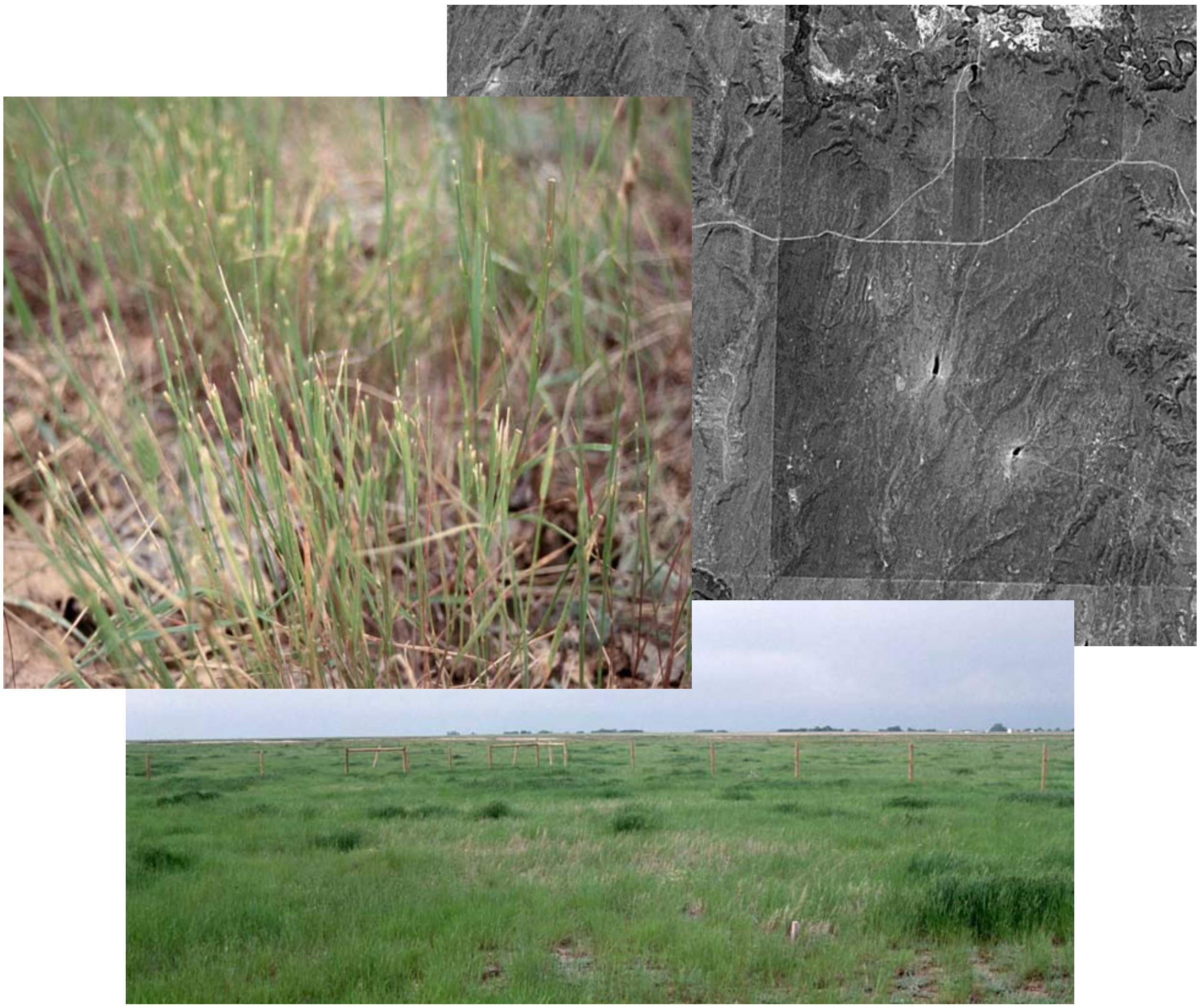
RESTORING GRAZING-INDUCED HETEROGENEITY

IN GRASSLANDS NATIONAL PARK OF CANADA



LANDSCAPE-SCALE EXPERIMENT & LONG-TERM MONITORING PLAN,

MARCH 9, 2006

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This plan has grown from previous collaborative efforts between Grasslands National Park and other stakeholders from the region. The Park Management Plan (Parks Canada 2002) and the Northern Mixed Prairie Transboundary Conservation Plan (Smith-Fargey 2004) integrated the input of more than 100 groups, who collectively identified a need for a grazing experiment. In 2004, the Southern Saskatchewan Field Unit Superintendent, Cheryl Penny, submitted the "Prairie Persists" funding proposal to the Priority Investment Fund – Ecological Integrity within Parks Canada, and the funds received in early 2005 have supported the staged development of this plan.

A stakeholder group was consulted in April 2005 to help formulate potential research objectives and conceptual experimental designs. At that meeting were Salman Rasheed, Pat Fargey, Robert Sissons and John Wilmshurst (Parks Canada Agency), Paul Jefferson, Walter Willms, Alan Iwaasa and Michael Schellenberg (Agriculture and Agri-Food Canada), Stephen Davis (Canadian Wildlife Service), Steve Forrest (World Wildlife Fund), John Carlson (US Bureau of Land Management), Xulin Guo (UofS Dept. Geography), Jeff Thorpe (Saskatchewan Research Council), Nicola Koper (UofM Natural Resources Institute), Darcy Henderson (UofA Dept. Renewable Resources), Susan Michalsky and Kelly Fitzpatrick (Ranchers), Don Fontaine and Larry Spearing (Saskatchewan Agriculture and Food), Tom Harrison and Dan Beveridge (Saskatchewan Watershed Authority).

A working group was formed to prepare a study plan following the initial stakeholder consultation, and consisted of Pat Fargey, Robert Sissons, John Wilmshurst, and Nicola Koper, with Darcy Henderson contracted as lead author. The working group reviewed and revised several drafts to help guide the vision, refine the objectives, and provide references and technical expertise for the literature review, experimental design and sampling methods. Colin Schmidt, Thomas Naughten and Catherine Shields (Parks Canada) provided valuable advice for the communication, data management, and publishing components respectively.

By October 2005, the working group began to seek out and receive external peer reviews of the penultimate draft from a diverse group of researchers and managers. Many thanks are due to Garry Scrimgeour (Alberta Conservation Association), Robert Roughley (UofM Dept. Entomology), Susan Michalsky (Rancher & Ecological Consultant), Michael Schellenberg (Agriculture and Agri-Food Canada), Brenda Dale (Canadian Wildlife Service), Elizabeth Madden (U.S. Fish and Wildlife Service), Brian Martin (The Nature Conservancy, Montana), James F. Cahill (UofA Dept. Biological Sciences), and Jeff Schoneau (UofS Dept. Soil Science) for in-depth and challenging reviews. Additional logistical problems were identified and brought to light by Jennifer Taylor, Debbie Kilfoyle and Adrian Sturch (Parks Canada Agency).

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EXECUTIVE SUMMARY

Grasslands National Park of Canada (GNPC) is undertaking a cattle grazing experiment as part of the adaptive management process for restoring ecological integrity to this portion of the northern mixed-grass prairie region. Since 1987, GNPC has proceeded with a policy of grazing exclusion as lands were acquired for the Park. As of 2005, monitoring indicates an increase in alien perennial grass cover and total standing crop, and alterations to vertebrate and invertebrate communities all attributable to grazing exclusion. Restoration of grazing disturbance is deemed necessary for conservation of biological diversity; with the aim of emphasizing aspects currently underrepresented in the region.

The primary objective of the proposed experiment is to determine how grazing intensity alters spatial and temporal heterogeneity in the multi-scale structure and function of mixed-grass prairie communities. This study was prepared to integrate the objectives of Parks Canada with recommendations of stakeholders, scientific and management knowledge gaps identified in a detailed literature review, and the physical, logistical and statistical limitations of conducting an experiment in a remote area. The most salient and novel features include:

- Beyond BACI experimental design and analytical procedures incorporating a manipulated grazing intensity gradient with multiple grazed and ungrazed controls to identify response thresholds along gradients of grazing intensity, time and space.
- Experimental control provided by 15 years of grazing exclusion across the area receiving manipulations, and the opportunity to design and sample units a priori.
- Landscape-scale experimental units (~300 ha), each of which incorporates equal proportions and juxtapositions of riparian, valley and upland landscapes typical of the region.
- Long-term (10+ years) commitment to implementing grazing treatments and annual monitoring of ecological integrity measures.
- Broad selection of compositional, structural and functional measures for monitoring, and an integrated regime of multi-scale field sampling and remote sensing.
- Application of standard methods for rangeland health, riparian health, breeding bird survey, and grasshopper forecast programs conducted in the region.
- Opportunity for stakeholders to use the site for training technical staff, educating students, monitoring other indicators, and researching additional questions.

Ultimately, the outcomes of this experiment achieve several GNPC objectives consistent with the 2002 Park Management Plan and 2000 National directives for Parks Canada as a whole.

- Restore the natural process and pattern of grazing-induced heterogeneity.
- Test ecological monitoring methods, and select appropriate measures for detecting grazing-induced change in ecosystem structure, function and composition.
- Implement adaptive ecosystem management and evaluate grazing treatments at relevant spatial and temporal scales for managing Species-at-Risk and biological diversity throughout the Park.

1.0 Introduction

The mandate of Parks Canada is to maintain or restore ecological integrity, a component of which is the historic range of variation in natural disturbance (Parks Canada 2000). In mixed-grass prairie, droughts associated with the semiarid continental climate have been the most severe natural process, while floods, wildfires and grazing helped generate further heterogeneity in ecosystem structure, function and composition (Fuhlendorf & Engle 2001). Wild fires ignited by lightning and aboriginal peoples occurred almost anywhere and anytime the grass wasn't green or covered in snow (Romo 2005), while sedentary and migratory herds of bison added variable patterns of grazing intensity, duration and frequency across the region (Epp 1988). European settlement has, in a very short period of time, threatened the integrity of this ecosystem through cultivation, species extirpations, wild fire suppression, alien species invasions, and altered grazing regimes. To differing degrees, Grasslands National Park of Canada (GNPC) must manage and monitor these threats to meet the maintenance and restoration goals of Parks Canada, on a landscape embedded in a matrix of conventionally grazed livestock ranches.

Conventional grazing refers to the season-long (June to October), moderate-intensity (50% utilization) regimes practiced on mixed-grass prairie within most federal and provincial community pastures in Saskatchewan, and provincial grazing associations and grazing reserves in Alberta (Abouguendia 1990; Adams et al. 2004). Although the variety of stock class, winter feeding practices, environmental or market constraints affecting private ranchers complicates applying this generalization to privately managed rangelands, enough ranchers practice this grazing regime to continue referring to the practice as conventional. Livestock are commonly fed hay and other feed through the winter (November to March), and graze seeded pastures of non-native crested wheatgrass (*Agropyron cristatum*) in spring (April to June). Rest-rotations where livestock are excluded in some years are not common, and the majority of northern mixed-grass prairie (perhaps >85% extent) experiences some livestock utilization every year (Willms & Jefferson 1993).

While these conventional systems represent a sustainable compromise between demand constraints imposed by the market, and supply constraints imposed by the environment, these systems may homogenize the structure, function and composition of a formerly more heterogeneous ecosystem. Complete exclusion of grazing animals also homogenizes the ecosystem, and this has been the standard practice in GNPC since 1987 as lands have been acquired (Dobson & Leonard 1987). Monitoring in GNPC (McCanny et al. 1996; Sutter 1997; Hall-Beyer & Gwyn 1998; Finnamore 1998; Thorpe & Godwin 2003; Guo et al. 2004) and elsewhere indicates that homogeneity created by landscape-scale, spatially uniform and temporally consistent management provides ideal habitat for only a subset of plants, insects and wildlife (Fuhlendorf & Engle 2001). Thus, ranching generates habitat suitable for one range of species, and extensive tracts of ungrazed land in GNPC provide habitat suitable for another range of species. However, to support the full-suite of biological diversity grazing-induced heterogeneity at a variety of spatial and temporal scales is necessary.

The GNPC Park Management Plan (Parks Canada 2002) proposed implementing a grazing prescription to represent regimes more consistent with historic patterns of migratory and sedentary bison herds, and thereby "*emphasize aspects that are under-represented in the regional landscape*". The prescription contains a mixture of year-long low-moderate intensity grazing on less than a third of the area, short-duration high-intensity grazing events on small patches, and in any given year most of GNPC would remain ungrazed. Either domestic livestock or bison could be used as tools to achieve this prescription, and prescribed fire was also suggested to help vary grazing animal distribution across the landscape from year to year.

As attractive and exciting as this prescription may appear, full implementation involves considerable risk because the impacts of grazing are not fully understood. As part of the adaptive management process, GNPC opted to test grazing prescriptions on an experimental scale, and expand the monitoring program to include adjacent ranchlands. Experimental results will help GNPC evaluate how, when and where grazing-induced change occurs, and the broad monitoring program will help evaluate how long-term ungrazed landscapes remain different from grazed ranch lands. This approach will demonstrate the biodiversity benefits of both conventional ranching used by neighbours and unconventional grazing systems used in GNPC. Further, data generated by the experiment will be integrated in the Grassland Ecosystem Management Support project (GEMS) to generate spatially explicit simulation models of grazing management decisions (Wilmshurst 2005). The experiment and GEMS combined will also assist in the bison reintroduction program elsewhere in GNPC (Sissons et al. 2005), by specifically testing grazing intensity effects and monitoring methods useful for adjusting target population sizes.

The vision for the experiment was to develop a research program into livestock grazing impacts on prairie ecosystems and biodiversity, particularly wildlife Species-at-Risk, not performed in any other North American national park (Penny 2004). This stemmed from a general interest to understand grazing impacts on ecological integrity measures identified in the GNPC Park Management Plan (Parks Canada 2002), the Frenchman River – Bitter Creek Site Conservation Plan (Smith-Fargey 2004), and the Saskatchewan Prairie Conservation Action Plan (PCAP 2003). There was also specific interest in strengthening partnerships with and leveraging funding for university, government and NGO research institutions to generate information of scientific, educational and interpretive value beyond GNPC. Simultaneously, the experiment could provide extension opportunities for partners in the Prairie Conservation Action Plan, and Frenchman River – Bitter Creek Site Conservation Plan.

While the vision provided tremendous scope to examine grazing, and a large area in the East Block of GNPC was set aside to conduct the experiment (Fig. 1), the specific goal of this experiment to

"Determine how grazing intensity affects heterogeneity in the multi-scale structure and function of mixed-grass prairie communities"

was decided upon after much consideration. This process included meetings with prospective collaborators to generate conceptual designs involving grazing and fire interactions at scales appropriate for some ecological integrity measures (Appendix A). A working group was struck following this meeting to develop a final set of objectives (Section 5.0) and design the experiment (Sections 6.0 and 7.0), following consideration of a literature review to identify knowledge gaps (Section 2.0), as well as consideration of the land available (Section 3.0), and multiple physical, logistical and statistical limitations of potential designs (Section 4.0). In essence, this process followed a model used by The Nature Conservancy (USA) to plan restoration and monitoring of grazing and fire on grassland conservation areas (Steuter et al. 1990). Throughout this process, the GNPC Park Management Plan provided essential direction to keep objectives, methods and expected results consistent with strategic goals for 2002 to 2007.

2.0 HETEROGENEITY AND DIVERSITY IN MIXED-GRASS PRAIRIE: A REVIEW

Ecologists have become increasingly interested in the variety of ecological patterns and processes at multiple spatial and temporal scales (a.k.a. heterogeneity), and the scientific challenge has been to accurately identify processes that create patterns and precisely quantify scales at which patterns change (Kotliar & Weins 1990; Levin 1992). In Great Plains semi-arid grasslands, grazing and fire create complex patterns in ecosystem structure, composition and function (Milchunas et al. 1988), and the spatial scales at which these processes produce an effect vary from individual plants to soil-landscape units (Adler et al. 2001). The temporal scales most relevant for observing effects are the large amplitude of seasonal and inter-annual shifts in climate (Fig. 2).

Spatial variation among landscapes and temporal variation among years can be greater sources of heterogeneity in community dynamics, relative to grazing and fire effects. Geomorphic variation is the most stable factor driving predictable patterns of soil organic matter mass, and plant and insect productivity and composition (Burke et al. 1999; Milchunas et al. 1989; Quinn et al. 1991; Kemp 1992; Kemp & Cigliano 1994). Among years, changes in annual precipitation correlate best with aboveground plant production (Sims et al. 1978; Smoliak 1986) and grasshopper populations (Johnson & Worobec 1988; Mukerji & Hayhoe 1988; Capinera & Horton 1989); and each can vary by an order of magnitude. The relative importance of grazing in light of these factors does vary among studies (Biondini et al. 1998; Milchunas et al. 1989), and the magnitude and direction of grazing effects in space and time may be overshadowed by more dominant climate and landscape factors.

2.1 Factors Influencing Grazing Animal Distribution

Large ungulate distribution across landscapes reflects behavioural adaptations to avoid predators and inclement weather, maintain breeding and feeding territories, and maximize foraging efficiency (Coughenour 1991). Much of this behaviour has been modified in domestic livestock (Oesterheld et al. 1992), but optimal foraging theory (MacArthur & Pianka 1966) remains applicable across a variety of situations. Essentially, an animal must balance or exceed the energy gained from a food item with the energy spent searching for and handling that food item in order to survive and reproduce. Thus, grazers must make decisions that accommodate forage quality and quantity variation in time due to climate and phenological development, and in space due to soil, plant species, and past disturbance (Sneft et al. 1987).

Spatially, cattle prefer areas less than 1 km from water with slope gradients less than 10-20% (Sneft et al. 1985; Ganskopp & Vavra 1987; Willms 1988; Pinchak et al. 1991). Bison also prefer areas within 2 km of water (Fortin et al. 2003) and open landscapes away from hills or forest cover (Steuter et al. 1995). Hart et al. (1993) found forage utilization declined exponentially with distance from water, with little or none beyond 4 km. Search costs are reduced on these landscapes because less energy is spent climbing hills and traveling between foraging patches and water sources. Where water and slope are not limiting, cattle prefer patches with greater soil moisture, forage production and forage protein content (Milchunas et al. 1989; Smith et al. 1992). These sites typically occur in the level bottom of swales, coulees and valleys, or level uplands. In contrast, bison appear to select grass-dominated patches regardless of productivity (Plumb & Dodd 1993; Peden et al. 1974).

Temporally, occupation of preferred sites during the growing season is relatively stable, but some movements are associated with phenological development and community succession (Willms et al. 1988; Steuter et al. 1995). The "grazing lawn" structure (McNaughton 1984) formed on preferred patches is most obvious at low animal density, but the boundaries expand and contract with changes in animal density or inter-annual droughts (Willms 1988). The greatest patchiness within the area influenced by grazing is expected at the lowest density of animals, because this favours selectivity (Fuhlendorf & Smeins 1999). Thus, some low to moderate density of animals allowed to graze during the active growing season of preferred plant species should result in the greatest heterogeneity in vegetation patch structure within a landscape.

Fire also affects grazing animal distribution by reducing handling costs and increasing energy gained per unit time foraging. Grazers avoid foraging in patches with a high proportion of litter (Willms 1988), and burning mixed-grass prairie reduces litter for several years (Pylepec & Romo 2003; Whisenant & Uresk 1989), increases the mineral content of grass regrowth (Coppock & Detling 1986), and may also increase aboveground forage production (Engle & Bultsma 1984; Pylepec & Romo 2003). Multiple studies indicate bison and cattle significantly prefer foraging in burnovers relative to adjacent unburned mixed-grass prairie for 1 to 3 years (Coppock & Detling 1986; Coppedge & Shaw 1998; Biondini et al. 1999; Erichsen-Arychuk et al. 2002). Burnover size is also a factor affecting utilization, and animals reside longer in the larger patches (Vinton et al. 1993). No studies involved burnovers >1.6 km from water or varied stocking rates, both of which may further influence selection of burned patches.

2.2 Effects of Grazing Intensity on Ecological Integrity

While several grazing variables can be manipulated, it is generally agreed that grazing intensity (density and duration) has the greatest effect on soils, plants and other ecosystem measures. It is important to distinguish between grazing intensity and range condition; the former involving manipulated stocking rates and duration in a controlled experiment, the latter involving described patterns of plant community composition relative to a potential natural community as a proxy for estimating historic grazing pressure (Dyksterhuis 1949; Friedel 1991). Manipulated experiments are few, and often limited in scale or replication. The largest experimental units are 265 ha near Onefour Alberta, the longest run treatments began in 1916 near Mandan North Dakota, and the largest number of independent replicates in any study is 3, but no experiment has replicated, pre and post-treatment measurements at similar spatial scales (Appendix B). There are far more cases where multiple exclosures have been established in one or a few grazed pastures, and over-the-fence comparisons are made after some time has elapsed (Stroup et al. 1986). Collectively, these studies provide useful information on soil structure and function, and alpha-scale diversity of plant communities, but are too small to measure most other responses. Landscape-scale studies are almost entirely descriptive and rely on range condition.

Grazing exerts top-down effects on prairie ecosystem composition, structure and function, and may cause reversible changes along a gradient of grazing intensity. This theory of retrogressive succession (Dyksterhuis 1949; Milchunas et al. 1988) assumes autogenic plant community change towards a potential climax community can be held back at earlier seral stages by allogenic grazing effects on plant functional groups. These changes are theorized to have bottom-up feedbacks on nutrient cycles and invertebrate and vertebrate species assemblages, with maximum species coexistence at intermediate durations since, or intensities of, disturbance (Collins & Glenn 1997a).

An alternative to this resilience theory, is that thresholds exist for individual or combined ecosystem processes (i.e. grazing, fire, drought, woody and alien species invasions), and once surpassed there is an irreversible compositional, structural and functional transition to one of several new stable states. These state and transition models are popular in rangeland ecology and management (Westoby et al. 1989; Laycock 1991; Friedel 1991), with interest focused on transition probabilities under different intensities and interactions of each factor. In reality, both retrogressive and state-transition models apply at different scales (Fig. 3), and integration of these concepts better reflects grassland dynamics (Stringham et al. 2003; Briske et al. 2005; Cingolani et al. 2005).

2.2.1 Biomass, Soil and Water Quality Responses to Grazing

Changes in belowground components of semiarid grasslands require either dramatic alterations (cultivation) or long time periods (decades) before management effects become detectable (Fahnestock & Detling 2002; Henderson et al. 2004a). Aboveground reductions in litter mass or vegetation standing crop are the most rapid and dramatic structural changes on grazed semiarid grasslands, but soil organic matter pools tend to be very stable (Frank et al. 1995; Schuman et al. 1999; Burke et al. 1999; Willms et al. 2002; Henderson et al. 2004b). However, rates of soil nitrogen turnover consistently appear to increase with grazing pressure (Knapp et al. 1999; Biondini et al. 1998), and roots either decline or become redistributed near the surface (Fuhlendorf & Smeins 1998; Sims et al. 1978). For instance, patches where livestock urinate may be avoided in the same year, then become more attractive than surrounding vegetation in the second year (Steinauer & Collins 2001). The magnitude of these changes is much less where conditions are more arid or saline (Willms et al. 2002; Henderson et al 2004b). The structural differences in vegetation are easily detected at landscape-scales through remote sensing imagery (Guo et al. 2004), but to detect changes in soil large samples are required given substantial spatial heterogeneity (Henderson et al. 2004a).

