GRASSLAND BIRD RESPONSE TO PATCH BURN-GRAZING IN A SAND SAGEBRUSH-MESQUITE RANGELAND

by

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ABSTRACT

Wildlife in the Great Plains evolved with fire and grazing interacting spatially and temporally to create a shifting mosaic landscape comprised of severely disturbed habitats, undisturbed habitats, and patches that vary in time since the most recent disturbance. When given the choice, bison grazed on the most recently burned areas, much as they were suspected of doing prior to European settlement of the Great Plains. Currently, rangeland managers try to achieve uniform cattle distribution or uniform coverage by prescribed burning in an effort to utilize their resources as efficiently as possible. Additionally, these two types of disturbance are nearly always used apart from each other. This traditional rangeland management promotes homogeneity of vegetative communities and may have a critical impact on biodiversity and wildlife habitat. With the increased interest in using prescribed fire to manage Rolling Plains rangelands for wildlife and livestock we propose the effects of patch burning and grazing in sand sagebrush (*Artemisia filifolia*)-honey mesquite (*Prosopis glandulosa*) grassland will positively impact the diversity and abundance of grassland birds, particularly northern bobwhites (*Colinus virginianus*).

This study was conducted within the Matador Wildlife Management Area (WMA), located in Cottle County, Texas approximately 10 km north of the town of Paducah, Texas in the Rolling Plains ecoregion from 2009-2011. My study site consisted of 619-ha of contiguous sand sagebrush-mesquite rangeland in the Entrance and Headquarters pastures of the Matador Wildlife Management Area (34.117721, -100.356536). The Entrance pasture was subjected to patch-burning with grazing as well as rotational grazing. The Headquarters pasture was subjected to patch-burning only. Vegetation and grassland birds were monitored throughout the entire study site, with northern bobwhites monitored for survival, home range, and nest success.

Due to severe drought effects during the duration of the study, grass and forb cover was reduced from 2009 to 2011. Grassland bird species richness and abundance declined from 2009 to 2011. Northern bobwhite survival from 2009-2011 was 19%, 5%, and 36%, for respective years. Northern bobwhites did not use treatments proportionately more than what was available during any year. Mean home range size did not differ among years ($P=0.0298$). Pooled nest survival was calculated using ProgramMARK for the 24 day incubation period and was observed at 29%. The model with the covariates of percent residual cover at nest site, percent shrub cover at nest site, and proximity to edge resulted in the strongest model ($AIC_c=0.0000$). Patch burning-grazing did not positively benefit grassland birds or northern bobwhites. Consideration for drought conditions should be applied when trying to implement a patch burning-grazing system.

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CHAPTER I

PATCH BURNING AND GRAZING EFFECTS ON VEGETATION IN A SAND SAGEBRUSH-HONEY MESQUITE RANGELAND

INTRODUCTION

The Rolling Plains ecoregion of Texas supports diverse vegetative communities throughout the landscape. Current land management practices are used in a manner that is counter to the ecological integrity of these communities. This region contains vast expanses of rangeland that harbors many ranches where cattle production is a chief economic land use. Prescribed fire is becoming increasingly popular as a management tool in this region. Many concerns have been raised about the effects of current practices on the vegetative communities. Most current practices that use burning and grazing are designed to promote vegetative homogeneity in order to maintain uniform and moderate grazing throughout a large landscape (Holechek et al. 1998). Some studies suggest this homogenous environment is not beneficial for animals that have evolved historically in heterogeneous habitat conditions.

Historically, the Great Plains evolved with fire and grazing to create a shifting mosaic of patches within the landscape, varying in time and space since their last disturbance (Fuhlendorf and Engle 2004). Prior to European settlement, native anthropegenic actions (Guyette et al. 2002) and lightning strikes were the primary natural source of ignition of vegetation (Komarek 1966). These lightning strikes, under the right conditions, would create fires that generate varying patches of disturbance that would concentrate grazers. These recently disturbed patches would contain new plant production that would create focal grazing areas for bison (*Bos bison*). When given the freedom to choose, bison prefer to graze on the most recently burned areas, which would presumably be the case prior to European settlement of the Great Plains (Coppedge and Shaw 1998). Through time another area would experience a fire event and ultimately shift the focus of grazing to the newly disturbed area, as bison would prefer the increased palatability of the new plant production and regrowth in the freshly burned area. This process allows the previously disturbed areas receiving heavy grazing pressure from focal grazing to rest and receive very little pressure allowing vegetation to mature and litter to accumulate. This interaction of fire coupled with grazing would continuously occur throughout the landscape, creating varying levels of disturbance (Weir et al. 2007). Prior to European settlement the main grazer in the Great Plains was the bison. Throughout time bison have all but been removed and replaced with domestic cattle. The introduction of cattle has brought about many changes to this landscape. The early culture of fire suppression in this region has allowed livestock to disperse seeds facilitating the encroachment of many woody species, namely honey mesquite (*Prosopis glandulosa*) (Wright 1974, Archer et al. 1988). As prairies are left unburned the grass cover tends to decline and you see an increase in woody encroachment (Gibson and Hulbert 1987). Today, with the threat of woody encroachment coupled with rancher's looking for ways to increase production of cattle and maximize grazing efficiency, the practice of prescribed burning has become a popular management tool.

Traditional rangeland management involves large scale burns designed to create homogeneous vegetative communities that maximize the efficiency in which cattle use the landscape (Fuhlendorf and Engle 2001). Homogeneous habitat within a landscape, however, limits biodiversity. For instance, grassland bird diversity has been shown to be greater in areas with multiple levels of disturbance that creates a heterogeneous habitat (Fuhlendorf et al. 2006). With an increased interest in the management of wildlife, many land use practices have shifted from traditional livestock production and focused more on game species such as white-tailed deer (*Odocoileus virginianus*) and northern bobwhite (*Colinus virginianus*) (Ruthven et al. 2002, Ruthven and Synatzske 2002). Consequently managers are shifting from traditional large-scale burns to a new approach called patch burning and grazing. While still a fairly new concept, this more targeted application of prescribed fire could prove to be beneficial as a management tool for both livestock and wildlife, because it promotes increased biodiversity at the vegetative level without compromising the vegetative communities.

Patch burning has been described as the purposeful grazing of a section of a landscape or management unit that has been prescribed burned, and then burning another section to refocus the grazing pressure to the newly disturbed unit, creating a shifting mosaic on the landscape (Weir et al. 2007). This process is supposed to emulate what would have happened naturally across the landscape, as the American bison would have sought the freshly disturbed areas that have experienced a fire event to intake the more palatable forage. In the Great Plains it is suggested that a new patch be burned every 6-12 months to shift the grazing focus (Weir et al. 2007). This approach allows for the previously burned unit to receive less grazing pressure and transition through different levels of standing biomass and litter accumulation to where it can be burned again in 2.5 to 3 years.

With the increased incentive to manage for wildlife as a means of income, as well as concerns about declining grassland species, this burning – grazing system has garnered more attention. One of the many benefits of this grazing system is that it has been promoted as a system that increases heterogeneity of the vegetative community (Fuhlendorf and Engle 2001, Fuhlendorf et al. 2006). Most investigations of the efforts of this new system have been conducted in tallgrass prairie ecosystems (Fuhlendorf et. al 2006, Vermeire et al.2004, Fuhlendorf and Engle 2004). Patch burning and grazing in these systems yields an initial decrease in litter cover and an increase in bare ground, while grass and forb cover increases to levels comparable with traditional grazing methods within the first short growing season (Fuhlendorf et. al 2006). With the improved heterogeneity in the vegetation, and the varying levels of succession that this system provides, many habitat types are available resulting in an increase in the biodiversity of the landscape (Fuhlendorf et al. 2006). No comparable studies have examined the effects of a patch-burn grazing system in sand sagebrush – honey mesquite rangelands located in the Rolling Plains ecoregion of Texas. The objective my study was to evaluate the effects of a patch-burn grazing system on the herbaceous and woody vegetation composition of sand sagebrush – honey mesquite rangelands as compared to traditional methods of homogeneous burning and rotational grazing.

STUDY AREA

Matador Wildlife Management Area

This study was conducted within the Matador Wildlife Management Area (WMA), located in Cottle County, Texas approximately 10 km North of the town of Paducah, Texas. The Matador WMA is 11,410-ha located in the Rolling Plains ecoregion of Texas for the purposes of wildlife research and management as well as public use. Matador WMA was purchased by the state of Texas in 1959 using Pittsman-Robertson funds and serves as a research and demonstration area that is managed by Texas Parks and Wildlife. Climate is described as subtropical with dry winters and hot, humid summers with an average annual rainfall of 56.2 cm (Richardson et. al 1974). Rainfall is quite variable monthly to yearly and occurs most frequently as a result of thunderstorms (Richardson et. al 1974). Months of greatest average rainfall are May (9 cm) and June (8.8 cm; Richardson et. al 1974; Table 8). Topography ranges from nearly level to very steep (Richardson et. al 1974). The predominant soil association is Miles – Springer consisting of soils nearly level to strongly sloping, deep, coarse textured and moderately coarse textured soils on outwash plains. In particular, the soils contained within my unique study area within Matador WMA consist of Miles (fine-loamy, mixed, thermic, alfisols), and Springer (coarse-loamy, mixed, thermic, alfisols; Richardson et al. 1974).

Predominant woody vegetation occurring within the Matador WMA included honey mesquite (*Prosopis glandulosa*), redberry juniper (*Juniperus pinchotii*), netleaf hackberry (*Celtis reticulata*), eastern cottonwood (*Populus deltoides*), salt cedar

(*Tamarix gallica*), Chickasaw plum (*Prunus angustifolia*), and sand sagebrush (*Artemisia filifolia*). Predominant grass species found on the area included little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), sideoats grama (*Bouteloua curtipendula*), purple threeawn (*Aristida purpurea*), Japanese brome (*Bromus japonicus*) and plains bristlegrass (*Setaria leucopila*). Predominant forb species on the area included western ragweed (*Ambrosia psilostachya*), woolly plantain (*Plantago insularis*), annual sunflower (*Helianthus annus*), and lamb's quarters (*Chenopodium album*, Hall 2005).

METHODS

Burning and Experimental Design

My study site consisted of 619-ha of contiguous sand sagebrush-mesquite rangeland in the Entrance and Headquarters pastures of the Matador Wildlife Management Area (34.117721, -100.356536). I compared patch-burning grazing treatment, rotational grazing treatment, summer and winter burn without grazing, and control (undisturbed) areas within this study. Space and timing constraints prevented one experimental design incorporating a combination of all these possible treatments of interest within a single grid. Consequently the patch burn-grazing and rotational grazing plots were analyzed separately from the patch burn without grazing plots, essentially being analyzed as separate studies.

Patch burning-grazing treatments consisted of 12 plots approximately 17-ha in size (Figure 1) located within the Entrance pasture. The 12 plots were randomly assigned one of four treatments; control (unburned), 2009 winter burn, 2010 winter burn, and 2011 winter burn. Hence, in 2009 the plots designated for 2010 winter burn and 2011 winter burn were treated as controls since they were scheduled for burn in following years. Further, plots designated for a 2011 burn treatment were used as controls during 2010. These plots were compared to rotational grazing only treatments consisting of 4, 18-ha plots separated by fencing (Figure 1.1) also located in the entrance pasture. These comparisons between patch burning-grazing, rotational grazing, and control treatments were analyzed using 3 separate repeated measures analysis of variance tests restricted to single years. Analyses were restricted to single years (2009, 2010, and 2011), because the number of replicates changed through the duration of the study as additional plots were burned in 2010 and 2011. Comparison of changes across years was accomplished using an additional 2 separate repeated measures analysis of variance tests. The first analysis compared metrics (cover, frequency, and density data) that could be followed for 3 years; from 2009 to 2011. Likewise, a second analysis was used to compare metrics from treatments that became available during 2010 and could be followed for only 2 years (2010 to 2011).

The patch burning-grazing and rotational grazing plots were grazed at the NRCS recommended stocking rate, which was approximately one animal unit per 14-ha. Water facilities were installed so that at any position within the study area cattle were within 0.8 km (1/2 mile) of water.

In the Headquarters pasture plots were not subjected to grazing and consisted of 15, 18-ha burn plots. The pasture was divided into a 3 x 5 grid containing 5 blocks with three treatments randomly assigned to the three plots located within each block. Using a randomized block design, the three plots within each block were randomly assigned the treatments control (non-burned), summer burn, and winter burn. The summer burns were conducted in August 2008 and winter burns were conducted in February 2009. All weather measures were recorded at time of burns (Table 1.1). Comparisons among treatments and years were accomplished using a single repeated measures analysis of variance with between subjects treatments of control, summer burn, and winter burn, and a within subjects variable, year. Mauchly's test for sphericity was used and when assumptions were not met Greenhouse-Giesser correction was used.

Herbaceous Sampling

Community – Percent cover was estimated for bare ground, litter, and the canopies of forbs and grasses using 100 randomly selected 50 x 20 cm quadrats (Daubenmire and Daubenmire 1968) during June of 2009-2011. Frequency of herbaceous species was recorded by determining what individual species were rooted within the quadrat. Quadrat locations were randomly selected by starting in the center of each plot and using a digital and analog watches set to different times to determine distance and direction. The seconds displayed on the digital watch was the determinant on the amount of paces to take. The second hand on the analog watch provided the direction in which to take the paces. Once a direction and distance were acquired and I had paced the distance the quadrat was blindly tossed over my shoulder and cover and frequency data were recorded. Upon completion of recording data the process was repeated from the position of the last quadrat (Poole thesis 2009). I selected individual species to be analyzed that were common throughout the study area and generally occurred at greater than 10 percent in my sampling effort.

Woody Vegetation Sampling

Horizontal woody canopy cover was measured within each plot using the line intercept method (Chambers and Brown 1983). Measurements were taken in July of 2009, 2010, and 2011. In the headquarters pasture where plots were more uniform (square blocks approx. 0.402 x 0.402 km) 3 evenly distributed 200-m transects running parallel north and south were placed within each plot. On each 200-m transect 6 30-m transects were evenly distributed 40-m apart. Each 30-m transect is perpendicular to the north-south running transect with direction east or west determined by a coin flip (heads-east, tails-west). Woody plant cover was then recorded as the centimeters that the canopy of any woody plant species that intersected with the 30-m transects. Woody density was calculated by counting the woody plants that were within 1-m alongside each of the 30-m transects. Due to irregularities in shape of the entrance pasture plots, modifications were made to the transects in which the 30-m transects were perpendicular to. Each plot still received a total of 18 30-m transects, however, in most cases the number and length of transects in which the 30-m transects were perpendicular to was altered. In most cases the transects were oriented east-west prompting a coin flip to determine if the 30-m transects would run north-south (heads-north, tails-south). Each 30-m transect was still located 40-m apart along the main transect and each main transect was 100-m from each other as in the headquarters pasture. In all cases there was a 70-m buffer maintained from each main transect to edge of the plot. Most species were individually measured separately, however, cacti species were lumped by the genus Opuntia and the category titled "other" was used for species that were uncommon.

RESULTS

Patch Burn-Grazing and Rotational Grazing Herbaceous Cover Results by Year

In 2009 bare ground varied among treatments ($F=32.17$, $P<0.0001$). Bare ground was greater in the 2009 burn treatment relative to the rotational grazing treatment as well as the control (Figure 1.2). Bare ground did not differ between rotational grazing treatment and the control. In 2009 litter cover varied among treatments ($F=31.46$, $P<0.0001$). Litter cover was greater in the rotational grazing treatment and control relative to the 2009 burn treatment (Figure 1.2). Litter cover did not differ between rotational grazing treatment and control. In 2009 forb cover did not vary among treatments ($F=2.30$, $P=0.1400$), but grass cover was different among treatments ($F=8.16$, $P=0.0051$). Grass cover was greater in the rotational grazing treatment and control relative to 2009 burn (Figure 1.2). Grass cover did not differ between rotational grazing and control treatments (Figure 1.2).

In 2010, bare ground and grass cover did not vary among treatments (2009 burn treatment, 2010 burn treatment, rotational grazing treatment, and control). However, litter cover varied among treatments ($F=7.04$, $P=0.0055$). Litter cover was greater in rotational grazing and control treatments than 2009 burn and 2010 burn treatments (P<

0.0221, Figure 1.3). Litter cover was not different ($P > 0.05$) between rotational grazing and control treatments and between 2009 burn and 2010 burn treatments (Figure 1.3).

In 2011, bare ground varied among treatments ($F=44.86$, $P<0.0001$). Bare ground was greater in 2011 burn treatment relative to all other treatments (Figure 1.4). Bare ground was greater in 2010 burn treatment relative to rotational grazing treatment and control (Figure 1.4). Bare ground was greater in 2009 burn treatment relative to rotational grazing treatment and control (Figure 1.4). Bare ground did not differ between 2010 burn treatment and 2009 burn treatment. Bare ground did not differ between rotational grazing treatment and control. Forb cover ($F=1.79$, $P=0.2019$) and grass cover ($F=2.50$, $P=0.1034$) did not vary among treatments in 2011. But litter cover varied among treatments ($F=54.65$, $P<0.0001$). Litter cover was greater in rotational grazing treatment then all other treatments (Figure 1.4). Litter cover in the control was greater than 2011 burn treatment, 2010 burn treatment, 2009 burn treatment but not rotational grazing (Figure 1.4). Litter cover did not vary between 2009 burn treatment and 2010 burn treatment (Figure 1.4). Litter cover in 2011 burn treatment was significantly lower than all other treatments.

Patch Burn-Grazing and Rotational Grazing Herbaceous Cover Results Across Years

2009 Treated Plots x 3 years

A treatment*year interaction was detected for bare ground ($F=4.30$, $P=0.0107$, Figure 1.5) and grass cover ($F=3.79$, $P=0.0274$, Figure 1.6) for plots treated in 2009. Changes across years were considered within treatments for these response variable effects, because of these interactions. There was no treatment*year interaction detected for forb cover ($F=1.20$, $P=0.3396$) or litter cover ($F=1.68$, $P=0.1932$) for plots treated in 2009. There was a significant difference among years for forb cover ($F=135.54$, $P<0.0001$, Figure 1.8). Forb cover in 2011 was lower than in 2009 ($P<0.0001$) and 2010 ($P<0.0001$). There was a significant difference among years ($F=108.30$, $P<0.0001$, Figure 1.8) and treatments ($F=27.96$, $P<0.0001$, Figure 1.8) for litter cover. Litter cover was higher in 2009 than both 2010 ($P<0.0001$) and 2011 ($P<0.0001$). Litter cover was lower in 2010 than 2011 ($P<0.0001$).

2010 Treated Plots x 2 years

There was no treatment*year interaction detected for bare ground ($F=0.14$, $P=0.8738$), grass cover ($F=4.58$, $P=0.0535$), forb cover ($F=0.51$, $P=0.6210$) or litter cover ($F=0.80$, $P=0.4846$) for plots treated in 2010 (Figure 1.9). There was a significant difference between years for bare ground ($F=11.52$, $P=0.0115$). Bare ground was significantly higher in 2011 when compared to 2010. There is a significant difference between years for forb cover ($F=322.67$, $P<0.0001$). Forb cover was higher in 2010. There is a significant difference between years for grass cover ($F=124.38$, $P<0.0001$). Grass cover was higher in 2010. There is a significant difference between years for litter cover ($F=64.42$, $P<0.0001$). Litter cover was greater in 2011. Consequently these results are presented without regard for treatment (Figure 1.9).

Patch Burn-Grazing and Rotational Grazing Herbaceous Frequency Results by Year

2009 Grasses

In 2009, treatments present in the Entrance pasture were 2009 burn treatment, rotational grazing treatment, and control (Table 1.1). Thus the 2009 burn treatment was a current year burn. Burn treatment in 2009 reduced the frequency of Blue Grama, Sideoats Grama, and Signalgrass as compared to the rotational grazing treatment and control (P=0.003, Table 1.1). There was no difference in Blue Grama, Sideoats Grama, and Signalgrass frequency between rotational grazing treatment and control (Table 1.1). Burn treatment in 2009 increased the frequency of Purple Threeawn in 2009 as compared to both rotational grazing treatment (P=0.0052) and control (P=0.0018, Table 1.1), but there was no difference in Purple Threeawn frequency between rotational grazing treatment and control. Sand Dropseed frequency was lower in rotational grazing treatment than both 2009 burn treatment (P=0.0032) and control (P=0.0042). There was no difference in Sand Dropseed frequency between 2009 burn treatment and control (Table 1.1).

2009 Forbs

In 2009, Erect Dayflower frequency was lower in the control than both 2009 burn treatment (P<0.00013) and rotational grazing treatment (P=0.0016), but there was no difference in Erect Dayflower frequency between 2009 burn treatment and rotational grazing treatment (Table 1.1). Narrow Leaf Globemallow frequency was greater in rotational grazing treatment than both 2009 burn treatment (P=0.0017) and control

(P<0.0001), but there was no difference between 2009 burn treatment and control (Table 1.1). Indian Blanket frequency was lower in 2009 burn treatment than both rotational grazing treatment (P<0.0001) and control (P<0.0001). And, Indian Blanket frequency was greater in the control than rotational grazing treatment (P=0.0011, Table 1.1). Pepperweed frequency in 2009 was lower in 2009 burn treatment than both rotational grazing treatment (P<0.0001) and control (P<0.0001) and lower in rotational grazing treatment than control (P<0.0001, Table 1.1). Plaintain frequency in 2009 was lower in the 2009 burn treatment than both rotational grazing treatment (P<0.0001) and control (P<0.00011), and lower in rotational grazing than control (P<0.0001, Table 1.1) as well. In 2009, treatment did not have an effect on Western Ragweed or Silver Leaf Nightshade ($P \geq 0.2296$, Table 1.1).

2010 Grasses

In 2010, treatments present in the Entrance pasture were 2009 burn treatment, 2010 burn treatment, rotational grazing treatment, and control (Table 1.2). The 2009 burn treatment was 1 year old and the 2010 burn treatment was a current year burn. In 2010, treatment did affect Blue Grama frequency (F=3.25, P=0.0598, Table 1.2). In 2010, Purple threeawn frequency in the rotational grazing treatment was lower than all other treatments ($P \leq 0.0171$, Table 1.2). Purple threeawn frequency was lower in 2010 burn treatment and the control as compared to the 2009 burn treatment (P<0.00016), but there was no difference in Purple threeawn frequency between the 2010 burn treatment and control (Table 1.2). Sand Dropseed frequency in 2010 was lower in the rotational grazing treatment than all other treatments ($P \leq 0.0043$), but there was no difference in

Sand Dropseed frequency between the 2009 burn treatment, the 2010 burn treatment, and control (Table 1.2). In 2010, Sideoats Grama frequency was lower in the 2010 burn treatment than all other treatments ($P \leq 0.0028$, Table 1.2). There was no difference in Sideoats grama frequency between the 2009 burn treatment, the rotational grazing treatment, and control (Table 1.2). Fringed leaf signal grass frequency in 2010 was lower in the 2010 burn treatment than all other treatments ($P \leq 0.0053$). Fringed leaf signal grass frequency was lower in 2009 burn treatment than rotational grazing ($P=0.0050$), but there was no difference detected between 2009 burn treatment and control. Fringed leaf signal grass frequency was significantly lower in control than rotational grazing treatment ($P=0.0383$, Table 1.2).

2010 Forbs

In 2010, treatments present in the Entrance pasture were 2009 burn treatment, 2010 burn treatment, rotational grazing treatment, and control. The 2009 burn treatment was 1 year old and the 2010 burn treatment was a current year burn. In 2010, Erect Dayflower frequency was higher in 2009 burn treatment than all other treatments ($P \leq 0.0006$). There was no difference in Erect Dayflower frequency detected between 2010 burn treatment, rotational grazing treatment, and control. In 2010, Narrow Leaf Globemallow frequency was greater in the rotational grazing treatment than all other treatments ($P=0.0011$, Table 1.2). Narrow Leaf Globemallow frequency was lower in 2009 burn treatment than control ($P=0.0482$). There was no difference detected in Narrow Leaf Globemallow frequency between 2009 burn treatment and 2010 burn treatment. There was no difference detected in Narrow Leaf Globemallow frequency between 2010 burn treatment and control (Table 1.2). In 2010, Indian Blanket frequency was lower in rotational grazing treatment than all other treatments ($P \leq 0.0351$). There was no difference detected in Indian Blanket frequency between 2009 burn treatment, 2010 burn treatment, and control (Table 1.2). In 2010, Pepperweed frequency was higher in control than 2009 burn treatment ($P<0.00015$) and 2010 burn treatment ($P<0.0001$). There was no detectable difference in Pepperweed frequency between control and rotational grazing. Pepperweed frequency was greater in rotational grazing treatment than 2009 burn treatment ($P=0.0135$) and 2010 burn treatment ($P<0.00017$). There was no detectable difference in Pepperweed frequency between 2009 burn treatment and 2010 burn treatment (Table 1.2). In 2010, Plaintain frequency was greater in rotational grazing treatment than all other treatments ($P \leq 0.0432$). Plaintain frequency was greater in control than 2009 burn treatment ($P<0.00012$) and 2010 burn treatment ($P<0.0001$). Plaintain frequency was also greater in 2009 burn treatment than 2010 burn treatment ($P=0.0113$, Table 1.2). Western Ragweed frequency was greater in 2009 burn treatment than all other treatments ($P=0.0028$). Western Ragweed frequency was also greater in 2010 burn treatment than control ($P=0.0303$). There was no difference in Western Ragweed frequency between 2010 burn treatment and rotational grazing treatment. Western Ragweed frequency was greater in rotational grazing treatment than control ($P=0.0204$, Table 1.2). In 2010, treatment did not affect Silverleaf Nightshade frequency ($F=1.02$, $P=0.4176$, Table 1.2).

2011 Grasses:

In 2011, treatments present in the Entrance pasture were 2009 burn treatment, 2010 burn treatment, 2011 burn treatment, rotational grazing treatment, and control. The 2009 burn treatment was 2 years old, the 2010 burn was 1 year old, and the 2011 burn treatment was a current year burn (Table 1.3). In 2011, Blue Grama frequency was greater in the rotational grazing treatment than 2011 burn treatment (P=0.0033) and control (P<0.00017, Table 1.3). There was no difference between rotational grazing and both 2009 burn treatment and 2010 burn treatment. Blue Grama frequency was greater in the 2009 burn treatment than 2011 burn treatment (P=0.0171) and control (P=0.0021). There was difference in Blue Grama frequency between 2009 burn treatment and 2010 burn treatment. Blue Grama frequency was greater in the 2010 burn treatment than control (P=0.0047). There was no difference in Blue Grama frequency between 2010 burn treatment and 2011 burn treatment, and there was no difference in Blue Grama frequency between 2011 burn treatment and control. In 2011, Purple Threeawn frequency was lower in rotational grazing treatment than all other treatments ($P \leq 0.0208$). There was no difference in Purple Threeawn frequency between 2009 burn treatment, 2010 burn treatment, 2011 burn treatment, and control (Table 1.3). In 2011, Sand Dropseed frequency was greater on the control treatment than the 2009 burn treatment (P=0.0474), 2010 burn treatment (P=0.0262), and rotational grazing treatment (P<0.00016). There was no difference in Sand Dropseed frequency between control and 2011 burn treatment. Sand Dropseed frequency was greater in the 2011 burn treatment than the 2010 burn treatment (P=0.0303) and rotational grazing treatment (P<0.00017). There was no detectable difference in Sand Dropseed frequency between the 2011 burn treatment and the 2009 burn treatment. Sand Dropseed frequency was greater on the 2009 burn treatment than rotational grazing treatment (P=0.0355). There was difference in Sand Dropseed frequency between 2009 burn treatment and 2010 burn treatment and no difference in Sand Dropseed frequency between the 2010 burn treatment and the rotational grazing treatment (Table 1.3). In 2011, treatment did not affect Sideoats Grama frequency. Fringed Leaf Signal Grass frequency in 2011 was greater on the 2009 burn treatment than 2010 burn treatment (P=0.0060), rotational grazing treatment (P=0.0017), and control (P=0.0079, Table 1.3). There was no difference in Fringed Leaf Signal Grass frequency between 2009 burn treatment and 2011 burn treatment. Fringed Leaf Signal Grass frequency was greater on the 2011 burn treatment than the 2010 burn treatment (P=0.0161), rotational grazing treatment (P=0.0048), and control (P=0.0219). There was no difference in Fringed Leaf Signal Grass frequency between control, 2010 burn treatment, and rotational grazing treatment (Table 1.3).

2011 Forbs

In 2011, treatments present in the Entrance pasture were 2009 burn treatment, 2010 burn treatment, 2011 burn treatment, rotational grazing treatment, and control. The 2009 burn treatment 2 years old, the 2010 burn treatment was 1 year old and the 2011 burn treatment was a current year burn (Table 1.3). In 2011, treatment did not have an effect on Erect Dayflower frequency (F=1.65, P=0.2298), Narrow Leaf Globemallow frequency (F=2.11, P=0.1481), Indian Blanket frequency (F=2.77, P=0.0815), Pepperweed frequency (F=0.0, P=1.0000), and Plaintain frequency (F=2.74, P=0.0834,

Table 1.3). Western Ragweed frequency was greater in the 2011 burn treatment than all other treatments ($P \leq 0.0001$). Western Ragweed frequency was greater in rotational grazing treatment than the 2009 burn treatment (P=0.0238). There was no difference in Western Ragweed frequency among rotational grazing, 2010 burn treatment, and control. Additionally, Western Ragweed frequency in the 2010 burn treatment and 2009 burn treatment were not different (Table 1.3). In 2011, Silverleaf Nightshade frequency was greater in the 2010 burn treatment than 2009 burn treatment (P=0.0198), rotational grazing treatment (P=0.0053), and control (P=0.0404). There was no difference in Silverleaf Nightshade frequency between 2010 burn treatment and control and there was no difference in Silverleaf Nightshade frequency among 2009 burn treatment, 2011 burn treatment, rotational grazing treatment, and control (Table 1.3).

Patch Burn without Grazing Herbaceous Results

There was no year*treatment interactions detected for bare ground. Bare ground was lower in 2009 than both 2010 (P=0.018) and 2011 (P<0.0001) and lower in 2010 than 2011 (P=0.017, Figure 1.10). Bare ground was lower in control than both summer burn treatment (P=0.002) and winter burn treatment (P=0.002). There was no difference in bare ground between summer and winter burn treatments. There was no year*treatment interaction detected for litter cover. Litter cover was greater in 2009 than both 2010 (P<0.0001) and 2011 (P<0.0001). Litter cover was also greater in 2011 than 2010 (P<0.0001, Figure 1.10). Litter cover in the control areas was greater than both summer burn treatment (P=0.019) and winter burn treatment (P=0.043). There was no difference in litter cover between summer and winter burn treatments. There was a significant year*treatment interaction detected for grass cover ($F=14.194$, $P<0.0001$). In 2009, there was a significant difference in grass cover among treatments ($F=12.326$, $P=0.001$, Figure 1.11). In 2009, grass cover was greater in the control than summer burn treatment ($P=0.005$) and winter burn treatment ($P<0.0001$). There was no difference in grass cover between summer and winter burn treatments in 2009. There was a significant year*treatment interaction detected for forb cover ($F=7.197$, $P=0.002$). In 2009, there was a significant difference in forb cover among treatments ($F=9.119$, $P=0.004$, Figure 1.11). In 2009, forb cover was greater in the control areas than summer burn treatment ($P=0.046$) and winter burn treatment ($P=0.001$). There was no detectable difference in forb cover between summer and winter burn treatments in 2009.

Grasses

There was a significant year*treatment interaction for blue grama frequency ($F=4.793$, $P=0.010$, Table 1.4), however, when you observe simple effects there are no detectable differences among treatments within years for blue grama frequency or treatment ($P=0.186$). There was no detectable year*treatment interaction for fringe leaf signal grass frequency. There was a difference among years for fringe leaf signal grass frequency ($F=3.620$, $P=0.050$, Table 1.4). In 2011, fringe leaf signal grass frequency was greater than in 2010 ($P=0.018$). There was no difference among treatments for fringe leaf signal grass frequency. There was no year*treatment interaction for sand dropseed frequency. Sand dropseed frequency was different among years ($F=12.604$, $P=0.001$, Table 1.4). In 2011, sand dropseed frequency was lower than in 2009 ($P=0.002$) and 2010 ($P<0.0001$). Sand dropseed frequency was not different among treatments. There was no year*treatment interaction for sideoats grama frequency. There was a difference among years for sideoats grama frequency (F=3.680, P=0.048, Table 1.4). In 2010, sideoats grama frequency was lower than in 2009 (P=0.023). There was no difference among treatments for sideoats grama frequency. There was a significant year*treatment interaction for purple threeawn frequency (F=6.508, P=0.003, Table 1.4), however, when you observe simple effects there are no detectable differences among treatments within years for purple threeawn frequency.

Forbs

There was no year*treatment interaction for Erect Dayflower frequency. However, Erect Dayflower frequency was different among years (F=27.780, P<0.0001, Table 1.4). In 2011, erect dayflower frequency was lower than in 2009 (P<0.0001) and 2010 (P<0.0001). There was no difference among treatments for erect dayflower frequency. There was a year*treatment interaction detected for globemallow frequency (F=5.181, P=0.007, Table 1.4), however, when simple effects were observed there were no differences among treatments within years. There was a year*treatment interaction detected for peppergrass frequency (F=5.500, P<0.00016, Table 1.4). In 2009, peppergrass frequency was greater in control than in winter burning treatment (P<0.0001) and greater in summer burning treatment than winter burning treatment (P=0.010). There was also a year*treatment interaction detected for plaintain frequency (F=4.833, P=0.010, Table 1.4). In 2009, plaintain frequency was lower in winter burn treatment than both summer burn treatment (P=0.003) and control (P=0.031). There was a year*treatment interaction for indian blanket frequency (F=8.514, P=0.006, Table 1.4). Additionally, there was a significant difference in treatments detected in years 2009 (F=20.746, P<0.0001) and 2010 (F=6.868, P=0.010) for indian blanket frequency. In 2009, indian blanket frequency was greater in control than both summer burn treatment (P<0.0001) and winter burn treatment (P<0.0001). In 2010, indian blanket frequency was greater in control than summer burn treatment (P=0.003). There was no year*treatment interaction detected for western ragweed frequency (Table 1.4). Western ragweed frequency was greater in 2010 than years 2009 (P=0.008) and 2011 (P=0.002). Western ragweed frequency was lower in summer burn treatment than winter burn treatment (P=0.019) but not and control. There was no year*treatment interaction detected for silverleaf nightshade frequency (Table 1.4). Silverleaf nightshade frequency was lower in 2011 than years 2009 (P<0.0001) and 2010 (P=0.014). There was no difference among treatments for silverleaf nightshade frequency.

