

**SMALL MAMMAL COMMUNITIES IN GLACIER NATIONAL PARK'S
FESCUE GRASSLANDS: IMPLICATIONS OF EXOTIC PLANT INVASIONS
FINAL REPORT**

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Prepared by
DEAN E. PEARSON and LEONARD F. RUGGIERO
Rocky Mountain Research Station, USDA Forest Service, PO Box 8089
Missoula, Montana 59807

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Abstract Exotic plant invasions threaten to transform fescue grasslands within Glacier National Park, but little is known about how such changes from native to exotic vegetation may affect wildlife species. We surveyed small mammal communities in six fescue grassland sites on the east side of Glacier National Park (Belly River East, Belly River West, Windy Flats, Two Dog Flats, Saint Mary Flats, and Two Medicine) to identify current small mammal communities and assess how small mammals may be affected by exotic plant invasions and reciprocally how exotic plant invasions may be facilitated by certain small mammal species. Deer mice (*Peromyscus maniculatus*) dominated small mammal communities followed by western jumping mice (*Zapus princeps*), meadow voles (*Microtus pennsylvanicus*), montane heather voles (*Phenacomys intermedius*), and yellow pine chipmunks (*Tamias amoenus*) in descending order of relative abundance. Additionally, one long-tailed vole (*M. longicaudus*) was collected from a glass bottle found at Windy Flats. Low capture success precluded habitat selection analyses for all species but deer mice. Deer mice selected microsites with significantly less exotic grass, and more kinninnik (*Arctostaphylos uva-ursi*), bare ground, and rock. Avoidance of exotic grasses suggests that deer mice, the most abundant small mammal species in this system, are negatively affected by invasion of exotic grasses. We believe the mechanism for this response is due to the inherent avoidance of microsites with heavy cover by deer mice, since invasion of these exotic grasses increases vegetative cover. Northern pocket gopher (*Thomomys talpoides*) sign was significantly positively correlated with exotic forbs, but not exotic grasses. Northern pocket gophers may be associated with exotic forbs through positive or negative interactions. For example, they could facilitate forb invasions through disturbance arising from digging, or they could help suppress forb invasion by foraging on exotic forbs. Very likely some combination of these two interactions is taking place. Experimental work would be necessary to determine the ultimate nature of this interaction. Vegetation analyses indicated exotic grasses were negatively correlated with native grasses and native forbs, and exotic forbs were negatively correlated with native forbs. These results suggest that invasions by exotic grasses and forbs such as timothy (*Phleum pratense*), Kentucky bluegrass (*Poa pratensis*), and dandelion (*Taraxacum officinale*) that have been both intentionally and accidentally introduced into GNP are directly negatively impacting native plants and indirectly negatively impacting at least some native small mammals. Although other species such as meadow voles may respond positively to increased invasion by these exotic grasses, due to both increased

food and cover, we were unable to evaluate this because these species were too rare for analyses. This research suggests that exotic plant invasions are altering both plant and animal communities within Glacier National Park's native bunchgrass habitats.

INTRODUCTION

Exotic plants dramatically impact native ecosystems throughout the world by displacing native plants and in some cases even altering disturbance regimes – the very processes that define vegetative communities (Williamson 1996, Begley 1998, Mirsky 1999, Brooks et al. 2004). However, not all plant communities are equally at risk. Arid grasslands of western North America have proven particularly susceptible to exotic plant invasions (e.g., Forcella and Harvey 1983, Mack 1986). For example, spotted knapweed (*Centaurea maculata*) and cheatgrass (*Bromus tectorum*) have come to dominate large expanses of western grasslands, establishing virtual monocultures in many locations (Mack 1981, Sheley et al. 1998). Spotted knapweed releases secondary compounds as root exudates capable of inhibiting the growth of other plants (Bais et al. 2002) and may employ mycorrhizal fungi to extract resources from native grasses such as Idaho fescue (*Festuca idahoensis*) (Marler et al. 1999). Cheatgrass insures its prominence in areas with historically infrequent fire return intervals by establishing fire as a rapidly recycled disturbance force that favors this fire-adapted annual to the exclusion of native species (Whisenant 1990).

Land management agencies in the West have responded to such highly invasive exotics by implementing chemical, mechanical, and biological control methods to combat their advance (e.g., Losensky 1987). Ironically, at the same time that such costly strategies are under way to control some exotic species, others are being intentionally planted by the very same agencies. For example, both the United States Forest Service and Bureau of Land Management revegetate areas disturbed by mining, roads, and wildfire using seed mixes comprised in part or whole of exotic plant seeds (Richards et al. 1998). In the case of fires, vast acreages may be treated with seed from exotic species that are chosen for their competitive abilities to successfully establish under a wide variety of conditions. Given these selection criteria, it is not surprising that many of the species used for revegetation are already classified as invasive exotics. For instance, half (47%) of the 17 species of plants listed by the Lolo National Forest as seed cultivars for reseeding disturbed areas in the year 2000 (2000 Seeding Guidelines: Lolo National Forest) are exotics (as determined from their status in the USDA PLANTS database 1999:

<http://plants.usda.gov/plants>) and 50% of these are currently recognized by The Nature Conservancy as invasive exotics based on their demonstrated ability to invade native systems (The Nature Conservancy Element Stewardship Database: <http://www.tncweeds.ucdavis/esadocs.html>). Other exotics used by the Lolo National Forest, but not yet recognized as invasive species, such as crested wheatgrass (*Agropyron cristatum*), are known to deleteriously impact soils (Lesika and DeLuca 1996).

