To the Graduate Council:

I am submitting herewith a thesis written by Michael Shelton Whittington entitled "Evaluation of Aquatic Macroinvertebrates Available to Wintering Waterfowl in Managed and Natural Wetlands in Western Tennessee." I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Sammy L. King, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor and
Dean of Graduate Studies

Evaluation of Aquatic Macroinvertebrates Available to Wintering Waterfowl in Managed and Natural Wetlands in Western Tennessee

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Michael Shelton Whittington

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Dedication

This thesis is dedicated to my wife Rachel for her help, support and love. I don't think I could have accomplished this without her. Also to my daughter Shirley Jane, who was born during the writing process. To the rest of my family who stood behind me and gave continuous support. Thank you all!

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Finally I greatly thank by wife Rachel for all of her love, patience and support. I have depended on her greatly in completing this work. I can not imagine finishing this project without here. I also greatly appreciate the encouragement from the rest of my family.

Abstract

Aquatic and wetland invertebrates are important protein sources for wintering waterfowl in the Lower Mississippi River Alluvial Valley (LMAV). Few studies have evaluated winter invertebrate abundance patterns in the LMAV, particularly in Western Tennessee. I examined aquatic macroinvertebrate biomass, density, and diversity in beaver ponds, moist soil units and flooded, harvested soybean fields in Western Tennessee. Moist soil units and flooded soybean fields are common wetland practices on public lands in Western Tennessee. Beaver ponds offer natural habitat that is greatly increasing in the southeastern United States (Arner and Hepp1989). The objective of this study was to compare invertebrate abundance and biomass of selected invertebrate groups in wetlands important to wintering waterfowl in Western Tennessee. Three beaver ponds at Ames Plantation, three moist soil units and three flooded soybean fields at Chickasaw and Lower Hatchie National Wildlife Refuges were randomly chosen for intensive study. Monthly samples were collected from January to March in 2003 and 2004 with a benthos core sampler (8.8 cm diameter x 10 cm depth). Invertebrates were counted and identified to family or lowest practical taxa and the density, diversity, and biomass of invertebrates were compared among months and habitat types. A total of 1,077 (2003) and 1,796 (2004) invertebrates were identified from 19 higher taxa and 34 families. Oligochaeta and Diptera were most common in all three habitats. Bivalvia were prominent in beaver ponds whereas Nematoda were highly prevalent in moist soil units and soybean fields. Mean invertebrate biomass in this study ranged from 0.9 g/m^2 $\pm$ 0.2 g/m^2 ($\bar{x} \pm$ s.e.) in soybean fields to 4.7 g/m^2 $\pm$ 1.6 g/m^2 in beaver ponds. Density of invertebrates ranged from 464/m^2 $\pm$ 10 m^2 in moist soil units to 883/m^2 $\pm$ 228 m^2 in beaver ponds. No differences were detected for density or biomass among beaver ponds, moist soil units, and soybean fields. Generally diversity showed little difference, however, for the month of March, diversity was slightly lower in soybean fields than in beaver ponds or moist soil units. I could not identify one treatment that provided more invertebrate resources than either of the other treatments.

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1. Introduction

Waterfowl Importance

Waterfowl are a diverse group of species that have important ecological roles in wetlands. Nesting, roosting, and feeding habitats vary among species (Mitsch and Gosselink 2000) and no single wetland habitat can provide all of the needs of a given species of waterfowl. Waterfowl are also a highly valued game animal. In Tennessee in 1996, $25,526,000 were spent by migratory bird hunters (migratory birds include ducks, geese, doves, woodcock, rails, coots, gallinules and snipe) and many millions more were spent by wildlife watchers (U.S. Department of the Interior, U.S. Department of Commerce, and U.S. Census Bureau 1996).

The diverse habitat needs of waterfowl and their status as a popular game animal, have resulted in the conservation of wetlands throughout North America. For example, the Federal Duck Stamp Program was initiated in 1934 as part of the Migratory Bird Hunting Stamp Act (Belanger 1988), a law requiring waterfowl hunters to purchase an annual duck stamp. Currently, about 1.6 million federal ducks stamps are sold each year nationwide (U.S. Department of the Interior 2003) with over 35,000 duck stamps sold in Tennessee in 2001 (U.S. Fish and Wildlife Service 2003). The proceeds of these funds are used to acquire and manage wetlands throughout the United States (Belanger 1988). Since 1934, the "Duck Stamp Act" has resulted in the acquisition and protection of over 2,020,000 ha of wetlands.

Although millions of ha of wetlands have been acquired through the Duck Stamp Act, wetland losses have exceeded 50% of original wetland area in the United States. At one time, Tennessee contained over 80,940 ha of high quality wetlands (Shaw and

Fredine 1956). However, extensive clearing of bottomland hardwood forests and channelization of rivers in Western Tennessee reduced the amount of available habitat for wintering waterfowl. Losses and alterations of wetlands have not been limited to Western Tennessee, but have occurred throughout the Lower Mississippi Alluvial Valley (LMAV). Only 2.8 million ha of an original 10 million ha of bottomland hardwood forests still exists in the LMAV and many of the remaining ha are highly degraded because of hydrologic alterations (National Research Council 1982, Hefner and Brown 1985, Delnicki and Reinecke 1986, Reinecke et al. 1989, King and Keeland 1999, Twedt and Nelms 1999). Wetland losses and alterations require intensive management of many remaining wetlands, including moist soil units, flooded agricultural crops, and beaver ponds, to insure that the annual life cycle requirements of waterfowl can be met.

Moist soil management units are impoundments containing grasses, sedges and other herbaceous plants designed to provide habitat for wetland wildlife primarily waterfowl and wetland birds (Reinecke et al. 1989). Various seasonal drawdowns and flooding are used to control or influence vegetation communities; these impoundments are generally only flooded for a portion of the year (Fredrickson 1991, Fredrickson and Laubhan 1996). Moist soil vegetation commonly found in these impoundments include favorable waterfowl foods such as sprangletop (*Leptochloa* spp.) rushes (*Eleocharis* spp.), smartweeds (*Polygonum* spp.), sedges (*Carex* spp. and *Cyperus* spp), foxtail (*Setaria* spp.), knotgrass (*Paspalum distichium*) and millets (*Echinochloa* spp) (Whitman 1976, USDA 2001). These habitats, combined with the remaining native bottomland hardwood systems that flood annually along the southern rivers, are needed to provide the wide range of resources required by wintering ducks (Fredrickson and Heitmeyer 1988, Reinecke et al. 1989).

The once-forested LMAV is now dominated by agriculture (McAbee 1994). Since the 1930's, agriculture has been an integral part of waterfowl management for wintering refuges (Reinecke et al. 1989). Many refuges use a system of cooperative farming, where crops are grown on refuge lands and profits from the sale of crops are shared by farmer and refuge (McAbee 1994). Crops are often grown on lands with some form of water level control enabling the refuge managers to flood fields after harvest. Flooded, harvested fields provide opportunities for ducks to forage on crop residues and also serve as loafing areas. Use of soybean fields as management units for wintering waterfowl is encouraged by the North American Waterfowl Management Plan for feeding and loafing areas (Manley 1999). Flooded crop residues of corn and rice are valuable food sources. In contrast, soybeans are less valuable because they deteriorate at a faster rate (Reinecke 1989, Nelms and Twedt 1996). These lands may have some other value in providing ducks with foraging opportunities for aquatic invertebrates.

Across the Southeast, including Western Tennessee, beaver populations have increased dramatically since the mid-1900's, leading to a tremendous loss of timber, changes in land use and highly altered hydrology in riparian zones. Beaver ponds typically offer more permanent hydroperiods. By having longer anoxic conditions (Sklar 1985) than moist soil or flooded soybean fields, beaver ponds may support different invertebrate communities. Most beaver ponds are located in forested areas, thus some of their invertebrate communities may be similar to other forested wetlands. Studies have shown that forested wetlands in the southern United States have yielded high numbers of invertebrates that are beneficial to waterfowl (Wehrle et al. 1995). Many of the beaver ponds include heterogeneous habitats such as living and dead flooded timber, water tupelo (*Nyssa aquatica L.*) and baldcypress (*Taxodium distichium* Richard), emergent and submergent vegetation, floating aquatic vegetation and deep open water.

Wintering Waterfowl

An understanding of the seasonal and spatial habitat needs of waterfowl is necessary to effectively manage wetlands to benefit waterfowl. Waterfowl have complex life cycles that demand a variety of resources at specific times from a variety of habitats. Most North American waterfowl are migratory and breed in more northern climates and winter in southern areas. In Western Tennessee, the wood duck (*Aix sponsa* L.), Canada goose (*Branta canadendsis* L.), and the hooded merganser (*Lophodytes cucullatus* L.) are exceptions, having resident populations as well as migrant populations.

