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LONG-TERM ABUNDANCE OF BREEDING SONGBIRDS DURING RESTORATION OF NORTHERN MIXED-GRASS PRAIRIE

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Abstract: There are no published, long-term accounts of responses of grassland passerine birds to the restoration of northern mixed-grass prairie through combined use of fire and grazing. During 1979-2001, we assessed abundance of passerine birds (9 grassland species and 1 shrub-associate species) on 2 brush-invaded, mixed-grass prairie tracts at Lostwood National Wildlife Refuge in northwestern North Dakota. Each tract encompassed 90 ha (220 ac) that were being restored through 4 prescribed fires then 3 consecutive years of grazing by cattle. Fires were separated by 2-4 years of rest (i.e., nondisturbance) and grazing was initiated 2 years after the last fire. Among 3 initially common species of passerines, abundance of Savannah sparrow (*Passerculus sandwichensis*) changed little from the beginning to end of the burn-graze sequence, but numbers of common yellowthroat (*Geothlypis trichas*) and clay-colored sparrow (*Spizella pallida*) declined. Six species of passerines, including the endemic Sprague's pipit (*Anthus spragueii*) and Baird's sparrow (*Ammodramus bairdii*), were absent or rare before restoration began but increased after burning occurred. Increases in abundance were most evident during rest years after the third and fourth burns, particularly for grasshopper sparrow (*A. savannarum*) and Baird's sparrow. Almost no increases occurred after the first burn. Changed abundances coincided with a shift from shrub-dominated to grass-dominated vegetation along with a decrease in vegetation structure; grass cover increased from 45% to 84% and a visual obstruction index that reflected vegetation height and density declined from 1.2 to 0.8 dm (4.7 and 3.1 in, respectively). During grazing, species abundance appeared unchanged except Sprague's pipit was not observed 2 of 3 years, and Baird's sparrow and grasshopper sparrow became less common. Our case history study supports the idea that the species diversity of breeding grassland birds can increase and be maintained when a combination of recurrent fire and grazing is used to restore degraded native prairie in the eastern part of the northern mixed-grass prairie region.

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Key words: grassland birds, habitat management, Lostwood National Wildlife Refuge, northern Great Plains, prescribed fire, prescribed grazing, species diversity

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Land managers entrusted with conserving the biodiversity of northern prairies often seek to influence competitive abilities of target plant species by using prescribed fire or livestock grazing to emulate historic disturbance processes that native plants evolved with (Bragg and Steuter 1995, Samson et al. 2004). These management strategies influence abundances of some species of prairie wildlife. For example, diversity of grassland bird species may increase after fire is reintro-

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duced to northern mixed-grass prairie (Johnson 1997, Madden et al. 1999). Depending on the grazing system employed, livestock grazing may reduce abundances of some species or species groups of grassland birds, while increasing others (Kantrud 1981, Renken and Dinsmore 1987, Buskness et al. 2001). However, there are no published accounts of long-term trends in occurrence or abundance of grassland passerine birds during the restoration of northern mixed-grass prairie through combined fire and grazing treatments. In fact, only 1 long-term study of fire effects on passerine birds in northern mixed-grass prairie has been published; it focused on shifts in occurrence among shrub-associated and grassland species during 24 years of periodic fire in central North Dakota (Johnson 1997). Danley et al. (2004) tracked bird species abundance during 3 successive years of rotational grazing on mixed-grass prairie tracts that had been prescribe-burned 3-6 times in previous years, but they did not follow changes throughout the entire burning and grazing process of restoration.

Informed, effective management of prairies that have been set aside chiefly to provide bird nesting habitat will be increasingly critical as population levels of most species of grassland-dependent birds continue to decline steadily (Sauer et al. 2004, Brennan and Kuvlesky 2005). Our objective was to document trends in the relative abundance of breeding species of grassland passerines and concurrent changes in vegetation structure and life form composition during the first 23 years of restoration of 2 tracts of brush-invaded, northern mixed-grass prairie, through the use of recurrent fire followed by livestock grazing.

STUDY AREA

We documented bird abundance during restoration of mixed-grass prairie at Lostwood National Wildlife Refuge (LNWR), in Burke and Mountrail counties, northwestern North Dakota (about 48°37'N;102°27'W). LNWR covers 109 km^2 (42 mi^2) of rolling to hilly moraine. The refuge is 55% native prairie; 21% previously cropped fields now covered by varied mixtures of native and introduced herbaceous plants; 20% wetlands; 2% trees; and 2% tall shrubs (Murphy 1993). Historically, the native prairie was a needlegrass-wheatgrass (*Stipa-Agropyron*) association (Coupland 1950), but the prairie vegetation changed following extirpation of bison (*Bos bison*) circa 1870 and with the suppression of fire that began during Euro-American settlement in the early 1900s (Grant and Murphy 2005). During the late 1930s through early 1970s, the refuge prairie was grazed by cattle at light stocking rates (< 0.6 Animal Unit Months [AUM]/ha [< 0.3 AUM/ac]) from spring through early or late fall, or was rested from disturbance. By the 1980s, the prairie had become heavily invaded by woody species, especially western snowberry (*Symphoricarpos occidentalis*), a low-growing (< 1.5 m [< 5 ft]), native shrub, plus 2 introduced species of grass, smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*).