Intentional planting of exotics threatens not only the integrity of lands managed for multiple use, but also lands managed as natural areas, where maintenance of ecological integrity is the primary goal. For instance the Flathead National Forest, which borders Glacier National Park, includes timothy (*Phleum pratense*) and smooth brome (*Bromus inermis*) as seed cultivars for revegetating disturbed sites (Larsen and Lesika 1998). Both species are recognized as invasive exotics in Glacier National Park (Larsen and Lesika 1998). Although providing a source of invasive exotics adjacent to a large national park obviously threatens the potential for successfully maintaining a native grassland within the natural area, the origins of GNP's problem with timothy likely arose from intentional introductions of this and other species within the park to provide forage for stock used by concessionaires (Tyser 1991). Timothy is currently the most widespread exotic plant invading GNP's east-side fescue grasslands (Tyser 1991).

Given the potential impacts that exotics can incur upon natural systems, the intentional introduction of exotic species is a questionable practice at best. One possible explanation for such introductions is that research and management addressing issues of exotic plant invasions have focused on large, domestic and wild herbivores. Such research has shown that while forage for cattle and elk (*Cervus elaphus*) is diminished by the invasion of exotics such as spotted knapweed (Watson and Renney 1974, Thompson 1996), Eurasian species such as timothy and orchardgrass (*Dactylis glomerata*) provide good forage for large grazers (Hash 1973, Stevens 1966). However, this is a rather limited perspective that ignores the complexity of outcomes that can result from exotic invasions. When intentionally or accidentally introduced exotic species expand, they displace native plants, reducing the diversity of the plant community (e.g., Ortega and Pearson in press). For example, expansion of spotted knapweed, cheatgrass, and timothy into native grasslands of GNP results in reduced richness and diversity of native grasses and forbs (Tyser and Key 1988, Tyser 1992, Tyser and Whorley 1992). Losses of diversity at the level of primary productivity will necessarily induce impacts at other trophic levels as well.

For instance, larvae of insects such as butterflies (Lepidoptera) tend to be host-specific (Opler 1999). Therefore, reductions of native plant species will likely reduce diversity of native butterflies and other such host-specific insect herbivores. Pollinator communities can also be impacted by exotic invasions (Kearns et al. 1998), especially if the process involves a transition from a native grass-forb community to one dominated by an exotic grass. Since grasses use wind for pollination, they do not provide nectar resources for pollinating insects, which are likely to decline as a result. Such insects are critical for other flowering plants within the system and their declines could create a positive feedback loop contributing further to losses of native forbs.

Exotic plant invasions are also likely to affect small mammals. Recent work on the effects of exotic plant invasions and the associated release of exotic insects as biological control agents suggests that the outcomes on small mammals within the systems can be complex and quite dramatic (Pearson et al. 2000, Ortega et al. 2004). Small mammals play important roles in grassland (Curtin et al. 2000) and forest ecosystems (Pearson 1999) such that impacts on small mammals are likely to cascade into effects elsewhere in the system, potentially affecting avian and small mammalian predators as well as disrupting ecological functions perpetuated by small mammals (e.g., Pearson and Callaway 2003). Moreover, small mammal activities can affect the process of weed invasion (e.g., Pearson and Ortega 2001, Seabloom and Richards 2003).

Given the current status of exotic plant invasions in GNP's east-side fescue grasslands, our objectives were to 1) determine the community composition and relative abundance of small mammals in order to provide baseline information on small mammal communities currently residing in GNP's grasslands, 2) identify the habitat relationships of small mammals within these grasslands, particularly as they relate to exotic plant invasions, 3) assess the potential impacts of exotic plants on small mammal communities within GNP's fescue grasslands, 4) assess the potential impacts of small mammals on exotic plant invasion.

METHODS

Study Sites

This research targeted bunchgrass habitats on the east side of GNP. These habitats are similar to Palouse prairie of the Columbia River Basin, but are unique plant communities associated with the intermountain regions of western North America (Mueggler and Stewart 1980). We selected study sites in six discrete grasslands in 4 major drainages, Belly river, Many Glacier, Saint Mary, and Two Medicine. This provides a comprehensive sample that essentially includes all of the GNP east-side bunchgrass locations large enough to

support small mammal communities. Grasslands on the east side of GNP receive about 30 cm of rainfall per year, mostly in the form of winter snow from November to March and spring rains in May and June. Although, bunchgrass habitats are xeric grasslands, those on the east side of GNP lay at the wettest extreme of the gradient as indicated by the dominance of rough fescue (*Festuca scabrella*) (see results), the moist site indicator species for bunchgrass habitats (Meuggler and Stewart 1981).