Riparian ecosystems, consisting of both stream banks and adjacent floodplains, are particularly susceptible to livestock impacts (Kauffman & Krueger 1984; Fitch & Adams 1998). Intense grazing of lush vegetation and trampling of moist soils leads to decreased vegetation cover and root mass, and increased bare ground and stream sedimentation (Scrimgeour & Kendall 2002; Schultz & Leninger 1990). Relative to grazing exclosures, riparian plant community diversity may actually increase with grazing (Green & Kauffman 1995). Where impacts are most intense, decreased vegetation will increase stream flow and channel incisement, which lowers the floodplain water table and results in irreversible state transitions to more drought tolerant vegetation (Stringham et al. 2001). Riparian health classification systems integrate this information into categories representing "healthy", "healthy with problems", and "unhealthy", and the ratio of these categories in pre-settlement times is assumed to have been 70:20:10 (Fitch & Ambrose 2003).

2.2.2 Plant Community Composition and Grazing

Plant community composition is modified by grazing animal selection for particular species and subsequent alterations to competitive interactions and successional directions (Plumb & Dodd 1993). This impact is most notable amongst the dominant mixed-grass prairie species, where both *Bouteloua* *gracilis* and *Artemisia frigida* increase, and both *Stipa comata* and *Agropyron smithii* decrease as grazing intensity increases (Smoliak et al. 1972; Milchunas et al. 1989; Willms et al. 2002). In a review by Milchunas et al. (1988) plant community diversity was maximized for subhumid grasslands after long periods of intermediate grazing intensities but this relationship disappeared as aridity increased. The latter conclusion was based on one experimental site in Colorado, but Hart (2001) sampled this same site and found diversity and evenness were maximized at intermediate grazing intensities after 50 years. Bai et al. (2001) found a similar but weak relationship among sites in Saskatchewan along a range condition gradient, and Willms et al. (2002) found moderately grazed grasslands were more diverse than adjacent 67 year old exclosures in Alberta.

Monitoring at GNPC indicates little compositional change occurred in upland grasslands after 4 to 10 years of grazing exclusion (McCanny et al. 1996), but the relative abundance of some dominant grasses did change in valley grasslands after 7 to 18 years of exclusion (Thorpe & Godwin 2003). Other studies of changed grazing regimes indicate little or no compositional effect for 2 to 7 years (Stanely & Knopf 2002; Fahnestock & Detling 2002; Gillen et al. 2000; Cid et al. 1991), so more than a decade may be necessary for changes to become detectable. Scale may also be a distinguishing factor, since community dissimilarity among sites within a grazing treatment can be greater than among treatments (Stohlgren et al. 1999), suggesting before and after measurements probably yield more accurate results than sampling spatially separated treatments after the effect has occurred.

At least 338 vascular plants are known in GNPC (Michalsky & Ellis 1994), and the identity and abundance of many species can change among spatially separate communities with little statistical change in richness or diversity (Stohlgren et al. 1997). Rare species of concern in GNPC include *Erigeron radicatus*, *Oxytropis besseyi*, *Boisduvalia glabella*, *Danthonia unispicata*, and *Juniperus scopulorum* (Michalsky & Ellis 1994), while the exotic invasive species of most concern include *Bromus inermis*, *Agropyron cristatum*, *Melilotus officinale*, *Euphorbia esula*, *Centaurea* spp., and *Bromus japonicus* (Michalsky et al. 2005). Patches of livestock dung, bison wallows, and burrowing animal mounds may be important sources of mortality for dominant perennial plants and help create microsites for these rare and invasive plants to get established (Coffin & Lauenroth 1988; Umbanhowar 1992). Collectively, these disturbances are important for maintaining natural plant community diversity, but may simultaneously facilitate a state transition to exotic vegetation.

2.2.3 Invertebrate Community Composition and Grazing

Invertebrates comprise most of the known biodiversity and serve many essential functions in grassland ecosystems as herbivores, carnivores, scavengers, detritovores, parasites, pollinators and prey. Arthropods are particularly important in northern mixed prairie, and individual species may have different functional roles at each developmental stage. Grazing has potentially positive or negative impacts among different invertebrate species, or upon different developmental stages of individual species. For those reasons, many have suggested grazing regimes that promote temporal and spatial heterogeneity will support the largest diversity of invertebrates (Capinera & Sechrist 1982; Sugden 1985; Schlicht & Orwig 1992).

Butterfly (Lepidoptera) adults are important pollinators, and 87 species are expected to occur in GNPC (Kondla 2004). Landscape heterogeneity correlates strongly with species richness (Kerr et al.

2001), and species develop and emerge in sequence over the frost-free season, such that disturbance at any time can have negative impacts on at least one species (Schlicht & Orwig 1992). Direct negative impacts of grazing include mortality of larvae from trampling or burial beneath dung (Ehrlich & Murphy 1987). Conversely, skipper butterflies in Minnesota tallgrass appeared to benefit from the abundance of favoured nectar plants in moderately grazed areas, and male skippers used heavily trampled areas near water for "puddling" (Dana 1991). Grazing impacts on the threatened Mormon metalmark (*Apodemia mormo*) in GNPC are unknown.

Grasshoppers (Orthoptera: Acrididae) are major herbivores that also serve an important role as prey for beetles, spiders and wildlife (Fair et al. 1995; Branson 2005). Up to 70 species are expected to occur in the GNPC region (Capinera et al. 2005), but grazing effects on grasshopper communities vary considerably perhaps due to the overriding importance of climate on population dynamics (Johnson & Worobec 1988; Mukerji & Hayhoe 1988). In Montana, Miller & Onsanger (1991) found grazing had no influence on grasshopper density. Conversely, density was higher in experimentally ungrazed or lightly grazed pastures in Colorado shortgrass prairie (Capinera & Sechrist 1982), and functional group changes were positively correlated with grass and forb biomass affected by grazing. These patterns remained constant after 20 years of consistent treatment application on these same sites (Welch et al. 1991). Quinn & Walgenbach (1990) also found ungrazed areas had greater evenness and richness of functional types, while obligate grass feeders dominated grazed areas. This contrasts with Joern's (2005) results that grazing was more important than fire or soil for promoting grasshopper diversity in tallgrass prairie, and Onsanger's (2000) documentation of greater grasshopper density in continuously grazed mixed prairie relative to more lightly grazed rotations.

Ground beetles (Coleoptera: Carabidae) are large mobile predators, are often species rich and abundant, and differ in composition along environmental and disturbance gradients (Lovei & Sunderland 1996; Larsen et al. 2003). Ground beetles are also significant predators on grasshoppers, and are most active when grasshopper nymphs are abundant in early summer (Quinn et al. 1993). At least 63 species have been recorded in and around GNPC, and community dissimilarity is greatest between sites differing in grazing intensity or range condition (Finnamore 1998; Pepper 1999). This dissimilarity is due to the absence or reduced abundance of several species in grazed grasslands; thus, these species may be useful indicators. This interpretation should be cautiously applied, since the 52% dissimilarity among grazing treatments (Finnamore 1998) was less than the 60% dissimilarity between these two studies. Abundance of individual species can change by two orders of magnitude among seasons and years at the same site (McIntyre 1995), which may contribute to difficulties finding subtle treatment effects among whole communities (Quinn et al. 1991).

A number of other invertebrates also respond to grazing intensity. Mound-building ants (Hymenoptera: Formicidae) generate predictable patterns of soil, vegetation and seedbank characteristics in the immediate vicinity of mounds (Coffin & Lauenroth 1990), and mound density appears to decrease with increased grazing intensity (Usnick & Hart 2002). Spiders (Arachnida: Araneae) are strictly predaceous arthropods, and differences in ground-dwelling species have been described between sites differing in range condition (Pepper 1999). Dragonfly and damselfly (Odonata) larvae are major predators in aquatic systems, and adults are aerial predators of flying insects. Adults are reduced in abundance and richness in riparian zones accessible to livestock, because trampling and grazing reduce availability of suitable emergence and oviposition sites (Rice

2003). Many leafhoppers (Homoptera) are obligate specialists on prairie plant species (Hamilton 2005), and shifts in plant abundance due to grazing could be related to shifts in the composition of leafhopper communities. Large numbers of flies (Diptera) and bees (Hymenoptera: Apoidea), as well as soil-dwelling mites (Arachnida: Acari) and springtails (Collembola) also occur, but little data are available relevant to grazing and biodiversity in native grasslands.

2.2.4 Wildlife Responses to Grazing

Songbird abundance has been evaluated in several studies, where structural vegetation changes along grazing intensity gradients are correlated with the relative abundance of the 10 to 15 songbird species most common in mixed prairie (Chapman et al. 2004; Fondell & Ball 2004; Sutter & Brigham 1998; Knopf 1996). Some species, like horned lark (*Eremophila alpestris*), are most abundant in low cover generated by high grazing intensity (Fritcher et al. 2004, Fontaine et al. 2004), while others, like the threatened Sprague's pipit (*Anthus spragueii*), prefer taller vegetation characteristic of ungrazed areas. Songbird diversity can be greatest under moderate intensity grazing that supplies habitat patches desired by all species (Chapman et al. 2004), but this pattern has not always emerged in landscape-scale studies (Kantrud 1981). Large patches of suitable habitat seem more important than within-patch heterogeneity within habitats for explaining species occupancy (Weins 1974). For instance, Davis (2004) found up to 150 ha were necessary for species like Sprague's pipit to occur with 95% confidence. For co-existence of species like the endangered mountain plover (*Charadrius montanus*) characteristic of severely overgrazed grasslands (Olson-Edge & Edge 1987), and the threatened loggerhead shrike (*Lanius ludovicianus excubitorides*) characteristic of ungrazed riparian shrublands (Prescott & Collister 1993), both landscape and grazing variation is needed.

Rodents, insectivores and lagomorphs in upland mixed prairie feed on plants and invertebrates (French et al. 1976), but responses of these species to livestock grazing are not well understood. Although Richardson's ground squirrel (*Spermophilus richardsonii*) is an important prey for several carnivores (Schmutz et al. 2001; Michener 2004) and predator of bird eggs (With 1994), the abundance of this species is only anecdotally related to grazing. Small mammal abundance most often appears correlated with climatic variability (Zhang et al. 2003) and richness or composition differs more among topographic and landscape positions (Chapman & Ribic 2002; Reynolds et al. 1999), while grazing may or may not have positive or negative influences on particular species (Schmidt et al. 2005; Fehmi et al. 2005; Chapman & Ribic 2002; Matlack et al. 2001). Scale also appears to be important, as Rosenstock (1996) found significant grazing effects on small mammal richness or abundance at landscape-scales but not among 1 ha exclosures. Collins (2000) could not distinguish fire frequency effects among songbird or small mammal communities in tallgrass prairie, and suggested factors larger than the experimental units (mean = 64 ha) were more important determinants.

Larger birds and mammals have home ranges that often exceed several square km, and utilize different habitats for nesting or denning, foraging and breeding, often independent of grazing regime (Reynolds et al. 1999). A further complication for study is that Species-at-Risk or of "special concern" like swift fox (*Vulpes velox*), ferruginous hawk (*Buteo regalis*), short-ear owl (*Asio flammeus*), burrowing owl (*Athene cunicularia*), greater sage grouse (*Centrocercus urophasianus*), and long-billed curlew (*Numenius americanus*) occur at low densities in GNPC, and may not be detected in otherwise suitable habitat. Thus, scales appropriate for controlled experiments may best address grazing effects on food supply and habitat structure for these wildlife species even if population level effects cannot be demonstrated.

2.3 Knowledge Gaps and Research Directions

Relatively few studies measured landscape-scale biotic responses or involved interactions along grazing gradients. At the largest scale, it may be useful to test how ungulate distribution changes on lightly grazed vs. heavily grazed landscapes, and to identify at which intensity gamma and beta heterogeneity is maximized. At smaller scales, the interaction of grazing animal density and distance among fixed resources (fences, water, slopes) provides an interesting context for studying alpha and beta diversity of songbirds, insects and plants and examining assumptions regarding optimal foraging theory of livestock. It may require more than a decade for some responses to emerge, but these questions interest a broad-range of managers and researchers.

Relatively few studies combined fire and grazing to examine heterogeneity at multiple spatial and organismal scales. Several studies illustrate ungulate preference for burnovers, but none experimentally controlled for distance from water nor replicated the grazing factor. Most studies were also conducted in subhumid prairies where fuel is sufficient to support frequent burns. It may be useful to test whether or not burning will encourage animal movement far from water and how the interaction of grazing and burning affect heterogeneity in semiarid mixed prairie. These questions directly address assumptions made in the GNPC management plan. Pursuing any one research objective and emergent experimental design means facing physical, logistical, and analytical constraints imposed by the available area and possible questions.

3.0 EXPERIMENTAL SITE DESCRIPTION

The East Block of GNPC is entirely within the Missouri River drainage basin, and several ephemeral and permanent streams flow south along an elevation gradient from 1030 to 750 m asl. Ecologically, this area is characteristic of northern mixed-grass prairie (Coupland 1950), and supports a wide range of landscapes varying in hydrologic, soil and vegetation characteristics. The area set aside for the experiment (portions of Townships 1 & 2, Ranges 6 & 7, West of the 3rd Meridian) occupies nearly 100 km^2 in the East Block, and is characterized by a relatively low relief and low elevation (750 to 850 m asl.) landscape of glacial till and alluvial deposits (Fig. 4). Upland soils on till are dominantly loamy, orthic brown chernozems with local swales supporting brown vertisols where clay has accumulated. Valley soils on alluvium are a complex of fine saline regosols, solonetz, and chernozems on upper terraces, while lower terraces adjacent to streams are loamy humic regosols (Saskatchewan Institute of Pedology 1992). Mean annual precipitation is approximately 350 mm.

Three broad vegetation-landscape units occur in the experimental area: riparian shrublands, upland grasslands, and valley grasslands (Michalsky & Ellis 1994). Riparian shrubland communities are dominated by western snowberry (*Symphoricarpos occidentalis*), prairie rose (*Rosa acicularis*) and sagebrush (*Artemisia cana*) with a herbaceous layer characteristic of moist nutrient-rich sites (i.e. *Solidago canadensis*, *Glycrrhizae lepidota*, *Poa compressa*). Upland grasslands are dominated by speargrass (*Stipa comata*), northern wheatgrass (*Elymus lanceolatus*), blue grama (*Bouteloua gracilis*), June grass (*Koeleria macrantha*) and western wheatgrass (*Pascopyrum smithii*) along with several ubiquitous forbs (*Artemisia frigida*, *Phlox hoodii*, *Sphaeralcea coccinea*) and clubmoss (*Selaginella densa*). The relative abundance of speargrass and wheatgrass change along edaphic gradients, with more speargrass on drier hill-crests and shoulder slopes, and more wheatgrass on moister toe slopes and swales. Valley grasslands are patchy, reflecting varied salinity and microtopography. Elevated salt flats support cactus (*Opuntia* spp.) and shrubs (*Artemisia cana*, *Atriplex* spp., *Chrysothamnus nauseosus*, *Sarcobatus vermiculatus*), along with wheatgrasses, bluegrasses (*Poa sandbergii*, *P. compressa*) and salt grasses (*Distichlis stricta*, *Puccinella nuttallii*). Shallow, gleysolic gullies and less saline terraces closely resemble wheatgrass-dominated uplands.

Perhaps the most significant features of this area include that it was never fragmented by cultivation, nor heavily utilized by livestock in the time between homesteading in the early 1900s and purchase by Parks Canada, and there are few cross-fences. Most of the area was divided in two portions known as the "Frazer-Lamb Ranch" and only a few impoundments along Horse and Weatherall Creek provided stock water (Fig. 5). Since the 1930s, the land was summer grazed by cattle and in some cases a combination of horses and cattle were grazed year-round, although no livestock grazing may have occurred from year to year due to the distance and poor access from other land holdings of the ranch (Poirier 1993). Analysis of 1982 infrared aerial photographs indicated livestock trails crossed the area in nearly parallel lines, perpendicular to the two creeks, and uplands between trails and away from creeks were lightly grazed relative to smaller pastures nearby. This light grazing pressure continued until complete livestock exclusion after purchase in 1990 (SW portion, Township 1) and 1991 (NE portion, Township 1).

Several GNPC monitoring projects have sampled sites within the experimental area, and these sites may be monitored in future as part of other Park-wide programs. Geospatial and dataset files are maintained by GNPC for annually monitored raptor nest, swift fox sightings, and sage grouse lek locations (Robert Sissons, pers. comm.), a large number of songbird point-count stations have been intermittently sampled in Horse Creek valley (Sutter 1998), and a series of "bioplots" were also established in four clusters within and adjacent to the experimental area, where vegetation sampling has occurred (McCanny et al. 1996).

4.0 Physical, Logistical and Statistical Constraints for Experimentation

Many field experiments suffer from a limited physical scale, lack of initial sampling, and lack of independent replicates that limit inference of results (Eberhardt & Thomas 1991). At GNPC there is a unique opportunity to greatly increase the size of experimental units and characterize baseline conditions prior to manipulation. The most accurate measurements of cause and effect are achieved through "before" and "after" measurements in adjacent treatments representing at least one "control" and one "impact"; known widely as a "BACI" design (Stewart-Oaten et al. 1986). The potential for establishing landscape-scale experimental units is novel and attractive to researchers because units can control for environmental variation in space (Dutilleul 1993), and replication of these units allows for independent estimates of population parameters within a large population of inference (Stroup et al. 1986). Despite these ideal goals, there are a limited number of experimental unit sizes and shapes that fit and this constrains the possible designs.

A balance must be achieved to create experimental units large enough to impose the treatments of interest, to measure the responses of interest, and to control for environmental variation among units. The consensus of local experts indicated the Hereford and Angus breeds of cattle commonly produced in northern mixed-grass prairie were unlikely to exhibit natural herding and foraging behaviour in fields less than 500 to 750 ha (Appendix A). As well, naïve grass-fed yearlings could help control for divergence between and variability among pastures that would otherwise occur by using experienced cows or cow-calf pairs. The juxtaposition of water, slope and vegetation types must also be consistent among units to encourage similar foraging patterns. Although the experimental area provides nearly 100 km^2, only 50 km^2 of upland and valley grassland adjacent to two creeks with associated riparian shrubland met these landscape criteria.

Two additional constraints were realized at an early stage. First, grazing disturbance by bison historically occurred throughout the year, and certainly will where bison are being reintroduced in GNPC (Sissons et al. 2005). However, grazing seasons are limited when using domestic livestock because animal care regulations applying to federal lands require supplemental feed and wind/snow shelters in winter. Supplemental feed risks introducing weeds and altering the expected responses, and shelter construction would increase landscape disturbance and alter foraging patterns, two consequences not desired by GNPC or the steering group. Thus, only the spring to fall season remained possible for grazing treatments.

Second, fire was an important natural disturbance in northern mixed prairie, and was an integral part of initial experimental designs to manipulate foraging behaviour and create patch-scale heterogeneity in grazing pressure. However, for any factorial arrangement of grazing and fire the minimum treatment unit must accommodate the most area-requiring species. Among songbirds of management concern, some were unlikely to be detected in patches less than 150 ha (Davis 2004), thus sufficient area for subplots of factorial prescribed burn treatments on just one vegetation type, within one experimental unit would require 300 ha. An operational problem was immediately identified, because executing prescribed burns of this size, in multiple units, in multiple years was not possible given weather, water, fuel, staff and equipment limitations. Without fire to manipulate animal distribution, other attractants were considered. The most effective option to ensure grazing pressure in both valleys and uplands is to supply water in uplands furthest from riparian water sources. These fixed resources create radiating gradients of grazing impact on the surrounding landscape most similar to adjacent ranches.

With limitations on grazing season and prescribed burning, grazing intensity remained the best option for experimentation. Multiple iterations of experimental unit sizes and locations were used to maximize replication and levels of the grazing intensity factor. To meet all of the above criteria, only three units >500 ha each could be accommodated and this eliminated any possibility of replicating two or more treatments. At a minimum, evaluating grazing intensity requires at least three treatments (i.e. high, medium, low) to determine if grazing exerts linear or non-linear (threshold) effects on the responses of interest, and three replicates of each to generate unbiased measures of variation. To accommodate nine units, the size of each must be reduced to ~300 ha. Alternatively, an unreplicated gradient of grazing intensity treatments could be analyzed using regression, in which case a minimum of eight units representing a range of intensities could be included. This second option may be more powerful for quantitatively identifying the threshold point for grazing-induced change, but there is a risk spatial variation could confound those analyses if baseline "before" conditions were not adequately documented (Oksanen 2001).

These rules of thumb for replication based on experience are no substitute for a priori analyses of minimum sample size for each response based on the known variability of those statistical populations, desired effect size and power (Toft & Shea 1983). In an effort to "hedge our bets", the 300 ha unit size was selected for the experiment with the intention of pursuing an unreplicated gradient, on the condition that preliminary sampling in Phase 1 (Section 6.1) would help estimate biologically relevant effect sizes and variation to calculate minimum sample sizes at pre-selected type 1 and 2 error rates (Appendix C).

5.0 Experimental Objectives and Hypotheses

The primary objective of this experiment is to answer the question: **How does grazing intensity affect heterogeneity in the multi-scale structure and function of mixed-grass prairie communities?** The components of this objective are defined below.

- **Grazing intensity** will be manipulated by setting different stocking rates of a single livestock class and grazing season, among units of equal size, shape, water and landscape distribution.
- **Heterogeneity** is a general term for measures of variability, diversity, dissimilarity or complexity in a given response (Appendix D).
- **Multiple scales** will be reflected in measurements of distance between sampling points (potentially 10 cm to 1000m), or predefined scales of organization (alpha, beta, gamma), and annually repeated monitoring to evaluate temporal trends.
- **Structure and function** are the non-compositional vegetation and soil measures of ecological integrity (i.e. plant production, available soil N, vegetation height, actual utilization, bare ground cover, dung pat density, burrow density, riparian health index).
- **Mixed-grass prairie communities** are the compositional plant, invertebrate and vertebrate measures of ecological integrity (i.e. focal species of exotic plants, wildlife Species-at-Risk and Richardson's ground squirrel, as well as multi-species communities of vascular plants, grasshoppers, ground beetles, and birds).

From this general objective, a number of specific hypotheses outline the expected responses to a gradient of grazing-intensity treatments, and contrasts that ensure comparisons with adjacent conventionally managed rangeland and the current grazing exclusion treatment (Table 1). In Phase 1 of the experiment, two years (2006 & 2007) of baseline sampling will occur in "ungrazed" control units inside GNPC and three "grazed" control units on adjacent ranchlands to determine biologically relevant effect sizes, sampling intensities for detectability, and baseline spatial heterogeneity. The constraints limiting the design of experimental units within GNPC will be used as selection criteria for delineating the conventionally grazed units on adjacent ranchlands. Phase 2 begins once the manipulated grazing treatments are implemented, and will continue for at least 10 years (2008 to 2017). Phase 2 involves integrated monitoring of heterogeneity through time, space and along a gradient of grazing intensity, and hypothesis testing based on known impacts from the literature, and theories of retrogressive – progressive succession and the intermediate disturbance hypothesis (Section 2.2). Phase 3 will address the primary Park Management question, how unconventional grazing regimes compare with conventional grazing.

