Background

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Livestock grazing is a dominant pressure on the majority of the range and prairie lands in Montana and is capable of modifying wildlife habitat in either positive or negative directions. It is vitally important for rangeland health to understand how arthropod food webs are influenced by these dominant pressures. It is becoming clear that arthropods alone can successfully drive ecosystems and that they are vital to the survival of many other species including game and non-game birds. Therefore it is vital to know, from the bottom up, how various grazing systems alter plant community structure which in turn alters the food resources and thermoregulations sites of arthropods. It is also of equal importance to know, from the top down, how grazing influences different predatory guilds of arthropods which, through hunting strategy alone, can produce a trophic cascade thus altering the arthropod community. Arthropods affect the detritus which in turn influences soil nutrients, which affects the vegetation, which impacts wildlife and their habitats. Our project is based on gathering data on a structural foundation of how, within grazing systems, arthropods influence wildlife populations and habitat.

We are conducting two intertwined projects which investigate how livestock grazing influences arthropods important to both sharp-tailed grouse and greater sage-grouse survival in Montana (MT). Project 1 investigates the MT Fish, Wildlife, and Parks (FWP) recommended three-pasture rest-rotation grazing program as implemented on a private ranch in eastern MT with an FWP conservation easement on it. Project 2 investigates the Sage-Grouse Initiative (SGI) rest-rotation grazing program as implemented on multiple private ranches in central MT.

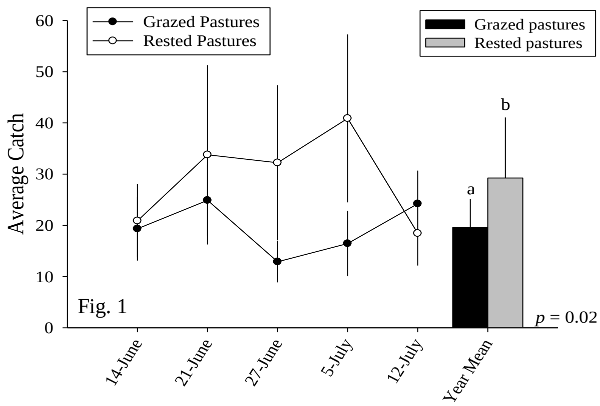
Project 1: Sharp-tailed grouse. The sharp-tailed grouse (*Tympanuchus phasianellus*) is one of three species of North American prairie grouse. The populations of many subspecies of sharp-tailed grouse have declined in recent years or become extirpated in much of their historic range. These declines are due to habitat loss resulting from the conversion of native habitats to cropland, excessive livestock grazing, and conifer encroachment (NRCS 2007). Due to these population declines, the sharp-tailed grouse is protected in portions of its present range.

The Plains sharp-tailed grouse (*T. p. jamesi*) occurs primarily on private lands of the Great Plains east of Rockies, from central Alberta and southwestern Manitoba south to northern Colorado and Nebraska. Grazing management, such as season long grazing, which does not include rest/deferred periods of vegetation regrowth has been suggested as one of the causes for reductions in sharp-tailed grouse numbers (Kessler and Bosch 1982, Johnsgard 1983, Kirby and Grosz 1995). In light of this, a search of the scientific literature revealed that the specific effects that livestock grazing systems, as a whole, have on the Plains sharp-tailed grouse has yet to be evaluated. Montana Fish, Wildlife, and Parks manages sharp-tailed grouse through their Upland Gamebird Enhancement Program which includes setting up livestock grazing systems; therefore a better understanding of livestock grazing is needed to address this gap in knowledge as it relates to the food insects of sharp-tailed grouse. Additionally, this research complements/supplements research occurring in central MT which is also studying the influence of grazing on the sagebrush ecosystem (sage-grouse, insects, songbirds) and grouse management.