Patch Burn-Grazing and Rotational Grazing Woody Cover

In 2009 treatments present in the entrance pasture were 2009 burn, control, and rotational grazing. In 2009 there was no difference in cover detected for honey mesquite among treatments (F=0.30, P=0.7433, Figure 1.12). However, there was a difference in 2009 in sand sage cover among treatments (F=4.51, P=0.0326, Figure 1.12). Sand sage means for treatments are (2009 burn=0.039, control=0.114, rotational grazing=0.097). In 2009 there was no difference in cover detected for Opuntia (F=0.84, P=0.4521, Figure 1.12) and Yucca (F=1.50, P=0.2600) among treatments and, there was no difference detected for cover for the category other among treatments (F=0.03, P=0.9710, Figure 1.12).

In 2010 treatments present in the entrance pasture were 2009 burn, 2010 burn, control, and rotational grazing. In 2010 there was a difference in cover detected for Honey mesquite among treatments (Figure 1.13). Honey mesquite means for treatments are (2009 burn=0.024, 2010 burn=0.026, control=0.037, rotational grazing=0.097). In 2010 there was no difference in cover detected for Sand sage among treatments (F=0.18, P=0.9052, Figure 1.13). In 2010 there was no difference in cover detected for Opuntia (F=1.32, P=0.3150, Figure 1.13) or Yucca among treatments (F=0.68, P=0.5810, Figure 13).

In 2011 treatments present in the entrance pasture were 2009 burn, 2010 burn, 2011 burn, control, and rotational grazing. In 2011 there was no difference in cover detected for Honey mesquite among treatments (F=0.09, P=0.9847, Figure 1.14). In 2011 there was a difference in sand sage cover among treatments (F=4.48, P=0.0217, Figure 1.14). Sand sage means for treatments are (2009 burn=0.051, 2010 burn=0.040, 2011 burn=0.019, control=0.090, rotational grazing=0.076). In 2011 there was no significant difference in cover detected for Opuntia (F=2.43, P=0.1101, Figure 1.14) or Yucca among treatments (F=2.76, P=0.0820, Figure 14). In 2011 there was no difference in hackberry cover among treatments (F=1.33, P=0.3182, Figure 1.14).

2009 Treated Plots x 3 years

Treatments present in 2009 were 2009 burn, rotational grazing, and control. The treatments applied during 2009 were compared across the years 2009, 2010, and 2011. There was no treatment*year interaction detected for honey mesquite cover (F=1.11, P=0.0233). In 2009, honey mesquite cover was lower than in 2010 (P=0.0205) and 2011

(P=0.0131, Figure 1.15). There was no treatment*year interaction detected for sand sage cover (F=1.79, P=0.1876) and there was no difference in sand sage cover among years (F=0.79, P=0.4713).

There was no treatment*year interaction detected for Opuntia cover (F=0.73, P=0.5872), but, Opuntia cover in 2011 was greater than in 2009 (P=0.0058) and 2010 (P=0.0036, Figure 1.15). There was no treatment*year interaction for yucca cover (F=1.01, P=0.4345) and no difference in yucca cover detected among years (F=0.12, P=0.8835).

2010 Treated Plots x 2 years

The treatments applied during 2010 were compared between the years 2010 and 2011. There was no treatment*year interaction detected for honey mesquite cover (F=1.80, P=0.2342) and no difference in honey mesquite cover between 2010 and 2011 (F=0.14, P=0.7158, Figure 1.16). There was no treatment*year interaction detected for sand sage cover (F=1.71, P=0.2480) and no difference in sand sage cover between 2010 and 2011 (F=2.28, P=0.1749, Figure 1.16).

In treatments applied in 2010 there was treatment*year interaction detected for Opuntia cover (F=9.44, P=0.0103, Figure 1.17). Opuntia cover was greater in rotational grazing treatment in 2011 than 2010 (P=0.0094). Opuntia cover was also greater in control in 2011 than 2010 (P=.0016). There was no treatment*year interaction detected for yucca cover (F=1.68, P=0.2544) and there was no difference in yucca cover between 2010 and 2011 (F=1.87, P=0.2143, Figure 1.16).

Patch Burn-Grazing and Rotational Grazing Woody Density

In 2009 treatments present in the entrance pasture were 2009 burn, control, and rotational grazing. In 2009 there was no difference in density detected for honey mesquite (F=2.80, P=0.0975), sand sage (F=2.40, P=0.1296), Opuntia (F=0.29, P=0.7520), yucca (F=2.23, P=0.1469), or the category other among treatments (F=3.16, P=0.0764, Figure 1.18).

In 2010 treatments present in the entrance pasture were 2009 burn, 2010 burn, control, and rotational grazing. In 2010, the rotational grazing treatment had a greater density of honey mesquite than all other treatments ($P \leq 0.0217$, Figure 1.19). Sand sage density was not different among treatments (F=0.56, P=0.6503, Figure 1.19) in 2010. During 2010 Opuntia density was greater in the control treatment than both 2009 burn treatment (P=0.0074) and 2010 burn treatment (P=0.0375). The rotational grazing treatment had a greater density of Opuntia than 2009 burn treatment (P=0.0467, Figure 1.19). In 2010 there was no difference in yucca density among treatments (F=0.48, P=0.7032, Figure 1.19).

In 2011 treatments present in the entrance pasture were 2009 burn, 2010 burn, 2011 burn, control, and rotational grazing. In 2011 there was no difference in density of honey mesquite (F=1.36, P=0.3106), sand sage (F=0.73, P=0.5918), or Opuntia (F=2.96, P=0.0693, Figure 1.20).

2009 Treated Plots x 3 years

Treatments present in 2009 were 2009 burn, rotational grazing, and control. The treatments applied during 2009 were compared across the years 2009, 2010, and 2011.

There was no treatment*year interaction detected for honey mesquite density (F=2.47, P=0.0764), but honey mesquite density was greater during 2009 (mean of 3.3823) than 2010 (mean of 1.9530; P<0.0001) and 2011 (mean of 1.7792; P<0.0001, Figure 1.21).

There was a treatment*year interaction for sand sage density (F=4.18, P=0.0188, Figure 1.22). In 2009 sand sage density was lower in the rotational grazing treatment than in 2010 (P=0.0150). In 2009 sand sage density was lower in the 2009 burn treatment than 2010 (P=0.0036). In 2010 sand sage density was also lower in control treatment than it was in 2011 (P=0.0271). There was no treatment*year interaction for opuntia density detected. However, in 2010 Opuntia density was lower than in 2009 (P<0.0001) and 2011 (P<0.00011, Figure 1.21).

2010 Treated Plots x 2 years

The treatments applied during 2010 were compared across the years 2010 and 2011. There was a treatment*year interaction detected for honey mesquite density (F=7.09, P=0.0209 Figure 1.24). Honey mesquite density was greater in rotational grazing treatment in 2010 than 2011 (P=0.0115). However, there was no difference detected for sand sage density in regards to year (F=0.84, P=0.3882 Figure 1.23), or treatment*year interaction (F=3.63, P=0.0817) for treatments applied in 2010. There was no treatment*year interaction detected for Opuntia density (F=0.16, P=0.8575), but Opuntia density was lower in the year 2010 than 2011 (P=0.0013, Figure 1.23).

For treatments applied in 2010 there was no difference detected for yucca density in regards to, year (F=1.16, P=0.3090), or treatment*year interaction (F=1.82, P=0.2209).

Patch Burning without Grazing Woody Cover

There was a year*treatment interaction detected for honey mesquite cover in the headquarters pasture (F=6.854, P=0.015, Figure 1.25). When the simple effects for honey mesquite cover were examined there were differences among treatments in 2009 (F=7.708, P=0.007) and 2011 (F=8.390, P=0.005). In 2009, control was greater than both summer burn treatment (P=0.007) and winter burn treatment (P=0.004). In 2011, control was greater for honey mesquite cover than both summer burn treatment (P=0.005) and winter burn treatment (P=0.003). There was a year*treatment interaction also detected for sand sage cover (F=6.565, P=0.008, Figure 1.26). When the simple effects for sand sage cover were examined there was a difference among treatments in 2010 (F=12.404, P=0.001). In 2010, sand sage cover was greater in control than both summer burn treatment (P=0.001) and winter burn treatment (P=0.002). There was no significant year*treatment interaction detected for Opuntia cover (F=1.426, P=0.293) and no difference among years for Opuntia cover (F=2.259, P=0.168) or treatment (P=0.415, Table 1.5). There was no significant year*treatment interaction detected for yucca cover (F=0.369, P=0.827) and no difference among years for yucca cover (F=0.543, P=0.591) or treatment (P=0.410, Table 1.5). There was no significant year*treatment interaction detected for sand plum cover (F=0.973, P=0.418) and no difference among years for sand plum cover (F=1.744, P=0.223) or treatment (P=0.973, Table 1.5). There was no significant year*treatment interaction detected for sand shinnery cover (F=1.103, P=0.378) and no difference among years (F=1.238, P=0.298) or treatment (P=0.906, Table 1.5). There was no year*treatment interaction detected for netleaf hackberry cover

(F=1.000, P=0.410), and no difference among years for netleaf hackberry cover (F=1.000, P=0.347) or treatments (P=1.00, Table 1.5). There was no significant year*treatment interaction detected for category other cover (F=1.040, P=0.400) and no difference among years (F=0.811, P=0.403) or treatments (P=0.726, Table 1.5).

Patch Burning without Grazing Woody Density

There was no year*treatment interaction detected for honey mesquite density (F=0.359, P=0.709). But, Honey mesquite density was greater in 2009 than both 2010 (P=0.013) and 2011 (P=0.013, Table 1.6). Treatment did not have an effect on honey mesquite density. There was no year*treatment interaction detected for sand sage density (F=3.162, P=0.083). Sand sage density was lower in 2010 than both 2009 (P=0.017) and 2011 (P=0.002, Table 1.6). Sand sage density was greater in 2011 than 2009 (P=0.001, Table 1.6). Treatment did not have an effect on sand sage density. There was no year*treatment interaction detected for Opuntia density (F=1.695, P=0.200). Opuntia density was greater in 2011 than both 2009 (P=0.028) and 2010 (P=0.028, Table 1.6). Treatment did not have an effect on Opuntia density. There was no year*treatment interaction detected for yucca density (F=0.559, P=0.696) and no difference among years (F=0.554, P=0.585) or treatments (P=0.467, Table 1.6). There was no year*treatment interaction detected for sand shinnery density (F=1.015, P=0.405) and no difference among years (F=0.979, P=0.352) or treatments (P=0.971, Table 1.6). There was no significant year*treatment interaction detected for sand plum density (F=0.446, P=0.655) and no difference among years (F=4.280, P=0.072, Table 1.6) or treatments. There was no year*treatment interaction detected for netleaf hackberry density (F=1.000, P=0.410) and no difference among years (F=1.000, P=0.347) or treatments (P=1.00, Table 1.6). There was no year*treatment interaction detected for category other density (F=1.107, P=0.377) and difference among years for category other density (F=1.096, P=0.326) or treatments (P=0.279, Table 1.6).

DISCUSSION

Herbaceous

Patch burning and grazing has been studied in the tallgrass prairie regions where it effectively reduces litter, especially in the short term after burning (Fuhlendorf et. al 2006). Traditional grazing (Fuhlendorf et. al 2006, Naeth et. al 1991) and burning treatments (Sharrow and Wright 1977, Pase and Knipe 1977) are also effective at reducing litter in a variety of ecosystems. Patch burning and grazing and burning alone were effective at reducing litter cover in my study on sand sagebrush-honey mesquite rangeland. However the rotational grazing treatment in my study did not reduce litter cover as in previous studies in different ecosystems (Fuhlendorf et. al 2006, Naeth et. al 1991). Litter is an important aspect affecting rangeland productivity for a multitude of reasons. It acts as an insulator regulating soil temperature and reduces the evaporative loss of moisture from the soil. By intercepting light and reducing soil temperatures, evaporative water loss from the soil is reduced (Facelli and Pickett, 1991). While litter accumulation has some inherent benefits, excessive build up of litter can negatively affect the condition of rangeland. Accumulated litter can intercept water before it reaches the soil and creates a barrier for seedlings (Facelli and Pickett 1991). Patch burning and grazing and burning alone appear to be equally effective methods of reducing litter cover in sand sagebrush honey mesquite rangelands.

It is intuitive that with the reduction of litter cover there is a related increase in bare ground, as exhibited in my study. Areas treated with patch burn-grazing and burning alone showed an initial increase of bare ground when a burning treatment was applied as reported in other studies (Sharrow and Wright 1977, Pase and Knipe 1977, Fuhlendorf et. al 2006). Bare ground percentage was lower in rotational grazing when compared to treatments that were burned but grazing was comparable to the control in my study. Rotational grazing was not effective at increasing bare ground in my study, in contrast to reports concerning bare ground and traditional grazing methods in the tallgrass prairie region (Fuhlendorf et. al 2006). For my study patch burning-grazing and patch burning without grazing were effective ways of reducing litter and increasing bare ground initially, while rotational grazing did not have the impact on litter and bare ground that has been shown in other ecosystems.

My results show that grass cover took the longest to recover following winter burning. In tallgrass prairie regions, grazers focus on areas dominated by warm season, C4 grasses during summer grazing months (Vinton et. al 1993). This focus could explain the lower grass cover in burn treated plots as compared to non-burned plots within the year. The focus of the grazing pressure was in the disturbed plots as grazers were selecting for the new growth, high quality grass produced after fire. In 2009 and 2010 grass cover was lower in the burn that took place in the 2009 treated plot as compared to the control and rotational grazing plots as would be expected. However, in 2011 while total grass cover was decreased in almost all treatments, grass cover was higher in the plots burned in 2009 than the rotational grazing treatment. With grazing focused in plots that were more recently disturbed with fire, grass cover increased in the 2009 burn treatment by being allowed to recover from lack of grazing pressure. Low grass cover in 2011 was due to sampling coinciding with extreme drought, and net primary production of plant species is directly related to precipitation across all types of treatments (Briggs and Knapp 1995). Plots burned in year one of the study produced more grass cover by year three than rotational grazing. Patch burning-grazing provides better heterogeneity in grass cover, by shifting grazing focus.

Ruthven et. al (2002) reported that winter burning is effective at increasing forb production in southern Texas, and treatments in my study exhibited similar forb responses. In plots burned and grazed the forb cover was comparable to plots that did not receive burning treatment, suggesting with proper moisture forb production was high with winter burning and returned to levels that can be associated with non burned areas; a plant response also reported in the tallgrass prairie regions (Knapp and Briggs 2001). Forb cover across the three years for plots treated in 2009 showed that forbs recovered in the first growing season following winter burning and remained at levels comparable to rotational grazing plots and control plots for the following 2 years. While there were no differences among these treatments for the 3 years individually, it should be noted that in 2011 forb cover dropped to less than 10 percent and was significantly lower than levels 2009 and 2010 due to drought effects. Grass cover and forb cover in patch burning-grazing and patch burning without grazing recovered well after burning. Grass cover and forb cover in my study reacted similarly to areas in the tallgrass prairie (Fuhlendorf et al. 2006) by recovering to percentages associated with non burned treatments within the first growing season. In my study these systems show that patch burning-grazing and patch burning are effective ways to create successional diversity within the landscape without losing much plant productivity when adequate moisture is available.

Patch burn-grazing in tallgrass prairie regions increases vegetative community diversity by increasing successional stages throughout a landscape (Fuhlendorf and Engle 2004). My results indicated that individual species response was variable by treatment and year. For instance, blue grama typically had lower frequencies in treatments that used burning during the first growing season after the burn, suggesting they do not recover as fast as other species, such as purple threeawn. Purple threeawn in most years exhibited higher frequencies in treatments that received burning than traditional rotational grazing treatment. The same response was also exhibited by sand dropseed. Responses of forb species were variable as well. Erect dayflower frequency was higher in treatments receiving burning and grazing than traditional rotational grazing treatment, except in 2011 which coincided with extreme drought conditions and plant production was extremely low regardless of treatment. The opposite response holds true for species like peppergrass and plaintain, where higher frequencies were realized in treatments that did not receive burning. Lack of consistency in responses by individual species can probably be attributed to the lack of consistency in climatic conditions. Lack of precipitation during the study likely influenced variable responses of grasses and forbs and long term monitoring would be necessary to make direct assumptions of burning and grazing effects on species when drought conditions are prevalent. With species responses variable by treatment and year with this study, patch burning-grazing does appear to hold a clear advantage over rotational grazing at increasing individual grass and forb species frequency.

Woody

My results indicated that a patch burn-grazing system is efficient at reducing sand sage canopy cover in the short term as treatments receiving burning and grazing had reduced canopy cover. However, sand sage canopy cover in winter and summer burns was variable. After burning, sand sage cover recovered to levels similar to control by the following growing season suggesting patch burn-grazing will not ultimately reduce sand sage cover in the long term. The same treatments for honey mesquite were variable by year. Summer and winter burning without grazing lowered honey mesquite cover. In contrast to mesquite, yucca canopy cover was not affected by burning and grazing. Canopy cover of honey mesquite, sand sage, and yucca were not different across years indicating they are less susceptible to the effects of drought as compared to herbaceous species measured in the same plots. Opuntia had a greater canopy cover in plots that received grazing in 2011, than years 2009 and 2010, which is interesting considering the extreme drought conditions in 2011. Opuntia cover was not affected by treatment in plots that just received burning. Opuntia cover was also unaffected by treatments applied in 2010 and monitored across years 2010 and 2011. As displayed by this study, first year mortality of Opuntia is typically not indicative of the fire's ability to decrease Opuntia since it resprouts after burning (Bunting et. al 1980). Successive years of burning are more effective at reducing Opuntia allowing interactions with insects and rodents to impact Opuntia species negatively (Bunting et. al 1980, Ruthven et. al 2003). When evaluating treatment effects within year on the density of woody species there are essentially no difference in regards to honey mesquite, sand sage, and yucca. It is well documented that honey mesquite and sand sagebrush have always been present in Texas (Wright et al. 1976) which would subject these species to fire disturbances. As a result these species are very tolerant of fire and able to resprout after burning (Heirman and Wright 1973). In 2009, a year of decent rainfall, Opuntia exhibited no difference in density among treatments; however, in 2010 Opuntia density was significantly lower in treatments that received burning. In 2011, a year of extreme drought conditions, there was no difference in Opuntia density among treatments. When treatments applied in 2009 were compared across years most woody categories were variable among treatments and years in regards to density except Opuntia. Opuntia had a treatment response resulting in a lower density in treatments receiving burning and grazing in all three years of the study. The same responses can be said for treatments applied in 2010. Patch burning-grazing and patch burning without grazing can be initially effective at reducing canopy cover for sand sage and honey mesquite in the short term. Density for most woody categories were variable without much effect suggesting patch burning- grazing and patch burning without grazing systems aren't effective at reducing density of fire tolerant species at least within the time frame and fire frequency of this study.

For land owners or managers that implement cattle production, but also want to create successional heterogeneity throughout the landscape to possibly benefit wildlife species that need varying levels of disturbance, can use the patch burn-grazing system to achieve this response. The varying responses of cover that are created through disturbance and time create a suite of habitat types that can accommodate multiple wildlife species that cannot be achieved through traditional and rotational grazing practices.

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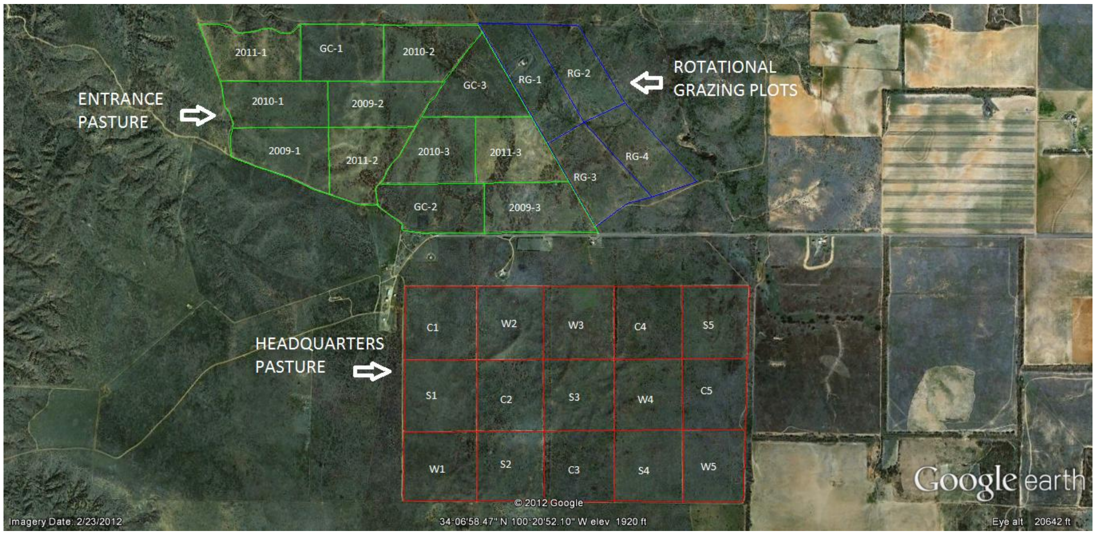

Figure 1.1. Diagrammatic representation of plots located within Entrance and Headquarters pastures at Matador Wildlife Management Area. Headquarters pasture was divided into a 3 x 5 grid with each of 5 blocks containing 3 plots approximately 18 ha in size. Utilizing a randomized block design, each block was randomly assigned 3 treatments consisting of summer burn, winter burn, and control. Entrance pasture was divided into 16 plots approximately 17 ha in size that were subjected to patch burn-grazing and rotational grazing. Due to area constraints, 12 plots were randomly assigned 3 replicates of treatments 2009 burn, 2010 burn, 2011 burn, and control. Additionally 4 plots were subjected to rotational grazing treatment only.

Table 1.1. Recorded weather data at time of burns.

Dat e	Month	Year	Plots Burned	Wind Speed Range (km/h)	Dry Temperature Range (Cº)	Relative Humidity Range (%)
12	August	2008	S1, S2, S3	1.6-16.1	22-36	31-67
26	August	2008	S4, S5	8.0-16.1	32-35	36-42
25	January	2009	2009-1, 2009-2, 2009-3, W5	3.2-12.9	7-18	24-41
29	January	2009	W1, W2, W3, W5	6.4-11.3	11-13	26-36
19	January	2010	2010-1, 2010-2, 2010-3	9.7-16.1	14-22	22-40
25	January	2011	2011-1, 2011-2, 2011-3	1.6-12.9	1-12	33-75

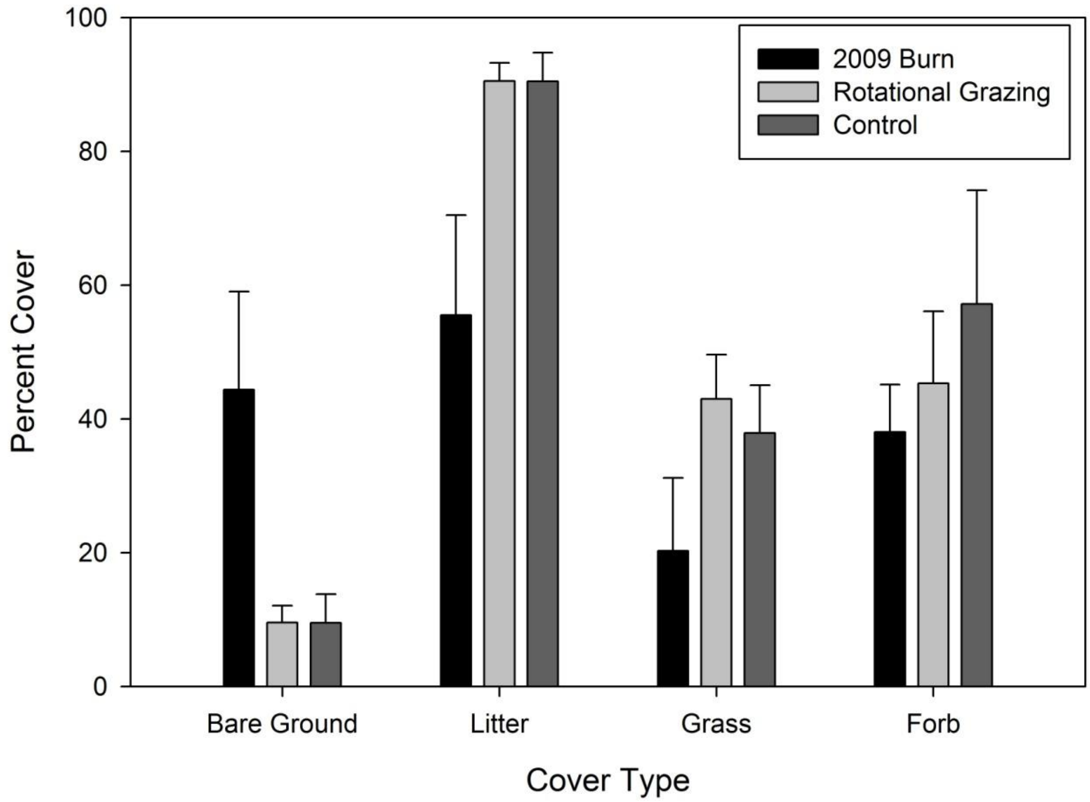

Figure 1.2. Within year 2009 cover comparison for patch burning-grazing and rotational grazing for treatments applied in 2009 (Mean±SD).

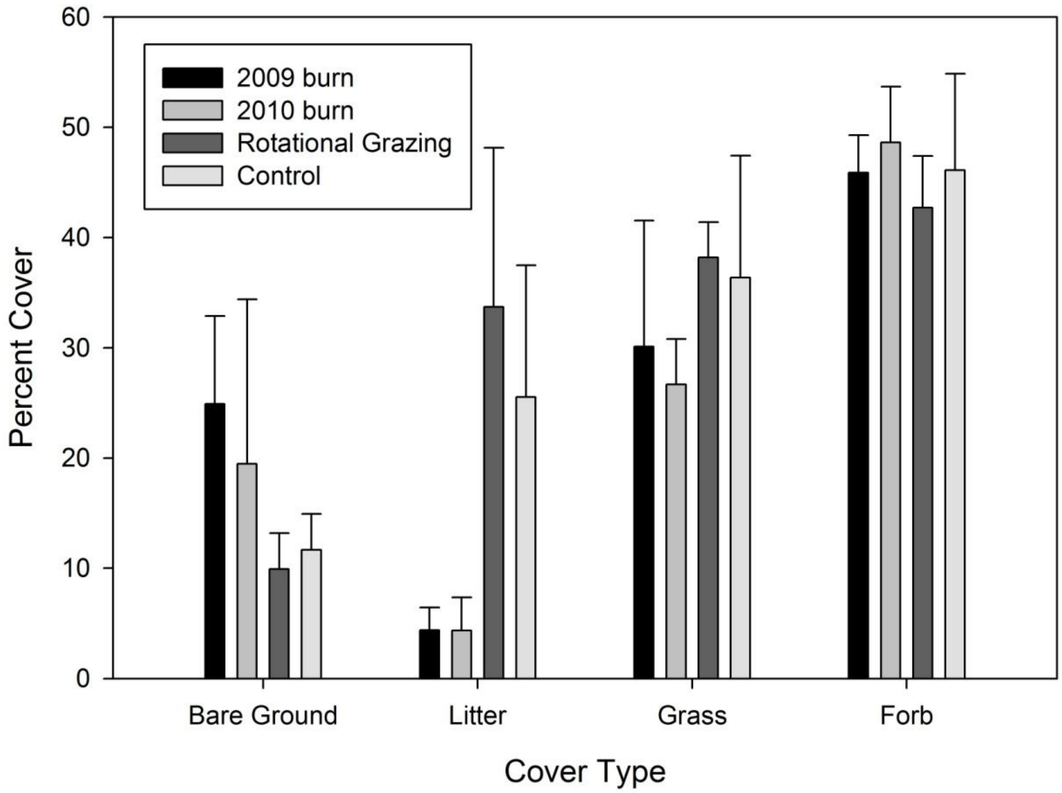

Figure 1.3. Within year 2010 cover comparison for patch burning- grazing and rotational grazing for treatments applied in 2010 (Mean±SD).

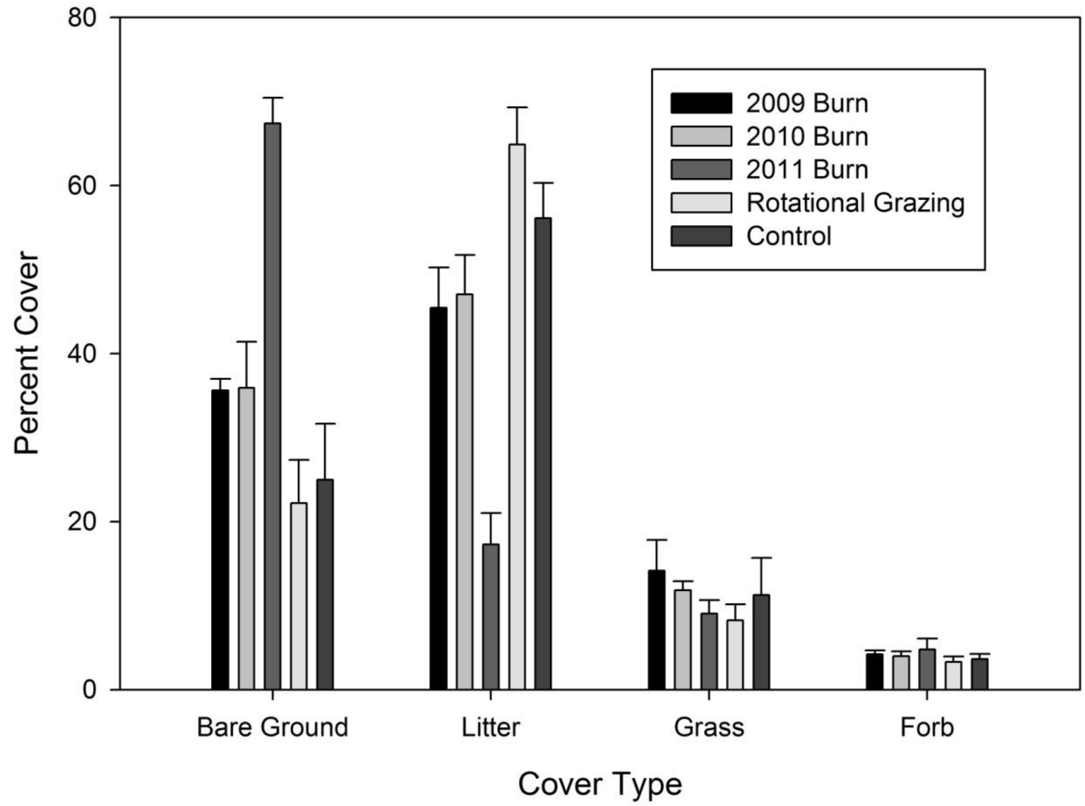

Figure 1.4. Within year 2011 cover comparison for patch burning-grazing and rotational grazing for treatments applied in 2011 (Mean±SD).

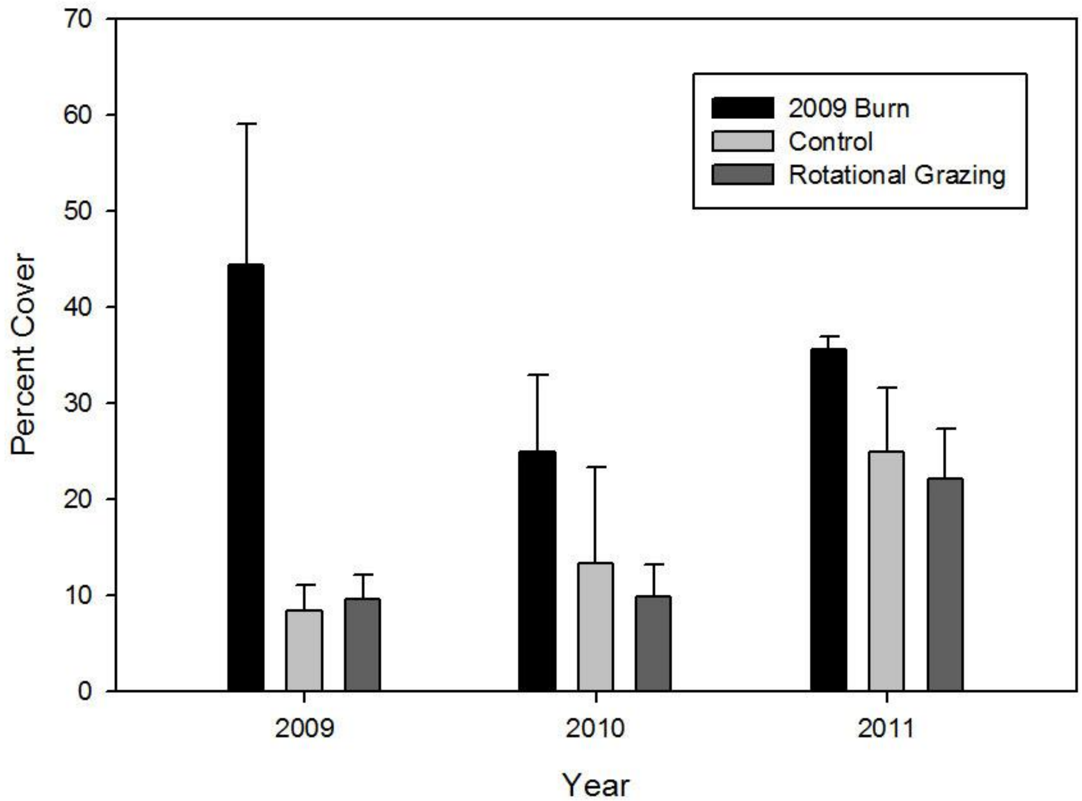

Figure 1.5. Bare ground for patch burning-grazing and rotational grazing for treatments applied in 2009 and comparing by treatment for years 2009-2011 (Mean±SD).