Vegetation

Small mammal habitat was assessed by ocular estimates of percent cover for vegetation and habitat structure within 5-m radius of each trap station. We estimated percent cover to the nearest 5% for (1) native bunchgrasses: primarily rough fescue, Idaho fescue (*Festuca idahoensis*), and bluebunch wheatgrass (*Agropyron spicatum*); (2) exotic grasses: primarily Kentucky bluegrass (*Poa pratensis*) and timothy; (3) tall shrubs: mostly snowberry (*Symphoricarpos alba*); (4) low shrubs: kinnikinnick (*Arctostaphylos uva-ursi*); (5) native forbs: a diverse and varied group; (6) exotic forbs: primarily dandelion (*Taraxacum officinale*); (7) ground cover; (8) woody debris ≥ 10 cm diam.; (9) rocks ≥ 10 cm diam.; (10) topography of microsite (i.e., concave, flat, or convex); as an indicator for low, moist sites. Vegetation nomenclature follows Hitchcock and Cronquist (1973).

Trapping

We live trapped small mammals during June of each year from 2000 - 2003. Small mammals were sampled using Sherman folding live traps placed at 10-m intervals along transects to maximize effectiveness of community sampling (Pearson and Ruggiero 2003). Each transect comprised 25 traps and spanned 240 m. We placed 4 transects in each location ≥ 50 m apart so as to maximize the effective sampling area within the grasslands while maintaining independence among transects (the exception was that Spot Mountain in Two Medicine drainage had six transects). We placed rebar at the start and end points of each transect to relocate stations each year, and transect end points were geographically located using global positioning systems to ± 3 m (GPS information is in Appendix 1). Transects were not randomly placed, but were placed to maximize their balance between invaded and uninvaded grasslands. Thus, exotics may be over-represented relative to a random sampling design particularly on sites such as Belly River East, Belly River West, Two Dog Flats, and Saint Mary Flats where large but discrete patches of exotics were targeted.

We baited traps with a mixture of peanut butter and whole oats. Traps were covered with foam insulators to exclude precipitation and prevent traps

from overheating during the day. We ran traps for 4 days and checked them each morning between 0700 and 1100. Small mammals were tagged with #1005-1 monel ear tags (National Band and Tag Company, Newport, Kentucky 41072-0430), and species, age, mass, sex, and reproductive condition were determined before release at the trap station. Mammal nomenclature follows Jones et al. (1997).

Sign Surveys

We surveyed for Columbian ground squirrels (*Spermophilus columbianus*) and northern pocket gophers (*Thomomys talpoides*), species not effectively sampled using Sherman traps, by counting the number of ground squirrel holes and estimating the percent cover (ocular estimate) of pocket gopher cores and mounds within a 5-m radius of the trap station. These indices provide an effective measure of disturbance for these species, which can facilitate exotic plant invasions, while also offering a crude measure for evaluating their relative abundance (e.g., Scrivner and Smith 1981).

Analytical Methods

We conducted logistic regression analyses using PROC MIXED as modified by the GLIMMIX macro (SAS Institute 1999) to determine which habitat variables best differentiated trap stations that captured deer mice from those that did not. Models were structured such that year was treated as a repeated measure and site was treated as a random factor. Trap stations having multiple captures were included only once in the analysis (Pearson et al. 2001). Equations produced by logistic regression serve as resource selection functions and the coefficients serve as selection coefficients ($\hat{\beta}$) whose values indicate the relative importance of the predictor variables in the equation (Manly et al. 1993). Positive coefficients indicate selection for the resource and negative coefficients indicate avoidance when coefficients differ significantly from zero. We used PROC MIXED to examine the relationship between exotic forbs and exotic grasses respectively with native forbs and native bunchgrasses and to evaluate the relationship between Columbian ground squirrel holes and pocket gopher sign respectively with percent cover of exotic forbs and exotic grasses. Models were structured as above so that year was treated as a repeated measure and site was treated as a random factor.

RESULTS

Vegetation

The dominant native bunchgrass on all sites was rough fescue indicating that the bunchgrass habitats sampled are at the wettest end of the moisture gradient

for intermountain bunchgrass habitats given that this species is indicative of the wettest bunchgrass habitats (Mueggler and Stewart 1980). In fact, bluebunch wheatgrass, the driest of the major bunchgrass species, was very rare at all sites. Idaho fescue, which is intermediate to the other two species in terms of its moisture requirements, was proportionally most abundant at Saint Mary Flats and Two Dog Flats, both of which are in the Saint Mary drainage. These two sites appear to be the driest of those sampled; a conclusion consistent with the fact that these sites had the lowest percent cover of native bunchgrasses (Table 1).

