EFFECTS OF PRESCRIBED BURNING ON
CATTAIL (*TYPHA LATIFOLIA*)
DOMINATED MARSHES

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PREFACE

This study evaluated effects of prescribed burning and subsequent reflooding on cattail-dominated marshes in eastern Oklahoma. Potential changes in cattail shoot densities, use of the marshes by wintering and migrating waterfowl, aquatic invertebrate populations, and water chemistry parameters were monitored in 6 comparable marsh units at Sequoyah National Wildlife Refuge (1998-2001).

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CHAPTER I

CATTAIL CONTROL AND WATERFOWL USE FOLLOWING PRESCRIBED BURNING

Abstract

The efficacy of prescribed burning at reducing densities of common cattail (*Typha latifolia*) and increasing marsh use by waterfowl was studied in east-central Oklahoma in 1998-2001. Three of 6 comparable marsh units were burned in February 2000, following about 18 months of pre-burn data collection. The remaining 3 units were left as controls. Cattail shoot densities decreased significantly in all treatment units following prescribed burning. Shoot densities in control units varied but increased throughout the study. Pre-treatment waterfowl use was similar for burned and control units. Waterfowl use of experimental units increased and differed significantly from control units following treatment. Density of waterfowl increased in burned units and decreased in controls following treatment. Habitat use also changed; the proportion of surveyed birds using interior open-water areas increased while use of perimeter

open water declined throughout the study. Use of prescribed fire to create areas of open water in cattail-dominant marshes and increase use by waterfowl was effective. Additional research is required to determine long-term results and applicability to various climates.

Introduction

Common cattail (*Typha latifolia*) is an important aquatic emergent plant to wildlife associated with wetlands and surrounding habitats (Ball 1990, Sojda and Solberg 1993). Cattails are a food resource to mammals such as muskrats (*Ondatra zibethicus*) (Smith and Kadlec 1985), provide substrate for aquatic invertebrates, and produce cover for other species such as bobcats (*Felis rufus*), swamp rabbits (*Sylviligus aquaticus*), white-tailed deer (*Odocoileus virginanus*), and many marsh bird species. When the natural disturbance regimes of wetlands are altered, by water-level regulation or fire suppression, they often lose the dynamic aspects that shaped the vegetative composition and faunal diversity that are vital to the productivity of the system. In many of these cases, the result is domination by one or a few vegetation types such as cattails. Without periodic disturbances to regulate cattail populations, these hardy plants produce both by seed germination and vegetatively, effectively crowding and shading out other wetland emergent and submergent flora and reducing the amount of open-water habitat available in the wetland. The "hemi-marsh" condition (Weller and Spatcher 1965, Weller and Fredrickson 1972), or a 50:50 ratio of open water to vegetation in an interspersed pattern typically is considered the optimum for avian and mammalian use and productivity (Kaminski and Prince 1981, Sojda and Solberg 1993). In cattail-dominated marshes, natural disturbances must be mimicked to create and maintain community structure of the vegetation.

I investigated prescribed burning followed by reflooding to mimic disturbance. Its effectiveness at reducing cattail densities in previous studies and the low expense relative to other methods make it a viable option for most resource managers. Prescribed burning also is more widely accepted as a management technique because it mimics naturally occurring disturbances.

Monitoring the change in cattail shoot densities resulting from a prescribed burn and reflooding in 3 of 6 cattail dominant wetland units was one objective of this study. The second objective was to record differences in waterfowl use and habitat use of treated and control units before and after prescribed burning. I predicted that prescribed burning and reflooding would reduce cattail shoot densities in treated units and increase use of these units by wintering and migrating waterfowl.

Study Area

This research was conducted in 6 wetland units at Sequoyah National Wildlife Refuge (SNWR) in Sequoyah County in east-central Oklahoma (35.45° N, 94.97° W). SNWR encompasses the confluence of the Arkansas and Canadian rivers and contains about 8,400 ha of bottomland, impounded reservoir, riparian, agricultural, and semi-permanent palustrine wetland habitat types. The refuge was established in 1970 for the protection of habitat important to migratory avifauna. Climate of SNWR is temperate sub-humid, and annual high and low temperatures averaged 31.1 and 1.7 °C, respectively. Average annual precipitation was 1,209.8 mm during the study in 1997-2001.

A system of constructed wetlands built in 1982 to provide additional habitat for migrating and wintering waterfowl in an area of the refuge closed to recreational activities was the focus of this project. The vegetation contained in this series of wetlands was dominated by common cattail (>90% cover) and black willow (*Salix nigra*)(<10% cover). Other species occurring less frequently (<5% cover) were cottonwood (*Populus deltoides*), sycamore (*Platinus occidentalis*), spikerushes (*Elocharus spp.*), hardstem bulrush (*Scirpus acutus*), buttonbush (*Cephalanthus occidentalis*), smartweed (*Polygonum spp.*), and blackberry (*Rubrus spp.*).

Methods

The wetland units under study were selected from a series of impoundments created by the construction of a levee in 1982 (Figure 1). Three of the larger (4.4-5.1 ha) marshes (units 1-3) created by that project were bisected by a 2.44-meter-wide fire break using a bulldozer. Created units were of comparable size (range = 1.98-2.47 ha, mean = 2.22 ha) and vegetative composition (> 90% common cattail), and all had similar water-control capabilities (Figure 1).