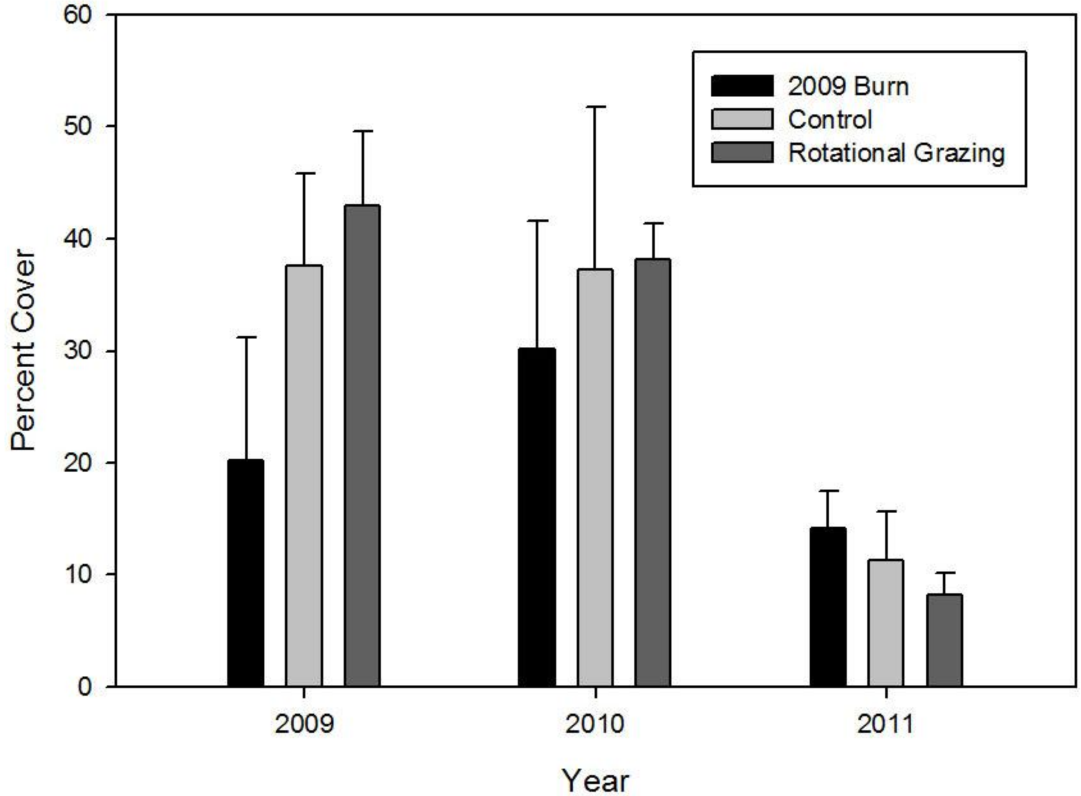

Figure 1.6. Grass cover for patch burning-grazing and rotational grazing for treatments applied in 2009 and comparing by treatment for years 2009-2011 (Mean±SD).

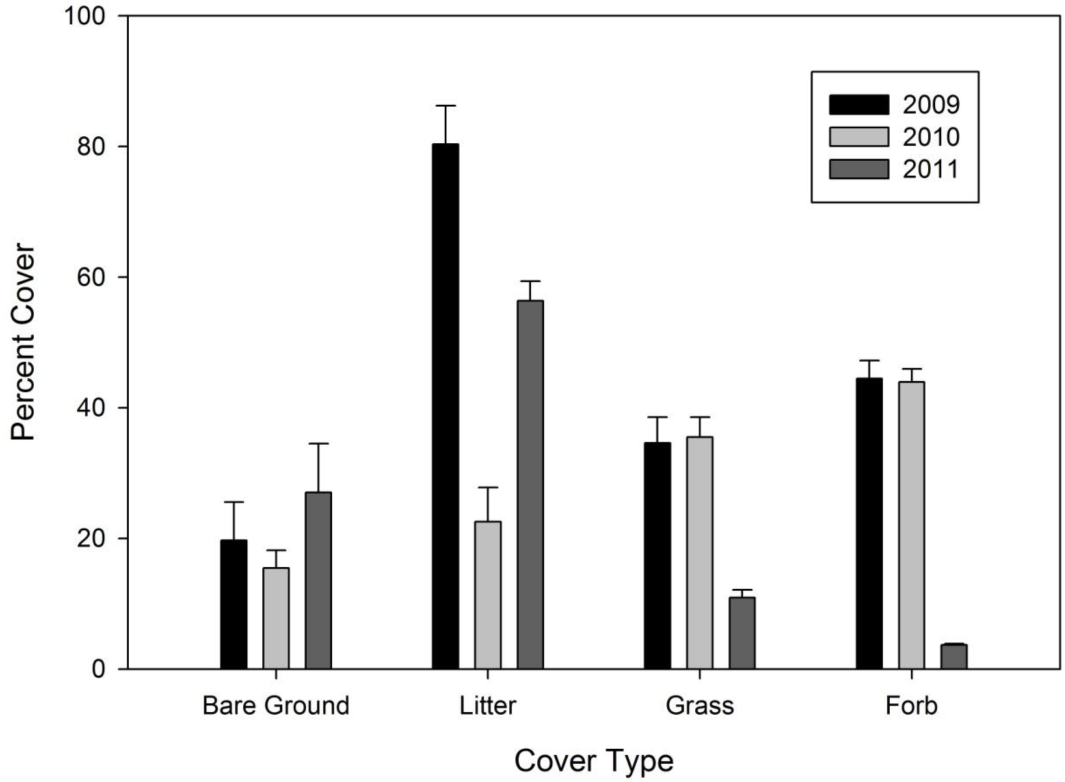

Figure 1.7. Cumulative treatment cover comparison for patch burning-grazing and rotational grazing across years for treatments applied in 2009 (Mean±SD).

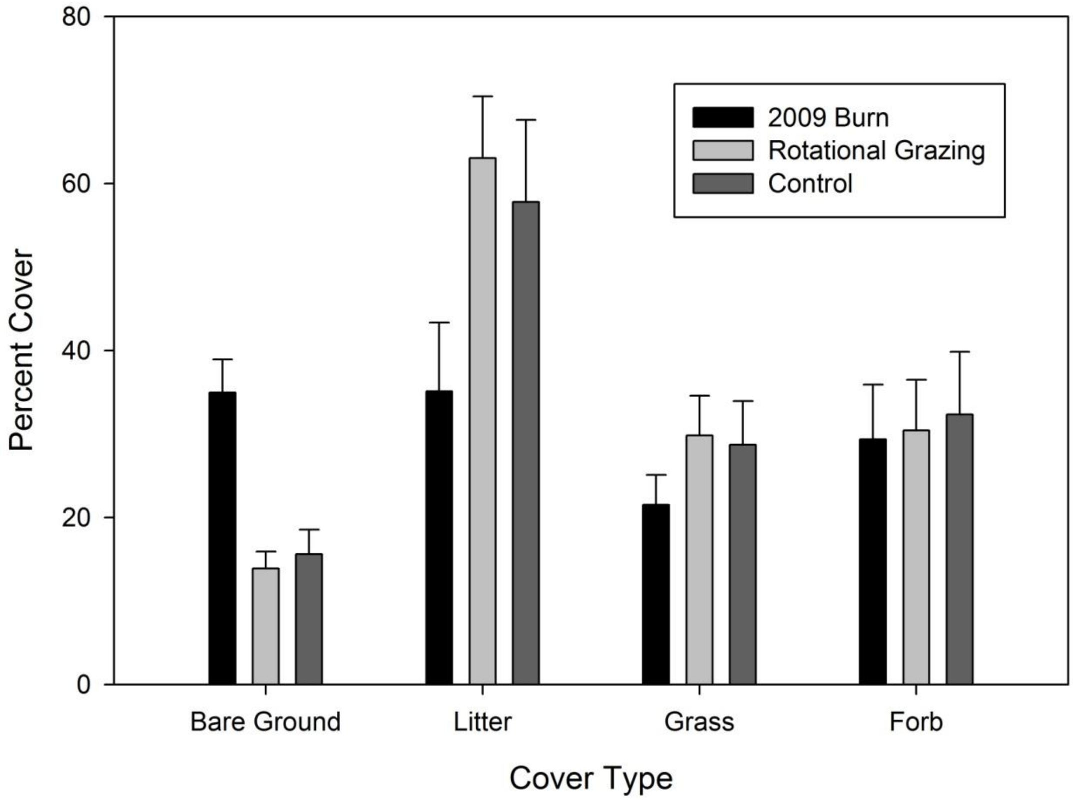

Figure 1.8. Cumulative year comparison for cover for patch burning-grazing and rotational grazing across treatments for treatments applied in 2009 (Mean±SD).

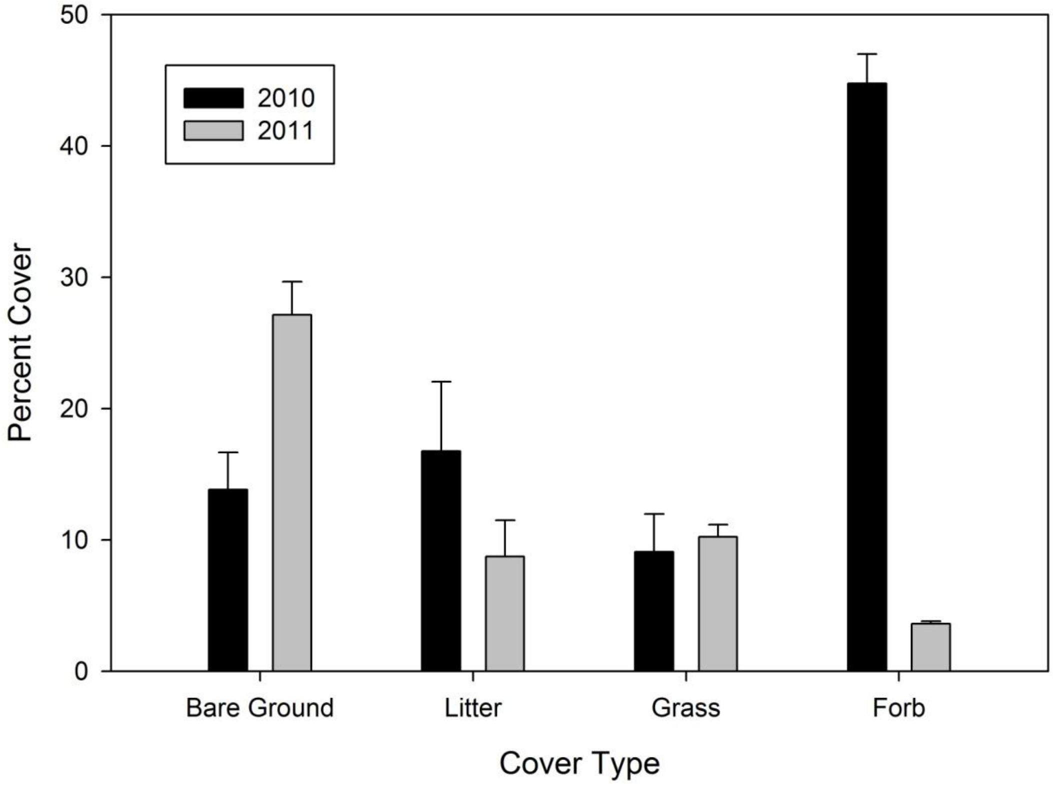

Figure 1.9. Cumulative treatment cover comparison for patch burning-grazing and rotational grazing across years for treatments applied in 2010 (Mean±SD).

Table 1.2. Within year 2009 species frequency comparison for patch burning-grazing and rotational grazing for all treatments 2009 (Mean±SD).

	2009 Burn	Rotational Grazing	Control	P-Value$^{0.05}$
Blue Grama	0.1700±0.02169	0.3125±0.02318	0.2789±0.01495	0.0030
Purple Threeawn	0.1733±0.02185	0.0875±0.01413	0.0900±0.00953	0.0037
Sand Dropseed	0.4567±0.02876	0.3225±0.02337	0.4244±0.01648	0.0056
Sideoats Grama	0.1267±0.01920	0.2275±0.02096	0.1944±0.01319	0.0169
Fringe Leaf Signal Grass	0.1533±0.02080	0.2950±0.02280	0.2822±0.01500	0.0017
Erect Dayflower	0.2200±0.02392	0.1900±0.01962	0.1078±0.01034	0.0005
Narrowleaf Globemallow	0.0433±0.01176	0.1375±0.01722	0.0433±0.00678	0.0001
Indian Blanket	0.4567±0.02876	0.7525±0.02158	0.8500±0.01190	<0.0001
Pepperweed	0.0400±0.01131	0.2900±0.02269	0.4656±0.01663	<0.0001
Plaintain	0.0600±0.01371	0.3225±0.02337	0.5756±0.01648	<0.0001
Western Ragweed	0.7567±0.02477	0.7000±0.02291	0.7400±0.01462	0.2296
Silverleaf Nightshade	0.1233±0.01898	0.1250±0.01654	0.1467±0.01179	0.4458

Table 1.3. Within year 2010 species frequency comparison for patch burning-grazing and rotational grazing for all treatments in 2010 (Mean±SD).

	2009 burn	2010 burn	Rotational Grazing	Control	P-Value$^{0.05}$
Blue Grama	0.1933±0.02280	0.1267±0.01920	0.1925±0.01971	0.1400±0.01417	0.0598
Purple Threeawn	0.3700±0.02787	0.1967±0.02295	0.1200±0.01625	0.2550±0.01779	<0.0001
Sand Dropseed	0.5600±0.02866	0.5467±0.02874	0.3950±0.02444	0.5083±0.02041	0.0032
Sideoats Grama	0.1433±0.02023	0.0366±0.01085	0.1225±0.01639	0.1167±0.01311	0.0087
Fringe Leaf Signal Grass	0.1833±0.02234	0.0866±0.01624	0.2975±0.02286	0.2317±0.01722	0.0002
Erect Dayflower	0.2600±0.02532	0.0933±0.01680	0.1150±0.01595	0.1333±0.01388	0.0004
Narrowleaf Globemallow	0.0533±0.01297	0.0733±0.01505	0.1925±0.01971	0.0966±0.01206	0.0004
Indian Blanket	0.8300±0.02196	0.7800±0.02392	0.6933±0.02662	0.7683±0.01722	0.0169
Pepperweed	0.2500±0.02500	0.1933±0.02280	0.3525±0.02389	0.4100±0.02008	0.0001
Plaintain	0.1867±0.02250	0.1000±0.01732	0.4300±0.02475	0.3600±0.01960	<0.0001
Western Ragweed	0.8000±0.02309	0.6633±0.02728	0.6625±0.02364	0.5783±0.02016	0.0003
Silverleaf Nightshade	0.2200±0.02392	0.2100±0.02352	0.1825±0.01931	0.1783±0.01563	0.4176

Table 1.4. Within year 2011 species frequency comparison for patch burning-grazing and rotational grazing for all treatments in 2011 (Mean±SD).

	2009 Burn	2010 Burn	2011 Burn	Rotational Grazing	Control	P-Value$^{0.05}$
Blue Grama	0.1100±0.01806	0.0933±0.01680	0.0466±0.01218	0.1350±0.01709	0.0200±0.00800	0.0030
Purple Threeawn	0.2767±0.02583	0.2700±0.02563	0.2333±0.02442	0.1525±0.01798	0.2567±0.02522	0.0141
Sand Dropseed	0.3733±0.02793	0.3600±0.02771	0.4600±0.02877	0.2875±0.02263	0.4633±0.02879	0.0030
Sideoats Grama	0.1800±0.2218	0.2233±0.02405	0.2167±0.02379	0.2125±0.02045	0.2800±0.02592	0.1271
Fringe Leaf Signal Grass	0.1133±0.01830	0.0366±0.01085	0.0966±0.01706	0.0300±0.00852	0.0400±0.01131	0.0037
Erect Dayflower	0.1900±0.02265	0.2033±0.02324	0.1300±0.01942	0.1900±0.01962	0.1767±0.02202	0.2298
Narrowleaf Globemallow	0.1000±0.01732	0.1233±0.01898	0.1167±0.01853	0.0650±0.1233	0.1133±0.01830	0.1481
Indian Blanket	0.1133±0.01830	0.0466±0.01218	0.1033±0.01757	$1.116e^{8}$±$5.281e^{6}$	0.0666±0.01440	0.0815
Pepperweed	$4.105e^{9}$±$3.699e^{6}$	$4.105e^{9}$±$3.699e^{6}$	$4.105e^{9}$±$3.699e^{6}$	$4.105e^{9}$±$3.203e^{6}$	$4.105e^{9}$±$3.699e^{6}$	1.0000
Plaintain	0.0366±0.01085	$3.033e^{8}$±0.00001	0.0066±0.00470	0.0100±0.00498	0.0066±0.00470	0.0834
Western Ragweed	0.2967±0.02637	0.3167±0.02686	0.6167±0.02807	0.3925±0.02442	0.3233±0.02701	<0.0001
Silverleaf Nightshade	0.0833±0.01596	0.1567±0.02099	0.1133±0.01830	0.0725±0.01297	0.0933±0.01680	0.0371

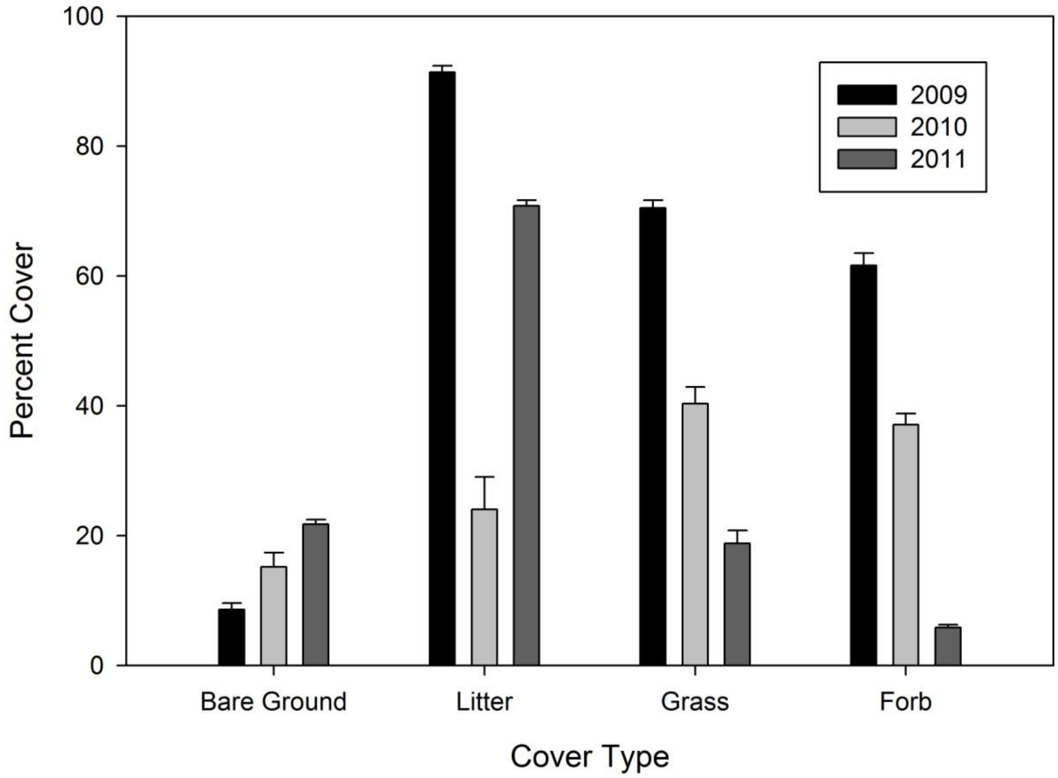

Figure 1.10. Cumulative treatment cover responses across years for patch burning without grazing (Mean±SE).

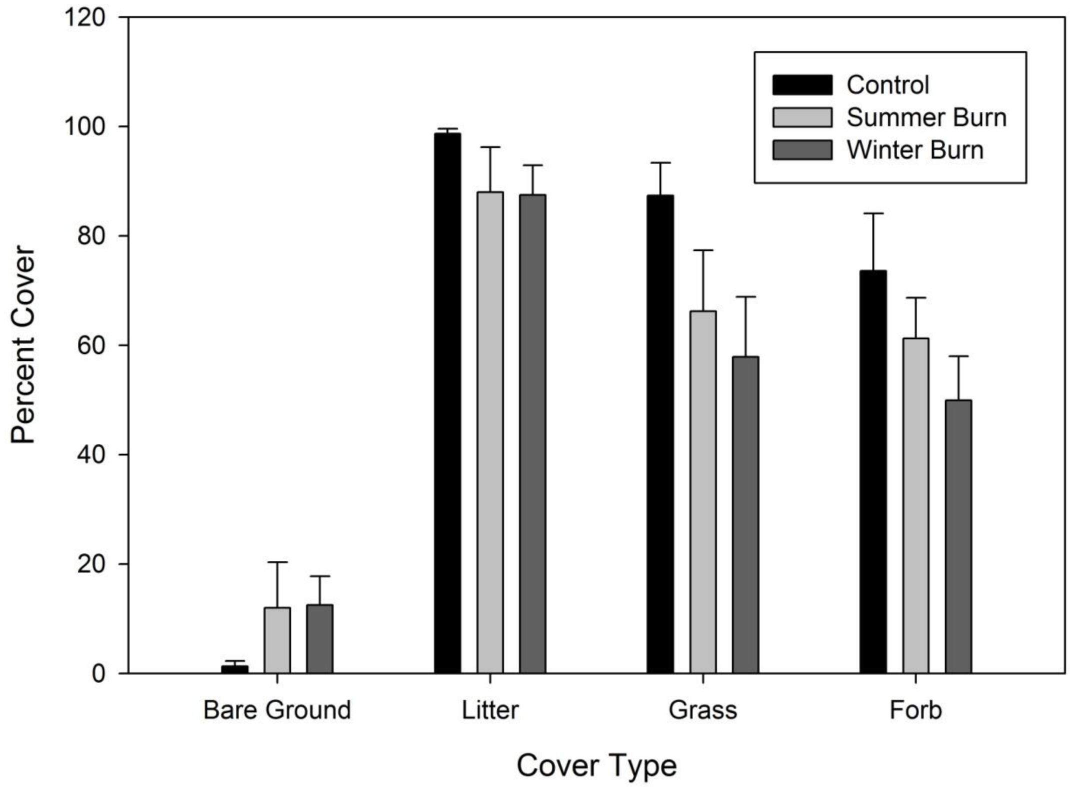

Figure 1.11. Cumulative year cover comparison for treatment for patch burning without grazing in 2009 (Mean±SE).

Table 1.5. Comparison of herbaceous species frequency in patch burning without grazing across treatments and years. (BLGR=blue grama, PUTH=purple threeawn, SADR=sand dropseed, SIGR=sideoats grama. FRSI=fringe leaf signal grass, ERDA=erect dayflower, NAGL=narrowleaf globemallow, INBL=indian blanket, PEPP=peppergrass, PLAI=plaintain. WERA=western ragweed, SINI=silverleaf nightshade) (Mean±SD).

	Control			Summer			Winter		
	2009	2010	2011	2009	2010	2011	2009	2010	2011
BLGR	30.6±32.05	18.2±20.90	26.4±34.8	31.4±27.21	14.6±20.73	23.0±26.30	9.2±9.68	2.6±1.14	19.4±18.30
PUTH	43.8±15.17	17.0±12.49	9.2±9.10	16.8±9.68	12.6±12.34	12.0±14.52	35.6±22.68	22.6±11.15	18.8±17.37
SADR	44.2±18.57	39.8±11.08	34.8±10.18	53.6±16.06	38.4±12.18	26.6±11.44	39.4±8.88	41.2±10.89	14.2±6.83
SIGR	30.8±11.19	21.2±16.75	16.6±10.21	32.4±22.73	25.8±14.48	37.2±20.09	38.6±26.44	27.6±15.27	40.2±28.53
FRSI	40.2±33.46	38.6±24.53	30.0±14.20	39.6±20.96	39.2±20.34	25.8±13.74	40.4±8.20	37.8±6.18	25.8±13.74
ERDA	13.8±11.92	23.2±17.43	9.4±8.08	17.0±8.72	19.4±8.02	4.8±4.09	28.2±8.17	25.2±10.43	5.0±3.08
NAGL	13.0±12.08	16.4±11.28	19.0±17.48	24.2±17.54	9.2±9.23	34.6±21.92	14.0±13.73	4.6±6.02	25.0±14.25
INBL	77.8±12.19	78.4±11.95	0.4±0.89	39.2±13.31	46.2±13.31	1.4±2.61	37.8±6.83	63.0±15.70	0.2±.45
PEPP	40.0±9.30	36.2±19.89	0.0±0.00	30.0±10.07	15.8±8.64	0.0±0.00	12.8±6.91	14.4±12.74	0.2±0.45
PLAI	38.8±13.70	25.4±13.16	1.2±1.30	48.8±13.68	29.4±10.06	4.2±4.60	19.8±9.04	21.2±8.76	6.4±8.14
WERA	58.8±29.18	62.0±18.65	43.6±11.13	29.4±20.28	43.2±17.56	29.8±12.50	61.0±12.71	80.2±3.11	41.8±11.3
SINI	25.4±15.01	21.8±12.68	13.2±10.33	31.8±16.87	26.2±14.92	15.8±9.68	21.6±13.11	15.0±7.48	7.2±2.50

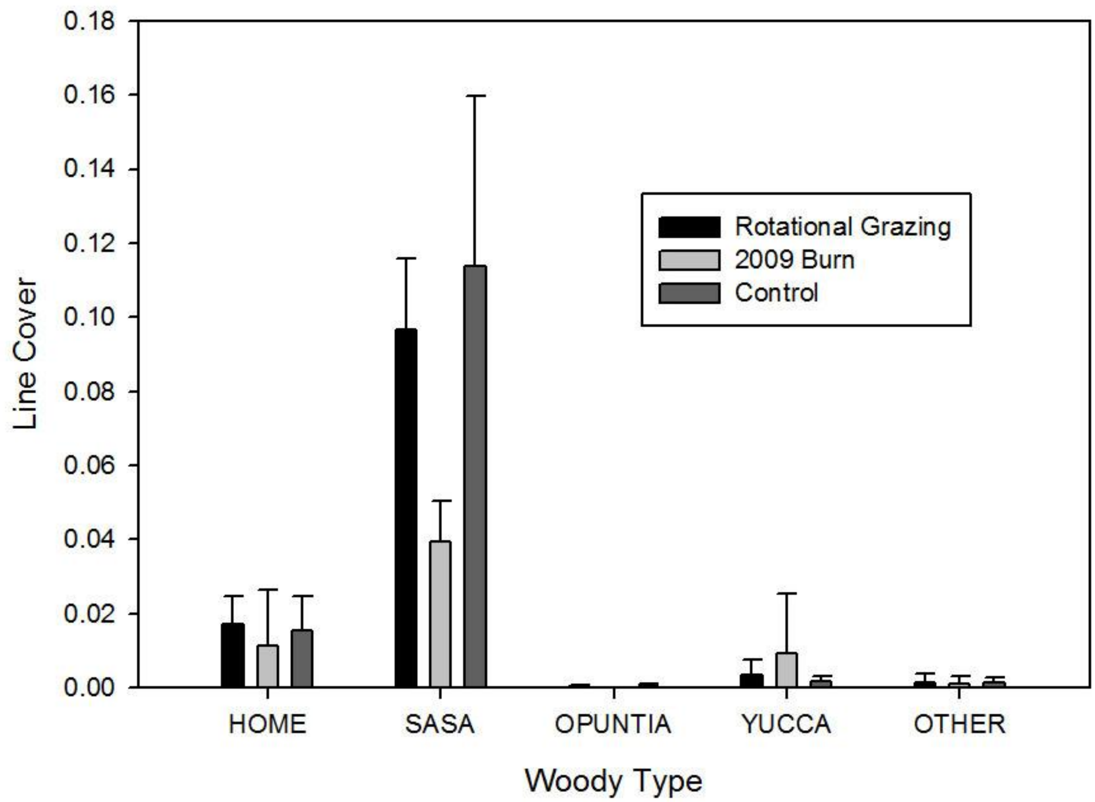

Figure 1.12. Within year 2009 woody line cover comparison for patch burning-grazing and rotational grazing for all treatments in 2009 (Mean±SD).

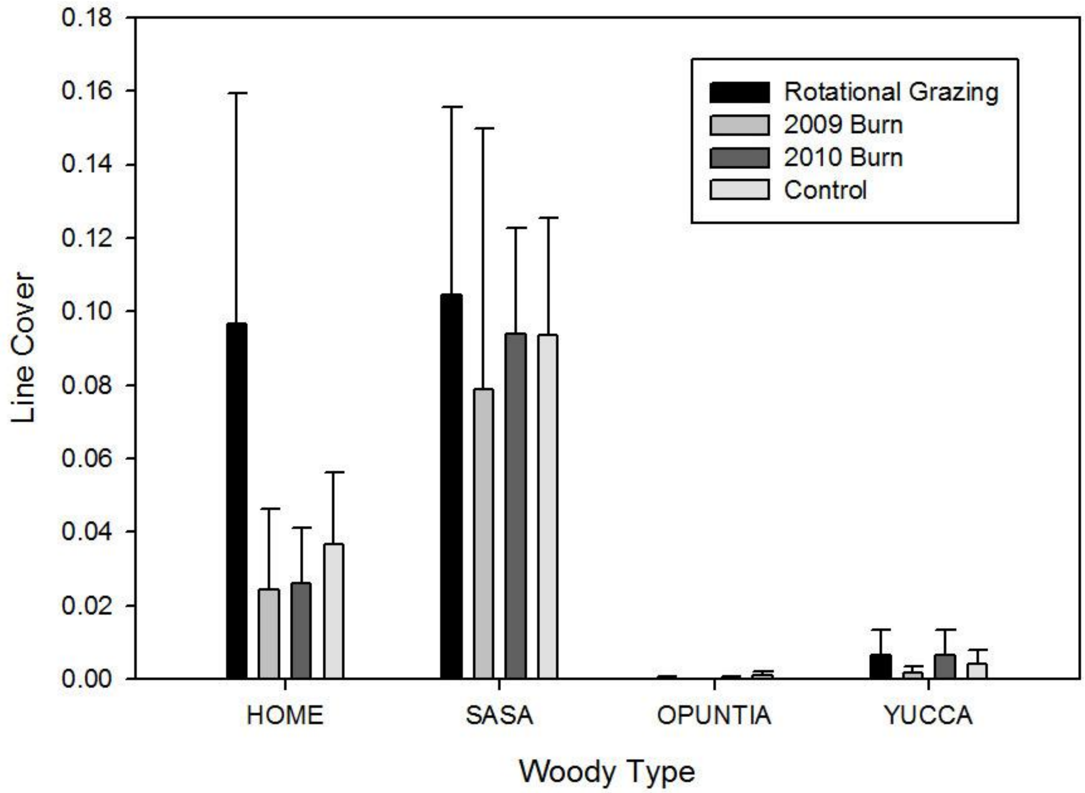

Figure 1.13. Within year 2010 woody line cover comparison for patch burning-grazing and rotational grazing for all treatments in 2010 (Mean±SD).

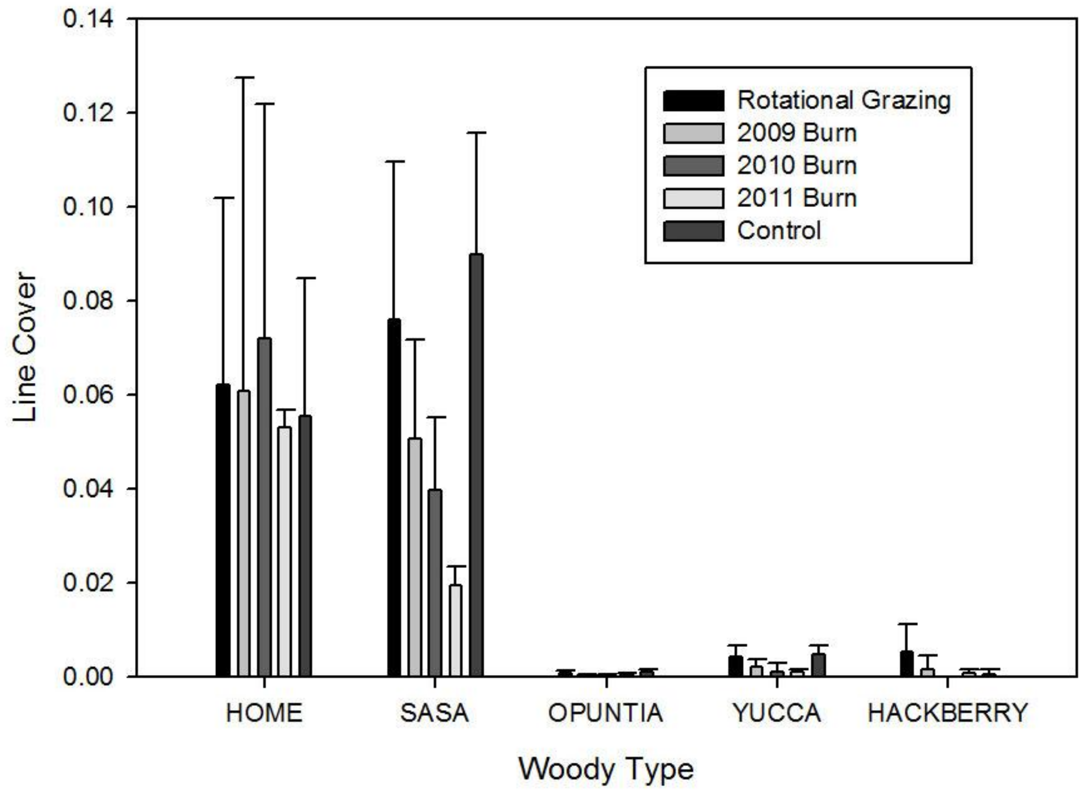

Figure 1.14. Within year 2011 woody line cover comparison for patch burning-grazing and rotational grazing for all treatments in 2011 (Mean±SD).

