X	X	9
2.49	5	1	2	X	X	X	X	X	X	X	0	X	X	X	X	X	X	5
3.96	4	X	X	X	5	0	0	X	6	X	X	2	X	X	X	X	X	7
8.68	0	X	X	X	1	X	0	X	X	X	X	X	X	X	X	X	X	2
15.57	0	X	4	X	6	X	X	X	5	X	X	X	X	X	X	X	X	8
16.79	0	X	X	2	3	X	X	4	X	X	X	X	5	0	X	X	4	6
19.59	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
20.11	1	X	X	0	1	X	X	3	X	X	X	X	4	2	3	X	X	5
20.24	7	X	X	1	6	X	X	X	2	X	X	X	3	X	X	1	X	11
20.46	4	X	X	X	8	X	X	X	X	5	3	X	X	X	X	X	X	8
28.38	2	X	X	0	4	X	X	2	3	X	X	X	2	X	X	X	X	5
32.92	5	X	X	0	3	X	X	0	X	X	X	X	5	1	3	X	X	6
58.79	0	X	0	X	X	X	X	X	X	X	5	X	X	6	X	X	X	6
Habitat richness	10	5	5	3	12	0	0	5	7	7	6	1	8	7	5	1	4	13

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

No effects were identified among the abundance data for Blanchard's cricket frog (Table 13), Fowler's toad (Table 15), or southern leopard frog (Table 17) in relation to the amount of forest cover (ANOVA, alpha level of 0.05). No effects were identified in relation to the abundance of Blanchard's cricket frog (Table 14), or southern leopard frog (18) in relation to forest cover. However, Fowler's toad abundance showed a significant relationship to habitat type at the 0.05 level (Table 16) I suggest that this interaction is a reflection of the abiotic conditions of the site because Fowlers toads dependence on ephemeral wetlands with loose sandy soils.

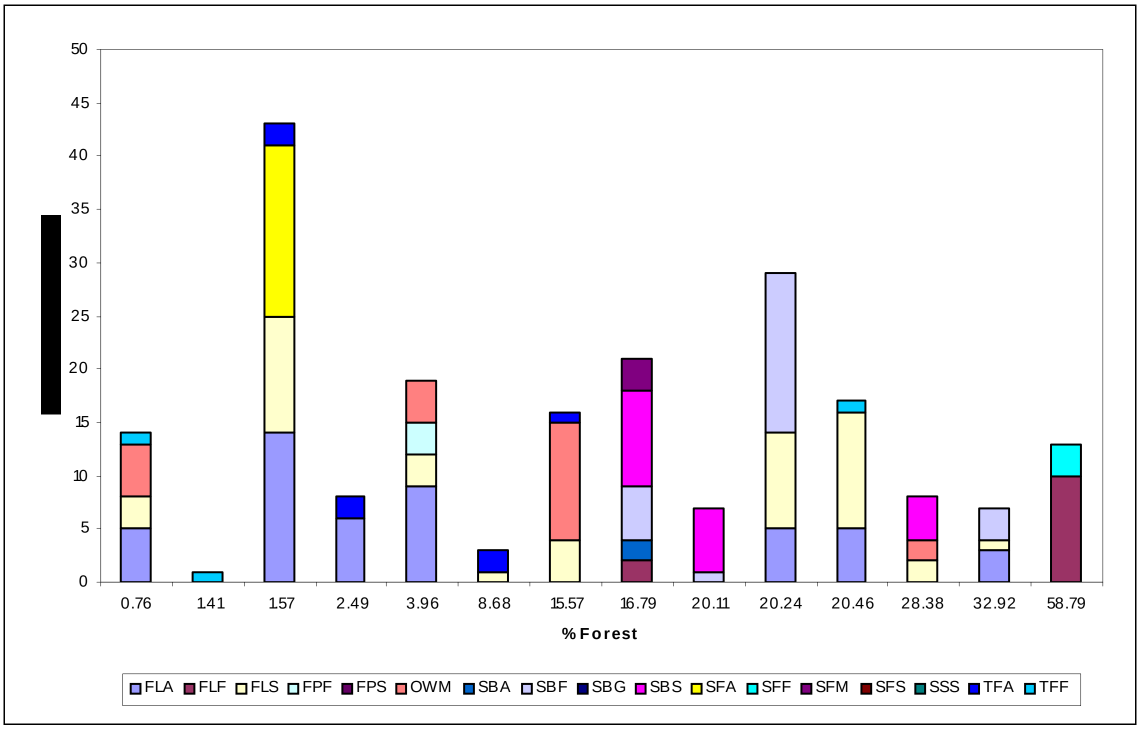

Figure 22. Abundance of Blanchard's cricket frog in relation to percent forest and habitat type during spring 1999.

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

Table 13. ANOVA Results of Blanchard's cricket frog abundance and forest cover spring 1999.

Groups	*Count*	*Sum*	*Average*	*Variance*
0.76	3	24	8	192
1.41	3	0	0	0
1.57	3	33	11	363
2.49	2	11	5.5	60.5
3.96	3	7	2.333333	16.33333
8.68	4	19	4.75	90.25
15.57	5	44	8.8	84.7
16.79	6	57	9.5	303.9
19.59	4	22	5.5	121
20.11	6	11	1.833333	20.16667
20.24	6	66	11	290.4
20.46	4	11	2.75	30.25
32.92	4	99	24.75	1804.917
34.83	3	22	7.333333	40.33333
58.79	3	44	14.66667	161.3333

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2061.049	14	147.2178	0.580591	0.865497	1.923574
Within Groups	11156.88	44	253.5655			
Total	13217.93	58				

Table 14. ANOVA Results of Blanchard's cricket frog abundance and habitat type spring 1999.

Groups	*Count*	*Sum*	*Average*	*Variance*
FLA	14	47	3.357142	18.40111
FLF	4	12	3	22.66667
FLS	12	45	3.75	17.65909
FPF	1	3	3	
FPS	1	0	0	
OWM	6	22	3.666667	17.06667
SBA	5	2	0.4	0.8
SBF	5	24	4.8	36.2
SBG	2	0	0	0
SBS	5	19	3.8	15.2
SFA	2	16	8	128
SFF	4	3	0.75	2.25
SFM	1	3	3	
SFS	2	0	0	0
SSS	1	0	0	
TFA	6	7	1.166667	0.966667
TFF	3	3	1	0

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	217.3595882	16	13.58497426	0.828014654	0.649593947	1.824346896
Within Groups	935.1809524	57	16.40668338			
Total	1152.540541	73				