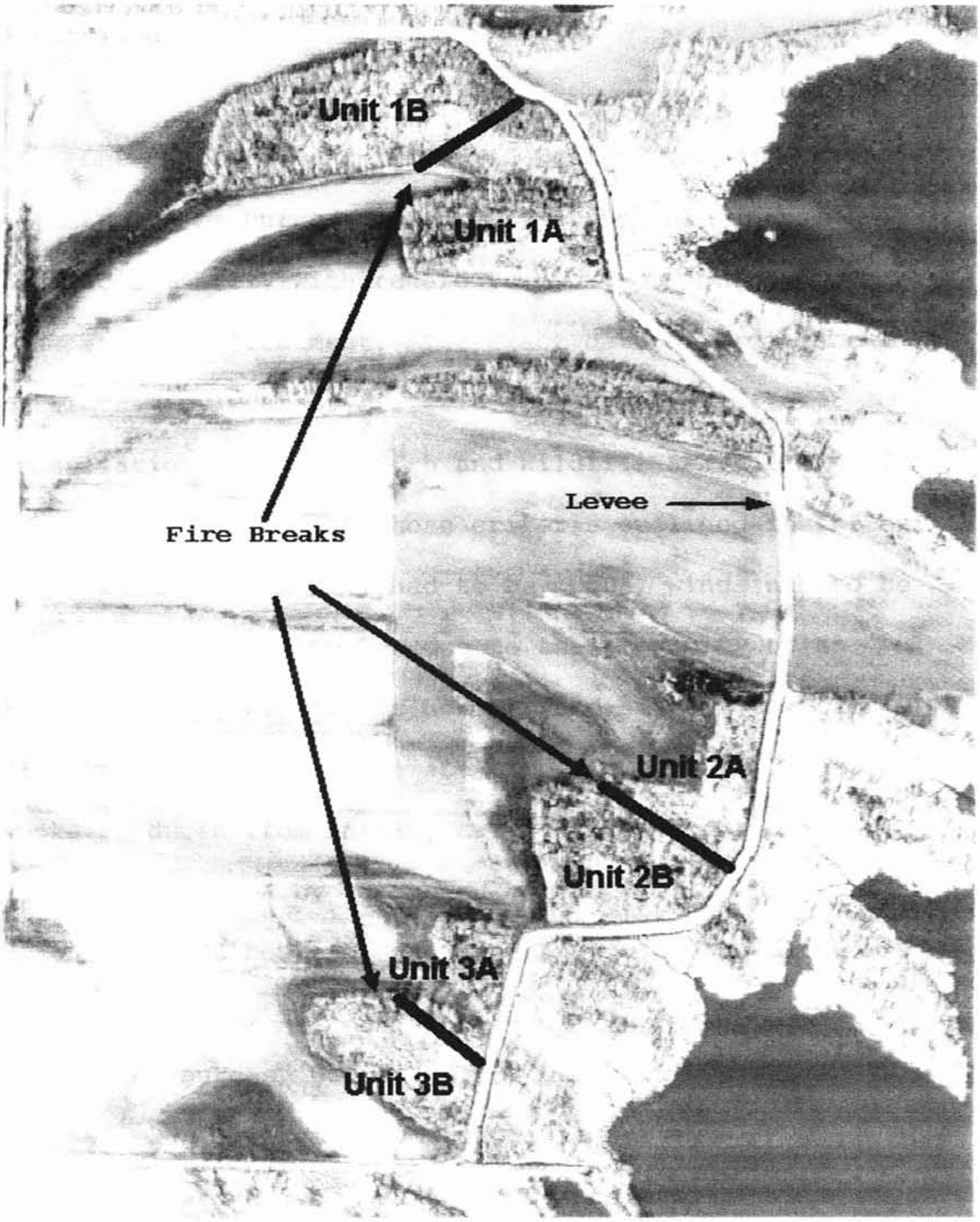

Figure 1. Aerial photo (1997) of study area depicting wetland unit and bulldozed fire break locations at Sequoyah National Wildlife Refuge, Oklahoma (1cm = 0.22km).

Prescribed Fire

One unit from each bisected wetland was randomly selected to be burned in February 2000. All units were managed similarly with regard to hydro-period during both pre- and post-treatment. The exact date of treatment was determined by weather criteria standards set after consultation with U.S. Fish and Wildlife Service (FWS) firefighters. To meet those criteria outlined in the burn plan, relative humidity had to be < 50%, winds had to be < 15 mph and not southerly (due to the proximity of an interstate highway to the north), and smoke dispersion conditions had to be moderate or better (so that the dark smoke produced from burning cattails would not obstruct visibility on nearby roads and communities). All fire weather and 60-hour forecasts were provided by Oklahoma State University's Division of Agricultural Sciences and Natural Resources, University of Oklahoma, Oklahoma Mesonet, and Oklahoma Climatological Survey (http://radar.metr.ou.edu/agwx/mos/mos.html).

Prescribed fires were lit with 11.36-liter drip torches (60 gasoline:40 diesel mixture) carried by qualified FWS firefighters. Strip fires were first lit at the head and flanks of the prevailing wind. The fire was then allowed to build and carry through the units. On occasion, fires failed to carry in light winds across beaver (*Castor Canadensis*) runs (channels of deeper open water created by repeated beaver movements). Large unburned patches of vegetation were ignited individually after the initial unit fire had lost intensity and was no longer spreading. All units were surrounded by agricultural fields or roads with little or no fuels present, making spotting and containment of the fires less problematic.

Immediately following prescribed burning, the wetland units were flooded to a depth of 45-75 cm by pumping water from a nearby reservoir across the levee. Pumping was conducted with 2 tractor driven 15.24-cm pumps. Maximum water levels were generally achieved following 72 hours of continuous pumping. This water was held in the units until April 15, 2000.

Vegetation

Within each unit, 10 randomly located permanent quadrats were established to monitor changes in vegetation. These 60 0.5-m^2 quadrats were sampled twice annually. The first sampling period was in February when cattails were senescent. The spring sampling period was in late May or early June and was designed to coincide with peak biomass of emergent vegetation.

Within each quadrat, vegetation was identified, and number of cattail shoots was counted. For the winter sampling period, only senescent cattail shoots from the previous growing season were counted. Rate of decomposition was sufficient to easily distinguish shoots and plant matter from previous seasons. At no time was detritus or live vegetation removed from units.

Waterfowl Use

Surveys to assess use by wintering and migrating waterfowl were initiated in January 1998. The surveys were conducted weekly by a single observer and continued through May. Waterfowl were surveyed weekly from October to May (1998-99, 1999-00, and 2000-01). That time frame encompassed the period in which migratory waterfowl were generally present at SNWR.

Waterfowl surveys began about one-half hour after sunrise and were conducted by traveling a service road bordering each unit. Unit size, shape, and road elevation allowed nearly full visibility of each unit. At the maximum view of the center of each unit, the surveyor stopped, exited the vehicle, and recorded birds present for 5 minutes. At each unit, the number of birds present, species, sex, and location were recorded. Unit proximity aided in preventing the survey of the same birds twice because flushed birds could be followed visually and usually exited the area.

Independent aerial and ground waterfowl surveys of the entire SNWR were conducted by refuge staff in October to March during the study. Those surveys were used in waterfowl density comparisons between the study area and the entire refuge.

Data Analysis

One-way analysis of variance was used to determine within-unit cattail shoot differences (pre- and post-treatment). Paired-*t* tests were used to analyze differences in cattail shoot density after treatment in each unit, shoot density differences between control and treated units (pooled data) prior to treatment, and within-season waterfowl use between control and treated units. Two-sample proportion tests were performed to determine differences in waterfowl locations between the 1999-00 and

2000-01 seasons (pre- and post-treatment). All analyses were conducted using STATISTIX 7 (Analytical Software Co., P.O. Box 12185, Tallahassee, FL, 1985-2000).

Results

Prescribed Fire

On 21 February 2000, 3 of the 6 units (1B, 2B, and 3B) were designated for treatment by prescribed fire. Unit 1B was ignited at about 1130 h, with a relative humidity of 41% and winds <5 mph and variable. Fires in units 2B and 3B were initiated at about 1230 and 1315 h with relative humidities of 31 and 29% on February 22 and 23, respectively. Wind speeds remained <5 mph, and direction was variable throughout the burning periods. During peak intensity, rate of spread (ROS) was often >2 chains/hour (1 chain = 20.12 meters), with flame-lengths of >7.5 m. The day following each fire, visual estimates of percent removal of standing vegetation were made for each unit. The estimated percentage of vegetative cover removed for the 3 experimental units was 85 (1B), 90 (2B), and 90 (3B).

Vegetation

Counts of cattail shoots across all 60 permanent quadrats ranged from 20 to 68 shoots/m^2 (Figure 2). Pre-treatment shoot densities in burn units did not differ between sampling periods (Unit 1B, $F_{2,27} = 0.71$, $P = 0.499$; Unit 2B, $F_{2,27} = 2.35$, $P = 0.115$; Unit 3B, $F_{2,27} = 1.04$, $P = 0.369$). Pre-treatment shoot densities in control units also did not differ among sampling periods (Unit 1A, $F_{2,27} = 0.25$, $P = 0.777$; Unit 2A, $F_{2,27} = 0.50$, $P = 0.614$; Unit 3A, $F_{2,27} = 0.84$, $P = 0.442$). No overall pre-treatment difference in shoot densities was found between experimental and control units ($t_2 = 0.66$, $P = 0.576$).

