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PREDICTED RESPONSES OF SMALL MAMMALS TO REINTRODUCTION OF FIRE ALONG A NORTHERN PRAIRIE RIVER VALLEY

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Abstract: Fire is being reintroduced to restore native mixed-grass prairie that has been invaded by woody vegetation and introduced species of grasses at 8000-ha (20,000-ac) Des Lacs National Wildlife Refuge (NWR) in northwestern North Dakota. Implications of this management for much of the local fauna are merely speculative without basic inventory data. We measured the occurrence and habitat relationships of small mammals (< 450 g [< 1 lb]) in prairie and woodland on the refuge. Using snap-traps, we captured 7 mammal species on 42 75-m (245-ft) radius plots in prairie during summer 1998 (*n* = 193 individuals in 5,208 trap-nights) and 5 species on 32 11-m (36-ft) radius plots in woodland during summer 2000 (*n* = 289 individuals in 2,560 trap-nights). We found 13-lined ground squirrel (*Spermophilus tridecemlineatus*) and western jumping mouse (*Zapus princeps*) almost exclusively in open prairie and southern red-backed vole (*Clethrionomys gapperi*) almost exclusively in woodland. Based on logistic regression analysis, occurrence of 13-lined ground squirrel related inversely to vegetation height, which generally decreases in northern mixed-grass prairie when recurrent fire is returned. Reintroduction of fire likely will expand the local distribution of 13-lined ground squirrel and western jumping mouse while decreasing that of southern red-backed vole.

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Key words: 13-lined ground squirrel, *Clethrionomys gapperi*, habitat management, masked shrew, mixed-grass prairie, northern Great Plains, *Sorex cinereus*, southern red-backed vole, species diversity, *Spermophilus tridecemlineatus*, western jumping mouse, woodland, *Zapus princeps*

The Des Lacs River originates in southeastern Saskatchewan and extends about 100 km (63 mi) into northwestern North Dakota before joining the Souris River. Vegetation of the river valley was mixed-grass prairie prior to Euro-American settlement in the early 1900s, but has changed markedly since. Nearly all the prairie was converted to annually tilled land, except for a 0.2- to 2-km (0.1- to 1.3-mi) wide band of prairie that remained along either side of the river. Additional

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prairie was lost to woodland expansion when a pattern of recurrent disturbances ended with the extirpation of bison (*Bos bison*) circa 1870 and the suppression of fire accompanying settlement (Grant and Murphy 2005). Nearly half the extant prairie of the Des Lacs River valley is on Des Lacs National Wildlife Refuge (NWR). Thus, the refuge presents an opportunity for preserving native prairie and its associated fauna.

The distribution and abundance of many contemporary vertebrate species are undocumented on the refuge and surrounding region. Thus, it is unclear how the fauna will respond to the reintroduction of fire to the refuge and the consequent expansion of native prairie. Most information on effects of fire on wildlife and wildlife habitats in northern mixed-grass prairie is anecdotal and unreliable, or is weakly inferred from different grassland ecosystems, especially tallgrass prairie. To plan and measure the effectiveness of such habitat management efforts on NWRs, inventories of fish, wildlife, and plants are required, per a recent congressional act (Gergely et al. 2000). Our goal was to coarsely predict influences of fire reintroduction on small mammals (< 450 g [< 1 lb]) at Des Lacs NWR. Specific objectives were to: 1) quantify occurrences of small mammals across prairie and invading woodland habitats, which we expected to increase and decrease, respectively, with recurrent fire, and 2) assess whether the distribution and abundance of small mammals in prairie related to vegetation structure and composition.

STUDY AREA

Des Lacs NWR is a 42-km (26-mi) long riverine tract that encompasses 7900 ha (19,500 ac) of the Des Lacs River valley in northwestern North Dakota (about 48°48' N; 102°07' W). Refuge boundaries include about 2200 ha (5435 ac) of native prairie on the Drift Plain, a major physiographic subregion (Bluemle 1991). Historically, this level to slightly rolling "drift prairie" was within the needlegrass-wheatgrass (*Stipa-Agropyron*) association of the northern Great Plains (Coupland 1950). However, the contemporary drift prairie is dominated by 2 native species of low (< 1.5 m [< 5 ft]) shrub, western snowberry (*Symphoricarpos occidentalis*) and silverberry (*Elaeagnus commutata*), plus 2 introduced grass species, smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) (Murphy and Grant 2005). Relatively low areas of drift prairie typically are interspersed with meadow vegetation, such as fowl bluegrass (*Poa palustris*) and Baltic rush (*Juncus balticus*). Woodland generally extends into the prairie from north- to east-facing slopes of the Des Lacs River valley and is dominated by green ash (*Fraxinus pennsylvanica*) with an understory principally of chokecherry (*Prunus virginiana*) and green ash saplings (Nenneman et al. 2003).

