Prepared in cooperation with the U.S. Fish and Wildlife Service

A Multi-Refuge Study to Evaluate the Effectiveness of Growing-Season and Dormant-Season Burns to Control Cattail

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U.S. Department of the Interior
U.S. Geological Survey

Cover. Burning cattail during a growing season fire. Photographs of U.S. Fish and Wildlife Service.

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi^2)
	Volume	
cubic centimeter (cm^3)	0.06102	cubic inch (in^3)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

NOTE TO USGS USERS: Use of hectare (ha) as an alternative name for square hectometer (hm^2) is restricted to the measurement of small land or water areas. Use of liter (L) as a special name for cubic decimeter (dm^3) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter. Metric ton (t) as a name for megagram (Mg) should be restricted to commercial usage, and no prefixes should be used with it.

Acknowledgments

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A Multi-Refuge Study to Evaluate the Effectiveness of Growing-Season and Dormant-Season Burns to Control Cattail

By Robert A. Gleason[1], Brian A. Tangen[1], Murray K. Laubhan[2], and Socheata Lor[2]

Abstract

Proliferation of invasive cattails (for example, *Typha* x *glauca*, *T. angustifolia*) is a concern of wetland managers across the country, and numerous methods have been used to control the spatial extent and density of the plant. To date, however, no single method has proven widely or consistently effective at reducing the long-term growth and spread of these species. We performed a multi-refuge study to evaluate the relative effects of growing-season and dormant-season prescribed burns on cattail production and to gain insight on variables such as soil moisture, groundwater, and biomass that affect the efficacy of burning as a control method. Results indicate total cattail cover recovers to pre-burn levels within 1 year regardless of whether the controlled burn was implemented during the growing season or dormant season. Growing-season burns, however, did result in lower aboveground and belowground cattail biomass 1-year post-burn, whereas no significant change in biomass was detected for dormant-season burns. Study results support the premise that burns implemented during the growing season should have a greater effect on nutrient reserves and cattail re-growth. Results from this and other studies suggest long-term research that incorporates multiple management strategies will be required to evaluate the potential of prescribed burning as a method to control cattail.

Introduction

The encroachment of cattail, principally *Typha* x *glauca* and *T. angustifolia*, in freshwater, emergent wetlands is a widespread problem across many regions of the United States (for example, Linde and others, 1976; Sojda and Solberg, 1993; Kostecke and others, 2004; Wilcox and others, 2008). A primary concern is that diverse wetland plant communities often are displaced by invasive cattails, resulting in monotypic stands of vegetation with reduced ecological values. The rate of vegetative transition often is accelerated when wetland hydrology is altered by human activities; thus, this issue is particularly relevant to managers of intensively managed wetland systems, including those of the National Wildlife Refuge (NWR) System of the U.S. Fish and Wildlife Service (USFWS) that are managed to support wetland-dependent wildlife. Many NWRs are embedded within a larger landscape that has been greatly modified by past land use and land management. In addition, many wetlands on NWRs have been intentionally modified in an attempt to create and improve wildlife habitat. Common modifications include the installation of levees, ditches, diversion channels, and water-control structures to manipulate water levels and flow paths. Although human-induced hydrologic changes (for example, artificially stabilized hydroperiods or elevated water levels) may provide abundant wetland resources for target wildlife species in the short-term, research and monitoring have documented that these systems often suffer long-term degradation because of disruption of important ecosystem processes (for example, drawdown, flooding) that facilitate the transition from relatively diverse wetland plant communities to cattail-dominated communities (Newman and others, 1998; Kostecke and others, 2004; Wilcox and others, 2008). For example, cattail expanded by greater than 8.1 hectares/year and biomass increased 56 percent because of constant inundation in a Wisconsin marsh (Boers and Zedler, 2008). Similarly, cattail cover increased from 30 to 80 percent in a 25-year period at Horicon Marsh in Wisconsin (Beule, 1979), 0 to 17–90 percent in a 39-year period at the Cheyenne Bottoms Wildlife Area (not shown) in Kansas (Von Loh and Oliver, 1999), and greater than 25 percent in more than 12 years in an Indiana wetland complex (Wilcox and others, 1984).

The objective of many NWR managers that have problems with cattail encroachment is not only controlling the distribution and density of cattail, but also promoting the growth of more desirable plant species that provide foods and structural requisites (for example, water depth, interspersion of cover) to meet temporally-dynamic (for example,

[1]U.S. Geological Survey.

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spring, summer, fall) habitat objectives. Various techniques have been used to accomplish this task, including water-level manipulation, physical disturbance (for example, crushing, cutting, disking, grazing, shading), herbicide application, and burning. Success of these techniques has varied, and effectiveness typically is related to factors such as hydrology and time of implementation relative to the autecology of cattail (Nelson and Dietz, 1966; Murkin and Ward, 1980; Apfelbaum, 1985; Smith and Kadlec, 1985a, b; Mallik and Wein, 1986; Smith, 1989; Ball, 1990; Sojda and Solberg, 1993; Urban and others, 1993; Kostecke and others, 2004; Ponzio and others, 2004).

Any attempt to use prescribed burning to control cattail in managed wetlands requires the ability to effectively dewater the wetland. Ideally, implementation of prescribed burns is timed to coincide with vulnerable periods in the annual growth cycle of cattail. During the growing season, most carbohydrates and nutrients are aboveground in the actively growing part of cattail. In contrast, carbohydrates and important growth limiting nutrients are concentrated belowground in the rhizomes during the dormant season. The growing season should be an ideal time to apply fire to reduce cattail assuming that this timing would have the greatest effect on aboveground plant reserves. We do recognize, however, that growing-season burns commonly are difficult to execute in many altered wetlands because water-control infrastructure is not designed properly, discharge restrictions prevent the export of water, or collateral effects to wildlife are deemed too severe. Burning during the fall, winter, or early spring when fuel and moisture conditions are often more conducive for fire is also a viable option, but to be effective, the fire must burn deep enough to damage the rhizome layer containing the plant's carbohydrate reserves. This is commonly difficult to achieve because of elevated groundwater tables or saturated soils, inadequate infrastructure, and fire prescriptions that limit the ability to implement intense fires. As a result, most dormant-season fires only remove aboveground biomass, which does not affect carbohydrate or nutrient reserves that have been translocated to belowground root structures.

Although the importance of timing prescribed fires to match certain parts of the cattail life-cycle is recognized, large-scale studies comparing pre-burn conditions and post-burn effects of growing-season and dormant-season burns are lacking. A multi-refuge study was performed to compare abiotic site conditions and the relative effects of growing-season and dormant-season burns on cattail. Objectives were to contribute additional information regarding variables that potentially affect the response of cattail to fire, improve fire planning by quantifying the effects of fire in relation to wetland biotic (for example, vegetation biomass) and abiotic (for example, hydrology) conditions, and provide land managers with guidance pertaining to factors that should be considered when developing management strategies to control cattail.

