

EFFICACY OF MOIST-SOIL MANAGEMENT
TECHNIQUES ON HACKBERRY FLAT
WILDLIFE MANAGEMENT AREA:
RESPONSE OF VEGETATION,
EXISTING SOIL SEED BANK,
AND WATERFOWL

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OWEN DEWAYNE MILLER

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Thesis Approved:


Thesis Advisor


David W. Engle


James A. Shaw


Dean of the Graduate College

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This study assessed the responsiveness of the soil seed bank profile, evaluated the botanical composition, distribution, and production of emergent vegetation in response to moist-soil management practices, and surveyed water-related birds (waterfowl, shorebirds, wading birds) and raptors in response to habitat preference on Hackberry Flat Wildlife Management Area in Tillman County, Oklahoma.

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I dedicate all the hard work I put into my class work, research, writing, and love for nature to my long lost daughter, Whitney Frances Lahey Miller, may God show her the truth.

PREFACE

Prior to the early 1900s, Hackberry Flat was one of the largest wetland basins in Oklahoma. It was a sanctuary for thousands of wintering and migratory ducks, geese, cranes, shorebirds, and wading birds. Located in the semi-arid region of Southwest Oklahoma, the basin is at the end of an approximate 9,000-acre closed drainage system. This unique ecosystem was driven by natural disturbances such as drought, fire, herbivores, and flooding. However, beginning in 1903, settlers began working in an attempt to drain and convert the basin to productive agriculture land. A ditch approximately 3.5 miles long was dug using horses with slips and freznos to drain the wetland. In 1909, a steam shovel was used to finish the last portion of the ditch. Once drained, the entire basin was converted to cropland and for the next 90 years, the basin hydrology remained altered due to the drainage system.

In 1993 the Oklahoma Department of Wildlife Conservation began a plan to restore Hackberry Flat to the wetland it once was. Since the project began, 7,120-acres have been acquired, encompassing 95% of the wetland basin. Structural measures include levees, water distribution canals, access roads, a water delivery system, a weir structure, a water storage reservoir, hunting areas, and wildlife viewing areas. Dividing the basin into various marsh units, combined with an independent water delivery system, and drawdown design, will enable

managers to use what limited water is available on any given year. It is a very ambitious project and will require much attention from biologists, wildlife enthusiasts, and others. The future of Hackberry Flat is alive and promising. Hackberry Flat Wildlife Management Area, once again, will become an oasis for waterfowl and all other wildlife associated with wetlands.

Oklahomans are concerned with what happens to their natural environments, and the wetlands Hackberry Flat provides will provide future generations a look at the beauty of pre-settlement Oklahoma.

TABLE OF CONTENTS

| Chapter | | Page |
|---------|------------------------------------------------------------------------------------------------------------------|------|
| I. | SEED-BANK RESPONSE FROM A RESTORED AND CREATED WETLAND IN THE CENTRAL FLYWAY IN SOUTHWESTERN OKLAHOMA..... | 1 |
| | ABSTRACT..... | 2 |
| | INTRODUCTION..... | 3 |
| | STUDY AREA AND METHODS..... | 6 |
| | RESULTS..... | 10 |
| | DISCUSSION..... | 12 |
| | LITERATURE CITED..... | 18 |
| II. | VEGETATION RESPONSE TO MOIST-SOIL MANAGEMENT AT A NEWLY RESTORED WETLAND IN SOUTHWESTERN OKLAHOMA..... | 35 |
| | ABSTRACT..... | 36 |
| | INTRODUCTION..... | 36 |
| | STUDY AREA AND METHODS..... | 38 |
| | RESULTS..... | 41 |
| | DISCUSSION..... | 42 |
| | LITERATURE CITED..... | 48 |
| III. | WATER-RELATED BIRD SPECIES RESPONSE TO A NEWLY RESTORED WETLAND IN SOUTHWESTERN OKLAHOMA..... | 62 |
| | ABSTRACT..... | 63 |
| | INTRODUCTION..... | 63 |
| | STUDY AREA AND METHODS..... | 66 |
| | RESULTS..... | 68 |
| | DISCUSSION..... | 70 |
| | LITERATURE CITED..... | 75 |

LIST OF TABLES

| Chapter | Page |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| I. Table 1. Thirty-two plant species that germinated from soil samples collected at Hackberry Flat Wildlife Management Area, Tillman County, Oklahoma and their wetland status (Reed 1988)..... | 23 |
| Table 2. Number of desirable and undesirable plant species that germinated per unit (U) and transect (T), and percentages of desirable species at Hackberry Flat Wildlife Management Area in Tillman County, Oklahoma..... | 24 |
| Table 3. Sedges, woody species, forbs, and grasses that germinated from soil samples taken from 14 experimental units at Hackberry Flat Wildlife Management Area, Tillman County, Oklahoma, 1998. Value in parentheses equals the number of plants that germinated for that species; plant species with no value had 1 individual germinate..... | 25 |
| II. Table 1. Frequency values (percent frequency is calculated by taking the number of quadrats in which a species occurred and dividing that number by the total number of quadrats. N = 52, total number of quadrats = 280) for plants occurring at Hackberry Flat Wildlife Management Area, Tillman County, Oklahoma..... | 52 |
| Table 2. A comparison of vegetation characteristics (percent ground cover, biomass (kg/ha), and vegetation height between treatments (control, irrigation, and non-irrigation) at Hackberry Flat Wildlife Management Area, Tillman County, Oklahoma 1999 and 2000..... | 60 |
| III. Table 1. Comparison between bird species composition based on bird surveys conducted at Hackberry Flat Wildlife Management Area in Tillman County, Oklahoma, August – December, 1999 and 2000..... | 78 |

| | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Table 2. Proportion (%) of migrating waterbirds (waterfowl, wading birds, and shorebirds) and raptors observed on 4 wetland habitat types and old field autumn 1999 (A99) and autumn 2000 (A00) at Hackberry Flat Wildlife Management Area in Tillman County, Oklahoma..... | 79 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|

LIST OF FIGURES

| Chapter | Page |
|------------------------------------------------|------|
| 1. Figure 1. Plain view of research units..... | 34 |

CHAPTER 1

SEED-BANK RESPONSE FROM A RESTORED AND ENHANCED WETLAND IN THE CENTRAL FLYWAY IN SOUTHWESTERN OKLAHOMA

Abstract: Wetlands are often depositional environments and are thus susceptible to stress resulting from surrounding land use and variations in environmental conditions. Assessing historic succession of plant communities is one way to examine the response of a wetland to this disturbance. A seed-bank profile in a depositional environment can be an historic record of how a community has changed over time. Agricultural practices have been well documented as a threat to the existence of wetlands. Extraction and identification of seeds in the soil and germination studies were used to determine the seed-bank composition at a highly altered wetland in southwestern Oklahoma. For germination studies, samples were subjected to chill treatments and planted in an emergent germination regime. Our germination study was conducted to determine richness and productivity of the soil-seed bank. A total of 412 plants germinated; 78 (18.9%) were desirable moist-soil species. Based on germination studies, the desirable and undesirable plant species capable of growing in this wetland following restoration. Knowledge of the current seed bank determines moist-soil management practices to be implemented. Succession in a highly altered wetland differed from succession in pristine wetlands.

Key words: germination, moist-soil management, propagule, seed bank, restoration, wetlands.

Introduction

Hackberry Flat was once one of the largest depositional wetland areas in Oklahoma. At the turn of the 20th Century, it was drained, and an effort was made to convert the entire basin to productive cropland. Prior to the beginning of our research, it was brought to our attention by Leigh Fredrickson of Gaylord Memorial Laboratory (University of Missouri – Columbia) that we should do a baseline inventory of the soil seed bank to determine if and how 90 years of agricultural production, pesticides, and herbicides affected the soil seed bank.

Wetlands have tremendous habitat diversity and represent ecotones between terrestrial and lotic systems. Wetlands have three attributes: (1) hydric soils, (2) flooding for at least part of growing season and (3) vegetation adapted to a particular hydrologic regime (Cowardin et al. 1979). Wetlands are being restored, created, and preserved throughout North America to offset losses (National Research Council 1992). Restoration usually involves reestablishment of wetland hydrology in areas that have been drained for agricultural production.

Prior to 1908, Hackberry Flat in southwestern Oklahoma served as a major migration stop-over for thousands of geese, ducks, and other waterbirds in the Central Flyway. Drainage of this natural basin was completed in 1908, and it has been under agricultural production for the past 90+ years, eliminating much of the basin wetland habitat. To negate the loss of critical wildlife habitat, the Oklahoma Department of Wildlife Conservation established a plan to reclaim Hackberry Flat. Restoration efforts at Hackberry Flat Wildlife Management Area (HFWMA) are considered among the most ambitious wildlife projects in the

State's history. With a network of dikes, canals, pools, moist-soil units, flooding and drying regimes, and an independent water-delivery system, HFWMA is being restored to a complex of wetland management units. Enhancement features have added considerable management flexibility and maximized habitat.

Sampling the propagule or the seed bank is an essential component for determining vegetation production (Fredrickson 1991). Furthermore, an understanding of the diversity and productivity of the seed bank will determine the best moist-soil treatments to use as restoration proceeds. Elements such as topography, type of drawdown, time of drawdown, soil type, time since disturbance, and seasonal variations interact to determine which seeds in the seed bank react and become established on an exposed mudflat (Fredrickson 1991). Organizations such as the Oklahoma Department of Wildlife Conservation, Ducks Unlimited, and United States Fish and Wildlife Service seek to restore formerly drained marshes to high-quality wildlife habitat. Because resources can limit restoration activities, site selection that offers a likelihood of successful restoration is critical.

Accurate indicators of vegetation production on restored wetlands would be useful to prioritize moist-soil treatments and site selection. Seed banks can be good indicators of the vegetation that will grow under specific environmental conditions in wetlands, especially when conducting drawdowns (van der Valk and Davis 1978; Pederson 1981; van der Valk et al. 1989). If seed banks influence vegetation dynamics in wetlands, especially in newly exposed soil, they could provide a good predictor of vegetative communities that develop during

restoration. However, major differences are often found between existing vegetation and species composition of seed banks in wetlands (Parker and Leck 1985; McGraw 1987; Unger and Woodell 1993; Wilson et al. 1993; Leck and Simpson 1995). Most seed-bank studies have correlated vegetation composition and seed banks in natural wetlands (Leck 1989, 1996), but the importance of remnant vegetation and seed-bank composition in newly restored wetlands has been studied less (Dunn and Best 1984; McKnight 1992). Seed banks can be a major source for the reestablishment of hydric plants that propagate by seed in prairie wetlands (van der Valk and Davis 1978; Welling et al. 1988), but it is not clear if seed banks are equally important in the reestablishment of hydric plants in wetlands that have been drained. At restored wetlands, the time since drainage can have a significant impact on the number of desirable viable wetland plant seeds remaining in the seed bank (Weinhold and van der Valk 1989). Wetland restoration sites with seed banks that include a relatively large number of plant species are expected to produce greater species diversity following the restoration of wetland hydrology. Understanding the relationships between productivity and relative diversity of species in the vegetative stage and productivity and relative diversity of species in the seed bank of the restored wetland would aid in predicting restoration outcomes.

Our study was designed to assess the responsiveness of the soil - seed bank profile (richness, productivity) at HFWMA to determine best types of moist-soil treatments. We predicted that richness and productivity of the soil seed bank were similar across the various subunits at the research site, and that despite

decades of tillage agriculture, the seed bank would contain viable seeds of desirable hydric plants.

Study Area and Methods

We collected soil samples in June and July 1998 on the HFWMA in Tillman County in southwestern Oklahoma (34° 17' N, 98° 55' W). The 2,721 ha of moist soil, agricultural flooding, and associated uplands was located 2.2 km southeast of Frederick, Oklahoma. Elevations ranged from 1,145 to 1,165 m above mean sea level, and annual precipitation averaged 65 cm (National Oceanic and Atmospheric Administration 1998). Ambient temperatures averaged 2.4°C in winter and 28°C in summer (National Oceanic and Atmospheric Administration 1998). Soils consisted of uniform clay in the subsoil and Roscow clay in the topsoil (National Resources Conservation Service 1998). Desirable wetland plant species included wild millet (*Echinochloa muricata*), sedges (*Carex brittoniana*, *Cyperus acuminatus*, and *C. esculentus*), spikerush (*Eleocharis macrostachya*), red sprangletop (*Leptochloa filiformis*), maygrass (*Phalaris caroliniana*), Pennsylvania smartweed (*Polygonum pennsylvanicum*), and curly dock (*Rumex crispus*). Undesirable wetland plant species included salt marsh aster (*Aster subulatus*), loosestrife (*Lythrum alatum*), blackwillow (*Salix nigra*), cottonwood (*Populus deltoides*), salt cedar (*Tamarix chinensis*), cattail (*Typha latifolia*), and cocklebur (*Xanthum strumarium*). Other vegetation that was abundant throughout the study area included ragweed (*Ambrosia* sp.), common sunflower (*Helianthus annuus*), kochia (*Kochia scoparia*), malvella (*Malvella leprosa*), carpetweed, (*Mullugo verticillata*), and Johnson grass

(*Sorghum halapense*).