The Mississippi Flyway, in which Western Tennessee lies, is the largest flyway in North America. This annual travel corridor serves as a linkage for ducks from their northern breeding grounds to the southern wintering areas. The earliest migrants, such as the blue winged teal (*Anas discors* L.), pass through in early September with most other species arriving in mid to late November. Although there are many influences that cause migration, this annual event is driven to a large degree by weather and the availability of food at fall staging areas and along the migration routes (Bellrose 1976).

Migration requires a large amount of energy, mostly derived from carbohydrates gained from agricultural crops, seeds, and acorns found in bottomland hardwood forests. The flight south is a tremendous energy demand for waterfowl. Many fly continuously for forty hours and arrive on the wintering grounds exhausted (Bellrose 1976). During the time between arrival and departure for the breeding grounds in the spring, waterfowl may undergo energetically costly stresses (Fredrickson and Heitmeyer 1988). In fact, the availability of quality wetlands on the wintering grounds is important to the recruitment of mallards (*Anas platyrynchos* L.) (Heitmeyer and Fredrickson 1981, Dubovsky and Kaminski 1994). Krapu (1981) demonstrated that winter wetlands are even more important to recruitment in mallards than the number of wetlands on the breeding grounds.

Reinecke et al. (1989) noted that during the winter in the LMAV, flight, pair formation or courtship, thermo-regulation and molt are important stressors for several species of waterfowl. Provisions of the necessary resources to meet these needs at the appropriate times are the key to successful waterfowl management. The LMAV is critical because it provides resources to meet demands of physiologically costly life cycle events that occur on the wintering grounds. Energy needs for flight, pair formation or courtship and thermo-regulation can be met with carbohydrates derived from a variety of foods such as acorns, grain crop residues, and moist soil seeds.

Molt, pre-breeding, and breeding activities, however, necessitate the acquisition of protein. All or part of at least one molt may be completed while ducks are along the migration route or on wintering grounds (Weller 1976). Requirements may be as much as a 3 g per day increase in protein at the peak of the molt (Heitmeyer 1985, Reinecke et al. 1989). Protein acquisition during late winter can also have profound impacts on reproduction at the breeding grounds because adequate protein is necessary for the onset of the pre-basic molt and egg laying in females. In mallards, poor feeding conditions on the wintering grounds, specifically protein restriction, could have negative effects on early nest laying and subsequent recruitment (Dubovsky and Kaminski 1994). In a similar study, body mass, survival and pairing of captive wood ducks in winter were negatively affected by a limited availability of protein in the diet (Demerest et al. 1997). In wood ducks it has been shown that condition of eggs is directly related to the nutritional condition of the hen (Bellrose and Holm 1994).

Invertebrates

Protein requirements of many waterfowl species are often met through consumption of invertebrates (Fredrickson and Heitmeyer 1988, Reinecke et al. 1989, Eldridge 1990, Anderson and Smith 1998). Additionally, calcium derived from the shells of some invertebrates can be important to waterfowl (Eldridge 1990, Krapu 1992). A Mississippi study (Delnicki and Reinecke 1986) revealed that winter diets of mallards contained 3% animal matter. Of this total, physid snails represented 58.7% of the sample. In southeastern Arkansas green tree reservoirs (GTRs), diets of mallards sampled were found to include Coleoptera, Diptera and Isopoda in greatest abundance (Dabbert and Martin 2000). These orders comprised 6% or more of the sample.

Although invertebrates can be important throughout the year (Drobney and Fredrickson 1979, Combs and Fredrickson 1996, Delnicki and Reinecke 1986), invertebrates are more important later in the winter than in mid-winter or fall (Delnicki and Reinecke 1986). Invertebrate abundance is determined by short and long-term hydrology, substrate, and chemical and physical conditions of the wetland (Pennak 1989, Fredrickson and Laubhan 1996). The short-term flooding used to manage the moist soil units and harvested soybean fields may not be long enough for many invertebrate communities to flourish (Fredrickson and Reid 1988b). Many invertebrates in orders such as Ephemeroptera and Odonata require more than two years to complete some stages of their life cycle (Eldridge 1990, Thorp and Covich 1991, Merritt and Cummins 1996). The type and structure of vegetation may also have a great influence on the invertebrates found within a particular wetland (Batema 1985, Duffy and LaBar 1994). Wetlands with numerous plants or detrital material, such as moist soil units, often support a large number of invertebrates (Pennak 1989). In contrast, sites with few plants or detrital material, such as harvested soybean fields, may support fewer invertebrates (Reinecke et al. 1989). Information regarding the abundance of invertebrates in wetlands that are important for wintering waterfowl is limited (Reinecke et al. 1989, McAbee 1994, Benke 1999), particularly for wetlands in Western Tennessee.

Objectives

The overall objective of this study was to compare invertebrate abundance and biomass of selected invertebrate groups in selected wetlands important to wintering waterfowl in Western Tennessee.

Based upon previous studies and an understanding of invertebrate ecology, I have developed the following predictions:

1. moist soil units will provide higher invertebrate abundance and biomass than flooded and harvested soybean fields,

2. beaver ponds will support a more diverse community of benthic invertebrates than the other wetland types in this study.

2. Methods

Description of Study Areas

Study areas include the Lower Hatchie National Wildlife Refuge (LHNWR), Chickasaw National Wildlife Refuge (CNWR), and Ames Plantation (AP) (Figure 1). The LHNWR (N 35° 36" 38', E 89° 53" 5') is situated near Henning, Tennessee in Lauderdale and Tipton Counties. LHNWR is located within the LMAV and is owned and operated by the U.S. Fish and Wildlife Service (USFWS). The LHNWR is 3,685 ha in size and is located within the floodplain of the Hatchie River at the confluence of the Hatchie and Mississippi Rivers. Major wetland habitats on the refuge include bottomland hardwood forests, open water, flooded croplands, and moist soil management units. Lauderdale County has an annual average precipitation of 125.9 cm. The average winter temperature is 3.3° C with –2.2° C being the average minimum. High temperatures in the summer time average around 25.5° C. The record high of 40.6° C was recorded in 1980 (Monteith 1990). The soil associations at LHNWR are of well drained to somewhat poorly drained silt soils that are of alluvium origin. These are the Adler-Covenant-Morganfield formations (Monteith 1990).

The CNWR, (N 35° 51" 58', E 89° 33" 27') is 9,751 ha in size, it is also located in the LMAV in Lauderdale County, and it is also owned by USFWS. The waterfowl management areas at CNWR are found near the Forked Deer River System and lie within the floodplain of the Forked Deer River and the Mississippi River. Habitats, management regimes, and climate are similar to those of Lower Hatchie NWR.