Many constraints limited which species or species-groups could be included in an annual monitoring program, and reviewers proposed many more (Appendix E) that were not listed in Table 1. Vascular plant communities were selected because these represent the producer components of the trophic web, and the composition of these communities directly responds to selective herbivory by livestock. Grasshoppers are perhaps the second most important group of herbivores, providing a key prey for ground beetles, and both grasshoppers and beetles are the most frequent items in the diet of prairie songbirds. Among the songbirds there are several Species-at-Risk that may change in abundance as cattle directly affect nesting cover and indirectly affect insect prey availability. While this does not cover the full gamut of biological communities, it does represent a range of taxonomic and functional groups representative of biological diversity.

Structure and function measurements help link grazing effects to habitat selection by Species-at-Risk, and resource availability affecting nutrient cycles and compositional change in biological communities. Some of the appropriate measures are specific soil chemical constituents or vegetation height, biomass, cover and density values, while other measures are indices of rangeland and riparian health that integrate qualitative measures into quantitative scores important for communicating grazing effects with a broader audience of land managers. A number of additional measures were proposed by the stakeholder group and reviewers, but could not be accommodated given constraints of scale, equipment and relevance to Parks Canada (Appendix E).

6.0 Experimental Design and Analyses

The analytical challenge for testing hypotheses in a landscape-scale unreplicated design is the lack of independence in estimates of variance. Subsample variation could be used to test for differences between adjacent treatments with the understanding that inferences are limited, but this approach is still vulnerable to drawing conclusions about treatment effects that may actually be due to spatial variation among the treatments prior to manipulations, or temporal variation in the year sampling occurred (Hurlburt 1984; Oksanen 2001). To control for these problems, a BACI design is generally recommended. Underwood (1994) suggested a BACI variant, “Beyond BACI” that physically replicates control treatments, but retains unreplicated impact treatments. The controls could include both continuously ungrazed GNPC lands and continuously grazed ranchlands, and is the only design allowing all comparisons desired by GNPC.

In total, 12 experimental units have been designed to equally represent the proportion and juxtaposition of riparian, valley and upland vegetation-landscape units (Fig. 6). Watering points have been selected to represent a similar distribution in “grazed controls” outside the park, and the “grazed control” units are also restricted to pastures of similar size and vegetation-landscape juxtaposition. Grazing history may have varied among these units, so interviews with previous landholders and current land managers will be conducted to create a detailed grazing history statement for each unit. The purpose of these controls is to ensure, as much as is possible, that cattle foraging behaviour and resulting patterns of grazing among units reflects stocking rate effects, and not uncontrolled variation from the location, area and juxtaposition of resources between units.

6.1 Phase 1 – Spatial heterogeneity of grazed and ungrazed treatments

Several options are available in Phase 1 to evaluate each measure at multiple spatial scales within between these two treatments, or between scales in a single treatment. This approach is most flexible for vegetation measurements taken at quadrat scales (1200), upland and valley sample station scales (120), riparian sample station scales (48), and experimental unit scales (12). Aggregates of these observations can be made within sample stations (among the 10 quadrats in a sample station), within experimental units (among the 4 to 14 sample stations in an experimental unit), or within grazing treatments (among the 3 conventionally grazed and up to 9 ungrazed experimental units representing each treatment). Statistical tests can employ univariate comparisons at one or more of these scales, using parametric or non-parametric single or multi-factor fixed-effect or mixed-effect models (Zar 1999; Fitzmaurice et al. 2004). Alternatively, multivariate differences among aggregates of quadrats, sample stations, or experimental units in ordination space can employ multiple response permutation procedure following an ordination of samples using plant, grasshopper, beetle and/or songbird community matrices. This approach explicitly relies on compositional dissimilarity, but correlations with vectors of all other population, structural and functional responses can be tested using canonical correspondence analysis or non-metric multi-dimensional scaling (Gurevitch & Collins 1994).

6.2 Phase 2 – Grazing-induced heterogeneity over time

Grazing intensity treatments represent a range of season-long (June to October) continuous grazing by yearling Hereford or Angus, grass-fed steers at stocking rates equal to, greater than and less than conventionally managed rangelands (Table 2). Stocking rates are set to utilize forage at targets based on median production values for the region, and the maximum target of 70% makes allowances for inter-annual variation so the probability of forage shortages necessitating premature animal removal will be reduced to 1 in 10 years. Should these forage shortages occur, supplemental feed will not be provided to avoid weed contamination and confounding of treatment effects. Stocking rates are presented in Animal Units (1 AU = 1000 lb) because the actual number of animals each year will depend on actual live body weights when animals are released each spring and the expected weight gains over the grazing period. Thus, actual densities may change from year to year, but the expected grazing pressure should be similar. Grazing intensity treatments will be assigned to experimental units in a stratified manner, following preliminary analyses of spatial variation among units. This will further ensure the highest or lowest grazing intensities do not end up aggregated in the lowest or highest elevations or other such problems that could result from simple random assignment.

Standard 3 strand barbed wire fences will enclose experimental units, and troughs of sufficient volume to water up to 65 AU will be used in each unit. Water source and supply systems are being developed. Metal "t-bar" posts will be used for fences to reduce landscape impacts, and if funds are available and stock adequately trained, electrified smooth wire may be used in place of barbed wire to prevent injury or mortality of wildlife that catch or get "hung-up" on barbed wire. Operationally, a process is under development for sourcing livestock of the desired class, negotiating grazing fees, weighing animals, and monitoring fences and herd health. This process will become part of a larger grazing management system used throughout GNPC.

Grazing gradient patterns and transition rates will involve repeated measurements over time and will potentially make use of several analytical tools to address the questions in Table 1.

- Autoregressive Integrated Moving Average (ARIMA) models (Box & Jenkins 1976) may be useful to detect before-after effects in each impact site relative to each other and single controls, but require the assumption of stationarity in a before and after time-series; thus these are not suitable for examining gradual change rates and patterns.
- Asymmetrical Analysis of Variance (ANOVA) models (Underwood 1994) may be useful to detect before-after effects in single impact sites relative to multiple control treatments, and rely on detecting significant interactions only; thus these are suitable for comparing conditions at two fixed periods in time but not over the whole span of time.
- Generalized Linear Mixed models (Fitzmaurice et al. 2004) use grazing intensity as the primary independent variable and may be useful to further partition variance due to several nested environmental factors and time, but must be balanced against how adding factors reduces degrees of freedom for detecting grazing-intensity effects.
- Model fitting approaches like Maximum-Likelihood (Juliano 2001), or Akaike's Information Criterion (Johnson & Omland 2004) could use either grazing intensity or time as the independent variable for examining how measured response functions compare with a priori response functions based on theory. This may be most useful for identifying and describing grazing and time response thresholds.
- Direct gradient analysis ordination (Gurevitch & Collins 1994) relies on a multivariate matrix of vegetation, grasshopper, beetle and/or songbird community data to arrange sample stations or experimental units in ordination space. Aggregations of these stations or units relative to known vectors of time and grazing intensity can be visually examined and quantitatively compared among groups using multiple response permutation procedure, or through correlations of groups relative to vectors.

6.3 Phase 3 – Complementary grazing regimes

An explicit desire of GNPC is to establish how conventional grazing on adjacent ranchlands, unconventional grazing exclusion, and unconventionally low and high grazing regimes compare in all measures of ecological integrity. This can be evaluated using the analytical tools described in section 6.2 only after the experiment has been completed in 2018, or through a meta-analysis approach that uses replicates of time and space to make comparisons of response ratios between these treatments (Gurevitch & Hedges 2001).

7.0 MONITORING PLAN FOR ECOLOGICAL INTEGRITY MEASURES

An efficient and effective monitoring plan must meet a number of criteria. Permanent sample stations with co-located, or nested, sampling of multiple variables makes possible analyses of cause and effect for top-down and bottom-up grazing effects (Fig. 7). Each experimental unit will contain

10 sample stations in upland and valley grasslands, and 4 stations in riparian shrublands. The narrow and variable width of riparian shrublands did not lend itself to all questions and sampling methods best suited for upland and valley grasslands, so only a subset of soil and vegetation measures will be sampled (Section 7.3). Sample stations will also be arranged to capture expected grazing intensity variation within and among vegetation-landscape units, in each experimental unit, with the restriction that stations must be >300 m apart to buffer songbird point-counts (Fig. 8).

Double sampling using a combination of georeferenced sample stations in the field with multi-spectral satellite images greatly facilitates scaling-up patterns (Stohlgren et al. 1997). Guo et al. (2005a) found ground-based measures of standing crop biomass and leaf-area-index (LAI) were significantly correlated, and the latter was also correlated with the remotely sensed "Adjusted Transformed Soil Adjusted Vegetation Index" (ATSAVI) (Guo et al. 2005b). Calibration field measurements of LAI at peak vegetation greenness in June, when discrimination with ATSAVI is maximized, could provide a useful remotely sensed link with all other ground-based measures. Interpolation to pixels in-between sample stations would then allow meaningful calculation of heterogeneity within and among experimental units. Analytical tools such as dissimilarity among pixels, a sliding-window textural scale analysis, or kernel size-frequency distributions may be employed for these purposes (Guo et al. 2004; Harris & Asner 2003).

The following sections identify optimum timing for sampling particular responses, but the operational challenge is to organize personnel and equipment to achieve the plan. A maximum of four seasonal technicians are required each year to permit training, access difficulties due to weather, and data collection during narrow windows of opportunity (Table 3). Time needed to implement treatments, train and supervise staff, and actually collect samples and enter data is included in these estimates.

7.1 Vertebrate and Invertebrate Sampling

Songbird richness and relative abundance will be sampled from within 120, 100-m radius point count stations (Hutto et al. 1986; Bibby et al. 1992, Ralph et al. 1995). These point-counts will be conducted from late-May to late-June during the breeding season, in the first four hours after sunrise, when excessive winds do not interfere with distance estimates of birdcalls. Extending the sample time at each point to 10 minutes, and dividing counts by several increments allows calibration of results with multiple standardized systems in North America and estimation of detection probabilities (Farnsworth et al. 2002). To improve survey accuracy and precision, two rounds of sampling separated by 10 days will be employed to compute average relative abundance measures for each species at each point (McCallum 2001).

Richardson's ground squirrel alarm call density will be simultaneously sampled with songbirds at the 120 point-count stations (Downey 2003). The 100-m fixed radius potentially accommodates several female home ranges, and ground squirrels are most active at this time of year (Michener 1978). Additional indices of wildlife habitat utilization and soil disturbance will be measured to monitor population trends and explanatory factors for vegetation change (Van Home et al. 1997; Coffin & Lauenroth 1988; Usnick & Hart 2002). In each of the largest vegetation sampling frames (1000 m^2, see Section 7.3), density of dung pats and pellet groups created by livestock, pronghorn

(*Antilocapra americana*) and deer (*Odocoileus* spp.), earthen mounds created by pocket gophers (*Thomomys talpoides*) and ants (Hymenoptera: Formicidae), and burrows excavated by badger (*Taxidea taxus*) and ground squirrels (*Spermophilus* spp.) will be recorded.

Grasshopper (Orthoptera: Acrididae) richness and density will be estimated with a two-phase sampling technique (Onsanger & Henry 1977). Total density will be estimated by counts in rings of fixed size (0.1m^2) placed on the ground at 10 m intervals along three 50 m transects at each point-count station. Proportional abundance of individual species will be estimated from the total sweep net catch at each site. Sweep nets will be dragged through vegetation, such that 50, 180º sweeps are taken while walking along each of three 50 m transects. Some geophilous species may not be detected in sweep nets, but this bias should be consistent among stations. Three transects (18 rings, 150 sweeps) achieves a sampling effort suitable for comparison with regional grasshopper forecasts. Ideally, three sampling rounds will occur each year to capture over-wintering adults in late May, and early to late-hatching species in late July and early August. If only a single round is possible, the late July to early August period should capture the maximum number of species (Cushing et al. 2000). Sampling on warm, dry, sunny and calm days in mid-afternoon will also improve detectability of species in sweep nets, and visual estimates of density in rings (Berry et al. 2000).

Ground beetle (Coleoptera: Carabidae) richness and relative abundance will be estimated using pitfall traps. Spence & Niemela (1994) recommend placing pitfall traps in a ring to maximize the effective sampling area, though there is no reliable means to calculate the density of beetles from such traps. Although Finnamore (1997) used 30 pitfall traps per site, arranged in 6, 10 m diameter rings of 5 traps each, the expected number of insects captured among the 120 point-count stations will be too great to effectively sort and enumerate on an annual basis. For the current design, a lower sampling intensity of 5 traps in a single 10 m diameter ring will be used and aggregated at each sample station. Although Finnamore (1996) recommends continuous season-long sampling to capture the full range of diversity, only two sampling events 3 days in duration will be conducted in early June and mid-August each year. Voucher specimens of both grasshoppers and ground beetles will be checked against Provincial Museum collections in Alberta and Saskatchewan.

7.2 Upland and Valley Vegetation and Soil Sampling

Plant community richness will be sampled at each point-count station within a 1000 m^2 modified Whittaker plot (Stohlgren et al. 1998) and vascular plant species relative abundance will be visually estimated in 10, 1 m^2 frames using the foliar cover class method (Daubenmire 1959). Lichen, bare ground, and litter cover will also be visually estimated in the ten smallest frames (1m^2), as will vegetation height to complete and partial visual obstruction (Robel et al. 1970). Leaf-area index will also be measured using a hand-held unit, to provide calibration data for remote sensing analyses. To reduce bias due to phenological changes, sampling will be stratified in time such that all upland vegetation plots are sampled in late-June to mid-July, and all valley vegetation plots are sampled in late-July to early-August. These measures will be integrated to calculate range condition scores (Abouguendia 1990), and rangeland health classes (Adams et al. 2004).

Aboveground net primary production can be estimated from the dry weight of current-year herbage within grazing exclusion cages, while the difference between herbage biomass inside and outside cages provides a direct estimate of utilization (Bork & Werner 1999). Four cages covering 1 m^2 will be placed at each sample station prior to livestock introduction in May of each year. Once livestock have been removed from experimental pastures in September, the current-year herbaceous production will be clipped and all standing and surface litter hand-raked from within cages and unprotected 1 m^2 frames placed 5 m from cages. Correlations between Robel pole measurements and biomass components will be evaluated to determine whether a more rapid and non-destructive technique can substitute for clipping each year as per Vermeire et al. (2002).

Available soil nitrogen will be sampled using Plant Root Simulator (PRS)™-probes (Western Ag Innovations, Saskatoon, SK, Canada) near each grazing exclusion cage. The probes consist of cation and anion exchange resin membranes encased in a plastic holding device, which are inserted vertically into the soil and among plant roots to measure nitrate (NO_3^-) and ammonium (NH_4^+) surplus in-situ (Qian & Schoenau 2002). Four pairs (4 cation, 4 anion) of probes will be combined for laboratory analysis. Seasonal variation and cumulative measures of nitrogen supply throughout the growing season will be obtained by removing buried probes after 14 to 21 days and then re-inserting fresh probes in the same soil slot; necessitating five replacements over the May to August season.

7.3 Riparian Vegetation and Soil Sampling

Riparian "health" indices will be evaluated in two phases. First, detailed maps of the primary and secondary riparian vegetation types, and stream channel meanders are required for each experimental unit to adequately stratify and select four meander cycles or "reaches" for sampling (48 in total, among 12 units). Vegetation descriptions will be based on a riparian site key developed by Thompson & Hansen (2001), and reaches will be selected based on criteria outlined in Fitch et al. (2001). Sampling will occur in July of each year, once potential floodwaters from spring snow melt and summer storms have subsided, and peak vegetation growth has occurred.

The second phase involves a detailed inventory of site characteristics, ranking of the state of each characteristic, and computing a riparian health score suitable for estimating change over time at reach and unit scales, and heterogeneity among reaches within a unit (Fitch et al. 2001). Biological characteristics include cover classes for total, exotic invasive, and weedy vegetation cover, proportional classes for regeneration and utilization of herbivory-sensitive woody shrubs, canopy cover classes for shrubs and standing dead woody material, and proportional classes for stream bank anchored by a "deep binding root mass". Physical characteristics include cover classes for bare soil, disturbed stream banks, livestock "pugging/hummocking", and categorization of the stream channel incisement stage. Double sampling whereby two people repeat the inventory each year can increase accuracy by averaging the results of the two. Also, digital photographs from fixed locations provide an archive of conditions for later reference and change analyses (Fitch & Ambrose 2003).

7.4 Climate Monitoring

Although experimental units have been carefully designed and grazing treatments are carefully controlled, inter-annual climatic variation remains a significant co-varying influence. For the duration of this experiment, a new meteorological station located on the experimental site will provide the following set of independent environmental data (daily precipitation, daily high and low temperatures, daily high and low humidity, hourly wind speed, daily evaporation, daily sunlight hours). Additional rain gauges will be placed in each pasture to measure precipitation over the May to September period, as spatial variation in rainfall is expected among treatments separated by up to 10 km. These data may be essential covariates for isolating grazing and spatial variation in any response measure. Other measures in the monitoring program also involve recording cloud cover, temperature and wind speed at the time of sampling to calibrate results (Section 7.0).

8.0 PROJECT RISK ASSESSMENT

The experiment will take place on lands owned by GNPC, the Province of Saskatchewan (Mankota Community Pasture), and independent ranchers. For activities on GNPC property, Parks Canada is required under the *Canadian Environmental Assessment Act* to complete an environmental assessment, and through this process will identify potential impacts and mitigative measures in cooperation with Agriculture and Agri-Food Canada (AAFC) for livestock care, with Environment Canada (EC) for Species-at-Risk and water quality, with Fisheries and Oceans Canada (FOC) for fish habitat protection, and with Parks Canada Agency archaeologists for cultural resource protection. Arrangements will be made with managers from Saskatchewan Agriculture and Food, and private landowners to permit sampling on their properties. No manipulations or changes to management are proposed for lands outside GNPC, so a similar environmental assessment process is not required. In anticipation of questions arising from the assessment, most concerns were addressed through careful experimental design and selection of contingency plans for specific problems.

8.1 Livestock Health Protection and Experimental Contingency Plans

Should drought-induced forage shortages occur in grazing treatments set at the 70% utilization rate, livestock will be prematurely removed from those treatments to protect animal health and weight gains. Either livestock will be moved to currently fenced and watered paddocks within GNPC but outside of the experimental area where abundant forage is available, or arrangements will be made to return livestock to the owners prematurely; the latter may be written into contract arrangements with owners depending upon procedures developed in the GNPC-wide grazing management plan. Livestock will be monitored almost daily throughout the grazing season but injuries, or escapes into adjacent experimental units or the surrounding ungrazed parts of GNPC may occur. Should this happen, animals will be rounded-up as quickly as is practical (within 48 hours), and notes made in the experimental treatment dataset file "EBGE_GRAZE" to accurately reflect changes in grazing treatments resulting from these escapes and possible removal of animals for veterinary treatment. <u>The duration and magnitude of these changes should not jeopardize the overall treatment effect</u>.

8.2 Riparian Health Protection and Experimental Contingency Plans

Livestock will have free access to stream channels in each experimental unit, but water for human consumption is not being drawn from the channel downstream within Canadian boundaries. The 10 year duration, and varying intensities of grazing are expected to induce temporary and reversible changes in riparian vegetation and water quality, and at the scale of the entire experiment the ratio of "healthy", to "healthy with problems", to "unhealthy" riparian areas should be near the recommended guideline of "60:25:15" (Fitch & Ambrose 2003). Monitoring of riparian health will be an early-warning system to detect these changes (Section 7.3). Should early signs of irreversible channel incisement or extensive bank slumping be observed, water quality monitoring will be immediately instituted (Appendix E), and those experimental treatments may cease prematurely to avoid irreversible damage. Alternatively, mitigative measures like fencing the riparian zone to exclude livestock access may be required, but must be implemented similarly in all manipulated treatments to maintain experimental control. This particular action jeopardizes any opportunity to compare these treatments with areas outside GNPC where riparian zone fencing is not practiced, and creates a fundamentally new experiment that may no longer be comparable among years. An important point to consider is how this experiment provides a unique opportunity for Parks Canada, AAFC, EC and FOC to accurately and precisely document grazing intensity effects on aquatic resources, thus providing quantitative evidence for establishing best management practice guidelines and regulations. Expansion of the riparian monitoring program in support of this direction is welcomed, but requires additional resources to do so.

8.3 Wildlife Species at Risk Protection

The experiment is purposely designed to create grazed habitat for Species at Risk known to be less abundant inside GNPC relative to grazed areas outside GNPC (Sutter 1997). The monitoring program (Section 7.0) in particular, will provide data suitable to evaluate impacts on most songbird Species at Risk. While grazing may reduce ungrazed habitat preferred by other Species at Risk, the proposed treatments affect 1.3% of GNPC, making them consistent with Park Management Plan strategic goals (Parks Canada 2002), statistically undetectable at the scale of populations within GNPC, and overall should have no net negative effect on Species at Risk as a whole. Specific concerns regarding treatment effects on nest destruction and nest success could be evaluated with artificial nest studies, and effects on artificially placed Leopard Frog egg mass and resulting tadpole density could be studied as part of the experiment. For general wildlife protection, temporary fences enclosing experimental units will be constructed with bottom wires set 45 cm above ground to allow passage by pronghorn, and all wires will be smooth (possibly electrified) to ease escape of deer or other wildlife that may otherwise get 'hung-up' on barbed wire.

8.4 Cultural Resource Protection

An extensive inventory of cultural resources, including geospatial data of locations, has been conducted for old homesteads, tipi rings, rock cairns, and other artifacts currently visible in the experimental area. These resources will be avoided during the fence and water pipeline construction phase of the experiment, and overlap between monitoring station locations and these cultural resources will also be avoided. Regular traffic by research staff and vegetation removal by livestock may help reveal more cultural resources, and existing conservation practices will be implemented to document those sites or artifacts. In cases where archaeologists recommend exclosures be erected around 1 ha or smaller sites, it should not affect the treatments or monitoring program.

8.5 Exotic Invasive Plant Species Prevention and Control

To avoid unintended invasions of exotic plant species, livestock will be quarantined outside GNPC for 10 days or fed certified weed-free hay for that same period of time prior to release on GNPC lands as per the exotic invasive plant management plan under development. Fencing crews, herdspersons, and monitoring staff will also keep vehicles and equipment clean of muddy clods, straw or hay bales from outside GNPC. The GNPC-wide exotic invasive plant monitoring plan will outline management actions that may be taken depending upon the species and the potential for threatening ecological integrity (Michalsky et al. 2005). These actions may affect livestock foraging behaviour, depending upon the scale of action required.

8.6 Wild Fire and Experimental Contingency Plans

Wild fire is always a risk, and the GNPC Fire Management Plan under development will provide direction for fire prevention, suppression and fuel load reduction within the experimental area. Individuals involved with experimental treatment implementation and monitoring will be educated in fire prevention strategies to reduce risks of accidental ignitions. Should a wild fire occur in the experimental area and affect a portion of the experimental units, the project management group will be consulted on a plan of action that protects the infrastructure and monitoring program investment of GNPC and research partners. Small fires may have little or no effect on livestock foraging behaviour, grazing treatments and ecological integrity measures in the monitoring program. Larger fires may indeed affect these things, and possible contingencies may involve instituting prescribed burns of similar size, shape and juxtaposition in presently unburned experimental units to maintain experimental control. Where a particularly large fire covers one or more experimental units (>300 ha), all or a portion of the units within the GNPC experimental area may be burned with the intention of equalizing fire effects across all units to maintain experimental control. Any of these prescribed burn options require careful planning by GNPC resource conservation staff, and approval from the Parks Canada National Fire Management Committee.