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

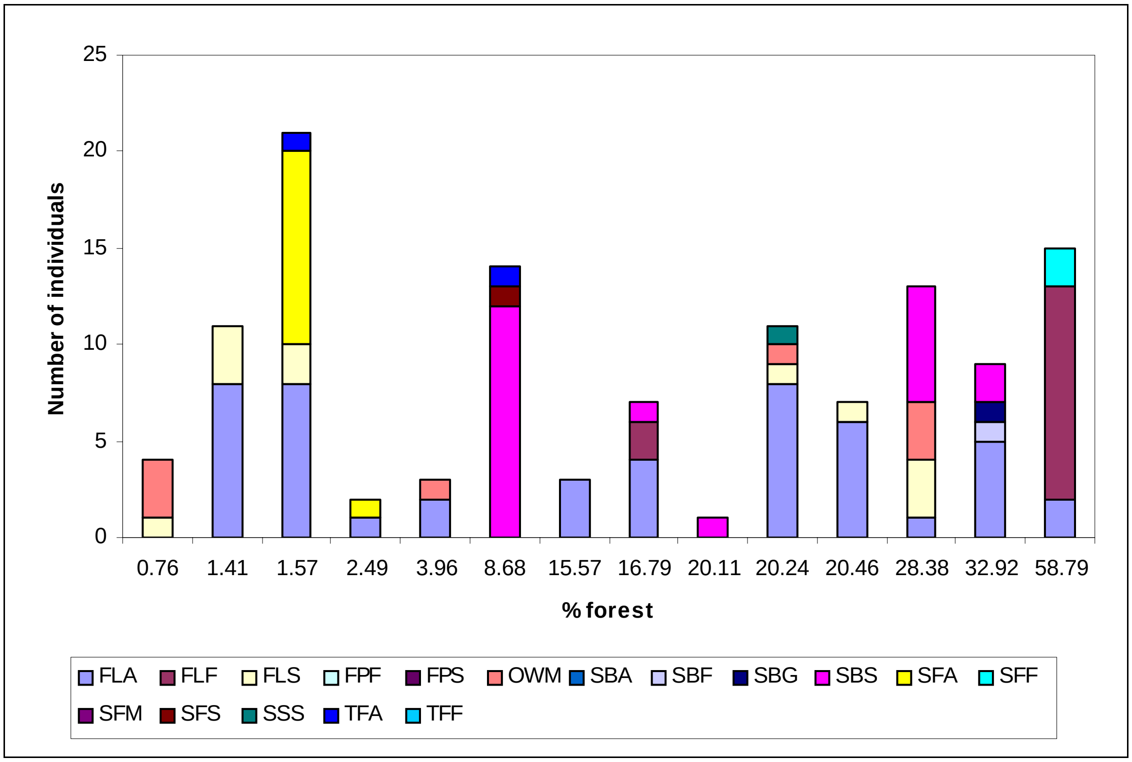

Figure 23. Abundance of Fowler's toad in relation to percent forest and habitat type during spring 1999.

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

Table 15. ANOVA Results of Fowler's toad abundance and forest cover spring 1999.

Groups	*Count*	*Sum*	*Average*	*Variance*
0.76	5	4	0.8	1.7
1.41	3	11	3.666667	16.33333
1.57	4	21	5.25	19.58333
2.49	4	2	0.5	0.333333
3.96	6	3	0.5	0.7
8.68	7	14	2	19.66667
15.57	4	3	0.75	2.25
16.79	7	7	1	2.333333
20.11	7	1	0.142857	0.142857
20.24	6	11	1.833333	9.366667
20.46	4	7	1.75	8.25
28.38	6	13	2.166667	5.366667
32.92	7	9	1.285714	3.238095
58.79	4	15	3.75	24.25

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	124.2296	13	9.556123	1.324422	0.224741	1.887017
Within Groups	432.919	60	7.215317			
Total	557.1486	73				

Table 16. ANOVA Results of Fowler's toad abundance and habitat type spring 1999.

Groups	*Count*	*Sum*	*Average*	*Variance*
FLA	14	48	3.428571	9.494505
FLF	4	13	3.25	27.58333
FLS	12	11	0.916666	1.356060
FPF	1	0	0	
FPS	1	0	0	
OWM	6	8	1.333333	1.866667
SBA	5	0	0	0
SBF	5	1	0.2	0.2
SBG	2	1	0.5	0.5
SBS	5	22	4.4	22.3
SFA	2	11	5.5	40.5
SFF	4	2	0.5	1
SFM	1	0	0	
SFS	2	1	0.5	0.5
SSS	1	1	1	
TFA	6	2	0.333333	0.266667
TFF	3	0	0	0

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	190.8867	16	11.93042	1.856687	0.045234466	1.824346896
Within Groups	366.2619	57	6.425647			
Total	557.1486	73				

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

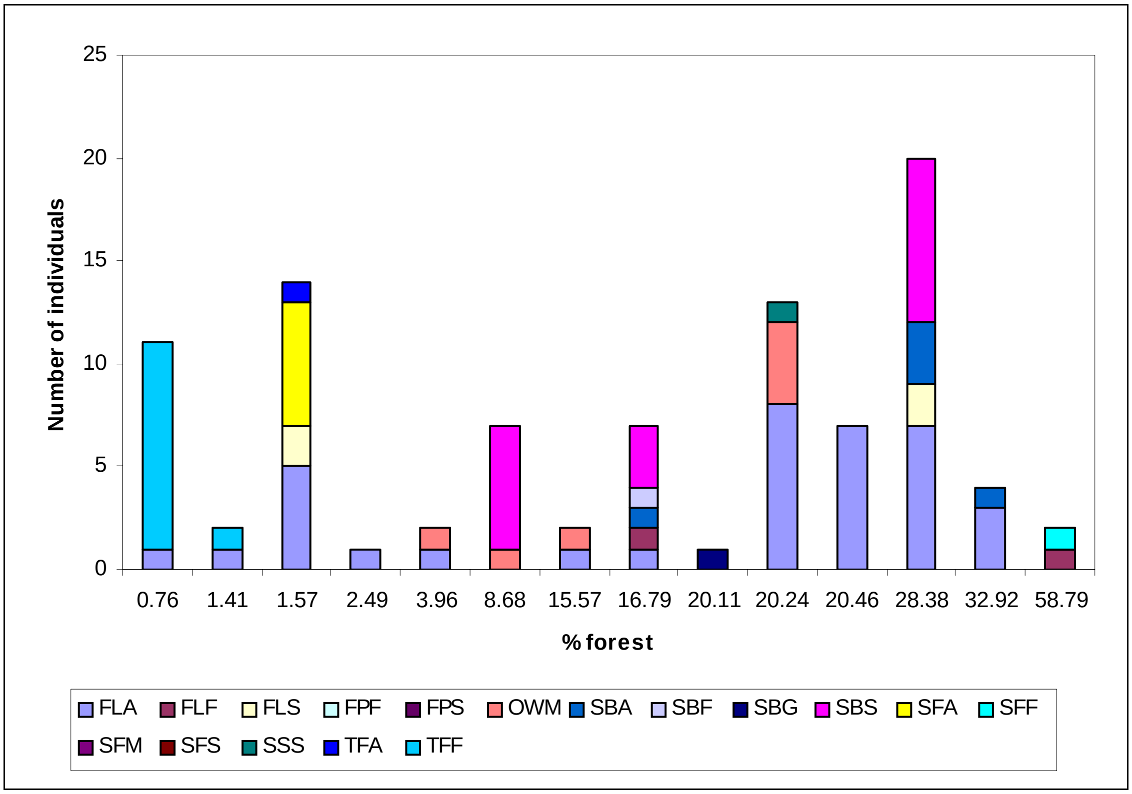

Figure 24. Abundance of southern leopard frog in relation to percent forest and habitat type during spring 1999.

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

Table 17. ANOVA Results of southern leopard frog abundance and forest cover spring 1999.

Groups	*Count*	*Sum*	*Average*	*Variance*
0.76	5	11	2.2	19.2
1.41	3	2	0.666667	0.333333
1.57	4	14	3.5	5.666667
2.49	4	1	0.25	0.25
3.96	6	2	0.333333	0.266667
8.68	7	7	1	5
15.57	4	2	0.5	0.333333
16.79	7	7	1	1
20.11	7	1	0.142857	0.142857
20.24	6	13	2.166667	10.56667
20.46	4	7	1.75	12.25
28.38	6	20	3.333333	11.86667
32.92	7	4	0.571429	1.285714
58.79	4	2	0.5	0.333333

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	84.08353	13	6.467964	1.32886	0.222314	1.887017
Within Groups	292.0381	60	4.867302			
Total	376.1216	73				

Table 18. ANOVA Results of southern leopard frog abundance and habitat type spring 1999.