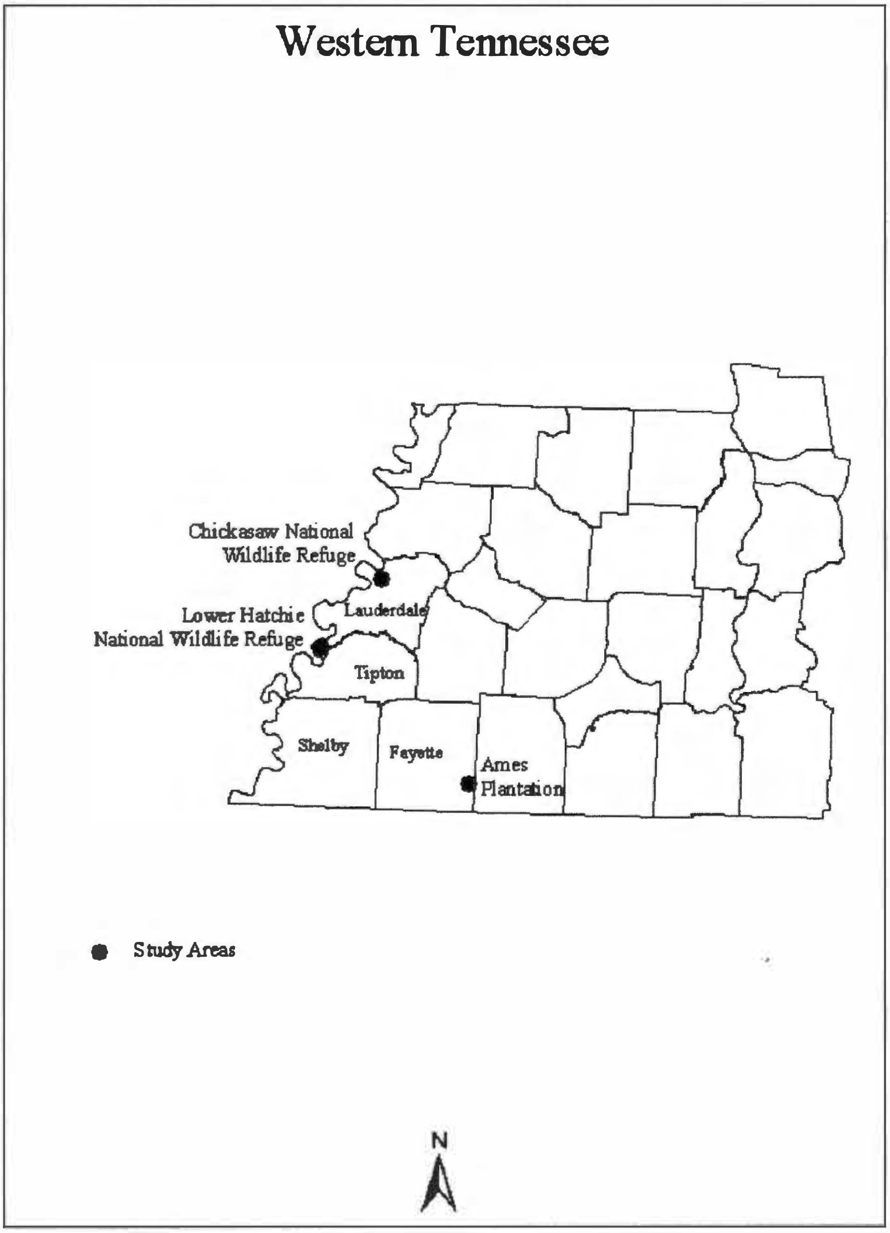


Figure 1. Map of Western Tennessee counties with study area locations

Ames Plantation in Fayette County (N 35° 7" 51', E 89° 13" 57'), is a private landholding totaling around 7,568 ha. It is owned by the Hobart Ames Foundation and is operated in cooperation with the University of Tennessee as an agricultural experiment station. AP is located within the Upper East Gulf Coastal Plain physiographic province of Tennessee. Loess covered rolling hills are the dominant land form (Houston 1991, Kreh 1997). These hills are drained by intermittent streams that flow to tributaries of the Mississippi River. Major wetland habitats on Ames Plantation are the North Fork Wolf River with its associated forested floodplain wetlands and beaver ponds. Beaver ponds are located on tributaries of the North Fork Wolf River and within the Waverly-Falaya-Collins soil associations (Flowers 1964). Daily temperatures range from 0° C to 12.8° C in January and from 18.33° C to 32.2° C in July with an annual average of 16.3° C. Precipitation averages 135 cm annually (Flowers 1964). The growing season is approximately 200 to 220 days.

Experimental Habitats

All habitat types were not available at all study locations and individual habitat types were sometimes not available on the same site each year of study. Therefore, harvested soybean fields and moist soil units were sampled at LHNWR when available, moist soil units and harvested soybean fields were sampled at CNWR when available, and only beaver ponds were sampled at AP. To determine invertebrate density and biomass, 3 wetlands of each habitat type were randomly selected for intensive study, however, there were only 3 flooded soybean fields available for selection at CNWR in 2004. Moist soil management units and soybean fields that were sampled at CNWR and LHNWR ranged from 4.5 ha to 16.2 ha at LHNWR and from 12 ha to approximately 30 ha at CNWR with actual flooded area varying at times. Flooding generally took place in November and water was drawn down near the end of March. Beaver ponds ranged from approximately 4.0 ha to under 8.1 ha. Many beaver ponds at AP were involved in previous research (Houston 1991) making an accurate age description difficult. Most, however, have been continuously flooded for approximately 15 years. One beaver pond sampled was less than 5 years old.

Sampling Protocols

Because no single sampling technique is effective in sampling all invertebrate communities (Fredrickson and Reid 1988a, Benke 1999), a combination of sampling techniques was used. Specifically, a benthic core sampler and D-ring net were used to sample invertebrates. Benthic cores quantified benthos invertebrates such as Gastropoda (e.g., snails), Oligochaeta (e.g., aquatic earthworms), and Dipterans (e.g., true flies), and captured some invertebrates in the water column such as Ostracoda and Amphipoda. Once per month from January –March, benthos core sub-samples were collected at 10 random points in each wetland with an 8.8 cm (diam) x 10 cm (deep) benthic core sampler following commonly accepted core sampling techniques (Swanson 1978, Murkin et al. 1996, Manley 1999). Sampling points were located along transects stratified in water depths $\leq$ 45 cm deep. This depth was chosen to approximate maximum feeding depths for dabbling ducks (Fredrickson and Reid 1988b).

In addition to benthic cores, a 30 cm D-ring net with 500 micrometer mesh was used to sample the water column. D-ring nets are more effective at sampling mobile invertebrates. The net was placed just above the bottom and pushed forward then raised through the water column (Wehrle et al. 1995). Sampling with the net was conducted only in the moist soil units and the soybean fields because beaver ponds contained too many debris obstructions for net sweeps. A net sweep was also collected for one meter at 5 locations at the margin of the moist soil and soybean impoundments.

D-ring samples and benthic cores were pre-washed through a 500 micrometer (No. 35) U.S. standard mesh sieve to remove excess mud and silt. Each sample was placed in a freezer bag and frozen until analysis. Frozen samples were later thawed and allowed to soak overnight in Rose Bengal solution to stain soft-bodied invertebrates, increasing detection rates (Duffy and LaBar 1994, Manley 1999). Samples were washed through a stacked set of brass sieves, with 2 mm (No. 10) and 500 micrometer (No. 35) U.S. standard sampling screens (Thorp and Covich 1991). Material from the 2 mm (No. 10) screen was placed in a white pan and covered with water to aid with sorting. The finer material from the 500 micrometer (No. 35) screen was sorted under a 10X stereoscope. Invertebrates were counted and identified to Order (2003) and Family (2004) level or lowest practical taxa (Sklar 1985, McAbee 1994, Manley 1999). Taxonomy follows Pennak (1989), Thorp and Covich (1991), Merritt and Cummins (1996), and Voshell (2002). The separated animal matter was oven-dried at 60° C for 24 hours, allowed to reach room temperature, and then weighed to the nearest 0.1 mg. Invertebrates were reported as standing stock biomass (Duffy and LaBar 1994).

Vegetation Substrate

To estimate vegetation substrate in each habitat type, samples were obtained by clipping all vegetation within a meter square frame. Five random samples were collected from each of the units that were sampled in 2004. The stubble and any remaining residue were recovered from the samples in the soybean fields and all vegetation was clipped inside the frames for beaver ponds and moist soil units. Vegetation biomass samples were oven-dried and weighed daily until no further loss of moisture was detected.

Statistical Analyses

I analyzed invertebrate biomass, density and Simpson's Diversity Index ($1-D=\Sigma(n/N)^2$) (Krebs 1994) by season and wetland type; results from 2003 and 2004 were analyzed separately because the same wetland units were not available each year. Further, in 2003, only soybeans were sampled at LHNWR and moist soil units were sampled only at CNWR. In 2004, soybeans and moist soil units were sampled at both LHNWR and CNWR. For the January sampling period in 2003, no beaver ponds were analyzed. The ten subsamples for each wetland were averaged to get a mean density, biomass and diversity for each wetland replicate. Lavene's equal variance test and Shapiro-Wilkes test were used to confirm the assumptions of equal variance and normal distribution of data for analysis of variance. While equal variance was met using a significance level of 0.05, data were not normally distributed. Because transformations failed to normalize the data, Kruskall-Wallis non-parametric one-way analysis of variance was used to test for differences among treatments (Sokal and Rohlf 1981, SAS 2002). Wilcoxon non-parametric 2-sample test were used to make comparisons where significant differences ($P \leq 0.05$) did occur (Conover 1999). Friedman's Test for the two-way classification (Steel and Torrie 1980) was used to test for block differences among locations and treatments for the 2004 density and biomass data, excluding beaver ponds.

Means of dry weight biomass of vegetation were compared with ANOVA (Steel and Torrie 1980, SAS 2002). Tukey-Kramer test was used to determine where differences occurred when significant differences ($P \leq 0.05$) were detected.

3. Results

Climate Conditions

Two of the three months preceding sampling in 2003 had rainfall amounts of approximately 9-11 cm above normal (SRCC 2005). Where data was available for that same time period, temperature ranged from about 1.7° C below normal to about 0.5° C above normal. Rainfall ranged from 15.3 cm above normal to 7.9 cm below normal during the 2003 sampling period. In 2004, rainfall in the three months preceding sampling ranged from 7.2 cm below normal to 5.2 cm above normal. For this same period, data was only available to show that December was 0.6° C above normal. Rainfall during 2004 sampling ranged from 4.9 cm above to 5.3 cm below normal. For January and February 2004, temperatures ranged from 2.23° C above normal to 1.7° C above normal.

Invertebrate Results

In 2003, 1,077 individual invertebrates representing 11 taxa were identified mostly to Order level. In 2004, 1,796 invertebrates representing 39 taxa were identified to Family where possible. Taxa found in 2004 and not recorded in 2003 included Arachnida, Ephemeroptera, Cladocera, Ostracoda, Megaloptera, Trichoptera and Homoptera. Homoptera is not usually considered in aquatic invertebrate studies and only combinations are dominated by two or three taxa (Figure 2).