The study design encompassed 32.4 ha separated into 14, 2.3-ha experimental units. In each unit, 2 100-m transects were randomly placed with 10 sampling sites along the transects at 10-m intervals. Seed-bank composition in soil samples was determined by direct counting seeds and germination studies. I used the emergence-germination method (van der Valk and Davis 1978, Smith and Kadlec 1983) for analysis of the seed bank because our primary goal was to determine diversity and productivity of viable seeds that could germinate under natural field conditions. Elutriation, by including nonviable seeds, gives higher estimates of seed density than emergence techniques (Gross 1990). The emergence method I used gives a more accurate assessment of productivity and diversity of seed species present compared with the actual identification of seeds (Poiani and Johnson 1988). In general, the emergence method gives biased assessments of the seed bank because greenhouse conditions are not the same as field conditions (Gross 1990), but it is the most appropriate method for measuring the relationship between seed-bank composition and field recruitment of wetland plants (van der Valk et al 1992). Few studies suggest appropriate sample numbers for seed-bank studies by exploring the relationship between sample number and number of plant species detected. Gross (1990) suggested that 15-20 samples was adequate in her study of agricultural fields, but Simpson et al. (1989) argued that a large number of small samples (>20) were preferable to fewer large ones. A total of 1,120 samples was collected for the entire research area. Each core sample

was about 2.5 x 2.5 cm to a depth of 12.5 cm. We collected 4 core soil samples at each 10-m interval along the 2 transects totaling 80 samples/14 experimental units; samples were mixed to form a composite sample for each unit. We sieved soil samples through a 10-mm wire mesh to remove rhizomes, tubers, rocks, and pieces of litter before placing the samples in cold storage. All samples were collected before construction of levees, canals, and water-control structures and before restoration of wetland hydrology. Therefore, soil samples reflected conditions in the field after nearly 100 years of agriculture and before restoration. We stored the soil samples for 6 weeks at 2-5 °C (Radwan and Crouch 1977); thus, temperature regime approximated what the same soil would have experienced in the field during initial germination and provided a period of stratification necessary to stimulate germination. We followed methodology of van der Valk and Davis (1978). In October 1998, we transferred soil samples to the greenhouse and sieved each sample again to ensure even soil distribution in standard greenhouse flats (60 cm x 60 cm). Each sample was placed on top of about 7.5 cm of sterilized sand in a standard greenhouse flat.

The greenhouse had a temperature regime between 24-29 C° and continuous light for 18 hrs. Artificial lighting was provided with 6, 250-watt metal halide lamps to ensure that all flats received 18 hrs of light. Humidity (55-60%) and temperature (24-29°C) were maintained with heaters and fans, and all flats were watered twice a day. This greenhouse regime can initiate germination in wetland plants (Galinato and van der Valk 1986). We identified and counted seedlings weekly. Unidentified seedlings were transplanted to separate

containers, and their growth continued until identification was possible.

Seedlings were identified according to Godfrey and Wooten (1981), with verification by pressed specimens and extant illustrations.

Species of plants were identified to genus and species. Plant species were divided into 5 categories (Reed 1988): 1) obligatory wetland (OBL), or those occurring usually at an estimated probability of >99% in wetlands under natural conditions; 2) facultative wetland (FACW), usually occurring in wetlands at an estimated probability of 67-99%, but occasionally found in uplands; 3) facultative (FAC), equally likely to occur in wetlands or uplands, estimated probability of 34-66%; 4) facultative upland (FACU), usually occurring in uplands at an estimated probability of 67-99%, but occasionally occurring in wetlands at an estimated probability of 1-33%; 5) obligate upland (UPL), occurring usually in uplands an estimated probability of > 99%. Plant species were classified as desirable or nondesirable wetland plant species relative to their food value to waterbirds (Baldassarre and Bolen 1994; Table 1).

A survey of the soil in the experimental units was conducted by United States Geological Survey (USGS) in September 1998. The main purpose of the survey was to determine amounts of herbicides, pesticides, heavy metals, and salts that might be present in the soil.

All data were analyzed using chi-square programs in the Statistical Analysis System (SAS Institute Inc. 1996). Unless otherwise noted, all probability levels refer to chi-square test and significance was set at $P < 0.10$.

Desirable and undesirable plants were compared within wetland units

and from the north side of the study area to the south side of the study area.

Results

Results of the survey conducted by USGS were negative; there was no evidence of any herbicides, pesticides, heavy metal, or salinity in the soil that would be detrimental to the overall health of the study area (USGS 1998).

Included in the report were 2 detailed descriptions that are typical of 2 of the transects that were collected in the study area. Pedon #98OK141001 was located in the southwestern corner of the study area and was typical of most soil samples along the southern side of Hackberry Flat. Pedon #98OK141002 was located in the northeastern part of the study area and was typical of most soil samples along the northern side of the area (USGS 1998).

The soils at Hackberry Flat appeared to be uniform in texture and color, and most interpretive differences in texture and color were quite small. Soil texture was uniformly clay in the subsoil and only a small variation of a heavy silty clay loam to silty clay in the topsoil. Differences in color and calcium carbonate content were attributed to differences in duration of water ponding, which occurred before the area was originally drained (USGS 1998).

Pedon #1 came from the southern side, which was lower and had standing water for longer periods than the northern side. That would account for the consistent gray colors to a depth of 150 cm. In western Oklahoma, soils of gray colors indicate wet soil conditions where oxygen has been excluded from the soil for long periods. Pedon #2 came from the northern side and was consistently gray only to 53 cm in depth. The zone from 53 to 123 cm had

mottled colors, which transitioned from gray in the upper part to brown in the lower part and was typical of soils that had alternating wet and dry cycles. Pedon #2 also had a higher calcium carbonate content because it did not have as much water moving through the profile to leach the carbonate (USGS 1998).

Germination of seeds from HFWMA began within 5 days of exposure to the germination regime. A total of 412 individual plants germinated in our emergent regime, and 78 (18.9%) were considered desirable (Table 2). A total of 32 plant species germinated, and 17 (53%) of those were desirable wetland plants relative to moist-soil management (Fredrickson and Taylor 1982; Table 1). Percentages of desirable plants in greenhouse trays ranged from 0% to 40%, and the average percentage of desirable plants for the entire research area was 18.9%. Units 5 and 6 had the lowest percentage of desirable plants (transect 1 and 2, respectively) at 0%, and unit 8 had the highest percentage of desirable plants (transect 2) at 40% (Table 2); however, there was no difference among the 8 units that could be compared ($X^2 = 7.821$, d.f. = 7, P = 0.349). The total number of plants that germinated per unit ranged between 7 in unit 5 (transect 2) and 28 in unit 1 (transect 1). Number of desirable plants ranged from 0 in units 5 (transect 1) and 6 (transect 2) to 7 in unit 8 (transect 1; Table 2).

Forbs were the dominant group of plants that germinated in our study, with 284 total individual plants. The desirable species of forbs that germinated in our study were Pennsylvania smartweed and curly dock (Table 3). The 3 undesirable species of forbs germinated that may cause management concerns were salt marsh aster, cocklebur, and cattail.

Wild millet, also called barnyard grass, was the dominant desirable graminoid that germinated. Of the 52 individual grasses that germinated 19 were wild millet, which comprised 36.5% of the grasses (Table 3). Other desirable species of graminoids that germinated, but not in abundance, were switch grass (7.7%), red sprangletop (5.8%), rush (3.8%), foxtail (3.8%), and crabgrass (1.9%; Table 3).

The 3 species of Cyperaceae that germinated were sedge, flat sedge, and spikerush. There were 20 individual sedges that germinated comprising about 5% of the total species that germinated (Table 3). That was a low percentage, but as the basin's hydrology is restored, we expect to see this percentage increase because of the vast amounts of seeds that these 3 species produce (Fredrickson and Taylor 1982).

Woody species of plants occurring on the study area included black willow and salt cedar, an exotic, both of which cause management problems (Harper 1977). Salt cedar dominated the woody species comprising about 69% of all woody species and about 9% of all plants that germinated.

Discussion

A significant factor affecting species composition of moist-soil plants that germinate on exposed mudflats is the occurrence of seeds in the soil in a particular wetland. Moist soils contain sufficient amounts of seeds to produce desirable moist-soil plants in dense stands that are indigenous to the area (Mitsch and Gosselink 1993). Seed bank composition and the resulting vegetation community are related to species seed productivity and seed diversity

of the soil-seed bank. Any wetland unit with $\geq 18\%$ desirable plants found in the seed bank can be considered adequate to conduct moist-soil management practices to stimulate natural emergent vegetation without the aid of artificial planting (Mitsch and Gosselink 1993). At HFWMA, 7 of the 14 total units had $\geq 18\%$ desirable wetland plants. Units with the highest percentages of desirable plants were located on the southern side of the study area ($X^2 = 2.919$, d.f. = 1, P = 0.088), which was most likely caused by the ditch (7.7 km long x 4 m wide x 1-2 m deep) that was dug to drain the basin ran parallel and in close proximity to units 8 –14. Those units had a lower elevation than the rest of the basin and acted like a sediment trap (Weinhold and van der Valk 1989) resulting in more desirable wetland plant seeds in the seed bank for those units. A wetland unit with a good germination rate of desirable vegetation (≥ 18) in a growing season likely will produce seeds of similar productivity and diversity the following year. Furthermore, undesirable species have the same likelihood to germinate. Management techniques to control seed production, germination, and growth are necessary (Fredrickson and Reid 1990).

Our results do not support the hypothesis that productivity and richness of the soil seed bank are the same for all 14 units. The propagules in units 8-14 had a significantly higher percentage of desirable seeds that germinated than units 1-7. The units near the drainage ditch, and the wetland vegetation that has occurred there, clearly provide the seed bank with an adequate proportion of wetland plant seeds. However, in units further away from the drainage ditch at higher elevations, the seed banks are significantly less desirable and more

upland in character. The prolonged drainage of the basin itself (≥ 90 years) was sufficient to result in the depletion of wetland plant seeds, which was similar to results reported by Weinhold and van der Valk (1989) during restoration and creation of a freshwater wetland using seed banks where $\leq 18\%$ desirable plants germinated. Although it has been reported in the literature that a seed bank with a composition of 18% desirable species is sufficient for conducting moist-soil management, units at HFWMA just barely achieved that level at 18.9%. The extended disturbance by row cropping and drainage significantly affected both the vegetation (see Chapter 3) and the seed bank in the restored units. The seed bank at HFWMA before hydrology was restored suggested that there would be fewer wetland plant seeds at the higher elevations where drainage was more effective, and most wetland plants could not recur. Our germination studies showed that units 1-7 have predominantly more undesirable plants and differ from units 8-14.

Effects of disturbance on wetland seed banks appear to vary with duration and intensity of disturbance. Disturbance from long-term drawdowns and fire did not cause changes in seed-bank composition or seedling regrowth in wetlands at the Great Salt Lake Marshes (Smith and Kadlec 1985). Burning vegetation does not affect species productivity or diversity of the seed bank, but long-term drainage and tillage of a wetland unit does (Kirkman and Sharitz 1994). Our study indicates that long-term drainage, linked with agricultural crop production, diminished the wetland seed bank, causing a reduction of richness and productivity in wetland plant species. Because of these apparent declines, the

role of the seed bank in reestablishing hydrophytic communities may take longer than in intact, undegraded wetlands and that some artificial seeding of native wetland species may be recommended.

Seed-bank data can be used to make accurate qualitative predictions of species productivity and richness, even when quantitative predictions are inaccurate (Haukos and Smith 1993). Our study of the seed bank found that even though we meet the minimum of 18% required desirable vegetation, these quantitative assessments were low. The units in this study were changed by drainage but still had remnant wetland seed banks. The depletion of wetland plant seeds over time after drainage is well documented (van der Valk 1986). Even if seed-bank samples do not predict species productivity and richness of restored wetland vegetation in sites with prolonged disturbance, there are still important management implications of seed-bank assessments. Numbers of undesirable species present in the seed-bank at HFWMA, such as cattails, salt cedar, and salt marsh aster, may be prominent detectors of the relative likelihood of a successful wetland restoration that meets management goals (van der Valk et al. 1992). Salt marsh aster is an early successional plant that invades newly disturbed sites. It has little to no value to wildlife (Fredrickson and Taylor 1982), except for offering some cover. This species is a transient and does not stay established if the site remains undisturbed over time. Furthermore, cocklebur and cattail have the potential to cause severe management problems and attempts to control these 2 species should be a top priority for any wetland manager.