METHODS

We surveyed small mammals in drift prairie that was undisturbed during the year before our study (1997). During the 2-3 previous years (1994-1996), however, roughly one-third had been burned (once), one-third had been grazed by livestock (1.5-1.8 Animal Unit Months/ha [0.6-0.7/ac]), and one-third had not been disturbed. We expected this mixed, recent history of disturbance to afford a broad range of vegetation structure and composition that was ideal for our analysis of species-habitat relationships. Light grazing and nondisturbance characterized the drift prairie during previous decades (Murphy and Grant 2005).

We used a random-systematic approach similar to that of Madden et al. (2000) to distribute 42 75-m (245-ft) radius, circular plots in drift prairie. Plots were at least 125 m (410 feet) from edges of woodland and other non-prairie habitat. At each plot we used 13 standard mouse traps, 13 Museum Special® traps, and 5 rat traps (Woodstream Corporation, Lititz, Pennsylvania). We placed a standard mouse trap and a Museum Special® trap at the plot center and at 25-m (82-ft) intervals along 4 75-m (245-ft) transects that emanated from the plot center, 90° apart. We used standard mouse traps in conjunction with Museum Special® traps in the drift prairie because, while slightly less effective, the standard traps have a reduced level of accidental release in windy and rainy conditions (Wiener and Smith 1972), which commonly occur in open grassland. A rat trap was placed at the plot center and at the end of each transect. We trapped each plot for 4 days during 19 June-9 July and 17-29 July, 1998 (total, 52 trap-nights with each of mouse traps and Museum Special® traps, and 20 trap-nights with rat traps). In woodland, we surveyed mammals on 32 11-m (36-ft) radius, circular plots that were randomly established by Nenneman et al. (2003). We used smaller plots in woodland than in drift prairie because we anticipated greater capture rates in woodland due to its more diverse habitat structure. Plots averaged only 22 m (72 ft) from woodland-prairie edges, and 8 (25%) bordered the edges. At each plot we used 8 Museum Special® traps and 2 rat traps. A Museum Special® trap was placed at 5 m (16 ft) and another at 10 m (33 ft) from the plot center along 4 10-m (33-ft) transects, 90° apart. A rat trap was placed at the end of each of 2 opposing transects. We trapped each plot for 4 days during 1-10 June and 20-30 June 2000 (total, 64 trap-nights with Museum Special® traps and 16 trap-nights with rat traps). We baited traps with peanut butter and rolled oats and checked them daily. Specimens were collected and frozen. Mammalogists at the University of North Dakota identified each specimen via standard keys (Wiehe 1978, Junge and Hoffman 1981). Specimens were deposited in the natural history collection at the University of North Dakota. To describe relative abundance in our results, we defined a species as being common, uncommon, or rare in a habitat if we detected it on > 35%, 10-35%, and < 10% of plots, respectively, based on natural breaks in our data.

We related the occurrence of common and uncommon species of mammals in the drift prairie to vegetation structure and composition by measuring litter accumulation, vegetation height, and the frequency of occurrence of major groups of plant species along transects used for snap-trapping on each plot. We recorded litter depth 15, 35, 55, and 75 m (50, 115, 180, and 245 ft) from the plot center of each transect, by measuring the height of any horizontal, dead vegetation that formed a mat extending continuously from the ground. Vegetation height was recorded at the same points along transects by measuring the highest (to nearest cm) vegetation contact on a 7-mm (0.1-in) diameter, vertical rod (Rotenberry and Wiens 1980). Every 0.5-m (1.6-ft) interval along each transect represented a "belt" that was assigned a dominant plant species or species group category (Grant et al. 2004). From this, the percentage frequencies of plant species or species groups were calculated for the plot.

We used logistic regression (Hosmer and Lemeshow 2000) to develop predictive models of species' occurrences based on vegetation structure and composition. Logistic regression seemed appropriate because a binary response (present or not present) characterized our data. In contrast, data to support linear regression based on measures of abundance (e.g., numbers captured/100 trap-nights) would have included many zeroes in our case, which would have violated assumptions of constant variance and linearity. Prior to conducting the regression, we used a Pearson correlation matrix to check for collinearity among predictor variables. If any 2 variables were correlated ($P \geq 0.1$) only 1 of the 2 was retained, depending on which we considered most biologically important and most likely to be influenced by prescribed fire. Logistic regression was then performed on remaining variables (% shrub, % native grass, % leafy spurge [*Euphorbia esula*], % wet meadow plants, vegetation height, litter depth), using stepwise elimination with an inclusion rate of $P > 0.1$, to seek a best predictive model for each mammal species.

RESULTS

Vegetation on the drift prairie plots was dominated by native low shrub, smooth brome, and Kentucky bluegrass, with little native herbaceous vegetation (Table 1). The vegetation was relatively tall with a moderate accumulation of plant litter; this structure was remarkably consistent across plots.