In 2003, the most dominant taxa for beaver ponds were Bivalvia and Oligochaeta. Moist soil units were sampled only at CNWR in 2003 and were dominated by Oligochaeta and Nematoda. Oligochaeta and Nematoda were also the most numerically common taxa in soybean fields. In 2004, Oligochaeta and Diptera, although weighted

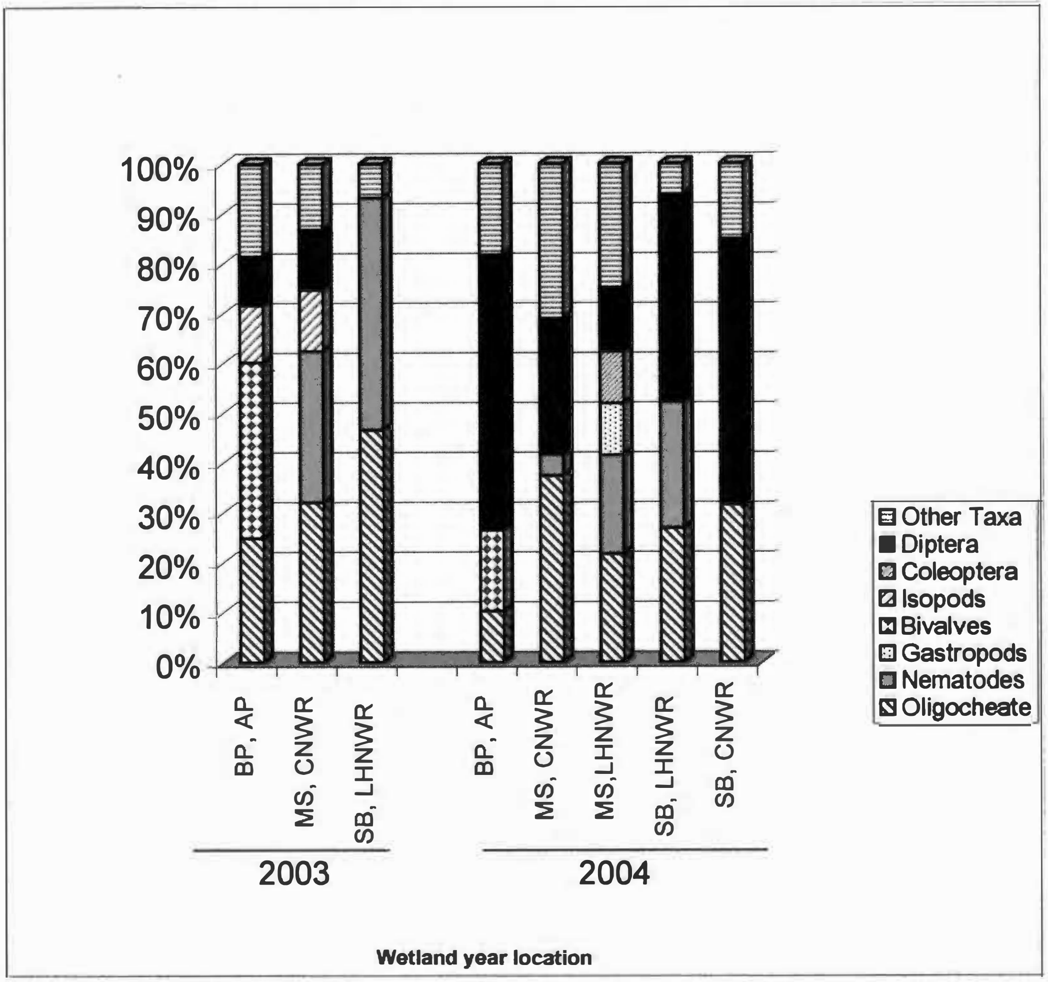


Figure 2. Common taxa by mean percentage of invertebrate taxa abundance within individual wetlands. Abbreviations are as follows; BP – beaver ponds, MS – moist soil units, SB – soybean fields, AP – Ames Plantation, CNWR – Chickasaw National Wildlife Refuge and LHNWR – Lower Hatchie National Wildlife Refuge. BP occurred only at AP. MS and SB occurred at CNWR and LHNWR.

differently in each, were dominant for all five treatment by location combinations. Moist soil units at LHNWR were the only wetland type that had five orders accounting for greater than 10 percent of invertebrates in both years.

Oligochaetes were important in all treatments and at all locations both years (Figure 2). Oligochaeta abundance values ranged from a low of 10.2% $\pm$ 3.8% ($\bar{x}$ + s.e.) for beaver ponds in 2004 to a high of 46.6% $\pm$ 19.3% for soybean fields in 2004. Diptera were also important in all treatment types, however, they were not abundant in the soybean fields at LHNWR in 2004. Diptera were dominant in beaver ponds in 2004 (55.3% $\pm$ 10.4%). Nematodes, abundant in soybean fields and moist soil units for both years, were not important in beaver ponds. Bivalves were dominant in beaver ponds in 2003 (35.3% $\pm$ 8.8%) and 2004 (16.3 % $\pm$ 9.4%), but were not important in any other wetland type.

Invertebrate Density

In 2003, overall mean invertebrate densities were 670/m^2 $\pm$ 160/m^2 for beaver ponds, 805/m^2 $\pm$ 256/m^2 for moist soil units, and 864/m^2 $\pm$ 309/m^2 for soybean fields (Figure 3). In 2004, mean densities were 883/m^2 $\pm$ 228/m^2 for beaver ponds, 464/m^2 $\pm$ 100/m^2 for moist soil units, and 849/m^2 $\pm$ 261/m^2 for soybean fields (Figure 3). Overall mean density did not differ among treatments in 2003 ($P = 0.9629$, df = 2, $\chi^2 = 0.0757$) or 2004 ($P = 0.2215$, df = 2, $\chi^2 = 3.0145$).

Mean invertebrate density (Figure 4) did not differ among months in beaver ponds (2003 : $P = 0.83$, df = 1, $\chi^2 = 0.05$; 2004 : $P = 0.88$, df = 2, $\chi^2 = 2.17$), moist soil units (2003 : $P = 0.84$, df = 2, $\chi^2 = 0.36$; 2004 : $P = 0.34$, df = 2, $\chi^2 = 2.17$) or soybean fields

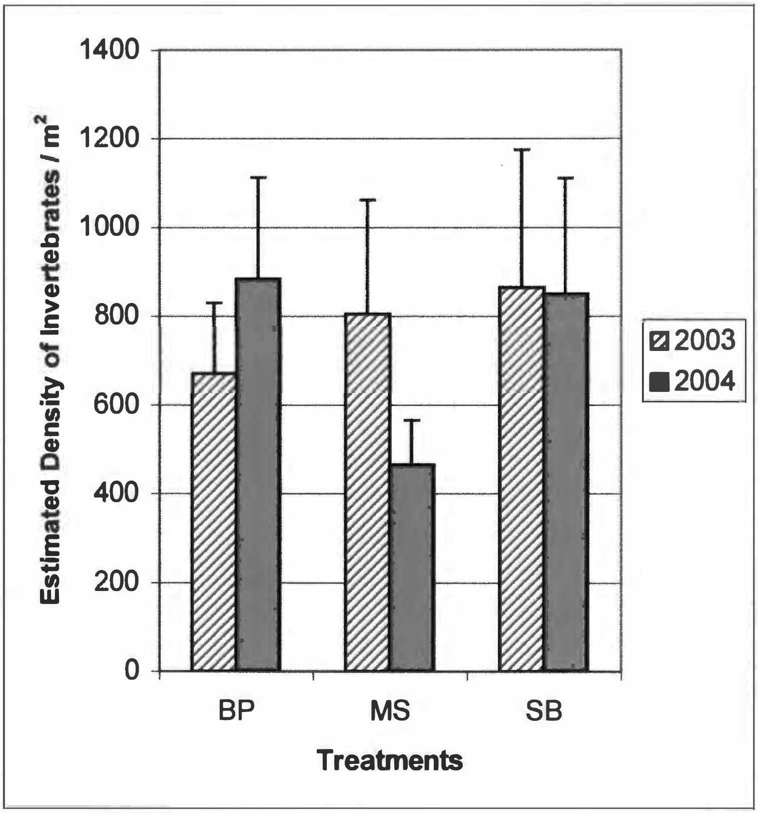
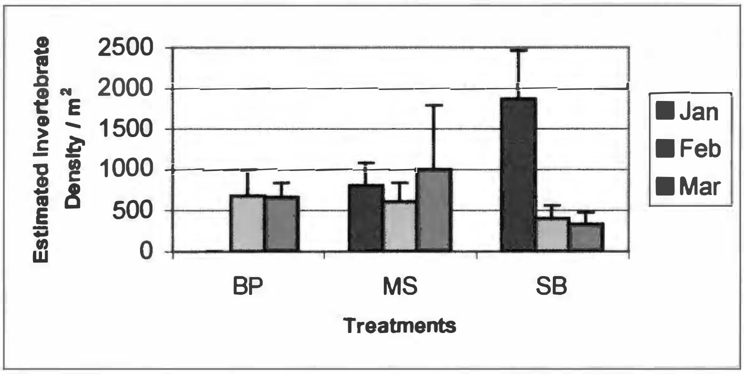


Figure 3. Invertebrate mean density (individuals /m^2) by years. Abbreviations are as follows; BP – beaver ponds, MS – moist soil units, SB – soybean fields. BP sampled at Ames Plantation. MS and SB sampled at Chickasaw NWR and Lower Hatchie NWR.