Project 2: Sage-grouse. Greater sage-grouse (*Centrocercus urophasianus)* populations have been in decline in the western U.S. since the 1950s (Connelly and Bruan 1997). Many factors have been highlighted as explanations of sage-grouse declines with chick and brood survival being directly linked to annual recruitment; however, the specifics of these vital rates are a poorly understood component of sage-grouse ecology (Crawford et al. 2004). Much research has been conducted on the selection criteria used by female sage-grouse when choosing a brood site (Drut et al. 1994, Sveum et al. 1998) and the results have provided a foundation for land management considerations aimed at improving sage-grouse habitat and ultimately recruitment of chicks (Connelly et al. 2000). However, the criteria that female sage-grouse use for habitat selection may not provide insight into the relationship between the site resources and chick and brood survival (Morrison 2001). The mechanisms which influence daily chick and brood survival need to be better understood and these data should be used to establish a prerequisite program which implements habitat management strategies that affect annual recruitment and, ultimately, sage-grouse populations (Gregg and Crawford 2009).

Projects 1 and 2: Food Arthropods. Grouse use a variety habitats including shrub steppe, meadow steppe, sage-brush steppe, mountain shrub, brushy grassland, and riparian/deciduous habitats (NRCS 2007). There have been no detailed studies of the food habits of sharp-tailed grouse chicks; however, evidence indicates that insects constitute a major portion of their diets for the first five weeks after hatching, which is similar to what is known about sage-grouse (Parker 1970, Johnsgard 1983, NRCS 2007). Primary insects utilized as food items (hereafter called 'food arthropods') fall into the orders of Coleoptera, Hymenoptera, Orthoptera, and Lepidoptera (Marshall and Jensen 1937, Hart et al. 1950, Jones 1966, NRCS 2007).

Our team conducted hypothesis driven research where we evaluated the NRCS SGI rest-rotation grazing program as implemented in central Montana. Our two year results suggest that food arthropods respond positively to pasture rest during the early brooding period (Goosey 2014; Figs. 1 and 2). However, the SGI grazing system differs substantially from the three pasture rest-rotation system recommended by MT FWP. Therefore, an information gap exists on how differing rest-rotation systems compare with respects to food arthropod abundance and diversity when compared among rest, deferred, and continuous grazing systems. These two projects allow MT FWP the opportunity to evaluate rest rotation, deferred, and season long grazing in eastern and central MT where the effects of management are often local and unique due to variability in precipitation, soil structure, and general climatic conditions.



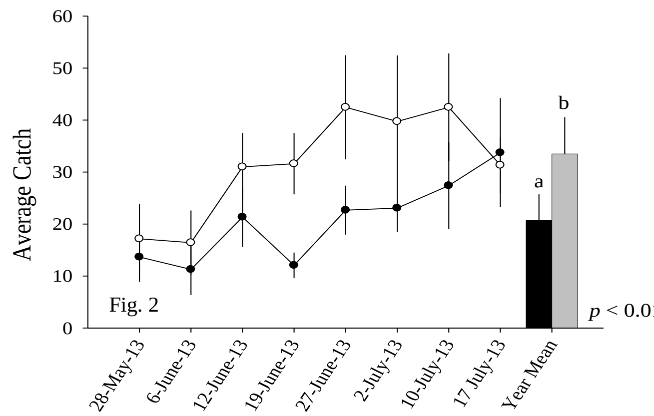


Figure 1 (2012; left column) and Figure 2 (2013; right column) of averaged catches across all in pastures which were either rested/deferred or grazed during the early brooding period of late May to early July in Golden Valley and Musselshell counties, MT. Lines represent average weekly catches, bars represent the averaged catch for the sampling year, and error bars represent the SEM.

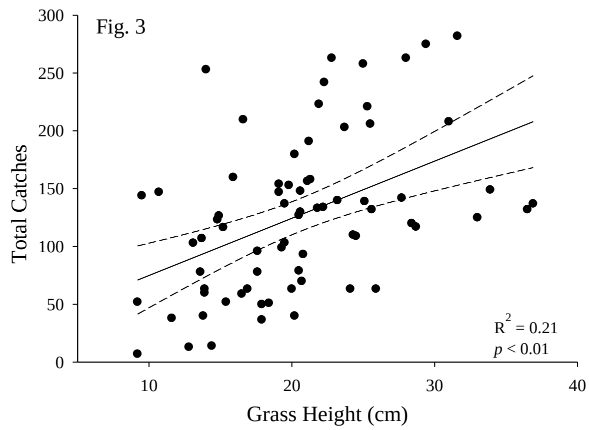
We have also recorded that arthropod abundance is positively associated with the height of live grass (Fig. 3). Rested pastures typically have taller live grass (Berkeley et al. 2013). Our results also suggest that the total abundance of food arthropods is negatively associated with bare ground (Fig. 4). Rest-rotation grazing, with time, can replace patches of bare ground with vegetative structure (Heitschmidt and Stuth 2003). These structural changes should be beneficial to food arthropod abundance and diversity. However, rest-rotation grazing has yet to be compared with deferred and season long grazing as it relates to arthropod conservation in the prairie and sage-brush steppe regions inhabited by sharp-tailed grouse and sage-grouse.