Shoot counts after the first growing season following treatment in burn units were lower than pre-treatment means (Unit 1B, $t_9 = 4.33$, $P = 0.002$; Unit 2B, $t_9 = 3.87$, $P = 0.004$; Unit 3B, $t_9 = 3.43$, $P = 0.008$). Mean shoot density declined from 34.0 to 28.8 shoots/m^2 in Unit 1B, 34.0 to 30.0 in Unit 2B, and 43.2 to 36.4 in Unit 3B. Shoot densities in control units between those same sampling periods did not differ (Unit 1A, $t_9 = -1.91$, $P = 0.089$; Unit 2A, $t_9 = -0.80$, $P = 0.443$; Unit 3A, $t_9 = -0.80$, $P = 0.443$). Mean shoot densities (shoots/m^2) for all control units a)

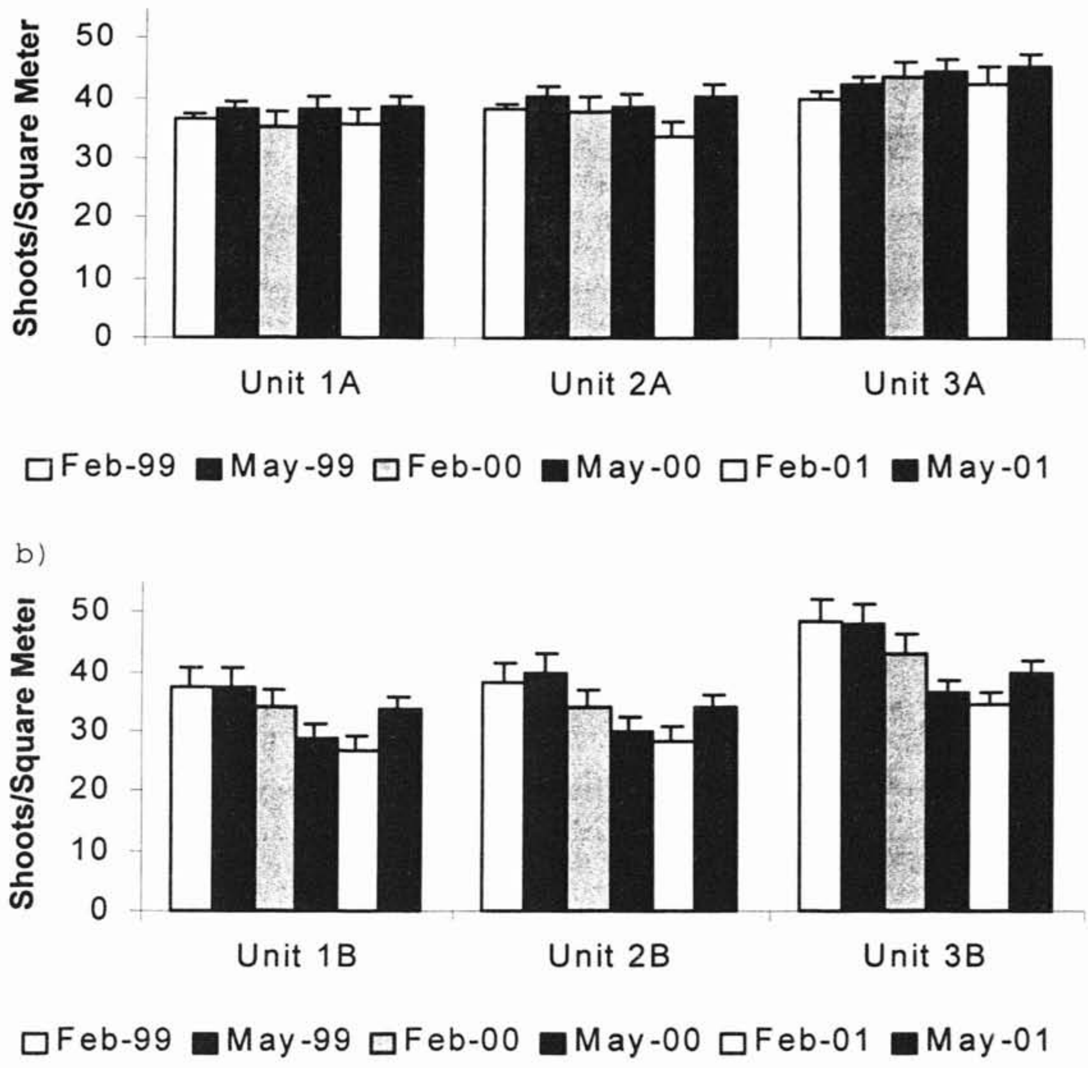

Figure 2. Mean shoot densities of cattails on (a) control units and (b) burned units at Sequoyah National Wildlife Refuge, OK. Prescribed burning was conducted following the February 2000 (Feb 00) sampling period.

increased between those two sampling periods (Unit 1A, 35.2 to 38.0; Unit 2A, 37.6 to 38.4; Unit 3A, 43.6 to 44.4).

Cattail shoot densities were variable among post-treatment samples and marginally significant in only control unit 2A ($F_{2,27} = 3.34$, $P = 0.051$). Post-treatment shoot densities for the remaining control units did not differ (Unit 1A, $F_{2,27} = 0.42$, $P = 0.660$; Unit 3A, $F_{2,27} = 0.49$, $P = 0.617$). Post-treatment shoot densities in burn units also did not differ (Unit 1B, $F_{2,27} = 2.86$, $P = 0.075$; Unit 2B, $F_{2,27} = 2.81$, $P = 0.078$; Unit 3B, $F_{2,27} = 1.12$, $P = 0.341$). Mean cattail densities in all units increased from treatment levels by 18 months post-treatment.

Hardstem bulrush and duckweed (*Lemna minor*) were the only other species encountered in quadrats, and hardstem bulrush was present only in one quadrat. Presence of duckweed appeared to be related to the distance of the quadrat from nearby beaver runs or other open-water areas and the density of the vegetation between them.

Waterfowl Use

A total of 697 birds was counted on waterfowl surveys from January 1998 to May 2001 (Figure 3). Eight species accounted for 97.8% of all birds surveyed. Mallards (*Anas* *platyrhynchos*) were most numerous comprising 58.5% of the sample population. The other species were gadwall (*Anas strepera*) at 10.0%, American coot at 7.3%, blue-winged teal (*Anas discors*) at 7.0%, wood duck (*Aix sponsa*) at 6.2%, green-winged teal (*Anas crecca*) at 5.4%, northern shoveler (*Anas clypeata*) at 3.3%, and pied-billed grebe (*Podilymbus podiceps*) at 1.56%.

Waterfowl numbers did not differ between control and experimental units pre-treatment in 1997-98 ($t_2 = -0.78$, $P = 0.520$), 1998-99 ($t_2 = -0.31$, $P = 0.787$), or 1999-00 ($t_2 = 1.78$, $P = 0.218$). Post-treatment (2000-01) waterfowl numbers were higher on burn units than control units ($t_2 = 5.70$, $P = 0.029$).

Differences occurred in waterfowl density between the study area and the entire refuge (aerial and ground waterfowl surveys) (Table 1). In all 4 seasons, duck density in the study area was greater than in the entire refuge. Mean density of waterfowl in burned units increased each season during the study, while control unit density increased from 1997-98 to 1998-99 and then decreased during the following 2 seasons.

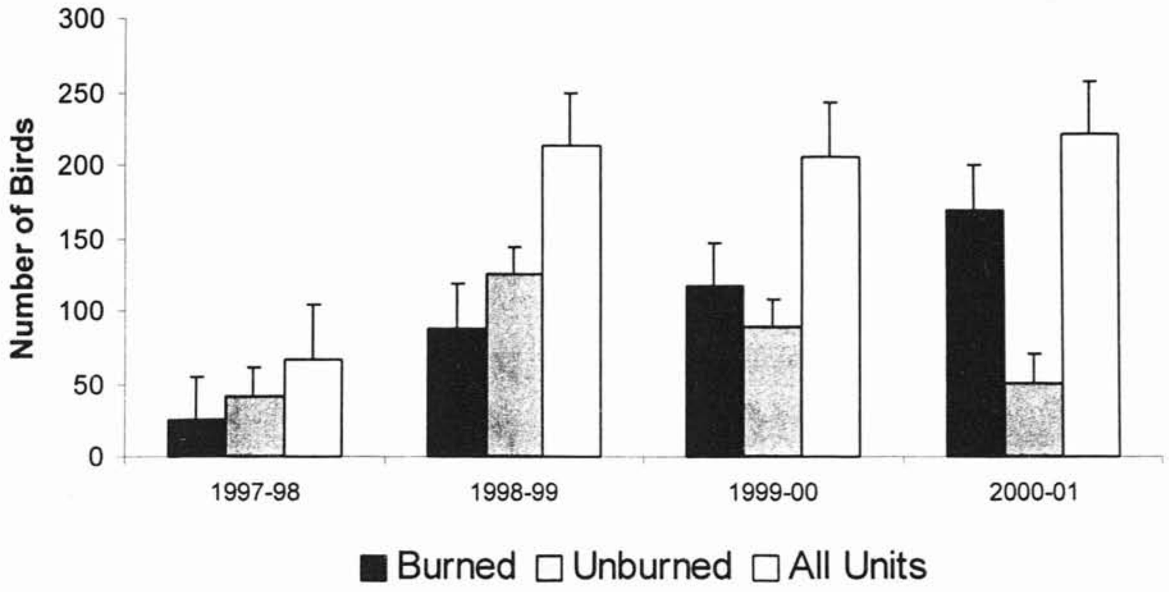

Figure 3. Annual number of waterfowl for experimental (burned), control (unburned), and total (all units) in (1997-2001). Prescribed burning was conducted in February 2000.