METHODS

To restore a flora dominated by native, herbaceous plants of many species, we reintroduced fire to the refuge during the late 1970s and added rotation grazing at moderate stocking rates in the late 1990s. During 1979-2001, we completed nearly identical, 23-year sequences of burning and grazing on 2 90-ha (220-ac) tracts while annually assessing bird abundance and general vegetation characteristics on each. The tracts were 2.4 km (1.5 mi) apart in the center of the refuge.

We planned to first reduce the dominance of woody vegetation by applying several prescribed fires that were timed to weaken such plants (Lauchbaugh and Owensby 1978). We typically conducted a burn in spring (May through early June) or late summer (mid-July through August), by setting a backfire, then flank fires, then a headfire. Burns were conducted with light to moderate winds (8-32 km/hr [5-20 mph]) and 25-50% relative humidity, and removed 90-99% of above-ground plant materials from uplands. We anticipated multiple burns would be needed to counteract resprouting by woody plants and deplete their below-ground carbohydrate reserves (Lauchbaugh and Owensby 1978). To accumulate plant litter as an important fuel for subsequent burning, we followed a burn with 1-3 years of rest, with the number of years depending on precipitation levels. After 4 burns were conducted,

the tracts were grazed by cattle for 3 consecutive years to stimulate nutrient cycling, slow litter accumulation, maintain a heterogeneous yet moderate structure, promote tillering among native cool-season grasses, and reduce the competitive ability of smooth brome. On both tracts we employed rotation grazing with a herd of cow-calf pairs. Each tract was divided into 3 equal-sized cells. Every year, each cell was grazed for 14 days, then 2 cells in each tract received a second grazing treatment for another 14 days, with 28 days of rest between grazing treatments. The grazing season was late May through mid-August (about 2.5 months). Stocking rates were 1.2 AUM/ha (0.5 AUM/ac), the rate recommended based on range condition and area soil types (Soil Conservation Service 1984).

We predicted that, by creating a grass-dominated plant community with structure that was more temporally dynamic and generally reduced (i.e., less litter, lower average plant height), our burn-graze restoration strategy would indirectly return the community of passerine species characteristic of upland, northern mixed-grass prairie. These species included Sprague's pipit (*Anthus spragueii*), common yellowthroat (*Geothlypis trichas*), clay-colored sparrow (*Spizella pallida*), grasshopper sparrow (*Ammodramus savannarum*), Baird's sparrow (*A. bairdii*), Savannah sparrow (*Passerculus sandwichensis*), vesper sparrow (*Pooecetes gramineus*), bobolink (*Dolichonyx oryzivorous*), western meadowlark (*Sturnella neglecta*), and brown-headed cowbird (*Molothrus ater*) (Stewart 1975:25). All but common yellowthroat are considered grassland species (Johnsgard 1978), but in North Dakota prairies the yellowthroat often is associated with upland, low shrub especially western snowberry (Stewart 1975:224). Horned lark (*Eremophila alpestris*) and chestnut-collared longspur (*Calcarius ornatus*) are characteristic too, but we anticipated that the very short, sparse vegetation structure they prefer would be temporally and spatially limited under the management regime we planned. Our rationale was that such sparse vegetation structure was available on many remnant prairies elsewhere in the northern mixed-grass prairie region, and that LNWR may better serve habitat needs of the region's grassland passerines by providing prairie of a relatively moderate physiognomy. Other passerine species characteristic of North Dakota's mixed-grass prairie are lark bunting (*Calomospiza melanocorys*) and red-winged blackbird *(Agelaius phoeniceus*)(Stewart 1975:25). Lark bunting is so nomadic we anticipated its occurrence would be sporadic. Red-winged blackbird mainly is associated with wetlands (Stewart 1975), which were excluded in our sampling.

We used a modified area-search method (Ralph et al. 1993) to count breeding birds in June by walking a permanent, 2.5-km (1.5-mi) long transect that followed a meandering circuit through each tract. All upland area on each tract was within 75 m (246 ft) of its respective transect. All species of grassland passerines can be detected within this distance on the refuge (Rotella et al. 1999). Walking slowly (about 2 km/hr [1 mph]), we tallied each indicated breeding pair of birds, which we defined as either a singing male or a pair of birds that exhibited nesting behavior such as threat calls or food carrying. Counts of brown-headed cowbird were of total individuals, regardless of sex; we divided totals by 2 for our summary analysis (Madden et al. 1999). A Sprague's pipit was tallied if its flight display was mostly or entirely over the count area. We were careful not to duplicate counts of individual birds. Surveys started at sunrise and took about 1.5 hr to complete, with winds < 15 km/hr (< 10 mph) and no precipitation. We personally conducted 87% of the surveys; others were conducted by 2 persons with expert knowledge of the local avifauna and survey method.