Groups	Count	Sum	Average	Variance
FLA	14	36	2.571428571	8.417582418
FLF	4	2	0.5	0.333333333
FLS	12	4	0.333333333	0.606060606
FPF	1	0	0	
FPS	1	0	0	
OWM	6	7	1.166666667	2.166666667
SBA	5	5	1	1.5
SBF	5	1	0.2	0.2
SBG	2	1	0.5	0.5
SBS	5	17	3.4	12.8
SFA	2	6	3	18
SFF	4	1	0.25	0.25
SFM	1	0	0	
SFS	2	0	0	0
SSS	1	1	1	
TFA	6	1	0.166666667	0.166666667
TFF	3	11	3.666666667	30.33333333

ANOVA

Source of variation	SS	df	MS	F	P-value	F crit
Between Groups	109.4430502	16	6.840190637	1.46202548	0.147039476	1.824346896
Within Groups	266.6785714	57	4.678571429			
Total	376.1216216	73				

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

SAMPLING INTENSITY AND OCCURRENCE OF SPECIES 2000

During 2000, 625 points counts were conducted (March-194, April-196, May-184, June-51) to determine calling anurans. In these surveys anurans called at 245 (39%) of the counts (Table 19). During 2000, 8 anuran species were encountered, 5 less than encountered during 1999. The 5 species encountered during 1999 but not during 2000 were the Illinois chorus frog, green tree frog, spring peeper, eastern spadefoot toad, and narrowmouth toad

Table 19. Percent occurrence of anurans Spring 2000 at 625 point counts

Species	May N = 194	April N = 196	May N = 184	June N = 51
Upland Chorus Frog	32.47	3.57	1.63	0
Illinois Chorus Frog	0	0	0	0
Blanchard's Cricket Frog	0	4.59	13.04	27.45
Gray Treefrog	0.52	2.04	2.72	0
Green Treefrog	0	0	0	0
Spring Peeper	0	0	0	0
Southern Leopard Frog	21.65	10.2	4.35	0
Bronze Frog	0	0	3.26	7.84
Bullfrog	0	0	5.43	7.84
American Toad	0.52	0	0.54	0
Fowler's Toad	0.52	0.51	5.43	0
Eastern Spadefoot Toad	0	0	0	0
Narrowmouth Toad	0	0	0	0

2000 results

I limited sampling in 2000 to anuran species. This allowed sampling for anurans to occur with higher frequency over a longer time period during spring. This more intense sampling design provided information on chronology of emergence for 8 anuran species (Table 2.).

In 2000 landscapes with <4% forested habitat, 4 anuran species were detected. Four species were detected in strip cover and agricultural habitat whereas in forest habitat only 1 species was detected. The number of anuran species detected in landscapes with 5-20% forested habitat was 7. Within these landscapes 4 anurans were detected in agricultural habitat, 5 in strip cover, 6 in forest habitat and 1 in agro-forestry. Eight anuran species were detected in landscapes with >20% forested habitat. Within these landscapes with more forest 7 anurans were detected in forest and strip cover habitat and 5 in agricultural habitat. American toads were documented only in forest habitat in landscapes with >20% forested habitat (Table 20).

The 2000 data had limitations similar to the 1999 data when analyzed at the cumulative anuran community level. I performed ANOVA on anuran species detections to determine if richness was affected by the amount of forest cover on the landscape. The variability of encounters throughout the season resulted in inclusive results and no effects were identified with a $P \leq$ of 0.05. I tested the abundance of selected species to investigate whether forest cover and habitat type were influencing species abundance. The cumulative data provided limited information because of the variability of encounters throughout the season. Although changing the sampling protocol reduced the number of zeros, the data provided presence/absence information rather than population estimates. I analyzed the 2000 anuran species richness using ANOVA, however, no interactions were identified with a $P \leq$ of 0.05.

Because ANOVA revealed no effects when comparing species richness with forest cover and habitat type, I selected anuran species that were encountered with greatest frequency for further testing. I tested the abundance of these selected anuran species to investigate whether forest cover and habitat type were influencing populations. I used the same anuran species as in 1999, (Blanchard’s cricket frog, Fowler’s toad, and southern leopard frog), to examine the effects of habitat and percent of forest cover on species abundance (Fig. 24).

No significant Analysis of Variance (ANOVA) (alpha level of 0.05) interactions were identified based on the abundance of Blanchard's cricket frog, Fowler's toad, or southern leopard frog in relation to forest cover (Tables 21-26; Figs. 25-27).

Table 20. Spring 2000 cumulative species richness by habitat and percent forest cover (X represents habitats not within landscape plot).

	Agriculture				Strip cover					Forest					Agro-forest	Swamp		
Percent forest	**FLA**	**SFA**	**TFA**	**SBA**	**FLS**	**FPS**	**SFS**	**SBS**	**OWM**	**TFF**	**SFF**	**FPF**	**SBF**	**FLF**	**SBG**	**SSS**	**SFM**	**Forest richness**
0.76	4	X	X	X	X	X	X	X	2	0	X	X	X	X	X	X	X	5
1.41	0	X	X	X	1	X	X	X	X	X	X	X	X	X	X	X	X	1
1.57	0	X	3	X	4	X	X	X	X	X	X	X	X	X	X	X	X	4
2.49	3	X	X	X	X	X	X	X	X	X	1	X	X	X	X	X	X	3
3.96	1	X	X	X	2	X	X	X	3	X	X	X	X	X	X	X	X	3
8.68	0	X	3	X	X	X	2	X	4	X	X	X	X	X	X	X	X	5
15.57	0	X	X	X	2	X	X	X	3	1	X	X	X	X	X	3	X	5
16.79	2	X	X	2	0	X	X	5	X	X	X	X	6	X	X	X	1	6
19.59	2	X	X	1	0	X	X	X	X	X	X	X	2	X	X	X	X	3
20.11	1	X	X	0	0	X	X	2	X	X	X	X	3	X	0	X	X	4
20.24	0	3	X	X	6	X	X	X	2	X	X	X	2	X	X	2	X	6
20.46	3	X	X	X	3	X	X	X	X	2	3	X	X	X	X	X	X	5
32.92	2	X	X	X	1	X	X	X	X	X	X	X	6	X	3	X	X	4
34.83	X	X	4	X	X	X	X	3	X	X	X	X	3	X	X	X	X	6
58.79	0	X	X	X	X	X	X	X	X	X	6	X	X	5	X	X	X	6
Habitat richness	4	3	5	2	6	X	2	5	5	3	7	X	6	5	3	5	1	8