We captured 7 species in drift prairie (Table 2). Common species included masked shrew (*Sorex cinereus*), 13-lined ground squirrel (*Spermophilus tridecemlineatus*), and western jumping mouse (*Zapus princeps*). Meadow vole (*Microtus pennsylvanicus*) and deer mouse (*Peromyscus maniculatus*) were uncommon, and southern red-backed vole (*Clethrionomys gapperi*) was rare. Although our trapping methods were not designed to detect northern pocket gopher (*Thomomys talpoides*), we nonetheless captured the species and often noted its characteristic subsurface burrows

Table 1. Characteristics of vegetation measured on 42 75-m (246-ft) radius plots in mixed-grass prairie at Des Lacs National Wildlife Refuge in northwestern North Dakota during early summer 1998. Percentages of certain attributes represent frequency of occurrences of major plant species or species groups, based on the proportion of 0.1 x 0.5-m (0.3 x 1.6-ft) belts along 4 75-m (246-ft) transects in each plot in which the given species or species group was the dominant vegetation type (Grant et al. 2004).

Vegetation attribute	Description	$\bar{x}$	SE	Range
% shrub	Chiefly western snowberry, silverberry	24.2	2.5	1.2 - 62.5
% native grass	Chiefly wheatgrasses and needlegrasses	5.9	1.6	0 - 62.2
% Kentucky bluegrass	Widespread, introduced grass species	19.2	2.3	0 - 63.5
% smooth brome	Widespread, introduced grass species	41.5	3.9	0 - 87.2
% leafy spurge [a]	Introduced weedy forb	2.7	1.8	0 - 74.3
% native forb	Chiefly Asteraceae and Fabaceae	2.5	0.4	0.2 -10.2
% wet meadow plants	Chiefly fowl bluegrass and Baltic rush	2.7	0.9	0 - 32.8
Vegetation height (cm)	Highest vegetation contact on 7-mm rod [b]	45.0	1.0	35 - 60
Litter depth (cm)	Depth of horizontal mat of litter	3.3	0.3	0 - 8.8

[a] *Euphorbia esula.*

[b] Rotenberry and Wiens (1980)

Table 2. Percentage frequency of occurrence, with total number of captures in parentheses, of small mammals on 42 75-m (246-foot) radius plots in mixed-grass prairie and on 32 11-m (36-ft) radius plots in adjoining green ash woodland at Des Lacs National Wildlife Refuge in northwestern North Dakota, as determined by snap-trapping during early summer 1998 and 2000, respectively (n = 5,208 and 2,560 trap-nights).

Common Name	Scientific Name	% of plots in prairie	% of plots in woodland
Masked shrew	*Sorex cinereus*	76.2 (97)	28.1 (11)
Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*	38.1 (31)	0.0 (0)
Northern pocket gopher	*Thomomys talpoides*	2.4 (2)	0.0 (0)
Deer mouse	*Peromyscus maniculatus*	28.6 (17)	53.1 (70)
Southern red-backed vole	*Clethrionomys gapperi*	7.1 (3)	81.3 (163)
Meadow vole	*Microtus pennsylvanicus*	26.2 (20)	37.5 (43)
Western jumping mouse	*Zapus princeps*	38.1 (24)	6.3 (2)

(Jones et al. 1983:168) in drift prairie on our study area.

We captured 5 species in woodland. Common species included southern red-backed vole, deer mouse, and meadow vole; the southern red-backed vole was particularly abundant and widespread. Masked shrew was uncommon, and western jumping mouse was rare. We captured 50% more individuals in woodland than in drift prairie, even though the number of trap-nights in woodland was 50% of that in drift prairie (Table 2).

Among species of mammals that were common in prairie, we found no strong evidence among models that occurrence could be predicted based on characteristics of vegetation structure and composition that we measured, except that occurrence of 13-lined ground squirrel was related inversely to vegetation height. The fitted model was: occurrence = 5.46 - 1.34 (height); $r^2 = 0.14$; percent correct classification = 60.0. This model was an improvement over a constant-only model (i.e., the base model that excluded vegetation variables): $\chi^2 = 4.46$, df = 1, $P = 0.035$.