Table 1. Mean density (birds/ha) of waterfowl surveyed at Sequoyah National Wildlife Refuge, Oklahoma, from October to May, 1997-2001.

	Season surveyed											
	1997-98			1998-99			1999-00			2000-01		
	$\bar{X}$	SD	*n*	$\bar{X}$	SD	*n*	$\bar{X}$	SD	*n*	$\bar{X}$	SD	*n*
Entire Refuge	1.0	0.3	17	1.2	0.6	20	3.7	1.3	18	2.1	0.0	23
Study Area	4.8	0.1	24	15.3	0.8	32	14.1	1.2	31	15.9	0.9	32
Burned Units	3.6	0.7	24	12.7	0.9	32	16.8	1.2	31	24.5	1.2	32
Control Units	6.0	0.5	24	18.0	0.7	32	11.4	1.3	31	7.3	0.8	32

Surveyed waterfowl locations within units also changed during the study (Table 2). Overall, 49.8% of the birds encountered were observed in open-water pockets within the unit's vegetation. Waterfowl located in open water at the unit's edge accounted for 46.6% of the birds surveyed, and those flying over the unit represented only 3.6% of surveyed birds. Proportions of birds located in open water within a unit and in open water at the edge of unit differed between pre- ($Z = -4.51$, $P < 0.0001$) and post-treatment ($Z = 4.19$, $P < 0.0001$). The proportion of flyovers did not differ between those 2 seasons ($Z = 0.74$, $P = 0.460$).

Discussion

Many cattail control techniques (herbicide, mechanical, hydro-period manipulation, and prescribed burning) have been effective in creating open water in marshes and allowing colonization by other aquatic vegetation. Use of herbicide in homogenous cattail stands to reduce plant densities and create open-water habitat has been successful (Solberg and Higgins 1993, Linz et al. 1996). Summer application of glyphosate herbicides disrupt metabolic pathways in cattails and are most effective when

Table 2. Percentage of waterfowl observed (all units) in various locations at Sequoyah National Wildlife Refuge, 1997-2001.

	Season Surveyed			
Location	1997-98	1998-99	1999-00	2000-01
Flying	1	2	6	4
Open water, unit edge	86	55	47	27
Open water, unit interior	13	43	47	69

applied with water-level manipulation (Sojda and Solberg 1993).

Mechanical control techniques (mowing, cutting, crushing, and disking) also can be effective (Sojda and Solberg 1993). Cutting stems below the water surface over frozen substrate where subsequent spring rains flood the marsh, effectively cutting off the supply of oxygen to the plants, creates open-water habitat in cattail marshes (Murkin and Ward 1980, Murkin et al. 1982). Ball (1990) found that mowing over frozen substrate in Ontario, Canada, reduced cattail shoot densities by 89% and that applying the same technique the following year resulted in a 99% reduction in cattail shoots.

Moist-soil vegetation also can be influenced by the manipulation of hydro-period. Kadlec (1962) noted changes in vegetation resulting from a draw-down. Cattails dominated suitable soils following a draw-down and reflooding in Minnesota, but just 3 years after reflooding, cattail populations were greatly reduced (Harris and Marshall 1963). A study of draw-down date and reflood depth in Manitoba, Canada (Merendino and Smith 1991) showed similar results. Cattails become well established following the draw-down and decrease with time following reflooding.

Weller and Fredrickson (1972) stated that constant changes in marsh vegetation were the result of water fluctuations, either natural or manipulated. By manipulating the draw-down at Rush Lake, Iowa, they were able to record marsh vegetation going through a cycle from open-water dominant to densely vegetated following draw-down to "hemi-marsh" and back to open-water. These vegetative changes, especially for cattails, were assisted by muskrat activity and herbivory.

Sojda and Solberg (1993) also documented the relationship between muskrat and cattail populations; populations of 10 muskrats/acre can nearly eliminate cattails if water levels are sufficiently high in spring. Grazing by muskrats (*Ondatra zibethicus*), waterfowl, and American coots (*Fulica americana*) was shown to be a significant factor in reduction of standing crop of cattail (Smith and Kadlec 1985). The role of mammals in influencing plant diversity in a cattail marsh was investigated by Hewitt and Miyanishi (1997); mimicking levels of trampling and herbivory, they found indications that animals create opportunities for other plants by disturbing cattail marshes.

Another widely accepted method for altering vegetative communities is prescribed burning. Recently, prescribed burning has become the tool of choice for many managers because of its acceptance by the public and the low cost relative to other management practices (Kirby et al. 1988). Like most other control techniques for cattail, burning has a greater effect when used with another control method such as water-level manipulation or mowing (Sojda and Solberg 1993). Smith and Kadlec (1985) analyzed effects of burning and grazing on marsh vegetation and found that burning reduced standing crop of cattail relative to controls. Areas that were both burned and grazed produced the greatest reduction in cattail biomass. In Ontario, Canada, Ball (1990) found that prescribed burning followed by reflooding resulted in a 70% reduction in cattail shoot density relative to controls.

In my study, prescribed burning and reflooding was effective at reducing shoot density of common cattail. Reducing cattail densities by 50% and creating the "hemi-marsh" condition, allowing increased germination of other emergent and submergent vegetation, are long-term management goals for this series of wetlands at SNWR. It is possible that with annual treatments, this management technique can achieve those results. After a 50:50 interspersion of vegetated and open-water habitat is achieved, fire frequency may then be decreased and used only to maintain the "hemi-marsh" condition. Effects of fire frequency and timing along with effects on plant diversity and germination are areas of evaluation that require additional long-term research.

Waterfowl and Marsh Vegetation

Waterfowl and other marsh bird species respond to vegetation alteration (Kadlec 1962, Weller and Fredrickson 1972, Kaminski and Prince 1981, Murkin et al. 1982, Solberg and Higgins 1993, Linz et al. 1996), whether by fire, draw-down, herbicide, mechanical manipulation, or any combination of these techniques.

The creation of an interspersion of vegetation and open water by glyphosate herbicide resulted in increased dabbling duck (*Anatini* and *Cairinini*) numbers (Linz et al. 1996). Solberg and Higgins (1993) found that wetlands treated with herbicide had overall greater breeding pair densities than both cattail and open-water controls. When creating the "hemi-marsh", or 50:50 cover-to-open-water ratio, Kaminski and Prince (1981) and Murkin et al. (1982) found that the highest density and diversity of waterfowl pairs were recorded on the "hemi-marsh" plots.

Prescribed fire and the resulting vegetation changes at SNWR increased use of experimental wetlands by waterfowl. Waterfowl use of control and burned units was similar pre-treatment, but post-treatment use showed an increase in burned units and a decrease in controls.

Waterfowl density showed a similar trend, increasing on burned units and decreasing on unburned units. Not only did more ducks use burned units, but their locations shifted from perimeter open-water areas to open-water within the units. This suggests that cattail densities were decreased sufficiently to provide adequate open-water within units for foraging and resting.