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

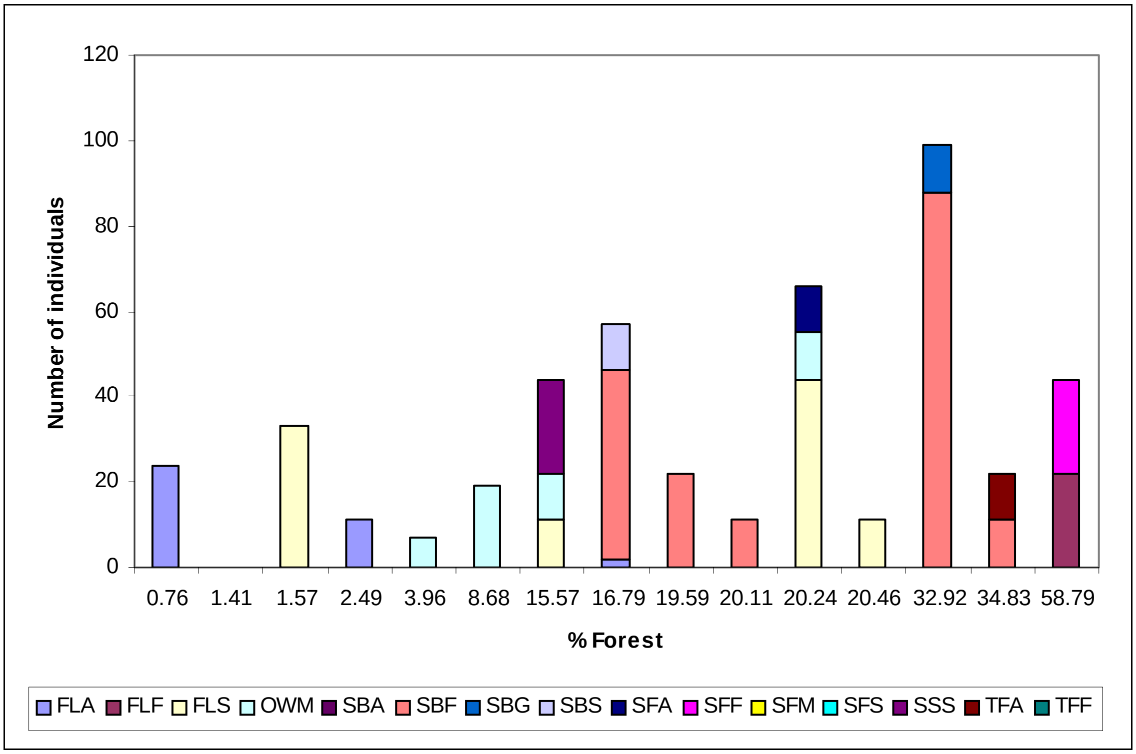

Figure 25. Abundance of Blanchard's cricket frog in relation to percent forest and habitat type during spring 2000.

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

Table 21. ANOVA Results of Blanchard's cricket frog abundance and forest cover spring 2000.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
0.76	3	24	8	192
1.41	3	0	0	0
1.57	3	33	11	363
2.49	2	11	5.5	60.5
3.96	3	7	2.333333	16.33333
8.68	4	19	4.75	90.25
15.57	5	44	8.8	84.7
16.79	6	57	9.5	303.9
19.59	4	22	5.5	121
20.11	6	11	1.833333	20.16667
20.24	6	66	11	290.4
20.46	4	11	2.75	30.25
32.92	4	99	24.75	1804.917
34.83	3	22	7.333333	40.33333
58.79	3	44	14.66667	161.3333

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2061.049	14	147.2178	0.580591	0.865497	1.923574
Within Groups	11156.88	44	253.5655			
Total	13217.93	58				

Table 22. ANOVA Results of Blanchard's cricket frog abundance and habitat type spring 2000.

Groups	*Count*	*Sum*	*Average*	*Variance*
FLA	14	37	2.642857143	46.4010989
FLF	1	22	22	
FLS	10	99	9.9	254.1
OWM	6	48	8	53.6
SBA	3	0	0	0
SBF	6	176	29.33333333	1048.666667
SBG	2	11	5.5	60.5
SBS	3	11	3.666666667	40.33333333
SFA	1	11	11	
SFF	3	22	7.333333333	161.3333333
SFM	1	0	0	
SFS	1	0	0	
SSS	2	22	11	242
TFA	3	11	3.666666667	40.33333333
TFF	3	0	0	0

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4029.984	14	287.8560417	1.378508712	0.204078231	1.923574189
Within Groups	9187.947	44	208.8169913			
Total	13217.9322	58				

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

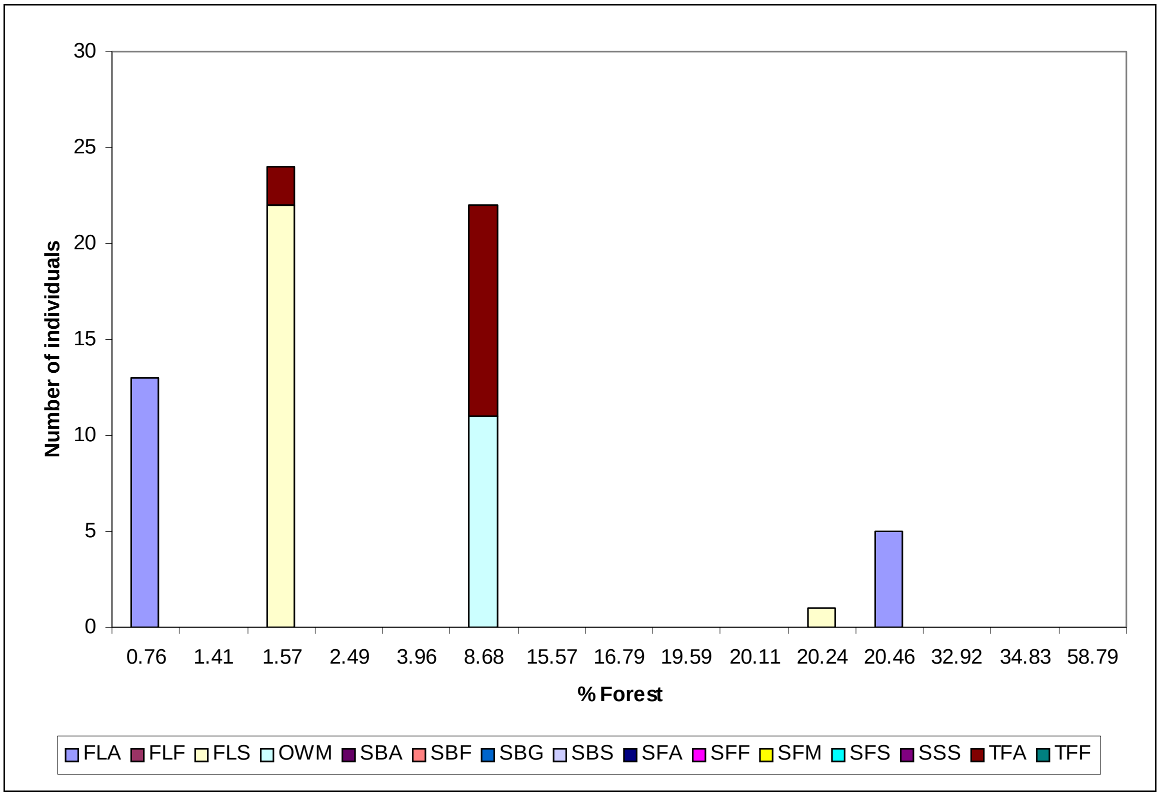

Figure 26 Abundance of Fowler's toad in relation to percent forest and habitat type during spring 2000.

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

Table 23. ANOVA Results of Fowler's toad abundance and forest cover spring 2000.