Herbaceous species dominate wetland seed banks. Perennials and annuals vary in importance within a wetland, and graminoids usually comprise >50% of the seed bank. Woody plant species are usually rare (Harper 1977). Our seed-bank germination trials showed that woody species other than salt cedar are not a management concern, but salt cedar can pose major problems. Salt cedar is an invasive exotic species with few if any natural competitors, and if left unmanaged, salt cedar, like cattail, can quickly reduce the value of wetlands to waterbirds (Merendino and Smith 1991). Salt cedar and cattail have been controlled with some limited success by a series of mowing, burning, and disking (Yeo 1964). However, for those methods to work, the impoundment must be kept dry for an extended period of time, which can be undesirable for some wetland units. Furthermore, control of invasive species in large wetland units with those techniques would be costly. Other methods of salt cedar and cattail control could be the use of herbicides such as Rodeo® and Roundup®. Those herbicides are similar chemically and are approved by the Environmental Protection Agency for use in wetlands. However, Roundup® cannot be used over water. A third method of control is the use of a backhoe. The backhoe can be used to shear the plants off with the bucket and digging them up. The backhoe can be used to remove cattail while restoring the borrow ditches that parallel levees. Cocklebur can be a serious problem on some sites that were previously in agricultural production. It can be controlled by flooding new emergents to one-half their height after they germinate (Fredrickson and Taylor 1982).

The dominant desirable species of plants that germinated at HFWMA were sedges, smartweed, curly dock, wild millet, red sprangletop, and switch grass. All these species germinate well on wet sites or exposed mudflats and produce abundant seed crops. Wild millet is an excellent annual moist-soil plant that produces copious amounts of seeds. Those species also respond well to mid-to-late season drawdowns (Fredrickson and Taylor 1982). This information will allow implementation of appropriate management strategies to conduct moist-soil management.

Johnson grass and common sunflower responded well in the germination trials and was found extensively throughout the basin. There is little information regarding the value of these 2 species as food for waterfowl, but waterfowl have been observed foraging on these 2 plants at HFWMA.

Seed-banks are a key to understanding vegetative dynamics and long-term survival of restored wetlands. It is the presence of viable seeds of emergent species in the soil substrate that enables closed basins such as Hackberry Flat to regenerate its emergent vegetation.

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Table 1. Thirty-one plant species that germinated from soil samples collected at Hackberry Flat Wildlife Management Area, Tillman County, Oklahoma and their wetland status (Reed 1988).

| | Wetland Status ^b | | | | |
|-------------------------------------------------------------|-----------------------------|------|-----|------|-----|
| | OBL | FACW | FAC | FACU | UPL |
| <i>Ambrosia</i> spp., ragweed | | | √ | | |
| <i>Amorphia fruticosa</i> , false indigo ^a | | √ | | | |
| <i>Aster subulatus</i> , salt marsh aster | √ | | | | |
| <i>Bromus secalinus</i> , cheat ^c | | | √ | | |
| <i>Carex</i> sp., sedge ^a | | √ | | | |
| <i>Cephalanthus occidentalis</i> , button bush ^a | √ | | | | |
| <i>Chenopodium album</i> , lambs quarters ^a | | √ | | | |
| <i>Croton</i> spp., dove weed ^a | | | √ | | |
| <i>Cynodon dactylon</i> , bermuda grass ^c | | | | √ | |
| <i>Cyperus</i> spp., flat sedge ^a | | √ | | | |
| <i>Digitaria</i> spp., crabgrass ^a | | | | √ | |
| <i>Echinochloa muricata</i> , wild millet ^a | | √ | | | |
| <i>Eleocharis macrostachya</i> , spike rush ^a | √ | | | | |
| <i>Helianthus annuus</i> , common sunflower | | | √ | | |
| <i>Juncus</i> spp., rush ^a | | √ | | | |
| <i>Kochia scoparia</i> , kochia ^c | | | | √ | |
| <i>Leptochloa filiformis</i> , red sprangletop ^a | | √ | | | |
| <i>Lythrum alatum</i> , loosestrife | √ | | | | |
| <i>Malvella leprosa</i> , malvella | | | | √ | |
| <i>Panicum capillare</i> , fall witchgrass ^a | | | | √ | |
| <i>Panicum virgatum</i> , switchgrass ^a | | | √ | | |
| <i>Polygonum</i> spp., smartweed ^a | √ | | | | |
| <i>Prosopis juliflora</i> , mesquite | | | | √ | |
| <i>Rumex crispus</i> , curly dock ^a | √ | | | | |
| <i>Salix nigra</i> , black willow | √ | | | | |
| <i>Setaria</i> spp., foxtail ^a | | | | √ | |
| <i>Solanum elaeagnifolium</i> , S.nightshade | | | | √ | |
| <i>Sorghum halapense</i> , johnson grass | | | | √ | |
| <i>Tamarix chinensis</i> , salt cedar ^c | √ | | | | |
| <i>Typha</i> spp., cattail | | √ | | | |
| <i>Xanthium strumarium</i> , cocklebur ^c | | √ | | | |

^aDenotes desirable moist-soil wetland food plant (Baldassarre and Bolen 1994).

^bWetland occurrence: Obligate Wetland (OBL) = >99% occurrence; Facultative Wetland (FACW) = 67-99%; Facultative (FAC) = 34-66%; Facultative Upland (FACU) = 1-33%; Upland (UPL) = <99%.

^cDenotes exotic plant species.

Table 2. Number of desirable and undesirable plant species that germinated per unit (U) and transect (T), and percentages of desirable species at Hackberry Flat Wildlife Management Area in Tillman County, Oklahoma.

| Unit, Transect | <u>Number of Plant Species</u> | | | |
|----------------|--------------------------------|-----------|-------------|---------------------|
| | Total Plant Species | Desirable | Undesirable | Desirable % Species |
| U1, T1 | 28 | 5 | 23 | 18 |
| U1, T2 | 22 | 4 | 18 | 18 |
| U2, T1 | 22 | 3 | 19 | 14 |
| U2, T2 | 23 | 3 | 20 | 13 |
| U3, T1 | 11 | 3 | 8 | 27 |
| U3, T2 | 14 | 2 | 12 | 14 |
| U4, T1 | 12 | 4 | 8 | 33 |
| U4, T2 | 14 | 2 | 12 | 14 |
| U5, T1 | 12 | 0 | 12 | 0 |
| U5, T2 | 7 | 1 | 6 | 14 |
| U6, T1 | 9 | 2 | 7 | 22 |
| U6, T2 | 12 | 0 | 12 | 0 |
| U7, T1 | 11 | 2 | 9 | 18 |
| U7, T2 | 13 | 2 | 11 | 15 |
| U8, T1 | 20 | 7 | 13 | 35 |
| U8, T2 | 15 | 6 | 9 | 40 |
| U9, T1 | 13 | 4 | 9 | 31 |
| U9, T2 | 10 | 1 | 9 | 10 |
| U10, T1 | 13 | 1 | 12 | 8 |
| U10, T2 | 15 | 4 | 11 | 27 |
| U11, T1 | 13 | 4 | 9 | 31 |
| U11, T2 | 14 | 2 | 12 | 14 |
| U12, T1 | 12 | 1 | 11 | 8 |
| U12, T2 | 8 | 1 | 7 | 13 |
| U13, T1 | 16 | 2 | 14 | 13 |
| U13, T2 | 14 | 2 | 12 | 14 |
| U14, T1 | 20 | 6 | 14 | 30 |
| U14, T2 | 19 | 4 | 15 | 31 |
| Overall | 412 | 78 | 334 | 19 |

Table 3. Sedges, woody species, forbs, and grasses that germinated from soil samples taken from 14 experimental units at Hackberry Flat Wildlife Management Area, Tillman County, Oklahoma, 1998. Value in parentheses equals the number of plants that germinated for that species; plant species with no value had 1 individual germinate.

| Location | Sedges | Woody | Forbs | Grasses |
|----------|--------------------------------|------------------------------|------------------------------------|-----------------------------|
| Unit 1 | <i>Cyperus sp.</i> (3) | <i>Prosopis juliflora</i> | <i>Aster subulatus</i> (8) | <i>Echinochloa muricata</i> |
| | <i>Eleocharis macrostachya</i> | <i>Tamarix chinensis</i> (3) | <i>Helianthus annuus</i> (2) | <i>Panicum virgatum</i> |
| | | <i>Salix nigra</i> | <i>Kochia scoparia</i> | <i>Sorghum halapense</i> |
| | | | <i>Malvella leprosa</i> (8) | |
| | | | <i>Polygonum pensylvanicum</i> (2) | |
| | | | <i>Typha sp.</i> (14) | |
| | | | <i>Xanthium strumarium</i> (3) | |
| Unit 2 | <i>Cyprus sp.</i> | <i>Tamarix chinensis</i> | <i>Ambrosia psilostachya</i> (2) | <i>Echinochloa muricata</i> |
| | | <i>Salix nigra</i> (3) | <i>Aster subulatus</i> (6) | <i>Panicum virgatum</i> |

Table 3. Continued.

| Location | Sedges | Woody | Forbs | Grasses |
|----------|------------------------------------------------------|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| Unit 2 | | | <i>Chenopodium album</i> (2) <i>Helianthus annuus</i> (6) <i>Kochia scoparia</i> (2) <i>Lythrum alatum</i> <i>Malvella leprosa</i> (6) <i>Polygonum pensylvanicum</i> (2) <i>Rumex crispus</i> <i>Solanum elaeagnifolium</i> <i>Typha</i> sp. (9) | |
| Unit 3 | <i>Cyperus</i> sp. <i>Eleocharis macrostachya</i> | <i>Tamarix chinensis</i> (2) | <i>Aster subulatus</i> (3) <i>Malvella leprosa</i> (8) <i>Mollugo verticillata</i> (4) | <i>Echinochloa muricata</i> <i>Leptochloa filiformis</i> |

Table 3. Continued.

| Location | Sedges | Woody | Forbs | Grasses |
|----------|--------------------|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Unit 3 | | | <i>Rumex crispus</i> <i>Typha sp.</i> | |
| Unit 4 | <i>Cyperus sp.</i> | <i>Tamarix chinensis</i> (2) | <i>Aster subulatus</i> <i>Helianthus annuus</i> <i>Kochia scoparia</i> <i>Malvella leprosa</i> (6) <i>Mollugo verticillata</i> (3) <i>Typha sp.</i> (3) <i>Rumex crispus</i> <i>Xanthium strumarium</i> (3) | <i>Digitaria sp.</i> <i>Leptochloa filiformis</i> <i>Panicum capillare</i> <i>Echinochloa muricata</i> |
| Unit 5 | | <i>Salix nigra</i> | <i>Aster subulatus</i> (5) <i>Malvella leprosa</i> (6) | <i>Echinochloa muricata</i> |

Table 3. Continued.

| Location | Sedges | Woody | Forbs | Grasses |
|----------|------------------------|--------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| Unit 5 | | | <i>Mollugo verticillata</i> (5) <i>Solanum elaeagnifolium</i> | |
| Unit 6 | <i>Cyperus sp.</i> | <i>Tamarix chinensis</i> | <i>Aster subulatus</i> (5) <i>Helianthus annuus</i> (4) <i>Malvella leprosa</i> <i>Typha sp.</i> (3) | <i>Bromus secalinus</i> (3) <i>Echinochloa muricata</i> <i>Sorghum halapense</i> (2) |
| Unit 7 | <i>Cyperus sp.</i> | <i>Tamarix chinensis</i> (5) <i>Salix nigra</i> (2) | <i>Aster subulatus</i> (6) <i>Helianthus annuus</i> (2) <i>Malvella leprosa</i> <i>Typha sp.</i> (2) | <i>Bromus secalinus</i> <i>Echinochloa muricata</i> (2) <i>Panicum capillare</i> <i>Sorghum halapense</i> |
| Unit 8 | <i>Cyperus sp.</i> (4) | <i>Amorpha fruticosa</i> <i>Salix nigra</i> (3) | <i>Ambrosia psilostachya</i> <i>Aster subulatus</i> (3) | <i>Echinochloa muricata</i> (3) <i>Leptochloa filiformis</i> |

Table 3. Continued.

| Location | Sedges | Woody | Forbs | Grasses |
|----------|------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| Unit 8 | | <i>Tamarix chinensis</i> (2) <i>Cephalanthus occidentalis</i> | <i>Lythrum alatum</i> (2) <i>Malvella leprosa</i> (3) <i>Mollugo verticillata</i> (2) <i>Polygonum pensylvanicum</i> (3) <i>Typha</i> sp. (4) <i>Xanthium strumarium</i> | <i>Sorghum halapense</i> |
| Unit 9 | <i>Carex</i> sp. | <i>Amorphia fruticosa</i> <i>Tamarix chinensis</i> (6) <i>Salix nigra</i> (20) | <i>Ambrosia psilostachya</i> (2) <i>Helianthus annuus</i> (2) <i>Malvella leprosa</i> (3) <i>Mollugo verticillata</i> (2) <i>Polygonum pensylvanicum</i> <i>Rumex crispus</i> | <i>Juncus</i> spp. <i>Sorghum halapense</i> |

Table 3. Continued.

| Location | Sedges | Woody | Forbs | Grasses |
|----------|--------------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Unit 10 | <i>Carex sp.</i> | <i>Tamarix chinensis</i> (3) | <i>Ambrosia psilostachya</i> <i>Aster subulatus</i> (4) <i>Croton sp.</i> <i>Helianthus annuus</i> (3) <i>Kochia scoparia</i> (3) <i>Malvella leprosa</i> (2) <i>Polygonum pensylvanicum</i> <i>Typha sp.</i> <i>Xanthium strumarium</i> | <i>Cynodon dactylon</i> <i>Panicum virgatum</i> <i>Sorghum halapense</i> (4) |
| Unit 11 | <i>Cyperus sp.</i> | <i>Salix nigra</i> <i>Tamarix chinensis</i> (2) | <i>Ambrosia psilostachya</i> <i>Aster subulatus</i> (2) <i>Chenopodium album</i> | <i>Echinochloa muricata</i> (3) <i>Sorghum halapense</i> <i>Panicum capillare</i> |

Table 3. Continued.