We applied either prescribed fire or cattle grazing to both tracts in roughly the same years. Thus, we considered the respective treatment years equivalent when we combined data from the 2 tracts. For prescribed burns, we classified treatment years for the combined data as (e.g.) B1, B2, B3, B4, i.e., for the first prescribed burn that was applied, second burn, and so forth. These years represented the count of birds in late spring following the year of a burn treatment; each count was separated by 1 growing season from a spring burn or, in the case of a summer burn, by nearly one-half of a growing season. We did not count birds during the same year a fire was applied

because we assumed that, in such years, breeding habitat was unavailable for the species of interest.

We considered grazing treatments differently. A grazing treatment encompassed 3 consecutive grazing seasons, during which time a given cell within a tract was grazed for a total of 56 days. We assumed that the most overt effects of grazing on bird abundance, if any, would occur the year after that in which grazing took place (and that effects over 3 years could be cumulative). Thus, we considered it a rest year when grazing was first introduced in late spring (i.e., just after birds had selected breeding territories) and considered the following year to be the first "grazing-effect" year. The year after the third (last) season of grazing was considered the third and final grazing effect year. This also was the last year of our study.

For each species, we plotted the average number and range of indicated pairs detected across the restoration sequence on the 2 tracts. To coarsely account for any substantial regional changes in annual abundance levels of the species of interest, we surveyed breeding birds each June across a prairie-and-farmland landscape 30 km southwest of LNWR. Birds were tallied at 25 3-min stops spaced every 0.8 km (0.5 mi) along a 39.4-km (24.5-mi) route established for the North American Breeding Bird Survey (BBS), using the standard protocol developed for the survey (Sauer et al. 2004). No marked changes in land use occurred along the route, but the height and density of herbaceous vegetation appeared to increase during years of relatively high precipitation after the early 1990s.

We also surveyed passerines on a third prairie tract at LNWR, which was about 1.6 km (1 mi) from the 2 burn-graze tracts and was similar in all general attributes except that it remained undisturbed through the years that the restoration tracts were being prescribe-burned. The tract was grazed by livestock during the same years and under the same prescription as the 2 burn-graze tracts we studied. On this "graze-only" tract, we counted birds in the first year and last year of our study.

We annually assessed vegetation structure on burn-graze tracts by using visual obstruction as an index of vegetation height and density (Robel et al. 1970). We recorded visual obstruction every 5 m (16 ft) along a 120-m (393-ft) long, permanent transect that traversed representative upland habitats across the center of each tract (n = 25 readings/tract). Along each transect, we also counted the number of visual obstruction readings at which grasses dominated the plant cover within 0.5 m (1.6 ft), to indicate general composition of the vegetation.

RESULTS

A year before we began to restore the 2 tracts of prairie with a series of prescribed burns, the passerine community was characterized by 3 species with > 20 indicated pairs each: common yellowthroat, Savannah sparrow, and clay-colored sparrow (Fig. 1). Abundance of common yellowthroat and clay-colored sparrow appeared to have decreased by the end of the burning sequence. What seemed to be changed abundance of Savannah sparrow probably related more to a shift in the species' local population level, based on a nearby BBS route (Fig. 1).

Six species of grassland birds were absent or rare before restoration began, but their abundances were elevated most rest years after the second through fourth prescribed burns: Sprague's pipit, vesper sparrow, and western meadowlark became evident (each, up to 6-10 indicated pairs); bobolink changed from uncommon to common (> 10 indicated pairs); and grasshopper sparrow and Baird's sparrow appeared and thereafter were common most years. Increases in abundance were most apparent after the third burn, particularly for grasshopper sparrow and Baird's sparrow, whereas almost no increases occurred after the first burn. Although we did not count birds the same year that a prescribed burn occurred, abundance of some species declined the year after a spring or summer burn (i.e., with a full or half growing season following the burn), especially those of bobolink and Baird's sparrow (Fig. 1).

The net increase in abundance of 6 species that we observed during years of prescribed burning coincided with a shift from shrub-dominated to grass-dominated vegetation along with a concurrent decrease in vegetation structure (Fig. 2). From before to after the burning sequence, grass