9.0 PROJECT MANAGEMENT: AUTHORITY, COMMUNICATIONS, DATA AND FUNDING

The Saskatchewan-South Field Unit Superintendent received funds for the initial design and implementation of this project, and lands are scheduled under the Parks Canada Agency Act as part of GNPC. Given this administrative structure, GNPC will lead project management. Specifically, the Saskatchewan-South Field Unit (SSFU) Superintendent will appoint members to a Project Management Group, issue annual *Research and Collection Permits*, and receive annual reports for inclusion in *State of the Park Reports* and presentations for the GNPC Advisory Committee and Staff. The Resource Conservation Manager for GNPC will be directly involved in assigning funds and work plans to staff members for coordinating the construction and maintenance of experimental infrastructure, and executing annual grazing treatment applications and monitoring program activities. In addition, the SSFU Superintendent will assign work plans for other staff to further develop and implement the draft communications strategy (Appendix F) and data management strategy (Appendix G). Ultimately, the experiment will be integrated into the next GNPC Park Management Plan as a Natural Resource Conservation activity.

The terms of reference for the Project Management Group include the following:

1. Review project reports prepared by GNPC staff for annual work plans and *State of the Park Reports*, to ensure completeness and accuracy of content.
2. Ensure changes to the experimental design and monitoring program over the lifetime of this project are accurately and precisely documented in reports (see above), and in metadata for each dataset and geospatial product.
3. Ensure quality control in annual data collection by participating in training exercises for seasonal staff in each field season, and review datasets for completeness at the end of each season. Datasets may be divided among members for review.
4. Assist GNPC staff to prepare budgets, grant proposals, *Research and Collection Permits*, and broker partnerships with other organizations for sustaining funds needed to operate the experiment and monitoring program. Also assist GNPC staff to prepare terms of reference for contracts (including but not limited to laboratory analyses and species identification).
5. Ensure intellectual property rights of the original working group (Appendix A) are respected in proposed products (including but not limited to refereed journal articles and scientific conference presentations) arising from use of datasets or the experimental design by other researchers over the lifetime of this project.

Membership in the Project Management Group is subject to approval by the SSFU Superintendent, Parks Canada Agency. Changes to group membership and the terms of reference will be proposed by the existing group, but are subject to approval by the SSFU Superintendent. At the time of writing (March, 2006) the original working group members remaining involved in the project included Robert Sissons of GNPC, John Wilmshurst of WNSC, Patrick Fargey of GNPC, Darcy Henderson of Environment Canada, and Nicola Koper of the University of Manitoba – Natural Resources Institute.

While the questions, design and methods reflect the interests of GNPC, the Project Management Group anticipated other researchers will bring forward additional questions and methods that make use of the experimental infrastructure and treatments, or accumulation of data generated by the monitoring program (Appendix E). Parks Canada Agency will review unsolicited proposals from researchers, and can assist in grant proposals to help leverage funds in support of those specific projects and for sustaining the larger monitoring program. Successful proposals will be subject to the Parks Canada, *Research and Collection Permitting System* (Parks Canada 2005), which addresses regulatory requirements, data ownership, and reporting requirements. Building research linkages with universities and institutions is a strategic goal of Parks Canada Agency, and building this experiment is intended to help form such arrangements for mutual benefit.

10.0 LITERATURE CITED

Abouguendia, Z.M. 1990. A practical guide to planning for management and improvement of Saskatchewan rangeland: Range plan development. New Pastures and Grazing Technology Project, Saskatchewan Rural Development. Regina SK.

Adams, B.W., Poulin-Klein, L., Moisey, D. & McNeil, R.L. 2004. Rangeland plant communities and range health assessment guidelines for the mixedgrass natural subregion of Alberta. Report T/03940. Public Lands Division, Alberta Sustainable Resource Development. Lethbridge AB.

Adler, P.B., Raff, D.A. & Lauenroth, W.K. 2001. The effect of grazing on the spatial heterogeneity of vegetation. Oecologia. 128: 465-479.
Bai, Y., Abouguendia, Z. & Redmann, R.E. 2001. Relationship between plant species diversity and grassland condition. Journal of Range Management. 54: 177-183.
Berry, J.S., Onsanger, J.A., Kemp, W.P., McNary, T., Larsen, J., Legg, D., Lockwood, J.A., & Foster, R.N. 2000. Assessing rangeland grasshopper populations. Section VI.10 in Cuningham, G.L.; Sampson, M.W. (eds). 2000. Grasshopper integrated pest management user handbook. USDA, Animal and Plant Health Inspection Service. Technical Bulletin No. 1809. Washington D.C.
Bibby, C.J., Burgess, N.D. & Hill, D.A. 1992. Bird census techniques. Academic Press Ltd. London.
Biondini, M.E., Patton, B.D. & Nyren, P.E. 1998. Grazing intensity and ecosystem processes in a northern mixed-grass prairie. USA. Ecological Applications. 8: 469-479.
Biondini, M.E., Steuter, A.A. & Hamilton, R.G. 1999. Bison use of fire managed remnant prairies. Journal of Range Management. 52: 454-461.
Bork, E.W., & Werner, S.J. 1999. Viewpoint: Implications of spatial variability for estimating forage use. Journal of Range Management. 52: 151-156.
Box, G.E.P. & Jenkins, G.M. 1976. Time series analysis: Forecasting and control. Holden-Day. San Franciso CA.
Branson, D.H. 2005. Direct and indirect effects of avian predation on grasshopper communities in northern mixed-grass prairie. Environmental Entomology. 34: 1114-1121.
Briske, D.D., Fuhlendorf, S.D. & Smeins, F.E. 2005. State-and-transition models, thresholds, and rangeland health: A synthesis of ecological concepts and perspectives. Rangeland Ecology and Management. 58: 1-10.
Burke, I.C., Lauenroth, W.K., Riggle, R., Brannen, P., Madigan, B. & Beard S. 1999. Spatial variability of soil properties in a shortgrass steppe: The relative importance of topography, grazing, microsite and plant species in controlling spatial pattern. Ecosystems. 2: 422-438.
Capinera, J.L. & Horton, D.R. 1989. Geographic variation in effects of weather on grasshopper infestation. Environmental Entomology. 18: 8-14.
Capinera, J.L. & Sechrist T.S. 1982. Grasshopper (Acrididae) - host plant associations: Response of grasshopper populations to cattle grazing intensity. Canadian Entomologist. 114: 1055-1062.
Capinera, J.L., Scott, R.D., & Walker, T.J. 2005. Field guide to grasshoppers, katydids, and crickets of the United States. Cornell University Press. Ithaca NY.
Chapman, E.W., & Ribic, C.A. 2002. The impact of buffer strips and stream-side grazing on small mammals in southwestern Wisconsin. Agriculture, Ecosystems & Environment. 88:49-59.
Chapman, R.N., Engle, D.M., Masters, R.E. & Leslie, D.M. 2004. Grassland vegetation and bird communities in the southern Great Plains of North America. Agriculture, Ecosystems and Environment. 104: 577-585.
Cid, M.S., Detling, J.K., Whicker, A.D., & Brizuela, M.A. 1991. Vegetational responses of a mixed-grass prairie site following exclusion of prairie dogs and bison. Journal of Range Management. 44: 100-105.
Cingolani, AM., Noy-Meir, I., & Diaz, S. 2005. Grazing effects on rangeland diversity: A synthesis of contemporary models. Ecological Applications. 15: 757-773.
Coffin, D.P. & Lauenroth, W.K. 1990.Vegetation associated with nest sites of western harvester ants (Pogonomyrmex occidentalis Cresson) in a semiarid grassland. Am. Midl. Nat..123:226-235
Coffin, D.P. & Lauenroth, W.K. 1988. The effects of disturbance size and frequency on a shortgrass

plant community. Ecology. 69: 1609-1617.
Collins, S.L. 2000. Disturbance frequency and community stability in native tallgrass prairie. American Naturalist. 155: 311-325.
Collins, S.L. & Glenn, S.M. 1997a. Intermediate disturbance and its relationship to within- and between-patch dynamics. New Zealand Journal Of Ecology. 21: 103-110.
Coppedge, B.R. & Shaw, J.H. 1998. Bison grazing patterns on seasonally burned tallgrass prairie. Journal of Range Management. 51: 258-264.
Coppock, D.L. & Detling, J.K. 1986. Alteration of bison and black-tailed prairie dog grazing interaction by prescribed burning. Journal of Wildlife Management. 50: 452-455.
Coughenour, M.B. 1991. Spatial components of plant-herbivore interactions in pastoral, ranching, and native ungulate ecosystems. Journal of Range Management. 44: 530-542.
Coupland, R.T. 1950. Ecology of mixed prairie in Canada. Ecol. Mon. 20: 273-315.
Cushing, W.J., Foster, R.N., Reuter, K.C., & Hirsch, D. 2000. Seasonal occurrence of common western North Dakota Grasshoppers. Section VI.8 in Cuningham, G.L.; Sampson, M.W. (eds). 2000. Grasshopper integrated pest management user handbook. USDA, Animal and Plant Health Inspection Service. Technical Bulletin No. 1809. Washington D.C.
Dana, R. P. 1991. Conservation management of the prairie skippers Hesperia dacotae and Hesperia ottoe: basic biology and threat of mortality during prescribed burning in spring. Minnesota Agricultural Experiment Station Bulletin 594-1991 (AD-SB-5511-S). University of Minnesota, St. Paul
Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33: 43-64.
Davis, S.K. 2004. Area sensitivity in grassland passerines: Effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in southern Saskatchewan. The Auk. 121: 1130-1145.
Dobson, R.B., & Leonard, R.D. 1987. Interim range management plant for acquired lands, proposed Grasslands National Park, Saskatchewan. Unpublished Report. Parks Canada, Prairie Region. Winnipeg MB.
Downey, B.A. 2003. Survey protocol for the Richardson's ground squirrel. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species-at-Risk Report No. 69. Edmonton AB.
Dutilleul, P. 1993. Spatial heterogeneity and the design of ecological field experiments. Ecology 74: 1646-1658.
Dyksterhuis, E.J. 1949. Condition and management of rangeland based on quantitative ecology. Journal of Range Management. 2: 104-115.
Eberhardt, L.L. & Thomas, J.M. 1991. Designing environmental field studies. Ecological Monographs. 61: 53-73.
Ehrlich, P.R. & Murphy, D.D. 1987. Conservation lessons from long-term studies of checkerspot butterflies. Conservation Biology 1:122-131
Engle, D.M. & Bultsma, P.M. 1984. Burning of northern mixed prairie during drought. Journal of Range Management. 37: 398-401.
Epp, H.T. 1988. Way of the migrant herds: Dual dispersion strategy among bison. Plains Anthro. 33:309-320.
Erdfelder, E., Faul, F. & Buchner, A. 1996. GPOWER: A general power analysis program. Behavior Research Methods, Instruments, and Computers. 28: 1-11.

Erichsen-Arychuk, C, Bork, EW & Bailey, AW. 2002. Northern dry mixed prairie responses to summer wildfire and drought. Journal of Range Management. 55: 164-170.
Fahnestock, J.T. & Detling, J.K. 2002. Bison-prairie dog-plant interactions in a North American mixed-grass prairie. Oecologia. 132: 86-95.
Fair, J.M., Kennedy, P.L. & McEwen, L.C. 1995. Diet of nesting Killdeer in North Dakota. Wilson Bulletin. 107: 174-178.
Farnsworth, G.L., Pollock, K.H., Nichols, J.D., Simons, T.R., Hines, J.E. & Sauer, J.R. 2002. A removal model for estimating detection probabilities from point-count surveys. Auk 119: 414-425.
Fehmi, J.S., Russo, S.E., & Bartolome, J.W. 2005. The effects of livestock on California ground squirrels (*Spermophilus beecheyii*). Rangeland Ecology & Management. 58: 352-359.
Finnamore, A.T. 1997. The effects of grazing and exotic grasses on the ecological integrity of upland prairie: arthropod diversity, a progress report. Pp. 27-34 in Jensen, O., Fargey, P. (eds). Heritage Resource Management, Grasslands National Park, 1996 Annual Report Vol. 2. Parks Canada. Val Marie SK.
Finnamore, A.T. 1998. The effects of grazing and exotic grasses on the ecological integrity of upland prairie: arthropod biodiversity, the ground beetle, ladybird beetle and longhorn beetle fauna (Coleoptera: Carabidae, Coccinellidae, and Ceramycidae). Pp. 33-34 in Fargey, P. (ed). Heritage Resource Management, Grasslands National Park, 1997 Annual Report Vol. 3. Parks Canada. Val Marie SK.
Fitch, L., Adams, B.W. & Hale, G. (eds) 2001. Riparian health assessment for streams and small rivers – field workbook. Cows and Fish Program. Alberta Environment. Lethbridge AB.
Fitch, L.; & Adams, B.W. 1998. Can cows and fish co-exist? Canadian Journal of Plant Science. 78: 191-198.
Fitch, L. & Ambrose, N. 2003. Riparian areas: A user's guide to health. Cows and Fish Program. Lethbridge AB.
Fitzmaurice, G.M., Laird, N.M. & Ware, J.H. 2004. Applied longitudinal analysis. John Wiley & Sons Inc. Hoboken NJ.
Fondell, T.F. & Ball, I.J. 2004. Density and success of bird nests relative to grazing on western Montana grasslands. Biological Conservation. 117: 203-213.
Fontaine, A.L., Kennedy, P.L. & Johnson, D.H. 2004. Effects of distance from cattle water developments on grassland birds. Journal of Range Management. 57: 238-242.
Fortin, D., Fryxell, J.M., O'Brodovich, L. & Frandsen, D. 2003. Foraging ecology of bison at the landscape and plant community levels: the applicability of energy maximization principles. Oecologia. 134: 219-227.
Frank, A.B., Tanaka, D.L., Hofmann, L. & Follet, R.F. 1995. Soil carbon and nitrogen of northern Great Plains grasslands as influenced by long-term grazing. Journal of Range Management. 48: 470-474.
French, N.R., Grant, W.E., Grodzinski, W., & Swift, D.M. 1976. Small mammal energetics in grassland ecosystems. Ecological Monographs. 46: 201-220.
Friedel, M.H. 1991. Range conditions assessment and the concept of thresholds: a viewpoint. Journal of Range Management. 44: 422-426.
Fritcher, S.C., Rumble, M.A. & Flake, L.D. 2004. Grassland bird densities in seral stages of mixed-grass prairie. Journal of Range Management. 57: 351-357.
Fuhlendorf, S.D. & Engle, D.M. 2001. Restoring heterogeneity on rangelands: Ecosystem management based on evolutionary grazing patterns. Bioscience. 51: 625-632.

Fuhlendorf, S.D. & Smeins, F.E. 1998. The influence of soil depth on plant species response to grazing within a semiarid savanna. Plant Ecology. 138: 89-96.

Fuhlendorf, S.D. & Smeins, F.E. 1999. Scaling effects of grazing in a semi-arid grasslands. Journal of Vegetation Science. 10: 731-738.

Ganskopp, D. & Vavra, M. 1987. Slope use by cattle, feral horses, deer and bighorn sheep. Northwest Science. 61: 74-81.

Gillen, R.L., Edkroat, J.A., & McCollum, F.T. 2000. Vegetation response to stocking rate in southern mixed-grass prairie. Journal of Range Management. 53: 471-478.

Green, D.M.; & Kauffman, J.B. 1995. Succession and livestock grazing in a northeastern Oregon riparian ecosystem. Journal of Range Management. 48: 307-313.

Guo, X., Wilmshurst, J., McCanny, S., Fargey, P., & Richard, P. 2004. Measuring spatial and vertical heterogeneity of grasslands using remote sensing techniques. Journal of Environmental Informatics. 3: 24-32.

Guo, X., Zhang, C., Wilmshurst, J.F., Sissons, R. 2005a. Monitoring grassland health with remote sensing approaches. Prairie Perspectives. 8: 11-22.

Guo, X., Wilmshurst, J., Zhang, C., Sissons, R. & Fargey, P. 2005b. Measuring grassland structure for recovery of grassland Species-at-Risk. Unpublished report. University of Saskatchewan. Saskatoon SK.

Gurevitch, J. & Collins, S.L. 1994. Experimental manipulation of natural plant communities. Trends in Ecology and Evolution. 9: 94-98.

Gurevitch, J. & Hedges, L.V. 2001. Meta-analysis: Combining the results of independent experiments. Pp. 347-370. In: Scheiner, S.M. & Gurevitch, J. (eds). Design and analysis of ecological experiments, second edition. Oxford University Press. New York NY.

Hall-Beyer, M., & Gwyn, Q.H.J. 1998. The relation between spectral classification (TM) and species maps, Grasslands National Park, Saskatchewan. Parks Canada Research Bulletin, ISSN 0710-0868. Ottawa ON.

Hamilton, K.G.A. 2005. Bugs reveal an extensive, long-lost Northern tall-grass prairie. BioScience 55: 49-59.

Harris, AT., & Asner, GP. 2003. Grazing gradient detection with airborne imaging spectroscopy on a semi-arid rangeland. Journal Of Arid Environments. 55: 391-404.

Hart, R.H. 2001. Plant biodiversity on shortgrass steppe after 55 years of zero, light, moderate, or heavy cattle grazing. Plant Ecology. 155: 111-118.

Hart, R.H., Bissio, J., Samuel, M.J. & Waggoner, J.W. 1993. Grazing systems, pasture size, and cattle grazing behaviour, distribution and gains. Journal of Range Management. 46: 81-87.

Henderson, D.C., Ellert, B.H. & Naeth, M.A. 2004a. Utility of C^{13} for ecosystem carbon turnover estimation in grazed mixed grass prairie. Geoderma 119: 219-231.

Henderson, D.C., Ellert, B.H. & Naeth, M.A. 2004b. Grazing impact on organic carbon across a gradient of Alberta native rangelands. Journal of Range Management 57: 402-410.

Hickman, K.R., Hartnett, D.C., Cochran, R.C. & Owensby, C.E. 2004. Grazing management effects on plant species diversity in tallgrass prairie. Journal of Range Management. 57: 58-65.

Hurlburt, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs. 54: 187-211.

Hutto, R.L., Pletschet, S.M., & Hendricks, P. 1986. A fixed-radius point count method for non-breeding and breeding season use. Auk 103: 593-602.

Joern, A. 2005. Disturbance by fire frequency and bison grazing modulate grasshopper assemblages

in tallgrass prairie. Ecology. 86: 861-873.
Johnson, D.L. & Worobec, A. 1988. Spatial and temporal computer analysis of insects and weather: Grasshoppers and rainfall in Alberta. Memoirs of the Entomological Society of Canada. 146: 33-48.
Johnson, J.B. & Omland, K.S. 2004. Model selection in ecology and evolution. Trends in Ecology and Evolution. 19:101-108.
Juliano, S.A. 2001. Nonlinear curve fitting: Predation and functional response curves. Pp. 178-196. In: Scheiner, S.M. & Gurevitch, J. (eds). Design and analysis of ecological experiments, second edition. Oxford University Press. New York NY.
Kantrud, H.A. 1981. Grazing intensity effects on the breeding avifauna of North Dakota native grasslands. Canadian Field Naturalist. 95: 404-417.
Kauffman, J.B.; & Krueger, W.C. 1984. Livestock impacts on riparian ecosystems and streamside management implications – A review. Journal of Range Management. 37: 430-438.
Kemp, W.P. 1992. Rangeland grasshopper (Orthoptera: Acrididae) community structure: a working hypothesis. Environmetnal Entomology. 21: 461-470.
Kemp, W.P. & Cigliano, M.M. 1994. Drought and rangeland grasshopper species diversity. Canadian Entomologist. 126: 1075-1092.
Kerr, J.T., Southwood, T.R.E., & Cihlar, J. 2001. Remotely sensed habitat diversity predicts butterfly species richness and community similarity in Canada. Proceedings of the National Academy of Sciences of the United States of America. 98: 11365-11370.
Knapp, A.K., Blair, J.M., Briggs, J.M., Collins, S.L., Hartnett, D.C., Johnson, L.C. & Towne, E.G. 1999. The keystone role of bison in North American tallgrass prairie. Bioscience. 49: 39-50.
Knopf, F.L. 1996. Prairie legacies – birds. Pp. 135-148 In: Samson, F.B. & Knopf, F.L. (eds). Prairie Conservation: Preserving North America's most endangered ecosystem. Island Press. Covelo CA.
Kondla, N.G. 2004. Overview of the status and distribution of butterflies and skippers in Saskatchewan and Manitoba National Parks and National Historic Sites. Parks Canada, Western & Northern Service Center. Calgary AB.
Kotliar, N.B. & Wiens, J.A. 1990. Multiple scales of patchiness and patch structure: a hierarchical framework for the study of heterogeneity. Oikos. 59: 253-260.
Larsen, K.I., Work, T.T., & Purrington, F.F. 2003. Habitat use patterns by ground beetles (Coleoptera : Carabidae) of northeastern Iowa. Pedobiologia. 47: 288-299.
Laycock, W.A. 1991. Stable states and thresholds of range condition on North-American rangelands - a viewpoint. Journal of Range Management. 44: 427-433.
Levin, S.A. 1992. The problem of pattern and scale in ecology. Ecology. 73: 1943-1967.
Lovei, G.; & Sunderland, K. 1996. Ecology and behaviour of ground beetles (Coleoptera: Carabidae). Annual Review of Entomology. 41: 231-256.
MacArthur, R.H. & Pianka, E.R. 1966. On optimal use of a patchy environment. American Naturalist. 100: 603-609.
Matlack, R.S., Kaufman, D.W., & Kaufman, G.A. 2001. Influence of grazing by bison and cattle on deer mice in burned tallgrass prairie. American Midland Naturalist. 146: 361-368.
McCallum, D.A. 2003. A conceptual guide to detection probability for point counts and other count-based survey methods. USDA Forest Service, Report PSW-191.
McCanny, S.J., Fargey, P., & Hohn, S. 1996. The effects of grazing and exotic grasses on the ecological integrity of upland prairie. Pp. 66-76 in Hohn, S., Fargey, P. (eds). Heritage

Resource Management, Grasslands National Park, 1995 Annual Report Vol. 1. Parks Canada. Val Marie SK.
McIntyre, N.E. 1998. Abundance and habitat affinities of *Cyclotrachelus substriatus* (Coleoptera: Carabidae) on northern shortgrass prairie. Prairie Naturalist. 30: 157-168.
McNaughton, S.J. 1984. Grazing lawns: animals in herds, plant form, and coevolution. American Naturalist. 124: 863-886.
Michalsky, S.J., & Ellis, R.A. 1994. Vegetation of Grasslands National Park. D.A. Westworth and Associates Ltd. Calgary AB.
Michalsky, S.J., Sturch, A. & Sissons, R. 2005. Invasive exotic plant assessment and ranking for Grasslands National Park. Parks Canada. Val Marie SK.
Michener, G.R. 1978. Spatial relationships and social organization of adult Richardson's ground squirrels. Canadian Journal of Zoology. 57: 125-139.
Michener, G.R. 2004. Hunting techniques and tool use by North American badgers preying on Richardson’s ground squirrels. Journal of Mammalogy. 85: 1019-1027.
Milchunas, D.G., Lauenroth, W.K., Chapman, P.L. & Kazempour, M.K. 1989. Effects of grazing, topography, and precipitation on the structure of a semiarid grassland. Vegetatio. 80: 11-23.
Milchunas, D.G., Sala, O.E. & Lauenroth, W.K. 1988. A generalized model of the effects of grazing my large herbivores on grassland community structure. American Naturalist. 132: 87-106.
Miller, R.H. & Onsager, J.A. 1991. Grasshopper (Orthoptera: Acrididae) and plant relationships under different grazing intensities. Environmental Entomology. 20: 807-814.
Mukerji, M.K. & Hayhoe, H.N. 1988. Probability analysis of fluctuations of grasshopper populations in Saskatchewan. Canadian Entomologist. 120: 1063-1070.
Oesterheld, M., Sala, O.E. & McNaughton, S.J. 1992. Effect of animal husbandry on herbivore carrying capacity at a regional scale. Nature. 356: 234-236.
Oksanen, L. 2001. Logic of experiments in ecology: is pseudoreplication a pseudoissue? Oikos 94: 27-38.
Olson-Edge, S.L. & Edge, W.D. 1987. Density and distribution of the mountain plover on the Charles M. Russell National Wildlife Refuge. The Prairie Naturalist. 19(4):233-238.
Onsanger, J.A. & Henry, J.E. 1977. A method for estimating the density of rangeland grasshoppers (Orthoptera: Acrididae) in experimental plots. Acrida 6: 231-237.
Onsanger, J.A. 2000. Suppression of grasshoppers in the Great Plains through grazing management. Journal of Range Management. 53: 592-602.
Parks Canada. 2000. Unimpaired for future generations? Protecting ecological integrity with Canada’s National Parks. Vol. 2. Setting a new direction for Canada’s National Parks. Report of the Panel on the Ecological Integrity of Canada’s National Parks. Ottawa ON.
Parks Canada. 2002. Grasslands National Park of Canada: Management Plan. Parks Canada, Western Canada Service Centre. Winnipeg MB.
PCAP 2003. Saskatchewan Prairie Conservation Action Plan 2003-2008. PCAP Partnership and Canadian Plains Research Center. Regina SK.
Peden, D.G., Van Dyne, G.M., Rise, R.W. & Hansen, R.M. 1974. The trophic ecology of *Bison bison* L. on shortgrass plains. Journal of Applied Ecology. 11: 489-498.
Penny, C. 2004. The prairie persists: Restoring ecological components and processes to a grasslands ecosystem. Business Case, Priority Theme Ecological Integrity Funding. Unpublished report. Parks Canada. Val Marie SK.
Pepper, J.L. 1999. Diversity and community assemblages of ground-dwelling beetles and spiders on

fragmented grasslands of southern Saskatchewan. MSc. Thesis, University of Regina. Regina, SK.