Methods

Study Area and Design

The study was carried out from 2006 to 2008 on USFWS lands located in Minnesota (Agassiz NWR, Sherburne NWR), New York (Iroquois NWR), and Wisconsin (Horicon NWR, Uihlein Waterfowl Production Area [WPA]) (fig. 1; table 1). Selection of sites was based on a questionnaire sent to NWR managers in Regions 3 and 5 of the USFWS that described general parameters (for example, presence of cattail, ability to manipulate water levels) of the study and requested voluntary participation. Managers that committed to participation concluded increases in cattail distribution and biomass in some wetlands had negatively affected waterbird abundance and diversity. With the exception of Iroquois NWR, all wetlands were associated with riverine systems.

Selection of study sites was restricted to managed impoundments characterized by dense cattail stands, moist-soil to shallow-water (typically less than 1 meter [m]) conditions, and the ability to manipulate water levels and apply prescribed fire. Two impoundments were selected at each location (fig. 1), with the exception of three units at Agassiz NWR, based on the recommendation of management staff. One impoundment at each site was randomly designated to receive a growing-season burn treatment and the other a dormant-season burn treatment, with the exception that two units were randomly selected for growing-season burns at Agassiz NWR. Growing-season burns were implemented as close as possible to the time when the color of cattail spikes indicate aboveground carbohydrate reserves are at their maximum concentration (Linde and others, 1976), whereas dormant-season burns were implemented in the fall (October–November) following cattail senescence or after the first hard frost. Before implementing burns, surface water was removed and groundwater was manipulated so that it was below the cattail rhizosphere (soil immediately surrounding the roots of a plant). Managers were unable to meet the groundwater criteria (below the rhizosphere) at the South Pool impoundment at Agassiz NWR; therefore, the burn was implemented when the surface water was removed to the extent possible.

Prescribed Burns

Prescribed burn plans were developed and approved for all burns implemented during the study and refuge staff implemented all prescribed burns according to USFWS policies and safety guidelines. Ignition was accomplished using a terratorch or drip torch, and backing or flanking fires were used to control rate of spread before igniting head fires to ring the burn unit. Following the application of fire, managers attempted to keep sites dry until the end of the following growing season to avoid confounding effects of hydrology and to facilitate data collection.

Figure 1. Location of study sites located on National Wildlife Refuges (NWR) and a Waterfowl Production Area (WPA) in Minnesota, Wisconsin, and New York.

Data Collection

To evaluate the immediate and short-term effects of prescribed burning on cattail, data were collected before (pre-burn), immediately following (post-burn), and approximately 1 year after (1-year post-burn) implementation of prescribed fire (table 1). Six plots (6 m × 6 m) were established at each site for collection of biotic and abiotic data. Each plot was divided into 9 subplots (2 m × 2 m), of which 6 were assigned as pre-burn, post-burn, and 1-year post-burn collection sites for vegetation biomass (3 subplots) and soils (3 subplots), 1 was used to estimate vegetative cover, and 1 was used to measure soil moisture and groundwater level. The remaining subplot was assigned for use in monitoring substrate temperature, but because of equipment malfunctions these data were not collected before or during burns.

During each collection period, plant biomass was collected by removing all aboveground and belowground material from three 0.25-square meter quadrats located within the subplot. Biomass was separated into live and dead fractions, dried at 105 degrees Celsius (°C) to a constant weight, and mass was determined to the nearest 1 gram using an electronic balance. Percent cover of live cattail, dead cattail, non-cattail vegetation, and non-cattail litter was visually estimated. Total nonstructural carbohydrate (TNC) concentration for biomass samples collected from the Pool 8 and Upper Roadside sites was determined following Smith (1981). Soil samples were collected from the center of the O and A soil horizons for determination of nutrient concentrations and bulk density. Bulk density samples, which were used to convert nutrient concentrations to mass per unit area, were collected by inserting a 75.0-cubic centimeter aluminum cylinder

Table 1. Date and season of prescribed burns and data collection. Prescribed fires were successfully implemented at 8 of the 11 selected wetlands located on U.S. Fish and Wildlife Service National Wildlife Refuge (NWR) and Waterfowl Production Area (WPA) lands.

[--, no data]

NWR/WPA, State site	Date of burn	Season	Date of data collection		
			Pre-burn	Post-burn	1-year post-burn
Agassiz NWR, Minnesota					
Madsen pool	16 August 2007	Growing	16 August 2007	17 August 2007	5 August 2008
Pool 8	22 August 2006	Growing	22 August 2006	23 August 2006	14 August 2007
South Pool	1 November 2007	Dormant	15 October 2007	1 November 2007	4 November 2008
Sherburne NWR, Minnesota					
Upper Roadside	20 November 2006	Dormant	8 November 2006	20 November 2006	15 November 2007
Teal Pool	No burn	--	--	--	--
Iroquois NWR, New York					
Galaxie	7 July 2006	Growing	21 June 2006	8 July 2006	28 June 2007
Knowlesville	31 October 2007	Dormant	24 October 2007	1 November 2007	12 November 2008
Horicon NWR, Wisconsin					
Luehring	No burn	--	--	--	--
Stoney Pool	No burn	--	--	--	--
Uihlein WPA, Wisconsin					
Pumphouse pool	20 June 2007	Growing	19 June 2007	21 June 2007	--
Waukau pool	1 November 2007	Dormant	31 October 2007	1 November 2007	20 October 2008

(5.0-centimeter [cm] length) horizontally into the soil profile. Soil bulk density was determined using the core method (Blake and others, 1986). Total carbon (TC) and total nitrogen (TN) were determined using the combustion method (Nelson and Sommers, 1982) and total inorganic carbon (TIC) was determined using a pressure-calcimeter method modified from Sherrod and others (2002). Soil extractable ammonium and nitrate were determined using potassium chloride extraction (Lachet Instruments, 2003a, b), soil extractable sulfate was determined according to Dick and Tabatabai (1979), and soil extractable phosphate was determined using the Olsen method (Frank and others, 1998). Vegetation total phosphorus (TP) was determined using the dry ash/vanadomolybdate method (Olsen and Sommers, 1982; Jones and Case, 1990). Groundwater levels were measured using sandpoint wells, and percent soil moisture was collected at the surface and rhizome level using a ThetaProbe type ML2x soil moisture meter.

Analyses

Data collection was performed at different times of the year for the growing-season (June–August) and dormant-season (October–November) burns. The study design allows for within-treatment (growing and dormant seasons) comparisons of sample periods (pre-burn, post-burn, 1-year post-burn), but does not allow for direct comparisons of sample periods among treatments because of temporal variation. For example, we expect that biomass collected during the growing season would be different than biomass collected during the dormant season; thus, comparisons between the two would not be valid since any differences detected would be confounded by natural, seasonal variation.