Projects 1 and 2: Pollinators. Pollination is one of the best known relationships occurring between two species and is performed by an extraordinary and diverse suite of insects, birds, and mammals representing over 200,000 different species (Harmon et al. 2011). The loss of pollinators may not be easily reversible because the ecological role they play in their communities is critical to plant diversity (Roubik 1993). The economic burden of reduced yields, crop production, and rangeland productivity from pollinator declines alone has been estimated at $5.7 billion a year (Southwick & Southwick 1992).

Bees, moths and butterflies, true flies, wasps, beetles, and other arthropods are critically important for ensuring effective pollination of both cultivated and wild plants. On rangelands, where insects are the primary group of pollinators, honey bees, native bees, moths, and butterflies are the primary pollinators with beetles, flies, wasps and ants included as less important and secondary (Allen-Wardell 1998).

As we begin to classify the components (vegetation composition and structure) of high quality pollinator habitat, it is increasingly apparent that an abundant and diverse array of flowering plants is the foundation (Allen-Wardell 1998). These flowering plants may include a wide variety of annual and perennial forbs and legumes, shrubs, vines, and trees that initiate flowering early in the spring and continue into the fall (Gilgert and Vaughan 2011). Diverse and abundant plants that produce nectar and pollen combined with a variety of thermoregulation and reproductive sites are the hallmarks of rich heterogeneous pollinator habitat. Rest-rotation grazing is reported to produce such vegetative changes into rangeland conditions (Heitschmidt and Taylor 2003).

Grouse and pollinators are inherently linked. Grouse are reported to rely on a variety of flowering forbs and berries of which a few are listed in Table 1. Interestingly, all cross pollination of these species is carried out through the services of pollinators. Without pollinators, these sources of grouse staples will not bear fruit.



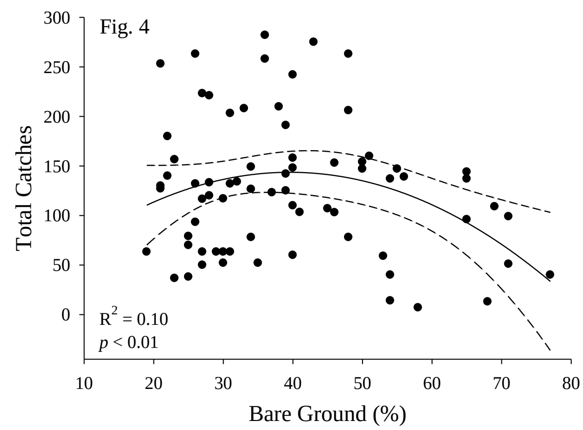


Figure 3 (left column) and Figure 4 (right column) of linear and polynomial relationships (solid lines), with 95% confidence intervals (dashed lines), between the total pitfall trap catches collected across all dates and live grass height and percent bare ground from sampling locations located in rested/deferred and livestock grazed pastures during 2012-2013 in Golden Valley and Musselshell counties, MT. Total abundance (catches) increases with taller grass height, which is typically found in rested pastures, and decreases with increasing bare ground. Rest rotation grazing, with time, decreases the amount of bare ground in pastures.

Our results thus far suggest that the abundance of pollinators is greatest in rested pastures during years of average and above average precipitation. In 2012 when precipitation was only 38% of normal, catches did not differ (Fig. 5 and 7); however, in 2013 when precipitation was 105 % of normal, pollinator catches were greatest in rested pastures (Fig. 6 and 8). In light of this we suggest that in years of average or above precipitation, flowering forb and legume plant diversity and abundance is greatest in rested pastures which acts as an attractant to pollinating species.