Pinchak, W.E., Smith, M.A., Hart, R.H. & Waggoner, J.W. 1991. Beef cattle distribution patterns on foothill range. Journal of Range Management. 44: 267-275.

Plumb, G.E. & Dodd, J.L. 1993. Foraging ecology of bison and cattle on a mixed prairie: Implications for natural area management. Ecological Applications. 3: 631-643.

Poirier, T. 1993. Grassland National Park History Project: Frazer-Lamb Ranch Profile. Prepared by Thelma Poirier for Parks Canada. Fir Mountatin, SK.

Prescott, D.R.C. & Collister, D.M. 1993. Characteristics of occupied and unoccupied Loggerhead shrike territories in southeastern Alberta. J. Wildl. Manage. 57: 346-352.

Pylepec, B. & Romo, J.T. 2003. Long-term effects of burning *Festuca* and *Stipa-Agropyron* grasslands. Journal of Range Management. 56: 640-645.

Qian, P. & Schoenau, J.J. 2002. Practical applications of ion exchange resins in agriculture and environmental soil research. Canadian Journal of Soil Science. 82: 9-21.

Quinn, M.A. & Walgenbach, D.D. 1990. Influence of grazing history on the community structure of grasshoppers of a mixed-grass prairie. Environmental Entomology. 19: 1756-1766.

Quinn, M.A., Kepner, R.L., Walgenbach, D.D., Foster, R.N., Bohls, R.A., Pooler, P.D., Reuter, K.C. & Swain, J.L. 1991. Effect of habitat characteristics and perturbation from insecticides on the community dynamics of ground beetles (Coleoptera, Carabidae) on mixed-grass rangeland. Environmental Entomology. 20: 1285-1294.

Quinn, M.A., Kepner, R.L., Walgenback, D.D., Foster, R.N., Bohls, R.A., Pooler, P.D., Reuter, K.C., & Swain, J.L. 1993. Grasshopper stages of development as indicators of non-target arthropod activity – implications for grasshopper management programs on mixed-grass rangeland. Environmental Entomology. 22: 532-540.

Ralph, C.J., Guepel, G.R., Pyle, P., Martin, T.E., & Desante, D.F. 1993. Handbook of field methods for monitoring landbirds. USDA Forest Service, Report PSW-44.

Reynolds, H.W., Barry, S.J., & Kiliaan, H.P.L. 1999. Small mammal component report: Canadian Forces Base Suffield National Wildlife Area, Wildlife Inventory. Canadian Wildlife Service, Prairie and Northern Region. Edmonton AB.

Rice, C.L. 2003. Odonates (dragonflies and damselflies) as biological indicators at grazed prairie wetlands. MSc Thesis, University of Alberta. Edmonton AB.

Robel, R.J., Briggs, J.N., Dayton, A.D., & Hulbert, L.C. 1970. Relationship between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management. 23: 295-298.

Romo, J.T. 2005. Reintroducing fire for conservation of fescue prairie association remnants in the northern Great Plains. Canadian Field Naturalist. 117: 89-99.

Rosenstock, S.S. 1996. Shrub-grassland small mammal and vegetation responses to rest from grazing. Journal of Range Management. 49: 199-203.

Saskatchewan Instiiute of Pedology. 1992. Grasslands National Park Soil Survey. University of Saskatchewan. Saskatoon SK.

Schellenberg, M.P., Holt, N.W. & Waddington, J. 1999. Effects of grazing dates on forage and beef production of mixed prairie rangeland. Canadian Journal of Animal Science. 79: 335-341.

Schlicht, D.W. & Orwig, T. T. 1992. Sequential use of niche by prairie obligate skipper butterflies (Lepidoptera: Hesperiidae) with implications for management. pp137-139 in Smith, D. D. and C. A. Jacobs, eds. Proceedings of the Twelfth North American Prairie Conference.

University of Northern Iowa, Cedar Falls, IA
Schmidt, N.M., Olsen, H., Bildsoe, M., Sluydts, V. & Leirs, H. 2005. Effects of grazing intensity on small mammal population ecology in wet meadows. Basic & Applied Ecology. 6: 57-66.
Schmutz, J.K., Houston, C.S., & Barry, S.J. 2001. Prey and reproduction in a metapopulation decline among Swainson's hawks, Buteo swainsoni. Canadian Field Naturalist. 115: 257-273.
Schulz, T.T.; & Leininger, W.C. 1990. Differences in riparian vegetation structure between grazed areas and exclosures. Journal of Range Management. 43: 295-299.
Schuman, G.E., Reeder, J.D., Manley, J.T., Hart, R.H. & Manley, W.A. 1999. Impact of grazing management on the carbon and nitrogen balance of a mixed-grass rangeland. Ecological Applications. 9: 65-71.
Scrimgeour, G.J.; & Kendall, S. 2002. Consequences of livestock grazing on water quality and benthic algal biomass in a Canadian natural grassland plateau. Environmental Management. 29: 824-844.
Sims, P.L., Singh, S. & Lauenroth, W.K. 1978. The structure and function of ten western North American Grasslands. 1. Abiotic and vegetational characteristics. Journal of Ecology. 66: 251-285.
Smith, M.A., Rodgers, J.D., & Dodd, J.L. 1992. Habitat selection by cattle along an ephemeral channel. Journal of Range Management. 45: 385-390.
Smith-Fargey, K. 2004. Shared prairie - shared vision: the northern mixed grass transboundary conservation initiative. Conservation site planning workshop proceedings and digital atlas. Environment Canada, Canadian Wildlife Service. Regina SK.
Smoliak, S. 1986. Influence of climatic conditions on production of *Stipa-Bouteloua* prairie over a 50 year period. Journal of Range Management. 39: 100-103.
Smoliak, S., Dormaar, J.F. & Johnston, A. 1972. Long-term grazing effects on *Stipa-Bouteloua* prairie soils. Journal of Range Management. 25: 246-250.
Sneft, R.L., Coughenour, M.B., Bailey, D.W., Rittenhouse, L.R., Sala, O.E. & Swift, D.M. 1987. Large herbivore foraging and ecological hierarchies. Bioscience. 37: 789-799.
Sneft, R.L., Rittenhouse, L.R. and Woodmansee, R.G. 1985. Factors influencing patterns of cattle grazing behavior on shortgrass steppe. Journal of Range Management. 38: 82-87.
Spence, J.R. & Niemela, J.K. 1994. Sampling carabid assemblages with pitfall traps - the madness and the method. Canadian Entomologist. 126: 881-894.
Stanley, T.R. & Knopf, F.L. 2002. Avian responses to late-season grazing in a shrub-willow floodplain. Conservation Biology. 16: 225-231.
Steidl, R.J. & Thomas, L. 2001. Power analysis and experimental design. Pp. 14-36 In: Scheiner, S.M. & Gurevitch, J. (eds). Design and analysis of ecological experiments, second edition. Oxford University Press. New York NY.
Steinauer, E.M. & Collins, S.L. 2001. Feedback loops in ecological hierarchies following urine deposition in tallgrass prairie. Ecology. 82: 1319-1329.
Steuter, A.A., Grygiel, C.E. & Biondini, M.E. 1990. A synthesis approach to research and management planning: the conceptual development and implementation. Nat. Areas J. 10: 61-68.
Steuter, A.A., Steinauer, E.M., Hill, G.L., Bowers, P.A. & Tieszen, L.L. 1995. Distribution and diet of bison and pocket gophers in a sandhills prairie. Ecological Applications. 5: 756-766.
Stewart-Oaten, A., Murdoch, W.W. and Parker, K.R. 1986. Environmental impact assessment: Pseudoreplication in time? Ecology 67: 929-940.

Stohlgren, T.J., Bull, K.A., & Otsuki, Y. 1998. Comparison of rangeland vegetation sampling techniques in the central grasslands. Journal of Range Management. 51: 164-172.
Stohlgren, T.J., Coughenour, M.B., Chong, G.W., Binkley, D., Kalkhan, M.A., Schell, L.D., Buckley, & D.J., Berry, J.K. 1997. Landscape analysis of plant diversity. Landscape Ecology. 12: 155-170.
Stohlgren, T.J., Schell, L.D., & Vanden Heuvel, B. 1999. How grazing and soil quality affect native and exotic plant diversity in rocky mountain grasslands. Ecological Applications. 9: 45-64.
Stringham, T.K.; Krueger, W.C.; & Thomas, D.R. 2001. Application of non-equilibrium ecology to rangeland riparian zones. Journal of Range Management. 54: 210-217.
Stringham, T.K., Krueger, W.C., & Shaver, P.L. 2003. State and transition modeling: An ecological process approach. Journal of Range Management. 56: 106-113.
Stroup, W.W., Waller, S.S. & Gates, R.N. 1986. Exposition on the selection of appropriate experimental design and statistical analysis for pasture improvement research. Journal of Range Management. 39: 200-207.
Sugden, E A. 1985. Pollinators of *Astragalus monoensis* Barneby (Fabaceae): new host records; potential impact of sheep grazing. Great Basin Naturalist 45 (2):299-312
Sutter, G.C. 1997. Songbird abundance, productivity and predation risk in managed grasslands: Initial results and recommendations. Unpublished Report. University of Regina. Regina SK.
Sutter, G.C. & Brigham, R.M. 1998. Avifaunal and habitat changes resulting from conversion of native prairie to crested wheat grass: patterns at songbird community and species levels. Canadian Journal of Zoology. 76: 869-875.
Thompson, WH; & Hansen, PL. 2001. Classification and management of riparian and wetland sites of the Saskatchewan prairie ecozone and parts of adjacent subregions. Saskatchewan Wetland Conservation Corporation, Regina SK.
Thorpe, J. & Godwin, B. 2003. Differences between grazed and ungrazed vegetation in sage grouse habitat at Grasslands National Park. Saskatchewan Research Council Publication 11475-1E03. Saskatoon SK.
Toft, C.A. & Shea, P.J. 1983. Detecting community-wide patterns: estimating power strengthens statistical inference. American Naturalist. 122: 618-625.
Umbanhowar, C.E. 1992. Abundance, vegetation, and environment of four patch types in a northern mixed prairie. Canaidan Journal of Botany. 70: 277-284.
Underwood, A.J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications. 4: 3-15.
Usnick, S.J. & Hart, R.H. 2002. Western harvester ants' foraging success and nest densities in relation to grazing intensity. Great Plains Research. 12: 261-273.
Van Home, B., Schooley, R.L., Knick, S.T., Olson, G.S., & Burnham, K.P. 1997. Use of burrow entrances to indicate densities of Townsend's ground squirrels. Journal of Wildlife Management. 61: 92-101.
Vermeire, L.T., Ganguli, A.C. & Gillen, R.L. 2002. A robust model for estimating standing crop across vegetation types. Journal of Range Management. 55: 494-497.
Vinton, M.A., Hartnett, D.C., Finck, E.J. & Briggs, J.M. 1993. Interactive effects of fire, bison grazing and plant community composition in tallgrass prairie. American Midland Naturalist. 129: 10-18.
Weins, J.A. 1974. Habitat heterogeneity and avian community structure in North American grasslands. American Midland Naturalist. 91: 195-213.
Welch, J.L., Redak, R. & Kondratieff, B.C. 1991. Effect of cattle grazing on the density and species of

grasshoppers (Orthoptera: Acrididae) of the Central Plains Experimental Range, Colorado: a reassessment after two decades. Journal of the Kansas Entomological Society 64(3):337-343
Westoby, M., Walker, B. & Noy-Meir, I. 1989. Opportunistic management of rangelands not at equilibrium. Journal of Range Management. 42:266-274.
Whisenant, S.G. & Uresk, D.W. 1989. Burning upland, mixed prairie in Badlands National Park, South Dakota. Prairie Naturalist. 21: 221-227.
Willms, W.D. 1988. Forage production and utilization in various topographic zones of the fescue grasslands. Canadian Journal of Animal Science. 68: 211-223.
Willms, W.D., Dormaar, J.F. & Schaalje, G.B. 1988. Stability of grazed patches on rough fescue grasslands. Journal of Range Management. 41: 503-508.
Willms, W.D., Dormaar, J.F., Adams, B.W. & Douwes, H.E. 2002. Response of the mixed prairie to protection from grazing. J. Range Manage. 55: 210-216.
Willms, W.D. & Jefferson, P.G. 1993. Production characteristics of the mixed prairie: Constraints and potential. Canadian Journal of Animal Science. 73: 765-778.
With, K.A. 1994. The hazards of nesting near shrubs for a grassland bird, the McCowns longspur. Condor. 96: 1009-1019.
Zhang, Z.B., Pech, R., Davis, S., Shi, D.Z., Wan, X.R. & Zhong, W.Q. 2003. Extrinsic and intrinsic factors determine the eruptive dynamics of Brandt's voles *Microtus brandti* in Inner Mongolia, China. Oikos. 100: 299-310.

Table 1. Hypotheses for heterogeneity measure (diversity, dissimilarity, coefficient of variation [CV]) responses to grazing intensity.

Ecological Integrity Measures	Hypotheses	Contrasts*	Time Frame
Compositional Measures			
Vascular plant community Ground beetle community Grasshopper community Upland songbird community	Diversity, richness and evenness are greater in conventional grazed than ungrazed treatments.	CG vs. UG	2006-2007
	Diversity, richness and evenness peak at intermediate intensities of grazing and intermediate durations since grazing began.	B vs. A	2008-2017
	Dissimilarity increases positively with grazing intensity and duration since grazing began.	B vs. A	2008-2017
Exotic plant species Songbird *Species-at-Risk* Richardson's ground squirrel	Grazing-sensitive species decrease, and grazing-adapted species increase, directly with grazing intensity and duration since grazing began.	B vs. A	2008-2017
Structural Measures			
Upland & valley vegetation, litter and soil cover Upland & valley vegetation height & litter depth Upland & valley vegetation & litter biomass Upland & valley vegetation leaf-area index Remotely sensed NDVI Riparian health components	CV is greater at patch-landscape scales in all grazed than ungrazed treatments.	CG vs. UG B vs. A	2006-2017
	CV is greater among years in grazed than ungrazed treatments.	CG vs. UG	2006-2017
	CV peaks at intermediate intensities of grazing and intermediate durations since grazing began.	B vs. A	2008-2017
Functional Measures			
Forage utilization (dung density, differential biomass) Soil available nitrogen Soil turbation (burrowing, mounding) Riparian health index Rangeland health index	CV is greater in conventional grazed than ungrazed treatments.	CG vs. UG	2006-2007
	CV is greater among years in grazed than ungrazed treatments.	CG vs. UG	2006-2017
	CV peaks at intermediate intensities of grazing and intermediate durations since grazing began.	B vs. A	2008-2017

*CG (conventional grazed "controls"), UG (ungrazed "controls"), B vs. A (before vs. after measurements along gradient of "impacts").

Table 2. Stocking rate calculations for achieving median forage utilization targets across the experimental grazing gradient. Appropriate targets for ungrazed and grazed control treatments are also described.

EU[a] #	Median Forage Supply[b] (kg/ha)	Grazing Duration (mo.)	Forage Demand[c] (kg/AU/mo.)	Target Utilization (%)	Target Utilization (AUM/ha)	Cattle Density (AU/ha)	EU size (ha)	Stocking Rate (AU/EU)
1	440	Ungrazed control		0	0	0	296	**0**
2	440	Ungrazed control		0	0	0	296	**0**
3	440	Ungrazed control		0	0	0	296	**0**
4	440	4	352	20	0.25	0.06	296	**19**
5	440	4	352	32	0.40	0.10	296	**30**
6	440	4	352	45	0.56	0.14	296	**42**
7	440	4	352	57	0.71	0.18	296	**53**
8	440	4	352	70	0.88	0.22	296	**65**
9	440	4	352	70	0.88	0.22	296	**65**
10	440	4	352	~50	0.63	0.16	Grazed control	
11	440	4	352	~50	0.63	0.16	Grazed control	
12	440	4	352	~50	0.63	0.16	Grazed control	

a. EU = experimental unit.
b. Back-calculated as the mean forage supply per unit area based on Animal Unit Month (AUM) recommendations for soil ecosites and range condition classes in Abouguendia (1990) most similar to those found in the experimental units.
c. Adapted from values in Abouguendia (1990).

Table 3. Annual schedule of estimated project management and sampling time (hours) for the grazing experiment, by two-week intervals.

Activity	May		June		July		August		September		October	
	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
Project Management												
Herd, fence & water maint.			60	80	60	60	60	60	60	60	80	
Meteorological station maint.	10	10	10	10	10	10	10	10	10	10	10	10
Training & Orientation	60	35	24	16		16				3		
TOTAL	70	45	94	106	70	86	70	70	70	73	90	10
Monitoring Program Sampling												
Nitrogen Probes	48		53		53	53		53	53			
Point Counts		40	72	32								
Pitfall Trapping		112	24			40	40	48				
Cattle ID & Weighing				30							30	
Whittaker Plots				108	180	72						
Grasshopper Density & Sweeps							96					
Grasshopper Sorting								96				
Riparian Health Assessment							96					
Forage Clipping & Weighing										128	64	
Travel, Data Entry, Repairs, etc.	60	78	55	66	67	71	68	103			8	
Student Training/Orientation	192	70	96	64		64				6		
TOTAL	300	300	300	300	300	300	300	300	53	134	102	0

Note: Approximately 4 seasonal technicians will be needed to complete 300 hours of work per 10 day (75 hour) shift.

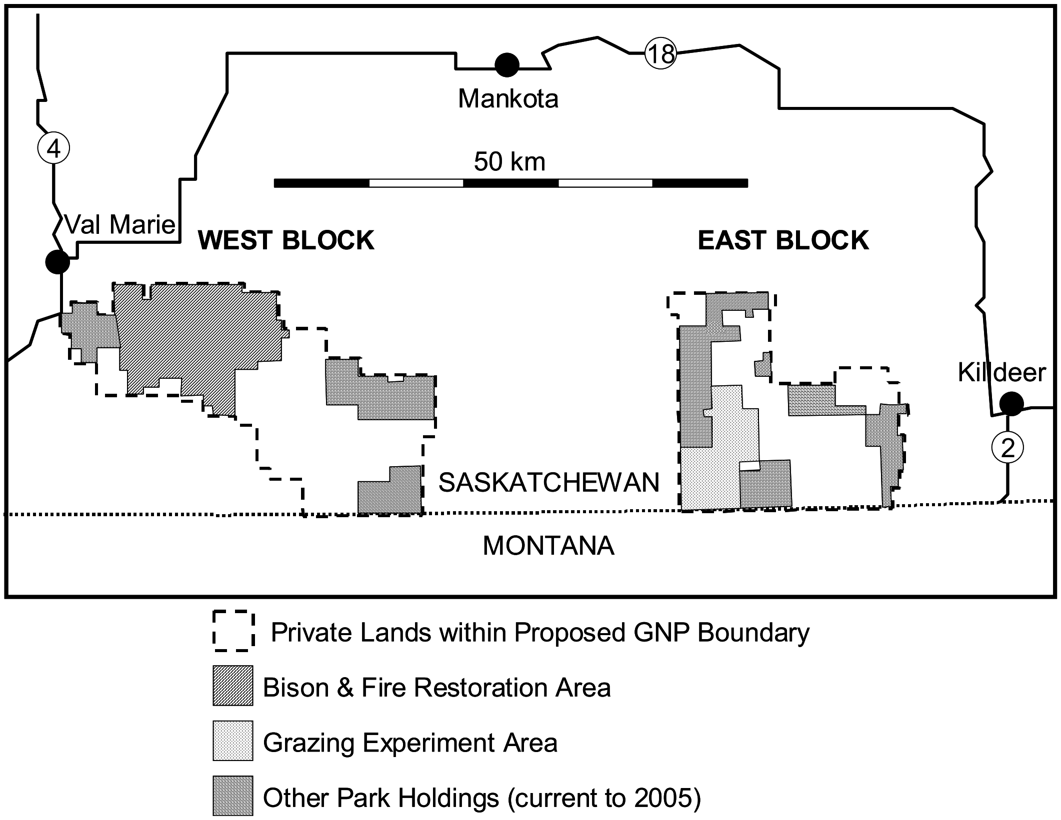

Figure 1. Grasslands National Park of Canada land holdings within the proposed boundaries, and division into management units.