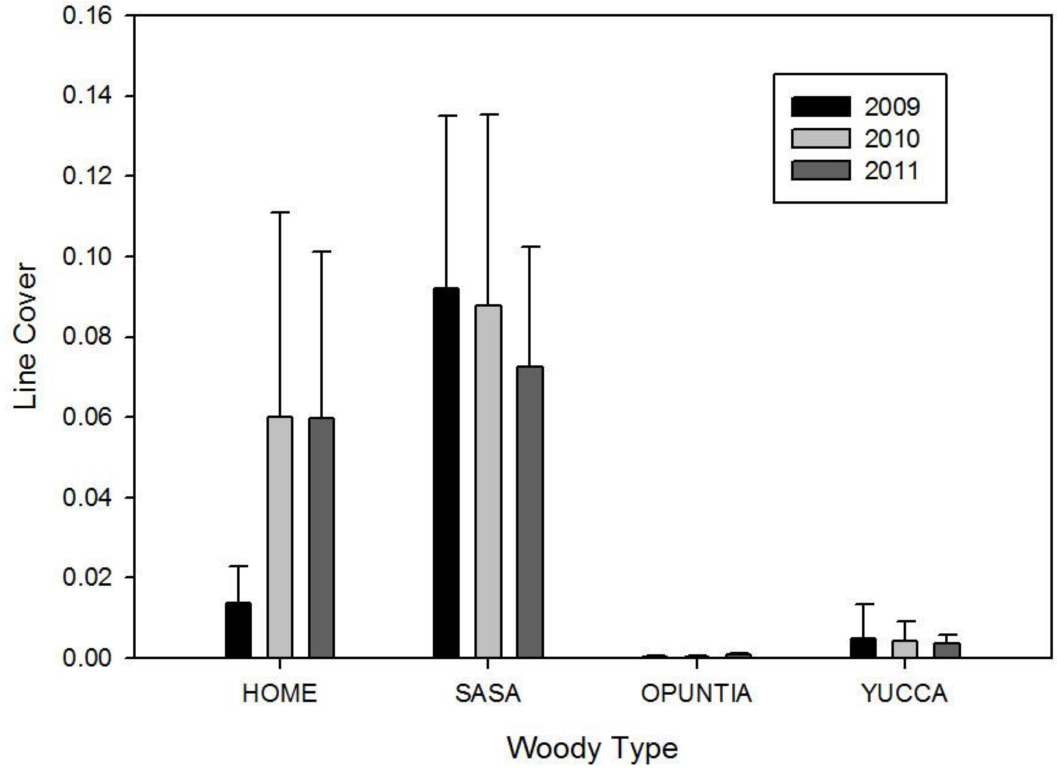

Figure 1.15. Cumulative treatment woody line cover comparison for patch burning-grazing and rotational grazing across years 2009-2011 (Mean±SD).

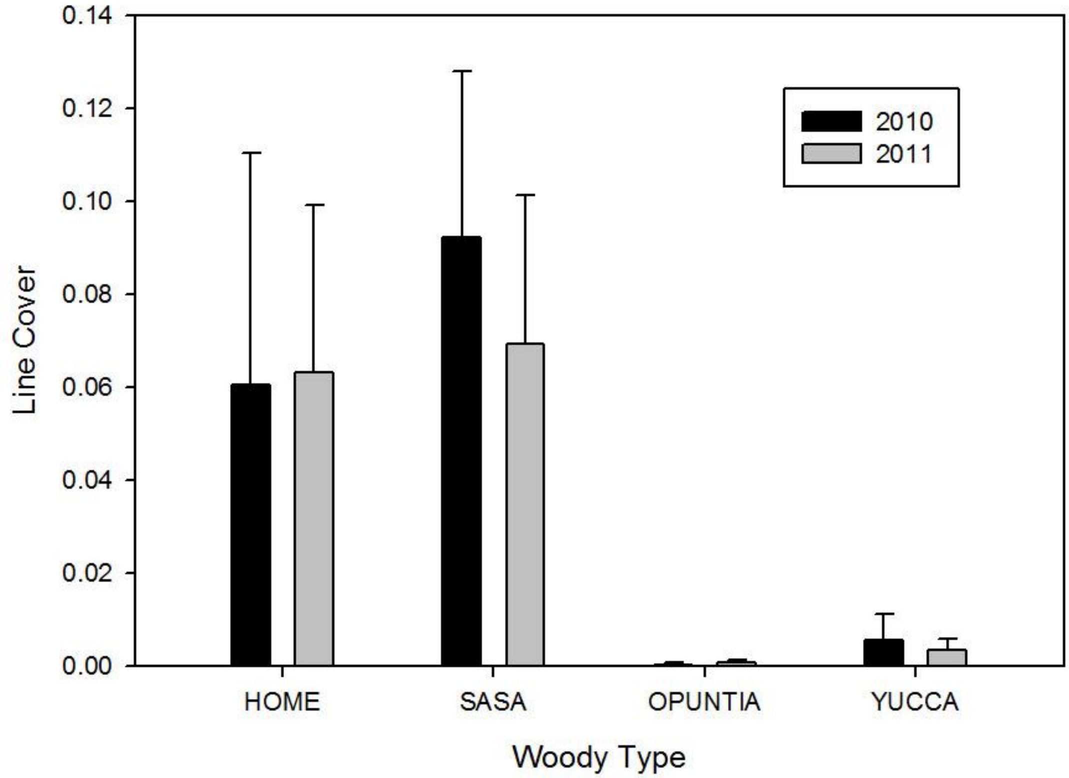

Figure 1.16. Cumulative treatment woody line cover comparison for patch burning-grazing and rotational grazing across years 2010 and 2011.

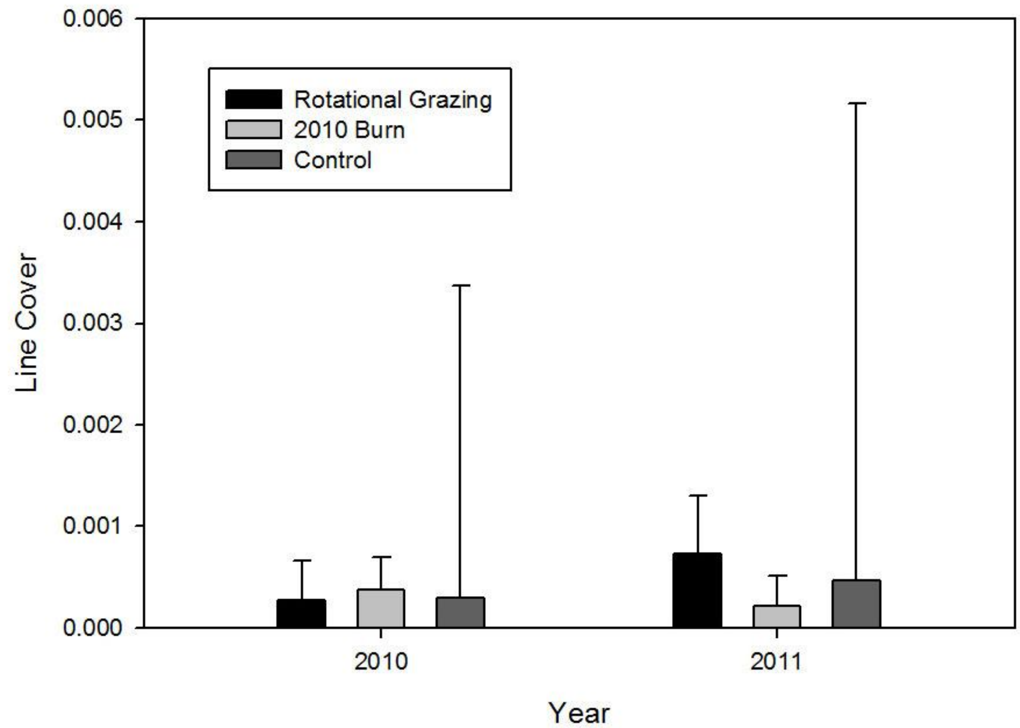

Figure 1.17. Line cover for patch burning-grazing and rotational grazing for Opuntia for treatments within years 2010 and 2011(Mean±SD).

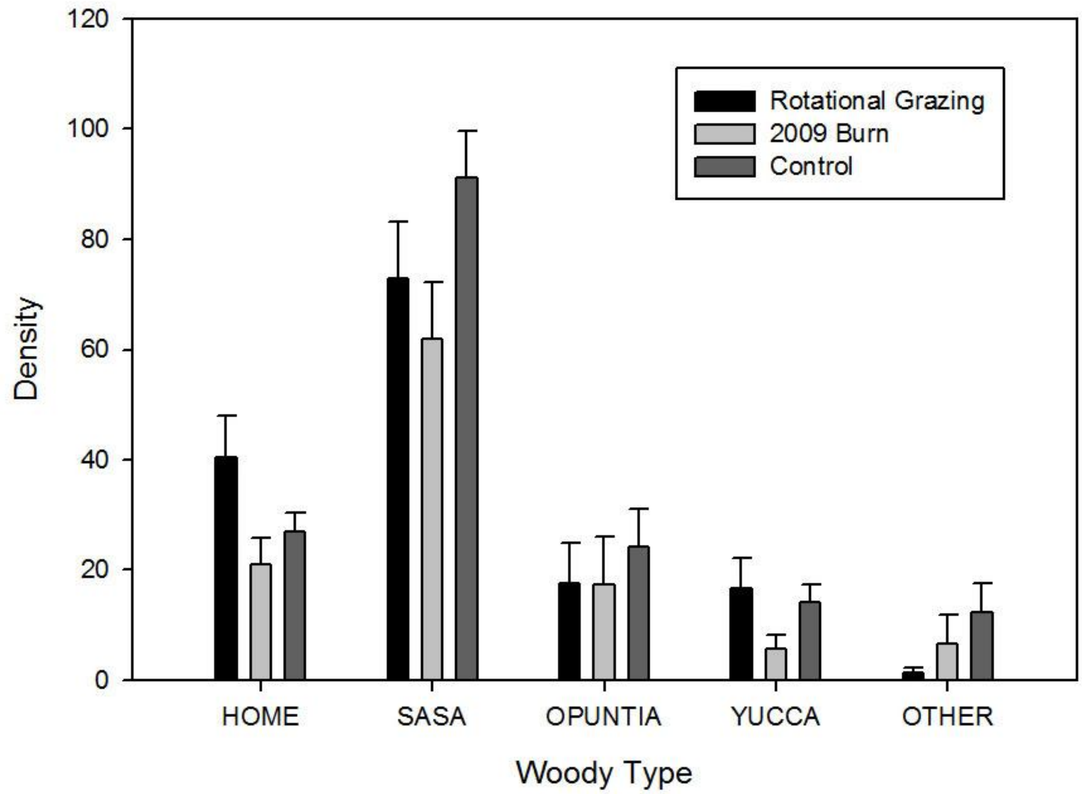

Figure 1.18. Within year 2009 woody density comparison for patch burning-grazing and rotational grazing for all treatments in 2009 (Mean±SD).

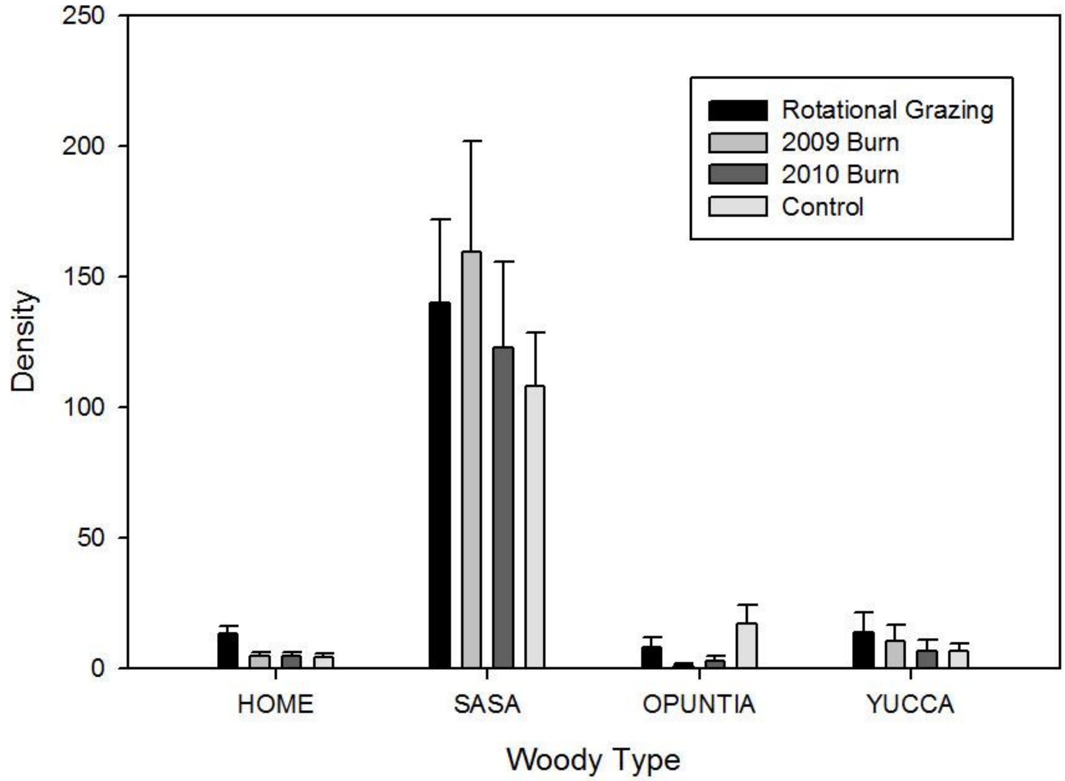

Figure 1.19. Within year 2010 woody density comparison for patch burning-grazing and rotational grazing for all treatments in 2010 (Mean±SD).

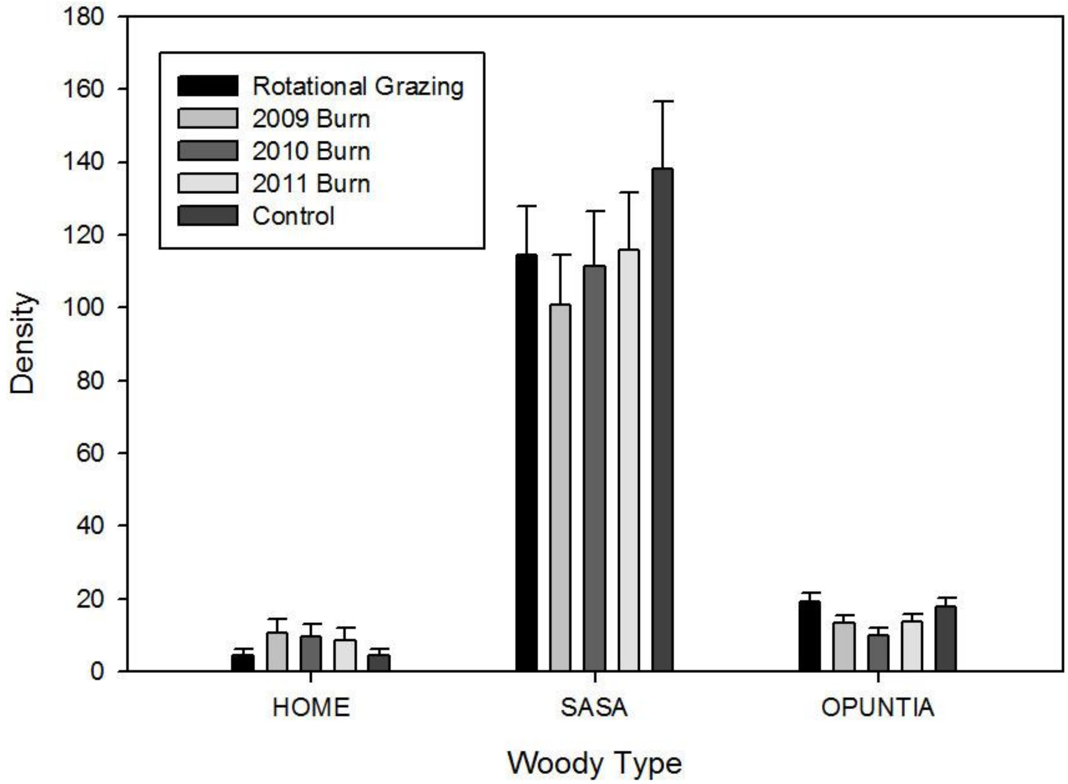

Figure 1.20. Within year 2011 woody density comparison for patch burning-grazing and rotational grazing for all treatments in 2011 (Mean±SD).

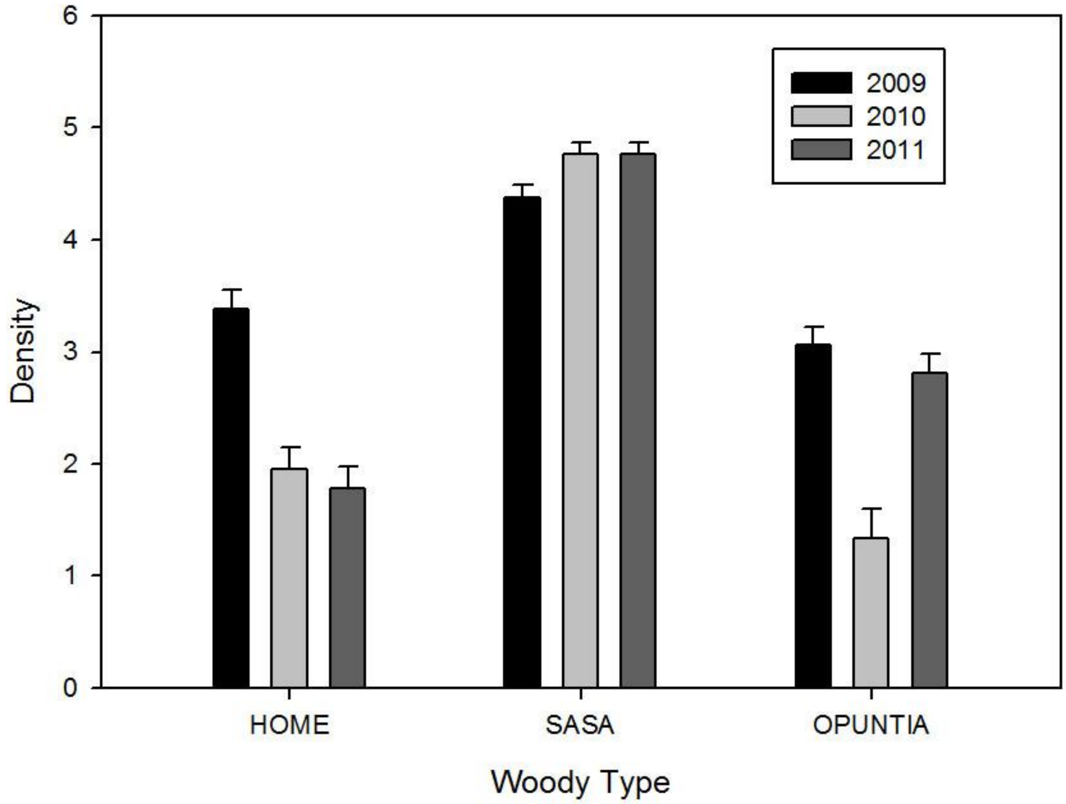

Figure 1.21. Cumulative treatment woody density comparison for patch burning-grazing and rotational grazing for years 2009-2011 (Mean±SD).

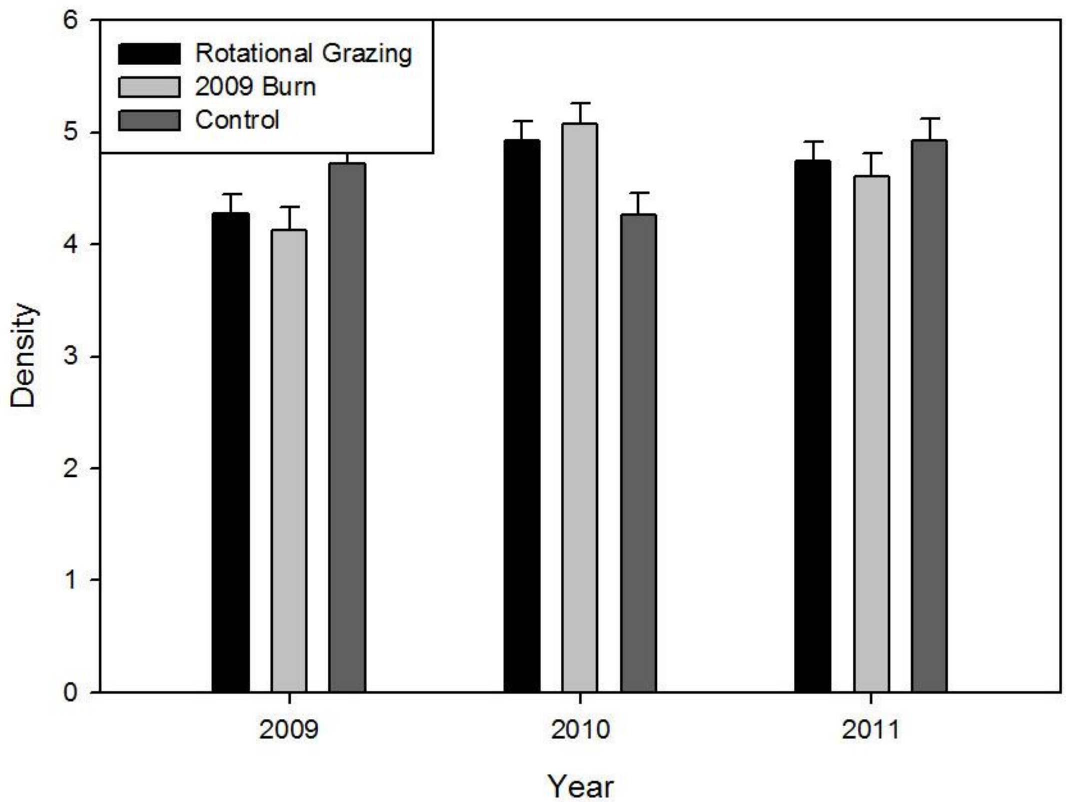

Figure 1.22. Density for sand sage in patch burning-grazing and rotational grazing for treatments across years 2009-2011 (Mean±SD).

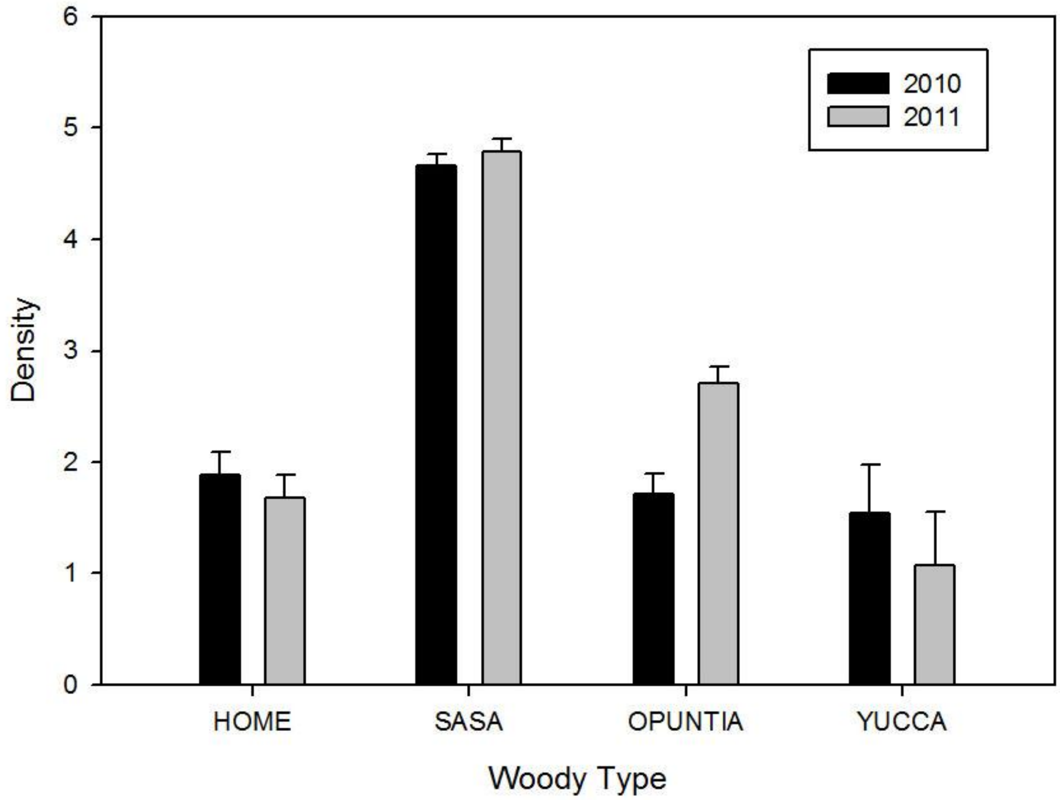

Figure 1.23. Cumulative treatment woody density comparison for patch burning-grazing and rotational grazing for treatments applied in 2010 for years 2010-2011 (Mean±SD).

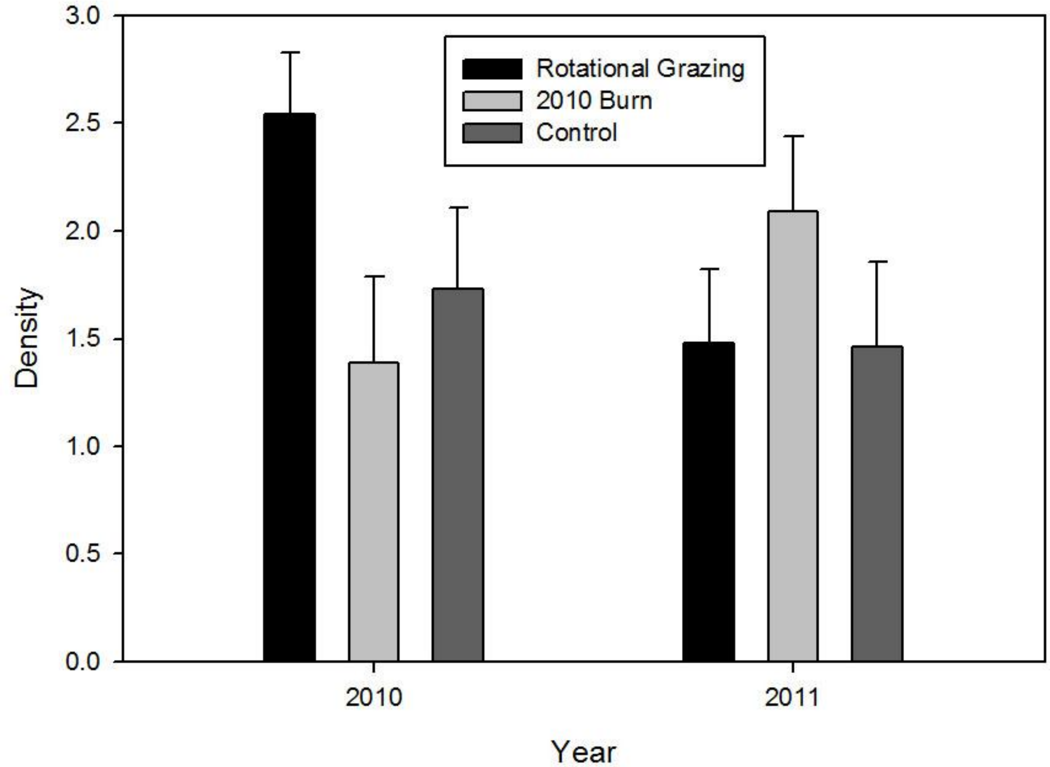

Figure 1.24. Density for honey mesquite in patch burning-grazing and rotational grazing for treatments across years 2010 and 2011 (Mean±SD).

Table 1.6. Comparison of woody species line cover in patch burning without grazing across treatments and years. (HOME=honey mesquite, SASA=sand sage, OPUN=Opuntia, YUCC=yucca, SHIN=sand shinnery, PLUM=sand plum, HACK=netleaf hackberry, OTHE=other) (Mean±SD).

	Control			Summer			Winter		
	2009	2010	2011	2009	2010	2011	2009	2010	2011
HOME	0.05±0.01	0.02±0.01	0.08±0.02	0.01±0.00	0.05±0.01	0.02±0.02	0.007±0.00	0.04±0.02	0.02±0.00
SASA	0.13±0.03	0.15±0.01	0.07±0.01	0.06±0.01	0.06±0.01	0.06±0.01	0.08±0.01	0.07±0.02	0.090.02
OPUN	0.002±0.00	0.0003±0.00	0.002±0.00	0.0002±0.00	0.0006±0.00	0.0004±0.00	0.004±0.00	0.0002±0.00	0.001±0.00
YUCC	0.005±0.00	0.005±0.00	0.004±0.00	0.003±0.00	0.001±0.00	0.004±0.00	0.004±0.00	0.002±0.00	0.005±0.00
SHIN	0.00±0.00	0.002±0.00	0.00±0.00	0.02±0.02	0.00±0.00	0.006±0.00	0.002±0.00	0.00±0.00	0.0008±0.00
PLUM	0.00±0.00	0.005±0.00	0.00±0.00	0.00±0.00	0.0009±0.00	0.00±0.00	0.00±0.00	0.00007±0.0	0.00±0.00
HACK	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
OTHE	0.00±0.00	0.00±0.00	0.0003±0.00	0.00±0.00	0.003±0.00	0.0004±0.00	0.00±0.00	0.0002±0.00	0.001±0.00

Table 1.7. Comparison of woody species density in patch burning without grazing across treatments and years. (HOME=honey mesquite, SASA=sand sage, OPUN=Opuntia, YUCC=yucca, SHIN=sand shinnery, PLUM=sand plum, HACK=netleaf hackberry, ACAC=acacia, OTHE=other) (Mean±SD).

	Control			Summer			Winter		
	2009	2010	2011	2009	2010	2011	2009	2010	2011
HOME	0.6±1.34	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	1.0±1.7	0.0±0.0	0.0±0.0
SASA	134.4±63.5	153.2±35.3	174.4±76.8	141.0±48.1	88.2±25.15	174.8±74.9	180.4±53.5	111.8±51.2	221.2±73.8
OPUN	20.6±28.3	6.6±6.0	32.0±12.6	2.8±4.1	7.4±3.0	7.0±5.7	30.0±51.9	5.2±2.4	39.4±54.5
YUCC	8.6±7.0	10.4±6.8	9.4±15.3	14.2±13.0	5.0±7.3	18.624.5	10.0±13.5	6.4±7.3	7.4±10.6
SHIN	0.0±0.0	2.4±5.4	0.0±0.0	1.6±3.6	0.0±0.0	102.6±229.4	0.4±0.9	0.0±0.0	0.2±0.4
PLUM	0.0±0.0	6.2±13.9	0.0±0.0	0.0±0.0	5.0±11.2	0.0±0.0	0.0±0.0	1.6±2.6	0.0±0.0
HACK	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.2±0.4	0.0±0.0	0.0±0.0	0.0±0.0
ACAC	0.6±1.3	0.0±0.0	0.0±0.0	1.2±1.3	0.0±0.0	0.0±0.0	1.0±1.73	0.0±0.0	0.0±0.0
OTHE	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.6±1.3	0.2±0.4	0.0±0.0	1.6±1.9	13.4±26.7

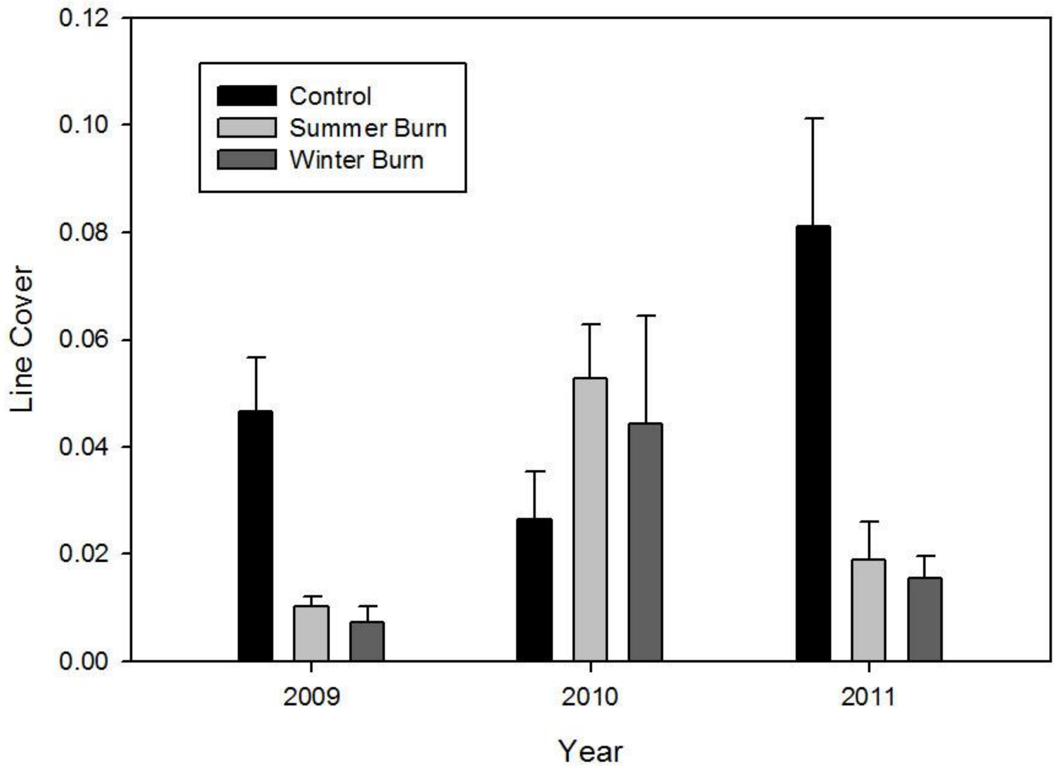

Figure 1.25. Comparisons of honey mesquite line cover in treatments across years 2009-2011 (Mean±SD).

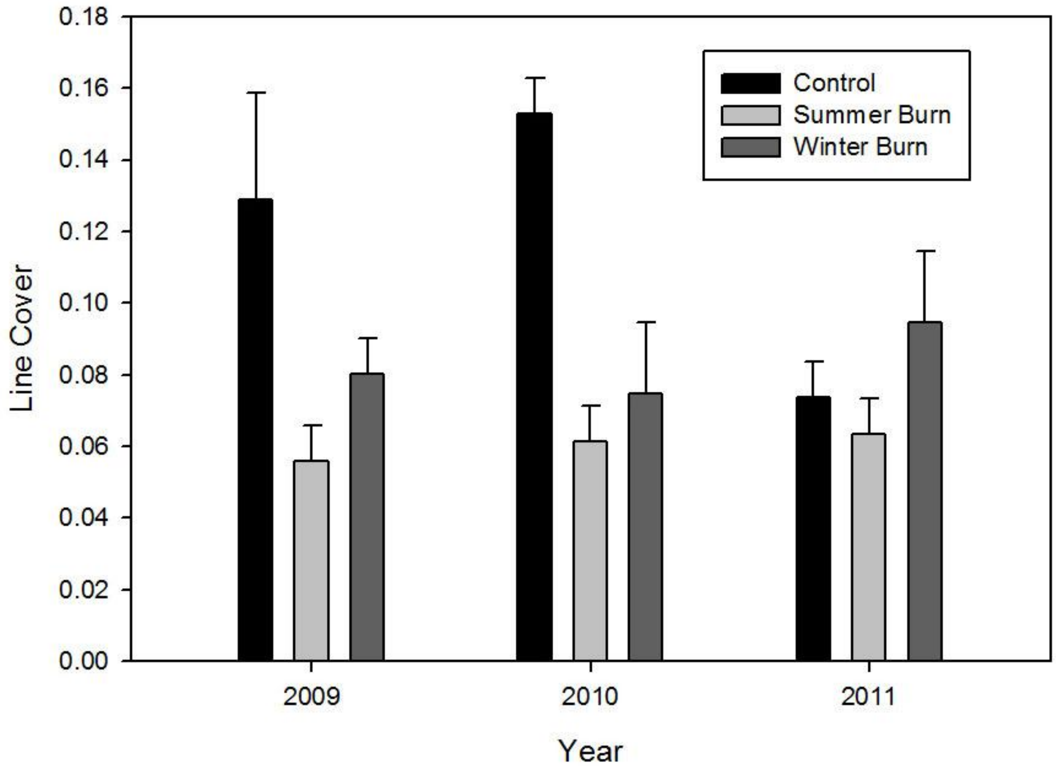

Figure 1.26. Comparisons of sand sage line cover in treatments across years 2009-2011 (Mean±SD).

