Effects of Spring and Fall Burning on Cattail in South Dakota

Jose H. Saenz Jr.
Department of Range and Wildlife Management, Texas Tech University, Lubbock, TX 79409

Loren M. Smith
Department of Range and Wildlife Management, Texas Tech University, Lubbock, TX 79409

ABSTRACT

Because monotypic stands of cattail (*Typha* spp.) can be poor wildlife habitat, we examined the effects of spring and fall burning on cattail biomass and screening cover at Lacreek National Wildlife Refuge, in southwestern South Dakota. Using exclosures we were able to examine the effects of herbivorous wildlife species on post-burn plant production and whether wildlife preferentially foraged in previously burned sites. We also examined fire prescription variables during prescribed burns. Two sites were burned in September, two in May, and two sites served as controls. Pre-burn data were collected from all six study sites. Following prescribed burning, each site was covered with 10 to 30 cm of water. Wildlife herbivory did not affect ($P>0.05$) post-burn cattail production and wildlife did not preferentially forage on new growth in burned sites. After the following growing season cattail biomass in fall and spring burned sites was about 50% less ($P<0.05$) than control sites. Fall burned site screening cover was less ($P<0.05$) the following season after burning but spring burned and control sites remained unchanged. Control of cattail depends on achieving complete cover removal and we recommend temperatures ranging from 10 to 24° C, wind speeds of 6 to 15 kph, and relative humidities from 25 to 50% to effectively burn cattail in the northern prairie wetlands.

Citation: Saenz, Jose H., Jr. and Loren M. Smith. 1995. Effects of spring and fall burning on cattail in South Dakota. Pages 151–157 *in* Susan I. Cerulean and R. Todd Engstrom, eds. Fire in wetlands: a management perspective. Proceedings of the Tall Timbers Fire Ecology Conference, No. 19. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Dense marsh vegetation often restricts foraging, nesting, and loafing by waterfowl (Smith and Kadlec 1985a, Higgins et al. 1986). Therefore researchers have studied the effects of cutting, grazing, crushing, cultivation, explosives, chemicals, and fire to control marsh vegetation, especially cattail (Nelson and Dietz 1966; Smith 1989). Of these methods, fire is least expensive and most often used. Fire has been used to control undesirable vegetation and benefit wildlife (Higgins et al. 1986). In addition, wildlife, such as muskrats (*Ondatra zibethica*) and geese (*Branta* spp., *Chen* spp.) often preferentially forage on new growth on burned sites and cause further reduction of marsh plant biomass (Smith and Kadlec 1985a).

We can better determine how prescribed burning affects cattail stands by conducting burns in different seasons, carefully monitoring conditions, and replicating them. To formulate prescriptions for burning cattail effectively, weather and fire data must be collected during burns. Possibly because fire prescription data in marshes have seldom been collected, and therefore results have been difficult to repeat, there are few long-term plans for using prescribed burning on National Wildlife Refuges (U.S. Fish and Wildlife Service 1983).

Our objectives were to compare the biomass (living and dead) and screening cover of cattail among fall burns, spring burns, and control sites and determine the impact of wildlife herbivory on cattail production following fires. We also recommend fire prescriptions for burning of cattail in fall and spring.

METHODS

Study Area

Study sites were selected at the Lacreek National Wildlife Refuge (NWR) in southwestern South Dakota. Lacreek NWR is 19.3 km southeast of Martin, South Dakota in Bennett County, on the northern margin of the Nebraska sandhills. Topography of the NWR consists of flat marsh, gently rolling upland areas, and choppy sandhills. Elevation ranged from 914 to 1,000 m. Average annual precipitation was 40.64 cm (U.S. Fish and Wildlife Service 1983). Temperatures were frequently > 38° C and as low as −40° C. Dominant grasses included bluegrass (*Poa* spp.), crested wheatgrass (*Agropyron cristatum*), and smooth brome (*Bromus inermis*). Marsh vegetation included bulrush (*Scirpus* spp.), arrowhead (Sagittaria *cuneata*), smartweed (*Polygonum* spp.), coontail (*Ceratophyllum demersum*), spikerush (*Eleocharis palustris*), wild rice (*Zizania aquatica*), and cattail. Cattails (*Typha latifolia* and *Typha angustifolia*) were the dominant species (U.S. Fish and Wildlife Service 1983).