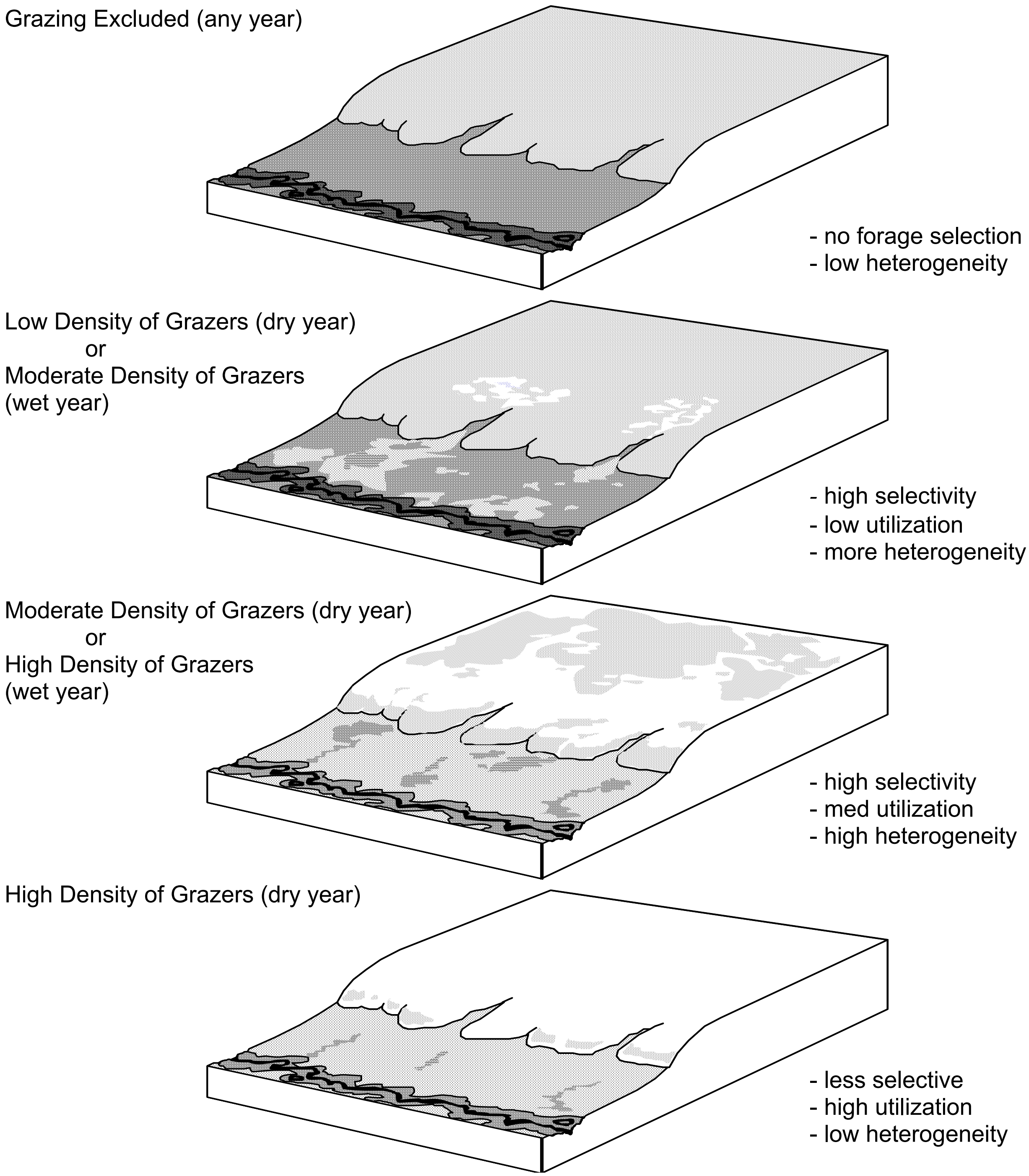

Figure 2. Conceptual model of among-patch, within-landscape grazing-induced heterogeneity in vegetation structure caused by the interaction of variable grazing animal density and climate, superimposed on a landscape typical of Grasslands National Park of Canada.

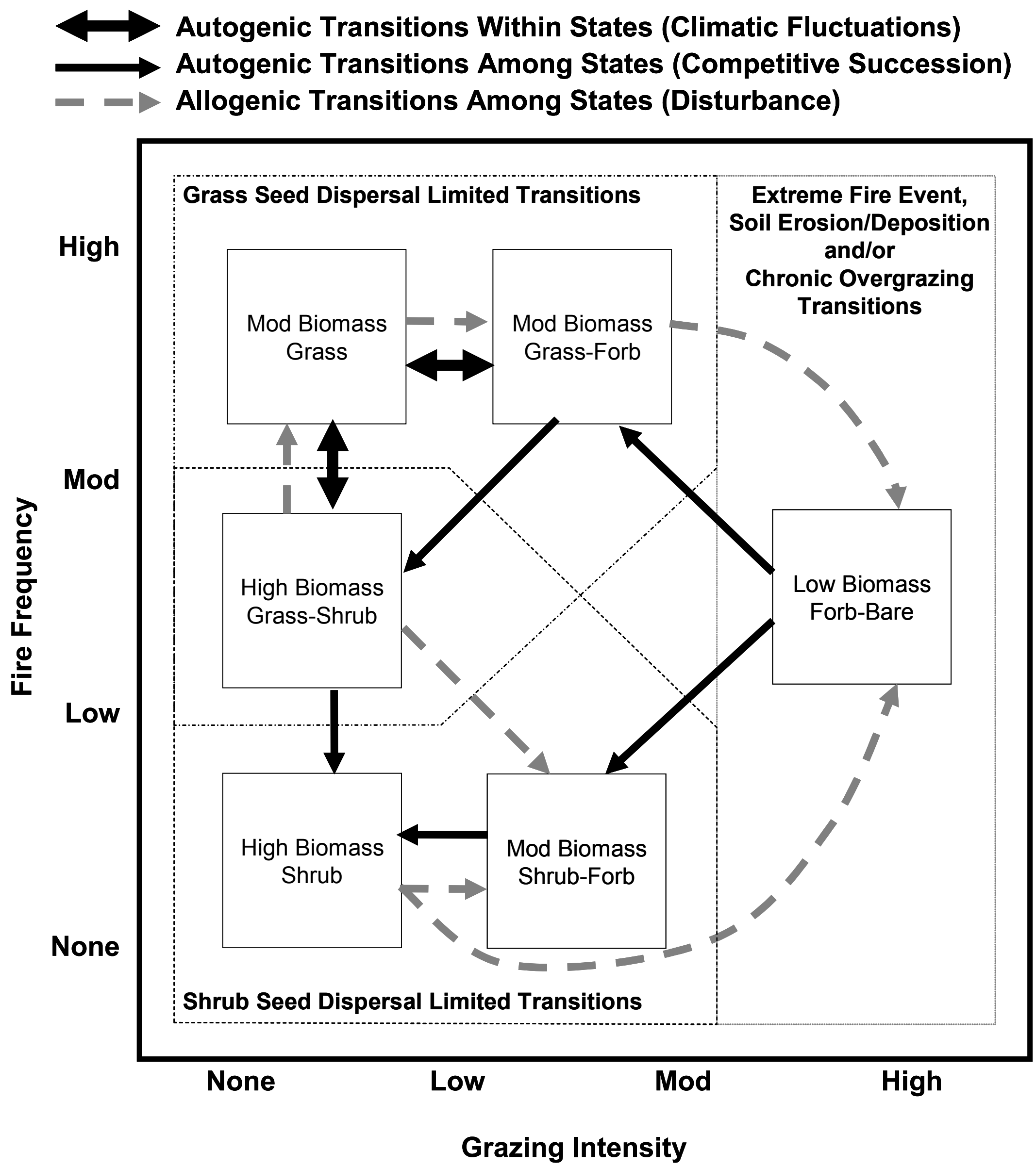

Figure 3. Hypothetical state and transition model of mixed-grass prairie responses to fire frequency and grazing intensity on a loam range site. Retrogressive succession becomes a component of the model where there are no grass seed dispersal limitations. Different range sites or range types invaded by alien invasive species could vary in pathways and states.

Figure 4. Vegetation-landscape types and vegetation community polygons in the East Block Experimental Area, Grasslands National Park of Canada. Classification and map based on Michalsky & Ellis (1994).

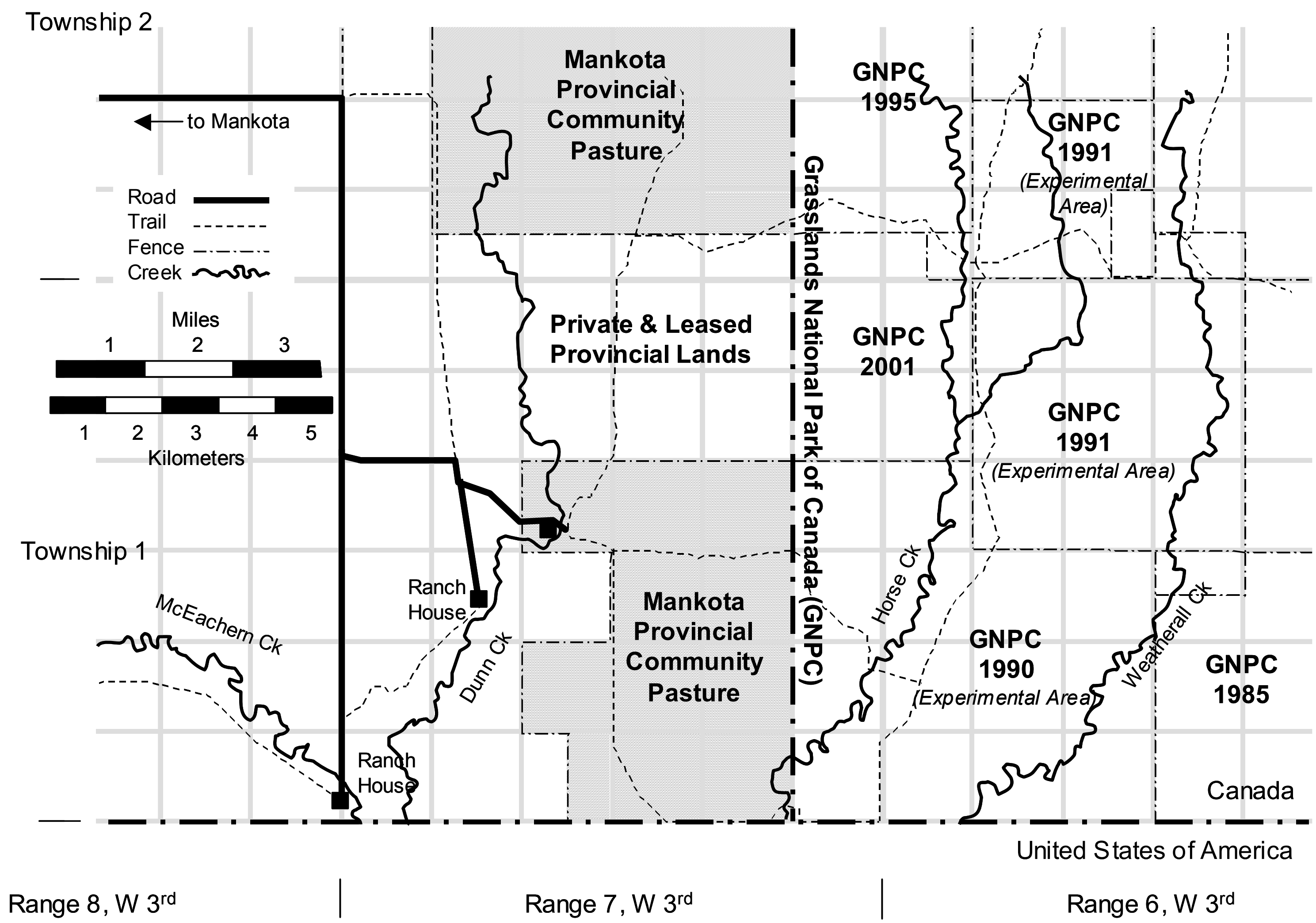

Figure 5. Cultural developments and land tenure in and adjacent to the East Block Experimental Area, Grasslands National Park of Canada. Dates on GNPC land indicate when livestock grazing was excluded following acquisition. Data current to 2005.

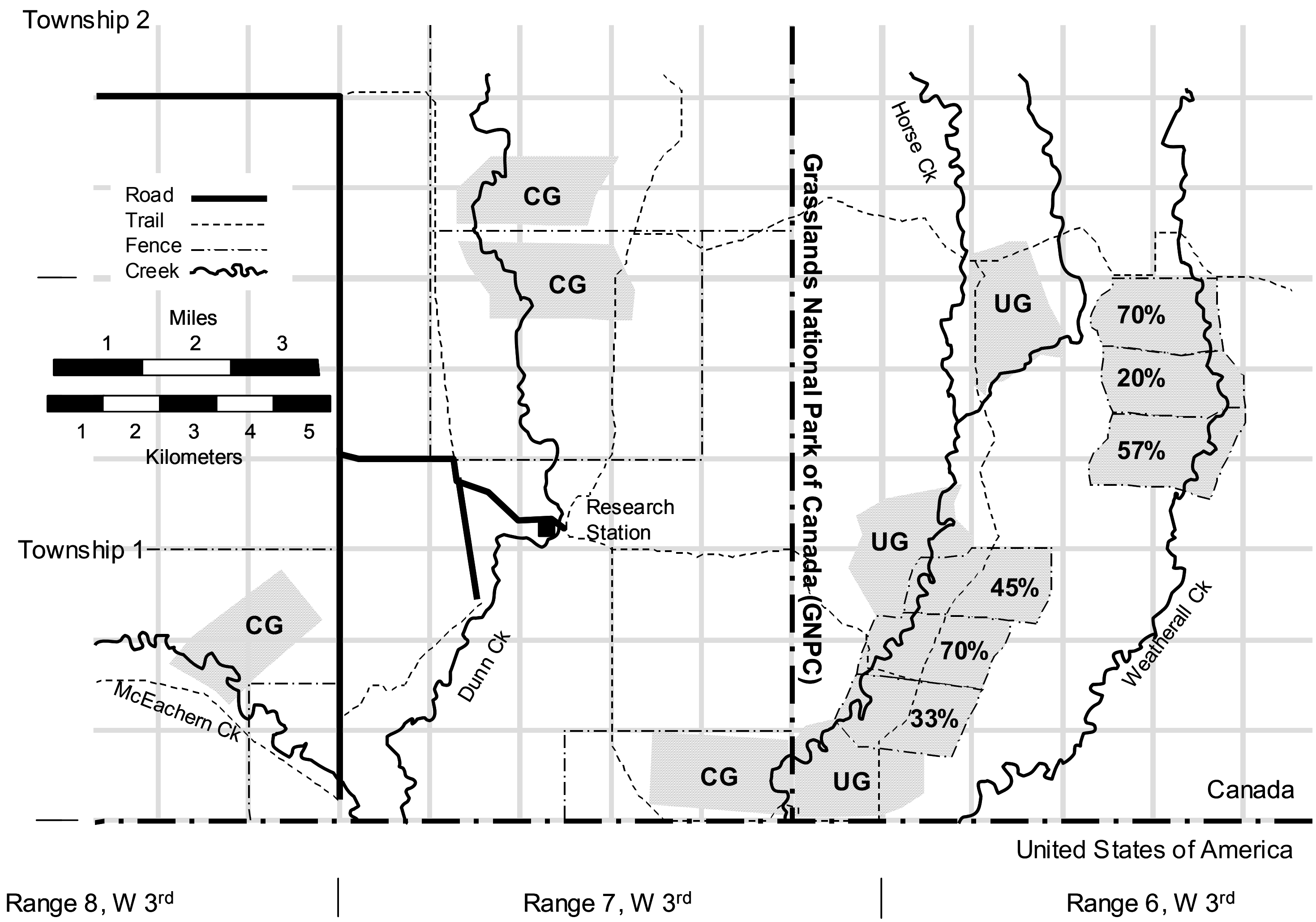

Figure 6. Proposed experimental unit arrangement. All units are ~300 ha and incorporate similar areas and juxtaposition of water, riparian, valley and upland landscapes. Four potential conventionally grazed (CG) units are represented, though only three are needed. Both CG and ungrazed (UG) units are simply sampled, and do not require additional fencing. Only the manipulated grazing intensity treatments (20 to 70% utilization) require new fences and water developments.

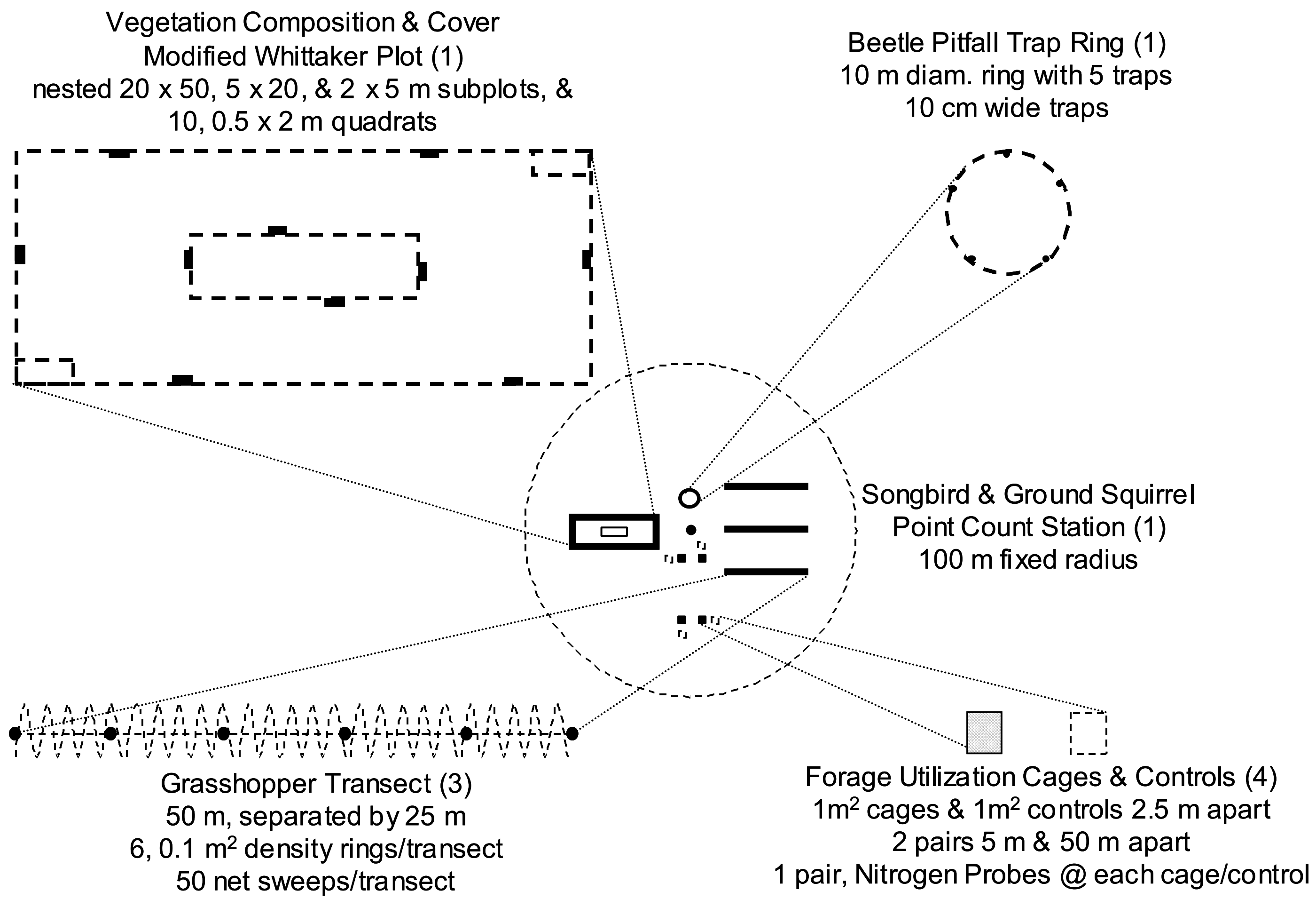

Figure 7. Proposed nested arrangement of sampling schemes for upland and valley sample stations. A point-count for recording birds and ground squirrels is the largest sampling unit, within which is a vegetation composition and structure plot, grasshopper sampling transects, ground beetle sampling ring, and plots for sampling plant production and available soil nitrogen.

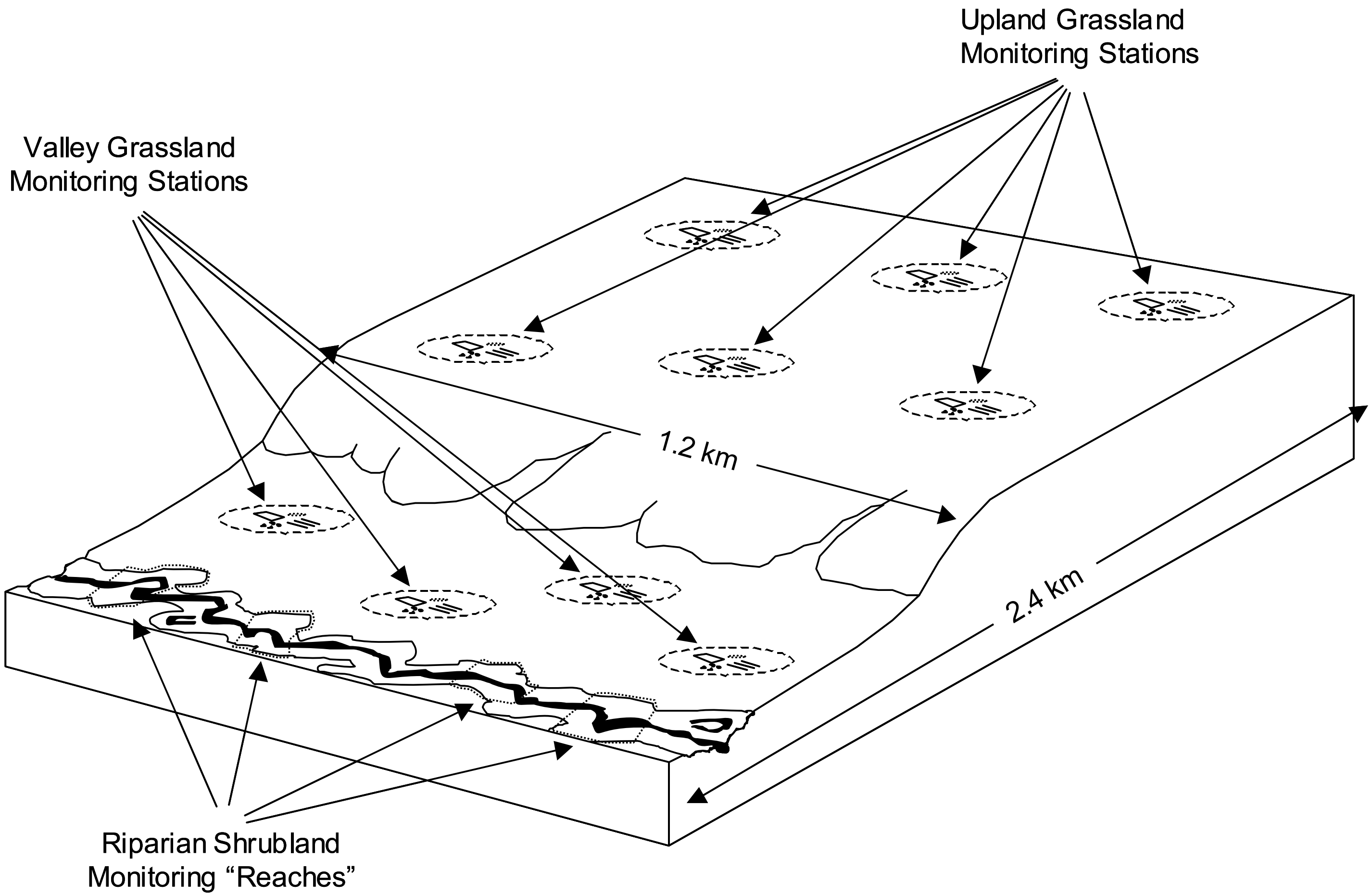

Figure 8. Proposed arrangement of sample stations within an experimental unit. Riparian sample stations permit a small subset of measures, while valley and upland sample stations permit a large number of co-located measures of ecological integrity.