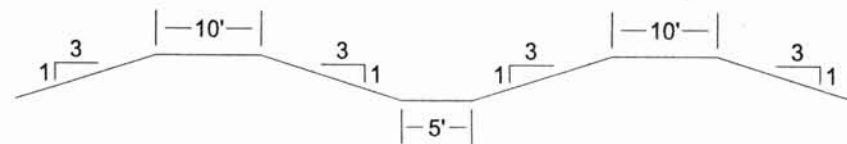
| Location | Sedges | Woody | Forbs | Grasses |
|----------|--------|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Unit 11 | | | <i>Croton sp.</i> <i>Helianthus annuus</i> <i>Kochia scoparia</i> (2) <i>Malvella leprosa</i> (2) <i>Mollugo verticillata</i> <i>Polygonum pensylvanicum</i> <i>Rumex crispus</i> <i>Typha sp.</i> (5) | |
| Unit 12 | | <i>Tamarix chinensis</i> (3) | <i>Aster subulatus</i> (2) <i>Helianthus annuus</i> (2) <i>Kochia scoparia</i> <i>Lythrum alatum</i> | <i>Echinochloa muricata</i> <i>Panicum capillare</i> <i>Setaria sp.</i> |

Table 3. Continued.

| Location | Sedges | Woody | Forbs | Grasses |
|----------|----------------------|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Unit 12 | | | <i>Malvella leprosa</i> (4) <i>Typha</i> sp. (4) | |
| Unit 13 | <i>Carex</i> sp. | <i>Tamarix chinensis</i> (4) | <i>Aster subulatus</i> (4) <i>Helianthus annuus</i> <i>Kochia scoparia</i> (3) <i>Malvella leprosa</i> (5) <i>Typha</i> sp. | <i>Echinochloa muricata</i> <i>Leptochloa filiformis</i> <i>Juncus</i> sp. <i>Panicum virgatum</i> <i>Sorghum halapense</i> |
| Unit 14 | <i>Carex</i> sp. (2) | <i>Tamarix chinensis</i> (2) <i>Salix nigra</i> | <i>Ambrosia psilostachya</i> (3) <i>Aster subulatus</i> (4) <i>Helianthus annuus</i> (2) <i>Malvella leprosa</i> (3) <i>Mollugo verticillata</i> | <i>Echinochloa muricata</i> (3) <i>Setaria</i> sp. <i>Sorghum halapense</i> (2) |

Table 3. Completed.

| Location | Sedges | Woody | Forbs | Grasses |
|----------|--------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| Unit 14 | | | <i>Polygonum pensylvanicum</i> (2) <i>Rumex crispus</i> (2) <i>Typha sp.</i> (6) <i>Solanum elaeagnifolium</i> (2) <i>Xanthium strumarium</i> | |



TYPICAL SECTION OF DISTRIBUTION DITCH

N.T.S.



Trt A = Irrigation
Trt B = Non Irrigation

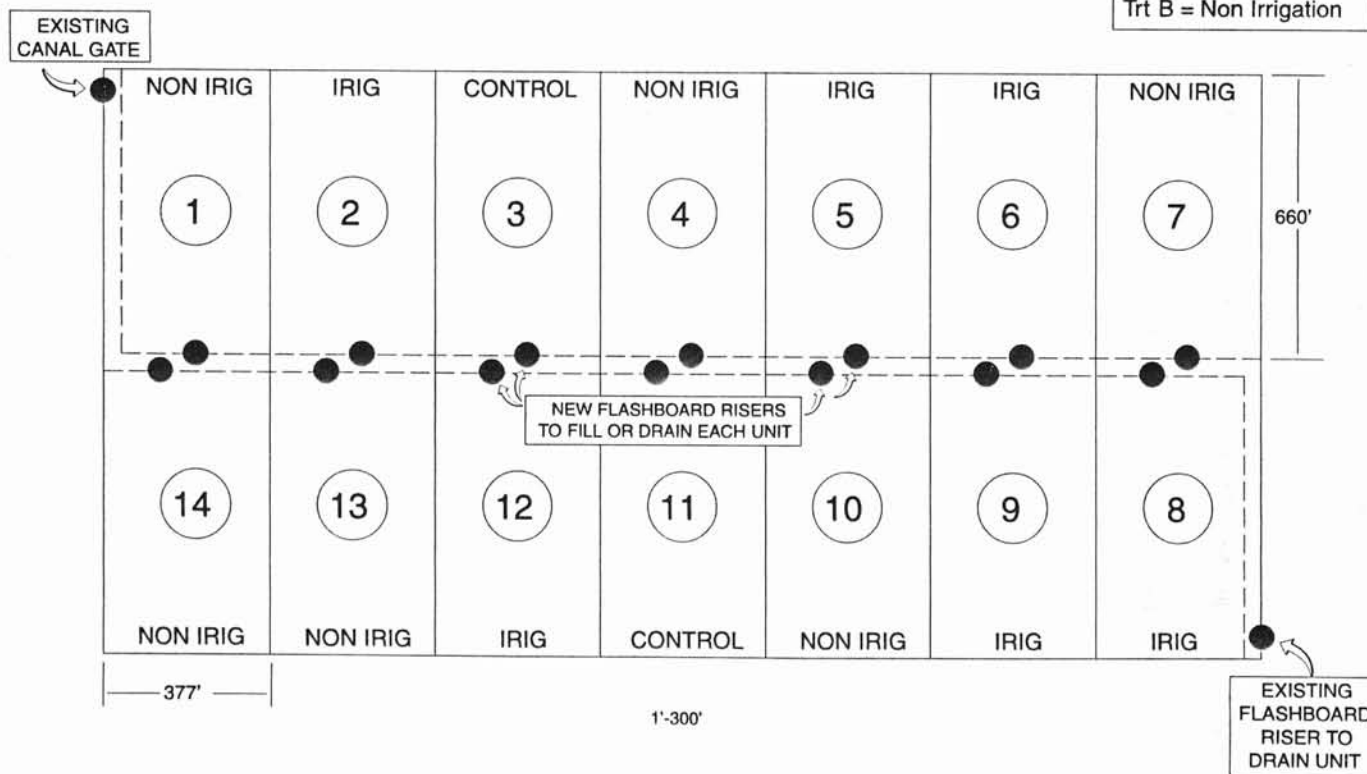


FIGURE 1. PLAIN VIEW OF RESEARCH UNITS

CHAPTER 2

VEGETATION RESPONSE TO MOIST-SOIL MANAGEMENT AT A NEWLY RESTORED WETLAND IN SOUTHWESTERN OKLAHOMA

Abstract: Wetlands consist of copious habitat diversity and represent ecotones between terrestrial and lotic systems. Moist-soil management of wetlands provides habitat to entice and retain waterfowl on restored wetland units. The most successful moist-soil management practices require control over hydrology, water-control structures for accurate water manipulation, and well-maintained levees. Accurate water manipulation will promote desirable native vegetation that is more nutritionally complete than producing waterfowl food from agricultural activities. Manipulating water also will provide cover for nesting waterbirds and substrate for invertebrates. Biomass sampling and assessment of vegetation cover were used to determine vegetative composition at Hackberry Flat, a highly altered wetland in southwestern Oklahoma. We calculated frequency of plants in wetland units to determine richness of genus and species and determined differences among treatments. Overall, species increased in units that were irrigated, and control and nonirrigated units did not differ. Knowledge of the current vegetation will determine the best moist-soil management practices to be implemented. Undesirable herbaceous plants and woody vegetation will need constant inspection and decisive actions to maximize cover and food beneficial to waterfowl on HFWMA.

Keywords: moist-soil management, restoration, vegetation, wetlands

Introduction

Wetlands are often depositional environments and thus are susceptible to stress resulting from surrounding land use and earth disturbances. Assessing historical succession of plant communities is one way to examine the response of

a wetland to this disturbance. Wetlands are being restored, created, and preserved throughout North America to offset historical losses (National Research Council 1992). Restoration usually involves reestablishment of wetland hydrology in areas that have been drained for agricultural production.

Prior to 1908, historical accounts from residents of southwestern Oklahoma stated that Hackberry Flat served as a major migration stop over for thousands of geese, ducks, and other waterbirds in the Central Flyway. Drainage of this natural basin was completed in 1908, and it has been under agricultural production for the past 90+ years, eliminating much of the wetland habitat in the basin. To negate the loss of critical wildlife habitat, the Oklahoma Department of Wildlife Conservation established a plan to reclaim Hackberry Flat. With a network of dikes, canals, pools, moist-soil units, flooding and drying regimes, and an independent water-delivery system, Hackberry Flat Wildlife Management Area (HFWMA) is being restored to a complex of wetland management units. Enhancement features have added considerable management flexibility and maximized wetland habitat. An understanding of the diversity and productivity of vegetation at HFWMA will determine the best moist-soil treatments to use as restoration proceeds. Elements such as topography, type of drawdown, time of drawdown, soil type, time since disturbance, and seasonal variations interact to determine which vegetation reacts and becomes established on an exposed mudflat (Fredrickson 1991). Drawdown techniques are used widely for managing water levels to promote use by waterfowl and other waterbirds (Uhler 1944). Accurate indicators of vegetation production on

restored wetlands are useful to prioritize moist-soil treatments and site selection. At restored wetlands, time since drainage can have a significant impact on the number of desirable wetland plants capable of growing on a site (Weinhold and van der Valk 1989). Correlations between productivity and relative diversity of species in the vegetative stage of the restored wetland would aid in predicting restoration outcomes.

Our study was designed to evaluate the botanical composition, distribution, and production of emergent vegetation in response to moist-soil management practices on HFWMA. We predicted that richness and productivity of the vegetation were similar across the various units at the research site and that despite decades of agriculture, vegetative response would contain desirable hydric plants.

Study area and methods

HFWMA is located in Tillman County in southwestern Oklahoma (34° 17' N, 98° 55' W). The 2,721 ha of moist soil, agricultural flooding, and associated uplands were located 2.2 km southeast of Frederick, Oklahoma. Elevations ranged from 1,145 to 1,165 m above mean sea level, and annual precipitation averaged 65 cm (National Oceanic and Atmospheric Administration 1998). Ambient temperatures averaged 2.4°C in winter and 28°C in summer (National Oceanic and Atmospheric Administration 1998). Soils consisted of uniform clay in the subsoil and variations of silty clay in the topsoil called Roscow (National Resources Conservation Service 1998). Desirable wetland vegetation included wild millet (*Echinochloa muricata*), sedges (*Carex brittoniana*, *Cyperus*

acuminatus, and *C. esculentus*), spikerush (*Eleocharis macrostachya*), red sprangletop (*Leptochloa filiformis*), maygrass (*Phalaris caroliniana*), Pennsylvania smartweed (*Polygonum pensylvanicum*), and curly dock (*Rumex crispus*). Undesirable wetland vegetation included salt marsh aster (*Aster subulatus*), loosestrife (*Lythrum alatum*), black willow (*Salix nigra*), cottonwood (*Populus deltoides*), salt cedar (*Tamarix chinensis*), cattail (*Typha latifolia*), and cocklebur (*Xanthum strumarium*). Other vegetation that was abundant throughout the study area included ragweed (*Ambrosia* sp.), common sunflower (*Helianthus annuus*), kochia (*Kochia scoparia*), malvella (*Malvella leprosa*), carpetweed, (*Mullugo verticillata*), and Johnson grass (*Sorghum halepense*).

We used frequency of occurrence of plants to compare units (Table 1). The experimental design encompassed 32.4-ha separated into 14, 2.3-ha experimental units. Water manipulation was controlled with a network of levees, 2, 1 meter screw gates, water distribution canals, and 14, 60 cm half-round riser water-control structures with 15 cm and 5 cm flashboards. Before taking any vegetative measurements, implementing drawdowns, and applying treatments (irrigation and non-irrigation) to units, all units were disked and then flooded, except in 1998. In 1998, construction of the research units had not begun, so we were not able to flood or apply treatments to units. In 1999, we conducted early drawdowns (<15 May) on all units and applied treatments as needed. At the end of the growing season and before fall migration of waterfowl, all units were flooded except 2 control units. In 2000, we again conducted early drawdowns (<15 May) on all units except the 2 control units, followed by flooding at the end

of growing season and prior to fall migration of waterfowl. In each unit, 2 100-m transects were placed randomly with 10 sampling points at 10-m intervals. Of the 14 units, 2 units acted as control, and replicated treatments were established on the research units that were subject to no irrigation ($n = 6$) and irrigation ($n = 6$) treatments to determine associations between treatments and years.