Conclusion

Many control techniques for reducing cattail populations have been studied. The bulk of this research has been conducted in the northern prairie region of the United States and southern Canada (Ball 1990, Linz et al. 1996, Murkin et al 1982, Murkin and Ward 1980, and Solberg and Higgins 1993) where there is a shorter growing season than in more southern climates. Monotypic cattail stands also are a concern in the southern parts of the United States. Under the right conditions, cattails have been shown to encroach in areas at rates of up to 800 ha/year (Newman et al. 1998).

During my study, cattail shoot densities were decreased, and waterfowl use was increased by the use of prescribed fire. Shoot densities were not decreased sufficiently to create the 50:50 ratio of open water to emergent vegetation considered optimum for wetland productivity. In this case, one year of prescribed burning could not achieve those results. My recommendation to SNWR managers is that these areas be burned annually until cattail shoot density is sufficiently decreased. At that time fire frequency should be reevaluated. Managers also should constantly evaluate the use, cost, and effectiveness of prescribed burning and other cattail control techniques.

Cattail control is important in maintaining diverse assemblages of marsh vegetation, and the faunal communities that depend on these areas for cover, foraging and nesting habitat. Control techniques that have proven useful need to be evaluated under different climatic conditions.

Acknowledgments

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CHAPTER II

AQUATIC INVERTEBRATE POPULATIONS AND WATER CHEMISTRY CHANGES IN CATTAIL DOMINATED MARSHES FOLLOWING PRESCRIBED BURNING

Abstract

Effects of spring prescribed burning on aquatic invertebrate communities and water chemistry in cattail (*Typha latifolia*)-dominated marshes was studied in east-central Oklahoma in 1998-2001. Three of 6 comparable marsh units were burned in February 2000, following about 18 months of pre-burn data collection. The remaining 3 units were left as controls. Invertebrate abundances were significantly higher in burned units versus controls after spring prescribed burning. In addition, mean differences (increases) in familial diversity were greater in burned units versus controls. Of the water chemistry parameters measured (temperature, pH, turbidity, dissolved oxygen, nitrate-nitrogen, and orthophosphates), none were significantly altered by prescribed burning. In this case, use of spring prescribed fire and reflooding increased the total number and familial diversity of sampled aquatic invertebrates. Although no changes were detected in water

chemistry, further investigations on the effects of fire on water quality in wetlands are recommended.

Introduction

Common cattail (*Typha latifolia*) is an important aquatic emergent plant to wildlife associated with wetlands and surrounding habitats (Ball 1990, Sojda and Solberg 1993). Cattails are a food resource to mammals such as muskrats (*Ondatra zibethicus*) (Smith and Kadlec 1985), provide substrate for aquatic invertebrates, and produce cover for other species such as bobcats (*Felis rufus*), swamp rabbits (*Sylviligus aquaticus*), white-tailed deer (*Odocoileus virginanus*), and many marsh bird species. When the natural disturbance regimes of wetlands are altered, by water-level regulation or fire suppression, they often lose the dynamic aspects that shaped the vegetative composition and faunal diversity that are vital to the productivity of the system. In many of these cases, the result is domination by one or a few vegetation types such as cattails. Without periodic disturbances to regulate cattail populations, these hardy plants produce both by seed germination and vegetatively, effectively crowding and shading out other wetland emergent and submergent flora and reducing the amount of open-water habitat available in the wetland. The "hemi-marsh" condition (Weller and Spatcher 1965, Weller and Fredrickson 1974), or a 50:50 ratio of open water to vegetation in an interspersed pattern typically is considered the optimum for avian and mammalian use and productivity (Kaminski and Prince 1981, Sojda and Solberg 1993). In cattail-dominated marshes, natural disturbances must be mimicked to create and maintain natural community structure of the vegetation.

I investigated prescribed burning followed by reflooding to mimic disturbance. Its effectiveness at reducing cattail densities in previous studies and the low expense relative to other methods make it a viable option for most resource managers. Prescribed burning also is more widely accepted as a management technique because it mimics naturally occurring disturbances.

Assessing aquatic macroinvertebrate assemblages in cattail-dominated marshes and their response to prescribed burning was one objective of this study. A second objective was to examine effects of prescribed burning on general water chemistry. Nutrient levels in freshwater wetlands vary seasonally, annually, and by site (Bookhout 1977, Van Der Valk 1987). Fire releases nutrients tied-up in vegetation and may increase turbidity temporarily. To provide a general view of the limnological affects of prescribed burning, the parameters monitored in this study included dissolved oxygen, pH, nitrate-nitrogen, orthophosphates, and water temperature.

In this study, I examined the relationships between aquatic macroinvertebrates and general water chemistry in cattail-dominated marshes experimentally manipulated by prescribed burning. I predicted that prescribed burning would alter aquatic macroinvertebrate assemblages and water chemistry.

Study Area

This research was conducted in 6 wetland units at Sequoyah National Wildlife Refuge (SNWR) in Sequoyah County in east-central Oklahoma (35.45° N, 94.97° W). SNWR encompasses the confluence of the Arkansas and Canadian rivers and contains about 8,400 ha of bottomland, impounded reservoir, riparian, agricultural, and semi-permanent palustrine wetland habitat types. The refuge was established in 1970 for the protection of habitat important to migratory avifauna. Climate of SNWR is temperate sub-humid, and annual high and low temperatures averaged 31.1

and 1.7 °C, respectively. Average annual precipitation was 1,209.8 mm during the study in 1997-2001.

A system of constructed wetlands built in 1982 to provide additional habitat for migrating and wintering waterfowl in an area of the refuge closed to recreational activities was the focus of this project. The vegetation contained in this series of wetlands was dominated by common cattail (>90% cover) and black willow (*Salix nigra*)(<10% cover). Other species occurring less frequently (<5% cover) were cottonwood (*Populus deltoides*), sycamore (*Platinus occidentalis*), spikerushes (*Elocharus spp.*), hardstem bulrush (*Scirpus acutus*), buttonbush (*Cephalanthus occidentalis*), smartweed (*Polygonum spp.*), and blackberry (*Rubrus spp.*).

Methods

The 6 individual wetland units under study were selected from a series of impoundments created by the construction of a levee in 1982. Three of the larger (4.4-5.1 ha) marshes created by this project were bisected by creating a 2.44-meter wide fire break through the center of each with a bulldozer. Created units were of comparable size (range = 1.98-2.47 ha, mean = 2.22 ha), vegetative composition (> 90 % common cattail), and all had similar water control capabilities (Figure 1).

Prescribed Burning

One unit from each bisected wetland was randomly selected to be burned in February 2000. All units were managed similarly with regard to hydro-period during both pre- and post-treatment. The exact date of treatment was determined by weather criteria standards set after consultation with U.S. Fish and Wildlife Service (FWS) firefighters. To meet those criteria outlined in the burn plan, relative humidity had to be < 50%, winds had to be < 15 mph and not southerly (due to the proximity of an interstate highway to the north), and smoke dispersion conditions had to be moderate or better (so that the dark smoke produced from burning cattails would not cause problems for nearby roads and communities). All fire weather and 60-hour forecasts were provided by Oklahoma State University's Division of Agricultural Sciences and Natural Resources, University of Oklahoma, Oklahoma Mesonet, and Oklahoma Climatological Survey (http://radar.metr.ou.edu/agwx/mos/mos.html).