Groups	*Count*	*Sum*	*Average*	*Variance*
0.76	3	13	4.333333	56.33333
1.41	3	0	0	0
1.57	3	24	8	148
2.49	2	0	0	0
3.96	3	0	0	0
8.68	4	22	5.5	40.33333
15.57	5	0	0	0
16.79	6	0	0	0
19.59	4	0	0	0
20.11	6	0	0	0
20.24	6	1	0.166667	0.166667
20.46	4	5	1.25	6.25
32.92	4	0	0	0
34.83	3	0	0	0
58.79	3	0	0	0

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	304.1398	14	21.72427	1.740315	0.081421	1.923574
Within Groups	549.25	44	12.48295			
Total	853.3898	58				

Table 24. ANOVA Results of Fowler's toad abundance and habitat type spring 2000.

Groups	*Count*	*Sum*	*Average*	*Variance*
FLA	14	18	1.285714286	13.14285714
FLF	1	0	0	
FLS	10	23	2.3	48.01111111
OWM	6	11	1.833333333	20.16666667
SBA	3	0	0	0
SBF	6	0	0	0
SBG	2	0	0	0
SBS	3	0	0	0
SFA	1	0	0	
SFF	3	0	0	0
SFM	1	0	0	
SFS	1	0	0	
SSS	2	0	0	0
TFA	3	13	4.333333333	34.33333333
TFF	3	0	0	0

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	80.9326876	14	5.780906261	0.329286716	0.986347752	1.923574189
Within Groups	772.457142	44	17.55584416			
Total	853.389830	58				

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

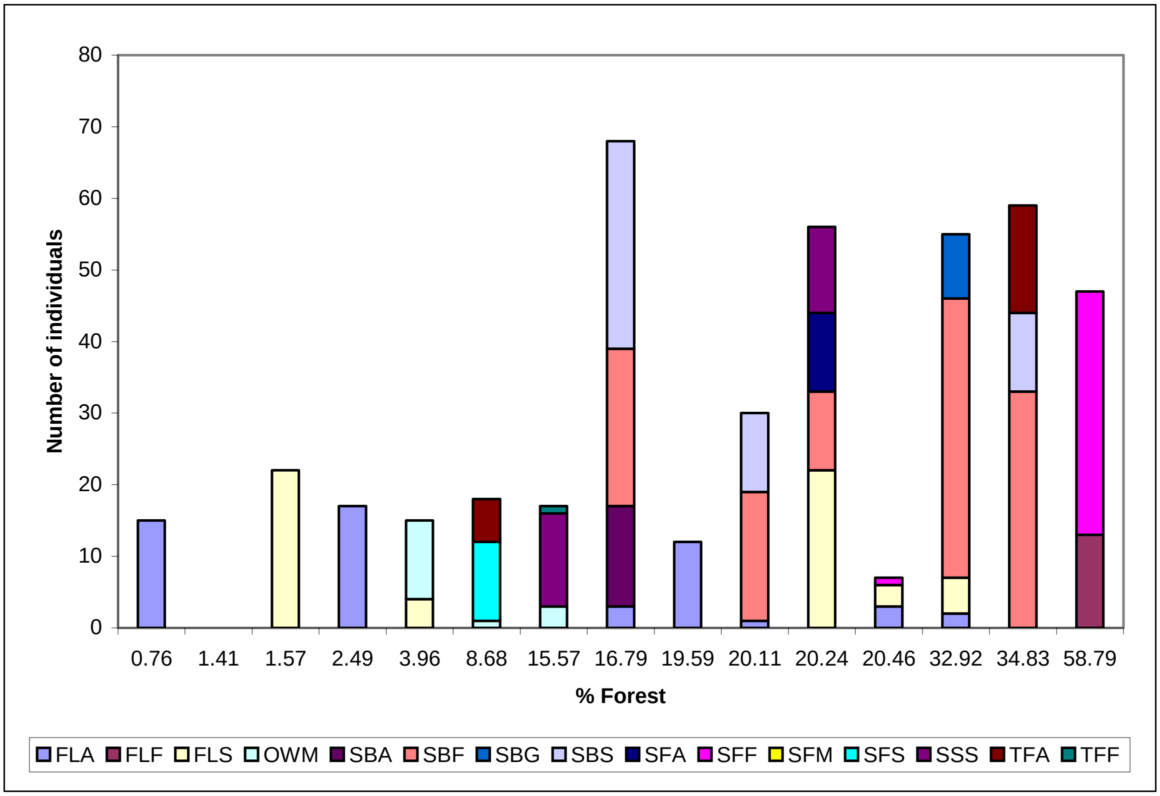

Figure 27. Abundance of southern leopard frog in relation to percent forest and habitat type during spring 2000.

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

Table 25. ANOVA Results of southern leopard frog abundance and forest cover spring 2000.

Groups	*Count*	*Sum*	*Average*	*Variance*
0.76	3	15	5	75
1.41	3	0	0	0
1.57	3	22	7.333333	161.3333
2.49	2	17	8.5	144.5
3.96	3	15	5	31
8.68	4	18	4.5	25.66667
15.57	5	17	3.4	30.3
16.79	6	68	11.33333	151.8667
19.59	4	12	3	36
20.11	6	30	5	59.2
20.24	6	56	9.333333	69.46667
20.46	4	7	1.75	2.25
32.92	4	55	13.75	291.5833
34.83	3	59	19.66667	137.3333
58.79	3	47	15.66667	294.3333

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1487.54	14	106.2529	1.131207	0.359615	1.923574
Within Groups	4132.867	44	93.92879			
Total	5620.407	58				

Table 26. ANOVA Results of southern leopard frog abundance and habitat type spring 2000.

Groups	*Count*	*Sum*	*Average*	*Variance*
FLA	14	53	3.785714286	36.95054945
FLF	1	13	13	
FLS	10	56	5.6	78.26666667
OWM	6	15	2.5	18.7
SBA	3	14	4.666666667	65.33333333
SBF	6	123	20.5	203.5
SBG	2	9	4.5	40.5
SBS	3	51	17	108
SFA	1	11	11	
SFF	3	35	11.66666667	374.3333333
SFM	1	0	0	
SFS	1	11	11	
SSS	2	25	12.5	0.5
TFA	3	21	7	57
TFF	3	1	0.333333333	0.333333333

ANOVA

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2073.64963	14	148.1178312	1.837505166	0.062942912	1.923574189
Within Groups	3546.75714	44	80.60811688			
Total	5620.40678	58				

FLA = Floodplain agriculture; FLF = Floodplain forest; FLS = Floodplain strip cover; FPS = Floodplain strip cover; OWM = Open water manmade; SBA = Seasonally flooded agriculture by backwater; SBF = Seasonally flooded forest by backwater; SBG = Seasonally flooded agro-forest by backwater; SBS = Seasonally flooded strip cover by backwater; SFA = Seasonally flooded agriculture; SFF = Seasonally flooded forest; SFM = Seasonally flooded marsh; SFS = Seasonally flooded strip-cover; SSS = Scrub/shrub swamp; TFA = Temporarily flooded agriculture; TFF = Temporarily flooded forest