Analysis of variance (ANOVA) was used to test for differences in vegetation and soil response variables among sample periods (pre-burn, post-burn, and 1-year post-burn). Analyses were performed separately for growing- and dormant-season burns. The mixed model procedure (PROC MIXED) of the software program SAS (version 9.1) was used to perform all analyses. Given the limited sample size and constraints to maintain constant hydrologic conditions during the study, we considered p less than or equal to 0.1 as the level of statistical significance for all tests to avoid discounting factors that may be important considerations in management.

Results

Prescribed Burn Conditions

Conditions meeting approved burn plans were met to successfully ignite fires in 8 of the 11 impoundments; however, managers were unable to remove surface water and meet the fire prescription requirements for burning both impoundments at Horicon NWR and the growing-season burn at Sherburne NWR (table 1). Hence, study results include only data from four growing-season and four dormant-season burns. Overall, pre-burn soil moisture and groundwater were lowest at the sites burned during the growing season (fig. 2). The lone exception was the Knowlesville impoundment at Iroquois NWR, which was burned during the dormant season and had the lowest pre-burn water table levels and

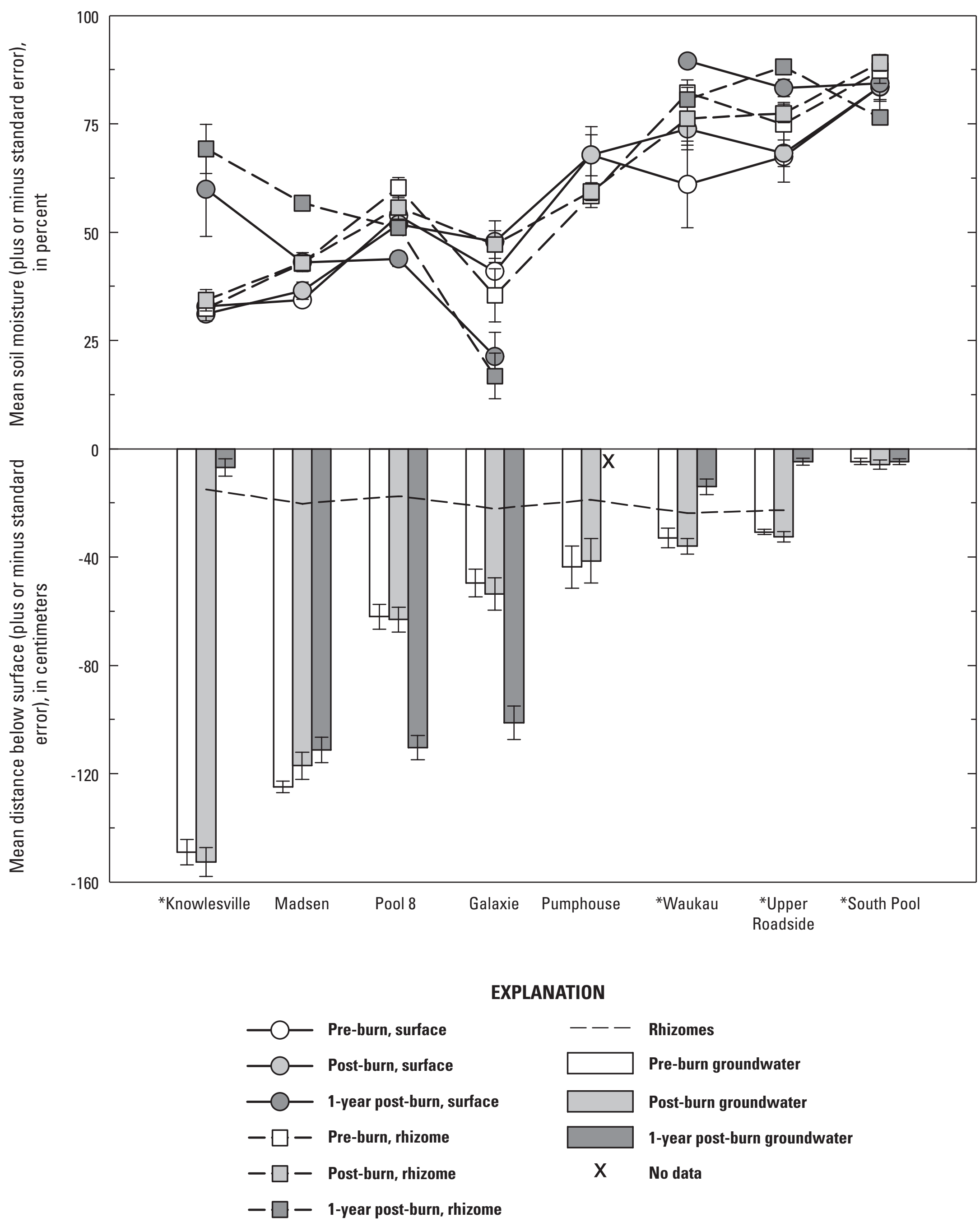

Figure 2. Mean water levels and soil moisture (surface and rhizome level) for each study site that was burned. The dashed horizontal line represents the mean maximum rhizome depth (rhizomes at South Pool were submerged). Sites burned during the dormant season are marked with an asterisk (*) along the x-axis.

soil moisture readings. Managers were able to remove free water from the sediments to the rhizome level (approximately 20 cm) or below at all locations except for South Pool on Agassiz NWR, which was designated for a dormant-season burn. Dry conditions (water below rhizomes) were maintained through the 1-year post-burn sample period for three of the four growing-season burn sites. In contrast, precipitation events led to all dormant-season burn sites having 1-year post-burn water levels noticeably higher (for example, water above rhizomes) than the pre-burn and post-burn levels. Consistent, quantitative data pertaining to the fires were not collected; however, qualitative accounts from field crews generally described all fires as being relatively complete surface burns that consumed a large portion of the vegetation and litter. Further, USFWS managers noted that, in some cases, it appeared that green vegetation (growing-season burns) slowed the rate that the fire spread, allowing it to consume more fuel and produce more heat.

Vegetative Cover

Overall trends indicate total percent vegetative cover was reduced immediately following prescribed fire (post-burn) during the growing season and dormant season, but recovered to approximate pre-burn levels within 1 year (fig. 3); post-burn total vegetation cover was significantly different than the pre-burn and 1-year post-burn periods for sites burned during the dormant-season only ($F_{2,6} = 4.64$, $p = 0.0607$). Although the overall (live and dead) percentage of vegetative cover was similar among the pre-burn and 1-year post-burn periods, growing-season ($F_{2,4} = 7.06$, $p = 0.0488$) and dormant-season burns ($F_{2,6} = 9.71$, $p = 0.0131$) exhibited increases in percent live vegetation 1-year post-burn. The overall pattern of reduced vegetative cover immediately following fire also was evident when examined on a site-by-site basis; the exception was the Upper Roadside impoundment where pre-burn and post-burn estimates were similar and 1-year post-burn estimates were reduced with less than 10 percent live vegetative cover (fig. 4).