In August of 1998, 1999, and 2000, measurements were taken to determine botanical composition, distribution, and production of emergent vegetation in response to moist-soil management practices on HFWMA. We used a 0.5-m² quadrat to characterize plant cover along the transect. Estimates of percent cover by group (forb, woody, grass, sedge, and bare ground) were recorded using Daubenmire's cover class (Daubenmire 1959). Percent cover was classified as 0-5%, >5-25%, >25-50%, >50-75%, >75-95%, and >95-100% for each vegetation group. Midpoints of cover classes were used in statistical analyses. Height (cm) of the tallest vegetation also was recorded in the quadrat. Biomass estimates (kg/ha) of plant species were determined in quadrats by clipping plants to ground level. Clippings were oven dried to a constant weight at 70°C and biomass for each plant species was recorded (Bonham 1989).

Frequency (number of quadrats in which a species occurred divided by the total number of quadrats) of individual plant species at HFWMA as calculated (Brown 1954; Mueller-Dombois and Ellenberg 1974). Species of plants were categorized into sedges, woody plants, forbs, and grasses and identified to species. Plant species were divided into 5 categories (Reed 1988): 1) obligatory wetland (OBL), or those occurring usually at an estimated probability of >99% in

wetlands under natural conditions; 2) facultative wetland (FACW), usually occurring in wetlands an estimated probability of 67-99%, but occasionally found in non-wetlands; 3) facultative (FAC), equally likely to occur in wetlands or non-wetlands at an estimated probability of 34-66%; 4) facultative upland (FACU), usually occurring in non-wetlands at an estimated probability of 67-99%, but occasionally found in wetlands an estimated probability of 1-33%; 5) obligate upland (UPL), occurring usually in uplands at an estimated probability of > 99%.

Analysis of variance (PROC GLM; SAS Institute Inc. 1996) and multiple comparison test of least squares means (SAS institute Inc. 1996), were used to examine treatment differences in vegetative cover and biomass, and among years. Statistical significance was set at $P = 0.05$.

Results

In 1998, prior to any treatments, bare ground was present in all quadrats (100%); however, as treatments were applied, percent bare ground diminished (55% in 1999, 29% in 2000). Cover of plant groups generally increased when treatments were applied. Moist-soil desirable species that increased the most after treatments were applied were barnyard grass (11.4% in 1998, 29.5% in 2000) and red sprangletop (4.3% in 1998, 15.5% in 2000); all sedge and *Polygonum* species increased moderately (Table 1). Sedges comprised about 5% of the total species. That is low relative to what occurs in undisturbed wetlands, but as the basin's hydrology is restored, sedges should increase in abundance because of the large amounts of seeds they produce (Fredrickson and Taylor 1982).

Undesirable moist-soil species that increased the most after treatments were applied included salt cedar (9.3% in 1998, 21.5% in 2000), cattail (1.4% in 1998, 25.8% in 2000), and cocklebur (7.8% in 1998, 33.7% in 2000). However, salt marsh aster and common devils claw moderately decreased (Table 1).

Forbs were the dominant group of plants in our study. Woody species of plants occurring on the study area included black willow and salt cedar, an exotic, both of which can cause management problems (Harper 1977). Salt cedar dominated the category comprising about 69% of all woody species and about 9% of all plants.

There were no treatment by year interactions ($P > 0.05$), so we pooled our data across years. Coverage of plant species, biomass (kg/ha), and vegetative height (cm) generally increased with irrigation; there were few differences between nonirrigated and control units (Table 2). Coverage of forbs ($P = 0.001$), woody ($P = 0.05$), grass ($P = 0.001$), and bare ground ($P = 0.001$) differed between irrigated and nonirrigated units (Table 2). Coverage of sedges did not show any differences between treatments (Table 2). Production of forb biomass ($P = 0.01$), woody biomass ($P = 0.05$), and grass biomass ($P = 0.01$) differed between irrigated and nonirrigated units (Table 2), but biomass of sedges and litter did not differ between irrigated and nonirrigated units (Table 2). Height of vegetation differed between irrigated and nonirrigated treatments ($P = 0.001$; Table 2).

Discussion

The HFWMA is an extremely important wetland for migrating waterfowl

and other waterbirds in the Central Flyway (Anderson and Smith 1999). The main goal of water manipulation and management of vegetation will be to provide high quality wetland habitat beneficial for waterfowl and other waterbirds including shorebirds, and wading birds. Providing habitat for waterfowl and other waterbirds, with the primary focus on waterfowl, will impose 2 different demands on available water. However, 2 factors contribute to making this goal attainable. First, HFWMA provides the opportunity for maximizing habitat diversity by manipulating water depths in the various units that will support a diversity of plant communities. Second, the completion of the pipeline and reservoir will allow increased storage of water and less water being loss through evaporation. Use of pipeline and stored water to irrigate units will allow at least some wetland plant species to persist even during drought. Furthermore, multiple impoundments can provide a range of water depths, resulting in abundant habitat diversity for waterbirds (Fredrickson and Reid 1990).

Management goals at HFWMA should emphasize production of naturally produced moist-soil plants. However, with the unpredictable water situation, use of supplemental food sources should be considered. Management of moist-soil plants provides a direct food source for waterfowl through seed production and an indirect source by providing habitat for invertebrates. Drawdowns should be conducted on at least one-half the units each spring to help maintain productivity of the wetland (Kadlec 1962). Drawing down a unit also will allow the substrate of a pool to dry out and compact (Bellrose 1954), reducing erosion caused by wave action. Drawdowns of pools should be done on a rotational basis.

Drawdowns should be coordinated with spring arrival of shorebirds. Peak populations of migrating shorebird usually occur during the end of April and the beginning of May (Bent 1963). Mudflats in the drawdown units should be exposed by 15 April. The drawdown should continue through May to allow for exposure of new mudflats throughout peak spring migration. If 2 pools are drained, they should not be adjacent to one another so that spatial diversity is maintained, and there should be ≥ 2 weeks between the start of the drawdown between the pools. Drawdowns that are slow (≥ 2 weeks) and initiated on different dates should increase vegetative diversity (Fredrickson and Taylor 1982).

After mudflats are exposed, seeding of Japanese millet could be implemented to enhance waterfowl use during fall migration. Seed application should take place between late June and early July at a rate of 6 - 7 pounds/acre sown in strips across mudflats. This will supplement natural food production. After the millet and/or the natural food plants such as barnyard grasses, red sprangletop, sedges, and smartweeds become established, shallow reflooding is needed to irrigate desirable plants and retard establishment of undesirable plants (Fredrickson and Taylor 1982). Mudflats need to be available for shorebirds through late September. Reflooding of some units should be done in September for early migrating waterfowl such as blue-winged teal and completed in October to provide maximum waterfowl habitat. Water depths should vary between units to maximize diversity of waterbirds at HFWMA. Depths of 10-25 cm should be maintained to maximize use by dabbling ducks

and geese (White and James 1978).

Significant factors for assuring species composition of moist-soil plants that germinate on exposed mudflats are production of vegetative biomass and seeds in a particular wetland. Moist-soil units that are managed well and have some hydrologic capabilities can produce desirable moist-soil plants in dense stands that are indigenous to the area (Mitsch and Gosselink 1993). The current vegetative communities at HFWMA are related to species productivity and diversity of the prior vegetative communities. Management techniques to enhance production of vegetation and growth are necessary (Fredrickson and Reid 1990).

Prolonged drainage of the basin at Hackberry Flat (≥ 90 years) was self-evident and sufficient to result in the depletion of wetland plants, which was similar to results reported by (Brown 1998) during restoration and creation of freshwater wetland while measuring remnant vegetation. The extended disturbance by row cropping and drainage significantly affected the vegetation and seed bank (Miller 2001) in the restored units (see chapter 1).

Effects of disturbance on wetland vegetation vary with duration and intensity of disturbance. Disturbance from long-term drawdowns and fire did not cause changes in seed-bank composition or seedling regrowth in wetlands at the Great Salt Lake marshes (Smith and Kadlec 1985). Burning vegetation does not decrease productivity or diversity of the next year's vegetation, but long-term drainage and tillage of a wetland unit does (Kirkman and Sharitz 1994). Studies have showed that long-term drainage, linked with agricultural crop production,

diminished wetland vegetation (Dahl and Johnson 1991). Because of these declines, reestablishing hydrophytic communities at HFWMA may take longer than at an undisturbed wetland, and some artificial seeding of native wetland species may be needed.

Vegetative data can be used to make accurate qualitative predictions of species productivity and richness, even when quantitative predictions are inaccurate (Haukos and Smith 1993). Herbaceous species dominate wetland habitat. Perennials and annuals vary in importance within a wetland, and graminoids usually comprise <50% of the vegetation. Our study of the vegetative community at HFWMA found that even though hydrophytic vegetation was present, it was not abundant. The units in this study were changed by drainage but still had remnant wetland vegetation. The depletion of wetland plants over time after drainage is well documented (van der Valk 1986). Even if vegetative studies do not predict species productivity and richness of restored wetland vegetation in sites with prolonged disturbance, there are still important management implications for vegetative composition. Numbers of desirable species present at HFWMA, such as barnyard grass, red sprangletop, and polygonums, may be prominent indicators of the relative likelihood of a successful wetland restoration that meets management goals (van der Valk et al. 1989). Salt marsh aster is an early successional plant that invades newly disturbed sites; it has little to no value to wildlife (Fredrickson and Taylor 1982), except for offering some cover. It is a transient and does not stay established if the site remains undisturbed over time. Weller (1975) stated that cattails have

the potential to cause severe management problems, and control of this plant should be a top priority for any wetland manager.

Our vegetative sampling showed that woody species other than salt cedar are not currently a management concern, but salt cedar can pose major problems. Salt cedar is an invasive exotic species with few limiting factors, and if left unmanaged, like cattail, can quickly reduce the value of wetland to waterbirds (Merendino and Smith 1991, Weller 1975). Salt cedar and cattail have been controlled with limited success by a series of mowing, burning, and disking (Yeo 1964). However, for those methods to work, the impoundment must be kept dry for an extended period of time, which can be somewhat unreasonable for some wetland units. Cocklebur can also be a serious problem on some sites that were previously in agricultural production. To control cocklebur, new emergents must be flooded to one-half their height after they germinate (Fredrickson and Taylor 1982).

The dominant desirable species of plants that germinated at HFWMA were sedges, smartweed, curly dock, wild millet, red sprangletop, and switch grass. All these species germinate well on wet sites or exposed mudflats and produce abundant seed crops. Wild millet is an excellent annual moist-soil plant that produces copious amounts of seeds in the inflorescence. These species also respond well to mid- to late-season drawdowns (Fredrickson and Taylor 1982). This information will allow implementation of appropriate management strategies to conduct moist-soil management.

Johnson grass and common sunflower were found extensively throughout

the basin. There is little information regarding the value of these 2 species as food for waterbirds, but waterbirds have been observed foraging on these 2 plants at HFWMA.

Vegetative studies coupled with knowledge of the seed bank are key to understanding vegetative dynamics and long-term survival of restored wetlands. It is the presence of remnant vegetation of emergent species that enables closed basins such as Hackberry Flat to regenerate its emergent desirable moist-soil vegetation.