Native bunchgrasses exhibited similar cover values for Belly River East, Belly River West, Two Medicine, and Windy Flats, which all had average total bunchgrass coverage between 45 and 55% (Table 1). Saint Mary Flats and Two Dog Flats, which both occur in the Saint Mary drainage, had total bunchgrass coverage of around 30%. Total native forb cover was comparable among all sites and averaged from 30 to 37% cover. Average percent cover for exotic grasses was $\leq 16\%$ for all sites except for Belly River East, which had an average cover of nearly 30% for exotic grasses. Windy Flats had the lowest mean percent coverage of exotic grasses at about 2%. Timothy and Kentucky bluegrass were the primary exotic grasses on all study sites and were more or less comparable in most areas other than Belly River East where timothy was more than 4 times more abundant than Kentucky bluegrass. Exotic forbs, which were primarily comprised of dandelions, were relatively uncommon reaching their highest cover on Belly River West and Belly River East at 6 and 11%, respectively. Shrub cover was comparable among sites, though Two Dog Flats and Saint Mary Flats had about half the shrub cover of the other sites. Bare ground averaged from 10 to 30% cover across sites. Percent cover of rock was generally low, but it was highest at Windy Flats. The degree of microsite topography varied little among sites and so is not reported here. Course woody debris data

are also not reported here as course woody debris only occurred at Two Medicine where historic tree encroachment had resulted in tree boles scattered across this site.

Exotic grasses were significantly negatively associated with native bunchgrasses ($F = 413.41$, $df = 1$, 2480 , $P < 0.001$) and native forbs ($F = 27.13$, $df = 1$, 2243 , $P < 0.001$). Exotic forbs were not significantly negatively associated with native bunchgrasses ($F = 0.96$, $df = 1$, 2564 , $P = 0.328$), but they were significantly negatively associated with native forbs ($F = 17.38$, $df = 1$, 1916 , $P < 0.001$).

Trapping

Small mammal community

Trapping at six locations in four drainages resulted in 10,400 trap nights that produced 297 captures of 202 individuals representing 5 species of small mammals. (Table 2). Deer mice (*Peromyscus maniculatus*) were by far the most abundant species with 171 individuals captured. Deer mice were present at all locations, though not in all years. Western jumping mice (*Zapus princeps*) were the second most abundant small mammal species captured, but only 14 individuals were captured over the course of the study. Western jumping mice occurred at all sites except for Saint Mary. Meadow voles (*Microtus pennsylvanicus*) were the next most common with 5 captures at three locations, Belly River West, Belly River East, and Two Medicine. Only 3 montane heather voles (*Phenacomys intermedius*) were captured. All of these were at Two Medicine. One of these individuals was previously identified as a northern bog lemming (*Synaptomys borealis*), but has since been re-evaluated and determined to be a heather vole, a species commonly confused with bog lemmings because of similar pelage and dental characteristics. Yellow pine chipmunks (*Tamias amoenus*) were represented by only 2 individuals, one captured at Two Medicine and one at Windy Flats. However, shrubs were generally avoided in laying out transects in order to focus on the effects of exotics on native grasses and

Table 1. Percent cover estimates ($\bar{x} \pm SE$) for variables collected at trap stations that were used in habitat analyses for all years 2000-2004 combined.

Variable	Location					
	Belly West	Belly East	Windy Flats	Two Dog Flats	Saint Mary Flats	Two Medicine
Native bunchgrass	50.0 $\pm$ 0.6	47.1 $\pm$ 0.8	51.2 $\pm$ 0.6	30.0 $\pm$ 0.7	32.4 $\pm$ 0.8	53.5 $\pm$ 0.6
Native forbs	37.3 $\pm$ 0.5	30.9 $\pm$ 0.5	33.6 $\pm$ 0.6	35.7 $\pm$ 0.6	32.2 $\pm$ 0.7	35.3 $\pm$ 0.6
Exotic grass	10.4 $\pm$ 0.5	28.5 $\pm$ 0.9	1.8 $\pm$ 0.2	16.0 $\pm$ 0.8	13.8 $\pm$ 0.8	4.0 $\pm$ 0.3
Exotic forbs	6.3 $\pm$ 0.3	10.6 $\pm$ 0.4	0.3 $\pm$ 0.0	2.3 $\pm$ 0.3	1.7 $\pm$ 0.3	0.2 $\pm$ 0.0
Tall shrubs	10.5 $\pm$ 0.5	9.7 $\pm$ 0.5	12.0 $\pm$ 0.6	5.2 $\pm$ 0.3	5.6 $\pm$ 0.4	11.0 $\pm$ 0.3
Kinnikinnik	2.3 $\pm$ 0.1	1.9 $\pm$ 0.2	5.5 $\pm$ 0.2	0.1 $\pm$ 0.0	1.0 $\pm$ 0.0	7.1 $\pm$ 0.3
Ground	20.9 $\pm$ 1.0	10.1 $\pm$ 0.5	21.5 $\pm$ 0.7	28.7 $\pm$ 1.0	30.1 $\pm$ 1.1	24.4 $\pm$ 0.9
Rocks	0.5 $\pm$ 0.0	0.2 $\pm$ 0.0	6.7 $\pm$ 0.	1.9 $\pm$ 0.2	3.2 $\pm$ 0.4	2.9 $\pm$ 0.2

Table 2. Small mammals detected by sign surveys or trapping in fescue grasslands on the east-side of Glacier National Park from 2000 to 2003. Numbers indicate number of individuals trapped. X's indicate species identified for the site by sign or other detection means.