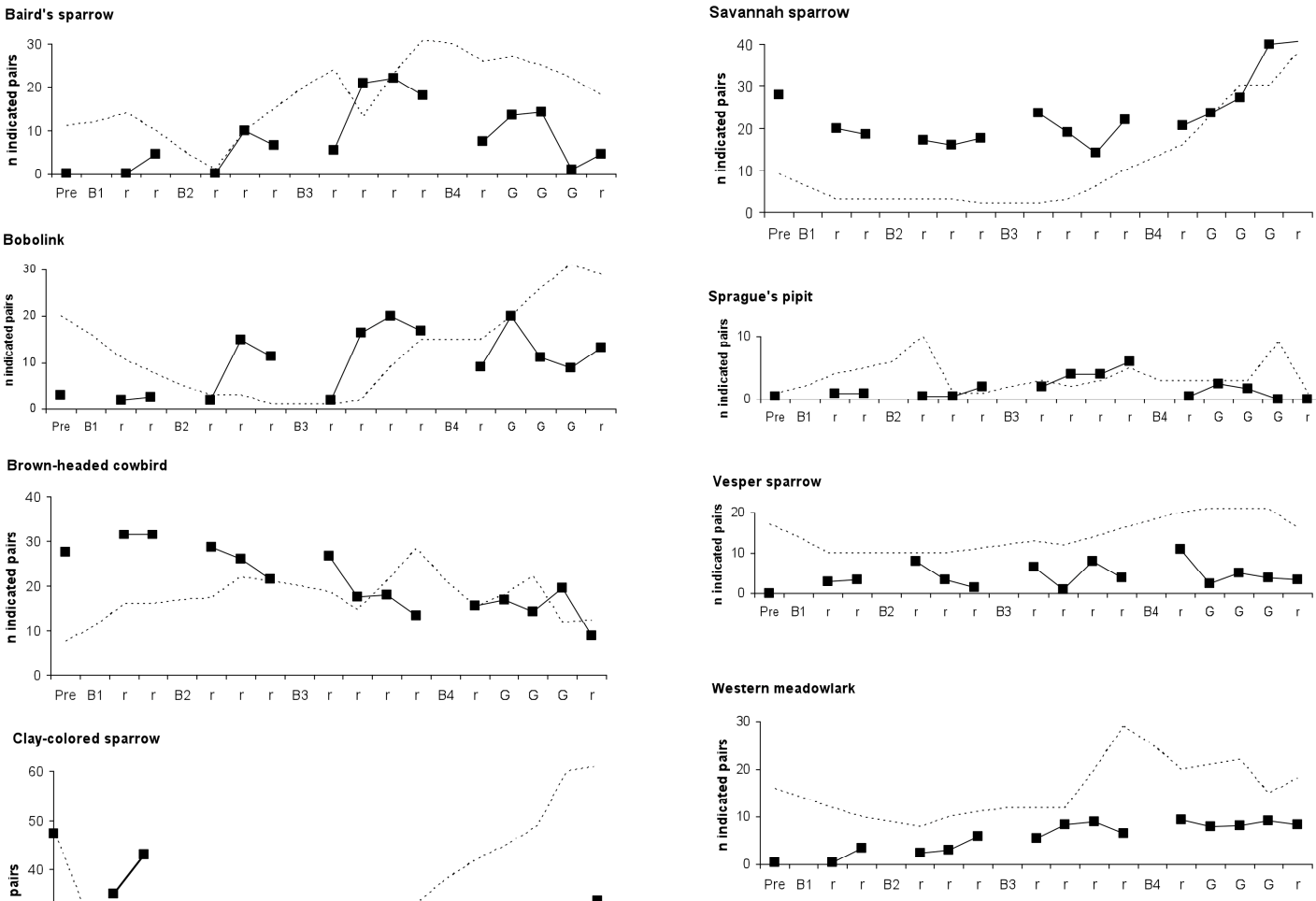

Fig. 1. Responses in abundance of 10 breeding species of passerine birds during the restoration of 2 90-ha (220-ac), brush-invaded tracts of northern mixed-grass prairie at Lostwood National Wildlife Refuge in northwestern North Dakota during 1979-2001, as measured by a modified area search. Abundance, indicated by black squares, is expressed as the number of indicated breeding pairs detected based mainly on counts of singing male birds. The year of each prescribed burn, conducted during spring (May through early June) or summer (mid-July through August), is indicated by "B" (e.g., B1 = first prescribed burn, B2 = second, and so forth). The year of each of 3 consecutive seasons of rotation grazing (June through mid-August) is indicated by "G." Years of rest (i.e., nondisturbance) are indicated by "r." Birds were not surveyed in the same year that a prescribed burn was conducted. The post-burn year of rest represented either half of a growing season since the previous burn (i.e., birds were counted in June following a burn the previous summer), or a full growing season (i.e., birds counted a full year after a burn the previous spring). A dashed line indicates abundance trends of respective species on a 39.4-km (24.5-mile) survey route about 30 km southwest of the refuge; the scale for the trend in western meadowlark abundance was reduced by a factor of 7 to fit the figure.