DISCUSSION

The community of small species of mammals in drift prairie at Des Lacs NWR was dominated by masked shrew, 13-lined ground squirrel, and western jumping mouse, species that typically are common in grasslands of the northern Great Plains (Jones et al. 1983). The 13-lined ground squirrel generally is tied to open grasslands (Streubel and Fitzgerald 1978, Finck et al. 1986). We found an inverse relationship between its occurrence and vegetation height on our study area. Because recurrent fire reduces the height of prairie vegetation at Des Lacs NWR and surrounding areas (Madden et al. 1999, Ludwick and Murphy 2006), 13-lined ground squirrels probably will occur more frequently on the refuge's prairie as fire is applied more often. Masked shrew is a habitat generalist that prefers grasslands especially those characterized by relatively dense, herbaceous vegetation in mesic sites (Jones et al. 1983, Snyder and Best 1988). Such conditions typified most of the Kentucky bluegrass- and smooth brome-dominated drift prairie of Des Lacs NWR (Murphy and Grant 2005). Western jumping mouse also prefers relatively dense, herbaceous vegetation (Jones et al. 1983:243, Cranford 1999). Broad habitat affinities of the 2 species may explain why we were unable to find models to predict their occurrence based on vegetation characteristics.

The meadow vole also is associated with dense, herbaceous grassland vegetation (Grant and Birney 1979, Reich 1981, Jones et al. 1983:222). We found the vole to be uncommon in drift prairie at Des Lacs NWR. Meadow voles were abundant in the region in 1999-2000 (Murphy et al. 2004), however, suggesting regional populations may have been relatively low during our study (1998), as 3- to 4-year cycles of abundance characterize the species (Krebs and Myers 1974, Reich 1981, Jones et al. 1983).

The small mammal community of the drift prairie at Des Lacs NWR appears roughly similar to that of mixed-grass prairie on other NWRs in North Dakota. Common species on the prairie at Lostwood NWR, 30 km (19 mi) southwest of Des Lacs NWR, included masked shrew, meadow vole, and western jumping mouse (Murphy et al. 2007). In the landscape of prairie and woodland at J. Clark Salyer NWR, 100 km (60 mi) east of Des Lacs NWR, 13-lined ground squirrel was found almost exclusively in prairie (Kadrmas 2005, Grant et al. 2006), similar to the species' distribution in our study. One mammal species conspicuously absent or rare on these NWR prairies, however, has been Richardson's ground squirrel (*S. richardsonii*). Historically, this colonial rodent was abundant and widespread in the open, frequently disturbed grasslands of the northern Great Plains north and east of the Missouri River (Jones et al. 1983:138). The species was common at present-day Des Lacs NWR in the early 1900s (Bailey 1913) and still occurs on heavily grazed, privately owned prairie adjacent to the refuge (R. Murphy, United States Fish and Wildlife Service, Kenmare, ND, unpublished data).

Among species captured in woodland at Des Lacs NWR, southern red-backed vole is the only one known to prefer this habitat (Iverson et al. 1967, Merritt 1981). Indeed, we found it to be abundant in woodland, occurring almost exclusively there. Similarly, red-backed vole was the only species found to occur almost entirely in woodland in north central North Dakota (Kadrmas 2005). In our study, deer mouse was common in woodland, as could be expected for this habitat generalist species (Jones et al. 1983:197). Meadow vole was common in woodland, but occurred mainly on plots that bordered prairie, which is consistent with its preference for grassland habitats (Grant and Birney 1979, Reich 1981). This distribution pattern agrees with that observed for the species in north central North Dakota (Kadrmas 2005). Meadow vole occurrence in woodland at Des Lacs NWR probably was elevated in 2000 due to the species' apparently high level of regional abundance that year (Murphy et al. 2004).

Surprisingly, we detected neither the prairie vole (*M. ochrogaster*) nor white-footed mouse (*P. leucopus*) during our study. Both species are thought to be widely distributed in the northern Great Plains, the vole mostly in relatively dry grasslands and the mouse typically in woodlands (Jones et al. 1983). We do not know why both species appeared to be rare or absent at Des Lacs NWR. However, this apparent rarity is corroborated by recent study at 2 areas within 100 km (60 mi); neither the prairie vole nor white-footed mouse were noted among a total of about 4,000 individuals of 18 species of small mammals captured, species identifications for which were validated by mammalogists from 2 universities (Kadrmas 2005, Murphy et al. 2007).

Diversity within some groups of grassland-dependent vertebrates declines as woodland expands on mixed-grass prairie preserves in the northern Great Plains (Grant and Murphy 2005). Based on our cursory data (i.e., only 1 season of data for each of prairie and woodland; the 2 habitats surveyed in different years) and support from published studies, fire-caused shifts from woodland toward open prairie at Des Lacs NWR probably will result in changes in local distribution of some small species of mammals. The most probable change is an increase in distributions of the grassland-associated masked shrew, 13-lined ground squirrel, and western jumping mouse and a decrease in distribution of the woodland-associated southern red-backed vole. Extirpation of the red-backed vole from the refuge is unlikely, because in some areas woodland has become so mature and extensive that it is no longer practical to reduce it by prescribed fire (Grant and Murphy 2005). In addition, we did not detect any unusual small species of mammal in woodland at Des Lacs NWR that may be threatened by local extirpation through alteration of its habitat via fire at the refuge.

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