Table 1. Some of the many pollinator friendly forbs and berries consumed by sharp-tailed grouse.

Buttercup (*Ranunculus glaberrimus*)	Goldenrod (*Solidago spp.*)	Sweet Clover (*Melilotus officinalis*)
Hawkweed (*Hieracium canadense*)	Rose (*Rosa spp.*)	Smartweed (*Polygonum spp.*)
Common Yarrow (*Achillea millefolium*)	Salsify (*Tragopogon spp.*)	Sunflower (*Helianthus spp.*)
Dandelion (*Taraxacum	Hawthorn (*Crataegus	Phlox (*Phlox spp.*)

officinale)	*spp.*)	
Chokecherry (*Prunus virginiana*)	Buffalo Berry (*Shepherdia spp.*)	Snowberry (*Symphoricarpos spp.*)

Projects 1 and 2: Dung Beetles. Dung Beetles play a remarkable role in rangeland and wildlife habitat health by decomposing the dung of large herbivores. It is estimated that they provide $380 million annually to range and pasture lands through improved soil health leading to improved vegetative structure and diversity (Lousy and Vaughn 2006). Dung beetle adults consume dung but also bury substantial amounts in the soil for their larvae. This process has many documented benefits to plant and animal communities through improved soil nutrient cycling and structure (Brown et al. 2010); decreased (95%) pest fly populations (Bornemissza 1970); greater earthworm populations; water retention; available phosphate, sulfur, carbon, and organic matter for plant growth (Doube 2008); decreased pest nematode populations which slow and disrupt vegetative growth; and decreased greenhouse gas emissions for habitat stabilization (Penttilä 2013). In fact, unprocessed dung pats prove to reduce rangeland vegetation structure/biomass and subsequent wildlife habitat by covering and smothering vegetative growth for 2 to 4 years (Anderson and Loomis 1978). Given the dependence of pollinators, food arthropods, grouse, and other prairie obligates on high quality vegetative habitat, dung beetles provide a beneficial service to most wildlife in areas where large herbivores (i.e., cattle and wild ungulates) are present; however little is known about how livestock grazing programs influence dung beetle communities.

Fig. 5

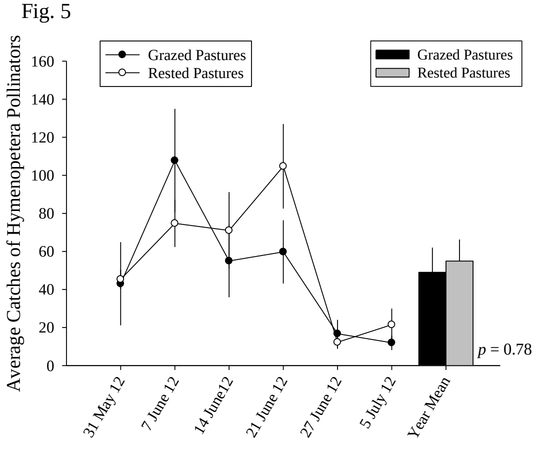


Fig. 6

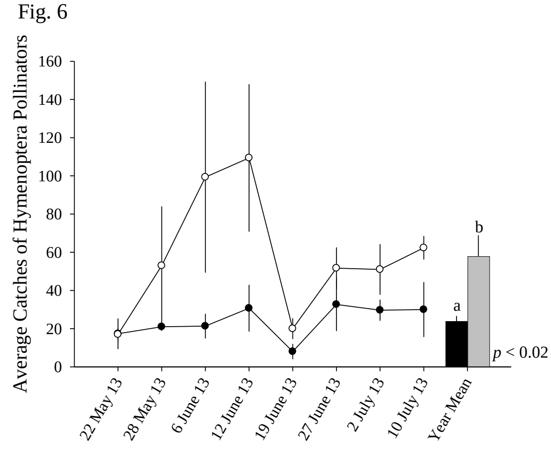


Figure 5 (2012; left column) and Figure 6 (2013; right column) of averaged Hymenopteran pollinator abundance during 2012 and 2013 from rested and livestock grazed pastures during the early brooding period of late May to early July in Golden Valley and Musselshell counties, MT. Lines represent average weekly catches, bars represent the averaged catch for the sampling year, and error bars represent the SEM. In non-drought years (2013) pollinators respond positively to increases in flowering plant diversity and abundance associated with pastures rested from grazing.