Study Sites

Six sites ranging from 6 to 8 ha were used for cattail studies. Two sites were burned in September 1992 and two in May 1993, and two unburned sites served as controls. All six sites were de-watered during summer 1992. Study sites were flooded with about 10 to 30 cm of water after burning. Fall sites were not flooded until November following September burns because water control structures needed maintenance. Following the two burns in May, we flooded the spring burned sites and the two control sites.

Cattail Biomass and Screening Cover

We determined pre- and post-burn cattail biomass by clipping 10, 1 × 0.5 m plots from each of the six sites in August 1992 and 1993. We examined pre-burn biomass to ensure that there were no obvious biomass differences before treatment. Cattail was clipped down to bare soil. Cattail samples were collected during August because that is the time that cattail reaches its peak biomass (Smith and Kadlec 1985b). Vegetation that was collected after clipping was placed in tagged burlap bags. Samples were then weighed immediately and oven dried at 60° C to a constant mass. We placed exclosures that were large enough to contain 1 × 0.5 m frames in control areas in September 1991 and immediately after fall and spring burns to determine vegetation utilization by herbivorous wildlife (Smith and Kadlec 1985a, 1985b). Ten exclosures were set up on each study site. We clipped exclosure plots in August 1993 along with the other biomass plots.

To estimate cattail screening cover before burning, we randomly took 25 Robel pole readings in each of the six study sites during August 1992 (Robel et al. 1970). We placed a 16 dm Robel pole in a random location in the cattail marsh and read the lowest dm mark on the pole that could be seen from 1 m height at a distance of 3 m from the pole. Readings were taken from the four cardinal directions at each of the 25 random locations. We then averaged 4 readings at each random spot so that we had a total of 25 readings for each study site. Finally, we averaged the 25 points in each study site to determine screening cover for that particular site. We collected post-burn cattail cover data in August 1993.

We compared post-burn cattail biomass (in and outside the exclosures) among fall burn, spring burn, and control sites using a two-factor analysis of variance. We used analysis of variance to compare pre-burn cattail biomass, pre-burn cattail cover (Robel pole readings), and post-burn cattail cover among treatments. If a difference was found between pre-burn treatments, an analysis of covariance was used to determine if pre-burn differences affected post-burn estimates and pre-burn estimates served as a covariate (SAS 1985). If a difference was found between post-burn treatments, a Least Significant Difference (LSD) test was used to determine which treatments were different. To compare pre-burn and post-burn biomass for each treatment, a t-test was used.

Fire Prescription Variables

The actual area of fire coverage ranged from 12 to 73 ha, although cattail study sites ranged from 6 to 8 ha. We burned sites using a headfire. Firelines were widened using a backfire and then a head fire was used to complete the burn. Sites were ignited with a drip torch that contained a gas/diesel mixture. Dikes and mowed lines were used as fire lanes. Mowed lines also were raked to remove cut vegetation. For some of our burns, foam lines were set down before starting the backfire.

We measured fuel load, fuel moisture, soil moisture, relative humidity, temperature, and wind speed prior to each fire. Fuel load was determined by clipping five quadrats (1 × 0.5 m) from each site prior to burning. Vegetation was weighed immediately and oven dried to a constant mass to determine fuel load and moisture. We also determined dead fuel moisture prior to burning using ten-hour fuel moisture sticks (Lancaster 1970). We used three sets of sticks per burned plot to determine the dead fuel moisture prior to burning. We determined soil moisture by collecting soil samples. We took ten soil samples 8 cm in length and 5 cm in diameter from each burned plot a few days prior to burning. Using a PVC pipe or a soil auger, soil samples were collected and placed in soil cans. They were immediately weighed and oven dried to a constant weight to determine soil moisture.