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Table 1. Frequency of wetland plants (as the number of quadrats in which a species occurred and divided by the total number of quadrats, $n = 52$), occurring at Hackberry Flat Wildlife Management Area, Tillman County, Oklahoma.

| NW class ^a | Plant species | Frequency (%) | | |
|-----------------------|------------------------------------------------------------------------|---------------|------|------|
| | | 1998 | 1999 | 2000 |
| Obligate | <i>Aster subulatus</i> Michx. Salt marsh aster | 10.4 | 8.9 | 8.2 |
| | <i>Cyperus acuminatus</i> ^b Torr. & Hook. Flat sedge | 0.4 | 2.1 | 3.5 |
| | <i>Eleocharis macrostachya</i> ^b Britt. Spikerush | 0.7 | 8.9 | 7.4 |
| | <i>Lythrum alatum</i> Pursh Loosestrife | 0.0 | 3.6 | 3.8 |
| Facultative Wetland | <i>Aristida purpurea</i> Nutt. var. <i>purpurea</i> Purple threeawn | 1.4 | 0.4 | 2.8 |
| | <i>Carex brittoniana</i> ^b Bailey Sedge | 1.1 | 7.5 | 7.5 |
| | <i>Cyperus esculantus</i> ^b L. Yellownut sedge | 3.2 | 7.1 | 6.8 |

Table 1. Continued.

| NWI class ^a | Plant species | Frequency (%) | | |
|------------------------|---------------------------------------------------------------------------|---------------|------|------|
| | | 1998 | 1999 | 2000 |
| Facultative Wetland | <i>Echinochloa muricata</i> ^b (Beauv.) Fern Barnyard grass | 11.4 | 28.9 | 29.5 |
| | <i>Heliotropium curassavicum</i> L. Salt heliotrope | 0.7 | 0.4 | 0.0 |
| | <i>Leptochloa filiformis</i> ^b (Lam.) Beauv. | 4.3 | 11.8 | 15.5 |
| | <i>Phalaris caroliniana</i> ^b Walt. Maygrass | 0.0 | 0.7 | 2.8 |
| | <i>Polygonum lapathifolium</i> ^b L. Pale smartweed | 1.8 | 0.7 | 2.8 |
| | <i>Polygonum pennsylvanicum</i> ^b L. Pennsylvania smartweed | 2.9 | 5.4 | 6.9 |
| | <i>Polygonum ramosissimum</i> ^b Michx. Knotweed | 0.4 | 0.4 | 0.7 |

Table 1. Continued.

| NWI class ^a | Plant species | Frequency (%) | | |
|------------------------|-------------------------------------------------------------|---------------|------|------|
| | | 1998 | 1999 | 2000 |
| Facultative Wetland | <i>Rumex altissimus</i> ^b Wood Pale dock | 1.8 | 0.7 | 2.2 |
| | <i>Rumex crispus</i> ^b L. Curly dock | 4.3 | 5.0 | 8.2 |
| | <i>Salix nigra</i> Marsh. Black willow | 2.5 | 2.1 | 3.9 |
| | <i>Tamarix chinensis</i> Lour. Saltcedar | 9.3 | 11.8 | 21.5 |
| | <i>Typha latifolia</i> Narrow-leaf cattail | 1.4 | 10.3 | 25.8 |
| Facultative | <i>Acacia angustissima</i> (Mill.) O.Ktse Prairie acacia | 0.0 | 0.4 | 0.9 |
| | <i>Ambrosia psilostachya</i> DC. Western ragweed | 1.8 | 2.5 | 3.8 |

Table 1. Continued.

| NWl class ^a | Plant species | Frequency (%) | | |
|------------------------|------------------------------------------------------------------------|---------------|------|------|
| | | 1998 | 1999 | 2000 |
| Facultative | <i>Chenopodium album</i> L. Lamb's-quarters | 2.9 | 3.5 | 4.9 |
| | <i>Convolvulus arvensis</i> L. Field bindweed | 0.7 | 1.4 | 3.5 |
| | <i>Digitaria sanguinalis</i> ^b (L) Scop. Hairy crabgrass | 0.0 | 0.7 | 1.6 |
| | <i>Elymus virginicus</i> ^b L. Virginia wild rye | 5.0 | 1.8 | 1.3 |
| | <i>Engelmannia pinnatifida</i> Gray ex Nutt. Engelmann's daisy | 1.1 | 0.4 | 0.8 |
| | <i>Helianthus annuus</i> L. Common sunflower | 10.4 | 19.6 | 17.8 |
| | <i>Malvela leprosa</i> (Ort.) Krapov. Malvela | 20.4 | 20.7 | 18.5 |

Table 1. Continued.

| NWI class ^a | Plant species | Frequency (%) | | |
|------------------------|----------------------------------------------------------------------|---------------|------|------|
| | | 1998 | 1999 | 2000 |
| Facultative | <i>Mollugo verticillata</i> L. Carpetweed | 0.7 | 7.8 | 10.2 |
| | <i>Panicum capillare</i> L. Common witchgrass | 2.9 | 2.5 | 1.8 |
| | <i>Panicum virgatum</i> L. Switchgrass | 0.0 | 1.1 | 12.3 |
| | <i>Populus deltoides</i> Marsh. Cottonwood | 0.0 | 0.7 | 1.5 |
| | <i>Portulaca oleracea</i> L. Common purslane | 1.4 | 0.7 | 0.4 |
| | <i>Proboscidea louisianica</i> (Mill.) Thell. Common devil's claw | 11.2 | 3.4 | 5.5 |
| | <i>Quincula lobata</i> (Torr.) Raf. Purple ground cherry | 1.8 | 0.0 | 0.0 |

Table 1. Continued.

| NWl class ^a | Plant species | Frequency (%) | | |
|------------------------|------------------------------------------------------------------|---------------|------|------|
| | | 1998 | 1999 | 2000 |
| Facultative | <i>Setaria glauca</i> ^b (L.) Beauv. Yellow foxtail | 0.4 | 4.3 | 8.2 |
| | <i>Solanum elaeagnifolium</i> Can. Silverleaf nightshade | 2.9 | 3.6 | 5.1 |
| | <i>Xanthium strumarium</i> Cocklebur | 7.8 | 28.6 | 33.7 |
| Facultative Upland | <i>Avena sativa</i> L. Cultivated oats | 1.4 | 0.0 | 0.0 |
| | <i>Amaranthus palmeri</i> Wats. Palmer's pigweed | 0.7 | 0.7 | 3.5 |
| | <i>Ambrosia artemisiifolia</i> L. Common ragweed | 0.0 | 1.8 | 1.3 |
| | <i>Bromus secalinus</i> L. Cheat | 0.0 | 1.1 | 2.3 |

Table 1. Continued.

| NWI class ^a | Plant species | Frequency (%) | | |
|------------------------|-------------------------------------------------------------|---------------|------|------|
| | | 1998 | 1999 | 2000 |
| Facultative Upland | <i>Buchloe dactyloides</i> (Nutt.) Englem. Buffalo grass | 1.4 | 0.7 | 0.8 |
| | <i>Croton</i> spp. Croton | 0.0 | 2.1 | 5.9 |
| | <i>Cynodon dactylon</i> (L.) Pers. Bermuda grass | 0.7 | 0.0 | 0.7 |
| | <i>Euphorbia marginata</i> Pursh Snow-on-the-mountain | 5.0 | 0.7 | 3.2 |
| | <i>Gutierrezia dracunculoides</i> (DC.) Blake Broomweed | 2.1 | 1.8 | 2.5 |
| | <i>Kochia scoparia</i> (L.) Schrad. Kochia | 1.4 | 16.1 | 11.7 |

Table 1. Completed.

| NWI class ^a | Plant species | Frequency (%) | | |
|------------------------|---------------------------------------------------------|---------------|------|------|
| | | 1998 | 1999 | 2000 |
| Facultative Upland | <i>Maclura pomifera</i> (Raf.) Schneid. Osage orange | 0.7 | 0.0 | 0.0 |
| | <i>Prosopis juliflora</i> (Swartz) DC. Mesquite | 2.1 | 0.0 | 3.5 |
| | <i>Sorghum halapense</i> (L.) Pers. Johnson grass | 24.6 | 29.3 | 28.4 |
| Other | Bare ground | 100 | 55 | 29 |

^aWetland occurrence Obligate Wetland (OBL) = >99%; Facultative Wetland (FACW) = 67-99%; Facultative (FAC) = 34-66%; Facultative Upland (FACU) = 1-33%; Upland (UPL) = <99%. ^bDenotes desirable moist-soil wetland food plant (Baldassarre and Bolen 1994).

Table 2. Frequency of 11 vegetative characteristics among treatments (control, irrigation, and nonirrigation) at Hackberry Flat Wildlife Management Area, Tillman County, Oklahoma (1999 and 2000 combined).

| | | Treatment ^A | | | | | | | | |
|-----------------------------------------------------|-----------------------|------------------------|---------|------|-----------|---------|------|-------------|---------|------|
| | | Contol | | | Irrigated | | | Nonirrigate | | |
| | | <u>n</u> | Mean | SE | <u>n</u> | Mean | SE | <u>n</u> | Mean | SE |
| Vegetation characteristics, bare ground, and litter | | | | | | | | | | |
| g | Forb cover (%) | 40 | 21.25 A | 3.14 | 120 | 45.50 B | 2.45 | 120 | 25.66 A | 1.82 |
| | Woody cover (%) | 40 | 23.25 A | 5.05 | 120 | 9.16 B | 2.02 | 120 | 16.25 A | 2.39 |
| | Grass cover (%) | 40 | 20.00 A | 3.53 | 120 | 33.83 B | 1.38 | 120 | 20.83 A | 1.48 |
| | Sedge cover (%) | 40 | 7.00 AB | 1.77 | 120 | 8.25 A | 1.11 | 120 | 3.75 B | 1.39 |
| | Bare ground (%) | 40 | 28.50 A | 7.17 | 120 | 3.25 B | 1.66 | 120 | 33.50 A | 4.23 |
| | Forb biomass (kg/ha) | 40 | 6.72 A | 1.93 | 120 | 15.65 B | 1.73 | 120 | 8.31 A | 1.07 |
| | Woody biomass (kg/ha) | 40 | 6.90 A | 2.21 | 120 | 4.60 A | 1.10 | 120 | 5.18 A | 1.22 |

Table 2. Completed.

| | Treatment ^A | | | | | | | | |
|--------------------------------------------------------|------------------------|--------|------|----------|---------|------|-------------|--------|------|
| | Contol | | | Irrigate | | | Nonirrigate | | |
| | <u>n</u> | Mean | SE | <u>n</u> | Mean | SE | <u>n</u> | Mean | SE |
| Vegetation characteristics, bare ground, and litter | | | | | | | | | |
| Grass biomass (kg/ha) | 40 | 7.43 A | 3.27 | 120 | 12.92 B | 1.17 | 120 | 6.97 A | 1.65 |
| Sedge biomass (kg/ha) | 40 | 1.65 A | 0.72 | 120 | 1.72 A | 0.32 | 120 | 1.14 A | 0.35 |
| Litter biomass (kg/ha) | 40 | 6.00 A | 0.49 | 120 | 4.24 A | 0.49 | 120 | 4.73 A | 0.73 |
| Vegetative height (cm) | 40 | 7.22 A | 1.11 | 120 | 15.89 B | 1.31 | 120 | 5.76 A | 1.21 |

^A Means within a row followed by the same letter do not differ (Least Squares Means, $P < 0.05$). Unit of measurement = kg/ha.

CHAPTER 3

RESPONSES OF WATER-RELATED BIRD SPECIES TO A NEWLY RESTORED WETLAND IN SOUTHWESTERN OKLAHOMA

Abstract: Migrating waterfowl, shorebirds, and wading birds were censused in southwestern Oklahoma at Hackberry Flat Wildlife Management Area (HFWMA) during autumns 1999 and 2000. A standardized bird survey using sampling points spaced at 0.55-km intervals was used to sample waterbirds using the basin area and characterize associated wetland habitat at HFWMA. Ground counts of migrating waterbirds using the inner basin area provided information on distribution of waterbird populations in response to restoration practices at HFWMA. Dabbling ducks used vegetated shallow water habitat (64%) over all other types of habitats. Shorebirds used open mud habitat (71%) over all other types of habitats. Wading birds used open shallow habitat (58%) over all other types of habitats. In 1999, 44 different species of wetland-related birds were sampled (544 individual waterbirds and raptors), and in 2000, those numbers increased to 54 and 3,820, respectively.

Key words: Oklahoma, restoration, shorebirds, wading birds, waterfowl, wetlands

Introduction

With the recent decline in wetland habitats, there is a need for restoration and creation of these valuable aquatic habitats. Interest in wetland creation and restoration has evolved from the fact that our wetland resources have been degraded since the turn of the 20th Century. Significant interest in the construction of wetlands for habitat replacement, coastal protection, and water-quality enhancement (Mitch and Gosselink 1993) is evident by activities of agencies such as the Oklahoma Department of Wildlife Conservation, Ducks

Unlimited, U.S. Fish and Wildlife Service, and Natural Resource Conservation Services.

In Oklahoma, as elsewhere in the Central Flyway, waterfowl, transcontinental wading birds, and shorebird migrants are dependent on freshwater wetlands for energy resources to help them through winter and prepare them for reproduction, nesting, and brood rearing (Miller et al. 2000). Because of the immense energy required for long-distance migratory flights, wetland habitats for refueling, rest, and stopover are crucial to successful reproduction and survival of these groups of birds (Baldassarre and Bolen 1984). Geographic locations, habitat types, and weather conditions influence migrating waterfowl and other waterbirds and can be correlated directly with reproduction, stopover lengths, and acquisition of nutrients (Heitmeyer and Fredrickson 1981). Hackberry Flat Wildlife Management Area (HFWMA) is a natural wetland basin located in southwestern Oklahoma about 9 km from the Red River. The first phase of the restoration work at HFWMA began in 1993, which entailed buying land within the targeted wetland restoration area. The Oklahoma Department of Wildlife Conservation purchased 2,721 ha in 1993. Phase 2 was designed to develop a system of interior dikes, water-distribution canals, water-control structures, and a weir structure to capture water that drained into the basin. Phase 3 was the installation of the Hackberry Flat aqueduct. The aqueduct is a gravity-fed pipeline of 36.3 km to provide donated water from Lake Fredrick to HFWMA. Phase 4 is the construction of a 153.5-ha water-storage reservoir, which will store additional water supplied by the

pipeline and run-off. The reservoir will enhance flooding of individual wetland pools by supplying large quantities of water quickly, depending on management needs.