(a)



(b)

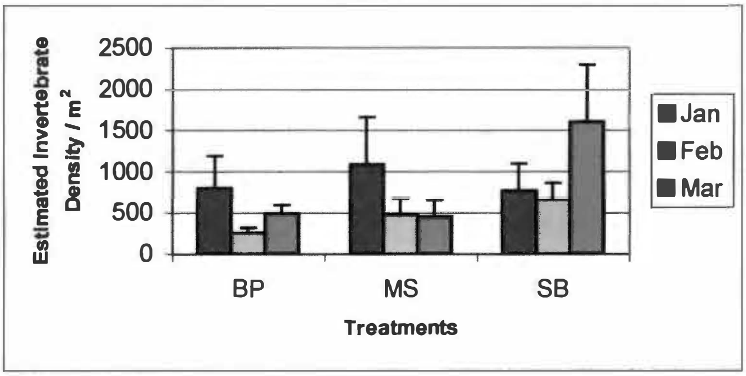


Figure 4. Mean density of invertebrates (individuals/m^2) by month of study during a) 2003 and b) 2004. Abbreviations are as follows; BP – beaver ponds, MS – moist soil units, SB – soybean fields. BP sampled only at Ames Plantation. MS and SB sampled at Chickasaw NWR and Lower Hatchie NWR. No differences were detected ($P \geq 0.05$).

(2003 : P = 0.07, df = 2, χ^2 = 5.43 ; 2004 : P = 0.07, df = 2, χ^2 = 5.35). In 2003, mean invertebrate densities did not differ among wetland types within January (P = 0.13, df = 1, χ^2 = 2.34), February (P = 0.65, df = 2, χ^2 = 0.88) or March (P = 0.56, df = 2, χ^2 = 1.56). Similarly, in 2004, mean invertebrate density did not differ among wetland types in January (P = 0.27, df = 1, χ^2 = 2.64), February (P = 0.28, df = 2, χ^2 = 2.52) or March (P = 0.33, df = 2, χ^2 = 2.21). In 2004, no effect on density was detected between moist soil units or soybean fields (P = 0.18, df = 1, F = 1.95) while blocking on location.

Invertebrate Biomass

Mean overall biomass was 3.1 g/m^2 $\pm$ 0.8 (2003) and 4.7 g/m^2 $\pm$ 1.6 (2004) for beaver ponds, 2.7 g/m^2 $\pm$ 1.2 (2003) and 1.7 g/m^2 $\pm$ 0.4 (2004) for moist soil, and 0.9 g/m^2 $\pm$ 0.2 (2003) and 1.1 g/m^2 $\pm$ 0.3 (2004) for soybean fields (Figure 5). Monthly biomass (Figure 6) did not differ among moist soil units (2003 : P = 0.74, df = 2, χ^2 = 0.61 ; 2004 : P = 0.13, df = 2, χ^2 = 4.08), beaver ponds (2003 : P = 0.28, df = 1, χ^2 = 1.19 ; 2004 : P = 0.84, df = 2, χ^2 = 0.36), or soybean fields (2003 : P = 0.08, df = 2, χ^2 = 5.07 ; 2004 : P = 0.06, df = .2, χ^2 = 5.70) in 2003 or 2004.

Mean biomass for each treatment also did not differ (2003 : P = 0.27, df = 2, χ^2 = 2.65; 2004 : P = 0.08, df = 2, χ^2 = 5.07). Similarly, no differences were detected at monthly intervals among treatments in 2003 (January : P = 0.28, df = 1, χ^2 = 1.1). February : P = 0.43, df = 2, χ^2 = 1.68 ; March : P = 0.29, df = 2, χ^2 = 2.49) or 2004 (January : P = 0.38, df = 2 , χ^2 = 1.96 ; February : P = 0.31, df = 2, χ^2 = 2.35 ; March : P = 0.60, df = 2, χ^2 = 1.03). No block effect was detected for biomass among moist soil units and soybean fields (P = 0.06, df = 1, F = 3.89) at locations, LHNWR and CNWR in 2004.

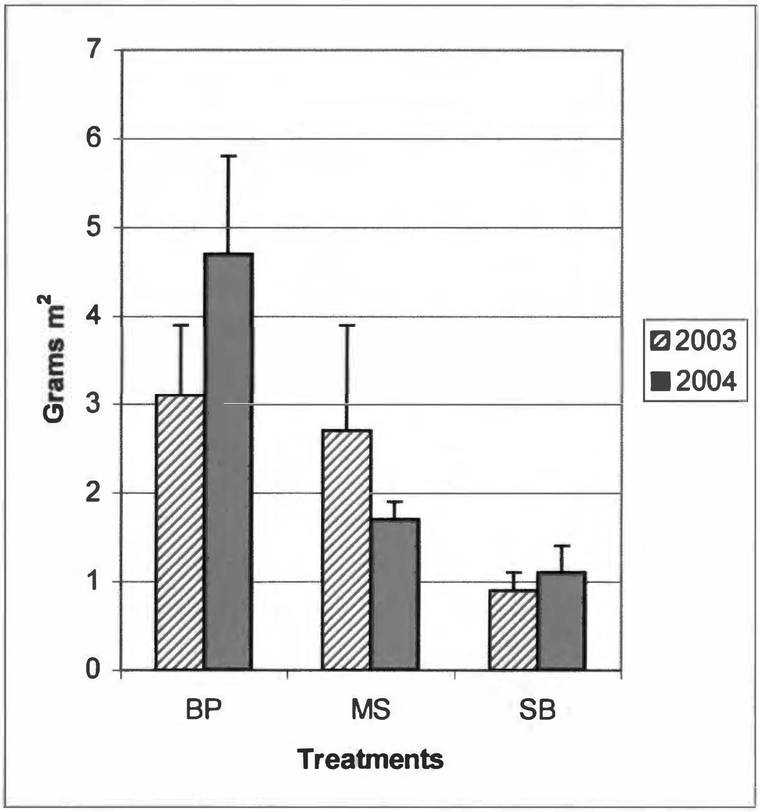
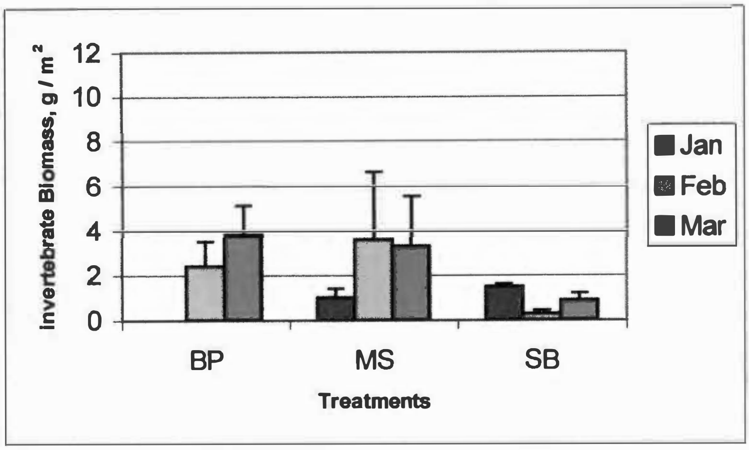


Figure 5. Mean invertebrate biomass (g/m^2) by year. Abbreviations are as follows; BP- beaver ponds, MS- moist soil units, SB- soybean fields. MS and SB sampled at Chichasaw NWR and Lower Hatchie NWR. BP sampled only at Ames Plantation. Means did not differ in 2003 (P=0.27) or in 2004 (P= 0.07)

(a)



(b)

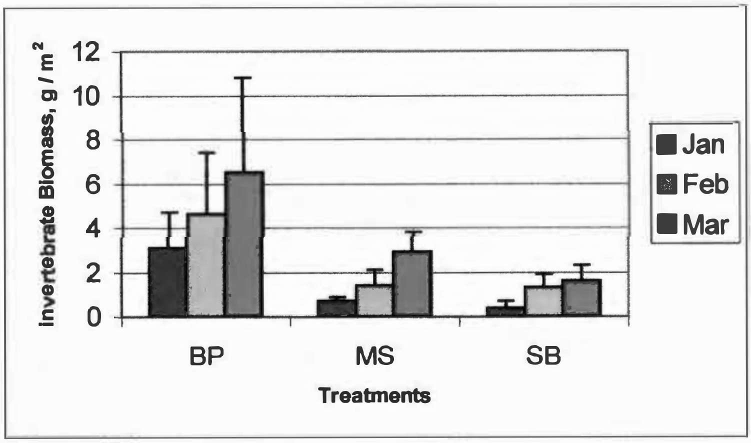


Figure 6. Mean invertebrate biomass (g/m^2) by month of study in a) 2003 and b) 2004. Abbreviations are as follows; BP – beaver ponds, MS – moist soil units, SB – soybean fields, AP – Ames Plantation, CNWR – Chickasaw National Wildlife Refuge and LHNWR – Lower Hatchie National Wildlife Refuge. BP sampled only at AP. MS and SB sampled at CNWR and LHNWR. Means did not differ (P>0.05).