On the day of the fire, a local weather forecast was received from the National Weather Service. In the field we measured relative humidity (sling psychrometer), wind speed (wind meter), and air temperature (thermometer) while following U.S. Fish and Wildlife Service prescriptions (U.S. Fish and Wildlife Service 1991).

Table 1. Pre-burn cattail biomass in kg/ha ($\bar{x} \pm$ SE) at the Lacreek National Wildlife Refuge, South Dakota, August 1992.

	Treatments		
Site no.	Fall burns (September)	Spring burns (May)	Control
1.	15,844 ± 1,416	19,206 ± 1,462	18,372 ± 1,351
2.	20,168 ± 1,553	14,596 ± 2,141	18,860 ± 1,802

Organic soil consumption on the soil surface also was estimated during the burns to determine if fires may have caused loss of below ground biomass. We measured consumption using duff spikes (Brown et al. 1985) placed flush to the organic layer in ten random locations in each of the four burn sites. The amount of organic soil consumed was estimated by measuring the length of the spike exposed after the fire.

RESULTS

Cattail Biomass

Cattail pre-burn biomass was not different (F=0.41, df=57, $P>0.05$) among treatments (Table 1). Post-burn biomass (inside and outside exclosures) was different among treatments (F=74.48, df=114, P<0.001) (Table 2). Cattail biomass in spring and fall burned sites was similar ($P>0.05$) but biomass was about 50% less for spring and fall burned sites ($P<0.05$) than control sites.

There was no difference between biomass estimates outside exclosures and biomass inside exclosures (F=0.01, df=114, $P>0.25$) and herbivorous wildlife species did not preferentially feed on new growth in burned sites. Biomass for fall pre-burn sites was 51% greater (t=9.05, df=58, $P<0.05$) than biomass for fall post-burn sites. Biomass for post-burn spring sites was about 56% less (t=8.17, df=58, $P<0.05$) than pre-burn biomass.

Cattail Screening Cover

Pre-burn cattail screening cover was different among treatments (F=33.45, df=147, $P<0.05$) (Table 3). Control and spring burned sites had similar ($P>0.05$) cover, but fall burned sites ($P<0.05$) had more cover prior to treatments. Post-burn cattail cover also varied among treatments (F=4.35, df=146, P=0.006) using pre-burn cover as a covariate. Screening cover for fall post-burn sites was greater ($P<0.05$) than spring and control post-burn sites, but spring and control sites were not different ($P>0.05$). One growing season after burning, screening cover was less (F=10.17, df=48, $P<0.05$) than pre-burn cover in fall sites but did not differ in spring (F=0.34, df=48, P>0.05) and control (F=0.02, df=48 >0.05) sites.

Prescribed Burning Variables

Fuel loads for fall burns were 15,672 kg/ha ± 2,228 and 16,080 kg/ha ± 2,388, and 17,006 kg/ha ± 2,006.29 and 13,196 kg/ha ± 2,493.34 in spring burns. Soil moisture during burning was 99.14% ± 10.84 and 36.51% ± 4.02 for fall burned sites and 123% ± 24.41 and 62.4% ± 7.04 for spring burned sites. During fall burning, total cattail fuel moisture readings were 90.27% ± 12.65 and 54.53% ± 8.97. Spring burned sites had total fuel moistures of 253% ± 55.69 and 41%± 7.02. Both fall burns had a 10% dead fuel moisture, and spring burns had 9% and 11% fuel moistures. Although there was variation among soil and fuel moistures it did not affect above ground fuel consumption because fire removed almost all above ground fuels. Because there were high soil moistures, no organic soil consumption was recorded (i.e., the soil surface did not go below any of the duff spikes). Fire weather was similar for all burns except for speeds and wind directions (Table 4).