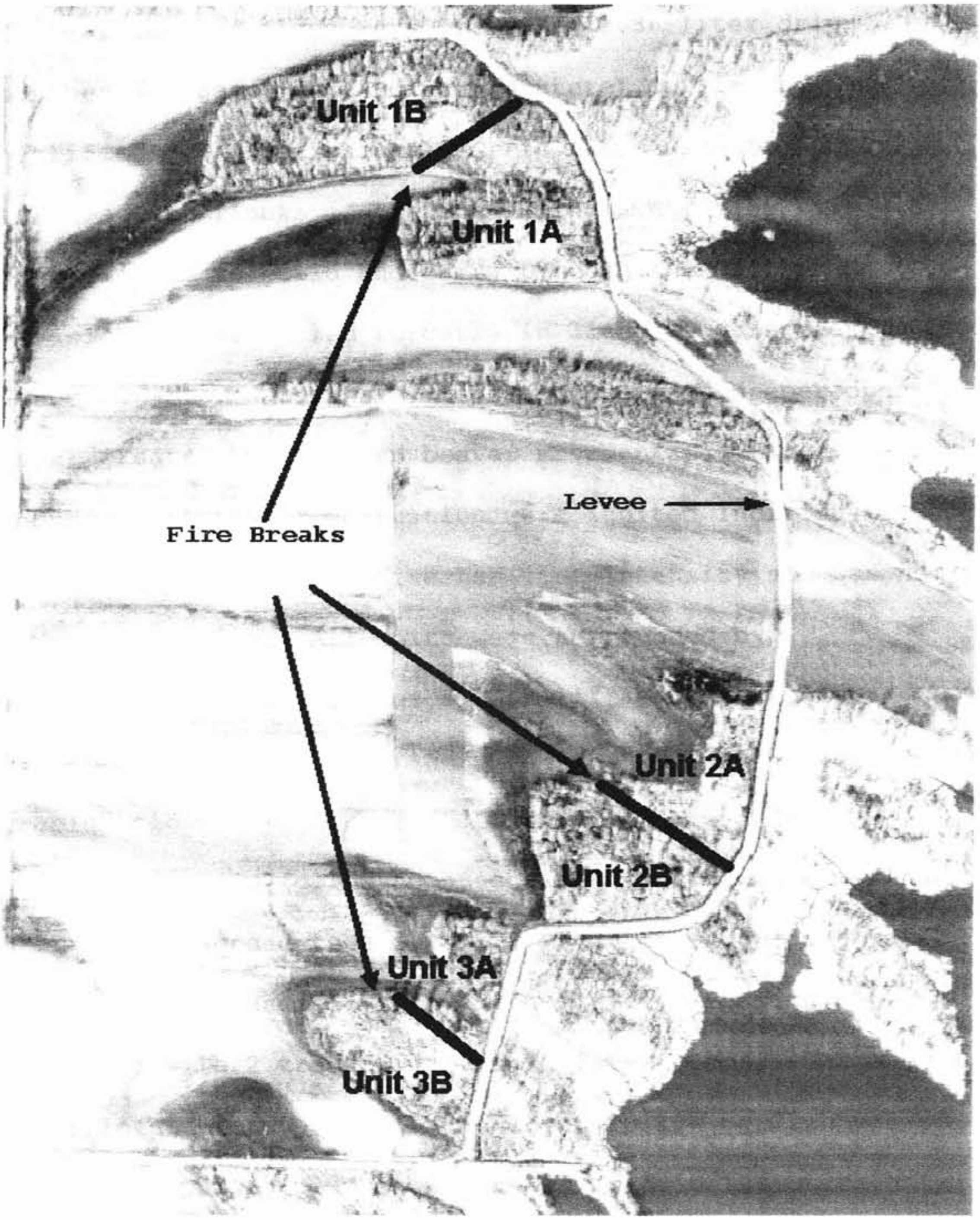

Figure 1. Aerial photo (1997) of study area depicting wetland unit and bulldozed fire break locations at Sequoyah National Wildlife Refuge, Oklahoma (1cm = 0.22km).

Prescribed fires were lit with 11.36-liter drip torches (60 gasoline:40 diesel mixture) carried by qualified FWS firefighters. Strip fires were first lit at the head and flanks of the prevailing wind. The fire was then allowed to build and carry through the units. On occasion, fires failed to carry in light winds across beaver (*Castor Canadensis*) runs (channels of deeper open water created by repeated beaver movements). Large unburned patches of vegetation were ignited individually after the initial unit fire had lost intensity and was no longer spreading. All units were surrounded by agricultural fields or roads with little or no fuels present, making spotting and containment of the fires less problematic.

Immediately following prescribed burning, the wetland units were flooded to a depth of 45-75 cm by pumping water from a nearby reservoir across the levee. Pumping was conducted with 2 tractor driven 15.24-cm pumps. Maximum water levels were generally achieved following 72 hours of continuous pumping. This water was held in the units until April 15, 2000.

Aquatic Invertebrates

Sampling for aquatic invertebrates was conducted twice annually (early spring and fall). Test sampling by sweep-netting, benthic core analysis, and artificial substrate (multi-plate) samplers was used to determine feasibility and efficiency of sampling methods in dense cattail vegetation. Sample "catch" rates were highest and analysis time shortest for multi-plate samplers.

Two multi-plate or "Hester-Dendy" samplers (surface area = 0.13-m^2 per sampler) were placed in random locations within each unit, and all units were sampled simultaneously. The samplers were left in place for 30-40 days before being retrieved and analyzed. Upon collection, invertebrates were placed in labeled containers and identified to family by microscope (3X) according to Thorp and Covich (1991). Samples that were not classified immediately were preserved in 100% ethyl alcohol.

Three nonparametric diversity measures were calculated for comparative purposes because they assume no statistical distribution. The 3 indices chosen were Brillouin's, Shannon-Weiner, and Simpson's.

Water Chemistry

To detect changes in water chemistry, 6 parameters were monitored twice annually (spring and fall). Water samples were taken from 3 random locations established within each unit. Water surface temperature (°C), turbidity (Jackson turbidity units (JTU's)), pH, dissolved oxygen (mg/L), nitrate-nitrogen (mg/L), and phosphate (orthophosphate phosphorus) in mg/L measurements were taken at each site during sampling.

Water surface temperature was taken with a digital thermometer (Taylor Precision Products, Oak Brook, IL). Turbidity was measured in Jackson turbidity units (JTU's) by comparison with standardized turbidity samples. Solution hydrogen ion activity or pH was assessed by use of an octet comparator (LaMotte Company, Chestertown, MD). The azide modification of the Winkler method (Lind 1985) was used to measure dissolved oxygen content in samples. Measurements of nitrate-nitrogen and soluble reactive phosphorus (orthophosphate phosphorus) were determined by comparing prepared samples with color standards in octet comparators (LaMotte Company, Chestertown, MD).

Whenever possible, all water chemistry analyses were performed on site. On occasion, water samples were transported on ice to a nearby facility for later evaluation.

Data Analysis

One-way analysis of variance (ANOVA) was used to determine between-unit differences in all water chemistry parameters. Paired-*t* tests were chosen to analyze (1) invertebrate sample differences between pre- and post-treatment samples within each unit and (2) water chemistry differences between control and treated units (pooled data). ANOVA's and paired-*t* analyses were conducted using STATISTIX 7 (Analytical Software Co., P.O. Box 12185, Tallahassee, FL., 1985-2000). Invertebrate diversity indices, maximum diversity, and evenness were calculated using the software program DIVERS as outlined in Krebs (1989).

Results

Prescribed Burning

On 21 February 2000, 3 of the 6 units (1B, 2B, and 3B) were designated for treatment by prescribed fire. Unit 1B was ignited at about 1130 h, with a relative humidity of 41% and winds <5 mph and variable. Fires in units 2B and 3B were initiated at about 1230 and 1315 h with relative humidities of 31 and 29% on February 22 and 23, respectively. Wind speeds remained <5 mph, and direction was variable throughout the burning periods. During peak intensity, rate of spread (ROS) was often >2 chains/hour (1 chain = 20.12 meters), with flame-lengths of >7.5 m. The day following each fire, visual estimates of percent removal of standing vegetation were made for each unit. The estimated percentage of vegetative cover removed for the 3 experimental units was 85 (1B), 90 (2B), and 90 (3B).