CHAPTER II

PATCH BURNING AND GRAZING EFFECTS ON GRASSLAND BIRDS IN A SAND SAGEBRUSH-HONEY MESQUITE RANGELAND

INTRODUCTION

The Rolling Plains ecoregion of Texas historically contained a diverse mixture of habitats that supported a large and diverse group of avifauna. This ecoregion evolved with fire and bison grazing that created a shifting mosaic of patches within the landscape, varying in time and space since their last disturbance (Fuhlendorf and Engle 2004). Prior to human involvement, lightning strikes were the primary natural source of ignition of vegetation (Komarek 1966). Following European settlement in the Great Plains there was an increase in fire suppression as well as a change in grazing practices that have contributed to a change in the vegetative dynamics of the Great Plains (Archer et al. 1988). The early culture of fire suppression in this region has allowed livestock to disperse seeds that have allowed the encroachment of many woody species, namely honey mesquite (*Prosopis glandulosa*) (Wright 1974, Archer et al. 1988). Most grazing and burning practices currently used focus on homogenous habitats designed for efficient grazing. Heterogeneity needed for the ecosystems to function is lost (Briske et al. 2003; Fuhlendorf and Engle 2001). A large scale homogenous habitat does not benefit multiple species that require differing levels of succession in their habitat (Weir et al. 2007).

Patch burning and grazing is a new emerging technique that can provide heterogeneity through varying disturbance temporally and spatially. This technique of patch burn-grazing mimics the interaction of fire and grazing that occurred prior to settlement of the Great Plains. Patch burning has been described as the purposeful grazing of a section of a landscape or management unit that has been prescribed burned, and then burning another section to refocus the grazing pressure to the newly disturbed unit, creating a shifting mosaic on the landscape (Weir et al. 2007). In the Great Plains it is suggested that a new patch be burned every 6-12 months to shift the grazing focus (Weir et al. 2007). This allows for the previously burned unit to receive less grazing pressure and transition through different levels of standing biomass and litter accumulation to where it can be burned again in 2.5 to 3 years. With the improved heterogeneity in the vegetation, and the varying levels of succession that this system provides, many habitat types are available (Fuhlendorf et al. 2006).

Patch-burn grazing could potentially be beneficial for wildlife, because many species are adapted to these varying levels of disturbance. Grassland birds, as an ecological grouping, have experienced a greater decline than any other grouping of species in North America (Knopf 1996, Rich et al. 2004). At local scales there are variable responses of different species of grassland birds to different management practices since some species prefer newly disturbed areas while others prefer undisturbed areas, consequently, there is evidence at regional scales that availability of habitat is influencing much of the regional grassland bird declines (Herkert et al. 1996). Not all species within the ecological grouping of grassland birds prefer the same type of disturbance or habitat and management practices that promote homogeneity can negatively impact many species of grassland birds. For instance, Eastern meadowlarks, grasshopper sparrows, Henslow’s sparrows, savannah sparrows and Baird’s sparrows tend to avoid areas that have too much woody encroachment (Arnold and Higgins 1986). The patch burning grazing system may provide superior habitat characteristics for grassland bird species as compared to traditional range management practices that use large homogenous burns and continuous or rotational grazing. The objectives of my study were to compare the effects of a patch-burn grazing system on grassland bird diversity and abundance as compared to traditional range management practices used in a sand sagebrush – honey mesquite rangeland.

STUDY AREA

Matador Wildlife Management Area

This study was conducted within the Matador Wildlife Management Area (WMA), located in Cottle County, Texas approximately 10 km North of the town of Paducah, Texas. The Matador WMA is 11,410-ha located in the Rolling Plains ecoregion of Texas for the purposes of wildlife research and management as well as public use. Matador WMA was purchased by the state of Texas in 1959 using Pittsman-Robertson funds and serves as a research and demonstration area that is managed by Texas Parks and Wildlife. Climate is described as subtropical with dry winters and hot, humid summers with an average annual rainfall of 56.2 cm (Richardson et al. 1974). Rainfall is quite variable monthly to yearly and occurs most frequently as a result of thunderstorms (Richardson et al. 1974). Months of greatest average rainfall are May (9 cm) and June (8.8 cm; Richardson et al. 1974; Table 8). Topography ranges from nearly level to very steep (Richardson et al. 1974). The predominant soil association is Miles – Springer consisting of soils nearly level to strongly sloping, deep, coarse textured and moderately coarse textured soils on outwash plains. In particular, the soils contained within my unique study area within Matador WMA consist of Miles (fine-loamy, mixed, thermic, alfisols), and Springer (coarse-loamy, mixed, thermic, alfisols; Richardson et al. 1974).

Predominant woody vegetation occurring within the Matador WMA included honey mesquite (*Prosopis glandulosa*), redberry juniper (*Juniperus pinchotii*), netleaf hackberry (*Celtis reticulata*), eastern cottonwood (*Populus deltoides*), salt cedar (*Tamarix gallica*), Chickasaw plum (*Prunus angustifolia*), and sand sagebrush (*Artemisia filifolia*). Predominant grass species found on the area included little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), sideoats grama (*Bouteloua curtipendula*), purple threeawn (*Aristida purpurea*), Japanese brome (*Bromus japonicus*) and plains bristlegrass (*Setaria leucopila*). Predominant forb species on the area included western ragweed (*Ambrosia psilostachya*), woolly plantain (*Plantago insularis*), annual sunflower (*Helianthus annus*), and lamb's quarters (*Chenopodium album*, Hall 2005).

METHODS

Burning and Experimental Design

My study site consisted of 619-ha of contiguous sand sagebrush-mesquite rangeland in the Entrance and Headquarters pastures of the Matador Wildlife Management Area (34.117721, -100.356536). I compared patch-burning grazing treatment, rotational grazing treatment, summer and winter burn without grazing, and control or undisturbed areas within this study. Space and timing constraints prevented one experimental design incorporating a combination of all these possible treatments of interest within a single grid. The patch burn-grazing and rotational grazing plots were analyzed separately from the patch burn without grazing plots, essentially being analyzed as separate studies.

Patch burning-grazing treatments consisted of 12 plots approximately 17-ha in size (Figure 2.1) located within the Entrance pasture. The 12 plots were randomly assigned one of four treatments; control (unburned), 2009 winter burn, 2010 winter burn, and 2011 winter burn. Hence, in 2009 the plots designated for 2010 winter burn and 2011 winter burn were treated as controls since they were scheduled for burn in following years. Further, plots designated for a 2011 burn treatment were used as controls during 2010. These plots were compared to rotational grazing only treatments consisting of 4, 18-ha plots separated by fencing (Figure 1) also located in the entrance pasture. These comparisons between patch burning-grazing, rotational grazing, and control treatments were analyzed using 3 separate repeated measures analysis of variance restricted to single years. Analyses were restricted to single years (2009, 2010, and 2011), because the number of replicates changed through the duration of the study as additional plots were burned in 2010 and 2011. Comparison of changes across years was accomplished using 2 separate repeated measures analysis of variance. The first analysis compared metrics (cover, frequency, and density data) that could be followed for 3 years; from 2009 to 2011. Likewise, a second analysis was used to compare metrics from treatments that became available during 2010 and could be followed for only 2 years (2010 to 2011).

The patch burning-grazing and rotational grazing plots were grazed at the NRCS recommended stocking rate, which was approximately one animal unit per 14-ha. Water facilities were installed so that at any position within the study area cattle were within 0.8 km (1/2 mile) of water.

In the Headquarters pasture plots were not subjected to grazing and consisted of 15, 18-ha burn plots. The pasture was divided into a 3 x 5 grid containing 5 blocks with three treatments randomly assigned to the three plots located within each block. Using a randomized block design, the three plots within each block were randomly assigned the treatments control (non-burned), summer burn, and winter burn. The summer burns were conducted in August 2008 and winter burns were conducted in February 2009.

Grassland Bird Sampling

Grassland birds were sampled using extensive point counts as described by (Ralph et. al 1993). In order to sample every treatment plot, a single point was placed within each treatment plot. Each plot was approximately 17-18 ha in size. The point was placed at the geometric center of each plot using ArcGIS®. Points were visited April-June to coincide with the breeding season when song birds are most vocal. In order not to bias data collection a protocol was developed through suggestions made by Ralph et. al 1993. Counts were conducted within the time block of 15 min before sunrise and 10 am. Counts were not to be performed if wind exceeded 16.09 km/h (10 m/h), if fog was present, or general inclement weather as it could affect the ability of an observer to detect songs or a birds potential to sing. Each point was visited for 5 min and each species located within the treatment plot that was identified by song or sight was recorded, as well as the individual number of each certain species that was identified within the plot. To avoid visiting the same point at the same time throughout the observation months, the route in which the counts were conducted was randomly changed with each observation day.

RESULTS

Patch Burn-Grazing and Rotational Grazing

Species Richness

In 2009, treatments available were 2009 burn, rotational grazing, and control. There was no visit*treatment interaction for species richness in 2009 (F=0.765, P=0.635). There was a difference in species richness between visits (F=6.265, P<0.0001, Figure 2.2). Visit 1 had a higher species richness than Visit 4 (P=0.004) and Visit 5 (P=0.031). Visit 2 had a higher species richness than Visit 4 (P=0.003) and Visit 5 (P=0.008). Visit 3 had a higher species richness than Visit 4 (P=0.007). There was no significant difference between treatments (F=0.870, P=0.442, Figure 2.3)

In 2010, treatments available were 2009 burn, 2010 burn, rotational grazing, and control. There was no visit*treatment interaction for species richness in 2010 (F=1.571, P=0.133). There was a difference in species richness between visits (F=3.060, P=0.025, Figure 2.4). Visit 5 had a higher species richness than Visit 1 (P=0.036) and Visit 2 (P=0.035). There was no difference in species richness between treatments (F=0.394, P=0.759, Figure 2.5).

In 2011 treatments available were 2009 burn, 2010 burn, 2011 burn, rotational grazing, and control. There was no visit*treatment interaction detected for species richness in 2011 (F=0.557, P=0.898). There was no significant difference detected between visits (F=1.853, P=0.136, Figure 2.6). There was no significant difference between treatments for species richness in 2011 (F=0.156, P=0.956, Figure 2.7).

Species Richness for Treatments Applied in 2009 from 2009-2011

There was no visit*treatment interaction for species richness (F=0.329, P=0.953). There was a visit*year interaction detected for species richness (F=5.724, P<0.0001, Figure 2.8). Since there was no difference in visit (F=0.686, P=0.649) so year can be examined. There was a significant difference in year for species richness (F=13.348, P<0.0001). Species richness was higher in 2009 than in years 2010 (P=0.001) and 2011 (P<0.0001). There was not a visit*treatment*year interaction detected (F=0.994, P=0.471). There was no significant difference among treatments (F=0.241, P=0.788).

Species Richness for Treatments Applied in 2010 from 2010-2011

There was no visit*treatment interaction detected for species richness (F=0.661, P=0.062). There was no significant difference in visits (F=2.881, P=0.062, Figure 2.9). There was no visit*year interaction detected (F=1.462, P=0.246). There was no visit*treatment*year interaction detected (F=1.462, P=0.246). There was no significant difference among treatments (F=0.99, P=0.959, Figure 2.10). There was no significant difference between years (F=0.734, P=0.406, Figure 2.11).

Total Bird Abundance

In 2009, treatments available were 2009 burn, rotational grazing, and control. There was no visit*treatment interaction detected for total bird abundance (F=2.077, P=0.103). There was a significant difference detected for visits (F=4.121, P=0.023, Figure 2.12). Total bird abundance lower in Visit 4 than Visit 1 (P=0.017), Visit 2

(P=0.036), and Visit 3 (P=0.020). There was a significant difference in treatment on total bird abundance in 2009 (F=13.116, P=0.001, Figure 2.13). Rotational grazing had a higher total bird abundance than both 2009 burn (P<0.0001) and control (P=0.019). Control had a higher total bird abundance than 2009 burn (P=0.004).

In 2010, treatments available were 2009 burn, 2010 burn, rotational grazing, and control. There was no visit*treatment interaction for total bird abundance in 2010 (F=0.915, P=0.540). There was a significant difference in visits detected (F=3.495, P=0.014, Figure 2.14). Visit 4 had a higher total bird abundance than Visit 2 (P=0.003), Visit 3 (P=0.023), and Visit 5 (P=0.030). There was no difference in treatment for total bird abundance in 2010 (F=0.519, P=0.677, Figure 2.15).

In 2011 treatments available were 2009 burn, 2010 burn, 2011 burn, rotational grazing, and control. There was no visit*treatment interaction detected for total bird abundance in 2011 (F=0.412, P=0.972). There was a significant difference in total bird abundance detected for visit (F=8.427, P<0.0001, Figure 2.16). Visit 4 had a higher total bird abundance than Visit 1 (P=0.001), Visit 3 (P=0.087), and Visit 5 (P<0.0001). Visit 2 had higher total bird abundance than Visit 1 (P=0.007) and Visit 5 (P<0.0001). Visit 3 had a higher total bird abundance than Visit 1 (P=0.023) There was no difference in total bird abundance for treatment in 2011 (F=0.287, P=0.880, Figure 2.17).

Total Bird Abundance for Treatments Applied in 2009 from 2009-2011

There was no visit*treatment interaction detected for total bird abundance (F=0.614, P=0.680). There was a visit*year interaction detected for total bird abundance (F=4.302, P=0.003, Figure 2.18). There was no significant difference in visit (F=0.598, P=0.579). There was a difference in year for total bird abundance (F=36.794, P<0.0001). Total bird abundance was higher in 2009 than years 2010 (P<0.0001) and 2011 (P<0.0001). There was no visit*treatment*year interaction detected for total bird abundance (F=1.591, P=0.141).

Total Bird Abundance for Treatments Applied in 2010 from 2010-2011

There was no visit*treatment interaction detected for total bird abundance (F=0.181, P=0.993). There was a visit*year interaction detected for total bird abundance (F=3.927, P=0.007, Figure 2.19). There was significant difference in visit for total bird abundance (F=5.592, P=0.001). Visit 4 had a higher total bird abundance than Visit 1 (0.003), Visit 2 (P=0.023), Visit 3 (P=0.031), and Visit 5 (P=0.001). Visit 2 had a higher total bird abundance than Visit 1 (P=0.032). Visit 3 had a higher total bird abundance than Visit 1 (P=0.035). There was no significant difference in total bird abundance between years (F=1.345, P=0.265). There was no visit*treatment*year interaction detected (F=0.604, P=0.771)

Cassin's Sparrow Abundance

In 2009, treatments available were 2009 burn, rotational grazing, and control. There was no visit*treatment interaction detected for Cassin's Sparrow abundance (F=1.154, P=0.344). There was no significant difference between visits for Cassin's Sparrow abundance (F=1.421, P=0.240, Figure 2.20). There was a significant difference between treatments for Cassin's Sparrow abundance (F=3.986, P=0.045, Figure 2.21). Rotational grazing treatment had a higher Cassin's Sparrow abundance than 2009 burn treatment (P=0.015).

In 2010, treatments available were 2009 burn, 2010 burn, rotational grazing, and control. There was no visit*treatment interaction detected for Cassin's Sparrow abundance ($F=0.724$, $P=0.721$). There was a significant difference between visits for Cassin's Sparrow abundance ($F=6.930$, $P<0.0001$, Figure 2.22). Visit 4 had a higher Cassin's abundance than Visit 2 ($P=0.024$) and Visit 5 ($P<0.0001$). Visit 3 was higher than Visit 5 (0.014). Visit 1 was higher than Visit 5 (0.004). Visit 2 was higher than Visit 5 ($P=0.038$). There was no significant difference between treatments for Cassin's Sparrow abundance ($F=0.169$, $P=0.915$, Figure 2.23).

In 2011 treatments available were 2009 burn, 2010 burn, 2011 burn, rotational grazing, and control. There was no visit*treatment interaction detected for Cassin's Sparrow abundance in 2011 ($F=1.089$, $P=0.0394$). There was a significant difference among visits for Cassin's Sparrow abundance in 2011 ($F=21.964$, $P<0.0001$, Figure 2.24). Visit 2 was higher than Visit 1($P<0.0001$), Visit 3 ($P=0.001$), and Visit 5 ($P<0.0001$). Visit 4 was higher than Visit 1 ($P<0.0001$), Visit 3 ($P=0.001$), and Visit 5 ($P<0.0001$). Visit 5 was higher than Visit 1 ($P=0.003$). There was no significant difference in treatment detected for Cassin's Sparrow abundance ($F=1.375$, $P=0.305$, Figure 2.25).

Cassin's Sparrow Abundance for Treatments Applied in 2009 from 2009-2011

There was no visit*treatment interaction detected for Cassin's Sparrow abundance ($F=0.522$, $P=0.837$). There was a visit*year interaction detected for Cassin's Sparrow abundance ($F=5.019$, $P<0.0001$, Figure 2.26). Since there was no difference between years ($F=1.371$, $P=0.276$), visit can be examined. There was a significant difference between visits (F=7.052, P<0.0001). Visit 4 had a higher Cassin's Sparrow abundance than Visit 1 (P<0.0001), Visit 2 (P=0.050), Visit 3 (0.014), and Visit 5 (P<0.0001). Visit 2 had a higher Cassin's Sparrow abundance than Visit 1 (P=0.007) and Visit 5 (P=0.039). There was no visit*year*treatment interaction detected (F=0.768, P=0.717). There was no significant difference in treatment detected (F=3.039, P=0.069).

Cassin's Sparrow Abundance for Treatments Applied in 2010 from 2010-2011

There was no visit*treatment interaction detected for Cassin's Sparrow abundance (F=0.969, P=0.470). There was a visit*year interaction detected for Cassin's Sparrow abundance (F=8.455, P<0.0001, Figure 2.27). Since there was no difference between years (F=0.366, P=0.555), visit can be examined. There was a significant difference between visits (F=10.995, P<0.0001). Visit 4 had a higher Cassin's Sparrow abundance than Visit 1 (P<0.0001), Visit 3 (0.006), and Visit 5 (P<0.0001). Visit 2 had a higher Cassin's Sparrow abundance than Visit 1 (P<0.0001), Visit 3 (P=0.030), and Visit 5 (P=0.002). There was no visit*year*treatment interaction detected (F=0.585, P=0.786). There was no significant difference in treatment detected (F=0.213, P=0.811).

Northern Bobwhite Abundance

In 2009, treatments available were 2009 burn, rotational grazing, and control. There was no visit*treatment interaction detected for northern bobwhite abundance (F=1.675, P=0.127). There was no significant difference between visits (F=2.506, P=0.053, Figure 2.28). There was a significant difference between treatments (F=6.185, P=0.013, Figure 2.29). Rotational grazing treatment had a higher northern bobwhite abundance than both 2009 burn treatment (P=0.004) and control (P=0.041).

In 2010, treatments available were 2009 burn, 2010 burn, rotational grazing, and control. There was no visit*treatment interaction detected for northern bobwhite abundance (F=4.791, P=0.696). There was a significant difference between visits (F=0.751, P=0.002, Figure 2.30). Visit 4 had a higher northern bobwhite abundance than Visit 2 (P=0.001) and Visit 3 (P=0.003). Visit 5 had a higher northern bobwhite abundance than Visit 3 (P=0.014). There was no significant difference between treatments (F=1.157, P=0.366, Figure 2.31)

In 2011 treatments available were 2009 burn, 2010 burn, 2011 burn, rotational grazing, and control. There was a visit*treatment interaction detected for northern bobwhite abundance (F=3.380, P=0.001, Figure 2.32). Treatments were significantly different for Visit 2 (F=8.829, P=0.002). During Visit 2, Control had a higher northern bobwhite abundance than 2009 burn treatment (P<0.0001) and 2011 burn treatment (P=0.003). During Visit 2, rotational grazing treatment had a higher northern bobwhite abundance than 2009 burn treatment (P=0.001) and 2011 burn treatment (P=0.009). During Visit 2, northern bobwhite abundance was higher in 2010 burn treatment than 2009 burn treatment (P=0.010).

Northern Bobwhite for Treatments Applied in 2009 from 2009-2011

There was a visit*treatment interaction detected (F=2.212, P=0.034, Figure 2.33). There was a visit*year interaction detected (F=5.707, P<0.0001, Figure 2.34).

Northern Bobwhite Abundance for Treatments Applied in 2010 from 2010-2011

There was no visit*treatment interaction detected for northern bobwhite abundance (F=1.360, P=0.234). There was a visit*year interaction detected for northern bobwhite abundance (F=12.781, P<0.0001, Figure 2.35).

Northern Mocking Bird Abundance

In 2009, treatments available were 2009 burn, rotational grazing, and control. There was no visit*treatment interaction detected for northern mocking bird abundance (F=0.705, P=0.595). There was a significant difference between visits (F=8.178, P=0.002, Figure 2.36). Visit 1 had a higher northern mocking bird abundance than Visit 3 (P=0.003), Visit 4 (P=0.007), and Visit 5 (P<0.0001). Visit 2 had a higher northern mocking bird abundance than Visit 4 (P=0.010) and Visit 5 (P=0.001). Visit 3 had a higher northern mocking bird abundance than Visit 5 (P=0.005). There was no significant difference between treatments (F=0.540, P=0.595, Figure 2.37).

In 2010, treatments available were 2009 burn, 2010 burn, rotational grazing, and control. There was no visit*treatment interaction detected for northern mocking bird abundance (F=1.277, P=0.293). There was no significant difference between visits (F=1.566, P=0.199, Figure 2.38). There was no significant difference between treatments (F=0.749, P=0.544, Figure 2.39).

In 2011 treatments available were 2009 burn, 2010 burn, 2011 burn, rotational grazing, and control. There was no visit*treatment interaction detected for northern mocking bird abundance in 2011 (F=0.555, P=0.900). There was no significant difference between visits (F=0.116, P=0.976, Figure 2.40). There was no significant difference between treatments (F=0.147, P=0.961, Figure 2.41).

Northern Mocking Bird Abundance for Treatments Applied in 2009 from 2009-2011

There was no visit*treatment interaction detected for northern mocking bird abundance (F=0.746, P=0.566). There was a visit*year interaction detected (F=4.386, P=0.005, Figure 2.42). There was no significant difference between visits (F=2.912, P=0.066), however there was a difference between years (F=51.577, P<0.0001). 2009 had a higher northern mocking bird abundance than year 2010 (P<0.0001) and 2011 (P<0.0001). There was no visit*treatment*year interaction detected (F=0.347, P=0.990). There was no significant difference between treatments (F=0.613, P=0.551).

Northern Mocking Bird Abundance for Treatments Applied in 2010 from 2010-2011

There was no visit*treatment interaction detected for northern mocking bird abundance (F=1.166, P=0.336). There was no visit*year interaction detected (F=0.770, P=0.549). There was no visit*treatment*year interaction detected (F=0.562, P=0.804). There was no significant difference between visits (F=1.324, P=0.273, Figure 2.43), treatment (F=0.638, P=0.543, Figure 2.44), or year (F=0.018, P=0.895, Figure 2.45).

Grasshopper Sparrow Abundance

In 2009, treatments available were 2009 burn, rotational grazing, and control. There was no visit*treatment interaction detected for grasshopper sparrow abundance in 2009 (F=0.738, P=0.561). There was no significant difference between visits for grasshopper sparrow abundance (F=2.540, P=0.106, Figure 2.46). There was no significant difference between treatments for grasshopper sparrow abundance (F=1.020, P=0.388, Figure 2.47).

In 2010, treatments available were 2009 burn, 2010 burn, rotational grazing, and control. There was no visit*treatment interaction detected for grasshopper sparrow abundance in 2010 (F=1.080, P=0.397). There was no significant difference between visits (F=2.364, P=0.066, Figure 2.48). There was no significant difference between treatments for grasshopper sparrow abundance (F=2.013, P=0.166, Figure 2.49).

In 2011 treatments available were 2009 burn, 2010 burn, 2011 burn, rotational grazing, and control. There was no visit*treatment interaction detected for grasshopper sparrow abundance in 2011 (F=0.578, P=0.883). There was no significant difference between visits (F=1.316, P=0.279, Figure 2.50). There was no significant difference between treatments for grasshopper sparrow abundance (F=0.578, P=0.685, Figure 2.51).

Grasshopper Sparrow Abundance for Treatments Applied in 2009 from 2009-2011

There was no visit*treatment interaction detected for grasshopper sparrow abundance (F=0.554, P=0.677). There was no visit*year interaction detected for grasshopper sparrow abundance F=1.158, P=0.343). There was no visit*year*abundance interaction detected for grasshopper sparrow abundance (F=0.604, P=0.751). There was a significant difference between visits (F=5.504, P=0.010, Figure 2.52). Visit 1 had a higher grasshopper sparrow abundance than Visit 2 (P=0.011), Visit 3 (P=0.027), Visit 4 (P=0.043), and Visit 5 (P=0.003). Visit 3 had a higher grasshopper sparrow abundance than Visit 5 (P=0.026). There was a significant difference between treatments (F=6.710, P=0.006, Figure 2.53). 2009 burn treatment had lower grasshopper sparrow abundance than both rotational grazing (P=0.003) and control (P=0.008). There was a significant difference between years (F=12.058, P<0.0001, Figure 2.54). In 2010 grasshopper sparrow abundance was higher than both 2009 (P=0.008) and 2011 (P<0.0001).

Grasshopper Sparrow Abundance for Treatments Applied in 2010 from 2010-2011

There was no visit*treatment interaction detected for grasshopper sparrow abundance (F=1.021, P=0.414). There was no visit*year interaction detected for grasshopper sparrow abundance (F=0.963, P=0.395). There was no visit*treatment*year interaction detected for grasshopper sparrow abundance (F=0.652, P=0.632). There was no significant difference between visits (F=1.363, P=0.272, Figure 2.55). There was no significant difference between treatments (F=2.406, P=0.126, Figure 2.56). There was a significant difference between years (F=42.080, P<0.0001, Figure 2.57). In 2010, grasshopper sparrow abundance was significantly higher than in 2011 (P<0.0001).

Scissor-Tailed Flycatcher Abundance

In 2009, treatments available were 2009 burn, rotational grazing, and control. There was no visit*treatment interaction, an F-value could not be obtained due to treatment only having one level in 2009. There was a significant difference between visits (F=6.458, P=0.011, Figure 2.58). Visit 1 had higher scissor-tailed flycatcher abundance than Visit 3 (P=0.014), Visit 4 (P=0.014), and Visit 5 (P=0.014). Visit 2 had higher scissor-tailed flycatcher abundance than Visit 3 (P=0.014), Visit 4 (P=0.014), and Visit 5 (P=0.014).

In 2010, treatments available were 2009 burn, 2010 burn, rotational grazing, and control. There was no visit*treatment interaction detected for scissor-tailed flycatcher abundance in 2011 (F=1.870, P=0.063). There was no significant difference between visits (F=1.447, P=0.233, Figure 2.59). There was no significant difference between treatments (F=3.076, P=0.069, Figure 2.60).

In 2011 treatments available were 2009 burn, 2010 burn, 2011 burn, rotational grazing, and control. There was no visit*treatment interaction detected for scissor-tailed flycatcher abundance in 2011 (F=0.790, P=0.688). There is a significant difference between visits (F=3.695, P=0.033, Figure 2.61). There is no significant difference between treatments (F=0.792, P=0.554). Visit 3 had a higher scissor-tailed flycatcher abundance than Visit 4 (P=0.020) and Visit 5 (P=0.020). There was no significant difference between treatments (F=0.792, P=0.554, Figure 2.62).

Scissor-Tailed Flycatcher Abundance for Treatments Applied in 2009 from 2009-2011

There was no visit*treatment interaction detected for scissor-tailed flycatcher abundance (F=0.681, P=0.707). There was a visit*year interaction detected for scissor-tailed flycatcher abundance (F=2.404, P=0.022, Figure 2.63). Since there is no difference between years (F=2.675, P=0.092), visit can be examined. Visit 2 had a higher scissor-tailed flycatcher abundance than Visit 4 (P=0.026) and Visit 5 (P=0.010). There was a significant difference between visits (F=4.341, P=0.003). Visit 3 had a higher scissor-tailed flycatcher abundance than Visit 4 (P=0.033) and Visit 5 (P=0.003). There was no visit*treatment*year interaction detected for scissor-tailed flycatcher abundance (F=1.047, P=0.018)

Scissor-Tailed Flycatcher Abundance for Treatments Applied in 2010 from 2010-2011

There was no visit*treatment interaction detected for scissor-tailed flycatcher abundance (F=1.502, P=0.210). There was no visit*year interaction detected (F=2.602, P=0.073). There was no visit*year*treatment interaction detected (F=1.074, P=0.392). There was no significant difference between visits (F=2.052, P=0.130, Figure 2.64). There was no significant difference between treatments (F=0.368, P=0.699, Figure 2.65). There was a significant difference between years (F=4.914, P=0.44, Figure 2.66). In 2010, scissor-tailed flycatcher abundance was higher than in year 2011 (P=0.044).

Painted Bunting Abundance

In 2009, treatments available were 2009 burn, rotational grazing, and control. There was no visit*treatment interaction detected for painted bunting abundance in 2009 (F=0.514, P=0.722). There was a significant difference between visits (F=7.884, P=0.002, Figure 2.67). Visit 5 had a higher painted bunting abundance than Visit 1 (P=0.004), Visit 2 (P=0.005), Visit 3 (P=0.017), and Visit 4 (P=0.011). There was no significant difference between treatments (F=0.651, P=0.538, Figure 2.68).

In 2010, treatments available were 2009 burn, 2010 burn, rotational grazing, and control. There was a visit*treatment interaction detected for painted bunting abundance in 2010 (F=3.747, P=0.035, Figure 2.69). There was a significant difference in painted bunting abundance for treatments during Visit 5 (F=4.00, P=0.035). During Visit 5 painted bunting abundance was higher in rotational grazing treatment than 2009 burn treatment (P=0.040), control (P=0.040), and 2010 burn treatment (P<0.0001).

In 2011 treatments available were 2009 burn, 2010 burn, 2011 burn, rotational grazing, and control. There was no visit*treatment interaction detected for painted bunting abundance in 2011 (F=1.362, P=0.205). There was a significant difference between visits (F=4.856, P=0.002, Figure 2.70). Visit 3 had a higher painted bunting abundance than Visit 1 (P=0.005). Visit 4 had a higher painted bunting abundance than Visit 1 (P=0.002). Visit 5 had a higher painted bunting abundance than Visit 1 (P=0.003). There was no significant difference between treatments (F=1.261, P=0.342, Figure 2.71).

Painted Bunting Abundance for Treatments Applied in 2009 from 2009-2011

There was no visit*treatment interaction detected (F=1.353, P=0.266). There was no visit*year interaction detected (F=1.648, P=0.179). There was no visit*treatment*year interaction detected (F=1.728, P=0.118). There was a significant difference between visits (F=11.924, P<0.0001, Figure 2.72). Visit 5 had a significantly higher painted bunting abundance than Visit 1 (P<0.0001), Visit 2 (P<0.0001), Visit 3 (P=0.002), and Visit 4 (P=0.007). Visit 4 had a significantly higher painted bunting abundance than Visit 1 (P=0.003). There was no significant difference between treatment (F=1.670, P=0.212, Figure 2.73) or year (F=0.465, P=0.634, Figure 2.74).

Painted Bunting Abundance for Treatments Applied in 2010 from 2010-2011

There was no visit*treatment interaction for painted bunting abundance (F=1.581, P=0.189). There was no visit*year interaction detected for painted bunting abundance (F=2.875, P=0.057). There was a significant difference between visits (F=3.802, P=0.008, Figure 2.75). Visit 5 had a higher painted bunting abundance than Visit 1 (P=0.003) and Visit 2 (P=0.021). Visit 4 had a higher painted bunting abundance than

Visit 1 (P=0.013). Visit 3 had a higher painted bunting abundance than Visit 1 (P=0.046). There was no significant difference between treatment (F=0.959, P=0.407, Figure 2.76) or year (F=4.330, P=0.056, Figure 2.77).

Patch Burning Without Grazing

Species Richness

There was a visit*treatment interaction (F=2.807, P=0.006, Figure 2.78) and visit*year interaction (F=4.851, P<0.0001, Figure 2.79) detected for species richness. There was a significant difference in species richness between treatments during visit 3 (F=3.509, P=0.039). Control had higher species richness than summer burn treatment (P=0.012). There was a significant difference in species richness between years for Visit 1 (F=20.293, P<0.0001), Visit 2 (F=16.055, P<0.0001), Visit 3 (F=4.029, P=0.025), Visit 4 (F=4.761, P=0.014). For Visit 1, species richness was higher in 2009 than both 2010 (P=0.002) and 2011 (P<0.0001). Year 2010 had a higher species richness than 2011 during Visit 1 (P=0.004). For Visit 2, species richness was higher in 2009 than both 2010 (P=0.038) and 2011 (P<0.0001). Year 2010 had a higher species richness than 2011 during Visit 2 (P=0.001). For Visit 3, species richness was higher in 2009 than in 2011 (P=0.007). For Visit 4, species richness was higher in 2009 than in 2010 (P=0.004).

Total Bird Abundance

There was no visit*treatment interaction detected for total bird abundance (F=0.759, P=0.613). There was a visit*year interaction detected (F=5.858, P<0.0001, Figure 2.80). There was a significant difference in total bird abundance between years for Visit 1 (F= 50.369, P<0.0001), Visit 2 (F=15.994, P<0.0001), Visit 3 (F=9.528, P<0.0001), Visit 4 (F=12.425, P<0.0001), Visit 5 (F=9.216, P<0.0001). For Visit 1, total bird abundance was higher in 2009 than both 2010 (P<0.0001) and 2011 (P<0.0001). 2010 had higher total bird abundance than 2011 for Visit 1 (P=0.027). For Visit 2, total bird abundance was higher in 2009 than both 2010 (P<0.0001) and 2011 (P<0.0001). For Visit 3, total bird abundance was higher in 2009 than both 2010 (P=0.001) and 2011 (P<0.0001). For Visit 4, total bird abundance was higher in 2009 than both 2010 (P<0.0001) and 2011 (P<0.0001). For Visit 5, total bird abundance was higher in 2009 than both 2010 (P=0.006) and 2011 (P<0.0001). There was a significant difference between treatments (F=9.383, P<0.0001, Figure 2.81).