DISCUSSION

After burning, above-ground cattail biomass in spring and fall burned sites was lower than above-ground biomass in control sites. Much of the biomass the growing season prior to burning was residual cover, but vegetation was all alive the growing season after fires. Fire effectively reduced above-ground cattail production, but whether these positive effects last more than one year is unknown. According to Thompson and Shay (1985), fire

Table 2. Post-burn cattail biomass in kg/ha ($\bar{x} \pm$ SE) determined from samples (n = 20 for each treatment and exclosure combination) collected inside and outside exclosures at Lacreek National Wildlife Refuge, South Dakota, August 1993. Each treatment included 2 study sites.

	Treatments[a]		
Exclosures	Fall burns (September)	Spring burns (May)	Control sites
Outside	8,073.8 ± 642	8,275.8 ± 1,200	15,667.2 ± 815
	8,419.2 ± 936	7,643.0 ± 653	15,766.4 ± 1,380
Inside	8,280.2 ± 605	6,340.6 ± 448	15,329.6 ± 1,457
	10,360.8 ± 936	7,766.2 ± 951	15,358.4 ± 1,123

[a]Difference among treatments determined with LSD = 1,384.82.

Table 3. Pre-burn and post-burn cattail cover in dm ($\bar{x} \pm$ SE)[a] at Lacreek National Wildlife Refuge, South Dakota, August 1992 and 1993. Each treatment during each year included 2 study sites.

Year	Treatments[b] Fall sites (September)	Spring sites (May)	Control sites
Pre-burn (1992)	14.26 ± 0.39	12.27 ± 0.55	10.49 ± 0.40
	14.63 ± 0.36	10.99 ± 0.27	12.36 ± 0.57
Post-burn (1993)	12.94 ± 0.34	9.60 ± 0.78	11.47 ± 0.55
	12.57 ± 0.61	12.72 ± 0.24	11.24 ± 0.37

[a]Visual obstruction readings measured in 0.10 m segments on a 16 dm Robel pole read at a 1 m height and distance of 3 m. Four readings (four cardinal directions) taken in each of 25 random locations were averaged. The 25 locations were then averaged to determine screening cover for each site.
[b]Differences among pre-burn treatments were determined with LSD = 0.81 and differences among post-burned treatments were determined with LSD = 0.98.

Table 4. Weather for fall and spring prescribed burns at Lacreek National Wildlife Refuge, South Dakota, September 1992 and May 1993.

Season	Date	Temp. (°C)	R.H. (%)	Wind (kph)
Fall	22 Sep. 1992	26	30	14 SW
	25 Sep. 1992	20	33	6 NW
Spring	3 May 1993	22	35	6 variable
	10 May 1993	19	37	12 NE

only affects vegetation growth one growing season or less after a fire unless there is a change in the species composition. A burn in early September in Utah caused decreased cattail production the following growing season (Smith and Kadlec 1985b). Thompson and Shay (1985) found that biomass of common reed (*Phragmites australis*) did not change the year after a fall burn but was higher after a spring burn. A similar study showed that biomass of common reed was higher after spring burns than fall burns or control areas (Thompson and Shay 1989). In a Utah marsh, alkali bulrush (*Scirpus maritimus*) were more dense after a fall burn or about equal to pre-burn stands possibly due to nutrient release or removal of litter (Smith and Kadlec 1985a).

Post-burn cattail biomass in exclosures was similar to biomass outside exclosures. In the Playa Lakes Region, wildlife herbivory also did not cause a reduction in cattail biomass (Smith 1988). However, Smith and Kadlec (1985b) recommended using exclosures to estimate cattail standing crop because of potential wildlife herbivory. Herbivory was a major cause of above-ground biomass reduction following prescribed burning in Utah. Grazing intensity of burned sites was 47.5% for cattail, 25.4% for hardstem bulrush, and 8.9% for alkali bulrush (Smith and Kadlec 1985b). It is possible that wetland wildlife can detect nutritive quality changes in marsh foods (Goldberg et al. 1980). Smith et al. (1984) found that fall burning increased the nutritive quality of cattail, saltgrass (*Distichlis spicata*), and hardstem bulrush. Prescribed burning has been used as a goose management tool because geese commonly feed on new green shoots (Lynch 1941). Grazers feed in nonburned areas in late summer but will feed through out the year in areas that had been burned (Smith and Kadlec 1985b). Some of the loss attributed to grazing also may have been due to other factors such as nesting and muskrat lodge building.