Those 4 phases entailed the main restoration work at HFWMA. However, a variety of other restoration activities have been completed at HFWMA; some of those include tree plantings and nesting structures for a variety of birds. HFWMA is home to numerous species of birds, mammals, reptiles, amphibians, invertebrates, and plants. Historically, seasonal waterfowl numbers approached tens of thousands at HFWMA. Habitats at HFWMA include shallow open water, vegetated shallow water, open mud, vegetated mud, old fields, mesquite grassland, mixed prairies, and disturbed areas. There have been 122 different bird species observed at HFWMA (Oklahoma Department of Wildlife Conservation 1999), but all avian surveys at HFWMA have been conducted from roadways with pickup trucks, also aerial mid-winter surveys for waterfowl. Our survey method included the use of an ATV and optical equipment and was conducted off-road to enhance observability of waterbirds and various habitats.

Wetlands can improve quality of water, help in nutrient recycling and downstream flooding, and provide opportunity for bird watching, hunting, and research. However, wetlands are endangered ecosystems. In the last 200 years, around 54% of the wetlands in the lower 48 states have been diminished (Tiner 1984). About 88% of those wetland conversions were for agricultural production (Tiner 1984). Oklahoma was not immune to such losses and

lost about 67% of its wetlands since the early 1900s (Shaw and Fredine 1956).

This chapter analyzes numbers of waterfowl, wading birds, shorebirds, and raptors that used HFWMA in autumn 1999 and 2000. Previous information on wetland use by waterfowl in autumn is based primarily on data derived from hunting information (Belrose et al. 1979, Heitmeyer and Vohs 1984). Our autumn surveys were conducted to evaluate waterbirds at HFWMA but also to assess habitat use.

Study area and methods

We censused waterfowl, wading birds, shorebirds, and raptors from August to December every 2 weeks for 3 days in 1999 and 2000 at HFWMA in Tillman County in southwestern Oklahoma (34° 17' N, 98° 55' W). Waterbirds were surveyed 5 times in autumn 1999 (26-28 August, 19-21 September, 13-15 October, 6-8 November, and 25-27 November) and 5 times in autumn 2000 (25-27 August, 18-20 September, 18-20 October, 3-5 November, and 27-29 November). The 2,721 ha of moist soil, agricultural flooding, and associated uplands were located 2.2 km southeast of Frederick, Oklahoma. Elevations ranged from 1,145 to 1,165 m above mean sea level, and annual precipitation averaged 65 cm (National Oceanic and Atmospheric Administration 1999). Ambient temperatures averaged 2.4° C in winter and 28° C in summer (National Oceanic and Atmospheric Administration 1999). Soils consisted of uniform clay in the subsoil and variations of silty clay in the topsoil called Roscow (Natural Resources Conservation Service 1998).

Waterfowl that are known to occur at HFWMA include mallard (*Anas platyrhynchos*), green-winged teal (*A. crecca*), blue-winged teal (*A. discors*), northern pintail (*A. acuta*), American wigeon (*A. americana*), and northern shoveler (*A. clypeata*). The various subspecies of Canada goose (*Branta canadensis*) are the most abundant geese; numbers of white-fronted geese (*Anser albifrons*) and snow geese (*Chen caerulescens*) are expected to increase as the basin matures following restoration.

Wading birds and shorebirds that are known to occur at HFWMA include great blue herons (*Ardea herodias*), little blue herons (*Egretta caerulea*), white-faced ibises (*Plegadis chihi*), black-necked stilts (*Pluvialis spuatrola*), American avocets (*Recurvirostra americana*), greater yellowlegs (*Tringa melanoleuca*), killdeers (*Chardrius vociferus*), and sandpipers (*Calidris* spp.). Other species include sandhill crane (*Rhus canadensis*), American coot (*Fulica americana*), and king rail (*Rallus elegans*).

A stratified-random sampling design with 16 survey stops at intervals of 0.55 km (0.25 mile) was used. The survey route was established relative to areas of key habitats in the basin area at HFWMA and targeted moist-soil management and crop flooding. Ten-minute point counts were conducted at each stop with observers counting all waterbird species heard or seen within a 0.55-km radius. Surveys began around sunrise and ended by noon. To identify waterbirds and raptors, we used 10 X 40 binoculars and 15 X 60 Bushnell spotting scope.

We identified 5 microhabitats at HFWMA: (1) open water, including water distribution canals, (2) vegetated water, (3) open mud, (4) vegetated mud, and (5) old field. We tallied waterbird use in relationship with the 5 microhabitats.

All data were analyzed using chi-square programs in the Statistical Analysis System (SAS Institute Inc. 1996). Unless otherwise noted, all probability levels refer to chi-square tests and significance was set at $P < 0.05$. I compared numbers of birds by groups (waterfowl, wading birds, shorebirds, and raptors) and by year (1999 or 2000). I also compared the number of birds by group and species with the 5 microhabitats.

Results

Seven times as many individual birds were tallied in autumn 2000 than in autumn 1999, and waterfowl were the most common group in both years (Table 1). Fifty-four species of birds were observed during the 5 bird surveys conducted at HFWMA in 2000 compared with 44 species in 1999 (Table 2). For comparison, birds were classified by classes (waterfowl, wading birds, shorebirds, and raptors) and were furthered categorized by habitat preference (Table 2). All wetland-related bird species increased from 1999 to 2000 ($X^2 = 667.27$, $d.f. = 3$, $P = 0.0001$). Abundance of the 3 groups of waterbirds (waterfowl, wading birds, and shorebirds) differed among the 5 habitats in autumn 1999 when 44 different species of wetland-related birds were sampled ($X^2 = 379.13$, $d.f. = 8$, $P = 0.0001$) and autumn 2000 when 54 different species of wetland-related birds were sampled ($X^2 = 1,796.08$, $d.f. = 8$, $P = 0.0001$). We observed 15 species of waterfowl at HFWMA (Table 2); 9 of those can be

considered common. Mallards, blue-winged teal, green-winged teal, northern pintails, and gadwalls had the highest abundance among the dabbling ducks (Table 2). Because of shallow water conditions at HFWMA, diving ducks were never as numerous as dabbling ducks. However, with the completion of the reservoir, we expect to see more diving ducks at HFWMA. Mallards and northern shovelers nested on HFWMA, and mallards were the most numerous in 1999 and 2000.

Shorebirds that were observed at HFWMA in 1999 and 2000 are listed in Table 2. Shorebirds mainly used HFWMA during autumn and spring migration although killdeer, American avocets, black-necked stilts, and upland sandpipers nested in the basin. Numbers of each species present on HFWMA varied during autumn migration and between years.

We observed 10 species of wading birds (herons, egrets, bitterns, ibis, and rails) at HFWMA. Two of those (king rails and soras, *Porzana carolina*) were game species. King rail and soras were observed in late September. The king rails occurred in dense vegetation and were difficult to census. Two white-faced ibis nested in stands of cattails (*Typha* spp.) in 2000.

Rare species of birds that were censused include cinnamon teal (*Anas cyanoptera*), American bittern (*Botaurus lentiginosus*), lesser golden plover (*Pluvialis dominica*), snowy plover (*Chardrius alexandrinus*), solitary sandpiper (*Tringa solitaria*), golden eagle (*Aquila chrysaetos*), and peregrine falcon (*Falco peregrinus*).

Discussion

The majority of restoration work at HFWMA has been completed, and the installation of a pipeline from Frederick Lake will provide a future water source for the wetland, especially during drought. HFWMA attracts a diversity of wetland-dependent waterbird species. Our bird surveys began in 1999 and ended in 2000 during the third phase of wetland restoration work. As restoration work progresses and more of the basin is transformed to wetland, the composition of the bird community should become more diversified, and abundance of waterbirds should increase.

The increase in waterbirds from 1999 to 2000 can be attributed to various factors: 1) Oklahoma experienced a more severe drought in 1999 than in 2000, coupled with high evaporation rate (>215 cm; National Oceanic and Atmospheric Administration 1999) leaving water in only a few of the deepest pools; 2) the pipeline was completed in 1999 providing year-round water to HFWMA in 2000; 3) chronologically, migration in 2000 was closer to normal than in 1999 because of the more severe drought in 1999 (National Oceanic and Atmospheric Administration 1999).

The goal of shorebird management at HFWMA should be to maintain shorebird populations for educational and economical value, recreational opportunity, and scientific study. To achieve this goal, management, protection, and control of the shorebird community and its habitats should be directed toward increasing populations at HFWMA. Because HFWMA is important as a resting-place for migrant shorebirds rather than a nesting area, management

should focus primarily on migrant species and secondarily on breeding species. Management for shorebirds during spring and autumn migrations will require slow drawdowns of wetland units to provide a range of substrate conditions from exposed mud to water <30 cm deep for a diversity of foraging shorebirds (Smith and Connors 1993). Drawdowns should be timed so appropriate substrate conditions are available during spring and autumn migration periods. Most shorebird species prefer foraging sites that are free of vegetation or sparsely vegetated (Skagen and Knopf 1994). Pools managed for shorebirds should have areas relatively free of vegetation. Other migrant shorebirds such as greater and lesser yellowlegs, common snipe, and pectoral sandpipers frequent vegetated sites; thus, an interspersed of vegetated sites should be maintained (Baker and Baker 1973).

Shorebird nesting habitat at HFWMA also should be enhanced. One wetland unit could be scraped periodically to control encroachment of vegetation and promote nesting sandpipers and plovers. To prevent disturbance of nesting killdeer along dike roads, dike maintenance should be scheduled before or after the nesting season (May-August). Drier areas surrounding the wetland units should be burned periodically to prevent encroachment by woody vegetation and maintain nesting by upland sandpipers. Shorebirds should be monitored with regular censuses (weekly during April, May, July, August, and September).

Wading birds are important consumers of invertebrates, amphibians, reptiles, and fish. They also are enjoyed by birdwatchers. Populations of

wading birds should be protected and enhanced. Management of wading birds at HFWMA requires some protection of dense stands of natural vegetation for nesting and maintenance of adequate water levels for their prey. Because fish and amphibians are important components of diets of wading birds (Kushlan 1976), white pelican (*Pelecanus erythrorhynchos*), and raptors, adequate water in 1 wetland unit should be maintained. The reservoir should maintain at least small populations of fish and amphibians year round (Reid 1989).

Hackberry Flat is most valuable to waterfowl as a migratory stopover and secondarily as a breeding area. The first goal of waterfowl management in Oklahoma is to provide quality habitat during autumn and spring migration. Waterfowl production should be maximized if it does not interfere with the ability to provide quality habitat during migration. Wetland units with good waterfowl foods should be flooded from late summer until the end of spring migration (Fredrickson and Taylor 1982). Waterfowl and shorebird management is not mutually exclusive within wetland units at HFWMA because there is sufficient variability of mudflats for shorebirds and shallow water for waterfowl (Payne 1992). The diversity of wetland units at HFWMA should be maintained and enhanced.

HFWMA should be monitored for the outbreak of avian diseases. During late summer, efforts to monitor for disease in shallow water areas need to be made (Baldassarre and Bolen 1994). Diseases such as fowl cholera and avian botulism have occurred in close proximity (Playa lakes region) and could be carried to HFWMA by migrating waterfowl (Baldassarre and Bolen 1994).

Food resources need to be available for waterfowl; naturally occurring vegetation such as smartweed or wild millet could be planted in ≥ 1 pool on an annual basis. Further investigations to determine which naturally occurring foods are preferred and how to best manage water levels to maximize their production should be continued (Fredrickson and Taylor 1982). Studies are needed to determine which invertebrates ducks eat. Invertebrate production should be monitored to assess effects of various management activities. After natural food preferences of invertebrates are determined, management techniques to promote invertebrate production should be implemented (Stenzel et al. 1976).

Since 1995, duck hunting regulations in the United States have been formulated under the Adaptive Harvest Management (AHM) system, introduced by the U.S. Fish & Wildlife Service (Johnson and Williams 1999) with the purpose of maximizing duck harvest, while also striving to maintain duck populations under the goals of North American Waterfowl Management Plan (National Wetland Policy Forum 1988). Efforts should be made at HFWMA to maximize waterfowl production. Studies of nest predation, brood survival, brood-rearing habitat, nest-site selection, and nest success should be initiated (Baldassare and Bolen 1994). Nesting baskets could be built, monitored, and maintained. Human disturbance needs to be kept to a minimum in the prime nesting areas. All native grasses need to be maintained and not destroyed. Marginal farming practices are a threat to nesting habitat because the highest quality nesting habitat (native grassland) was converted to cropland long ago

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(Higgins 1977).

When managing food resources for geese, emphasis needs to be placed on winter wheat plantings (Hobaugh 1985). All crop fields designated for geese should be large enough to supply ample amounts of food throughout the winter. At least 166-ha should be planted to wheat annually at HFWMA to increase geese numbers. Areas bordering HFWMA could be leased to provide adequate foraging opportunities for geese and additional hunting opportunities.

Management of the marsh habitat for waterfowl and other waterbirds involves providing a range of water depths in wetland units, diverse native vegetation, and development and maintenance of a 50:50 interspersion of open water and emergent vegetation (Mitsch and Gosselink 1993). The system of water distribution canals and dikes should help break up solid stands of cattails and provide areas of shallow water to promote habitats for invertebrates and brood rearing. The completed reservoir could become a site for reestablishment of pondweeds (*Potamogeton* spp.), duckweed (*Lemna* spp.), and coontail (*Ceratophyllum demersum*), which are important duck foods (Miller et al. 2000).