Invertebrate Diversity

In 2004, a total of 34 families from 19 orders were identified as compared to the identification of only 16 orders in 2003. In 2003, beaver ponds supported 7 taxa, moist soil units supported 10 taxa, and soybean fields supported 6 taxa (Table 1). In 2004, beaver ponds supported 24 taxa (15 orders), moist soil units supported 23 taxa (16 orders), and soybean fields supported 23 taxa (12 orders).

In 2003, mean Simpson's diversity indices were 0.64 for beaver ponds, 0.53 for moist soil units, and 0.42 for soybean fields (Figure 7). In 2004, the diversity indices for beaver ponds were 0.56, moist soil units were 0.58, and soybean fields were 0.45 (Figure 7). Mean diversity indices did not differ among treatments (2003 : $P = 0.07$, $df = 2$, $\chi^2 = 5.27$) ; 2004 : $P = 0.09$, $df = 2$, $\chi^2 = 4.75$). Within treatments, diversity did not differ among months (Figure 8) for beaver ponds (2003 : $P = 0.83$, $df = 1$, $\chi^2 = 0.05$; 2004 : $P = 0.08$, $df = 2$, $\chi^2 = 5.144$), moist soil units (2003 : $P = 0.57$, $df = 2$, $\chi^2 = 0.51$; 2004 : $P = 0.16$, $df = 2$, $\chi^2 = 3.61$) or soybean fields (2003 : $P = 0.79$, $df = 2$, $\chi^2 = 0.47$; 2004 : $P = 0.61$, $df = 2$, $\chi^2 = 0.99$.). Within months for 2003, diversity indices did not differ among treatments for January ($P = 0.51$, $df = 1$, $\chi^2 = 0.25$), February ($P = 0.08$, $df = 2$, $\chi^2 = 0.43$) or March, ($P = 0.33$, $df = 2$, $\chi^2 = 2.21$). In 2004, diversity did not differ among treatments within January ($P = 0.38$, $df = 2$, $\chi^2 = 2.29$) and February ($P = 0.07$, $df = 2$, $\chi^2 = 5.19$), however, a difference was found to exist among treatments within the month of March ($P = 0.0492$, $df = 2$, $\chi^2 = 6.03$). In March, soybean fields supported a lower diversity of invertebrates than beaver ponds and moist soil units. While blocking on locations, no treatment differences were found among moist soil units or soybean fields ($P = 0.16$, $df = 1$, $F = 2.74$).

Table 1. Occurrence of invertebrate orders and families by treatments and years. *

		Beaver Ponds		Moist Soil Units		Soybean Fields	
Higher Taxa	**Family**	2003	2004	2003	2004	2003	2004
Oligochaeta		X	X	X	X	X	X
Nematoda		X	X	X	X	X	X
Podocipida					X		X
Cladocera					X		X
Gastropoda		X		X		X	
	Viviparidae		X				X
	Hydrobiidae				X		
	Planorbidae						
	Physidae		X		X		X
Bivalvia	Sphaeriidae	X	X	X			X
Arachnida(class)			X				
Acariformes	Hydrachnellae		X		X		X
Araneae	Lycosidae		X		X		
Isopoda	Asellidae	X	X	X	X		X
Amphipoda		X	X	X	X	X	X
Decapoda	Cambaridae		X	X	X		X
Ephemeroptera	Bagidae				X		
Odonata		X					
	Coenagrionidae		X				
	Libellulidae		X				
	Lestidae				X		
Hemiptera				X			
	Corixidae		X				
	Notonectidae				X		
Megaloptera							
	Corydalidae		X				
Trichoptera							
	Rhyacophilidae		X				
Coleoptera		X		X		X	
	Cantheridae						X
	Carabidae				X		X
	Haliplidae		X				X
	Dysticidae		X		X		X
	Elateridae						X
	Gyrinidae				X		

Table 1. Continued.

		Beaver Ponds		Moist Soil Units		Soybean Fields	
Higher Taxa	**Family**	2003	2004	2003	2004	2003	2004
	Hydrophilidae		X		X		X
	Crysomelidae		X		X		X
	Curculionidae				X		X
Diptera		X		X		X	
	Chironomidae		X		X		X
	Ceratopogonidae		X		X		X
	Culicidae						X
	Tipulidae						
	Stratiomyidae		X				
	Tabanidae		X				X
	Empididae		X				
Homoptera							
	Cicadidae				X		

* Beaver ponds occurred only at Ames Plantation. Moist soil units and Soybean fields occurred at Lower Hatchie and Chickasaw National Wildlife Refuges in 2004.

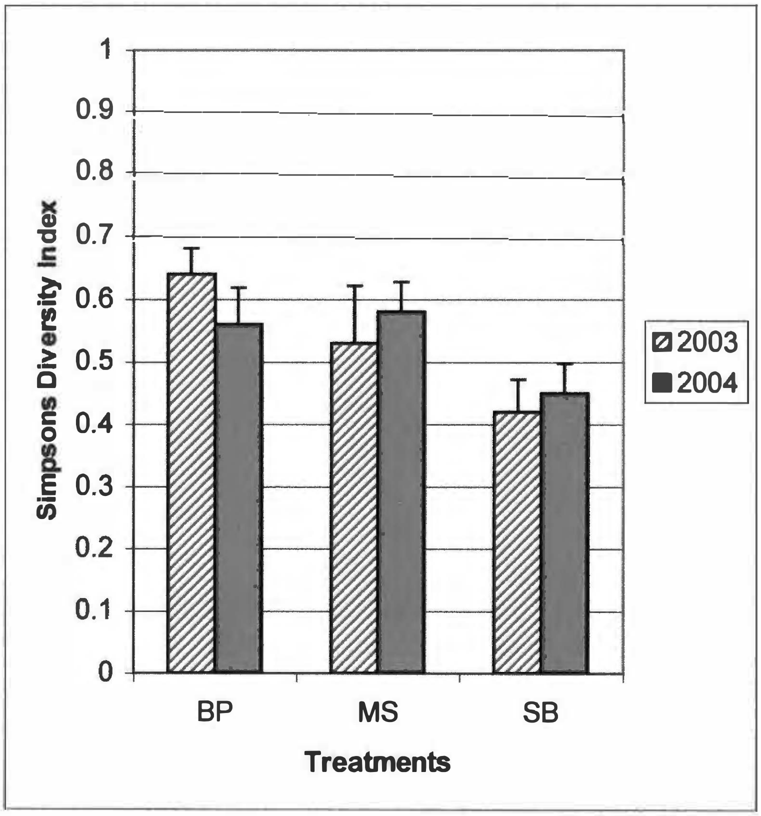
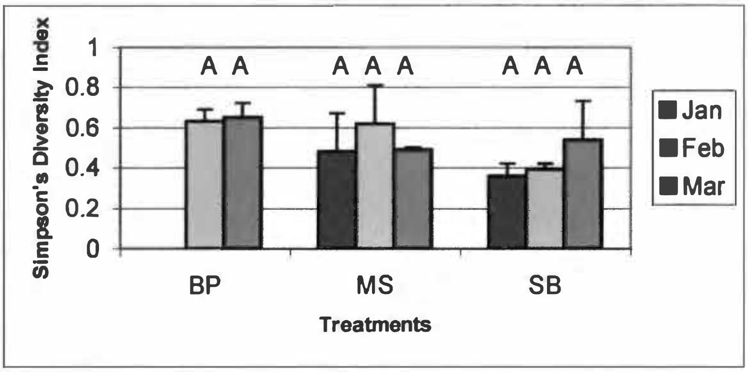


Figure 7. Mean diversity indices (Simpson's Diversity Index) of invertebrates by year. Abbreviations are as follows; BP – beaver ponds, MS – moist soil units, SB – soybean fields. BP sampled only at Ames Plantation. MS and SB sampled at Chickasaw NWR and Lower Hatchie NWR. Means did not differ in 2003 (P = 0.07) or 2004 (P = 0.09).