Cassin's Sparrow Abundance

There was no visit*treatment interaction for Cassin's Sparrow abundance (F=0.972, P=0.460). There was a visit*year interaction for Cassin's Sparrow abundance (F=2.562, P=0.013, Figure 2.82). There was a significant difference for Cassin's sparrow abundance between years for Visit 2 (F=6.695, P=0.003) and Visit 5 (F=9.369, P<0.0001). For Visit 2, Cassin's sparrow abundance was higher during 2011 than 2009 (P=0.009) and 2010 (P=0.001). For Visit 5, Cassin's sparrow abundance was higher during 2009 than 2010 (P<0.0001). Cassin's sparrow abundance was also higher during 2011 than 2010 during Visit 5 (P=0.006). There was a significant difference between treatments (F=4.354, P=0.019, Figure 2.83).

Northern Bobwhite Abundance

There was no visit*treatment interaction detected for northern bobwhite abundance (F=0.817, P=0.565). There was a visit*year interaction detected for northern bobwhite abundance (F=3.356, P=0.003, Figure 2.84). There was a significant difference in northern bobwhite abundance among years for Visit 1 (F=25.131, P<0.0001), Visit 2 (F=30.277, P<0.0001), Visit 3 (F=13.266, P<0.0001), Visit 4 (F=16.078, P<0.0001), and Visit 5 (F=16.734, P<0.0001). For Visit 1, northern bobwhite abundance was higher in 2009 than 2010 (P<0.0001) and 2011 (P<0.0001). For Visit 2, northern bobwhite abundance was higher in 2009 than 2010 (P<0.0001) and 2011 (P<0.0001). For Visit 3, northern bobwhite abundance was higher in 2009 than 2010 (P<0.0001) and 2011 (P=0.001). For Visit 4, northern bobwhite abundance was higher in 2009 than 2010 (P<0.0001) and 2011 (P<0.0001). For Visit 5, northern bobwhite abundance was higher in 2009 than 2010 (P<0.0001) and 2011 (P<0.0001). There was a significant difference between treatments (F=16.281, P<0.0001, Figure 2.85).

Northern Mocking Bird Abundance

There was no visit*treatment interaction detected for northern mocking bird abundance (F=1.197, P=0.304). There was a visit*year interaction detected for northern mocking bird abundance (F=16.853, P<0.0001, Figure 2.86). There was a significant difference in northern mocking bird abundance among years for Visit 1 (F=50.369, P<0.0001), Visit 2 (F=15.994, P<0.0001), Visit 3 (F=9.528, P<0.0001), Visit 4 (F=12.425 P<0.0001), and Visit 5 (F=9.216 P<0.0001). For Visit 1, northern mocking bird abundance was higher in 2009 than 2010 (P<0.0001) and 2011 (P<0.0001). Northern mocking bird abundance was also higher in 2010 than 2011 for Visit 1 (P=0.027). For Visit 2, northern mocking bird abundance was higher in 2009 than 2010 (P<0.0001) and 2011 (P<0.0001). For Visit 3, northern mocking bird abundance was higher in 2009 than

2010 (P=0.001) and 2011 (P<0.0001). For Visit 4, northern mocking bird abundance was higher in 2009 than 2010 (P<0.0001) and 2011 (P<0.0001). For Visit 5, northern mocking bird abundance was higher in 2009 than 2010 (P=0.006) and 2011 (P<0.0001). There was no significant difference in treatments (F=1.937, P=0.157, Figure 2.87).

Grasshopper Sparrow Abundance

There was no visit*treatment interaction detected for grasshopper sparrow abundance (F=0.487, P=0.995). There was a visit*year interaction for grasshopper sparrow abundance (F=4.844, P<0.0001, Figure 2.88). There is a significant difference in years for Visit 1 (F=6.125, P=0.005), Visit 2 (F=36.978, P<0.0001), Visit 3 (F=18.439, P<0.0001), and Visit 4 (F=7.258, P=0.002). For Visit 1, 2010 had higher abundance than 2009 (P=0.011) and 2010 (P=0.002). For Visit 2, 2010 had higher abundance than 2009 (P<0.0001) and 2010 (P<0.0001). For Visit 3, 2010 had higher abundance than 2009 (P<0.0001) and 2010 (P<0.0001). For Visit 4, 2010 had higher abundance than 2009 (P=0.002) and 2010 (P=0.002). There was no significant difference between treatments (F=0.738, P=0.484, Figure 2.89).

Scissor-tailed Flycatcher Abundance

There was no visit*treatment interaction detected for grasshopper sparrow abundance (F=1.017, P=0.421). There was no visit*year interaction detected for grasshopper sparrow abundance (F=1.200, P=0.307). There was a significant difference between visits (F=4.760, P=0.002, Figure 2.90). Visit 2 had a higher scissor-tailed flycatcher abundance than Visit 4 (P=0.034) and Visit 5 (P<0.0001). Visit 1 had a higher scissor-tailed flycatcher abundance than Visit 5 (P=0.007). Visit 3 had higher scissor -

tailed flycatcher abundance than Visit 5 (0.002). There was a significant difference among treatments (F=4.134, P=0.023, Figure 2.91). Control had a lower scissor-tailed flycatcher abundance than summer burn (P=0.010) and winter burn (P=0.037). There was no significant difference between years (F=2.141, P=0.131, Figure 2.92).

Painted Bunting Abundance

There was no visit*treatment interaction for painted bunting abundance (F=1.592, P=0.131). There was a visit*year interaction for painted bunting abundance (F=2.625, P=0.027, Figure 2.93), however a one-way anova for visit by year showed no differences. There was a significant difference among treatments (F=10.374, P<0.0001, Figure 2.94). Control had higher painted bunting abundance than both summer burn (P<0.0001) and winter burn (P=0.003).

DISCUSSION

Patch burning-grazing has been studied in tallgrass prairie regions in relation to grassland birds. This practice has been shown to increase habitat variability temporally and spatially to accommodate different species with different habitat preferences (Fuhlendorf et al. 2006). For example, the horned lark and grasshopper sparrow seek contrasting vegetation requirements in their preferred habitat (Weins 1973). In other ecoregions it has been shown that this heterogenous quality in the habitat increases grassland bird diversity (Fuhlendorf et al. 2006, Coppedge et al. 2008). The results in this study incorporating patch burn-grazing and rotational grazing did not exhibit a distinct difference in species richness between patch-burning and rotational grazing. Total bird abundance was actually highest in the rotational grazing treatment in 2009, but there were no differences in treatments in 2010 or 2011. A possible influencing factor contributing to lack of difference among treatments could potentially be patch size. In studies that exhibited difference in grassland bird diversity (Fuhlendorf et al. 2006, Coppedge et. 2008) average patch size ranged from 100 to 200 hectares, whereas, this study had an average patch size of approximately 18 hectares and it has been shown different grassland birds are sensitive to patch size (Davis 2004). Species richness and total bird abundance did decline in progression from 2009 to 2011. This effect is likely due to extreme drought conditions starting in 2010 and extending through 2011. It has been exhibited that grassland bird density does decline when coinciding drought conditions persist (George et al. 1992). Individual observed species were variable by treatment and visit number, but in general most species abundance decreased from 2009-2011.Visit variation was likely due to staggered arrival to the study site during the breeding season. In the case of patch burning and grazing relative to rotational grazing during drought conditions, there seemed to be no inherent benefits in overall species richness or abundance.

Burning at different time schedules can influence the way vegetation responds also influencing grassland bird responses. Summer burning in Texas gulf coast prairie produced a response of specific species avoiding the burned areas while others utilized the burned areas (Marx et al. 2008). In some cases, burning has shown little to no effects on relative abundance or species richness in relation to winter burning (Reynolds and Krausman 1998). My results indicated that in a patch burning system without grazing there was higher species richness and total abundance associated with the unburned control plots, rather than the summer burn and winter burn treatments. Species richness and total abundance were higher in 2010 and 2009, respectively. 2011 was a year of extreme drought conditions and likely influence the lower species richness and total bird abundance. For most individual species analyzed there was not a difference between treatments, except for scissor-tailed flycatcher and painted bunting that preferred the control. For all individual species, except Cassin’s sparrow, there was a general decline from 2009 to 2011. Declines in 2011 are likely do to coinciding drought effects (George et al. 1992).Once again, with grassland bird sensitivity to patch sizes (Davis 2004) the results could have been influenced by patch size being smaller than previously done studies that showed increases in grassland bird diversity and abundance (Fuhlendorf et al. 2006, Coppedge et. 2008). Patch burning without grazing had little positive effect in regards to grassland bird species richness or abundance.

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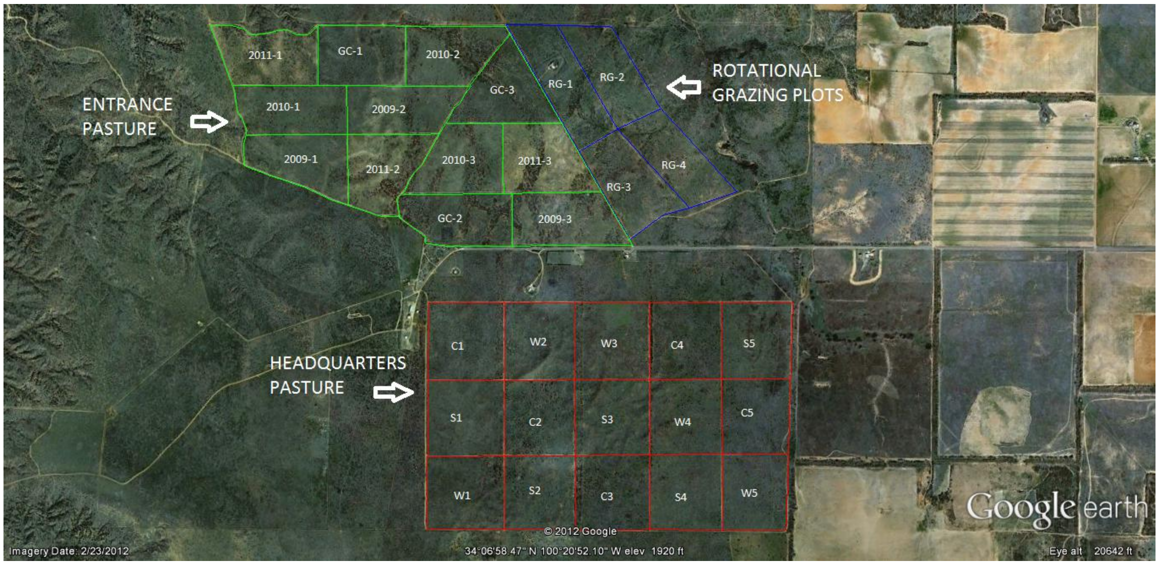

Figure 2.1. Diagrammatic representation of plots located within Entrance and Headquarters pastures at Matador Wildlife Management Area. Headquarters pasture was divided into a 3 x 5 grid with each of 5 blocks containing 3 plots approximately 18 ha in size. Utilizing a randomized block design, each block was randomly assigned 3 treatments consisting of summer burn, winter burn, and control. Entrance pasture was divided into 16 plots approximately 17 ha in size that were subjected to patch burn-grazing and rotational grazing. Due to area constraints, 12 plots were randomly assigned 3 replicates of treatments 2009 burn, 2010 burn, 2011 burn, and control. Additionally 4 plots were subjected to rotational grazing treatment only.

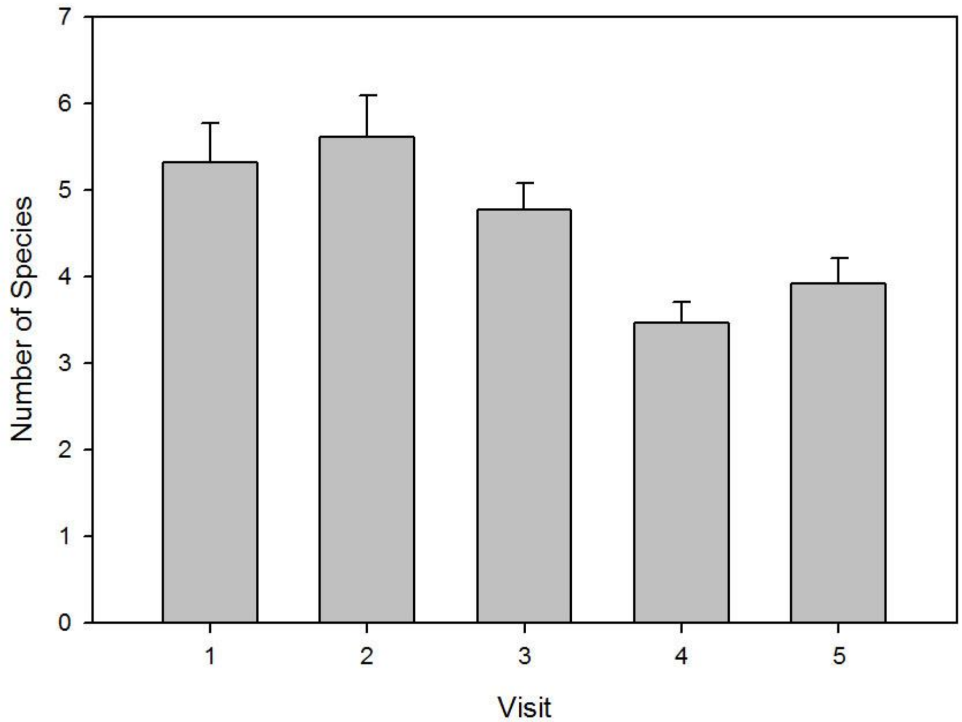

Figure 2.2. Comparison of average number of species per visit in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

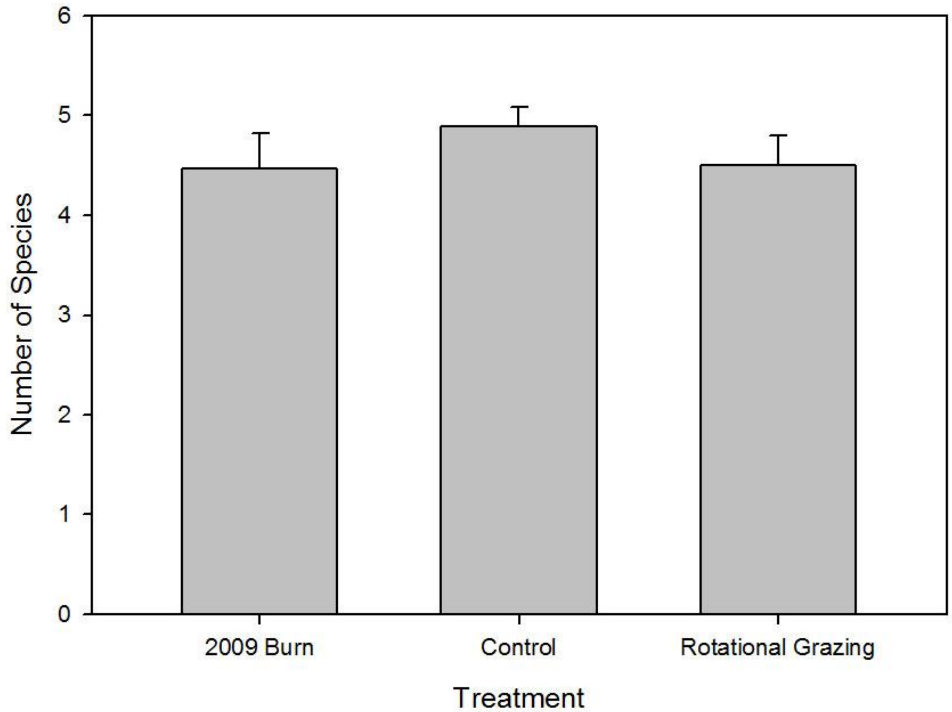

Figure 2.3. Comparison of average number of species per treatment for patch burn-grazing and rotational grazing in 2009 (Mean±SE).

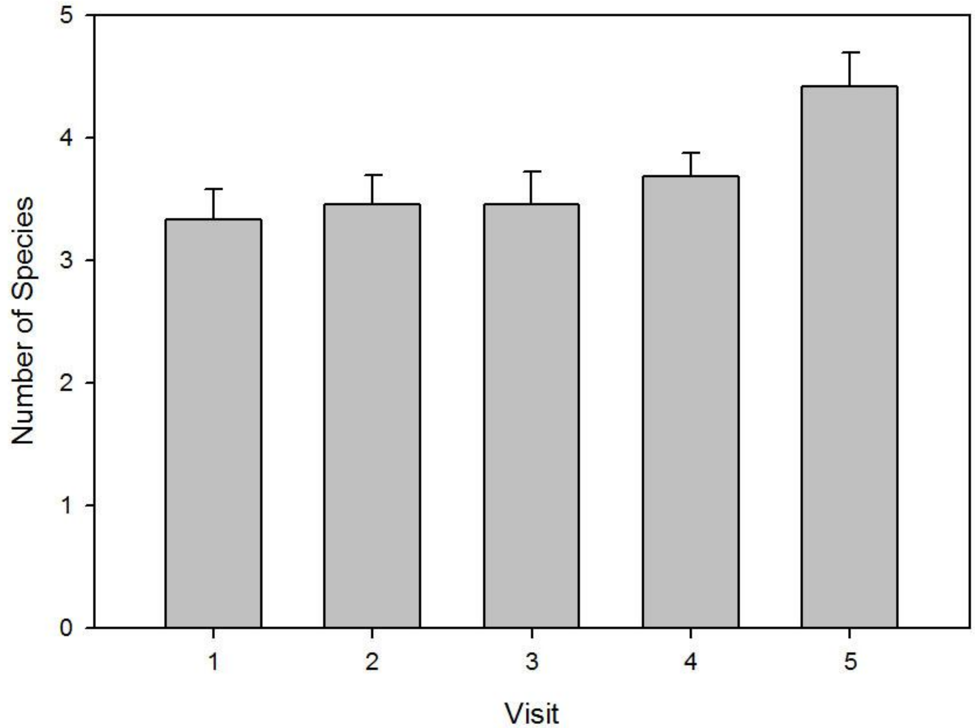

Figure 2.4. Comparison of average number of species per visit in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

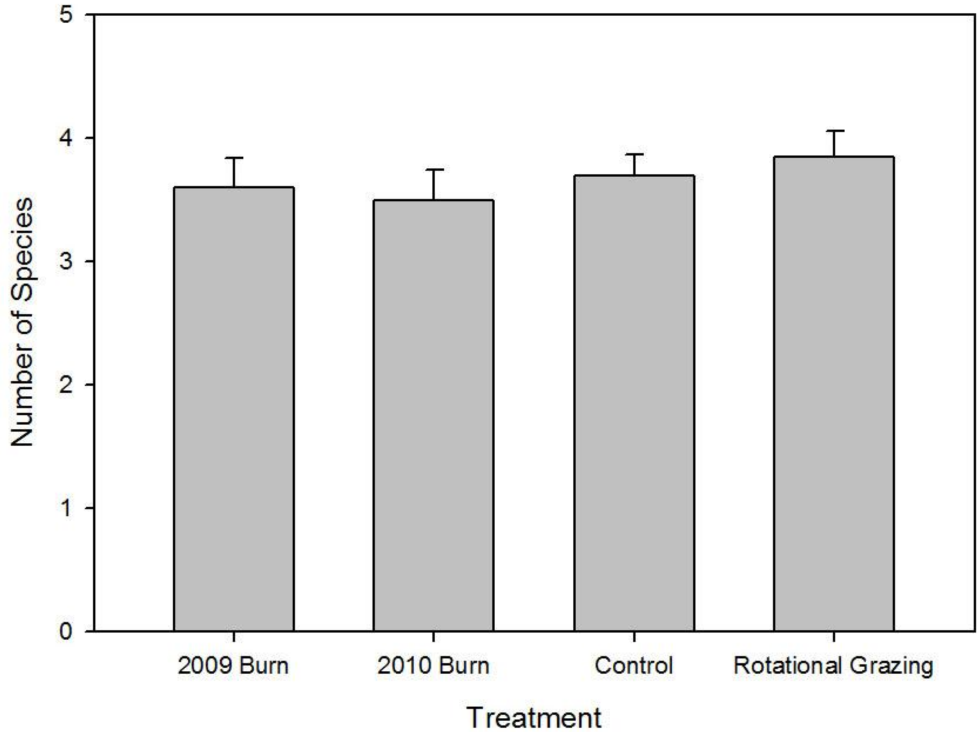

Figure 2.5. Comparison of average number of species per treatment for patch burn-grazing and rotational grazing in 2010 (Mean±SE).

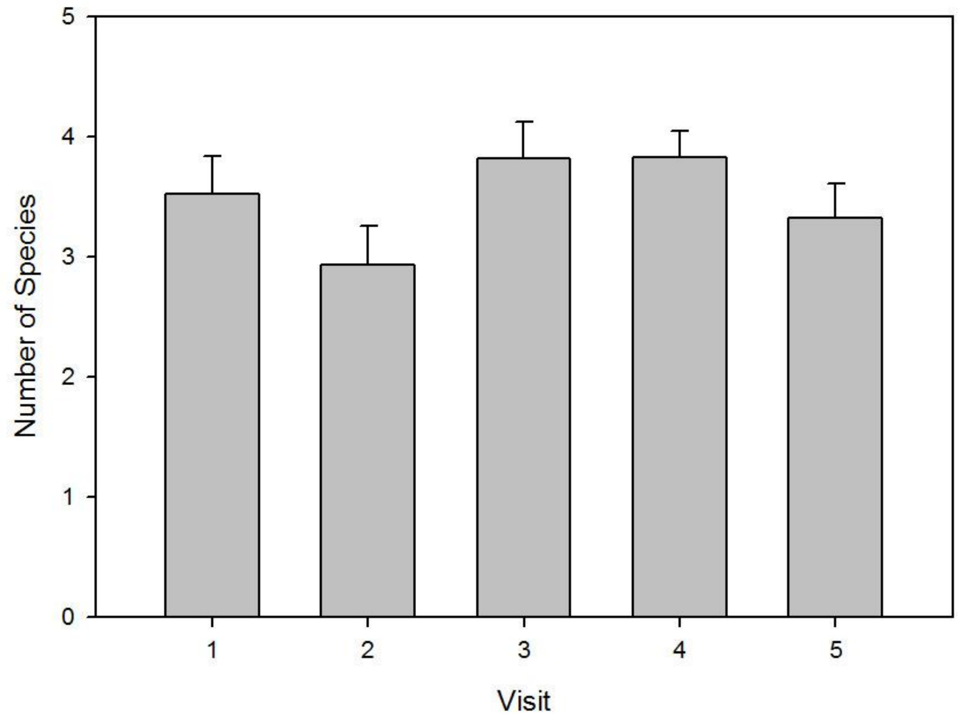

Figure 2.6. Comparison of average number of species per visit in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

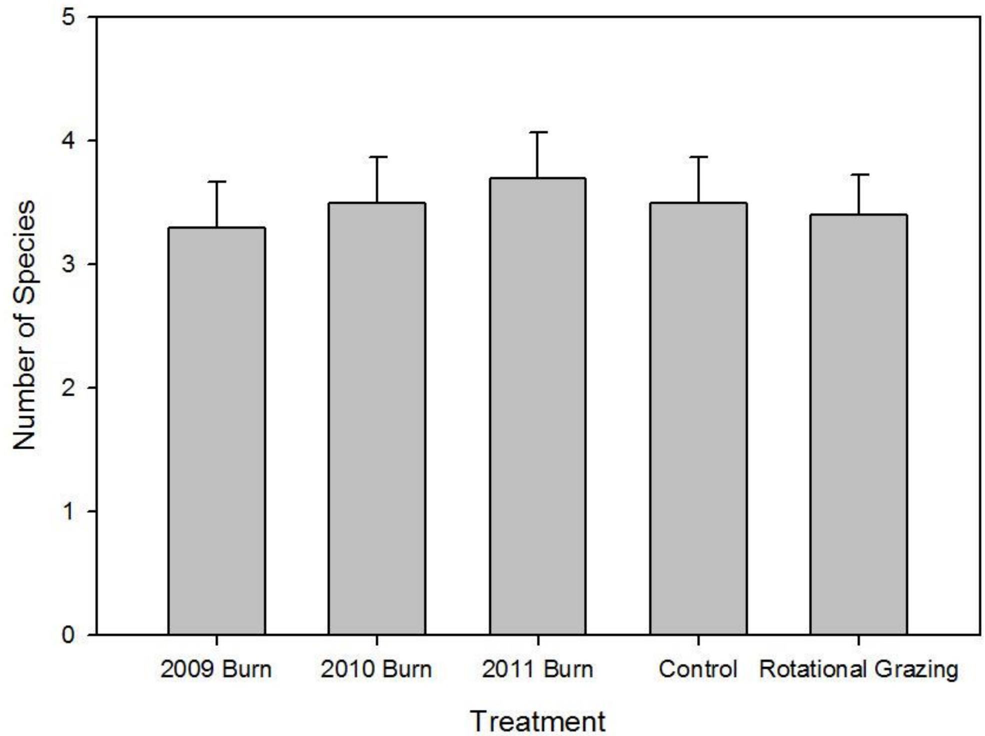

Figure 2.7. Comparison of average number of species per treatment for patch burn-grazing and rotational grazing in 2011 (Mean±SE).

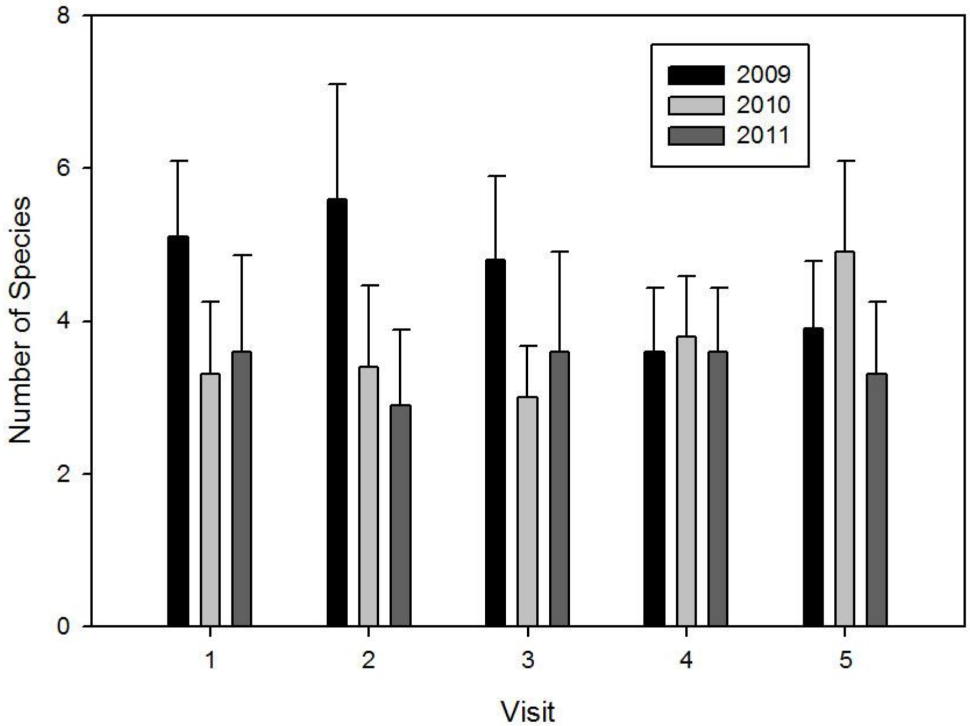

Figure 2.8. Comparison of average number of bird species per year within visits for all treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

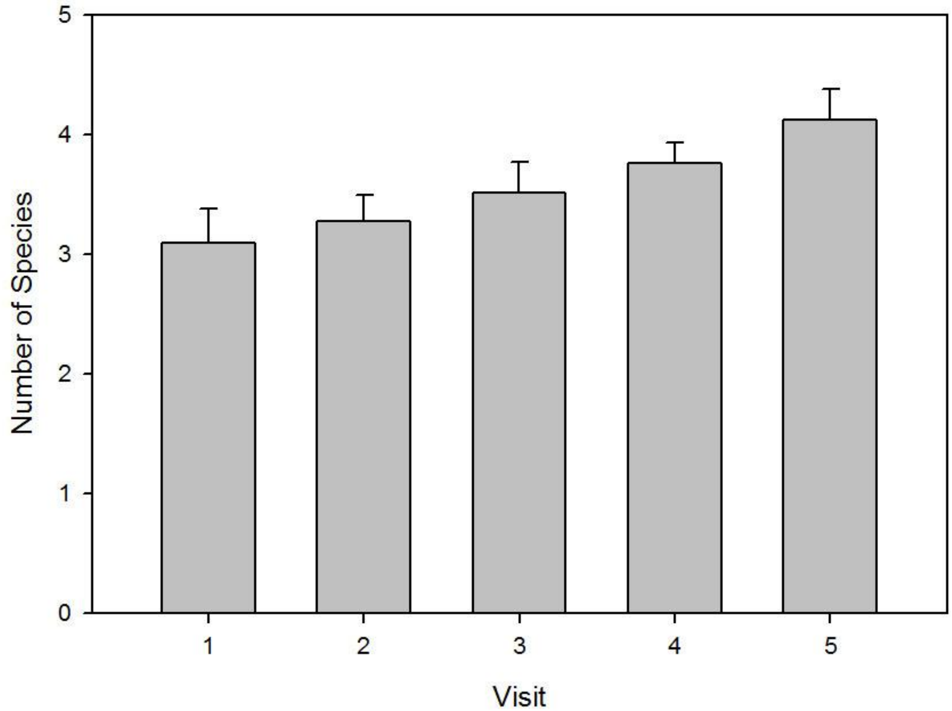

Figure 2.9. Comparison of average number of bird species per visit for treatments applied in 2010 for years 2010-2011 for patch burn-grazing and rotational grazing (Mean±SE).

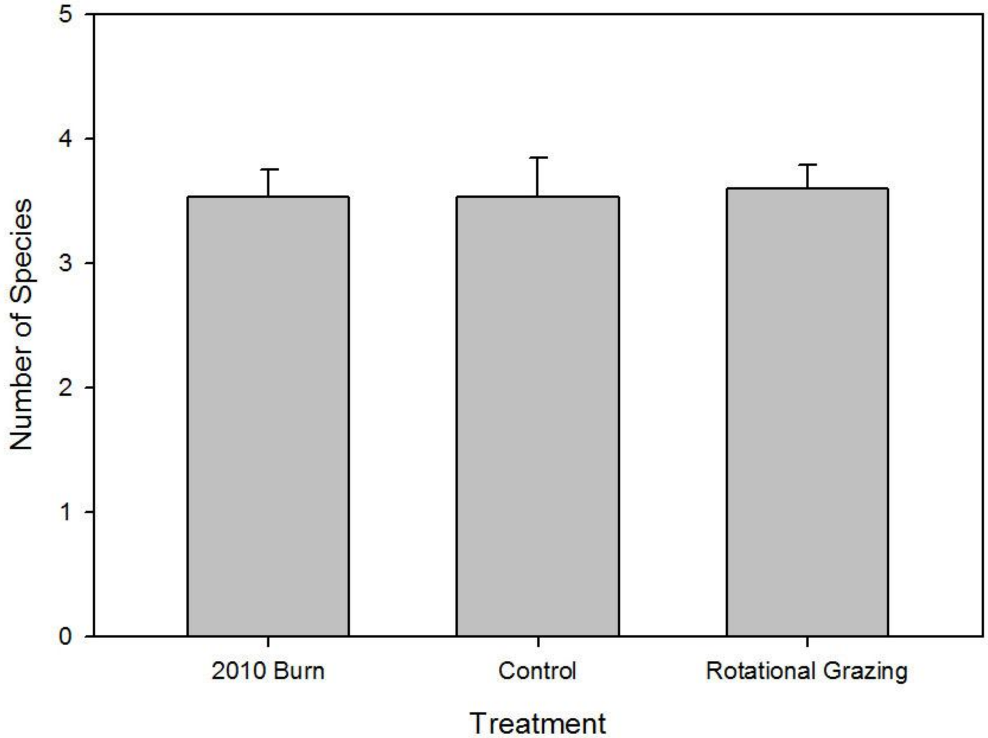

Figure 2.10. Comparison of average number of bird species per treatment for treatments applied in 2010 for years 2010-2011 for patch burn-grazing and rotational grazing (Mean±SE).

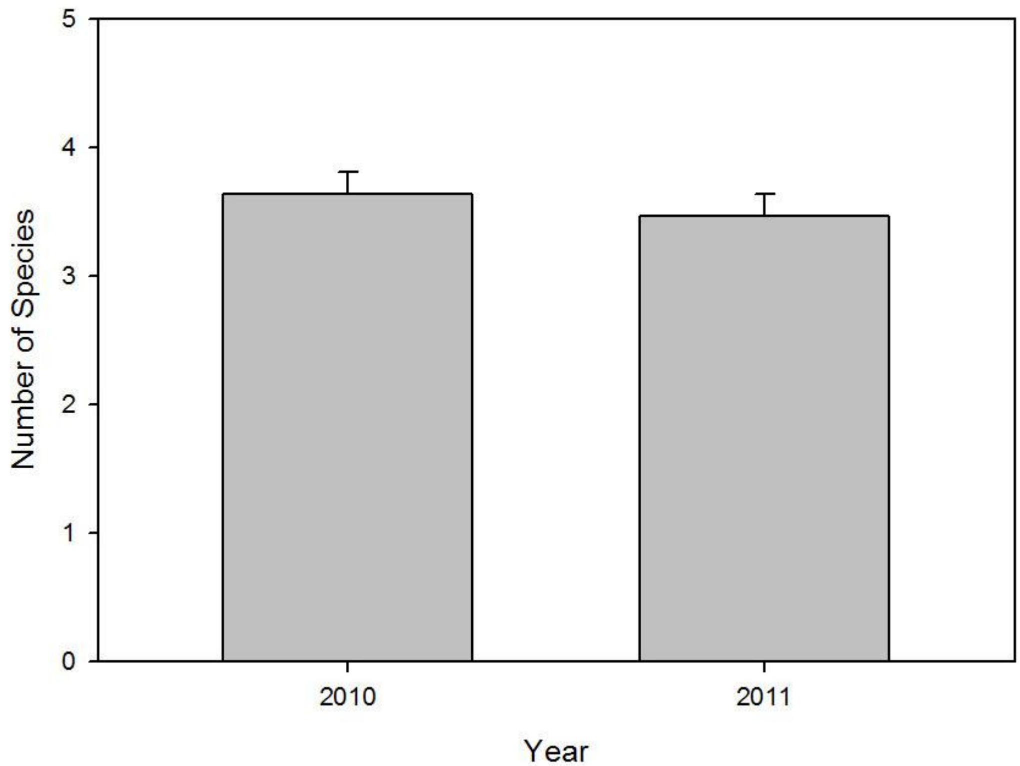

Figure 2.11. Comparison of average number of bird species per year for treatments applied in 2010 for years 2010-2011 for patch burn-grazing and rotational grazing (Mean±SE).