Cattail screening cover was only affected by burning in the fall burned sites. Mallik and Wein (1986) found that cattail cover in New Brunswick decreased after fall burning by 14.2% and spring burning decreased screening cover 3.1%. In our study, burning did not cause a major change in cattail cover in spring burned sites, but it did remove old growth and cause a significant reduction in biomass. The U.S. Fish and Wildlife Service generally uses prescription ranges with temperatures of 2 to 24° C, mid-flame wind speeds of 8 to 24 km/hr, and relative humidities of 20 to 70% for marsh burning (U.S. Fish and Wildlife Service 1991). However, Smith and Kadlec(1985b) burned during early fall with a mean air temperature of 28.5° C, dew point of 5° C, and 16.6 km/hr wind. Weather conditions for Young's (1986) December burn included temperatures of 3 to 5° C, relative humidities of 27 to 34% and wind speeds of 2 to 16 km/hr. Young's (1986) spring burns had air temperatures of 4 to 9° C, relative humidities of 31 to 35%, and wind speeds of 6 to 10 km/hr. Young (1986) recommended avoiding burning bulrush species with high temperatures and wind speeds, and low relative humidities until we have a better understanding of fire behavior in marshes. High temperatures (>27° C) in combination with winds >15 km/hr and relative humidities <20% can be dangerous. However, a fire conducted with low temperatures (<10° C), low wind speeds (<6 km/hr), and high relative humidities (>50%) can be time consuming or not even burn at all if humidity is very high. Although conditions varied in all of these studies, almost all emergent vegetation above ground was consumed, but vegetation was not entirely controlled with fire alone.

In our study, even though fuel moisture (41 to 253%) and soil moisture (36 to 123%) varied within and between burning treatments, they had little effect on aboveground fuel consumption. Cattail was almost entirely removed by fire at each burned site. However, high soil moisture contents in burned sites did result in no organic soil consumption. When surface water is present fire will cause little damage, but during drought years a fire may destroy marsh dominants (Penfound 1952). Ward (1968) in the Delta Marsh, Manitoba showed that fire did not affect regrowth of marsh vegetation due to moist substrates. Uhler (1944) found that in dry conditions cattail can be controlled for many years if burns consume 8 to

15 cm in the organic soil. However, he did not provide prescriptions for "dry" conditions. Cattail also was killed by a peat fire that burned in a dry (moisture was not measured) marsh (Beule 1979). Lay and O'Neil (1942) reported that fall fires following severe drought led to deep peat burns and created holes that filled with water.

When trying to control cattail, water level must also be considered as a variable (Linde et al. 1976). Fire followed by reflooding can control emergent plants (Kadlec and Smith 1992). Cattail is composed of many stems that grow parallel to the surface (Linde et al. 1976). These stems interlace and interconnect with parts of one plant spreading over considerable areas and have many aerial shoots (Linde et al. 1976). It is important that aerial shoots are consumed by fire and flooded with water. Zonteck (1966) mentioned that cattail control depends on flooding cattail burns before new growth begins. The shoots that extend above water supply oxygen to underground organs and allow cattail to grow (Ball 1984). Ball (1984) suggested that flooding over stubble can kill shoots under water because of anaerobic conditions that develop in the rhizomes. If cattail is flooded deep enough to cover burned stalk stubble cattail can be killed (Ball 1985).