Species	Location					
	BW	BE	WF	TD	SM	TM
PEMA	8	2	63	45	40	13
ZAPR	1	1	6	5		1
MIPE	1	3				1
VOLE	2	2		X ^a		3
MILO			X ^b			
PHIN						3
SOCI				X ^a	X ^a	
TAAM			1			1
SPCO ^c	X	X	X	X	X	X
THTA ^c	X	X			X	X

a - Species detected by Tyser (1991) that were not detected in this study.

b - This individual was collected from a glass bottle (see results).

c - Species sampled using sign surveys rather than trapping data.

PEMA = *Peromyscus maniculatus*, ZAPR = *Zapus princeps*, MIPE = *Microtus pennsylvanicus*, VOLE = unknown species of vole, MILO = *Microtus longicaudus*, PHIN = *Phenacomys intermedius*, SOCI = *Sorex cinereus*, TAAM = *Tamias amoenus*, SPCO = *Spermophilus columbianus*, THTA = *Thomomys talpoides*.

forbs, so trapping would be biased against capturing chipmunks, which tend to associate with structural components such as shrubs, logs, and large rocks (Pearson 1999). Additionally, unidentified voles were captured at Belly River East, Belly River West, and Two Medicine. Since these voles were released alive, they could not be identified to species, but they would have likely been either meadow voles or montane heather voles. Long-tailed voles (*M. longicaudus*) were not captured in Sherman traps, but we recovered the skeleton and skull of one individual long-tailed vole from inside an old glass bottle lying within the trapping area at Windy Flats. The skeleton was firmly attached to the inner bottle surface and positioned at the bottom of the bottle suggesting it had not been disturbed since the animal died within, i.e., the animal had been captured on site. This was likely a dispersing individual, since long-tailed voles tend to inhabit forested habitats or wetter herbaceous vegetation than that associated with arid bunchgrass (Pearson 1999).

Populations and demographics

Only deer mice were sufficiently abundant for population and demographic analyses and even for deer mice numbers were too low for effective population estimation (Menkins and Anderson 1988, McKelvey and Pearson 2001), so results are based on number of unique individuals captured (m^{+1} in the terminology of White et al. 1982). Deer mouse populations showed no pattern in fluctuations over time at sites where they were consistently captured, and they showed no consistency in fluctuations across sites (Fig. 1).

Reproductive activity for deer mice at Windy Flats and Saint Mary Flats was generally good in all years with more than 50% of males and females showing signs of reproductive activity in all years. At Two Dog Flats, reproductive activity was much more varied running from no activity for females in 2001 to 100% for females in 2003. Other sites and other species had too few captures to evaluate reproductive activity. Juvenile mice were captured at all sites except Belly River East, but substantial numbers of juvenile mice were only captured at Saint Mary Flats in 2003 where 6 of 16 mice captured were juveniles.

Habitat relationships

Only deer mice were sufficiently abundant for

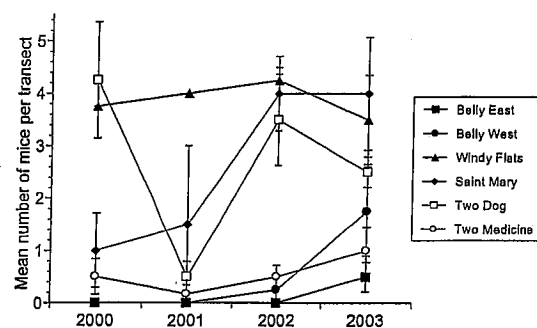


Figure 1. Mean ($\pm$ SE) number of deer mice trapped per transect on each study site in bunchgrass habitats on the east side of Glacier National Park from 2000 to 2003

habitat selection analyses. Since topography varied very little across study sites and large woody debris was largely absent from all but the Two Medicine site, these two variables were not included in the logistic analysis. Logistic regression results indicated that deer mice responded negatively to most forms of cover including native and exotic grasses and forbs and tall shrubs, but responded positively to increasing kinnikinnik, rock, and bare ground (Fig. 2). However, only half of the variables were significant, so we reran the logistic model with only the significant variables ($P \leq 0.05$) from the overall model. These results indicated that deer mice significantly avoided trap stations with exotic grasses ($F = 4.66$, $df = 1$, 2457, $P = 0.031$, $\hat{\beta} = -0.015$), and significantly selected for trap stations with higher cover of kinnikinnik ($F = 19.51$, $df = 1$, 1990, $P < 0.001$, $\hat{\beta} = 0.038$), bare ground ($F = 18.10$, $df = 1$, 2520, $P < 0.001$, $\hat{\beta} = 0.013$), and rock ($F = 23.24$, $df = 1$, 2365, $P < 0.001$, $\hat{\beta} = 0.051$).