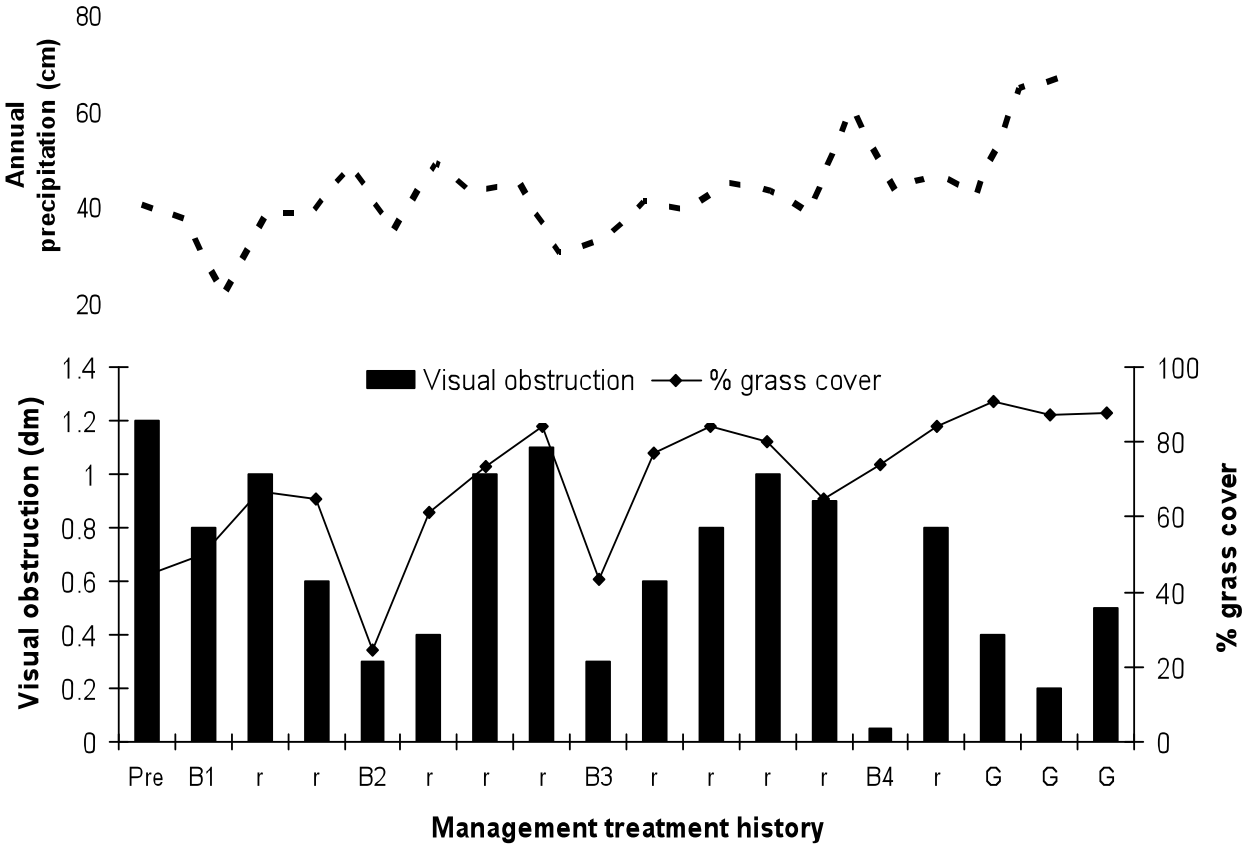

Fig. 2. Variation in the general structure and composition of vegetation on 2 90-ha (220-ac), brush-invaded tracts of northern mixed-grass prairie at Lostwood National Wildlife Refuge in northwestern North Dakota, while the tracts were being restored by prescribed fire and livestock grazing during 1979-2001. Included is the concurrent trend in annual precipitation (United States Fish and Wildlife Service, Kenmare, North Dakota, unpublished weather station data), as vegetation structure and composition in a given year may be strongly influenced by precipitation during 1-2 previous years. The year of each prescribed burn, conducted during spring (May through early June) or summer (mid-July through August), is indicated by "B" (e.g., B1 = first prescribed burn, B2=second, and so forth). Each of 3 consecutive seasons of rotation grazing (June through mid-August) is indicated by "G." Years of rest (i.e., nondisturbance) are indicated by "r." Visual obstruction was used a measure of vegetation height and density (Robel et al. 1970). Percentage grass cover was based on the proportion of visual obstruction readings at which grass-dominated vegetation was observed. Vegetation data were unavailable for the final year of rest.

cover increased from 45% to 84% and visual obstruction declined from 1.2 dm to 0.8 dm (4.7 in and 3.1 in, respectively).

During grazing years, species abundance appeared unchanged except Sprague's pipit was not observed 2 of 3 years, and Baird's sparrow and grasshopper sparrow became less common (Fig. 1). We attributed an apparent decline in abundance of brown-headed cowbird to a like change in the species' population level in the wider area. Too few pipits were detected annually on the nearby BBS route to provide a reference for area population trend.

Vegetation structure declined during grazing despite relatively high levels of precipitation and was lower towards the end of the restoration sequence than it was before restoration began (Fig. 2). Vegetation cover remained heavily dominated by grasses during grazing (Fig. 2).