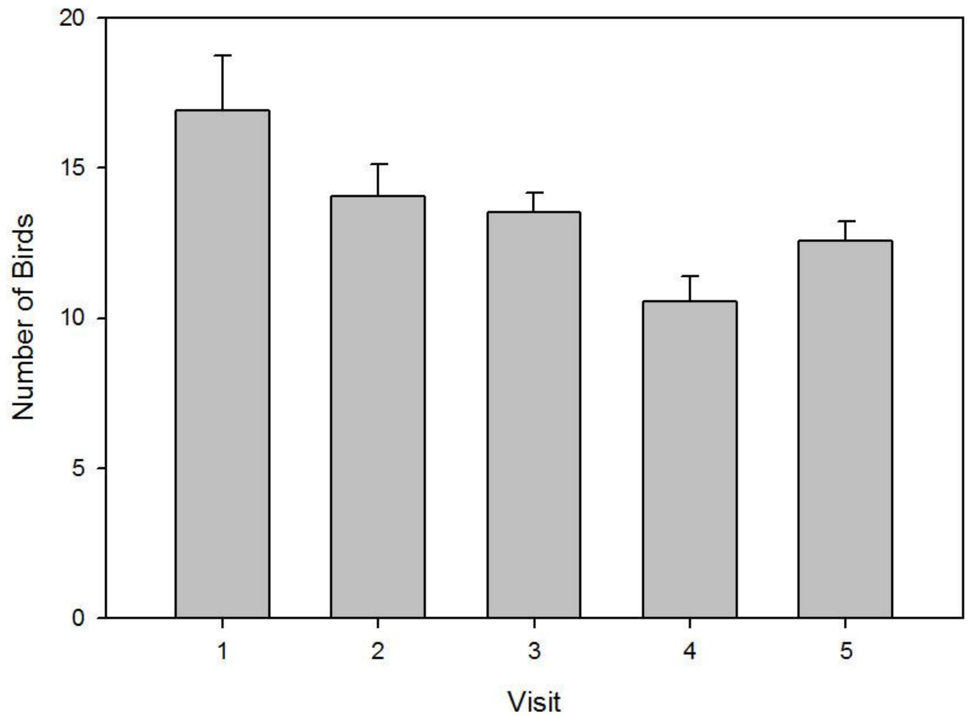

Figure 2.12. Comparison of average total number of birds per visit in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

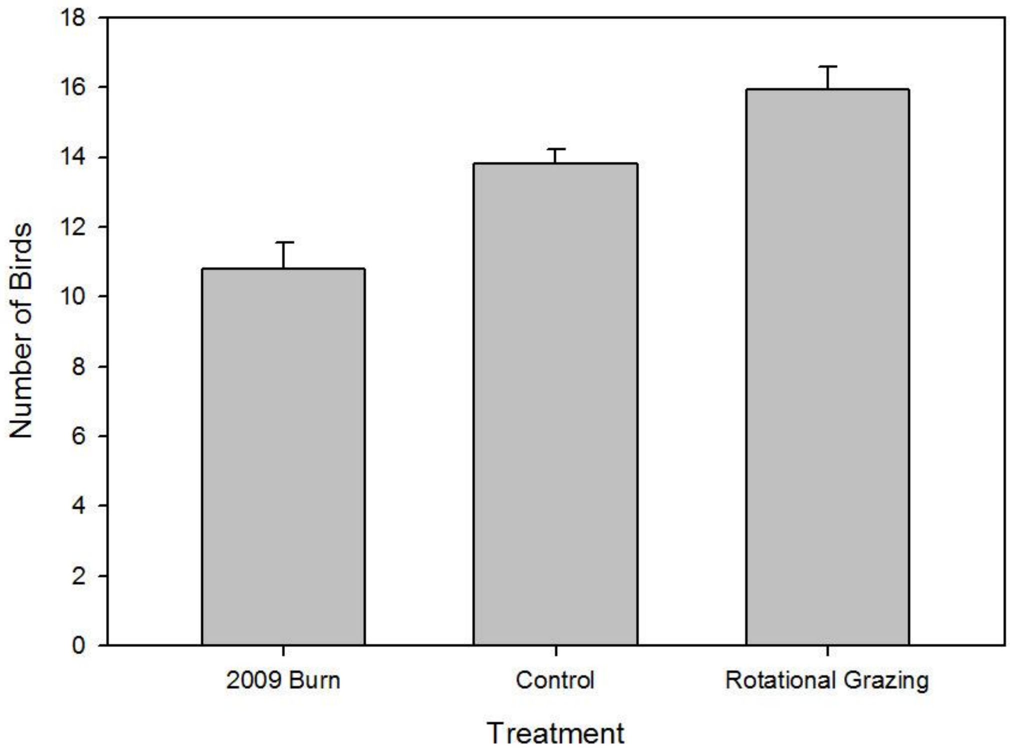

Figure 2.13. Comparison of average total number of birds per treatment in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

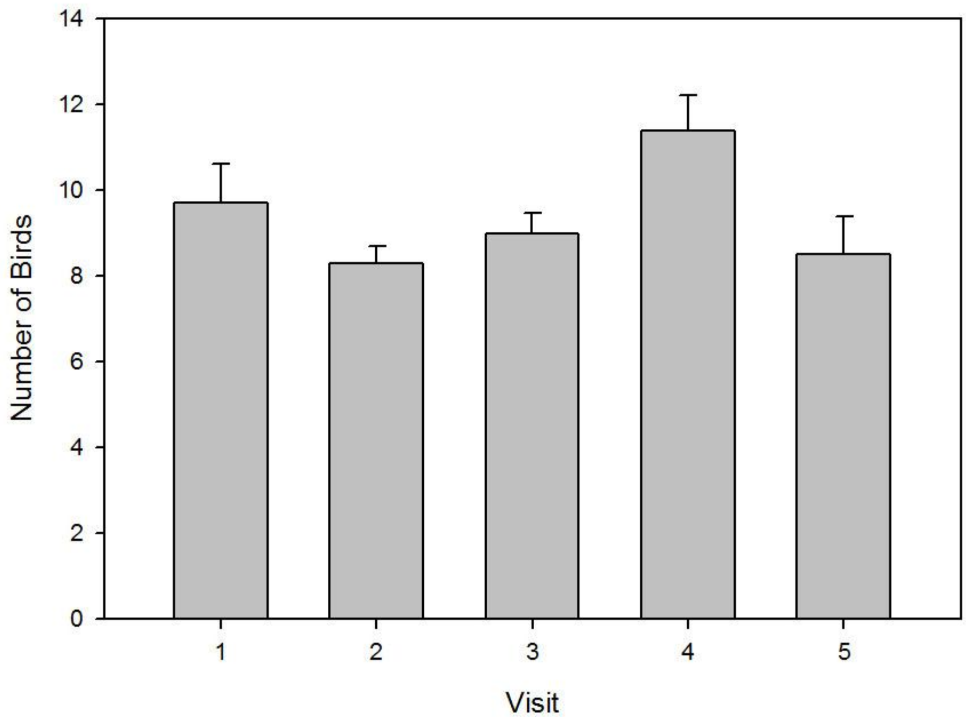

Figure 2.14. Comparison of average total number of birds per visit in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

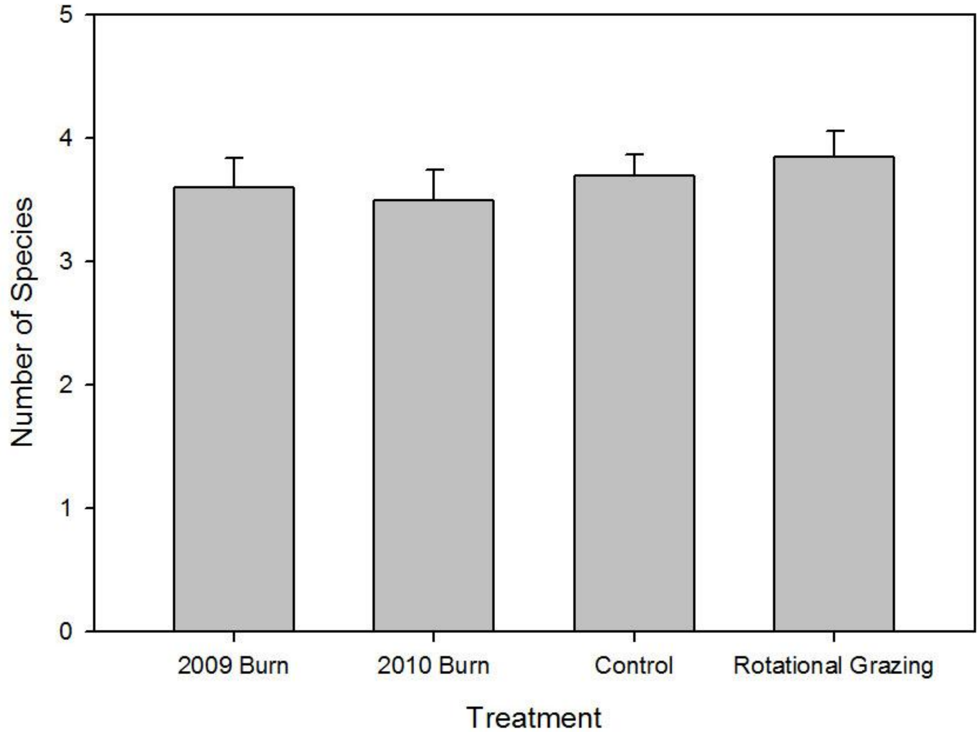

Figure 2.15. Comparison of average total number of birds per treatment in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

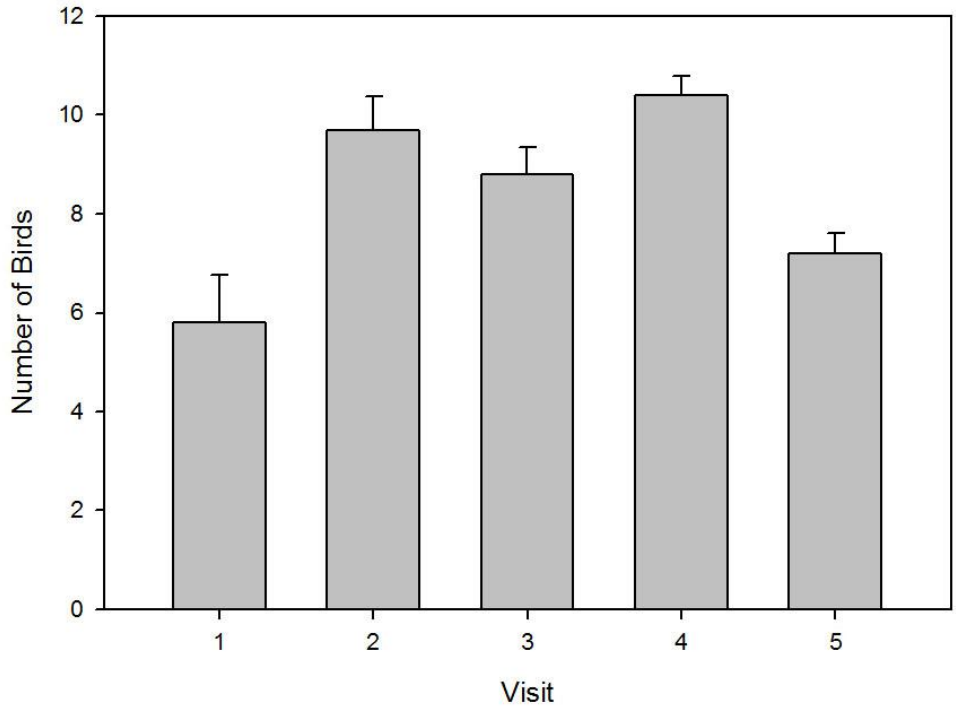

Figure 2.16. Comparison of average total number of birds per visit in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

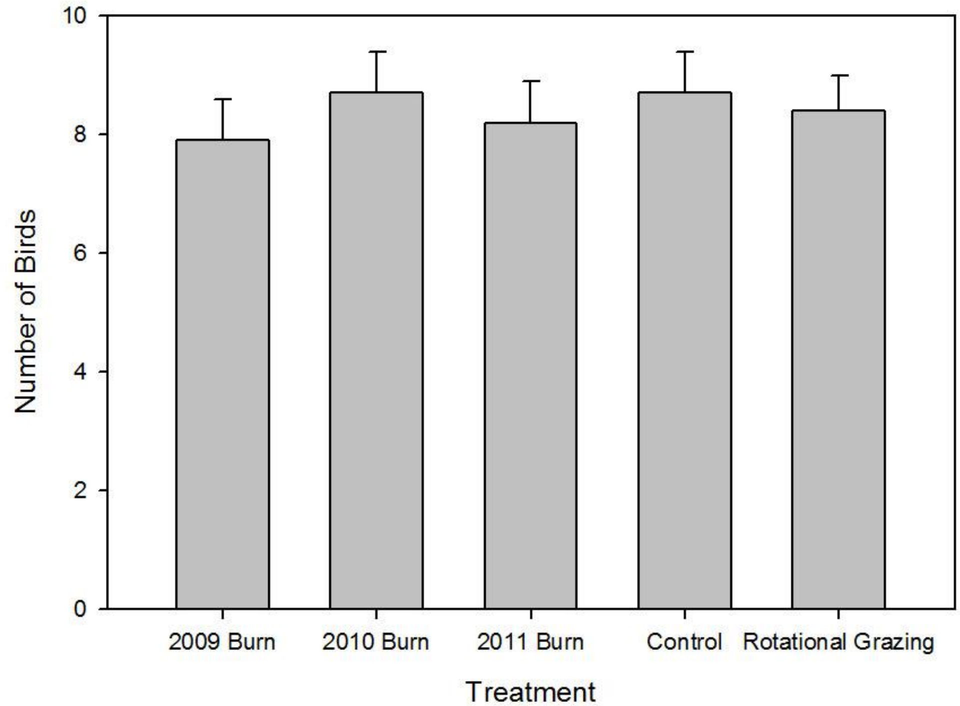

Figure 2.17. Comparison of average total number of birds per treatment in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

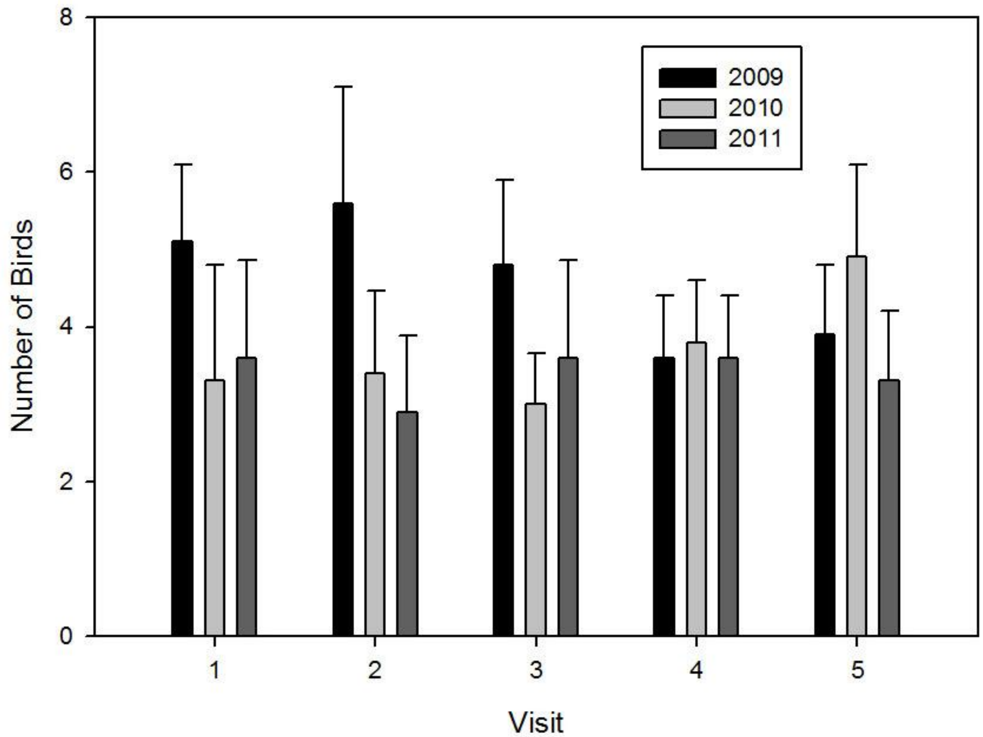

Figure 2.18. Comparison of average total number of birds per year within visits for all treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

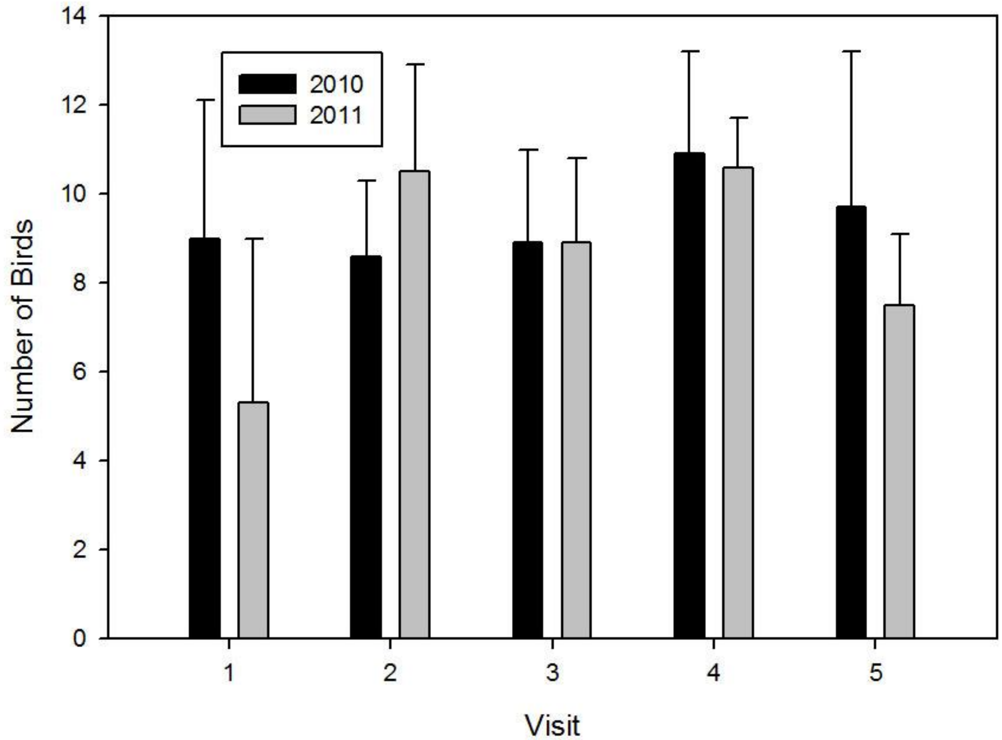

Figure 2.19. Comparison of average total number of birds per year within visits for all treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

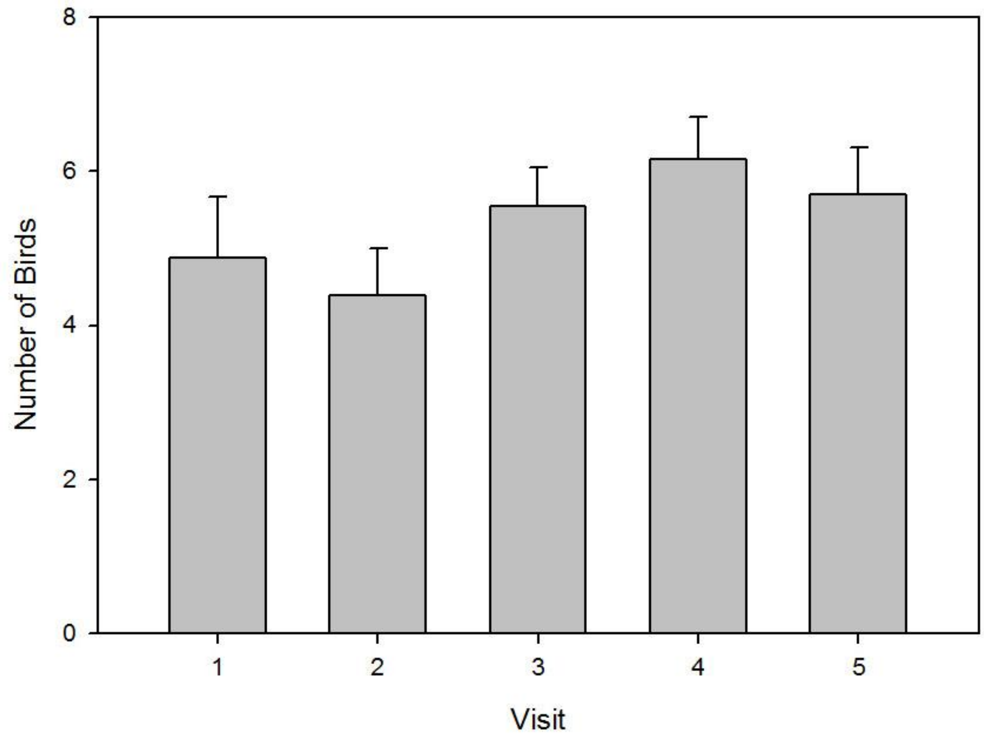

Figure 2.20. Comparison of average number of Cassin's sparrow per visit in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

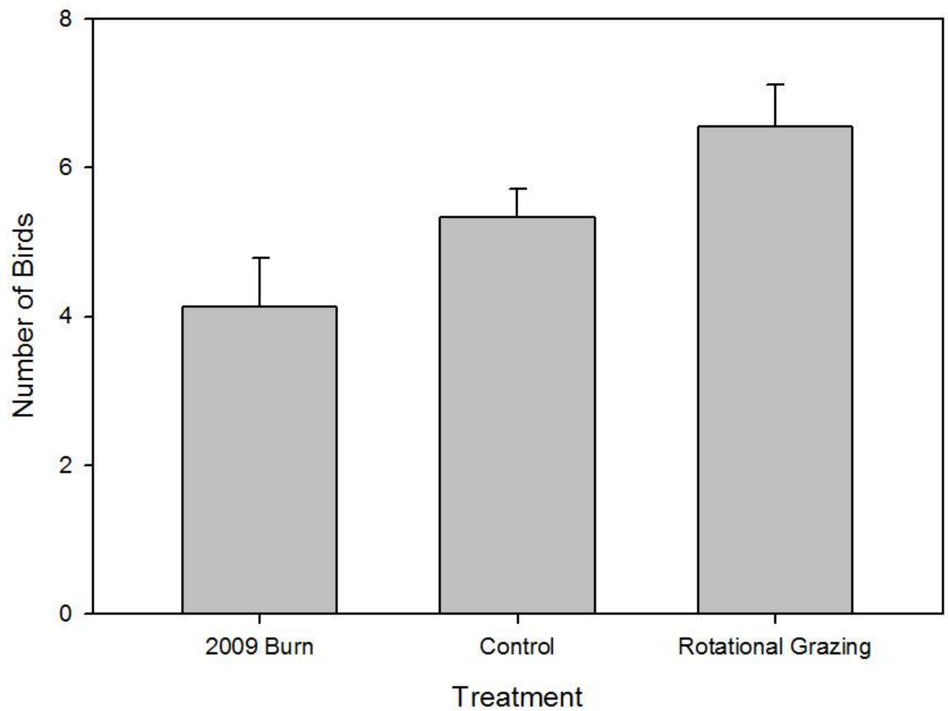

Figure 2.21. Comparison of average number of Cassin's sparrow per treatment in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

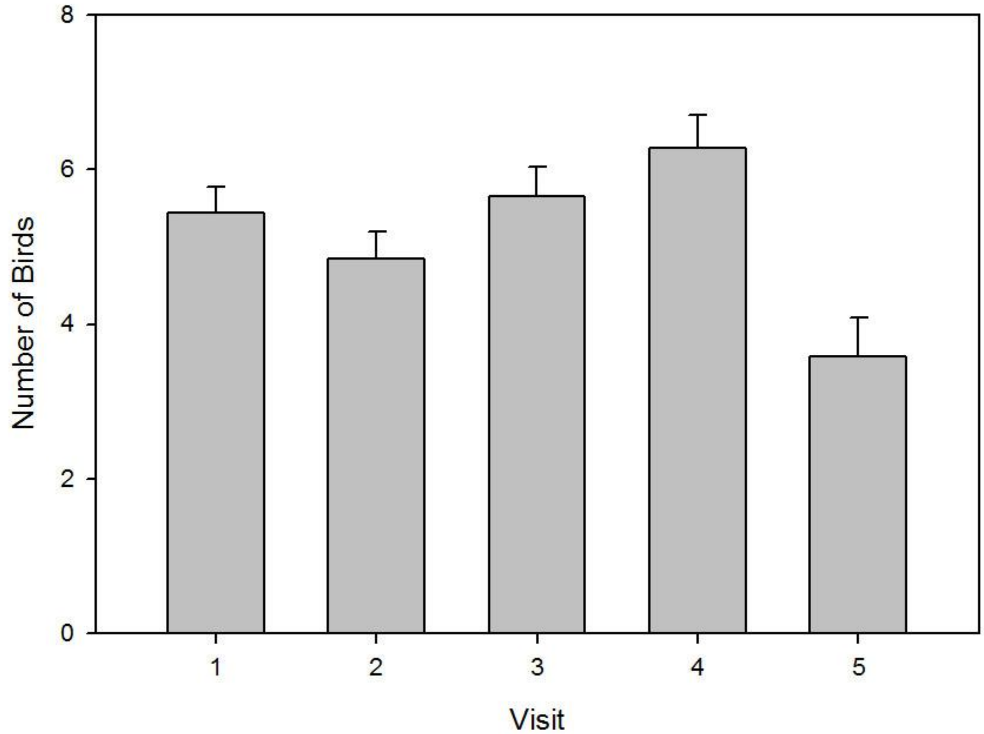

Figure 2.22. Comparison of average number of Cassin's sparrow per visit in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

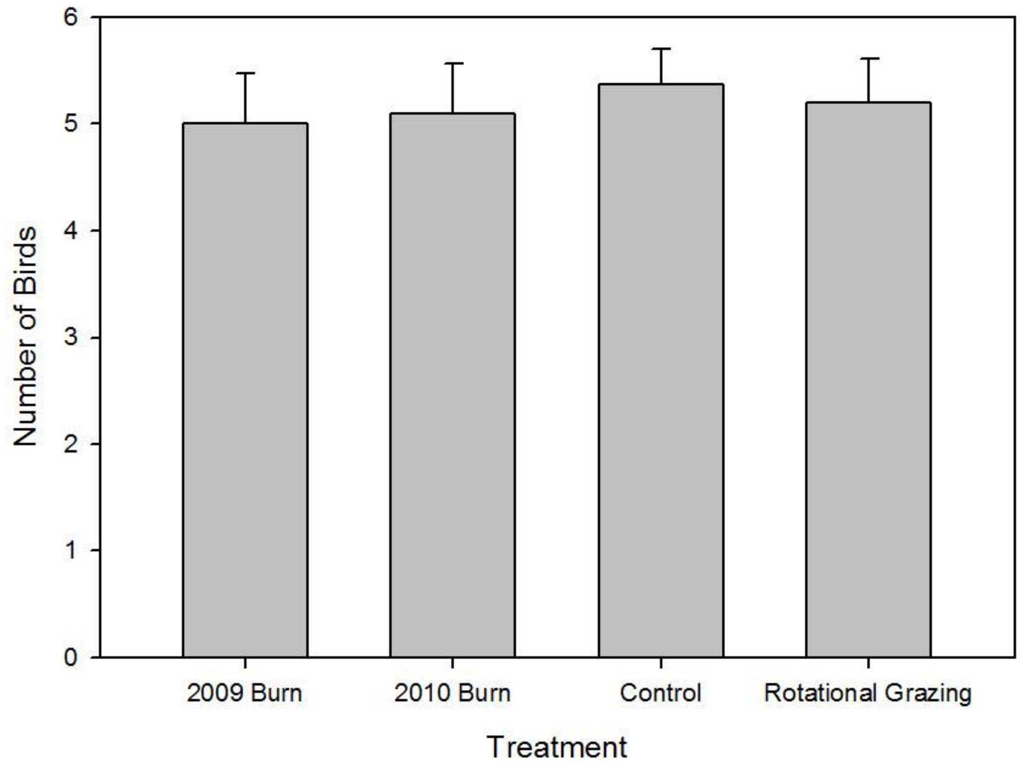

Figure 2.23. Comparison of average number of Cassin's sparrow per treatment in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

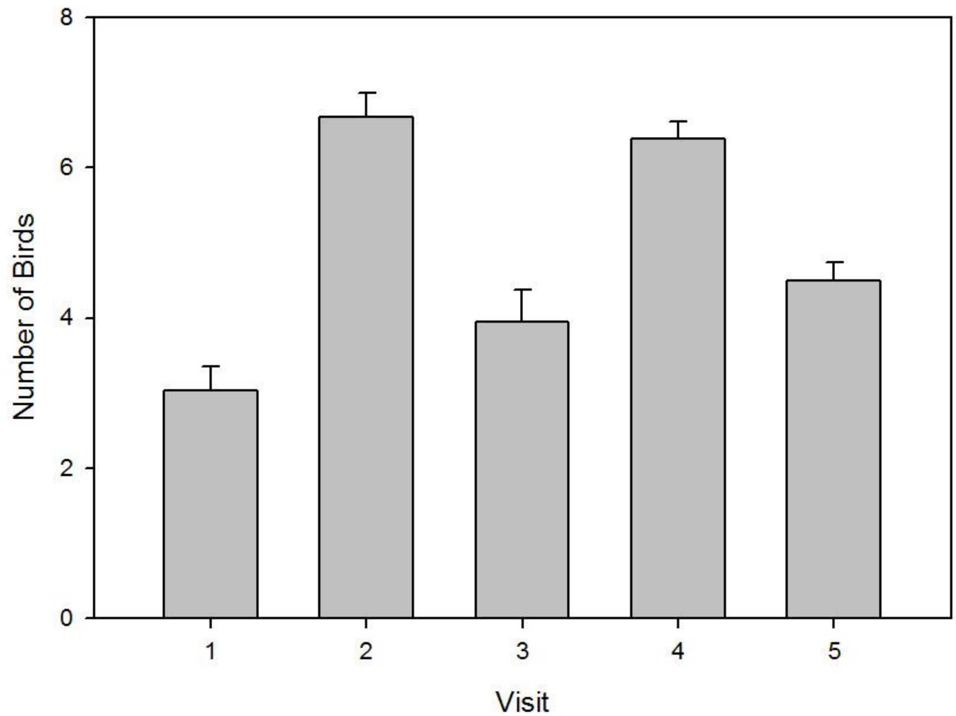

Figure 2.24. Comparison of average number of Cassin's sparrow per visit in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

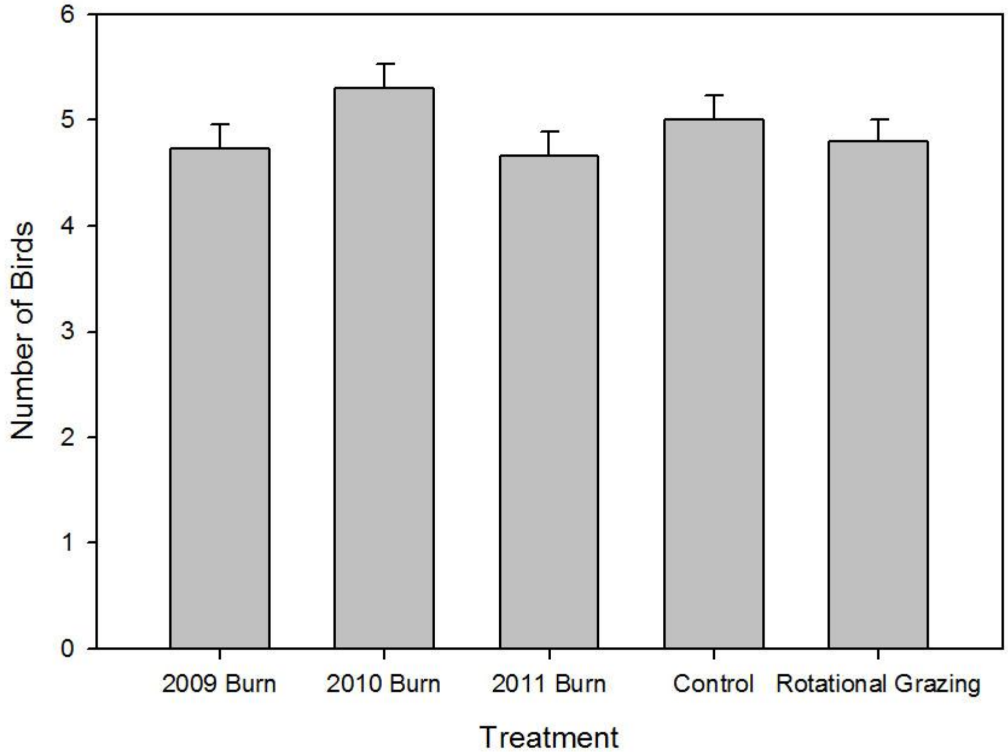

Figure 2.25. Comparison of average number of Cassin's sparrow per treatment in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