CHAPTER VII

EFFECTS OF HABITAT TYPE AND FOREST AREA ON HERPTILE COMMUNITIES IN FLOODPLAIN FORESTS

Much of the information collected during my study was statistically insignificant. Nevertheless my experience on the study area in combination with recognition of the geomorphic setting and highly variable hydrologic conditions provide insight into the design and interpretation of future investigations of herptiles at large spatial scales. The initial objective of this study was to determine distribution, richness, and abundance of the herptile community of southeast Missouri in relation to forest cover, habitat types, and agro-forestry practices. Another part of this study was to determine what sampling protocols are most effective for herptiles at a large spatial scale. During 1999 season, I attempted to gain information on the entire herptile population within 15 plots in southeast Missouri. However, I did not have the time to successfully sample the entire herptile population because of the size of the study area and the limited time and personnel I had for sampling. Because of time and personnel constraints, I only focused on anurans during 2000. Thus, I used different techniques between the years making comparisons of results between field seasons inappropriate. However, the 1999 field season allowed me to test techniques to determine their effectiveness as well as aided in determining the technique to provide the most comprehensive information on anurans during the second field season. My hypothesis was that herptile richness in landscapes with forest cover $<4\%$ would be lower than in landscapes with more forest. The spring 1999 surveys indicated a positive spatial relationship between herptile species richness and the amount of forested habitat present on a landscape. Population censuses indicated that herptile species richness was 21 in landscapes with <4% forest cover, and 26 species on moderately (5-20% forest) and heavily (>20%) forested landscapes. Generally species richness was similar despite differences in forest cover. The 1999 results indicate variability in anuran richness with increasing percent forest cover. Because richness decreased from moderate forest cover (5-20% forest) to heavy forest cover (>20% forest) there appears to be a suite of factors other than forest cover alone that determines species richness. Possibly, species abundance and richness in a particular patch may be influenced by characteristics of contiguous patches (Dunning et al. 1992). The ability of an animal to utilize a resource patch is dependent upon its mobility and is determined by the distance between patches as well as the biophysical nature of the route between the patches (Heniein and Merriam 1990). As forest cover increased, corridors of forested habitat were present as strip cover between remnant forest patches. This connectivity facilitates or impedes movement among patches (Taylor et al. 1993). On moderately forested (5-20% forest) sites these forest corridors (strip cover) accounted for a large percentage of the forested habitat. These corridors usually were associated with ditches and waterways and provided the vegetative communities important to herptiles as well as the aquatic resources required to meet life cycle requirements. I assumed that when forest cover increased, herptile species richness would increase as well. This assumption was supported by other studies where amphibian species richness had a negative relationship with decreased landscape connectivity (Lehtinen et al. 1999) in deciduous forest landscapes that were fragmented by agricultural practices. However results from my study suggest that species richness remained the same on landscapes with 5-20%

forest cover indicating that connectivity alone is not the sole factor that determines species richness.

My collection of herptile data in 1999 was ineffective for the scale of the study. Because of the scale my project, I did not have the time to use multiple techniques that were possible when a study was restricted to a specific location. Realizing this limitation I tried to determine if the pattern of use by anurans was similar to patterns of use by other taxon. Additionally, I examined average anuran richness in response to plots, percent of forest cover, and habitat type. Variation among plots within the three categories of forest cover suggests cover alone is not the sole factor driving anuran species richness. Examination of the anuran richness data was inconclusive. Average richness on sites with forest cover of < 4% was 6 species (high of 9), 5 on sites with 5-20% forest cover (high of 8), and 7 on sites with >20% forest cover (high of 11). Tremendous annual fluctuations in the abiotic conditions are likely within plots. Differences in abiotic conditions (e.g., hydrology) could create microhabitat conditions ranging from poor to excellent for anurans. Numerous studies indicate that leaf litter and hydroperiod drive pH, dissolved oxygen, and vegetation community composition. More species were present in forest habitat regardless of area in forest cover suggesting a more complex relationship among anurans and abiotic conditions but these differences were not significant based on the analyses I used. The variation of richness among habitat categories and percent of forest cover suggests complex biological responses that may be accounted for by abiotic variables. Based on species richness, my data suggests strip cover (richness of 9) is more valuable to anurans in landscapes with little forest (<4%) than in landscapes with intermediate areas of forest (5-20%) (richness of 6). I suggest the limited forest cover in low-forested landscapes restricts anuran species to patches of remnant habitat. In these highly disturbed landscapes, strip cover often represents the only remaining forest. Because forest remnants typically are associated with aquatic habitats such as drainage ditches, microhabitat is present to fulfill life cycle requirements for several species. Additionally as forest patches become more common on the landscape, species have a greater opportunity to colonize these locations. Thus, more investigations are required to determine temporal use and importance of forest corridors. Of interest is that as area of forest cover increased within a plot more species were observed in the adjacent agricultural habitat. Often sites with more forest are associated with low-lying areas where farming is difficult. Such sites have hydrologic features that are relatively intact, and agriculture fields have surface water for a portion of the growing season. Thus, these highly disrupted forested systems have hydroperiods during some years that emulate the natural hydrologic regimes in which these species evolved despite the fact they are modified extensively by agriculture. Thus, some agricultural habitats adjacent to forest patches provide open ephemeral wetlands that were interspersed as vernal pools in a forested bottomland system historically (Klimes et al 2005).

Changes in sampling design in 2000 provided more comprehensive information across spatial and temporal scales for anuran species than was possible with the 1999 sampling protocol. The average anuran species richness forest cover of < 5% was 3.2 species, but the plot with 1.57% of forest had a richness of 5 species. The average species richness for moderate cover (5-20%) was 4.6 species but the plot with 16.79% forest cover had a richness of 6. The average species richness in forest cover >20% was 5.4 species. Plots with cover of 20.24%, 34.83%, and 58.79% forest cover had a richness of 6. Unlike the 1999 data, the 2000 data indicated an increase in species richness with increased forest cover.

Considering that species richness varied among the amount of forest cover, understanding what forest habitats within these remnant patches were used is important. Amphibian populations are most abundant when there is a mosaic of habitats within a regional landscape (Mann et al. 1991). In this study where forest cover was <5%, species richness was 4 in strip cover habitat. In contrast plots with 5-20% forest cover had a richness of 6 where forests were flooded by seasonal backwater. Where forest cover was >20%, species richness was 6 in strip cover, seasonally flooded forests, and forests flooded by seasonal backwater.

The species richness associated with these landscapes provides insights into the anuran communities of this highly modified system, however species-specific data are important in determining population interactions. Abundance data provides insights into how species populate landscapes and habitats as well as the effect of fragmentation on anuran population size. Metapopulations may develop which result in a dynamic equilibrium through time. However, if populations become fragmented, emigration and immigration may be inhibited or stopped, thus preventing recolonization from source populations (Sjoren 1991).

Species abundance was determined for all species encountered, however sample sizes required for comparative purposes were only large enough for Blanchard's cricket frog (a habitat generalist), Fowler's toad (open sandy soils), and southern leopard frog (forested wetlands). Results from 1999 indicate that cricket frogs were encountered more frequently on plots with little forest cover and abundance fluctuated with increases in forest cover. Cricket frogs were present in flooded agriculture habitat in landscapes with <5% forest and in flooded forest and strip cover in landscapes with 5-20% forest. Results from 2000 indicate a different cricket frog distribution and abundance compared to 1999. Abundance of cricket frogs generally increased with forest cover in 2000. Use of specific habitats was similar to use in 1999 with the exception that cricket frogs were encountered with the second highest frequency in strip cover for sites with <5% cover.

Although the abundance of cricket frogs in relation to percent forest between 1999 and 2000 were different, the distribution by habitat type remained the same. I suggest this reflects hydrologic patterns between years. Although an ANOVA did not support a significant relationship between abundance and forested habitat, that variation in habitat conditions between years influenced the amount of data that I collected. For example, cricket frogs were present in the same habitats between years, however breeding habitat availability for this species was limited in 1999 because of dry conditions. Because cricket frogs are habitat generalists, the 1999 results indicate that the species takes advantage of habitat as it occurs on the landscape. However, the 2000 results indicate forested habitat may be important.