Two passerine species characteristic of northern mixed-grass prairie that use very short, sparse vegetation were detected during the study. We observed 1 to several horned larks on 1 or both of the 2 burn-graze tracts each year of the study. Chestnut-collared longspur (1 territorial male) was observed only during the grazing treatment phase. We detected many other bird species on the tracts incidental to our work (Appendix A), but these generally were rare.

At the start of our study (1979), a year before any restoration was initiated, makeup of the bird community on the burn-graze tracts was similar to that on a nearby graze-only tract. Species characteristic of both types included common yellowthroat, clay-colored sparrow, and Savannah sparrow (Fig. 3). Other species of interest were absent or nearly so except for bobolink and brown-headed cowbird. Species makeup changed little on the graze-only tract by the end of our study (i.e., 1 year after grazing), except abundance of common yellowthroat appeared to have increased (Fig. 3). This compares to increased evenness among species of interest on burn-graze tracts, i.e., abundance of 2 initially common species declined while abundance increased among 5 species that initially were absent or rare.

DISCUSSION

Fire, Grazing, and Bird Species Diversity

We observed increases in the diversity and abundance of breeding species of passerines characteristic of northern mixed-grass prairie during a 23-year sequence of burning and grazing treatments that were implemented to restore 2 brush-invaded tracts of prairie in northwestern North Dakota. Ours may be the first such case history. The only other long-term study of trends in abundance of passerines during restoration of northern mixed-grass prairie focused on the relationship between species abundance and years since prescribed burning (Johnson 1997). To examine relationships between occurrence or abundance levels of passerines and restoration of northern mixed-grass prairie via prescribed fire or fire and grazing, others have used a "snapshot" approach to document birds across multiple treatment histories at 1 point in time.

Trends in abundance of birds that we observed during successive prescribed burns over many years corroborate findings in such a snapshot at LNWR by Madden et al. (1999). They assessed bird abundance across prairie tracts of various fire histories that ranged from no fire for > 80 years to 4 fires in the previous 15 years. In their study, most species of mixed-grass prairie passerines were rare or absent on tracts that lacked fire but occurred on tracts that had been prescribe-burned, and species abundance generally increased with the number of burns that had occurred. They found positive relationships between fire and abundances for nearly the same suite of bird species that we

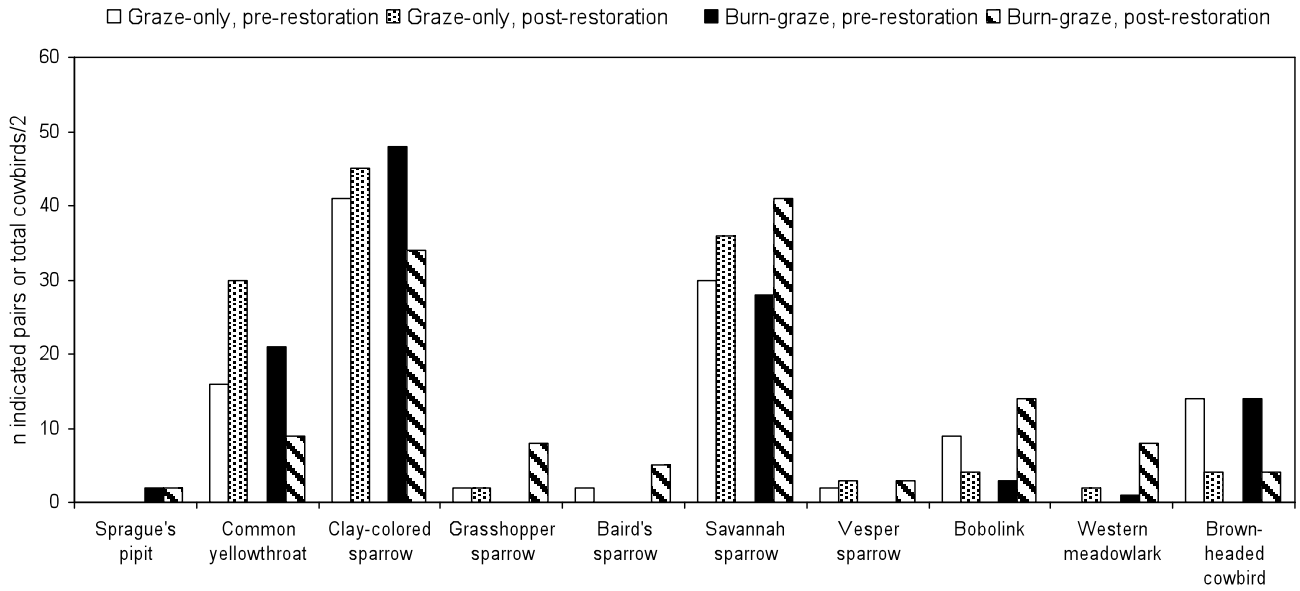

Fig. 3. Relative abundances of 10 species of passerine birds on 1) a 90-ha (22-ac) tract of northern mixed-grass prairie that was rested (i.e., undisturbed) for 18 years then grazed by livestock for 3 consecutive years, and 2) on 2 nearby, 90-ha (220-ac) tracts of mixed-grass prairie that were prescribe-burned 4 times then grazed by livestock during the same years as the graze-only tract. Abundance for burn-graze tracts was averaged. Abundance is presented for 1979, the year before prescribed burning began ("pre-restoration"), and for 2001, the year after grazing ended ("post-restoration"), at Lostwood National Wildlife Refuge in northwestern North Dakota.