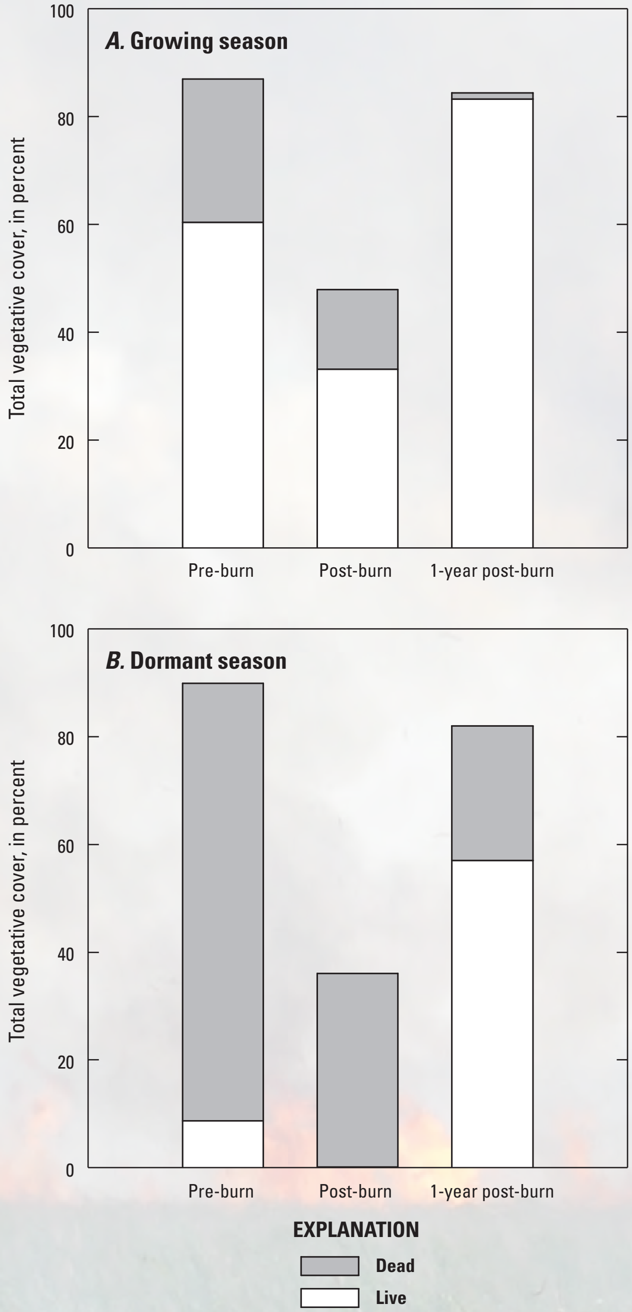

Figure 3. Mean total (cattail and “other”) live and dead vegetative cover for sites (excluding the Pumphouse site) burned during the *A*, growing and *B*, dormant seasons.

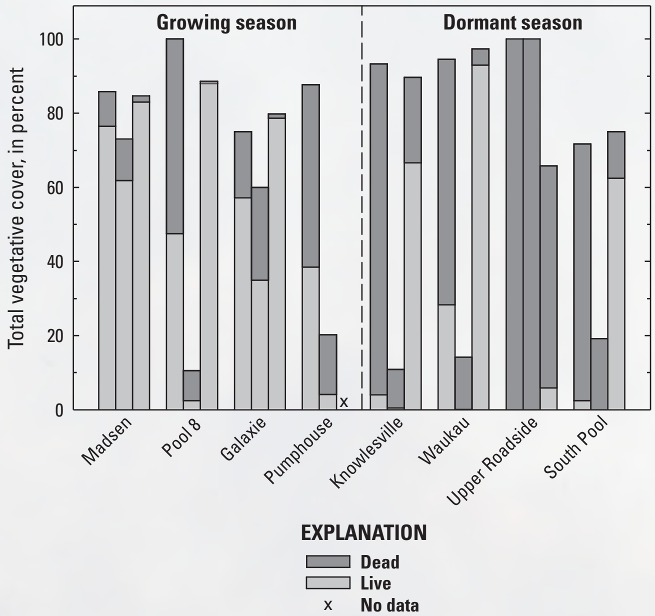

Figure 4. Mean total (cattail and "other") live and dead vegetative cover for each study site that was burned. For each site, bars represent pre-burn, post-burn, and 1-year post-burn estimates, respectively. The vertical dashed line separates sites burned during the growing and dormant seasons.

Vegetative Biomass

General trends indicate total (live and dead) aboveground and belowground biomass on sites burned during the growing season decreased immediately following prescribed fires and continued to decrease 1-year post-burn (figs. 5*A*, *C*); however, this decreasing trend was only significant ($F_{2,4} = 5.66$, $p = 0.0682$) for aboveground biomass. In contrast, sites burned during the dormant season exhibited a decrease in aboveground biomass immediately following prescribed fire, with biomass increasing from the post-burn levels after 1 year (figs. 5*B*, *D*). Belowground biomass increased 1-year post-burn relative to pre-burn and post-burn (figs. 5*B*, *D*); however, these trends were not significant. Overall, similar patterns were evident when examining biomass changes on individual impoundments, although there was some variation among sites (fig. 6).

Vegetative Nutrients

Before the prescribed burns, aboveground live vegetation contained more TN ($F_{1,2} = 188.8$, $p = 0.0053$) and TP ($F_{1,2} = 36.04$, $p = 0.0266$) compared to aboveground dead vegetation (fig. 7), whereas concentrations of TC were similar (table 2). There were no differences in pre-burn TN, TP, or TC between live and dead belowground vegetation (fig. 7, table 2). No significant differences in mean TN, TP, and TC attributable to sample period (pre-burn, post-burn, 1-year post-burn) were detected, with the exception that TP of belowground live biomass was lower ($F_{2,4} = 35.96$, $p = 0.0028$) 1-year post-burn, compared to pre-burn and post-burn, at sites that were burned during the growing season (table 2).

The TNC data were not analyzed because of a lack of replication. General observations, however, revealed that belowground percent TNC in vegetation was greater than aboveground percentages for the Pool 8 (growing-season) and Upper Roadside (dormant-season) locations. Further, TNC concentrations were consistently greater in the aboveground vegetation collected during the growing season compared to the dormant season, whereas belowground concentrations were similar among the growing and dormant seasons (fig. 8).

Soil Nutrients

The mass of TN, TC, TIC, TOC, sulfate, nitrate, ammonium, and phosphorus were calculated using chemistry and bulk density data from soil samples. The mean values by season of burn, sample period, and soil horizon are presented in table 3. Overall, there were no significant differences attributed to sample period with the exception that ammonium in the O horizon at sites burned during the growing season was lower ($F_{2,4} = 5.95$, $p = 0.0633$) 1-year post-burn compared to pre-burn and post-burn.