Fowler's toads require sandy soils with ephemeral wetland characteristics to meet their life cycle requirements. In 1999, 41 Fowler's toads were observed in landscapes with <4%, whereas moderately forested landscapes (5-20%) had 25 toads, and heavily forested landscapes (>20%) had 55 toads. In sites with <4% forest cover more toads were encountered in agriculture (19) than in flooded agriculture (12), strip cover (6), and forest habitat (0). In 2000, 37 Fowler's toads were in landscapes with <4%, 22 in landscapes with 5-20% forest, landscapes with >20% forest had 6. Toads were encountered most commonly in strip cover (22) and agriculture (15) in landscapes with <4% forest. In landscapes with 5-20% forest, 11 species were encountered in strip cover and 11 in man-made open water habitats. In heavily forested landscapes (>20%), agriculture (5) and strip cover (1) were sites where these toads were encountered. An ANVOA indicated a positive relationship between habitat type and Fowler's toad abundance, but a correlation between percent forest cover and Fowler's toad was not supported by ANOVA. The relationship between percent of forest cover and habitat types indicated a different pattern of distribution and abundance during the two years. In landscapes with >20% forest more toads were encountered in 1999 compared to landscapes with, <4% forest or 5-20% forest. Fewer Fowlers toads were encountered in 2000 and their abundance decreased as the percent of forest cover increased. Data on soil types or cropping practices were unavailable, however this information would likely shed light on factors that determine the distribution and abundance of Fowler's toads. The loose sandy soils required by Fowler's toads for dormancy occur in old point bars of the Mississippi River. These sites tend to be heavily farmed throughout the study area. My experience suggests during some years seasonal hydrologic conditions and the timing of farming practices coincide in a manner that provides the conditions for Fowler's toads to proliferate. Deep disking disrupts toads that have entered dormancy but disking is less frequent during springs with heavy rainfall. Thus conditions most likely to favor toads occur in years when deep disking is infrequent. Thus wet conditions not only have the potential to provide ephemeral pools for mating and tadpole development but farming operations and especially deep disking is limited. Other techniques such as no-till farming, are important in farm efficiency and desirable for soil conservation, they can be lethal to anuran populations because the use of herbicides preceding planting to kill invasive plants can be detrimental to dormant or emerging toads. For example, I encountered the lowest numbers of calling Fowler’s toads on sites where no-till farming practices were used. In contrast, sites immediately adjacent to the study plots had several species of anurans calling during the same periods.

Southern leopard frogs are considered a forest generalist and have life histories that match the natural hydrologic patterns of forested bottomland systems. In the 1999 field season, 93 leopard frogs were encountered on the study area; 30 on sites with >4% forest, 17 in sites with 5-20% forest, and 46 on sites with >20% forest. In landscapes with the least forest 10 leopard frogs were encountered in temporarily flooded forest and 9 were in floodplain agriculture. In landscapes with 5-20% forest 9 frogs were encountered in strip cover flooded seasonally by backwater, whereas and in landscapes with >20% forest 24 were in agriculture and 8 in strip cover flooded seasonally by backwater. In 2000, 438 leopard frogs were encountered; 69 in sites with <4% forest, 145 in sites with 5-20% forest, and 224 in landscapes with greater than 20% forest. In landscapes with <4% forest leopard frogs were encountered most in floodplain agriculture (32) and strip cover (26). In landscapes with 5-20% forest 40 leopard frogs were in forests flooded seasonally by backwater, 40 were in strip cover, and 30 were in agriculture. In landscapes with >20% forest, 83 leopard frogs were in forests flooded seasonally by backwater and seasonally 30 were in flooded forests.

Several anurans were present in low densities on the study area but appeared to be abundant within the region. Of particular interest was the lack of spring peepers (*Hyla crucifer crucifer*) on the study area. In 1999 I encountered a single spring peeper on the entire study area and no spring peepers were encountered in 2000. In contrast on Mingo National Wildlife Refuge and Duck Creek Conservation Area that are within 112 km of the study area a considerable population of spring peepers probably occurs because calling is extensive there. Personal communications with landowners across the study area indicated choruses of this species being so loud in the past that it was difficult to sleep in the spring. An interesting observation given that I only encountered one spring peeper with my sampling protocol. Other species with similar life histories including the upland chorus frog and Blanchard's cricket frog appear to be maintaining populations despite extensive landscape alteration. Why then the reduction and near extirpation of spring peepers on my study area? Small, isolated populations are particularly susceptible to environmental perturbations (Sjoren 1991) and to stochastic variation in demography that can lead to extirpation even without external perturbations (Lande 1998, Pimm et al 1998). Similar downward population trends seem to be occurring for the Illinois chorus frog in southeast Missouri. Although populations of this chorus frog were doing well across the Mississippi river in Illinois at the time of my study. I encountered only a few 1999 and none in 2000 when I had increased research presence on my study area.

Implications for Future Studies

I believe these data provide baseline documentation of the distribution of herptiles as well as chronology of emergence particularly anurans, across a large regional scale. This baseline documentation will be valuable in developing future conservation initiatives in the region. Based on my results a combination of techniques would be appropriate to investigate the effects of habitat and forest cover on the presence and distribution of herptiles.

Developing sampling strategies for herptiles was a constant struggle with this study because of the issues with scale. Initial sampling protocols were developed with the expectation that a diverse suite of herptiles could be sampled with equal catchability. It appeared that this assumption was not met thus data from all species were not comparable between treatments and between years. Additionally the techniques chosen assumed that data would be distributed normally to meet the assumptions required for ANOVA techniques. It became apparent early in the first year that the techniques chosen did not provide the data to meet the objectives of the study. Thus a different sampling protocol was developed for year two.

I suggest a continuation of the call censuses but frequency of visitations as well as efficiency of site sampling must be improved. The modified road sampling technique addressed frequency of sampling however this technique it did not address sampling efficiency. Efficiency can be addressed by increasing the number of observers. My suggestion is that five qualified surveyors could intensively sample the entire study area in a week. At this rate the entire area could be sampled multiple times throughout the spring thus increasing statistical power with repeated measures analysis. In combination with call sampling representative sites should be randomly chosen for precision sampling techniques including drift fences to better quantify richness and abundance. This intensive sampling should include abiotic variables including soils and water chemistry that could be used as a covariate in analysis.

Because of time constraints in my study there was inadequate time to address how abiotic factors influenced anuran distribution and abundance. When abiotic factors are included in the analysis, statistical power decreases because of the number of zeros throughout the data. Thus, I restricted forest and habitat classifications to a few categories where abiotic variables were included but I still had enough anuran encounters for analysis. The analysis offered some insight into anuran distribution and abundance, but it did not account for the complex interactions of geomorphic setting, hydrologic conditions, soils, and climate. Future studies should attempt to include abiotic factors and how these factors influence species richness and abundance among seasons.

Analysis

Initially data analysis was designed with a split block and time ANOVA that allowed analysis of several covariates between years. Sample design was developed based on the assumptions for this analysis. When data collection proved to have gaps early in the first season I should have considered changes in the sampling protocol as well as in the analytical approach. However, data were collected over the two field seasons under the assumption that analyses selected in the initial proposal would be acceptable. I made a decision to continue with the original analysis. Because I wanted to avoid statistical "fishing" and I used the predetermined analytical technique. In retrospect I should have recognized that the data were not normally distributed and determined that ANOVA was inappropriate. The data set is binary and I should have tested or utilized other techniques such as regression modeling for analysis.