(a)



(b)

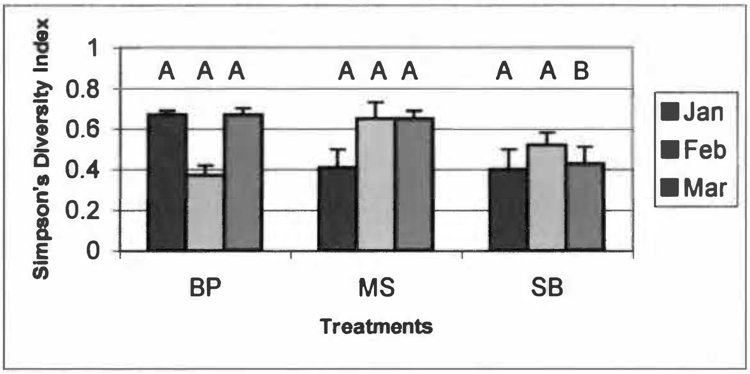


Figure 8. Mean diversity indices (Simpson's Diversity Index) of invertebrates by month of study in a) 2003 and b) 2004. Abbreviations are as follows; BP – beaver ponds, MS – moist soil units, SB – soybean fields. BP sampled only at Ames Plantation. MS and SB sampled at Chickasaw NWR and Lower Hatchie NWR. Means sharing a letter in the same year do not differ (P > 0.05).

Vegetation Substrate Results

Mean of vegetation substrate biomass for beaver ponds (214 $g/m^2 \pm 58$), moist soil units (343 $g/m^2 \pm 41$), and soybean fields (79 $g/m^2 \pm 41$) differed ($P < 0.001$, $df = 2$, $F = 24.6$) (Figure 9). Moist soil units supported higher mean biomass than beaver ponds or soybean fields. Beaver ponds also supported higher mean biomass than soybean fields. Vegetation collected in soybean fields was limited to short pieces of post harvest stubble and leaf and stem litter, which is not evenly distributed. The vegetation in moist soil fields was dominated by Polygonum sp., Panicum sp., Xanthium sp., and Ambrosia sp. Beaver pond vegetation consisted primarily of Sparganium sp., Cyperus sp. Echinocloa sp. and Leersia oryzoides (L.) SW.

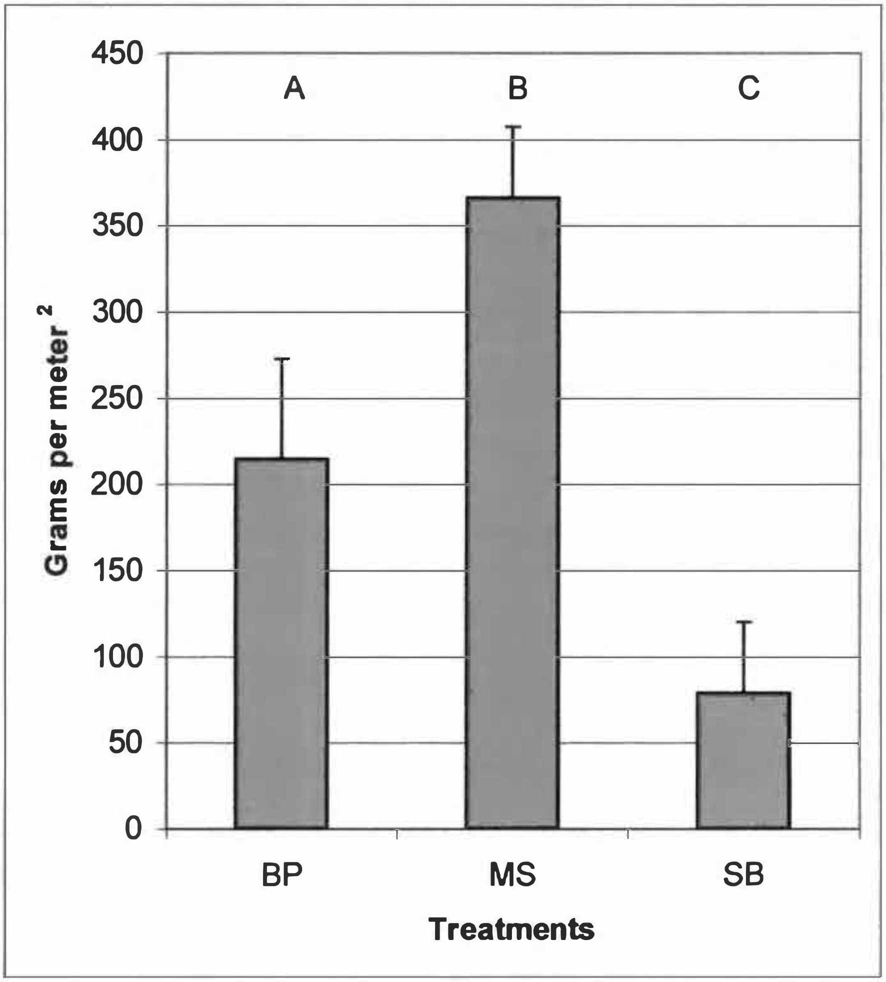


Figure 9. Mean dry weight biomass of vegetation substrate. Samples taken in 2004. Abbreviations are as follows; BP – beaver ponds, MS – moist soil units, SB – soybean fields. Means sharing a letter do not differ ($P \leq 0.05$).

4. Discussion

Results of this study indicate that there were few differences in invertebrate density, biomass, and diversity in beaver ponds, moist soil units, and flooded soybean fields during January, February and March, 2003 and 2004. Contrary to a priori predictions, in winter, moist soil units did not support higher invertebrate biomass or abundance than flooded soybean fields. Nor did beaver ponds support a more diverse assemblage of aquatic invertebrates than moist soil units or flooded soybean fields. The varied and short hydroperiod in these wetland habitats, low winter temperatures, and high variability of invertebrate populations and habitat conditions within wetland types (Thorp and Covich 1991), likely confounded my results. Hydroperiods of varying duration were used in the moist soil units, thus potentially affecting invertebrate communities differently within the same treatment type. Cold weather was common during my sampling period, and it may have depleted some aquatic invertebrate populations (White 1985). Seasonal removal of water from soybean fields for spring planting may influence diversity and density of wetland invertebrates (Mitsch and Gosselink 2000, Keiper et al. 2002).

Net sampling was intended to capture invertebrates in the open water column and at wetland margins. Although sweep nets are very common for sampling aquatic macroinvertebrates (Murkin et al. 1983, Wehrle et al. 1995, Gray et al. 1999), neither of the net sampling strategies attempted yielded enough of a sample for statistical analyses. Of nearly 400 net samples, only 6 organisms were captured demonstrating there is very little macro-invertebrate life in the water column in January, February, and March. A more intensive study of additional microhabitats within some beaver ponds and moist soil units, however, may show a more abundant and diverse community.

Invertebrate Density

Densities in this study were much lower than similar studies where density was reported (Sklar 1985, Duffy and LaBar 1994). However, Batema et al. (1985) observed similar winter invertebrate densities in Missouri GTRs for the same months during this study. Density estimates that were considered to be a high number ($>100/m^2$) ranged from $117/m^2 \pm 61.6$ to $658/m^2 \pm 258/m^2$. The first estimate was for Diptera in soybean fields and the second was for Bivalvia in beaver ponds. Duffy and LaBar (1994) had large numbers of Copepoda ($18{,}965/m^2$ in moist soil units and $2{,}355/m^2$ in beaver ponds) and Cladocera ($2{,}087/m^2$ in moist soil units) that increased their overall density estimates. Neither order was numerically common or dominant in this study. Invertebrates with high densities in my study were Oligochaeta, Nematoda, Bivalvia, and Diptera; of these, only Oligochaeta and Diptera also had high densities in Duffy and LaBar's (1994) study.

Sklar (1985) evaluated invertebrate densities in winter flooded cypress-tupelo backswamps in hardwood forests of Louisiana and reported higher densities than this study. Louisiana, however, has a more temperate winter climate than Western Tennessee. Numerically dominant invertebrates found in his study included Nematoda, Amphipoda, Diptera, and Isopoda, but not Copepods or Cladocera. Although common in Sklar's study and my study, densities of Nematoda ($4{,}768/m^2$) and Diptera ($2{,}969/m^2$) were higher in Sklar's study than in the three habitats of my study. In Batema's study (1985), of Missouri GTRs and naturally flooded forests, the dominant winter invertebrates were Chironomid (Diptera), Bivalvia, and Oligochaeta that were also common in my study. Additionally Isopods and Amphipods were common in Batema's study but were uncommon in my study.

In 2004 moist soil units, invertebrate density was only about one-half of the density for moist soil units in 2003. This variation may be attributed to different impoundments being studied each year because the same units were not managed in moist soil in successive years. Similarly, impoundments managed in soybeans were also available differently between years, but densities were nearly the same in soybean fields in both years.