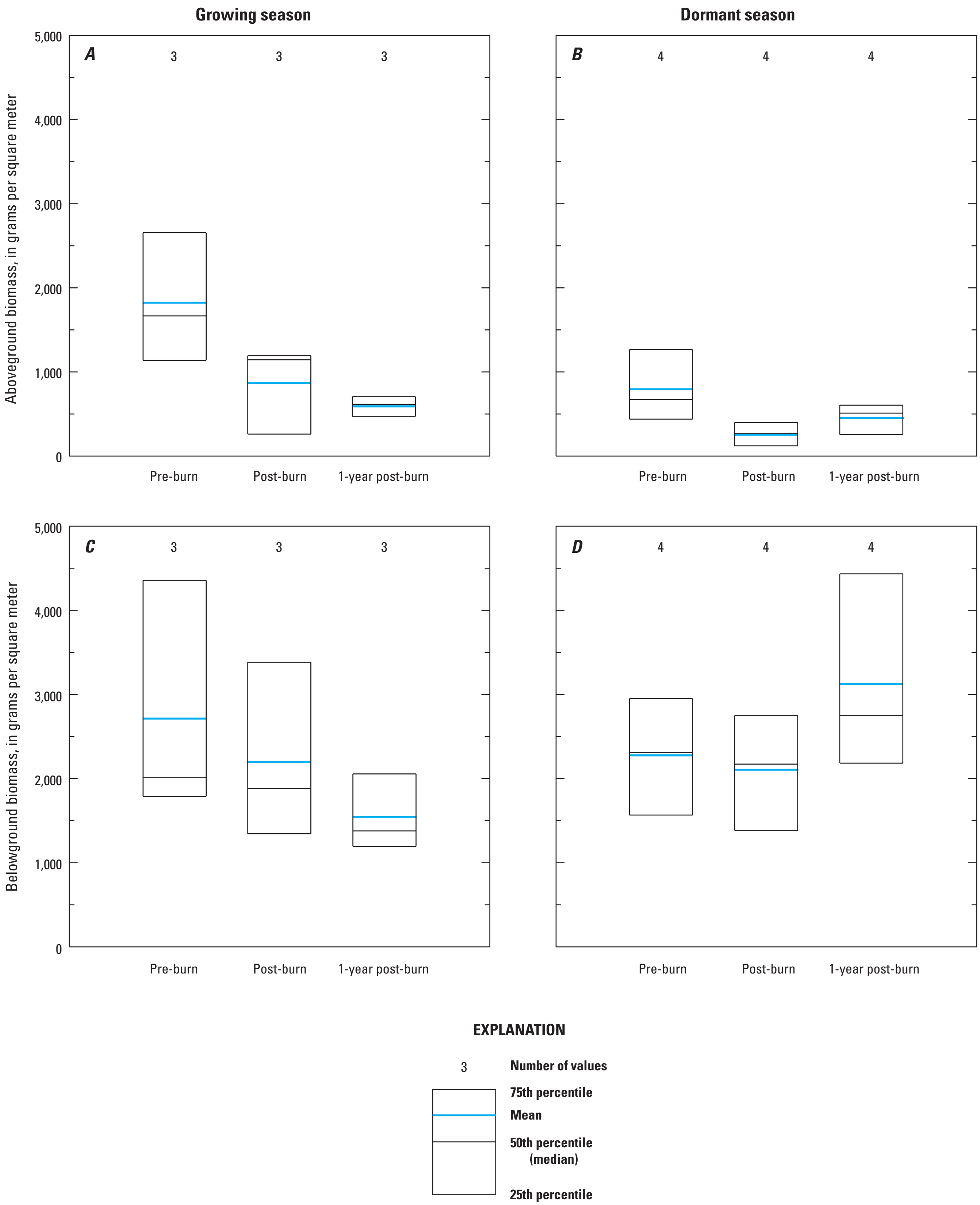

Figure 5. Total (live and dead) aboveground and belowground plant biomass for sites (excluding the Pumphouse site) burned during the (*A*, *C*) growing and (*B*, *D*) dormant seasons.