Management Implications

Natural resource managers are faced with challenges each day including appropriate monitoring. Monitoring programs implemented on management areas may assess populations of big game or neotropical migrants or address the distribution and abundance of native and invasive vegetation. Thus, additional monitoring adds a greater burden for any land manager. Understanding the need to develop appropriate monitoring strategies for anurans on managed lands is one of the products that I envisioned for this study. I approached this study, with the recognition that land managers are not researchers with more time and experience in developing and testing sampling strategies. However their intuitive sense about the lands they manage as well as those adjacent should help identify the type, frequency, and method of monitoring. What information is needed to make informed decisions that balance habitat management and restoration with species life history needs? To answer that question managers need to determine what species currently exist, how they are distributed, and how are they responding to current environment conditions. The road sampling methodology was developed based on this thought process. Information gathered in 1999 was inadequate to make informed decisions in the context of land management. Because I was on the study area more often in 2000, I improved my opportunity to gather information in a way that provided insights into how these animals used this altered landscape. This road sampling technique was tested at Grays lake National Wildlife Refuge in Idaho and will be tested at Bosque del Apache National Wildlife Refuge in central New Mexico during spring of 2007. Because of the national concern for anuran populations, developing techniques that will be effective and repeatable within a long-term monitoring program is key to collecting critical information to aid in making sound management decisions. Better-informed decisions require data that reflect life history strategies and landscape features associated with suitable habitat. Such information has the potential to guide management to maintain and expand anuran populations.

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APPENDIX A

Herptile Species Encountered in the Fragmented Forests of Southeast Missouri during 1999 and 2000

COMMON NAME	SPECIES
Western Lesser Siren	**Siren intermedia nettingi**
Spotted Salamander	*Ambystoma maculatum*
Marbled Salamander	*Ambystoma opacum*
Mole Salamander	*Ambystoma talpoideum*
Smallmouth Salamander	*Ambystoma texanum*
Eastern Tiger Salamander	*Ambystoma tigrinum tigrinum*
Central Newt	*Notophthalmus viridescens louisianensis*
Three-toed Amphiuma	*Amphiuma tridactylum*
Mudpuppy	*Necturus maculosus*
Eastern Spadefoot	*Scaphiopus holbrookii holbrookii*
Dwarf American Toad	*Bufo americanus charlesmithi*
Woodhouse's Toad	*Bufo woodhousei fowleri*
Blanchard's Cricket Frog	*Acri crepitans blanchardi*
Green Treefrog	*Hyla cinerea*
Northern Spring Peeper	*Hyla crucifer crucifer*
Cope's Gray Treefrog	*Hyla versicolor*
Illinois Chorus Frog	*Pseudacris streckeri illinoiensis*
Upland Chorus Frog	*Pseudacris triseriata feriarum*
Eastern Narrowmouth Toad	*Gastrophryne carolinensis*
Plains Leopard Frog	*Rana blairi*
Southern Leopard Frog	*Rana sphenocephala*
Bullfrog	*Rana Catesbeina*
Bronze Frog	*Rana clamitans clamitans*
Pickerel Frog	*Rana Palustris*
Common Snapping Turtle	*Chelydra serpentina serpentina*
Alligator Snapping Turtle	*Macroclemys temminckii*
Mississippi Mud Turtle	*Kinosternon subrubrum hipporepis*
Stinkpot	*Sternotherus odoratus*
Southern Painted Turtle	*Chrysemys picta dorsalis*
Western Chicken Turtle	*Deirchelys reticularia miaria*
Map Turtle	*Graptemys geographica*
Mississippi Map Turtle	*Graptemys kohnii*
False Map Turtle	*Graptemys pseudogeographica pseudogeographica*
Missouri River Cooter	*Pseudemys concinna metteri*
Three-toed Box Turtle	*Terrapene carolina triunguis*
Red-eared Slider	*Trachemys scripta elegans*
Midland Smooth Softshell	*Trionyx muticus muticus*
Eastern Spiny Softshell	*Trionyx spinifer spinifer*
Northern Fence Lizaed	*Sceloporus Undulatus hyacinthinus*
Five-lined Skink	*Eumeces fasciatus*
Broadhead Skink	*Eumeces laticeps*

Ground Skink	*Scincella lateralis*
Six-Lined Racerunner	*Cnemidophorus sexlineatus*
Western Slender Glass Lizard	*Ophisaurus attenuatus attenuatus*
Western Worm Snake	*Carphophis amoenus vermis*
Southern Black Racer	*Coluber constrictor priapus*
Mississippi Ringneck Snake	*Diadophis punctatus stictogenys*
Black Rat Snake	*Elaphe obsoleta obsoleta*
Western Mud Snake	*Farancia abacura reinwardtii*
Dusty Hognose Snake	*Heterodon nasicus gloydi*
Eastern Hognose Snake	*Heterodon platyrhinos*
Prairie Kingsnake	*Lampropeltis calligaster calligaster*
Speckled Kingsnake	*Lampropeltis getulus holbrooki*
Red Milk Snake	*Lampropeltis triangulum syspila*
Green Water Snake	*Nerodia cyclopion cyclopion*
Yellowbelly Water Snake	*Nerodia erythrogaster flavigaster*
Broad-banded Water Snake	*Nerodia fasciata confluens*
Diamondback water Snake	*Nerodia rhombifer rhombifer*
Midland Water Snake	*Nerodia sipedon pleuralis*
Rough Green Snake	*Opheodrys aestivus*
Graham's Crayfish Snake	*Regina grahamii*
Midland Brown Snake	*Storeria dekayi wrightorum*
Northern Redbelly Snake	*Storeria occipitomaculata occipitomaculata*
Western Ribbon Snake	*Thamnophis proximus proximus*
Eastern Garter Snake	*Thamnophis sirtalis sirtalis*
Western Earth Snake	*Virginia valeriae elegans*
Southern Copperhead	*Agkistrodon contortrix contortrix*
Western Cottonmouth	*Agkistrodon piscivorus leucostoma*
Timber Rattlesnake	*Crotalus horridus*

APPENDIX B

Description of Fragmented Forest Study Sites in Southeast Missouri during 1999 - 2000

Plot Name	Percent forest	Forest Category	Dominant Forest Type	County
Henderson Mound	0.76%	Low	Hardwood Patches	New Madrid
Shew & Presson	1.41%	Low	Softwood/shrub Patches	Mississippi
Powers Island	1.57%	Low	Riparian Strip	Scott
Dorena	2.49%	Low	Cypress Patch	Mississippi
Levee District 3	3.96%	Low	Riparian Strip	Mississippi
Point Pleasant	8.68%	Medium	Hardwood/Shrub Strip	New Madrid
Gertrude Jones	15.57%	Medium	Hardwood Patches	Mississippi
Eagles Nest	16.79%	Medium	Softwood Patches	New Madrid
Sunburst	19.59%	Medium	Riparian Softwood Patches	Mississippi
Wincheser Chute	20.11%	Medium	Softwood Patches	New Madrid
Big Lake	20.24%	High	Cypress Forest	Mississippi
Whitesell Woods	20.46%	High	Hardwood Forest	Scott
North Ten Mile	28.38%	High	Hardwood Forest	Mississippi
Westvaco Levee	32.92%	High	Mix Hard and Softwood	New Madrid
Girvin	34.83%	High	Softwood Patches	Pemiscot
Donaldson Point	58.79%	High	Softwood Forest	New Madrid