Invertebrate Biomass

Biomass estimates for my study are within ranges of other similar studies. In Missouri, an invertebrate study in BLH during winter indicated a mean cumulative invertebrate biomass of 1.37 g/m^2 (White 1985), consistent with ranges determined for this study of 0.9 g/m^2 to 1.1 g/m^2 and 1.7g/m^2 – 2.7 g/m^2 found in soybean and moist soil units, respectively. Gray et al. (1999) reported 0.17 – 0.74 g/m^2 in various control and experimental moist soil plots in Mississippi. Wehrle et al. (1995) reported biomass means ranging from 1.7 kg/ha (0.17 g/m^2) to 80.05 kg/ha (8.0 g/m^2) in GTRs and naturally flooded forests at two different locations in Mississippi. McAbee (1994) surveyed soybean and moist soil fields in Louisiana, finding no invertebrates in soybean fields one winter then 0.53 kg/ha (0.053 g/m^2) in soybean fields the following winter. In the same study, invertebrate biomass in moist soil units ranged from 0.17 - 0.62 kg/ha (0.017 g/m^2 - 0.062 g/m^2). In Mississippi, Duffy and LaBar (1994) found 1.58 g/m^2 in moist soil units and about 1.00 g/m^2 in beaver ponds during winter. In Tennessee, invertebrate biomass (2003 : 3.1g/m^2; 2004: 4.7 g/m^2) in beaver ponds was much higher than Duffy and LaBar (1994), where mean biomass was about 1.00 g/m^2.

Invertebrate Diversity

Comparing invertebrate diversity is difficult because most authors either do not report diversity indices or have reported different indices (e.g. Gray et al. 1999). Comparisons of diversity and community structure should be confined to the taxa reported in similar studies. This research illustrates variability in invertebrate diversity and community structure among the wetland types. Three taxa, Diptera, Bivalvia, and Oligochaeta, were found in both years in beaver ponds. In 2003, Isopoda were also collected, but were not as prevalent in 2004. Similarities in diversity are evident in Duffy and LaBar (1994) where Oligochaeta, Isopoda, and Diptera were three of four most common taxa in a Mississippi study in beaver ponds. Naturally flooded forests and GTRs may offer related comparisons from the standpoint that these habitats are also wetlands associated with forests. In Mississippi, Oligochaeta, Isopoda, Gastropoda and Diptera were common in naturally flooded forests and GTRs. Two other taxa, Amphipoda and Decapoda, were not common in my study (Wehrle et al. 1995). Bivalves were relatively abundant in beaver ponds 2003 and 2004, in contrast with similar studies. Thorp and Covich (1991) discuss many reasons that bivalve populations are variable, however, differences are frequently species-specific and are beyond the scope of this study.

Soybean fields at LHNWR were dominated by Nematoda and Oligochaeta in 2003, while in 2004, Diptera were also dominant. This was similar to soybean fields at CNWR in 2004 that were dominated by Diptera and Oligochaetes. McAbee (1994) in winter flooded soybean fields in Louisiana reported finding only Annelida (Oligochaeta), Odonata, Hemiptera and Coleoptera. In that study, no Diptera or Nematoda were found in soybean fields.

The moist soil units at CNWR were dominated by Oligochaeta and Nematoda with Diptera and Isopods also being important in 2003. In 2004, Oligochaeta and Diptera were found on these sites as Nematodes and Isopods declined in importance. The LHNWR moist soil units supported a lower proportion of Oligochaeta and Diptera but Nematodes, Coleoptera, and Gastropods replaced Isopods in importance. In Mississippi, moist soil units were dominated by Cladocera, Copepoda, Isopoda, and Diptera (Duffy and LaBar 1994). In Louisiana, diversity was represented by seven taxa: Oligochaeta, Gastropoda, Coleoptera, Odonata, and a combination of Copepoda and Cladocera (McAbee 1994). It is possible that the lack of importance of Copepoda and Cladocera in my study is due to varying habitat conditions, including water quality and substrate composition. However, typically these species are abundant and well distributed throughout freshwater wetlands (Pennak 1989, Thorp and Covich 1991). It is also possible that these two invertebrates could have been destroyed in the washing process.

Vegetation Substrate

Using biomass as an indicator of potential nutrient input, soybean fields were shown to have much less vegetation than beaver ponds or moist soil units. This demonstrates that after harvest there is a much smaller input of organic matter into the detritus base in flooded harvested soybean fields. Moist soil units have a tremendous potential organic matter input due to the leaves and stems of plants grown in them. Most important, is that moist soil units which are managed, have the potential to produce greater amounts of vegetation, than beaver ponds which are natural wetlands. This comparison was made within the vegetated zone of beaver ponds, which are a naturally occurring wetland type. Due to the varied depths of most beaver ponds, this potential vegetation input is not available over the entire area of a beaver pond. One could conclude that, seasonally, moist soil units have a greater potential to produce greater quantities of invertebrates.

5. Considerations for Research and Management

Invertebrate biomass may be an important variable for waterfowl managers to consider on wetland management units, however, biomass is difficult to measure in the field and density is often used instead (Wirwa, Tennessee Wildlife Resources Agency pers. comm.). Some species, such as Cladocera and Copepods, represent high protein values (Anderson and Smith 1998) and can occur at high densities (Duffy and LaBar 1994), but are nearly microscopic in size. Thus, actual biomass values are low because available protein for waterfowl is actually limited. It is difficult to interpret the practical meaning of biomass figures (e.g., g / m^2 or kg/ha), and manage for biomass in invertebrate populations, unless a nutritionally meaningful target biomass value has been established. No target biomass for protein-rich foods alone has been determined, although Reinecke (1989) suggested that 50 kg/ha was the minimum amount of total food (i.e., agricultural grains, natural seeds and vegetation and invertebrates) needed to attract waterfowl. McAbee (1994) found through observations of feeding ducks that 75 kg/ha may be the actual requirement. It would be beneficial to have some standard target protein level such as those for energy food levels to compare and evaluate invertebrate resources for waterfowl.

Mean biomass of invertebrates for treatments in this study ranged from approximate (beaver ponds and moist soil units) to well below (soybean fields) the minimum total winter food amounts suggested by Reinecke (1989) and McAbee (1994), although no differences were found among these treatments. Variability within my study and other studies suggests that realistic estimates of invertebrate biomass, density, and diversity among treatments, as well as within a wetland, are difficult when studying winter benthic invertebrates. This is likely due to a wide range of habitat conditions, annual and seasonal weather conditions, habitat management variables, and invertebrate responses to those conditions.

Winter diet can affect body condition of waterfowl as they arrive on the breeding ground and, therefore, recruitment (Dubovsky and Kaminski 1994). Knowledge is needed about the impacts of protein availability on a range of survival parameters, especially where available protein can be highly varied or limiting. Information is also needed to facilitate the development of management practices that will produce conditions that fulfill habitat requirements of invertebrates and thus provide adequate protein for wintering waterfowl.

The high variability within this study, despite a relatively large sample size within each wetland, indicates that future studies should focus on the processes that influence each of the habitat or treatment types. Management of soybean fields varies from one location to another, thus not all flooded soybean fields should be expected to respond similarly. For example, no-till farming may be implemented on some fields, whereas in others, such as the soybean fields at the LHNWR and CNWR, conventional tillage practices may be used. These farming practices may have different effects on benthic invertebrates because of differences in chemical regimes, type and frequency of equipment needs, as well as the amount of residual organic matter left in the post-harvest soil (Denton and Tyler 2002). Among fields, the timing of flooding of soybean fields may differ because of differences in maturation dates among soybean varieties (Allen, Johnson, and Williams 2004).

Differences among wetlands within the same treatment are not limited to soybean fields. Vegetation in moist soil units also differ depending upon date and rate of drawdown, time since disturbance, type of disturbance, and depth of flooding among others (Murkin et al. 1992, Fredrickson and Laubhan 1996, and Gray et al. 1999). Underlying soil characteristics of beaver ponds, specifically those at AP, can vary among wetlands. The floodplain that contains these beaver ponds has been impacted tremendously by sand deposition and these ponds have also been affected, albeit to varying degrees. Beaver ponds in other locations will likely have different characteristics due to this sand impact. The age of beaver ponds and their connectivity to the river may also have a profound effect on invertebrate populations.

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Vita

Shelton Whittington was born in 1974 and was raised in Jackson, Mississippi. He graduated from Wingfield High School then attended Hinds Community College. After receiving an Associate of Science degree in Forestry from Hinds, he finished his Bachelor of Science degree in Wildlife and Fisheries Science at Mississippi State University in 1997. During his college career and after graduation he worked as a research assistant at Mississippi State on Wood Duck and other waterfowl and wetlands related projects. In 1998 Shelton began working at Ames Plantation as a research assistant on a long-term research project on Bobwhite Quail. Ames Plantation conducted the research in cooperation with Tall Timbers Research Station and Mississippi State University. In January of 2002, Shelton began working on his Master of Science degree in the Forestry Wildlife and Fisheries Department of The University of Tennessee in Knoxville. After graduating with a major in Wildlife and Fisheries Science, Shelton returned to Ames Plantation as a research associate working primarily in wetlands ecology and waterfowl management. He is married to Rachel Whittington and has a child, Shirley Jane.