Aquatic Invertebrates

Overall, 1,428 individual aquatic invertebrates representing 17 families were sampled and identified during the study. Three families (Asellidae (order Isopoda), Culicidae (order Diptera, and Hyalellidae (order Amphipoda)) comprised nearly one-half of all invertebrates sampled (19.7, 14.8, and 14.3%, respectively).

Total numbers of invertebrates increased in all burned units following treatment (Figure 1). Pre- and post-burn invertebrate samples differed in all treated units (Unit

1B, $t_{16} = 4.81$, $P = 0.0002$; Unit 2B, $t_{16} = 3.97$, $P = 0.001$; Unit 3B, $t_{16} = 3.56$, $P = 0.003$). Families showing notable increases after treatment (pooled data for all burned units) were Calopterygidae (Odonata) (+276.5%), Chironomidae (Diptera) (+1,150.0%), Dixidae (Diptera) (+266.7%), Dytiscidae (Coleoptera) (+400.0%), Gomphidae (Odonata) (+271.4%), Nepidae (Heteroptera) (+850.0%), and Tricladidae (Macroturbellarians) (+950.0%).

Conversely, invertebrate samples in control units did not differ pre- and post-treatment (Unit 1A, $t_{16} = -1.23$, $P = 0.236$; Unit 2A, $t_{16} = -0.730$, $P = 0.476$; Unit 3A, $t_{16} = -1.85$, $P = 0.083$), although the number of individuals sampled per family in control units was generally lower following treatment. Exceptions were Physidae (Gastropoda), Ephemerellidae (Ephemeroptera), and Tricladidae, in which sampled individuals increased in control units (pooled data for all controls).

For comparative purposes, diversity calculations, maximum diversity, and evenness were assessed with 3 indices pre- and post-treatment. Mean differences between controls and burned units were 0.175 and 0.472 for Brillouin's, 0.247 and 0.339 for Shannon-Weiner, and 0.043 and 0.024 for Simpson's (Table 1).

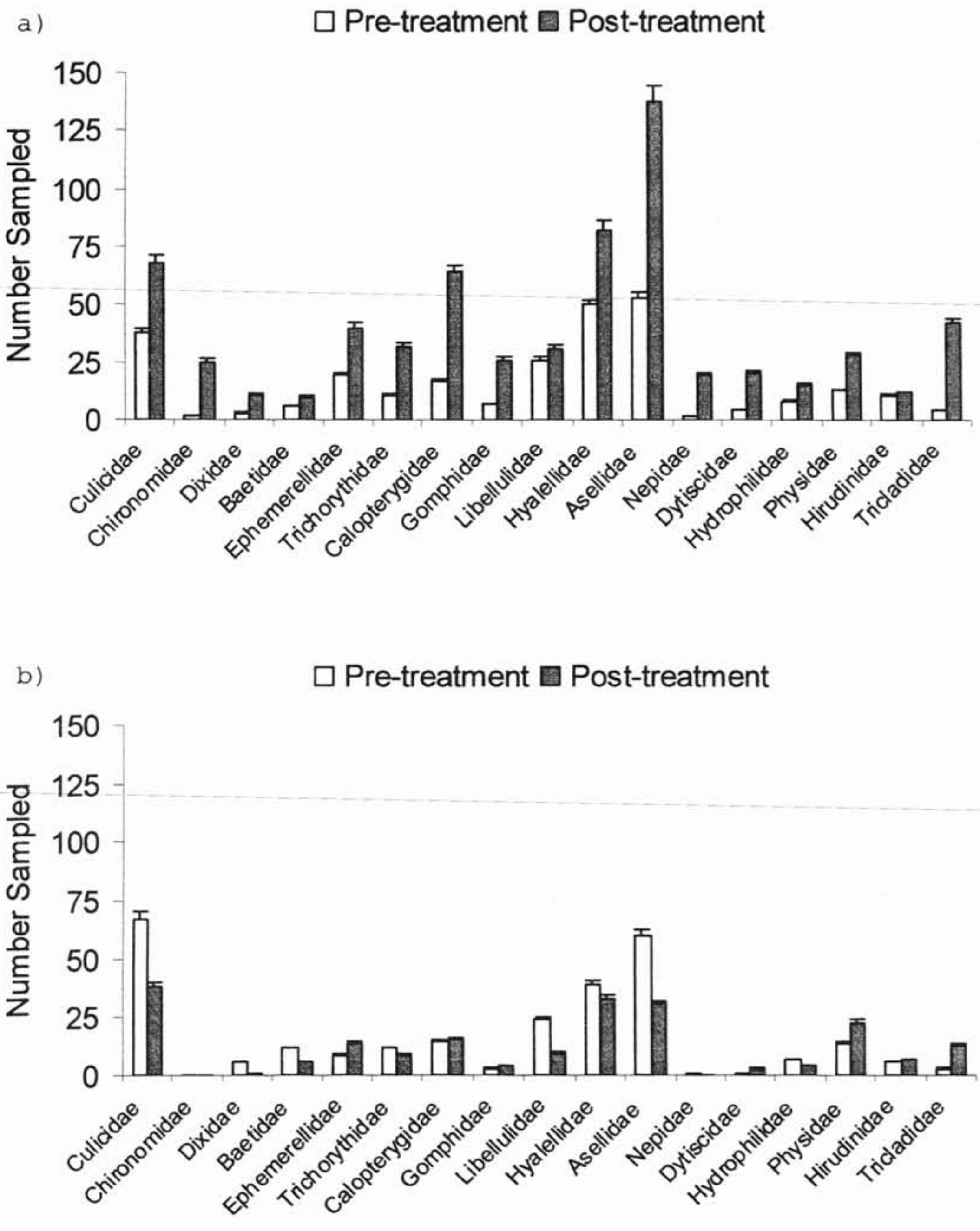

Figure 2. Numbers of aquatic invertebrates (1.56-m^2 area sampled), pre- and post-treatment in (a) burned units and (b) control units at Sequoyah National Wildlife Refuge, Oklahoma.

Table 1. Pre- and post-treatment diversity indices of aquatic invertebrates sampled from treated units (1B, 2B, and 3B) and control units (1A, 2A, and 3A) at Sequoyah National Wildlife Refuge, Oklahoma, 1998-2001.

	Pre-treatment, 1998-99						Post-treatment, 2000-01					
Indice	1A	2A	3A	1B	2B	3B	1A	2A	3A	1B	2B	3B
Brillouin's[1]	2.530	2.756	2.840	2.862	3.060	2.961	2.788	3.062	2.802	3.467	3.403	3.428
Maximum	3.188	3.266	3.421	3.481	3.596	3.380	3.801	3.224	3.161	3.801	3.780	3.862
Evenness	0.794	0.844	0.830	0.822	0.851	0.876	0.912	0.950	0.886	0.912	0.900	0.888
Shannon-Wiener[1]	2.762	3.027	3.168	3.139	3.405	3.337	3.110	3.405	3.182	3.654	3.608	3.636
Maximum	3.459	3.585	3.807	3.807	4.000	3.807	4.000	3.585	3.585	4.000	4.000	4.087
Evenness	0.798	0.844	0.832	0.824	0.851	0.877	0.914	0.950	0.888	0.914	0.902	0.890
Simpson's[2]	0.808	0.865	0.865	0.854	0.890	0.889	0.878	0.907	0.882	0.905	0.902	0.898
Maximum	0.918	0.926	0.940	0.937	0.947	0.941	0.914	0.928	0.931	0.941	0.942	0.945
Evenness	0.880	0.933	0.921	0.911	0.939	0.945	0.962	0.977	0.947	0.962	0.958	0.950

[1]Brillouin's index (H) and Shannon-Wiener (H') calculations expressed as bits per individual.

[2]Simpson's index (1-D) calculations expressed as the probability of picking two individuals of the same species.

Water Chemistry

None of the water-chemistry parameters changed following prescribed burning ($P > 0.05$). Water surface temperature ranged from 9.55 to 13.03 °C in spring samples and from 17.00 to 24.10 °C in samples taken in the fall. No differences in water chemistry occurred among units (P = 1.000) or between burned and unburned units through all sampling periods ($t_5 = 1.33$, $P = 0.242$).