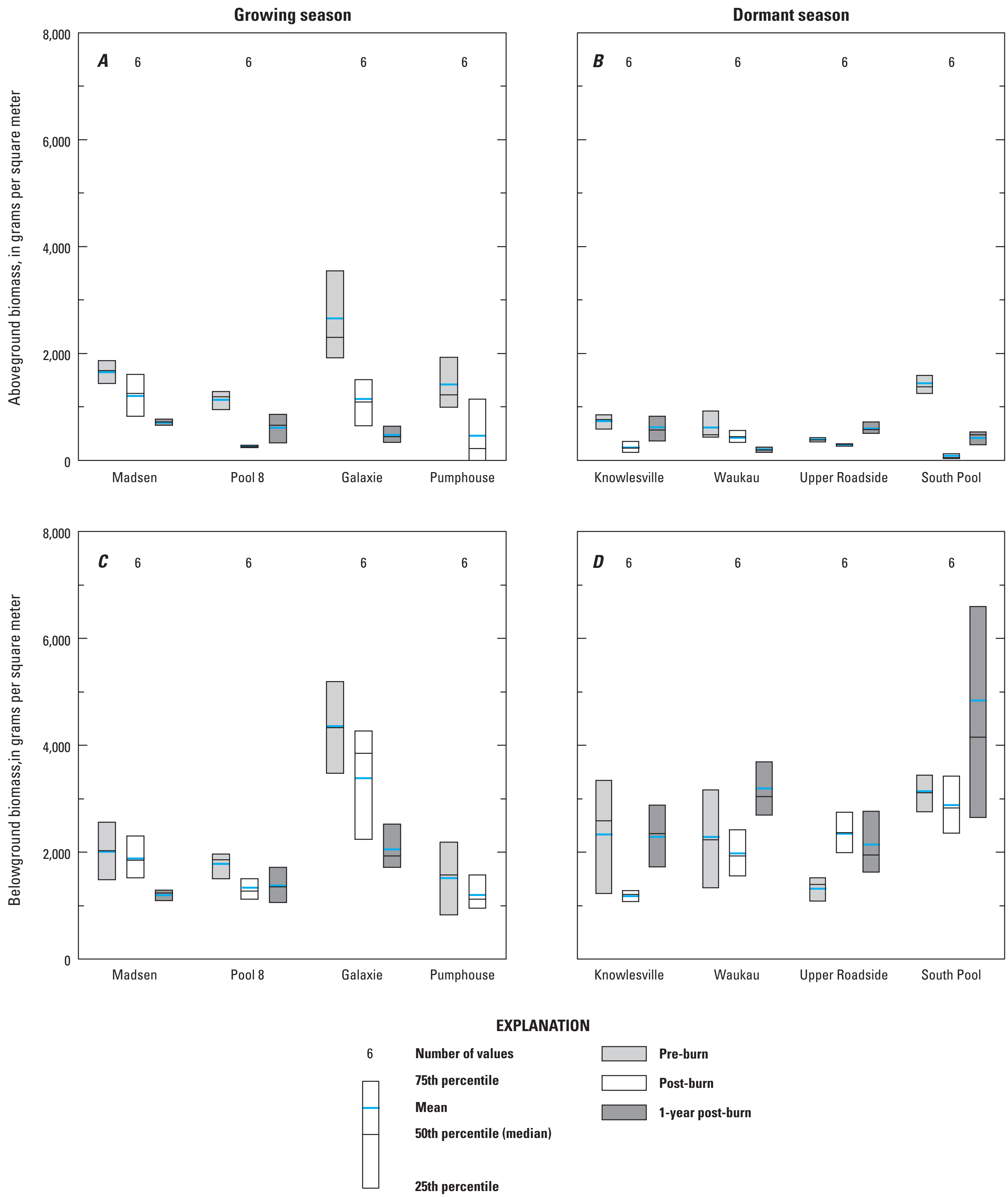

Figure 6. Total (live and dead) aboveground and belowground plant biomass for each study site that was successfully burned during the (*A*, *C*) growing and (*B*, *D*) dormant seasons.

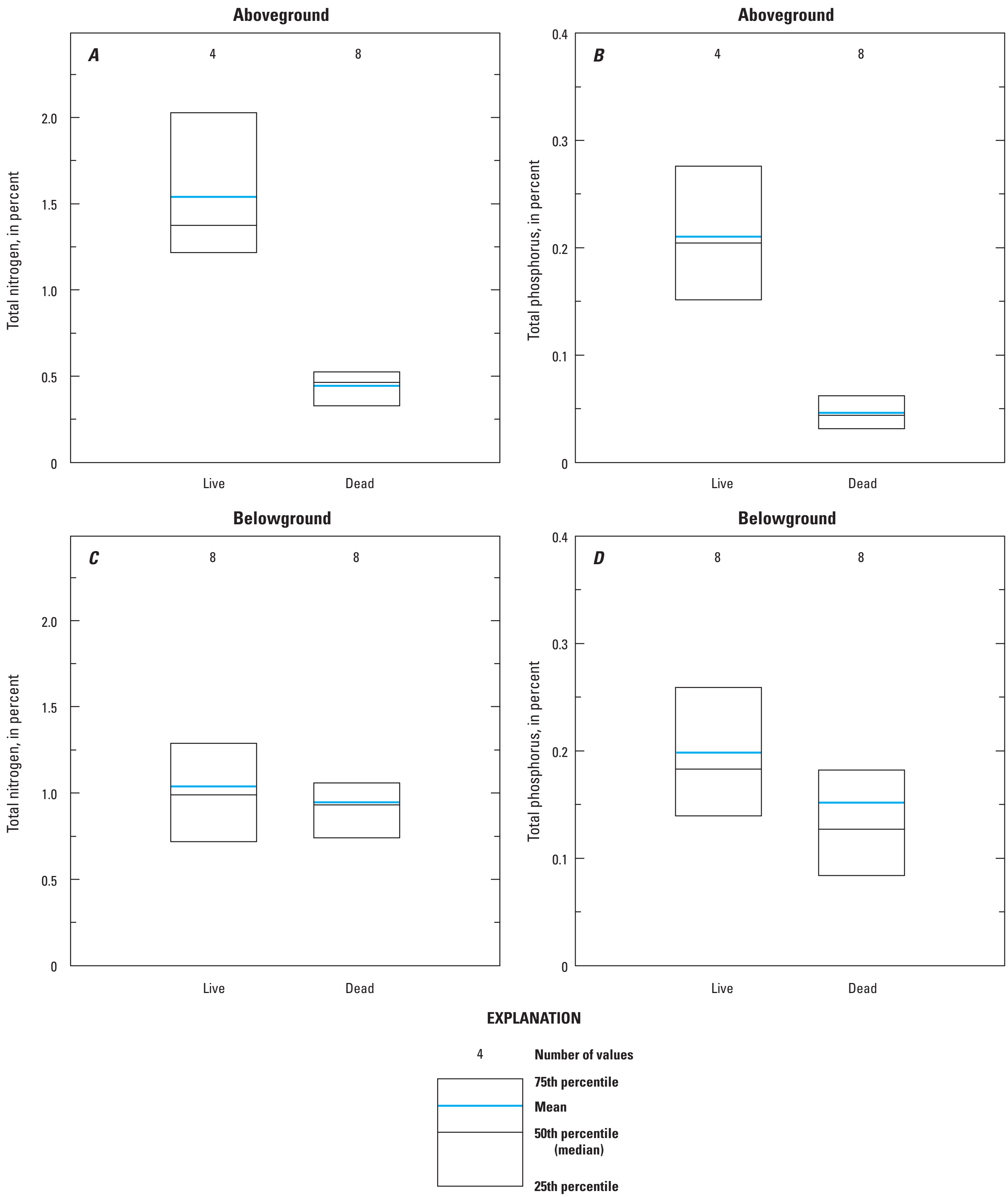

Figure 7. Total nitrogen and phosphorus from the pre-burn (*A*, *B*) aboveground and (*C*, *D*) belowground plant biomass samples.

Table 2. Mean (standard error [se]) percent of total nitrogen (TN), total phosphorus (TP), and total carbon (TC) from aboveground and belowground plant biomass (live and dead) samples from growing-season and dormant-season burns.

[Biomass samples were collected before and immediately and 1 year after implementation of prescribed fire. Bolded numbers differed significantly (p less than 0.1) by sample period (pre, post, 1-year post). --, no data]

Season	Stratum	Phase	Pre-burn						Post-burn						1-year post-burn					
			TN	se	TP	se	TC	se	TN	se	TP	se	TC	se	TN	se	TP	se	TC	se
Growing	Above	Live	1.54	0.23	0.21	0.03	44.25	0.61	1.25	0.39	0.19	0.04	44.47	0.75	1.24	0.18	0.15	0.03	44.32	0.53
		Dead	0.42	0.07	0.06	0.01	45.91	0.26	0.59	0.15	0.09	0.03	45.42	0.46	0.50	0.11	0.06	0.01	45.23	0.51
	Below	Live	1.08	0.24	**0.23**	0.04	41.68	1.43	1.05	0.31	**0.26**	0.05	41.84	1.50	0.78	0.21	**0.16**	0.05	41.50	1.96
		Dead	0.92	0.25	0.18	0.06	41.61	1.51	0.75	0.11	0.17	0.06	42.52	0.70	0.80	0.16	0.13	0.03	41.32	1.20
Dormant	Above	Live	--	--	--	--	--	--	--	--	--	--	--	--	0.33	0.01	0.02	0.00	46.91	0.14
		Dead	0.47	0.08	0.03	0.00	47.04	0.53	0.50	0.09	0.06	0.02	46.42	0.24	0.38	0.06	0.04	0.00	46.32	0.34
	Below	Live	1.00	0.13	0.16	0.01	43.15	0.35	0.99	0.11	0.16	0.01	42.49	0.57	0.82	0.05	0.14	0.01	42.75	0.69
		Dead	0.97	0.07	0.12	0.02	44.69	0.59	0.89	0.10	0.13	0.01	44.18	0.70	0.89	0.06	0.11	0.02	44.08	0.82

Table 3. Mean (se) mass (g/m²·cm) of total nitrogen (TN), total carbon (TC), total inorganic carbon (TIC), total organic carbon (TOC), sulfate (SO_4), nitrate (NO_3), ammonium (NH_4), and phosphorus (OP [Olsen]) from soil samples.