Sign Surveys

Northern pocket gopher sign was observed at all sites except Windy Flats and Two Medicine, while Columbian ground squirrel sign was observed at all sites. However, holes attributed to Columbian ground squirrels at Belly River East and Belly River West were rare and possibly may have been holes dug by other animals that were incorrectly attributed to Columbian ground squirrels. No Columbian ground squirrels were ever directly observed in Belly River. Northern pocket gopher sign was positively correlated with exotic grasses ($F = 2.03$, $df = 1$, 1933, $P = 0.155$) and exotic forbs ($F = 9.10$, $df = 1$, 1606, $P = 0.003$), but this relationship was only significant for exotic forbs. Columbian ground squirrels showed negative, but nonsignificant correlations with exotic grasses ($F = 2.81$, $df = 1$, 2528, $P = 0.094$) and exotic forbs ($F = 2.95$, $df = 1$, 2496, $P = 0.086$).

DISCUSSION

Vegetation

Vegetation within GNP's fescue grasslands is generally similar to that observed for other fescue grasslands within western Montana where small mammal communities have been studied (e.g., Pearson et al. 2001, 2000, Ortega et al. 2004) except that rough fescue and native forbs are far more prominent in GNP resulting in a condition of higher total ground cover and thereby less interstitial space and bare ground. For instance, rough fescue was rare at small mammal study sites in westcentral Montana while forb cover was less than half that for GNP grasslands, and bare ground cover was twice that observed in GNP using the same methods employed in this study (see Pearson et al.

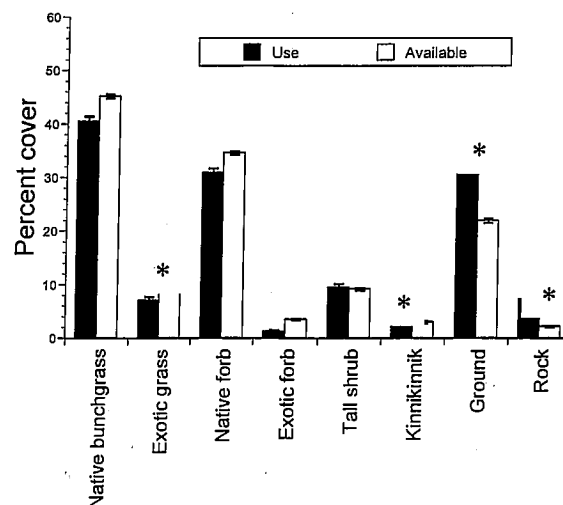


Figure 2. Percent cover values ($\bar{x} \pm SE$) estimated for habitat variables at used (stations where deer mice were captured at least once during the trapping period) versus available (stations where deer mice were not captured during the trapping period) trap stations for all sites and all years combined for the period from 2000 to 2004 in Glacier National Park's east-side grasslands. Asterisks indicate significant differences at $\alpha = 0.05$.

2001). These conditions probably result from higher soil moisture, since rough fescue, which is abundant in GNP, is known to favor more mesic conditions than Idaho fescue and bluebunch wheatgrass, the other prominent bunchgrasses within intermountain bunchgrass habitats (Mueggler and Stewart 1980).

With regard to exotic plant invasions, GNP's fescue grasslands lie toward the lower end of the invasion gradient. Although timothy and Kentucky bluegrass are prominent and locally heavy within some of GNP's east-side bunchgrass, GNP's grasslands are in much better condition than most of the Missoula and Bitterroot valleys where spotted knapweed and other exotics can commonly reach >45% cover (Pearson et al. 2000). Nonetheless, timothy, Kentucky bluegrass, and dandelion have already begun to take their toll on GNP grasslands as shown by the significant negative relationships between these exotic grasses and forbs with native grasses and forbs. Recent work in bunchgrass habitats elsewhere in western Montana shows that such invasions can ultimately lead to serious declines in richness of native plant communities (Ortega and Pearson in press). Moreover, these impacts on native plants appear to be affecting native animals as well.

Small Mammal Communities

Trapping in GNP's east-side fescue grasslands produced relatively few species of small mammals.

Deer mice were common and dominated the small mammal communities overall. Voles and western jumping mice were captured, but both were relatively rare and did not occur at all sites. Although not all voles captured were identified, it is interesting that no montane voles were captured in this study or ever documented in GNP (Shea 1971) given that their current range encompasses GNP (Jannett 1999), and they appear to be the primary species of *Microtus* found in the dry conditions of fescue grasslands elsewhere in the state (Hodgeson 1972, Grant et al. 1982, Pearson et al. 2000, 2001).

Tyser (1991) trapped Two Dog Flats and Saint Mary Flats in 1989 and 1990 and observed results similar to ours. Deer mice dominated his captures followed by western jumping mice and voles, which were uncommon, and shrews, which were rare. Tyser (1991) tentatively identified his voles as meadow voles based on pelage characteristics (R. Tyser, University of Wisconsin-La Crosse, pers. comm.), but dentition and skull characteristics are necessary to conclusively distinguish among heather voles and meadow voles (Hoffmann and Pattie 1968). We captured no voles at either Two Dog Flats or Saint Mary Flats and so were unable to confirm Tyser's conclusions. However, based on our confirmed captures at other sites, it seems mostly likely that Tyser's voles were meadow voles, though heather voles cannot be ruled out. The small mammal results of Tyser (1991) are quite comparable to ours for GNP's east-side grasslands, except that heather voles and cinereus shrews were each captured in only one of the two studies.