Turbidity measurements between units had insufficient variability for statistical analysis. Fall turbidity was 14.00 JTU's (1998,1999) during pre-treatment and 8.00 JTU's (2000) post-treatment. Pre-treatment spring turbidity was 11.00 (1999) and post-treatment recordings were 14.00 (2000) and 10.00 JTU's (2001).

As with turbidity, pH varied little between units ($F_{5,30} = 0.05$, $P = 0.999$). Fall pH readings were 0.1-0.6 higher than spring samples. No differences were found between burned and unburned units ($t_5 = 0.54$, $P = 0.611$).

Dissolved oxygen in samples ranged from 9.30 to 9.87 mg/L in fall and 10.47 to 11.10 mg/L in spring; differences among units were insignificant ($P = 1.000$). Likewise, no significant difference was found between burned and unburned units ($T_5 = 0.00$, $P = 1.000$).

Levels of nitrate-nitrogen and orthophosphate were consistent among units in all sampling periods. Fall nitrate-nitrogen levels were 0.50 mg/L (1998, 1999) and 0.25 mg/L (2000). Levels were greater in spring than fall and increased following treatment (1.00 mg/L in 1999, 1.50 mg/L in 2000), then decreased in 2001 (0.75 mg/L). Orthophosphate levels remained < 1.00 mg/L during the entire study.

Discussion

Invertebrate populations are an important food source for waterfowl and have been correlated positively with duck use on marshes (Joyner 1980, Murkin et al. 1982). Of the selected bodies of water in Joyner's study (1980), those with the greatest abundances and number of taxa also had the highest numbers for dabbling ducks. Murkin and Kadlec (1986) suggested that invertebrate densities affect breeding waterfowl densities in Manitoba, Canada. Invertebrates are of such importance to waterfowl that invertebrate management by inoculation from brood stock ponds has been reviewed to increase carrying capacity of the marsh by waterfowl (Euliss and Grodhaus 1987).

Alteration of marsh vegetation also has been shown to affect invertebrate populations (Kadlec 1962, Voigts 1976, Kaminski and Prince, 1981a, 1981b, Murkin et al. 1982, Neckles et al. 1990, Solberg and Higgins 1993, and Jeffries 1994). Abundance of aquatic invertebrates in artificially (herbicide) manipulated cattail marshes was greater in treated versus controls in South Dakota (Solberg and Higgins 1993). Our results support these findings in that invertebrate densities were greater and familial diversity increased in units treated by fire to reduce vegetation (cattail) densities. Kaminski and Prince (1981a, 1981b) obtained varied results monitoring invertebrate abundance and biomass in a mechanically manipulated marsh. Levels varied more in response to treatment method (mowing, rototilling) than to cover-water ratio. In a similar study, Murkin et al. (1982) found that invertebrate populations were not affected significantly by the initial cutting of cattails to create desired cover-water ratios, and invertebrate levels surpassed control levels during the later sampling periods.

During the first year following a draw-down, Kadlec (1962) found that invertebrate populations were reduced detrimentally. Later increases in invertebrate abundance were attributed to repopulation or an altered environment.

Invertebrates were monitored by Voigts (1976) in 4 Iowa marshes at similar stages of the marsh cycle based on length of time since draw-down and revegetation; invertebrate abundance increased as emergents were replaced by submergents and peaked when there was an interspersion of emergent and submergent vegetation. Prescribed fire was used with water-level manipulation in my study to alter the vegetative composition and promote submergent establishment. Although increased submergent cover was not assessed, open-water pockets were created, which may have accounted for the increased invertebrate diversity and abundance.

Neckles et al. (1990) found that invertebrate densities were affected negatively by semi-permanent flooding but unaffected by detritus removal in experimental marshes in Manitoba, Canada. My study area had been semi-permanently flooded since establishment, which may have explained the relatively low populations of invertebrates in all units throughout the study.

Debate still exists over the applicability of diversity indice(s) among ecologists (Krebs 1989). Brillouin's and Shannon-Weiner indices are both type I diversity indices which are more sensitive to changes in rare species within the sample. Simpson's is a type II diversity index that is more sensitive to changes in the more common species (Krebs 1989). Brillouin's index is a better fit for this project as it treats samples as collections, and sampling is conducted without replacement. Shannon-Weiner diversity assumes the total number of species in the sampled community is known. Regardless, mean differences (increases) in familial diversity were greater for burned units versus controls with both type I indices.

Water Chemistry and Marsh Alteration

Nutrient levels in freshwater wetlands vary seasonally, annually, and by site (Bookhout 1977, Van Der Valk 1987). Except for site variation, that tenet was supported by my results. The parameters measured in this project were selected to give an overall limnological view of the wetlands studied and possible effects of prescribed burning.

Temperature is important in regulating rates of chemical reactions and biological processes (Horne and Goldman 1994). For invertebrates, hatching, feeding, and emergence patterns are all influenced by temperature (Reid 1983). In my study, water temperatures were higher in fall sampling periods than spring. Invertebrate abundances and diversity did not seem affected by season.

Turbidity or total suspended solids was a parameter we suspected would be affected by prescribed fire. I believed that ash and partially combusted plant matter would suspend in the water column for a short period of time. I was unable to support this; turbidity measures were constant between burned and control sites throughout the study.

Fall pH measurements were generally lower than spring measurements in this study. Heitmeyer et al. (1989) found that fall pH readings were lower following initial flooding in late fall and increased in spring with increased rainfall. In southeastern Missouri, Laubhan (1995) found no differences between control and burned wetland sites relative to soil pH. Water pH differences between burned and controls in this study also were not detected.

With direct links to temperature and pH, dissolved oxygen (D.O.) is produced by photosynthetic plants and is readily consumed in respiration by both aquatic plants and animals (Horne and Goldman, 1994). Spring and fall D.O. levels remained high throughout the study (range = 9.3 - 11.1 mg/L). No changes resulting from prescribed burning were detected between control and burn sites.

Availability of nitrogen in aquatic systems influences variety, abundance, and nutritional value of aquatic plants and animals (Horne and Goldman, 1994). Nitrate-nitrogen levels were recorded during this study as nitrate concentrations, and rate of supply likely were closely connected to land use practices within the watershed (Horne and Goldman, 1994). Although nitrate levels fluctuated among seasons, no differences were found between control and burned units. These findings are consistent with Laubhan (1995), who found no differences in concentrations of soil nitrate between control sites and those burned in spring and summer.

Because it is often present in low concentrations, phosphorus generally is considered the most limiting nutrient in fresh water systems (Horne and Goldman, 1994). Orthophosphate sampling in my study was designed to measure significant "spikes" or increases in the system and therefore were not precise in recording actual orthophosphate levels in project wetlands. A more in-depth analysis of orthophosphate levels in relation to prescribed fire is needed to make more definitive conclusions.

Conclusion

Aquatic macroinvertebrates are an important food source for wintering and migrating waterfowl (Joyner, 1980; Murkin and Kadlec, 1986). As an important food source and a source of primary productivity, management of invertebrates with prescribed fire may be useful to enhance wetland productivity. In my study, invertebrate abundance and familial diversity were affected positively by prescribed burning in spring followed by reflooding. This effect, however, merits further investigation to determine effectiveness in other wetland ecotypes and climates. The duration of increased invertebrate productivity also requires additional research to develop long-range fire management plans for wetland sites.

The effects of fire on water chemistry in wetlands also needs further exploration. Although simplified, none of the parameters measured in this study were affected by prescribed burning in spring. The water chemistry monitoring conducted during this study was designed to evaluate major changes in the designated parameters. A closer look may reveal subtle, short-term changes in these and other variables associated with fire. I predict that fire releases some nutrients bound in standing biomass, and the effect of these added nutrients on the system need further investigation.

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VITA 2

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