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Table 1. Composition of birds during surveys conducted at Hackberry Flat Wildlife Management Area in Tillman County, Oklahoma, August – December, 1999 and 2000.

| Year | Total number of birds | Wading birds | Shorebirds | Waterfowl ^a | Raptors |
|------|-----------------------|--------------|------------|------------------------|---------|
| 1999 | 544 | 64 | 212 | 231 | 37 |
| 2000 | 3,820 | 85 | 345 | 3,348 | 42 |

^a Includes grebes, geese, coots, and cranes.

Table 2. Proportion (%) of migrating waterbirds (waterfowl, wading birds, and shorebirds) and raptors observed on 5 habitat types during autumn 1999 (A99) and autumn 2000 (A00) at Hackberry Flat Wildlife Management Area in Tillman County, Oklahoma.

| Species, Season (n) | Habitat type | | | | |
|------------------------|--------------|--------------------|----------|----------------|-----------|
| | Wetland type | | | | |
| | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| Grebe, pied-billed | | | | | |
| A99 (11) | 45.4 | 54.6 | - | - | - |
| A00 (9) | 33.3 | 66.7 | - | - | - |
| Pelican, white | | | | | |
| A99 (0) | - | - | - | - | - |
| A00 (8) | 100.0 | - | - | - | - |
| Cormorant, dbl.crested | | | | | |
| A99 (3) | 100.0 | - | - | - | - |
| A00 (6) | 100.0 | - | - | - | - |
| Bittern, American | | | | | |
| A99 (0) | - | - | - | - | - |
| A00 (3) | - | - | - | 100.0 | - |

Table 2. Continued.

| | Species, Season (n) | Habitat type | | | | |
|---|------------------------|--------------|--------------------|----------|----------------|-----------|
| | | Wetland type | | | | |
| | | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| | | | | | | |
| 8 | Heron, great blue | | | | | |
| | A99 (17) | 64.7 | 35.3 | - | - | - |
| | A00 (19) | 52.8 | 47.2 | - | - | - |
| | Heron, little blue | | | | | |
| | A99 (1) | - | - | 100.0 | - | - |
| | A00 (2) | 50.0 | 50.0 | - | - | - |
| | Heron, green | | | | | |
| | A99 (2) | - | 50.0 | 50.0 | - | - |
| | A00 (2) | 50.0 | 50.0 | - | - | - |
| | Egret, great | | | | | |
| | A99 (7) | 42.8 | 42.8 | - | 14.4 | - |
| | A00(11) | 72.8 | 27.2 | - | - | - |
| | Egret, snowy | | | | | |
| | A99 (7) | 57.1 | 42.9 | - | - | - |
| | A00 (7) | 57.1 | 42.9 | - | - | - |
| | Egret, cattle | | | | | |
| | A99 (8) | 37.5 | - | - | 25.0 | 37.5 |
| | A00 (12) | 50.0 | - | - | 25.0 | 25.0 |

Table 2. Continued.

| Species, Season (n) | Habitat type | | | | |
|------------------------|--------------|--------------------|----------|----------------|-----------|
| | Wetland type | | | | |
| | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| Ibis, white-faced | | | | | |
| A99 (7) | - | 14.4 | 42.8 | 42.8 | - |
| A00 (23) | - | - | 34.7 | 34.7 | 30.6 |
| Goose Canada | | | | | |
| A99 (11) | - | 100.0 | - | - | - |
| A00 (58) | 24.2 | 75.8 | - | - | - |
| Goose, snow | | | | | |
| A99 (0) | - | - | - | - | - |
| A00 (4) | 100.0 | - | - | - | - |
| Goose, white-fronted | | | | | |
| A99 (6) | - | 100.0 | - | - | - |
| A00 (12) | 33.3 | 66.7 | - | - | - |
| Mallard | | | | | |
| A99 (36) | 22.2 | 58.3 | 8.3 | 11.2 | - |
| A00 (2350) | 38.0 | 55.1 | - | 6.9 | - |

Table 2. Continued

| Species, Season (n) | Habitat type | | | | |
|------------------------|--------------|--------------------|----------|----------------|-----------|
| | Wetland type | | | | |
| | | | | | |
| | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| Gadwall | | | | | |
| A99 (25) | 44.0 | 40.0 | 8.0 | 8.0 | - |
| A00 (260) | 70.0 | 25.0 | 5.0 | - | - |
| Pintail, Northern | | | | | |
| A99 (14) | 35.7 | 50.0 | - | 14.3 | - |
| A00 (250) | 52.0 | 43.2 | - | 4.8 | - |
| Shoveler, Northern | | | | | |
| A99 (29) | 37.9 | 58.6 | - | 3.5 | - |
| A00 (33) | 54.4 | 45.6 | - | - | - |
| Wigeon, American | | | | | |
| A99 (11) | 27.2 | 63.6 | - | 9.2 | - |
| A00 (80) | 30.0 | 60.0 | - | 10 | - |
| Teal, green-winged | | | | | |
| A99 (7) | - | 100.0 | - | - | - |
| A00 (90) | 30.0 | 70.0 | - | - | - |
| Teal, blue-winged | | | | | |
| A99 (29) | 41.4 | 59.6 | - | - | - |
| A00 (130) | 45.3 | 54.7 | - | - | - |

Table 2. Continued.

| Species, Season (n) | Habitat type | | | | |
|------------------------|--------------|--------------------|----------|----------------|-----------|
| | Wetland type | | | | |
| | | | | | |
| | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| Teal, cinnamon | | | | | |
| A99 (0) | - | - | - | - | - |
| A00 (1) | 100.0 | - | - | - | - |
| Redhead | | | | | |
| A99 (0) | - | - | - | - | - |
| A99 (2) | 100.0 | - | - | - | - |
| Canvasback | | | | | |
| A99 (0) | - | - | - | - | - |
| A00 (4) | 100.0 | - | - | - | - |
| Ruddy duck | | | | | |
| A99 (1) | 100.0 | - | - | - | - |
| A00 (0) | - | - | - | - | - |
| Coot, American | | | | | |
| A99 (11) | 100.0 | - | - | - | - |
| A00 (24) | 71.3 | 28.7 | - | - | - |
| Sora | | | | | |
| A99 (1) | - | - | - | 100.0 | - |
| A00 (20) | - | - | - | 100.0 | - |

Table 2. Continued.

| Species, Season (n) | Habitat type | | | | |
|------------------------|--------------|--------------------|----------|----------------|-----------|
| | Wetland type | | | | |
| | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| Rail, king | | | | | |
| A99 (4) | - | - | - | - | 100.0 |
| A00(8) | - | - | - | - | 100.0 |
| Plover, blk. bellied | | | | | |
| A99 (0) | - | - | - | - | - |
| A00 (1) | - | - | 100.0 | - | - |
| Plover, lesser golden | | | | | |
| A99 (0) | - | - | - | - | - |
| A00 (2) | - | - | - | 100.0 | - |
| Plover, snowy | | | | | |
| A99 (2) | - | - | 100.0 | - | - |
| A00 (0) | - | - | - | - | - |
| Plover, semipalmated | | | | | |
| A99 (5) | - | - | 100.0 | - | - |
| A00 (10) | - | - | 80.0 | 20.0 | - |
| Killdeer | | | | | |
| A99 (69) | - | - | 72.4 | 20.3 | 7.3 |
| A00 (90) | - | - | 60.0 | 30.0 | 10.0 |

Table 2. Continued.

| | Species, Season (n) | Habitat type | | | | |
|---|--------------------------|--------------|--------------------|----------|----------------|-----------|
| | | Wetland type | | | | |
| | | | | | | |
| | | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| 8 | Stilt, black-necked | | | | | |
| | A99 (7) | - | - | 100.0 | - | - |
| | A00 (25) | - | 24.0 | 40.0 | 36.0 | - |
| | Avocet, American | | | | | |
| | A99 (11) | - | 9.0 | 72.7 | 18.3 | - |
| | A00 (25) | - | 20.0 | 72.0 | 2.0 | - |
| | Yellowlegs, greater | | | | | |
| | A99 (8) | - | - | 50.0 | 50.0 | - |
| | A00 (36) | - | - | 64.1 | 35.9 | - |
| | Yellowlegs, lesser | | | | | |
| | A99 (0) | - | - | - | - | - |
| | A00 (2) | - | - | - | 100.0 | - |
| | Sandpiper, Baird's | | | | | |
| | A99 (9) | - | - | 77.7 | 22.3 | - |
| | A00 (10) | - | - | 70.0 | 30.0 | - |
| | Sandpiper, buff-breasted | | | | | |
| | A99 (5) | - | - | - | 100.0 | - |
| | A00 (11) | - | - | - | 100.0 | - |

Table 2. Continued.

| | Species, Season (n) | Habitat type | | | | |
|---|------------------------|--------------|--------------------|----------|----------------|-----------|
| | | Wetland type | | | | |
| | | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| | | | | | | |
| 8 | Sandpiper, least | | | | | |
| | A99 (15) | - | - | 80.0 | 20.0 | - |
| | A00 (24) | - | - | 66.9 | 33.1 | - |
| | Sandpiper, pectoral | | | | | |
| | A99 (7) | - | - | - | 100.0 | - |
| | A00 (12) | - | - | 50.0 | 50.0 | - |
| | Sandpiper, spotted | | | | | |
| | A99 (12) | - | - | 60.0 | 40.0 | - |
| | A00 (20) | - | - | 70.0 | 30.0 | - |
| | Sandpiper, solitary | | | | | |
| | A99 (0) | - | - | - | - | - |
| | A00 (3) | - | - | 66.6 | 33.4 | - |
| | Sandpiper, stilt | | | | | |
| | A99 (9) | - | - | 100.0 | - | - |
| | A00 (20) | - | - | 80.0 | 20.0 | - |
| | Sandpiper, upland | | | | | |
| | A99 (42) | - | - | 52.3 | 47.7 | - |
| | A00 (50) | - | - | 64.0 | 36.0 | - |

Table 2. Continued.

| Species, Season (n) | Habitat type | | | | |
|------------------------|--------------|--------------------|----------|----------------|-----------|
| | Wetland type | | | | |
| | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| Sandpiper, western | | | | | |
| A99 (7) | - | - | 100.0 | - | - |
| A00 (7) | - | - | 100.0 | - | - |
| Dowitcher, long-billed | | | | | |
| A99 (4) | - | - | - | 100.0 | - |
| A00 (8) | - | - | 50.0 | 50.0 | - |
| Snipe, common | | | | | |
| A99 (1) | - | | | | |
| A00 (8) | - | - | - | - | 100.0 |
| Crane, sandhill | | | | | |
| A99 (34) | 0 | 100.0 | - | - | - |
| A00 (40) | - | 100.0 | - | - | - |
| Harrier, Northern | | | | | |
| A99 (9) | - | 44.4 | - | - | 55.6 |
| A00 (10) | 60.0 | 20.0 | - | 10.0 | 10.0 |

Table 2. Completed.

| Species, Season (n) | Habitat type | | | | |
|------------------------|--------------|--------------------|----------|----------------|-----------|
| | Wetland type | | | | |
| | Open shallow | Vegetative shallow | Open mud | Vegetative mud | Old Field |
| | | | | | |
| Merlin | | | | | |
| A99 (2) | - | - | 100.0 | - | - |
| A00 (6) | 50.0 | 50.0 | - | - | - |
| Eagle, golden | | | | | |
| A99 (0) | - | - | - | - | - |
| A00 (1) | - | 100.0 | - | - | - |
| Falcon, Peregrine | | | | | |
| A99 (1) | - | - | 100.0 | - | - |
| A00 (2) | - | 50.0 | 50.0 | - | - |
| Hawk, red-tailed | | | | | |
| A99 (25) | 10.0 | 10.0 | - | - | 80.0 |
| A00 (30) | 20.0 | 20.0 | - | - | 60.0 |

VITA²

Owen Dewayne Miller

Candidate for the Degree of

Master of Science

Thesis: EFFICACY OF MOIST-SOIL MANAGEMENT TECHNIQUES ON
HACKBERRY FLAT WILDLIFE MANAGEMENT AREA: RESPONSE
OF VEGETATION, EXISTING SOIL SEED BANK, AND WATERFOWL

Major Field: Wildlife and Fisheries Ecology

Biographical:

Personal Data: Born in Stillwater, Oklahoma, November 23, 1961, the
son of Owen Dickerson Miller and Jean Loutrissia Miller and the
Grandson of Harley and Helen Miller.

Education: Received a Bachelor of Art Degree in Political Science with
main focus of study in Environmental and Wildlife policy from
Oklahoma State University, in December 1995; completed
requirements for Master of Science degree at Oklahoma State
University in August 2002.

Experience: Field Supervisor for Ducks Unlimited, Wildlife Research
Assistant at Oklahoma State University, Taught Wetland Science
at Oklahoma State University, Habitat Consultant, Wildlife
Outfitter and Guide, Arborist, and Farm and Ranch Hand.

Professional Organizations: The Wildlife Society, Wetland Science
Society