[Soils were collected from the O and A horizons of sites burned during the growing and dormant seasons; samples were collected before and immediately and 1 year after implementation of prescribed fire. Bolded numbers differed significantly (p less than 0.1) by sample period (pre, post, 1-year post). standard error, se; g, gram; m², square meter; cm, centimeter]

Season	Sample period	Soil horizon	TN	se	TC	se	TIC	se	TOC	se	SO_4	se	NO_3	se	NH_4	se	OP	se
Growing	Pre	O	66.96	13.06	725.39	150.26	1.76	0.75	723.63	150.39	25.41	13.45	0.09	0.04	**0.10**	0.01	0.09	0.04
	Post		71.33	17.51	715.17	165.75	2.95	1.97	712.23	165.27	29.11	18.16	0.10	0.02	**0.09**	0.01	0.07	0.02
	1-year post		56.08	9.95	644.32	126.30	0.45	0.20	643.87	126.29	16.78	9.85	0.09	0.02	**0.06**	0.01	0.06	0.02
	Pre	A	65.08	12.63	711.13	159.38	4.43	0.59	706.70	158.91	45.10	23.96	0.07	0.03	0.22	0.11	0.08	0.02
	Post		85.97	22.82	876.29	201.83	2.27	1.16	874.02	201.04	36.61	24.94	0.07	0.02	0.12	0.02	0.09	0.02
	1-year post		57.50	6.88	662.82	133.71	1.16	0.86	661.67	133.39	22.15	10.41	0.07	0.02	0.06	0.00	0.05	0.03
Dormant	Pre	O	53.65	3.29	677.73	54.86	2.47	2.15	675.25	53.37	0.72	0.23	0.16	0.06	0.08	0.02	0.11	0.04
	Post		54.77	6.64	657.41	103.78	2.92	2.52	654.48	102.65	1.03	0.17	0.15	0.05	0.07	0.01	0.17	0.07
	1-year post		49.81	5.89	585.19	86.29	0.40	0.23	584.80	86.08	2.21	1.27	0.20	0.14	0.04	0.01	0.09	0.04
	Pre	A	57.44	10.48	713.47	172.56	0.35	0.06	713.12	172.55	1.61	0.82	0.13	0.07	0.08	0.01	0.09	0.06
	Post		52.87	7.46	657.32	151.59	0.60	0.09	656.72	151.61	1.60	0.82	0.12	0.07	0.05	0.01	0.09	0.06
	1-year post		60.94	9.81	716.05	170.93	0.35	0.18	715.70	171.06	6.42	4.92	0.09	0.04	0.04	0.01	0.07	0.06

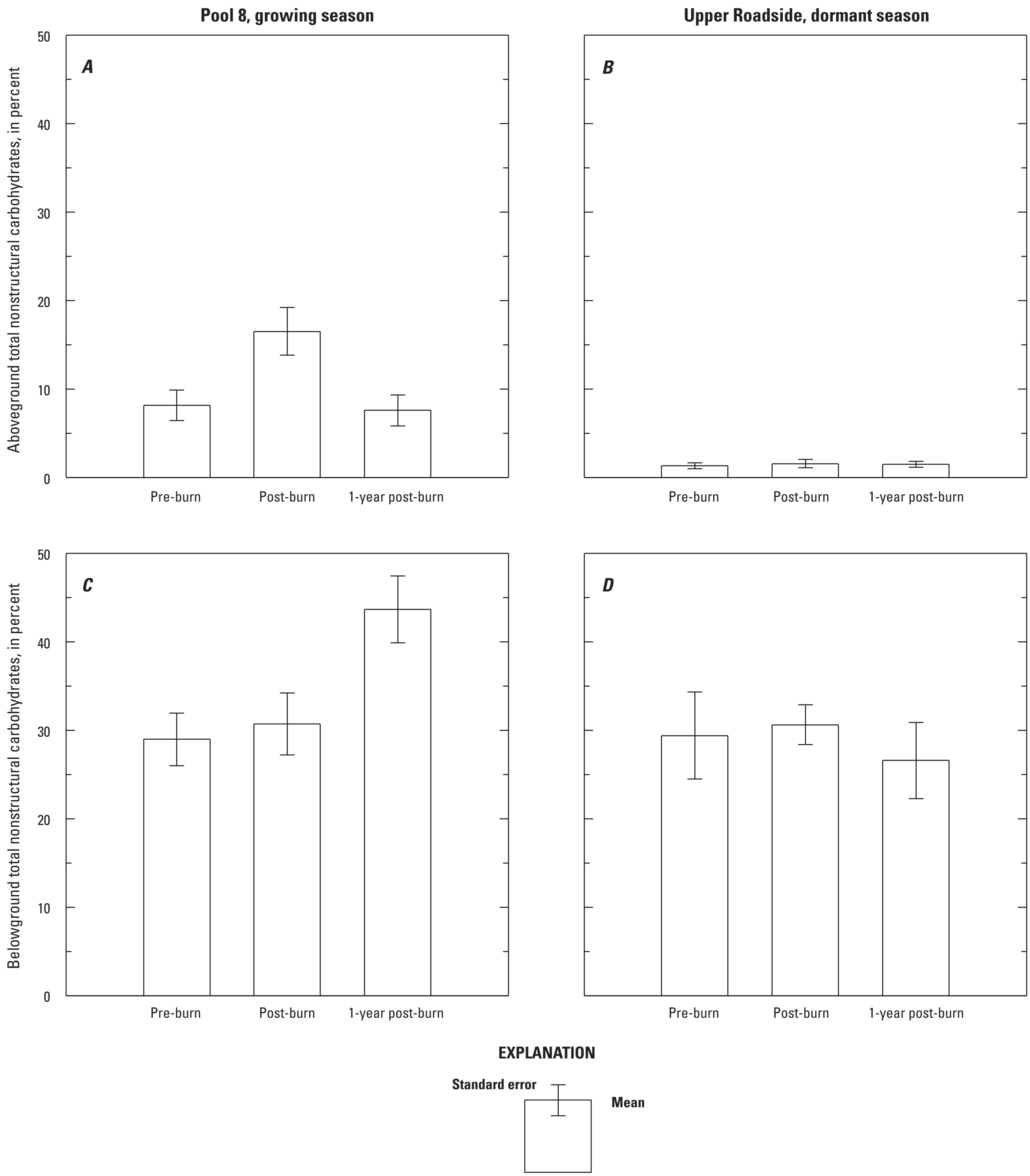

Figure 8. Mean percent total nonstructural carbohydrates (TNC) in aboveground and belowground vegetation (live and dead) for (*A*, *C*) one site burned during the growing season and (*B*, *D*) one site burned during the dormant season.