Fig. 7

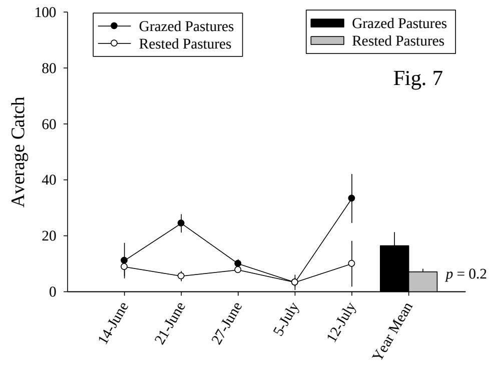


Fig. 8

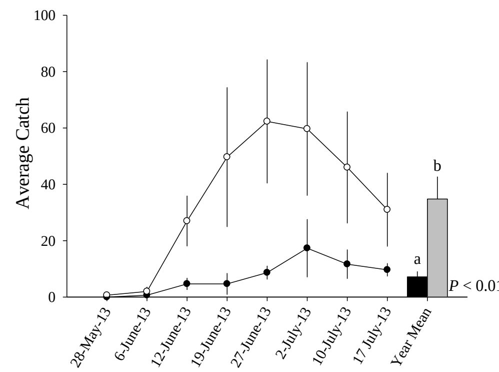


Figure 7 (2012; left column) and Figure 8 (2013; right column) of averaged Lepidopteran pollinator abundance during 2012 and 2013 from rested and livestock grazed pastures during the early brooding period of late May to early July in Golden Valley and Musselshell counties, MT. Lines represent average weekly catches, bars represent the averaged catch for the sampling year, and error bars represent the SEM. In non-drought years (2013) pollinators respond positively to increases in flowering plant diversity and abundance associated with pastures rested from grazing.

Rest rotation grazing could offer improved dung beetle habitat through variable grazing patterns which concentrate dung pats within pastures however spread that dung over the entire pasture, making them more readily accessible by the beetles. As with other wildlife species, the structure of dung beetle communities is greatly influenced by vegetation cover, soil characteristics, and climatic conditions (Davis 1996). Borer et al. (2012) suggests that increased plant biomass and diversity will also increase arthropod biomass and diversity. Rest-rotation grazing can increase plant biomass and diversity by returning nutrients to the soil in liable forms (e.g. dung and urine) leading to positive effects on soil biota (Bardgett and Wardell 2003). Consequently, high quality detritus therefore produces the necessary environment to increase plant diversity and subsequent food arthropod diversity. High quality detritus is provided by dung beetles which contribute yearly services to rangelands. This proposal addresses a novel study on how rest-rotation, deferment, and season long grazing, in both prairie and sage-brush steppe habitats, influence this key player of vegetative structure and diversity and grouse health.

Projects 1 and 2: Livestock Grazing. In 2014, approximately 2.5 million cattle and 225,000 sheep were on-farm in Montana with 68.5 % of the state's surface area classified as 'Pasture and Rangeland' (NASS 2014). Livestock grazing can alter plant communities and habitats including sites in Montana (O'Neill et al. 2003, Courtois et al. 2004). This either directly or indirectly influences arthropod communities in a negative or positive way, depending upon the grazing strategy (Price 1997)

For example, Kruess and Tscharntke (2002) reported a 50% reduction in insect diversity and abundance which they attributed to the intensity and timing of grazing. They concluded that increased insect diversity and abundance are associated with taller vegetation which is typically located in non-grazed or strategically grazed areas. Price (1997) suggests that moderate levels of disturbance produce the greatest arthropod abundance and diversity because disturbances open up habitats for colonists by preventing resource monopolization by competitively dominant species. Goosey et al. (2013) suggested that livestock grazing, as a weed management tool in sustainable crop rotations, increased non-crop flowering plant diversity resulting in higher visitations by Hymenoptera to grazed plots. Sjödin (2007), who investigated changes in insect pollinator behavior as a response to grazing intensity and timing, reported that pollinators appeared to choose habitats based on flower density, suggesting that the number of flowers in a given area may reflect the amount of reward for visitors. Newbold et al. (2014) reports from a large-scaled grazing project in north-central Colorado that increasing intensity of livestock grazing can produce both positive and negative effects on arthropod populations. Specifically, Tenebrionidae beetles, which are known food arthropods of obligate prairie and sagebrush steppe bird species, exhibited population increases and decreases as a response to various grazing strategies based on the preferred habitat structure of each species.