Together this study and that of Tyser (1991) suggest that bunchgrass-habitats in GNP are, like other xeric grasslands in the Northern Rocky Mountains, relatively species-poor communities dominated by deer mice. However, GNP's grasslands contain western jumping mice as well as potentially several species of voles in small numbers and shrews as rare components, suggesting that these grasslands may exhibit higher species richness than other fescue grasslands in the Northern Rocky Mountains. Pearson et al. (2001) and Grant et al. (1982) both found fescue grasslands to be species-poor small mammal communities mostly dominated by deer mice. Pearson et al. (2001) hypothesized that deer mice generally dominate fescue grasslands in the Northern Rocky Mountains, but that voles may at times dominate within these habitats. That deer mice seem to generally dominate these systems is supported by the current study and that of Tyser (1991), as well as more recent work by Ortega et al. (2004). However, the potential for voles to become abundant or numerically dominant in these systems remains to be seen. It is puzzling that 4 years of intensive sampling showed no evidence of any vole species ever becoming abundant at any point during this study. We can offer

only 2 hypotheses as to why voles are not at least periodically abundant in this system. First, GNP has a shorter growing season than other locations in the state where small mammals have been studied. Thus, the growing season may simply be too short for populations to express their full potential. However, this seems unlikely given that large population densities are reached by meadow voles at higher latitudes in North America. Second, voles in GNP could be suppressed by predators given the park carries a full complement of native predators that may reach higher densities than outside the park given the protection they receive. However, an ongoing small mammal predator exclusion study underway in comparable rough fescue dominated habitats in the Blackfoot valley of western Montana has not yet shown an effect of predators in 2 years of implementation (J. L. Maron and D. E. Pearson, unpublished data). This study has so far excluded all mammalian and avian predators except weasels (*Mustela* spp.), so it is still possible that weasels may be the key to the suppression of voles within these habitats. Weasels have been shown to be important predators of voles in Europe (Erlinge et al. 1991), and so weasel exclusion now underway on this predator exclusion study may yet be insightful.

Habitat Selection

Deer mice were the only species sufficiently abundant for habitat selection analysis. Deer mice tended to be captured more at sites with higher percent cover of kinnikinnik, rock, and bare ground and lower percent cover of exotic grasses. Selection coefficients indicated that rock was the most important variable followed by kinnikinnik, exotic grasses and bare ground. Deer mouse selection for microsites with higher percent cover of rock is consistent with results observed by Pearson et al. (2001) for similar though drier grasslands in south-central Montana. Pearson et al. (2001) also found that deer mice selected for microsites with less vegetative cover, i.e., higher percent cover of bare ground. In Wyoming grasslands, Elliott et al. (1997) similarly found that deer mice avoided heavy vegetative cover in favor of sites with more bare ground exposed, and deer mice have been shown to increase in response to grazing, which also reduces vegetative cover (Larrison and Johnson 1973, Grant et al. 1982, Rosenstock 1996). Selection by deer mice for sites having more kinnikinnik has not been documented before, and it is unclear just why mice might select for such sights. Kinnikinnik does produce berries that may serve as food in the late summer, but trapping was conducted in the spring. As cover kinnikinnik offers little more protection than herbaceous vegetation as it is a low-grown, ground-hugging shrub. Kinnikinnik did show a consistent negative correlation with native forbs, which mice would tend to avoid, and

somewhat of a positive association with rocks and bare ground, which mice tend to favor, so it is possible that kinnikinnik is somehow indicative of an interface of optimal microhabitat conditions for these mice. Previous work in GNP grasslands by Tyser (1991) did not include habitat analyses, so we could not compare our results with his data. Deer mouse avoidance of exotic grasses is consistent with their general avoidance of microsites with heavy vegetative cover. Thus, invasion of these exotic grasses within this system may serve to reduce deer mouse habitat availability and ultimately deer mouse populations by increasing cover and reducing access to more open vegetation.

Sign Surveys

Sign surveys indicated that northern pocket gopher sign was relatively common except at Windy Flats and Two Dogs Flats. Soils may explain this to some extent for Windy Flats since this was the rockiest site, and pocket gophers avoid rocky soils, but Two Dog Flats was not that rocky. Columbian ground squirrel holes were common except in the Belly River drainage. Though a few holes were detected at Belly River West and Belly River East, no ground squirrels were observed. Tyser (1991) also surveyed for Columbian ground squirrel sign, but not for northern pocket gopher sign. He found ground squirrel sign to be common at Two Dog and Saint Mary Flats, but observed no sign of ground squirrels in the Belly River drainage. It would appear that Columbian ground squirrels are common in most of GNP's fescue grasslands, but that they are absent or nearly absent from the Belly River drainage. The holes we attributed to ground squirrels at the Belly River East and Belly River West could have either been misidentified as Columbian ground squirrel holes, or they could indicate that ground squirrels are very rare within the Belly River or just beginning to disperse there from other locations. Holes of golden mantled ground squirrels (*Spermophilus lateralis*) could be misidentified as columbian ground squirrel holes, but golden-mantled ground squirrels, which are effectively sampled using Sherman traps (e.g., Pearson et al. 2003), were not captured or reported as sighted within the fescue grasslands in either Tyser's (1991) study or ours.