initially found to be absent or rare but that increased with fire. During Johnson's (1997) long term study, grasshopper sparrow, Savannah sparrow, bobolink, and western meadowlark were common 2-5 years after burning occurred. Just as in Madden et al. (1999), common yellowthroat and clay-colored sparrow were most abundant on unburned areas (Johnson 1997). In a study of bird-fire relationships in northern mixed-grass prairie 30 km northeast of LNWR, occurrence and abundance of grassland passerines were not strongly affected by fire history (Ludwick and Murphy 2006). Despite prescribed burning, Baird's sparrow remained rare and Sprague's pipit was absent, results that were attributed in part to a pervasive influence of smooth brome on vegetation structure across fire history levels. Other studies of bird-fire relationships in northern mixed-grass prairie have been based on responses to single fires and generally demonstrated that abundance declines 1-2 years after burning, then increases (Huber and Steuter 1984, Pylypec 1991).

The only study that relates passerine abundance to restoration via prescribed burning and grazing in northern mixed-grass prairie is that by Danley et al. (2004), which occurred at LNWR but was independent of ours. They tracked bird species abundance during 3 successive years of rotational grazing on mixed-grass prairie tracts that had been prescribe-burned 3-6 times in previous years, but did not follow changes throughout the entire burning and grazing process of restoration. Makeup of breeding species changed little during grazing except that brown-headed cowbird occurred more frequently on the burned-grazed tracts than on tracts that had been burned but not grazed, probably because the species typically associates with cattle (Lowther 1993). In our study, abundance of brown-headed cowbirds seemed unchanged during grazing that followed several prescribed fires. Danley et al. (2004) also found that the abundance of individual species of birds generally resembled a post-fire response by decreasing the first year of grazing then increasing in the following 2 years of grazing. This pattern was not consistently apparent during grazing in our study, in nearly identical years on the same area. Instead, Baird's sparrow abundance decreased, Sprague's pipit became difficult to find, and abundances of other species appeared unchanged. These dissimilarities may be attributed partly to differences in grazing pressure between the 2 studies. In both, initial stocking rates were 1.2 AUM/ha (0.5 AUM/ac). This rate was reduced by 33% in the second and third years in Danley et al. (2004) but was unchanged among grazing years in our study.

Relationships Between Birds and Vegetation

Based on current knowledge of species-habitat relationships, changes in abundance we observed for most species related predictably to the coinciding transition from shrub- to grass-dominated prairie and decreasing vegetation structure that occurred with successive burning treatments and that continued, at least for structure, during grazing. Abundance of common yellowthroat and clay-colored sparrow declined as grass cover increased (conversely, as shrub cover decreased), as could be expected for these shrub-associated species (Knapton 1994, Guzy and Ritchison 1999). Both species associate with western snowberry in North Dakota, especially the sparrow (Stewart 1975). However, data from LNWR suggest clay-colored sparrow can remain quite common when snowberry and other low shrub species make up as little as 3-20% of plant cover (Madden et al. 2000).

We observed little change in abundance of Savannah sparrow. The species is relatively generalized in its use of grassland habitat and, in an earlier study at LNWR, occurrence of the sparrow was difficult to predict based on vegetation attributes (Madden et al. 2000). Brown-headed cowbird can use many habitat types and its abundance probably relates more to that of the brood parasite's many potential host species rather than to habitat structure and composition (Lowther 1993).

Among less common species, apparent increases in abundance of grasshopper sparrow and bobolink on burn-graze tracts likely related to increased grass cover, but also to changes in grass species composition not measured by us. Madden et al. (1999) found that occurrences of the 2 species related positively to increases in relatively wide-leaved, introduced grass species especially smooth brome, which increased with fire history. Although

we did not measure plant species composition during our study, smooth brome was invading stands of western snowberry before restoration was initiated and its cover seemed to steadily increase during the restoration period, both on burn-graze tracts and on the graze-only tract. The appearance and increase of Baird's sparrow on burn-graze tracts also coincided with expanding grass cover. Abundance of the sparrow is positively related to the percentage of grass cover, especially native grass species (Madden et al. 2000). Conversely, Baird's sparrow avoids brushy areas. Probability of occurrence of the species is 50% when grass cover is about 42%, the approximate level at the beginning of our study, and continues to increase with greater grass cover (Madden et al. 2000).