From this, it is logical to suggest that a rest-rotation grazing program which leaves sufficient vegetative structure and increases plant biomass and diversity could be viewed as a moderately disturbing event with direct benefits to both food arthropods and pollinators. However, this has yet to be studied in relation to grouse management. This proposal addresses that need.

Project Linkages. Community assembly theory predicts that a series of ecological filters selectively favors or excludes species from the regional pool in a local community (Keddy 1992, Funk et al. 2008, Myers and Harms 2009). Given the extent that livestock occupy grasslands inhabited by grouse, grazing then becomes a dominant filter capable of altering the arthropod community.

Sharp-tailed and sage grouse chicks are dependent on insects as a sole source of food for the first five weeks of life (Johnsgard 1983, NRCS 2007, Gregg et al. 2007). We know that diverse flowering forb communities are crucial habitat components for pollinator survival (Reis et al. 2002) as well as grouse and songbirds (Klebenow and Gray 1968); and that managing rangelands for a diverse flowering plant community will greatly assist in increasing the abundance of pollinators (Reis et al. 2002) which also serve as a staple of grouse chick diets. We know that dung beetles are a beneficial component of grouse habitats through the addition of high quality detritus and serving as food (Lousy and Vaughn 2006). What has not been addressed by science is if rest-rotation, deferred, and season-long grazing will elicit the same or different ecological outcomes on these fundamental components of grouse habitat. This proposal addresses that need from a habitat management perspective.

Just as grouse are dependent, at times, on flowering forbs and berries, many key arthropods are also dependent on the same vegetation. Grazing then becomes the pressure which can alter habitats in either a positive or negative direction. That direction depends on the grazing strategy and using it as a tool to beneficially modify wildlife habitats while keeping ranching operations profitable and native landscapes intact.

The specific goals of this project are listed below.

Project 1: Sharp-tailed Grouse

Quantify the influence of the MT FWP three pasture rest-rotation grazing, deferred grazing, and season-long grazing on:

a) the relative abundance and diversity of ground-dwelling arthropods serving as food items for sharp-tailed grouse and other grassland associated avifauna,
b) the relative abundance and diversity of above ground and plant-dwelling arthropods serving as food items for sharp-tailed grouse and other grassland associated avifauna,
c) the relative abundance and diversity of wild pollinators,
d) the relative abundance and diversity of dung beetles, and
e) the vegetative community biomass and diversity and percent bare ground (so that we have vegetative data specific to our sampling locations which will complement other veg data).

Project 2: Sage-grouse

- Past sampling focused on the impact of grazing on food insects of sage-grouse. We sampled insect diversity and abundance and community structure randomly in grazed and rested pastures.
- Future sampling will focus more specifically on insect food availability at nest/early-brood rearing pastures of sage-grouse and songbird survey sampling sites.

Quantify the influence of the NRCS SGI rest-rotation grazing and non-SGI season long grazing on:

a) the relative abundance and diversity of ground-dwelling food arthropods at sage-grouse nesting and songbird survey locations,
b) the relative abundance and diversity of above ground and plant-dwelling arthropods at sage-grouse nesting and songbird survey locations,
c) the relative abundance and diversity of wild pollinators,
d) the relative abundance and diversity of dung beetles, and
e) the vegetative community biomass and diversity and percent bare ground (so that we have vegetative data specific to our sampling locations which will complement other veg data).

Projects 1 and 2: Overall Goals

The overall goals of both projects are to:

1. Transfer knowledge to wildlife and land management agencies at the federal and state levels through local and regional meetings and to private individuals and landowners at the stakeholder level through agricultural associations.
2. Disseminate the results to the scientific community by publishing results in topic specific peer-reviewed journals.