Cattails tolerate shallow flooding, and control and management of cattail only can be achieved with water if water levels can be manipulated (Linde et al. 1976). Nelson and Dietz (1966) flooded a cattail burn with 2.54 to 44.72 cm of water and found that cattail did not grow in the deeper water for a few years, but grew immediately in shallow areas. Burned salt grass stubble that was flooded with about 10 cm of water was almost completely killed (Smith and Kadlec1985a). Flooding alone has been known to eliminate cattail.

Slow reflooding and low water levels may have not enabled us to completely control cattail. Cool-wet weather delayed our spring burns from March until May. Vegetation had already started growing when spring burns were conducted. Following spring fire we were unable to get enough water over shoots in time to outpace cattail growth from reaching above the water surface. Even though our fall burns were flooded before growth had begun, we were only able to flood fall sites with about 30 cm of water.

RECOMMENDATIONS

We did not detect a difference between cattail biomass inside exclosures and outside exclosures, but the potential for wildlife herbivory exists. The use of wildlife exclosures is recommended when estimating vegetation production following prescribed burns (Smith and Kadlec 1985b).

We controlled cattail somewhat by flooding after burning, but we may have had better cattail control if we had been able to use higher water levels. We recommend flooding cattail burns with >30 cm in an attempt to better control cattail. We recommend burning with lower soil moistures (<30%) than we used to determine if below ground plant structures can be killed and cattail controlled.

If maximum fuel consumption is the management objective, U.S. Fish and Wildlife prescription ranges may be too broad. We recommend burning at 10 to 24° C, wind speeds of 6 to 15 km/hr, and relative humidities of 25 to 50% to conduct a safe but clean burn. We suggest burning under our prescriptions and monitoring fuel consumption and fire behavior in order to be sure that these are the correct conditions for burning cattail stands. Burning with high air temperatures (12 to 25° C) will create hotter fires and help remove more fuel load. Burning with very low wind speeds may help keep suppression costs low. Also, costs of burning may be kept low by using clean fire breaks. Disked or graded fire breaks are safer than mowed fire breaks and will allow fire crews to complete prescribed burns faster while keeping fire costs low.

We also recommend burning during fall so that burn sites can be flooded before spring growth occurs and for the prevention of avian nest destruction. Finally, prescribed marsh burning occurs infrequently (every 10 to 20 years) on the prairies. Experiments should be conducted at more frequent intervals (e.g., 4 to 5 years) to determine how fire affects cattail and wildlife.

ACKNOWLEDGMENTS

Financial support was provided by the U.S. Fish and Wildlife Service (Region 6) and Texas Tech University (TTU ms #T-9-688, College of Agricultural Sciences and Natural Resources). The Lacreek National Wildlife Refuge provided field assistance. Rolf Kraft, Dan Severson, John Cornely, Ray Rauch, Herb Troester, and Henry Wright provided comments on the study.

LITERATURE CITED

Ball, J. P. 1984. Habitat selection and optimal foraging by mallards: a field experiment. Masters Thesis. University of Guelph, Ontario.

Ball, J. P. 1985. Marsh management by water level manipulation or other natural techniques: a community approach. Pages 263–277 *in* H. H. Prince and F. M. D'Itri, eds. Coastal wetlands. Lewis Publ. Inc., Chelsea, MI.

Beule, J. D. 1979. Control and management of cattails in southeastern Wisconsin wetlands. Wisconsin Department of Natural Resources Technical Bulletin 112. Madison, WI.

Brown, J. K., M. A. Marsden, E. D. Reinhardt, and K. C. Ryan. 1985. Predicting duff and woody fuel consumed by prescribed fire in the Northern Rocky Mountains. Research Paper Int-337. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Goldberg, M., N. R. Tabroff, and R. H. Tamarin. 1980. Nutrient variation in beach grass in relation to beach vole feeding. Ecology 61:1029–1033.