Summary

Although native to North America, cattail is considered invasive by many wetland managers where the species displaces native plant communities and forms extensive, dense monotypic stands that diminish habitat values for wildlife. Past recommendations to control cattail in managed wetlands commonly have included prescribed burns, herbicide application, or some method of mechanical disturbance (for example, mowing or disking) followed by flooding to levels above remaining stalks to prevent regrowth (see Linde and others, 1976; Sojda and Solberg, 1993). Unfortunately, such options are becoming increasingly difficult to implement because of several factors, including limitations in water availability and inadequate water-management infrastructure, which makes it virtually impossible to maintain flooded conditions for recommended periods to control cattail. Even if these techniques are successful, periodic drawdowns must eventually be performed to stimulate growth of desired plant species to provide the foods and structure required to support wetland-dependent wildlife. Given these limitations, it is essential that additional techniques be developed to assist managers in more reliably controlling cattails and simultaneously promoting the growth of desirable vegetation communities. Based on this premise, our study was a collaborative attempt with NWR managers to broaden existing perspectives on cattail control by evaluating differences in the efficacy of growing-season and dormant-season burns during drawdown conditions.

Similar to other studies (for example, Smith and Newman, 2001; Ponzio and others, 2004; Flores and others, 2011), this study demonstrated total cattail cover is immediately reduced after growing-season and dormant-season burns, but cattail cover readily recovered to pre-burn levels 1-year post-burn (figs. 3, 4) and the ratio of live to dead vegetative cover was greater 1-year post-burn. Collectively, these results indicate that controlled burns, regardless of timing, were effective at removing standing and accumulated litter, but also stimulated vigorous regrowth of cattail. This was not unexpected given that fire can expose bare substrates, increase light penetration to the soil surface, and potentially increase availability of certain nutrients, all of which can stimulate germination and regrowth of vegetation (Simpson and others, 1989). Results from this study indicate that concentrations of plant (table 2) and soil (table 3) nutrients did not change significantly from the pre-burn to 1-year post-burn periods, which suggests that a single fire may not greatly alter local nutrient pools within the first year after implementation.

In contrast to vegetative cover response, changes in aboveground and belowground biomass did indicate differences in the efficacy of growing-season and dormant-season burns. Specifically, aboveground and belowground vegetative biomass for sites burned during the growing season were significantly lower 1-year post-burn, whereas biomass estimates for sites burned during the dormant season were similar among the pre-burn, post-burn, and 1-year post-burn sample periods (figs. 5, 6). A basic premise of this study was that growing-season burns would affect aboveground energy stores and nutrient reserves before they are transferred to the rhizomes during late summer and fall, and subsequently used to promote plant growth for the following year. Study results indicate some support for this hypothesis because overall nutrient concentrations in the live aboveground biomass were greater compared to dead biomass (fig. 7), and the reduction in percent of TNC in aboveground biomass of a site burned during the growing season was higher (not tested statistically) than that of a site burned during the dormant season (fig. 8). Given the greater concentration of nutrients and nonstructural carbohydrates (sugars, starches, fructosans) associated with live biomass, growing-season burns likely impeded development of belowground rhizomes and contributed to findings of reduced aboveground cattail biomass 1-year post-burn. One confounding factor that affects interpretation of biomass results is that dry conditions (water below rhizomes) were maintained through the 1-year post-burn sample period for most of the growing-season burn sites, whereas greater precipitation led to wetter conditions 1-year post-burn in dormant-season burn sites (fig. 2). Hence, the decrease in vegetative biomass 1-year post-burn associated with growing-season sites likely reflects both effects of water stress to plants and fire on aboveground nutrients.

Results suggest that cattail appears to recover quickly after fire regardless of timing, but the aboveground biomass of plants burned during the growing season tends to be suppressed for at least 1 year following fire. This is consistent with other studies that report summer burns appear to be more effective than spring and fall burns at controlling cattail (Krusi and Wein, 1988). Although we were unable to separate the relative contribution of soil moisture and prescribed fire in this response, this information is still potentially useful to managers because growing-season burns may provide a short-term opportunity to stimulate growth and establishment of other plant species. The ability to exploit this opportunity largely will depend on water-management capabilities that facilitate drawdowns at appropriate times within the first growing season following fire. In addition, the literature suggests that repeating the same treatment or implementing a combination of treatments may result in greater effects to cattails (Nelson and Dietz, 1966; Murkin and Ward, 1980; Ball, 1990; Kostecke and others, 2004); therefore, growing-season burns may be more effective than dormant-season burns when used in combination with other treatments (for example, herbicides, grazing) because they appear to reduce aboveground biomass to a greater extent.

One of the most important lessons learned from this study is that manipulation and control of water levels is critical in order to implement prescribed burns during a pre-defined time period and also create suitable conditions to promote establishment of more desirable plant species post fire. Unfortunately, at three sites in this study it was not possible to sufficiently remove water and implement burns, and at four sites it was not possible to maintain dry conditions through the 1-year post-burn sample period, indicating that current (2012) water-management infrastructure is limited on many NWR wetlands. A common water-management issue encountered during this study was the inability to completely discharge water from wetlands, particularly during periods of heavy rain or with an above-average snow pack, because of lack of sufficient water-control structures or siting of existing structures at elevations above the surface of the impoundment. In addition, cattail production has accelerated accretion of organic sediments that has resulted in elevated substrates relative to existing water-control structures; increased substrate elevation and the ability of organic soils to retain soil moisture has further degraded the ability of managers to discharge water from impoundments. Thus, considerable investments will be needed to improve existing water-control structures and enhance the ability of wetland managers to manipulate water levels to the extent necessary to manage plant community composition.

Based on results from this and other studies, the response of cattail to prescribed burns is complex, and proper evaluation of the effects of controlled burns will likely require multi-year studies and long-term monitoring. Additionally, it is apparent that implementation of multiple control methods throughout a period of time will likely be most effective at controlling cattail. More complete understanding of effective cattail control is expected with studies that evaluate control methods such as prescribed burns, and investigate the integration of other methods, such as flooding and chemical and mechanical treatments that are executed at appropriate times relative to the autecology of cattail. Accomplishing these types of studies will require close collaboration between research and management personnel. As part of these efforts, communication regarding the types of management capabilities that exist on each site, as well as the constraints involved in implementing various management actions, will be key to designing studies that yield reliable results and are applicable to management.

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