Soil disturbance produced by rodents could facilitate invasion of exotic plants (e.g., Seabloom and Richards 2003). We detected significant positive relationships between northern pocket gophers and exotic forbs, but there was no significant relationship between pocket gophers and exotic grasses or between Columbian ground squirrels and exotic grasses or exotic forbs. Northern pocket gophers may be associated with exotic forbs through positive or negative interactions. For example, they could facilitate forb invasions through disturbance arising from digging, or they could help suppress forb invasion by foraging on exotic forbs.

Very likely some combination of these two interactions is taking place. Experimental work would be necessary to determine the ultimate nature of this interaction. The role that small mammals play in facilitating exotic plant invasions is an important component of the ecology of exotic invasions and should be studied in more detail.

This study provides some of the first evidence that exotic grasses intentionally introduced for ecological restoration and for subsidies to large domestic herbivores can deleteriously impact native fauna. Such exotic grasses have generally been considered benign toward native species because of the emphasis on large native herbivores, which appear to benefit from these introductions. However, exotic organisms whether accidentally or intentionally introduced can have very profound impacts on native ecosystems through a variety of mechanisms both predictable and unpredictable (Louda et al. 1997, Begley 1998, Mirsky 1999, Pearson and Callaway 2003, Ortega et al. 2004, Ortega and Pearson in press). Although the introduction of exotic grasses in GNP likely has both positive and negative affects on native species, we were only able to document negative impacts here, and the overall outcome of these introductions is likely to result in declines in native plant and animal diversity with unknown implications for the system as a whole. The intentional introduction of exotic species for any management objective is a risky strategy that requires careful research and consideration. However, the introduction of exotic plants with high invasive potential is a risky endeavor at best. More research will be necessary to better understand the potential impacts associated with intentionally introduced exotic grasses in native bunchgrass habitats and to determine whether there are any species or conditions under which such introductions may truly be justified.

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APPENDIX 1

GPS COORDINATES FOR TRAPPING LOCATIONS

Location	Transect	Trap	Northing	Easting	Elevation
Belly West	1	1	5426874	302886	1420
Belly West	1	25	5426620	302984	1401
Belly West	2	1	5426949	302985	1413
Belly West	2	25	5426725	303062	1405
Belly West	3	1	5426945	303220	1409
Belly West	3	25	5426871	303447	1400
Belly West	4	1	5427033	303297	1405
Belly West	4	25	5426935	303522	1398
Belly East	1	1	5425780	302755	1412
Belly East	1	25	5425883	302538	1403
Belly East	2	1	5425852	302882	1417
Belly East	2	25	5425943	302655	1413
Belly East	3	1	5426027	302855	1414
Belly East	3	25	5425993	302614	1404
Belly East	4	1	5426051	302997	1418
Belly East	4	25	5426266	302889	1413
Two Medicine	1	1	5377038	327751	1828
Two Medicine	1	25	5377023	327992	1799
Two Medicine	2	1	5377096	327770	1826
Two Medicine	2	25	5377120	328000	1800
Two Medicine	3	1	5377173	327854	1833
Two Medicine	3	25	5377346	328026	1837
Two Medicine	4	1	5377322	327900	1848
Two Medicine	4	25	5377480	328087	1843
Two Medicine	5	1	5377202	328016	1808
Two Medicine	5	25	5377408	328123	1832
Two Medicine	6	1	5377022	327505	1858
Two Medicine	6	25	5376902	327694	1832
Saint Mary	1	1	5401290	320628	1372
Saint Mary	1	25	5401366	320415	1372
Saint Mary	2	1	5401346	320643	1374
Saint Mary	2	25	5401419	320415	1372
Saint Mary	3	1	5401558	320613	1380
Saint Mary	3	25	5401612	320377	1373
Saint Mary	4	1	541619	320637	1378
Saint Mary	4	25	5401366	320407	1318
Two Dog	1	1	5400414	318598	1423
Two Dog	1	25	5400331	318829	1395
Two Dog	2	1	5400513	318583	1436
Two Dog	2	25	5400417	318803	1407
Two Dog	3	1	5400594	318614	1447
Two Dog	3	25	5400483	318829	1407
Two Dog	4	1	5400654	318621	1438
Two Dog	4	25	5400543	318836	1406
Windy Flats	1	1	5409595	309000	1470
Windy Flats	1	25	No data*	No data*	No data*

Windy Flats	2	1	5409558	309029	1470
Windy Flats	2	25	5409691	309233	1458
Windy Flats	3	1	5409520	309062	1455
Windy Flats	3	25	5409656	309264	1469
Windy Flats	4	1	5409460	309060	1462
Windy Flats	4	25	5409596	309265	1460

* Coordinates for this station were lost. However, this station would lie 50 m toward the west of transect 2 trap station 25 and in line with transects 2, 3, and 4 trap station 25.