Sprague's pipit is sensitive to vegetation height-density and prefers shorter, sparser vegetation than generally was available on burn-graze tracts during our study. Probability of occurrence reaches 50% when visual obstruction is about 0.8 dm but drops rapidly with increased visual obstruction (Madden et al. 2000). Several pipits occurred annually after initial burning treatments in our study, when structure of some of the vegetation apparently was becoming suitable. However, we were unable to find Sprague's pipit on burn-graze tracts after the second year of grazing. During a concurrent study at LNWR, Sprague's pipit remained relatively common during grazing of prescribe-burned prairie (Danley et al. 2004). We may have overlooked some Sprague's pipits because we only counted birds once each year, generally in mid-June when territorial activity of male pipits often subsides (Robbins and Dale 1999).

MANAGEMENT IMPLICATIONS

Our case history shows that a diverse community of indigenous, breeding passerines will develop when multiple prescribed burns and grazing are applied to restore degraded northern mixed-grass prairie. Shifts in evenness of species mostly occur after the third or fourth burns. Our example also supports the contention of Danley et al. (2004) that grazing may extend fire-mediated structural attributes of vegetation to continue to support a relatively high diversity of breeding grassland bird species. While our case history may be unique, it is limited in scale, scope, and rigor. Clearly, study of effects of a combined fire and grazing regime in northern mixed-grass prairie should include replication, random treatment and control assignment, and a more extensive post-grazing component, although such studies may be inordinately expensive. Ours represents only the beginning of what may be a 50- to 60-year restoration sequence. Our example probably is germane only to prairies that still are dominated by native plant species (i.e., not overwhelmingly dominated by cool-season, introduced grasses, as those in Murphy and Grant [2005]), and only to those in the eastern part of the northern mixed-grass prairie where, historically, fires occurred roughly every 5 years (Bragg 1995).

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APPENDIX: Table

Appendix Table. 1. Species of breeding birds detected during restoration on 2 90-ha (220-ac) brush-invaded tracts of northern mixed-grass prairie at Lostwood National Wildlife Refuge northwestern North Dakota, 1979-2001. Excludes waterfowl and gamebirds (Anseriformes, Galliformes).

Common Name	Scientific Name
American goldfinch	*Carduelis tristis*
Baird's sparrow	*Ammodramus bairdii*
Baltimore oriole	*Icterus galbula*
Bank swallow	*Riparia riparia*
Barn swallow	*Hirundo rustica*
Black-billed cuckoo	*Coccyzus erythropthalmus*
Black-billed magpie	*Pica pica*
Bobolink	*Dolichonyx oryzivorus*
Brewer's blackbird	*Euphagus cyanocephalus*
Brown thrasher	*Toxostoma rufum*
Brown-headed cowbird	*Molothrus ater*
Cedar waxwing	*Bombycilla cedrorum*
Chestnut-collared longspur	*Calcarius ornatus*
Clay-colored sparrow	*Spizella pallida*
Common grackle	*Quiscalus quiscula*
Common yellowthroat	*Geothlypis trichas*
Eastern kingbird	*Tyrannus tyrannus*
European starling	*Sturnus vulgaris*
Grasshopper sparrow	*Ammodramus savannarum*
Gray catbird	*Dumetella carolinensis*
Horned lark	*Eremophila alpestris*
House wren	*Troglodytes aedon*
Killdeer	*Charadrius vociferus*
Lark bunting	*Calamospiza melanocorys*
Least flycatcher	*Empidonax minimus*
LeConte's sparrow	*Ammodramus leconteii*
Marbled godwit	*Limosa fedoa*
Morning dove	*Zenaida macroura*
Nelson's sharp-tailed sparrow	*Ammodramus nelsonii*
Orchard oriole	*Icterus spurius*
Savannah sparrow	*Passerculus sandwichensis*
Sedge wren	*Cistothorus platensis*
Song sparrow	*Melospiza melodia*
Sprague's pipit	*Anthus spragueii*
Tree swallow	*Tachycineta bicolor*
Upland sandpiper	*Bartramia longicauda*
Vesper sparrow	*Pooecetes gramineus*
Warbling vireo	*Vireo gilvus*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Sturnella neglecta*
Willet	*Catoptrophorus semipalmatus*
Willow flycatcher	*Empidonax traillii*
Wilson's snipe	*Gallinago gallinago*
Yellow warbler	*Dendroica petechia*
Yellow-shafted flicker	*Colaptes auratus*

APPENDIX: Illustrations

Appendix Fig. 1. Invasion of the Lostwood National Wildlife Refuge in northwestern North Dakota by woody plants, especially western snowberry, *Symphoricarpos occidentalis*, as shown here.

Appendix Fig. 2. Fires in the area of Lostwood National Wildlife Refuge were suppressed with Euro-American settlement in the early 1900s in northwestern North Dakota. The prairie was only lightly grazed or undisturbed for about 50 years after the refuge was established in 1935. However, recurrent fire was restored to most of the refuge by the mid-1990s, such as this area.