APPENDIX A - MINUTES FROM COLLABORATOR MEETINGS

A.1 INITIAL PERSPECTIVES OF AGENCY REPRESENTATIVES TO EXPERIMENTAL RESTORATION AND MONITORING OF GRAZING AND FIRE INTERACTIONS (APRIL 13/05 – SWIFT CURRENT SK)

Jeff Thorpe, Saskatchewan Research Council – Saskatoon

- Need specific empirical data to support contentions about grazing and fire interaction benefits to biodiversity.
- Landscape biodiversity is an understudied area for research.
- Grazing animal distribution and patchy grazing intensity within landscapes is key to monitor.

Steve Davis, Canadian Wildlife Service – Saskatoon

- In all proposed experimental treatments must think about the biologically significant and statistically detectable effect size, and scale at which this change is likely to occur.
- Parallel grazing monitoring study at Last Mountain Lake may be useful comparison at landscape-scale, and data could be used to estimate minimum sample sizes.

Dan Beveridge, Saskatchewan Watershed Authority – Regina

- Most interested in the effect of grazing and fire treatments on water quality.
- Believe whole watersheds should be used as minimum experimental unit, and use some water quality metrics to monitor change.

Xulin Guo, University of Saskatchewan – Department of Geography

- Effects must be large enough for remote sensing detection (minimum 20 x 20 m), like the large patches at Konza prairie in Kansas.
- Factors affecting remote sensing at the ground level include vegetation biomass, soil moisture content, plant community type and vegetation structure which are good indicators of bird habitat availability and predicting population density.

John Carlson, US Bureau of Land Management – Glasgow MT

- If you measure livestock weight gains among grazing treatments this becomes an important communication tool for neighbouring ranchers.
- Benefits to both cattle and wildlife can then be evaluated by private landowners.

Sue Michalsky, (formerly of) Nature Conservancy of Canada – Eastend SK

- Need baseline information to show the benefits of grazing and identify where grazing becomes detrimental.
- Consider similar treatments and monitoring systems employed by "The Nature Conservancy" in tallgrass prairie.

- Interested in plant community responses to continuous cattle vs. continuous bison grazing.

Walter Willms, AAFC – Lethbridge Research Center

- If the goal is to achieve heterogeneity through grazing, the important treatment variables to manipulate are timing, duration, density and frequency.

Kelly FitzPatrick, Rancher – Fir Mountain SK

- Grazing is a symbiotic land practice, unlike land alteration, and will keep the grass healthy.

Mike Schellenberg, AAFC – Semiarid Prairie Agriculture Research Center

- Interested in finer resolution responses, such as assisting with diet selection and nutritional analyses of native plant material from treatment areas; with the ultimate aim of developing optimal nutritional seed mixes for reseeding cultivated lands to pasture/forage crops.
- Also interested in climate change impacts, and the effects of sustained drought on range condition under consistent management practices.

Darcy Henderson, (formerly of) University of Alberta – Department of Renewable Resources

- BACI designs more clearly demonstrate cause and effect on ecological integrity, but need spatial replication to avoiding problems of autocorrelation (i.e. use adjacent lands for current comparisons of grazed and ungrazed).
- At landscape-scales, use NCC Old Man on His Back, Charlie Russel NWA and Roosevelt NP as replicates for comparing bison grazing impacts in the West Block.
- Much work conducted on alpha scale responses of vegetation, but need beta and larger scales of biodiversity responses.

Nicola Koper, University of Manitoba – Natural Resources Institute

- Heterogeneity within pastures not well quantified, and metrics like variance could be used as a response variable.
- Interaction of grazing and fire not clear.
- Best to use analysis of change over time (BACI) and comparison of observed trends relative to expected trends (fits to theoretical models).
- Focus on the scales appropriate to management actions that are or will be undertaken.

Steve Forrest, World Wildlife Fund – Helena, MT

- Bison movements could be described within pastures with GPS to evaluate how observed grazing patterns match expected patterns, or vary (behavioural response).
- Explore potential for matched studies within the region for landscape-scale comparisons.
- Need to develop a regional approach suitable for monitoring grazing within, around and beyond GNP.

A2. Interim Recommendations for Experimental and Sampling Design of the Grazing and Fire Restoration Project (April 14, 2005 – Swift Current SK)

Discussion facilitated by:
Sal Rasheed, Parks Canada Agency – Western & Northern Service Center
Pat Fargey, Parks Canada Agency – Grasslands National Park

Important considerations identified by meeting participants were summarized as:

1. Identify important scales for applying treatments and monitoring responses;
2. Identify important biodiversity indicators and metrics for responses;
3. Estimate detectability and significance of treatment effects on response variables when selecting treatments;
4. Incorporate comparisons to lands outside of Grasslands National Park;
5. Define ecological integrity for communication with and buy-in from larger audience.

1. Treatment Unit and Monitoring Unit Scales

- Minimum monitoring scale dictated by expected scale of spatial heterogeneity in biodiversity response variable, and measurement tools (i.e. community species area curves among taxa, remote sensing pixel minimum 20 x 20 m; point count radius minimum 100 m).
- Minimum treatment scale dictated by desired incorporation of landscape heterogeneity (i.e. riparian, valley, slope and upland complex in each).
- Minimum treatment scale dictated by management systems of interest for comparison (i.e. smallest community pasture units typically 1280 acre 2 section units).
- Minimum treatment scale dictated by maximum size of burned subplots in each landscape type (i.e. if 11 ha mean burn patch size, need equal unburned area within each pasture).
- Minimum treatment scale dictated by desired grazing animal behaviour to elicit (i.e. herd movements restricted where population <100 animals and area <3000 acres).
- Maximum treatment scale dictated by infrastructure restrictions (i.e. does Parks Canada want to dig wells and dugouts or lay pipelines to supply water to dry uplands, ungulates rarely travel more than 1.6 km for water).
- Maximum treatment scale dictated by intensity of monitoring effort logistically possible to capture heterogeneity (i.e. low density impacts of bison within Larson block).
- Maximum treatment scale dictated by available land under consistent past management to provide experimental control at experiment onset, and space for replication (n=2 minimum).
- Statistically, the experimental unit can be variable in size as long as habitat type proportional representation within units is consistent; then vary sampling intensity within each unit.
- Consensus for experimental unit size around 3 - 4 sections

2. Biodiversity/Heterogeneity Indicators and Metrics

- Large animal (pronghorn, deer, badger, swift fox) abundance or utilization best dealt with through landscape-scale comparisons (i.e. NCC-OMB, Comm. Pastures, Charlie Russel NWA).
- Migratory songbird richness and abundance responses limited by territory size for some species (i.e. one pair of McCowan's Longspur may require 160 acre quarter section of suitable habitat).

- Migratory songbird productivity (nest success) estimated from intensive nest searches in 400 x 400 m areas may be more useful than point counts in small experimental plots.
- Resident bird species may be more sensitive to land management than migratory species.
- Small mammal signal to noise ratio problematic and requires intense sampling effort (especially Microtines), but pocket gopher mound density and ground squirrel alarm call stations or mound density may be useful.
- Arthropods (herbivorous grasshoppers and predaceous carabid beetles) are easily sampled and functionally link to prey diversity and abundance for birds. Taxonomic challenges may be overcome by simpler Family-level diversity, abundance or biomass.
- Plant species distribution and abundance and plant community types with associated diversity statistics. Particular attention required to detect rare or invasive alien species.
- Vegetation vertical structure (field Robel Pole measurements, remote sensing of Leaf-Area-Index) are key to characterizing songbird habitat.
- Vegetation nutritional content among grazing and fire treatments, and over the growing season may provide clues to cattle movement patterns.
- Soil root distribution, carbon sequestration and microbial community composition can also be sampled in the field and scaled-up using remote sensing imagery of LAI, etc.
- Variance metric like coefficient of variation (CV), or dissimilarity (Jaccard's, Sorensen's) useful to assess heterogeneity among multiple scales within and among treatment units.
- Stratification and replication important in sampling to capture spatial variation at landscape and community scales.

3. Treatment Selection and Effect Size

Grazing Logistics:

- Livestock class must be consistent among units and from year to year (big differences between horses, bison herds [1:1 sex ratio + mixed age-class], cow-calf pairs, yearlings or bulls, breeds [British vs. European], animal condition).
- Logistically, explore local cattle producers' ability to provide cattle for grazing treatments, or SPARC approach of "Horned Cattle Trust", legal limitations on Parks Canada owning or generating revenue from livestock grazing, AAFC Animal Care Committee restrictions, and consider hiring a single learned person to make all arrangements at arm's length (sending out bids, choosing the best bid, dealing with producers).
- Winter grazing not comparable to adjacent lands, and difficult to accommodate ACC requirements for shelter and supplementary feed.
- Summer (season-long) grazing or some variant most similar to adjacent lands, and consistent with animal availability, producer interests, and ecological impacts.
- Based on 0.25 average au/acre for 1000lb cow and 4-month grazing season over the proposed area translates to 720 animals, and might entail a bid from several producers.
- Shape of pasture corners could be rounded and placed some distance from the water's edge to avoid cattle congregations.
- Shape of grazing unit could be rectangular to incorporate landscape variation and maximize distance from watering points to elicit variation in grazing distribution.
- Monitor livestock movement patterns with GPS collars to evaluate whether treatments are having desired effect on grazing distribution.

Grazing Treatments (Main Plots):

- Stocking rate (grazing intensity) differences must be large enough to elicit response in bird diversity.
- Stocking rate (grazing intensity) could be fixed effects (replicates of a few rates suited to ANOVA) or random effect (gradient of a greater spectrum of rates suited to Regression).
- Latter approach requires 2 ungrazed control, 2 heavy grazing, and at least 4 intermediate rates (some of which could be obtained from sampling adjacent PFRA, SAF or BLM lands). The shape of the response (trend line) and significance from a slope = 0 could be tested (need 8 point minimum to test for significant polynomial fit). Weakness is lack of independence for making inferences beyond the site, but strength is identifying specific ecological threshold points.
- Randomization vs. planned interspersion should be considered. Both control treatments should not be spatially associated. Should be dealt with at the final statistical peer-review.
- Crossover between treatment units may be considered after the 10+ year horizon, to incorporate at least one drought cycle, increase heterogeneity in time and monitor recovery rates from grazing and protection treatments.

Fire Logistics:

- Administratively constrained by need for overall Fire Management Plan in GNP.
- Technical constraint on timing, frequency and size by trained staff availability, site access, water availability.
- Social constraint on timing, frequency and size by local fears and insurance risks.

Fire Treatments (Nested Subplots):

- Size of burns should simulate natural range of variation (median 11 ha, skewed right), be maximized to elicit a grazing animal utilization response (extent = 5-10% of pasture), songbird response (12.5 ha circle fits one point count station with 100 m buffer) and be detectable from remote sensing imagery (0.25 ha square pixel).
- From year to year, fire size will vary in response to weather/fuel conditions.
- Within a year, fires should be applied to all affected grazing units and same habitat types to avoid confounding statistical comparisons.
- Intensity of each burn needs to be monitored as a potential covariate in analyzing fire effects.

4. Incorporate Comparisons to Adjacent Lands

- Conventional moderately grazed and unburned treatments on community pastures (PFRA, SAF, BLM) or private ranchlands could be demarcated for statistical comparison to similar sized experimental units within GNP.
- Test whether livestock habitat utilization is more variable at low stocking densities within GNP, relative to conventionally managed ranches outside GNP.
- Test whether livestock weight gains differ between GNP treatments and conventionally managed ranches outside GNP (important to ranchers).
- Test whether management costs of low density stocking, prescribed burning and fencing inside GNP differ from moderate density stocking, dugout construction, salt block placement and fencing outside GNP (important to ranchers).

5. Ecological Integrity Communication Plan (not discussed)

Appendix B – Characteristics of manipulated grazing experiments in North American mixed-grass and short-grass prairie.

Location	Initiated (Ceased)	Treatments	N[c]	Area (ha)	References (Section 9.0)
WY "High Plains Experiment Station"	1982	Exclusion	2	~2.5	Hart et al. 1988; Schuman et al. 1999
		17% utilization	2	~64.0	
		33% utilization	2	~12.0	
		50% utilization	2	~9.0	
ND "Mandan"	1916	Exclusion	1	<0.1	Frank et al. 1995
		Mod utilization	1	46.0	
		High utilization	1	16.0	
ND "Streeter"	1979	Exclusion	3	13.2	Biondini et al. 1998
	1988	45% utilization	3	13.2	
	1988	77% utilization	3	13.2	
CO "Central Plains Experiment Station"	1939	Exclusion	3	2.0	Milchunas et al. 1989 Hart 2001
		Light utilization	1	138.0	
		Mod utilization	1	138.0	
		High utilization	1	138.0	
KS "KSU RRU"	1992	Exclusion	1	29.0	Hickman et al. 2004
		30% utilization	1	29.0	
		50% utilization	1	29.0	
		70% utilization	1	29.0	
TX "Sonora"	1948	Exclusion	2	12.0	Fuhlendorf & Smeins 1998
		High utilization	2	32.0	
SK "Swift Current"	1989	May-Jun[a]	2	1.6	Schellenberg et al. 1999
		Jul-Aug[a]	2	1.6	
		Aug-Sep[a]	2	1.6	
		Sep-Oct[a]	2	1.6	
AB "Onefour Blacktail"	2001	Exclusion	6	0.3	Willms pers. comm.
		Jun-Aug[b]	3	265.0	
		Sep-Nov[b]	3	265.0	
AB "Onefour Sheep"	1950 (1970)	Exclusion	1	<0.1	Smoliak et al. 1972
		Light utilization	1	~16.0	
		Mod utilization	1	~16.0	
		High utilization	1	~16.0	

a. Short-duration (40 days), high utilization (65%) in each of the four season treatments.
b. Moderate utilization in each of the two season treatments.
c. Number of experimental units, defined as the smallest fenced area within which a group of grazing animals are managed, or excluded, to produce the treatment effect.

APPENDIX C – MINIMUM SAMPLE SIZE ANALYSES FOR SELECTED ECOLOGICAL INTEGRITY MEASURES.

Minimum sample size and power analyses are prudent in scientific investigations using statistics to ensure the study design has sufficient replication to detect hypothesized effects at pre-selected type 1 and type 2 error rates, or evaluate the power of statistical tests after the fact and estimate how much replication would have been necessary to improve a study design (Toft & Shea 1983). Generally speaking, as biologically significant effect sizes become smaller, more replication is needed to decrease variance and increase the power of statistical tests. Manipulated experiments generally have very little replication compared to descriptive investigations, because the effect size generated by experimental treatments is relatively large and controlled at specified levels. Not all experimental designs and questions lend themselves easily to power analyses, despite the development of commercially-available software, because the population variance structure is not always known. This is particularly true of repeated measures over time, where temporal variation and autocorrelation are usually unknown prior to the study (Steidl & Thomas 2001). The following analyses are based upon preliminary data collected in 2005 at a subset of 32 sample stations in 4 experimental units, using the free software GPOWER (Erdfelder et al. 1996).

STATISTICAL MODELS used in the analyses below include a ***T-Test*** contrast in support of hypotheses in Phase 1 (Section 6.1), and a single parameter linear ***Regression*** in support of hypotheses in Phase 2 (Section 6.2). These were selected because the most extreme limitation on replication proposed in this experimental design is at the ~300 ha experimental unit scale. Each experimental unit is comprised of 10 sample stations or subsamples, such that any analyses at this subsample scale will provide an order of magnitude more replication. No attempt could be made to estimate the power of tests using non-linear regression, asymmetrical ANOVA for BACI, nor a repeated measures model incorporating multiple years of data.

EFFECT SIZES were estimated for selected ecological integrity measures (EIM) to represent a range of expected grazing treatment effects based on patterns observed in preliminary samples taken in 2005. ***Minimum*** effect size for any EIM was based on the observed difference between ungrazed units within the upland vegetation type, and ***Maximum*** effect size for any EIM was based on the observed difference between upland and valley vegetation types within ungrazed units. These minima and maxima were based on the hypothesis that grazing-induced changes for any EIM should be greater than pre-existing variation within a vegetation type, but less than pre-existing differences between vegetation types. Observed EIM means and sample variance (sigma) from 2005 were used as inputs to directly estimate minimum sample sizes for the t-test model, however, GPOWER requires regression coefficients (r^2) in place of sigma to calculate the same estimates for a regression model. To generate these r^2 values, a simulated dataset was created using data collected in 2005 and modifications to the structure based on a number of assumptions outlined below:

1. For each EIM, generate a mean among the 4 ungrazed experimental units sampled in 2005.
2. For each EIM, generate all possible permutations of 8 experimental unit values. Because only 4 experimental units were sampled, each unit was repeated twice in this operation.

3. For each experimental unit value generated in #2 above, calculate a coefficient representing the positive or negative difference from the EIM mean generated in #1 above, keeping the same unit of measurement.
4. For each effect size (minimum or maximum) estimated in the original unit of measurement, generate a bivariate distribution of coordinates representing the linear regression trend line. At 0% grazing intensity the associated y coordinate would equal the EIM mean, and at 70% grazing intensity the associated y coordinate would equal the EIM mean plus (for positive relationships) or minus (for negative relationships) the effect size. For intermediate grazing intensities the effect size will be multiplied by a proportional value before adding or subtracting it from the mean, such that 57% intensity = 0.8143 * effect size; 45% intensity = 0.6429 * effect size; 32% intensity = 0.4571 * effect size; and 20% intensity = 0.2857 * effect size.
5. Create a simulated regression dataset by listing the eight independent grazing-intensity values from 0 to 70% in one column, and in all subsequent columns add the effect size coefficients from #4 above to the coefficients from #3 above, such that 28 unique but simulated distributions of EIM are created for the minimum effect size, and 28 unique but simulated distributions of EIM are created for the maximum effect size.
6. Calculate r^2 for all bivariate relationships between grazing intensity (utilization rate) and the simulated EIM distributions generated in #5 above, then calculate the mean r^2 for use in minimum sample size and power estimates in GPOWER.

A PRIORI TYPE 1 & TYPE 2 ERROR RATES were selected to represent a ***Conservative*** (alpha = 0.05, beta = 0.1) and a ***Liberal*** (alpha = 0.10, beta = 0.3) range of expected error, in keeping with the conventions of most ecological and agricultural research. Type 1 error (alpha) represents the probability of rejecting the null hypothesis of no effect when in fact there was no effect. Type 2 error (beta) represents the probability of failing to reject the null hypothesis of no effect when in fact there was an effect. The risk associated with Type 1 error is that investments made to implement a grazing treatment elsewhere in GNPC may not have any effect on a given EIM, despite there being a statistically significant effect detected in this grazing experiment. The risk associated with Type 2 error is that experimental grazing treatments will change some EIM, but this effect will not be detected because sample sizes are small or variation is large. The latter is particularly important in the context of Species at Risk where low densities limit statistical sample sizes. Power analyses describe the risk of committing Type 2 errors, and are of utmost importance for this experiment.

All of the raw and simulated data used to calculate minimum sample sizes in the tables below are contained in the dataset file "EBGE_POWER_05". To help evaluate these minimum sample size analyses, keep in mind that no T-Test model with $n < 4$ or Regression model with $n < 5$ is possible given the low tolerance for type 2 error (beta = 0.9 to 0.7). Also keep in mind the proposed design will have n = 3 for T-Test models in Phase 1, and n = 8 for Regression models in Phase 2. Overall, results demonstrate how the large difference between valley and upland bird communities permitted a broad range of sample sizes for detecting change in the most common species, diversity and richness. Grasshopper abundance in 2005 was very low due to a wet spring, so estimates of minimum sample size may be high, relative to what is expected in most other years. Plant community changes are subtle, and the sample size range is more narrow than for comparable measures in bird communities. Conclusion - the proposed design should opt for liberal error rates.

Table C1. Minimum sample sizes to test for change in Sprague's Pipit abundance.

Effect Size	T-Test Model		Regression Model	
	Conservative	Liberal	Conservative	Liberal
Minimum	26	12	38	15
Maximum	8	4	12	6

Note: Based on average number detected in 2005 among 4 point counts (100 m fixed radius) in upland vegetation of each experimental unit.

Table C2. Minimum sample sizes to test for change in Chestnut Collared Longspur abundance.

Effect Size	T-Test Model		Regression Model	
	Conservative	Liberal	Conservative	Liberal
Minimum	22	10	45	21
Maximum	8	4	13	7

Note: Based on average number detected in 2005 among 4 point counts (100 m fixed radius) in upland vegetation of each experimental unit.

Table C3. Minimum sample sizes to test for change in upland bird community diversity.

Effect Size	T-Test Model		Regression Model	
	Conservative	Liberal	Conservative	Liberal
Minimum	34	14	34	16
Maximum	4	4	7	5

Note: Based on average number detected in 2005 among 4 point counts (100 m fixed radius) in upland vegetation of each experimental unit.

Table C4. Minimum sample sizes to test for change in upland bird community evenness.

Effect Size	T-Test Model		Regression Model	
	Conservative	Liberal	Conservative	Liberal
Minimum	22	10	28	14
Maximum	same	same	same	same

Note: Based on average number detected in 2005 among 4 point counts (100 m fixed radius) in upland vegetation of each experimental unit.

Table C5. Minimum sample sizes to test for change in upland bird community richness.

Effect Size	T-Test Model		Regression Model	
	Conservative	Liberal	Conservative	Liberal
Minimum	24	10	25	12
Maximum	4	4	5	5

Note: Based on average number detected in 2005 among 4 point counts (100 m fixed radius) in upland vegetation of each experimental unit.

Table C6. Minimum sample sizes to test for change in grasshopper density.

Effect Size	T-Test Model		Regression Model	
	Conservative	Liberal	Conservative	Liberal
Minimum	34	14	40	19
Maximum	26	12	34	16

Note: Based on average number per m^2 detected in 2005 among 4 sample stations (18, 0.1 m^2 rings distributed along 150 m of transect) in upland vegetation of each experimental unit.

Table C7. Minimum sample sizes to test for change in Northern wheatgrass abundance.

Effect Size	T-Test Model		Regression Model	
	Conservative	Liberal	Conservative	Liberal
Minimum	26	10	38	18
Maximum	10	4	16	8

Note: Based on average foliar cover estimates in 2005 among 4 Whittaker plots in upland vegetation of each experimental unit.

Table C8. Minimum sample sizes to test for change in Blue grama grass abundance.

Effect Size	T-Test Model		Regression Model	
	Conservative	Liberal	Conservative	Liberal
Minimum	36	16	26	13
Maximum	24	10	21	11

Note: Based on average foliar cover estimates in 2005 among 4 Whittaker plots in upland vegetation of each experimental unit.

Table C9. Minimum sample sizes to test for change in upland plant community diversity.