Kadlec, J. A., and L. M. Smith. 1992. Habitat management for breeding areas. Pages 590–610 *in* B. D. Batt, A. D. Afton, M. G. Anderson, G. D. Ankney, D. H. Johnson, J. A. Kadlec,and G. L. Krepu, eds. Ecology and management of breeding waterfowl. Univ. of Minnesota Press, Minneapolis.

Higgins, K. F., A. D. Kruse, and J. L. Piehl. 1986. Effects of fire in the Northern Great Plains. U.S. Fish and Wildlife Service & Cooperative Extension Service, South Dakota State University, Brookings.

Lancaster, J. W. 1970. Timelag useful in fire danger rating. Fire Control Notes 31(3):6–8, 10.

Lay, D. W., and T. O'Neil. 1942. Muskrats on the Texas coast. Journal of Wildlife Management 6:301–312.

Linde, A. F., T. Janisch, and D. Smith. 1976. Cattail—the significance of its growth, phenology, and carbohydrate storage to its control and management. Wisconsin Department of Natural Resources Technical Bulletin 94. Madison, WI.

Lynch, J. J. 1941. The place of burning in management of the Gulf Coast refuges. Journal of Wildlife Management 5:454–458.

Mallik, A. U. and R. W. Wein. 1986. Response of a *Typha* marsh community to draining, flooding, and seasonal burning. Canadian Journal of Botany 64: 2136–2141.

Nelson, N. F., and R. H. Dietz. 1966. Cattail control methods in Utah. Utah Department of Fish and Game Publication 66–2. Salt Lake City, UT.

Penfound, W. T. 1952. Southern swamps and marshes. Botanical Review 18:413–446.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

SAS. 1985. SAS User's Guide: Statistics. 5th edition. SAS Institute. Cary, North Carolina.

Smith, L. M. 1988. Lack of vertebrate herbivory in playa wetlands. Wetlands 8:193–197.

Smith, L. M. 1989. Effects of grazing and burning on nutritive quality of cattail in playas. Journal of Aquatic Plant Management 27:51–53.

Smith, L. M. and J. A. Kadlec. 1985a. Fire and herbivory in a Great Salt Lake marsh. Ecology 66: 259–265.

Smith, L. M. and J. A. Kadlec. 1985b. A comparison of marsh plant loss estimates in production techniques. American Midland Naturalist 114:393–395.

Smith, L. M., J. A. Kadlec and P. V. Fonnesbeck. 1984. Effectsof prescribed burning on nutritive quality of marsh plants in Utah. Journal of Wildlife Management 48:285–288.

Thompson, D. J. and J. M. Shay. 1985. The effects of fire on *Phragmites australis* in the Delta Marsh, Manitoba. Canadian Journal of Botany 63:1864–1869.

Thompson, D. J. and J. M. Shay. 1989. First-year response of a *Phragmites* marsh community to seasonal burning. Canadian Journal of Botany 67: 1448–1455.

Uhler, F. M. 1944. Control of undesirable plants in waterfowl habitats. Transactions North American Wildlife Conference. 9:295–303.

United States Fish and Wildlife Service. 1983. Fire management plan: Lacreek National Wildlife Refuge. U.S. Department of Interior. Lacreek National Wildlife Refuge, Martin, SD.

United States Fish and Wildlife Service. 1991. Prescribed burning plan: Lacreek National Wildlife Refuge. U.S. Department of Interior. Lacreek National Wildlife Refuge, Martin, SD.

Ward, P. 1968. Fire in relation to waterfowl habitat of the Delta marshes. Proceedings of the 8th Annual Tall Timbers Fire Ecology Conference 8:255–268.

Young, R. P. 1986. Fire ecology and management in plant communities of Malheur National Wildlife Refuges, Southeastern Oregon. Doctoral Dissertation. Oregon State University, Corvallis.

Zontek, F. 1966. Prescribed burning on the St. Marks National Wildlife Refuge. Proceedings of the 5th annual Tall Timbers Fire Ecology Conference. 5:195–201.