	T-Test Model		Regression Model	
Effect Size	Conservative	Liberal	Conservative	Liberal
Minimum	28	12	30	14
Maximum	10	4	15	8

Note: Based on average foliar cover estimates in 2005 among 4 Whittaker plots in upland vegetation of each experimental unit.

Table C10. Minimum sample sizes to test for change in upland plant community evenness.

	T-Test Model		Regression Model	
Effect Size	Conservative	Liberal	Conservative	Liberal
Minimum	24	10	30	14
Maximum	22	10	28	14

Note: Based on average foliar cover estimates in 2005 among 4 Whittaker plots in upland vegetation of each experimental unit.

Table C11. Minimum sample sizes to test for change in upland plant community richness.

	T-Test Model		Regression Model	
Effect Size	Conservative	Liberal	Conservative	Liberal
Minimum	24	10	24	12
Maximum	12	4	15	8

Note: Based on average foliar cover estimates in 2005 among 4 Whittaker plots in upland vegetation of each experimental unit.

Table C12. Minimum sample sizes to test for change in among-patch variation (coefficient of variation) in upland vegetation height.

	T-Test Model		Regression Model	
Effect Size	Conservative	Liberal	Conservative	Liberal
Minimum	26	12	28	14
Maximum	18	8	24	12

Note: Based on 10 measurements averaged within in a Whittaker plot in 2005 (the “patch”), but the coefficient of variation is among 4 Whittaker plots in upland vegetation of each experimental unit.

APPENDIX D – SELECTED HETEROGENEITY METRICS AND CALCULATIONS

Note that "species" in dissimilarity, diversity, evenness and dominance indices can be substituted with any two or more exclusive objects such as reflectance value classes from remote sensing.

Metric	Equation	Interpretation
Coefficient of Variation	$CV\% = 100 * (\sigma / \mu)$	> 0, increases proportionately with variability, sensitive to n and scale
Autocorrelation (Moran's I)	$I = (n / \sum w) * (\sum w*[y_i - \mu]*[y_j - \mu])$ / $(\sum(y_i - \mu)^2)$	-1 > I > +1, with -1 indicating fine-scale patchiness, +1 indicating large-scale, and 0 indicating a random distribution, sensitive to scale
Species Richness	$S = \sum$ species	> 0, increases additively with scale
Qualitative Dissimilarity (Jaccard's)	$Dj\% = 100 * (c / [a + b + c])$	100 > Dj > 0, low values indicate high similarity, based on presence/absence
Quantitative Dissimilarity (Sorensen's)	$Ds\% = 100 * (2 \min c' / [a' + b'])$	100 > Ds > 0, low values indicate high similarity, based on relative abundance
Diversity (Shannon-Weiner H')	$H' = -\sum_s (p_i * \ln p_i)$	~4 > H' > 0, most sensitive to species richness and less sensitive to relative abundance, increases with scale
Evenness (Shannon-Weiner E)	$E = H' / (\ln S)$	1 > E > 0, increases as equality of relative abundances do among species
Dominance (Simpson's D)	$D = \sum_s pi^2$	1 > D > 0, most sensitive to relative abundance and less sensitive to species richness, decreases with scale
Effective Richness (Simpson's 1/D)	$1/D = 1 / (\sum_s pi^2)$	S > D > 1, most sensitive to relative abundance and less sensitive to species richness, increases with scale

σ = sample standard deviation
μ = sample mean
n = sample size
w = weighting factor assigned "1" if two similar objects are adjacent and "0" if two dissimilar objects are adjacent
yi = value of a single observation within a sample
S = species richness
a = cumulative number of species unique to one sample, relative to a second
b = cumulative number of species unique to the second sample
c = cumulative number of species co-occurring in two samples
a' = cumulative proportional abundance of species in one sample = 1.0
b' = cumulative proportional abundance of species in a second sample = 1.0
min c' = cumulative minimum proportional abundance of species co-occurring in two samples
pi = proportional abundance of a single species relative to all species in a sample

Appendix E – Supplementary List of Ecological Integrity Measures

The final experimental design and ecological integrity measures selected represented some logistical compromises given the funds and methods available. Several additional ecological integrity measures were suggested in previous planning exercises, by potential collaborators, and by external reviewers of the plan. We have included a list of these measures below and suggestions for how these could be undertaken by other researchers, or by Parks Canada should additional funds or new methods become available. The focused effort required for many of these variables could form the basis of multiple graduate student theses, and GNPC encourages this approach.

E.1 Compositional Richness and Abundance

Microtines include nearly a dozen species of rodents and one shrew. Previous experience in GNPC indicated low catch rates per trap effort (McCanny et al. 1996), but greater success has been achieved elsewhere in northern mixed prairie (Reynolds et al. 1996). Although destructive snap traps tend to be more efficient, there was concern this could affect the response pattern in an annual monitoring program, and may be best left to longer intervals of before-after sampling.

Frogs and Toads potentially include six species, and the Leopard Frog (*Rana pipiens*) is considered a Species at Risk. Although call count surveys for amphibian monitoring could be conducted, it may be difficult to detect treatment differences at the scale of these experimental units, and autocorrelation of water quality where single streams flow through multiple experimental units may confound results.

Butterflies can be abundant, and the Mormon Metalmark (*Apodemia mormo*) is considered a Species at Risk. Current butterfly survey methods are more qualitative presence-absence measures that could allow analysis of species richness or qualitative dissimilarity among experimental units, but dedicated effort to frequent sampling over the summer season is needed to capture the phenology of most species (Kondla 2004).

Dragonflies and damselflies are potentially useful indicators of stream water quality and riparian health, but dedicated effort to frequent sampling over the summer season is needed to capture the full suite of indicator species (Rice 2003), and autocorrelation of water quality where single streams flow through multiple experimental units may confound results.

Spiders, Leafhoppers, Springtails and Mites are all abundant invertebrates in grasslands, and the first two groups will be part of by-catches in pitfall and sweep net samples. The time required to sort and enumerate these samples, and taxonomic uncertainties within all these invertebrate groups, in addition to destructive soil sampling required for springtail and mite collection, complicates inclusion in an annual monitoring program. These may be best left to longer intervals of before-after sampling in a subset of experimental units, on a subset of vegetation types.

E.2 Structure and Function

Water quality includes a number of biological, chemical and physical variables that vary considerably over the season and among reaches of the same stream at any one time. The riparian health index was selected as a rapid indicator of grazing-induced change in and around stream channels (Section 7.3), but it was too challenging to select one or more water quality indicators for annual monitoring and analysis, and the autocorrelation of streams among pastures could confound results. This category of variables is probably best suited to a subset of experimental units, on a subset of stream reaches, sometime after treatments have taken effect, with a clear set of hypotheses to drive selection of specific variables.

Soil organic matter pool size and soil respiration are potentially affected by grazing, and are of tremendous interest in relation to climate change. However, the scale of destructive sampling required to account for spatial variation, and the likelihood that treatments would have no effect on pool size in a 10 year time horizon, makes it difficult to justify inclusion in an annual monitoring program. In-situ respiration measurements are likely to generate short-term results, but are probably better suited to a subset of experimental units, on a subset of vegetation types sometime after treatments have taken effect.

Root biomass and turnover rates are potentially affected by grazing, and help explain observed changes in plant community composition, production and soil respiration. However, tremendous expense is required to install a sufficient density of minirhizotron access tubes in all experimental units and efficiently sample root growth. Such an effort is probably best suited to a subset of experimental units, on a subset of vegetation types sometime after treatments have taken effect.

Seed production and seedbank dynamics are potentially affected by grazing, and help explain observed changes in plant community composition. However, the scale of destructive sampling required and time constraints for capturing the phenology of all species complicates including these variables in an annual monitoring program. These variables may best be sampled among a subset of experimental units, on a subset of vegetation types.

Songbird productivity may respond to grazing treatments in different ways from songbird relative abundance sampled in point counts (Section 7.1). To sample the full range of grazing treatments, at a sufficient intensity, requires the dedicated effort of two or more persons in June and July when vegetation sampling is also a priority. This variable may be very important for evaluating population dynamics of Species at Risk such as Sprague's Pipit (*Anthus spragueii*) and mountain plover (*Charadrius montanus*).

Livestock foraging behaviour and forage quality were both considered key variables to study when fire was under consideration as a subplot factor. Seasonal distributions may change depending on forage quality changes, and livestock may be more selective at low grazing intensities, and these questions are of interest to both agricultural producer groups and Parks Canada. Weight gains and total forage utilization will be measured, but could be complimented by precise measures of utilization in time and space relative to phenological changes in dominant forage species.

APPENDIX F – GRAZING EXPERIMENT DRAFT COMMUNICATIONS STRATEGY

Note: This draft strategy borrows the format and much content from the Fire Management and Bison Grazing Communications Strategies developed by Colin Schmidt, GNPC. This draft may be integrated into a more comprehensive, GNPC-wide Grazing Communications Strategy.

F.1 COMMUNICATION ISSUES

Many neighbours believe grazing exclusion in Grasslands National Park of Canada reflects bad decision making, because it:

- Wastes forage resources for cattle, especially during droughts when forage supplies are limited (utilitarian economic value);
- Risks high intensity wild fires that could damage property and threaten lives, especially following wet spring seasons when fuel loads are highest (safety perception); and
- Is an inappropriate ecological state for maintaining healthy swards of grass (traditional knowledge of grassland ecology).

Many neighbours may perceive the unconventional experimental grazing regimes for restoring ecological integrity as inconsistent with cattle production goals (utilitarian economic values) and long-term sustainability (environmental impact and animal health concerns).

Many visitors may perceive the presence of domestic cattle and infrastructure developments like fencing and well drilling as inconsistent with conservation expectations for National Parks (wilderness and naturalness values).

Many conservation ecologists will argue that grazing exclusion in Grasslands National Park provides a much needed landscape type to support conservation of the full range of biological diversity in the region (big picture), and reintroducing grazing will eliminate this much needed habitat type and baseline system for long-term monitoring (thinking ahead).

Many researchers may perceive the unconventional and innovative experimental design as a risky and poor second-cousin to more conventional and simple designs (reductionist vs. integrative, and experimental vs. descriptive views of science).

The National Park restriction that precludes grazing by domestic livestock was changed in December 2005 to allow domestic grazing for ecological objectives in Grasslands National Park. This change was recent enough that many visitors, neighbours and other stakeholders are unaware.

F.2 PUBLIC ENVIRONMENT

Grasslands National Park is actively applying the principles of adaptive ecosystem management in a way no other National Park has. Internally, there is cautious excitement surrounding the reintroduction of grazing disturbance to the ecosystem.

Externally, the reintroduction of grazing will satisfy many neighbours that their concerns about grazing exclusion are finally being addressed. The inevitable questions arising will be how much land is "opening-up" for grazing and when, followed by the more controversial subject of "who's cattle" will be permitted to graze and how much revenue will be generated. The latter is controversial because the process for sourcing cattle must be unbiased to avoid the perception of favoritism and further entrenchment of negative feelings against the Park by some neighbours. It must also proactively discourage any 'sense of entitlement' over grazing access, whereby park management is challenged to alter or discontinue a prescription because of this 'sense of entitlement'.

Conversely, visitors and other stakeholders may perceive the use of cattle, instead of bison, and cross-fencing, instead of fire, as a step backwards in Park management and inconsistent with their conservation philosophy.

Finally, this experiment, (and reintroduction of grazing), is consistent with the Park Management Plan and neighbours and stakeholders are anxiously waiting for the park to fulfill its commitments.

F.3 KEY AUDIENCES

It is critical that GNP communicates first with those audiences which will have the greatest interest and impact on management and research actions related to grazing. The audiences have been prioritized accordingly.

External Audiences

- GNP Neighbours - including the ranchers, mixed farmers, rural municipality representatives, regional school groups, and residents of towns such as Val Marie, Mankota, Ferland, McCord, Glentworth, Fir Mountain, Wood Mountain and Rockglen.
- GNP Advisory Committee - includes all representatives
- Research Collaborators - including individuals from universities and government research agencies that will actively participate in data collection and reporting throughout the experiment.
- Visitors - primarily the on-site visitors who may venture into the East Block back-country.
- School groups – including students participating in The Prairie Learning Centre, who may become directly involved in monitoring programs.
- Government Departments and Non-government Agencies - including PCAP partners who may wish to conduct training exercises or field tours of the site throughout the experiment.
- Elected or Appointed Government Officials - including MPs, MLA's, Senators and department ministers.
- Mass Media - including South West Booster, Prairie Post, Western Producer, Eagle FM, CKSW/CJSW, CBC.

Internal Audiences

- GNP Staff - all will be posed with questions from family, friends, neighbours and the public regarding the purpose and operation of the experiment. The messages they communicate must be consistent and concise. This includes seasonal technicians and herdspersons employed to directly manage experimental treatments and the monitoring program.

- Parks Canada Senior Managers - including Superintendent, Director General Western and Northern Canada, CEO. The Superintendent in particular must be provided timely and accurate information related to all grazing management and monitoring activities in the Park.

F.4 Communication Outcomes

1. Neighbours understand and support the park's different ecological objectives, as guided by the GNP Management Plan, and the use of cattle grazing as a tool. They will experience the park as a supportive, albeit unique neighbour. This will be measured by a reduction of less-than-favourable correspondence with the Superintendent and other staff regarding land management practices, and attitudinal surveys of neighbours.

2. Visitors understand the importance of grazing disturbance to maintain or restore biological diversity, and the need to develop infrastructure and use cattle to evaluate grazing impacts in a portion of the Park as a cautious precursor to any widespread application throughout the Park. They will be able to distinguish between the 'tool' (cattle vs. bison) and the 'process' (grazing). This will be measured by attitudinal surveys of visitors.

3. Neighbours and visitors respect the experimental goals and infrastructure by keeping fences mended, gates closed, and stakes or other equipment undisturbed. This will be measured by the absence of escaped livestock on site and vandalism of the infrastructure.

4. Land Management stakeholders welcome the experiment as a means to answer questions of direct applicability to grazing management and biodiversity conservation. This will be measured by the number of field tours and training exercises held on the experimental site.

5. Grassland Researchers welcome the experiment as a means to answer questions regarding grazing effects on a full spectrum of ecological responses at a scale and in a way never before attempted. This will be measured by the number of participating researchers in the monitoring program, additional projects utilizing the experimental site, and the number of refereed journal articles arising from the research.

F.5 Key Messages

A pair of statements looking back and highlighting the legacy that enabled creation of the park, and highlighting the park's unique role as a place inviting Canadians to connect with the prairie.

> *Grasslands National Park of Canada recognizes and appreciates the rich ranching tradition and stewardship of this distinctive landscape that has enabled the creation of a grassland park.*
>
> *We all Canadians and others to enjoy this unique park and connect with the beauty of the prairies.*

A pair of statements looking forward and highlighting the good stewardship efforts of our neighbours, and highlighting the park's unique role in the overall landscape.

On many of our neighbour's lands, you will find native plants and animals, including Species-at-Risk, living sustainably with livestock production. In fact, ranching is considered one of the best examples of sustainable development in Canada. (PCAP Action Plan 2003-08).

Grasslands National Park of Canada will complement the surrounding prairie ecosystem by shaping management to provide unique habitats that are not as well represented in the conventionally grazed land around the park.

The previous four statements are derived from the GNP Communications Strategy, and are considered the most important. They should be contained, implied or supported in every communications product. Messages of specific relevance to the grazing experiment include:

The reintroduction of grazing as a natural disturbance in Grasslands National Park of Canada is key to maintaining biological diversity and ecological integrity in the Park.

National Park ecosystem management objectives differ from those of community pastures and the park's ranching and farming neighbours. However, unlike for many other national parks, neighbouring land uses around Grasslands National Park of Canada have in the past tended to contribute rather than detract from ecological integrity, a trend that is expected to continue.

Grasslands National Park of Canada does not currently have sufficient understanding of the impacts of grazing intensity to warrant a landscape-scale prescription throughout the Park. Grasslands National Park of Canada will not implement any landscape-scale grazing prescription until we have that understanding.

Grasslands National Park of Canada provides long-term ungrazed conditions on a landscape-scale not found anywhere else in North America, which is ideal for conducting research to address grazing impacts on ecological integrity, rangeland and riparian health, and wildlife Species-at-Risk.

Grasslands National Park of Canada research will demonstrate biodiversity benefits of conventional ranching by our neighbours, and unconventionally low and high stocking rates proposed for the Park.

Grasslands National Park of Canada has solicited external scientific review of the experiment to ensure the objectives are achievable, and the design is logistically and statistically sound.

Grasslands National Park of Canada has developed a fair and unbiased plan for sourcing cattle and managing cattle grazing within Park boundaries that respects the production goals of cattle owners and follows the animal care guidelines of Agriculture and Agri-Food Canada.

Grasslands National Park of Canada invites neighbours to participate in research by providing land access and expert knowledge to help monitor the biodiversity benefits of conventional ranching.

Grasslands National Park of Canada invites research collaborators to participate and to leverage additional funding in support of the operating and monitoring program.

Grasslands National Park of Canada invites visitors to learn more about the 'grazing experiment', and 'adaptive management', and understand its connection to the ecological integrity of the park.

Grasslands National Park of Canada also invites 'Prairie Conservation Action Plan Committee' members, and 'The Prairie Learning Centre' to organize or attend field tours, training and monitoring activities to evaluate grazing impacts on rangeland health, riparian health and Species-at-Risk.

F.6 STRATEGIC CONSIDERATIONS

Communications regarding the grazing experiment must be proactive. The development of infrastructure and presence of research and monitoring staff in the area will capture the attention of neighbours and visitors. Strategic preparation of communications need to take place prior to baseline monitoring and development activities scheduled for 2006, and again prior to the release of cattle scheduled for 2008.

Audiences most affected by or involved in the experiment should be the first to receive information, so as to avoid a perception of "being the last to know". In our case, the park neighbours and research collaborators are those that will be most affected. This is a perfect opportunity to build linkages and support within our ranching community, and demonstrate appreciation for 'their way of life'.

Communications about the grazing experiment should be considered in light of it's relationship to other issues and projects, such as ecosystem management (bison grazing, fire) and visitor opportunities/access (area restrictions during particular seasons).

F.7 COMMUNICATIONS ACTIVITIES AND TOOLS (PRELIMINARY)

Activity	Tools	Audience(s)	Responsibility
Researcher Orientation (May of each year)	Powerpoint Presentation Training Manual Field Tour	Research Collaborators GNPC Staff School Groups	GNPC Res Con WNSC Ecologists
Advisory Committee Meeting (Dec of each year)	Powerpoint Presentation	GNPC Advis. Comm. GNPC Staff	GNPC Res Con
Experimental Site Security (after May 2006)*	Pamphlets/Leaflet Fence-post Signs	Neighbours Visitors	GNPC Interpreters GNPC Res Con
PCAP Meetings & PCES Conferences (after May 2006)	Powerpoint Presentation Large-Format Poster	PCAP Partners	GNPC Res Con WNSC Ecologists
State of Park Reports (Dec of each year)	Technical Reports	PCA Senior Managers GNPC Staff GNPC Advis. Comm.	GNPC Res Con
Phase 1 Open House	Pamphlet/Leaflet Large-Format Poster Feature Article for Media Technical Reports	All	GNPC Interpreters GNPC Res Con
Phase 2 Open House	Pamphlet/Leaflet Large-Format Poster Feature Article for Media Technical Reports	All	GNPC Interpreters GNPC Res Con

APPENDIX G – GRAZING EXPERIMENT DRAFT DATA MANAGEMENT STRATEGY

The Parks Canada *Management Bulletin 2.4.9, Ecological Data Management* (2001) provides justification and guidance to strengthen the systematic collection, access, storage, retrieval and application of data, information and knowledge. The following are relevant excerpts from the bulletin, and a number of project-specific components have been added.

Management of ecological data is defined as a set of specific procedures that are necessary to ensure that data are useable for analysis and interpretation. **Geospatial** data includes remotely sensed imagery, geographic information system (GIS) data layers, data derived from broad-scale sampling efforts, as well as fine-scale sampling of spatially explicit patterns and processes. **Document** data include everything from email correspondence, press releases and feature articles, to policies, management plans, environmental assessments, published and unpublished reports, and scientific articles. **Datasets** are tabular spreadsheets, databases or textfiles with numeric or categorical variables associated with sample observations. Images and presentations can also be stored.

The Park-level *Data Management Plan* is the key document that guides the use, storage and protection of data. Each Park will adhere to the following guiding principles:

- All Parks Canada personnel, including contractors, researchers and staff, will use the core set of metadata elements.
- Metadata will be entered by individuals with knowledge of the ecological databases and will make it available upon request.
- A copy of updated ecological databases will be stored in a secondary location away from each individual's working environment (preferably in a non-attached building).
- An ecological data library will be developed by each field unit in cooperation with the National Parks Documentation Centre (NPDC) and/or the Western & Northern Service Centre (WNSC) as a way of sharing and archiving core databases.

The *Core Metadata Set* represents elements that apply equally to all of Parks Canada's information resources regardless of discipline or resource type. This set contains Descriptive and Administrative metadata that is valuable for the following purposes:

- Describing information resources created in the undertaking of Parks Canada's activities.
- Collaboration and sharing of information throughout Parks Canada.
- Improving search and retrieval functions related to information resources.
- Managing external and internal linkages between information resources.
- Controlling short and long-term access to the resources.
- Maintaining information resources in the context of their creation and use.

The selection of a core metadata element set acts on the assumption that the information needed to properly manage, access and maintain information resources will not differ significantly if that resource is an image, a document or a data set. It is acknowledged that certain resources may require more information than can be applied using only the core elements. Additional metadata can be added to define methods for each type of variable in a dataset, or changes to methods over time.

Table G.1. Core MetaData Elements and Definitions.

Element	**Definition or *Suggested Entry***
Title	The name of the resource, should be descriptive but brief.
Description	Sentence outlining the intellectual content of the resource.
Creator	Individual(s) names credited as responsible for the intellectual content. Includes the creator, plus names and dates of modifiers.
Publisher	*Parks Canada Agency*
Subject	Any number of keywords, phrases or a sentence that describes the topic and content of the resource.
Site Name	*East Block Grazing Experiment, Grasslands National Park of Canada*
Site Type	*National Park of Canada*
Content Type	Enter *Geospatial*, *Document* or *Dataset*
Management Unit	Enter *Saskatchewan South Field Unit*, or *Western & Northern Service Center*
Activity	*Research and Collection for Adaptive Ecosystem Management*
Record Series	A grouping name for resources sharing the same record keeping requirements. Suggest "*EBGE*" for East Block Grazing Experiment.
Language	*English*
Security Classification	Identify the highest security classification or designation of the resource.
Date Created	Date the original digital information resource was created (not the date data was collected in the field, if delay due to transcription).
Date Modified	Date of the most recent addition, deletion or editing done to the resource.
File Format	Format of the digital information resource, i.e. *MS Excel (2000) *.xls*.
Media Format	Format of the physical carrier of the information resource, i.e. *spreadsheet*.
Record Identifier	A unique, system-assigned number or character string applied to each information resource. For example, vegetation data may be identified as "*EBGE_VEG*", regardless of the digital file extension, since a *.xls file can be converted to *.txt, *.db1, or another format altogether.

Geospatial information requires additional metadata, i.e. georeferencing. For more information read:

Parks Canada Agency. 2001. Parks Canada Agency Metadata Standards. Draft Version 1.10, 2001-05-27. The Data Administration Group, and The Geomatics Metadata Working Group. Parks Canada Agency, Information Office. Hull QB.