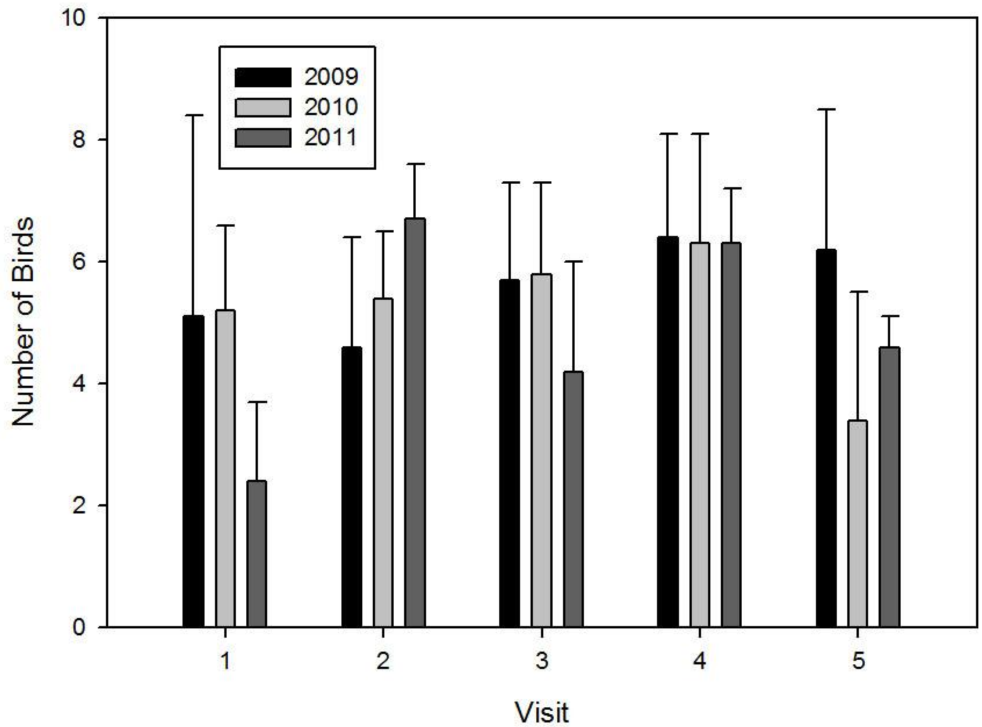

Figure 2.26. Comparison of average number of Cassin's sparrows per year within visits for all treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

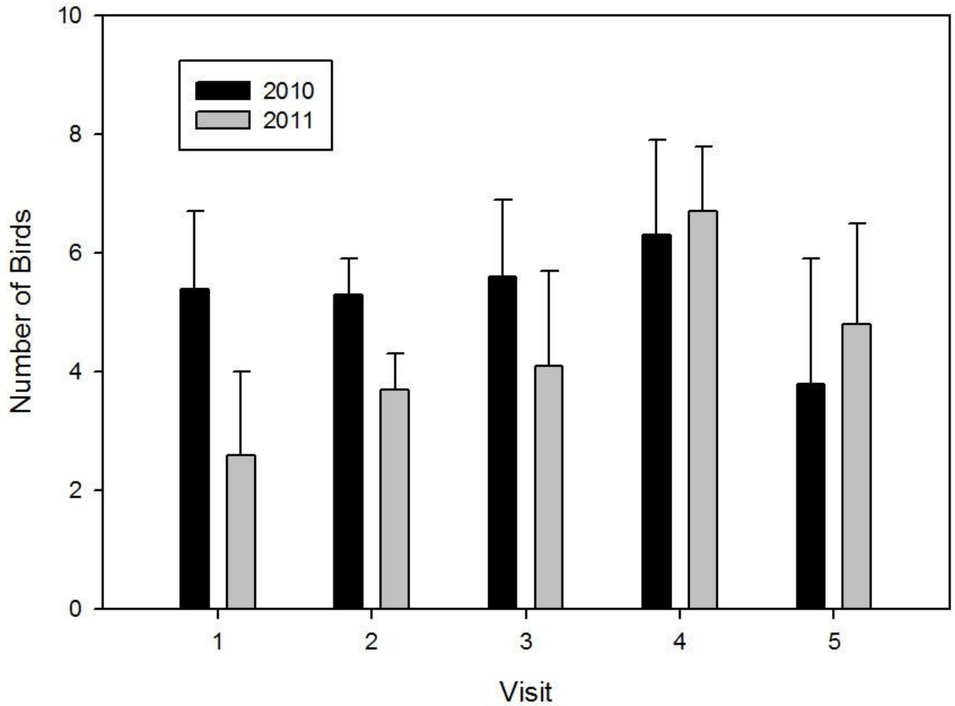

Figure 2.27. Comparison of average number of Cassin's sparrows per year within visits for all treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

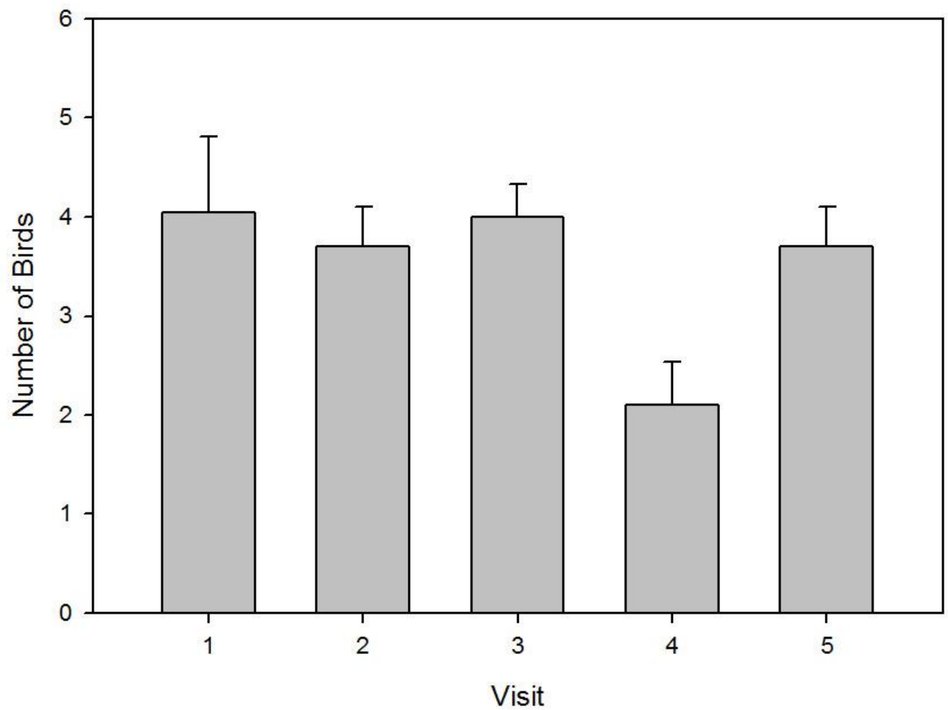

Figure 2.28. Comparison of average number of northern bobwhite per visit in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

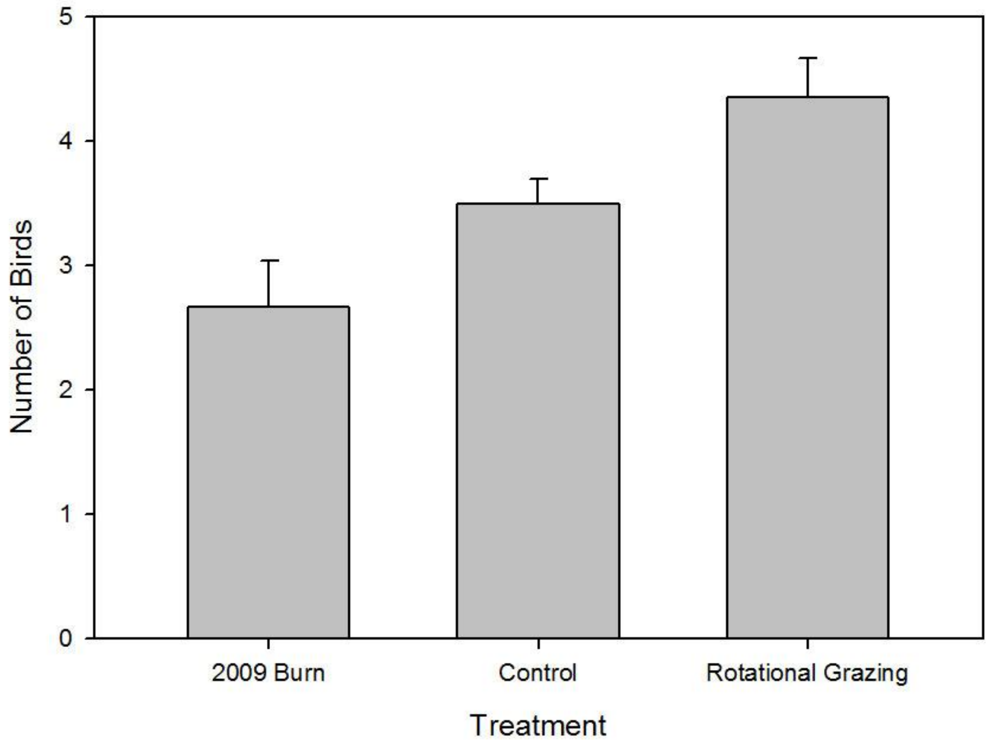

Figure 2.29. Comparison of average number of northern bobwhite per treatment in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

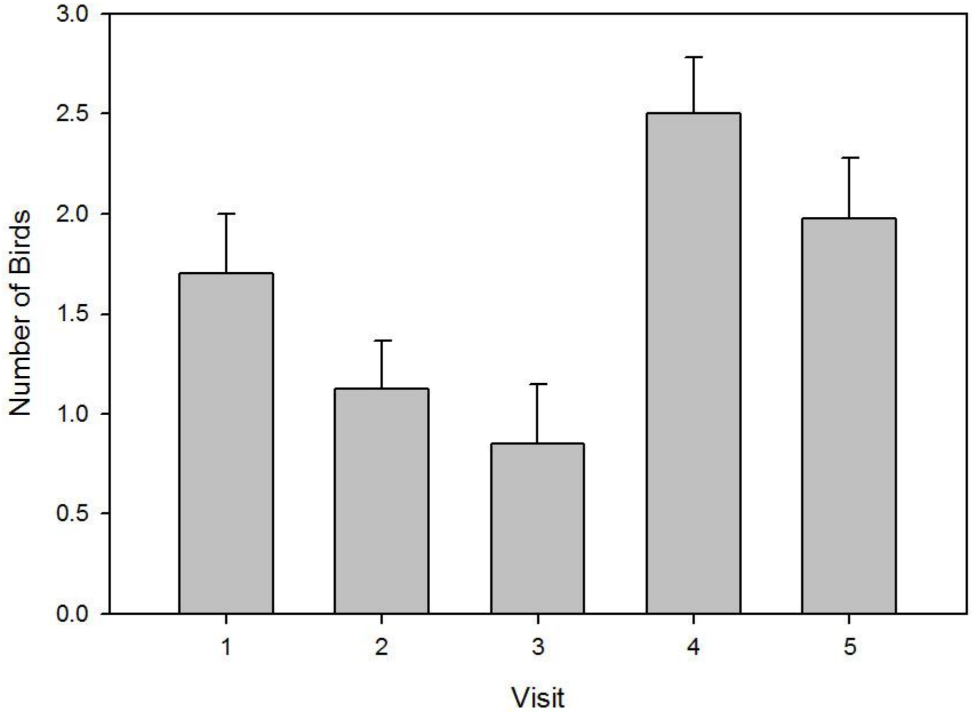

Figure 2.30. Comparison of average number of northern bobwhite per visit in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

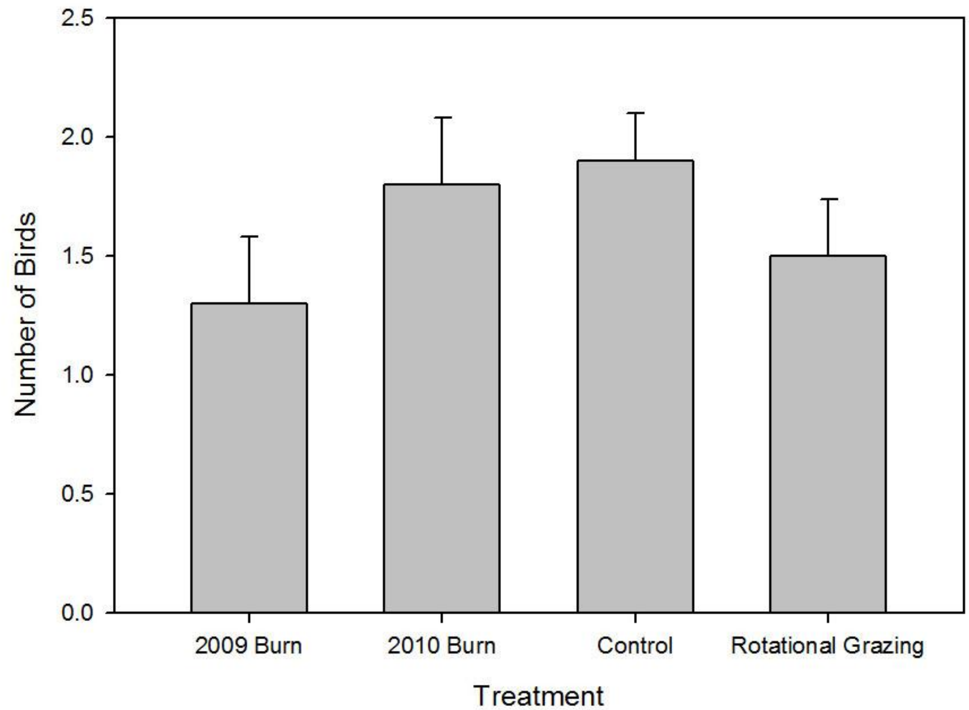

Figure 2.31. Comparison of average number of northern bobwhite per treatment in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

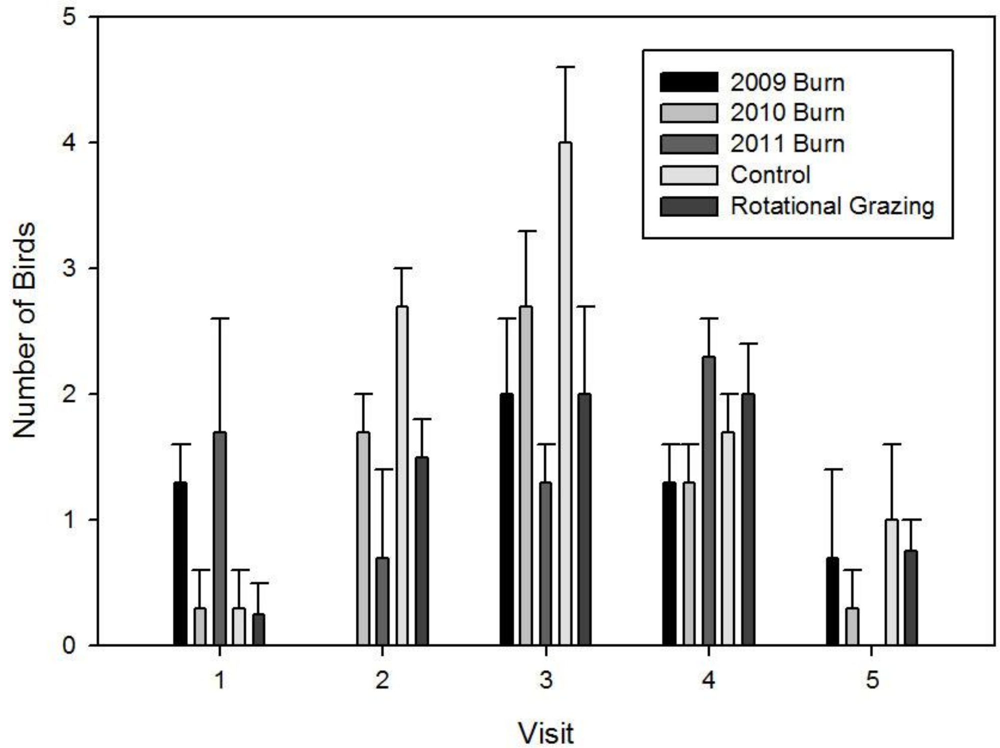

Figure 2.32. Comparison of average number of northern bobwhite per treatment within visits for all available treatments in 2011 for patch burn-grazing and rotational grazing (Mean±SE).

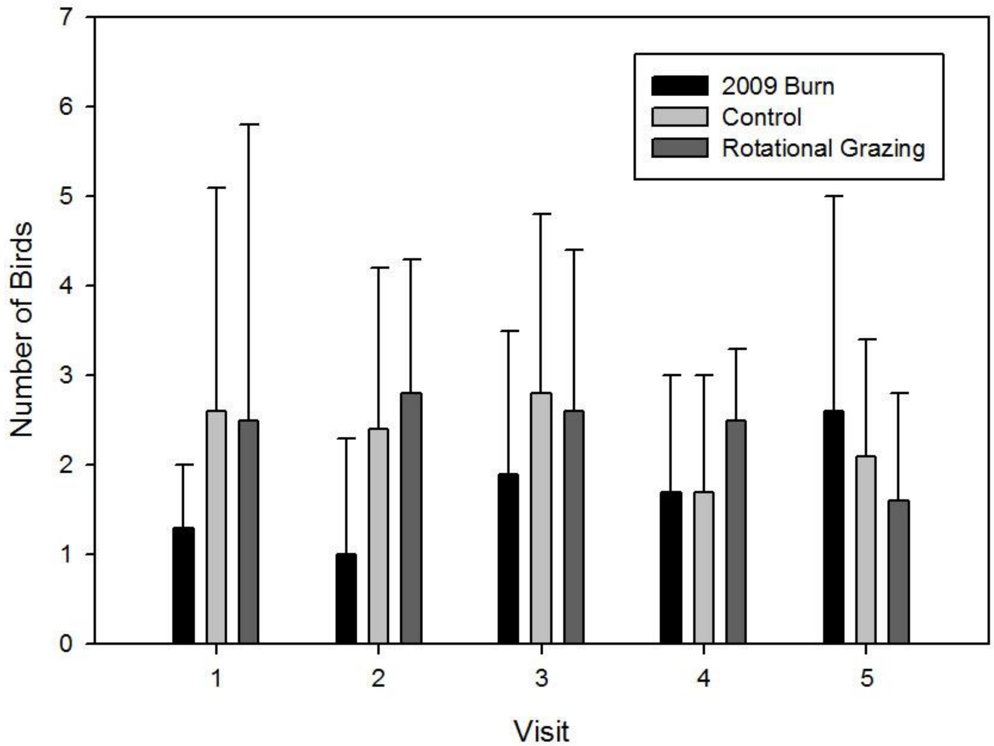

Figure 2.33. Comparison of average number of northern bobwhite per treatment within visits for all treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

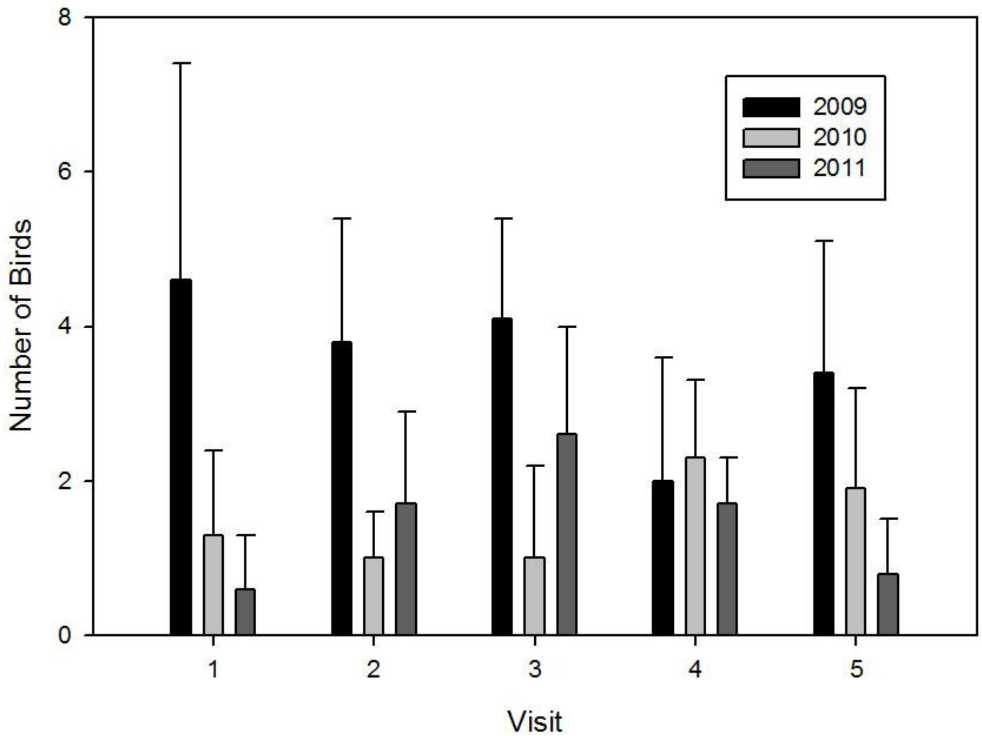

Figure 2.34. Comparison of average number of northern bobwhite per year within visits for all treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

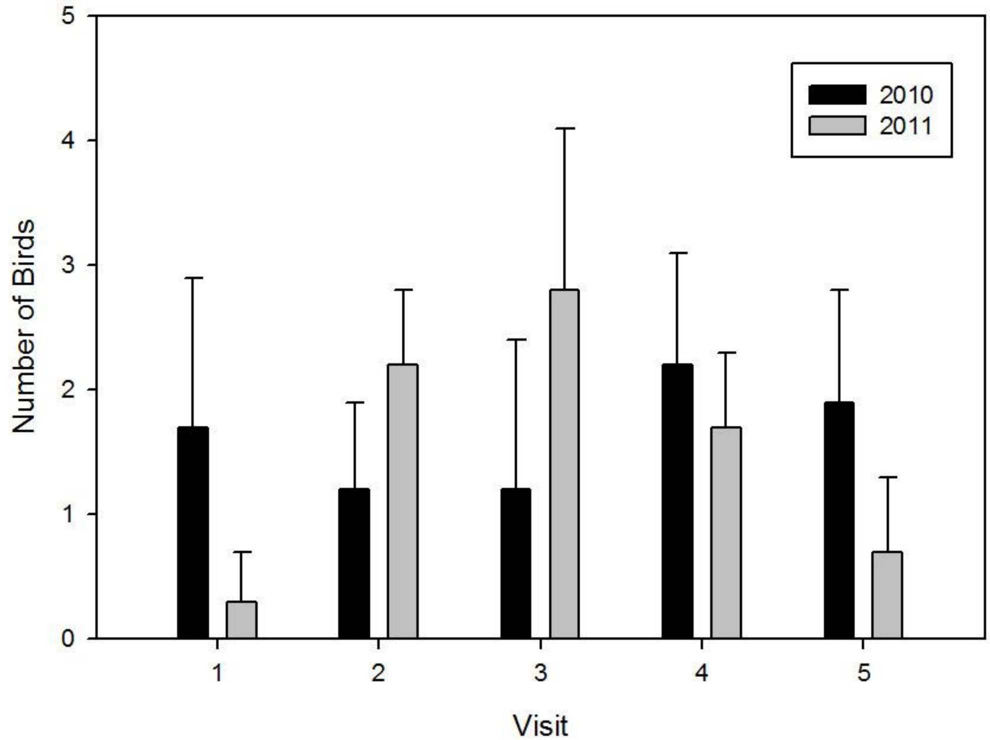

Figure 2.35. Comparison of average number of northern bobwhite per year within visits for all treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

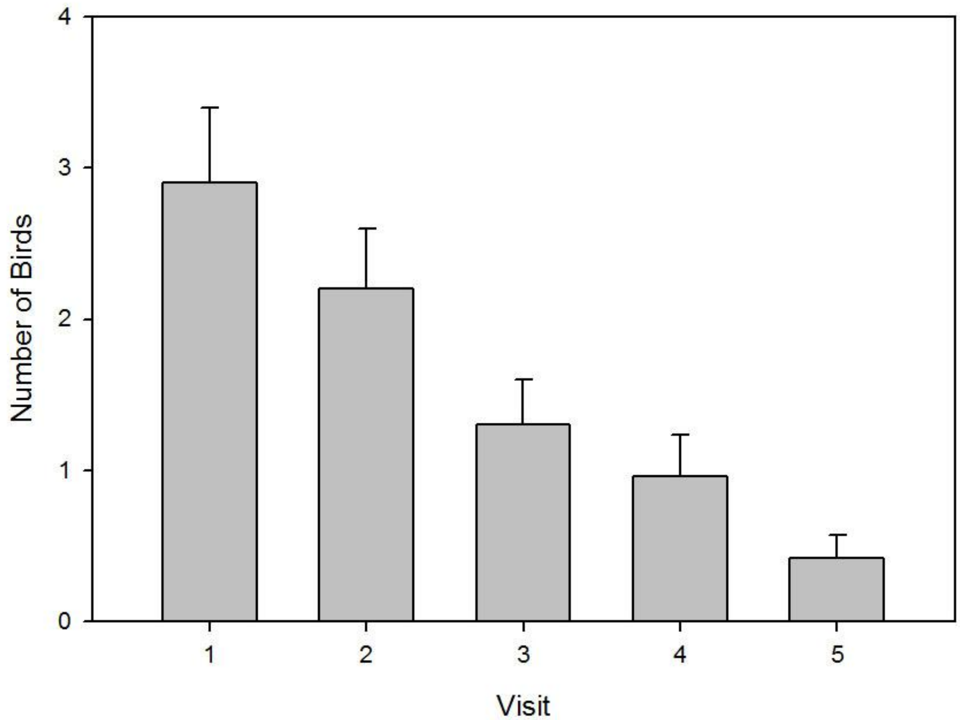

Figure 2.36. Comparison of average number of northern mocking birds per visit in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

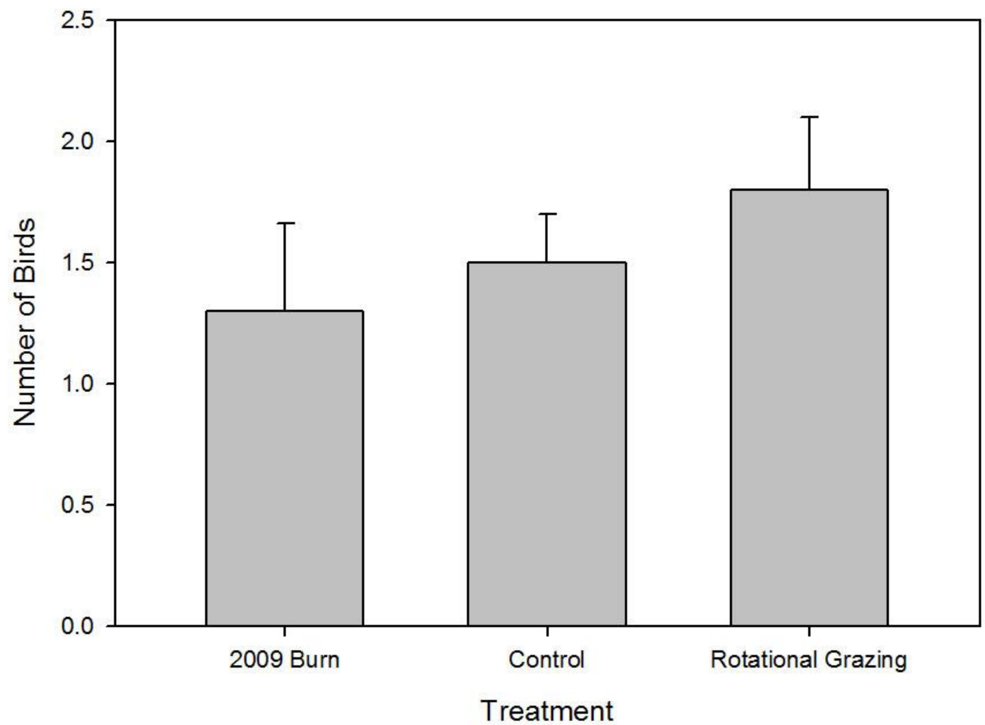

Figure 2.37. Comparison of average number of northern mocking birds per treatment in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

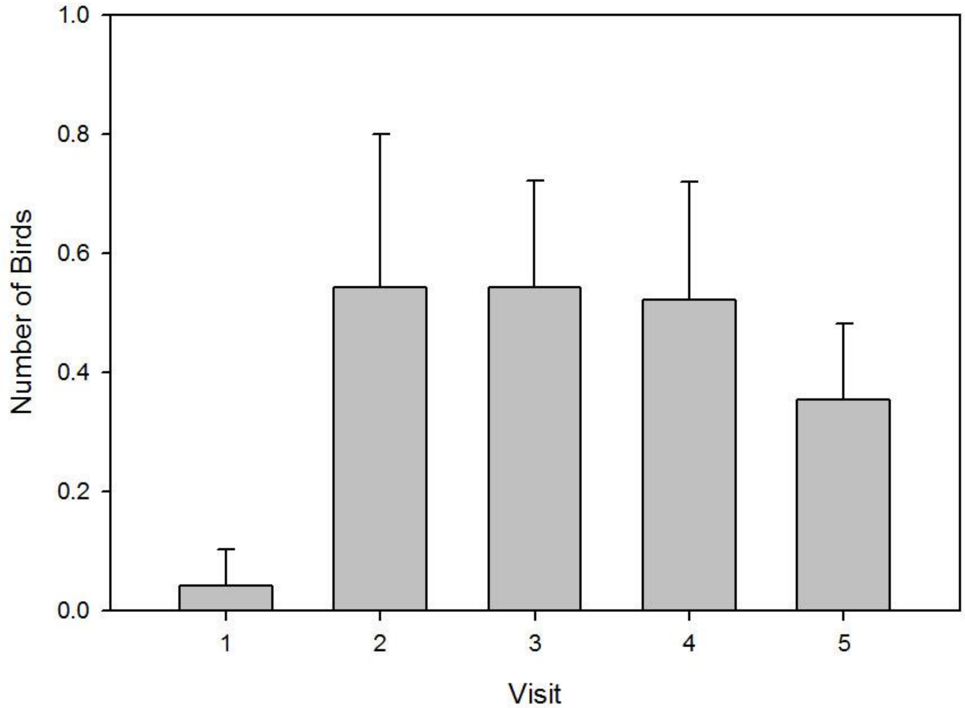

Figure 2.38. Comparison of average number of northern mocking birds per visit in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

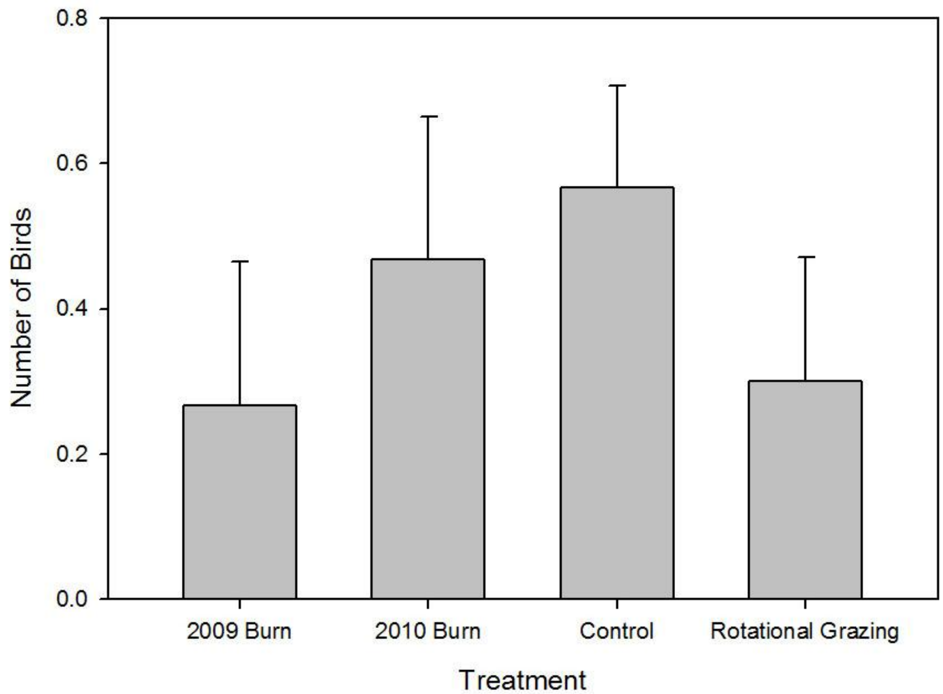

Figure 2.39. Comparison of average number of northern mocking birds per treatment in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

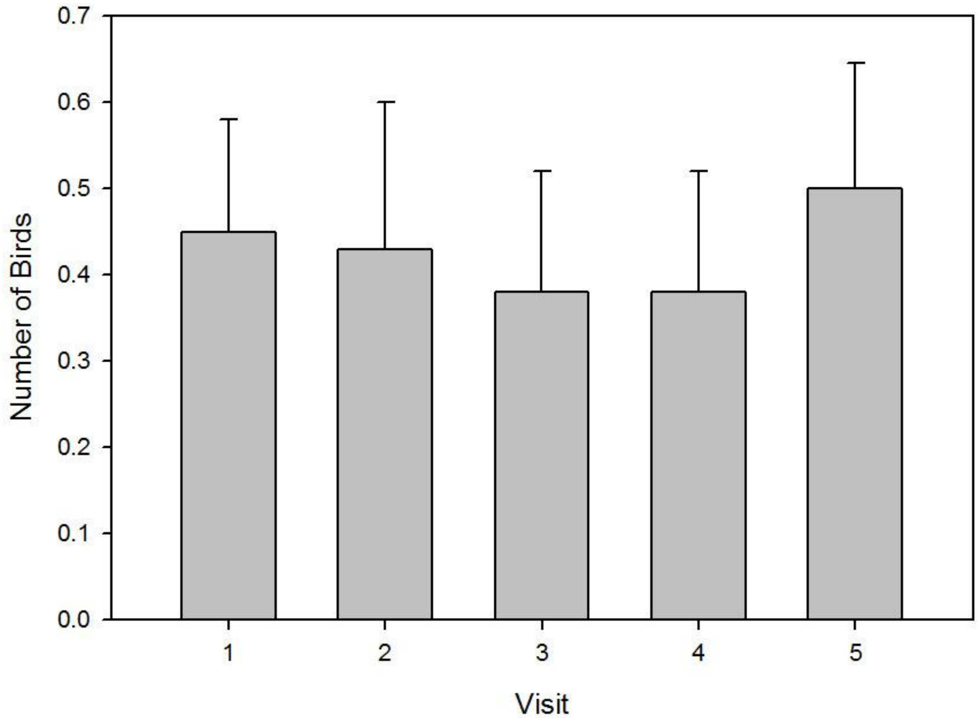

Figure 2.40. Comparison of average number of northern mocking birds per visit in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

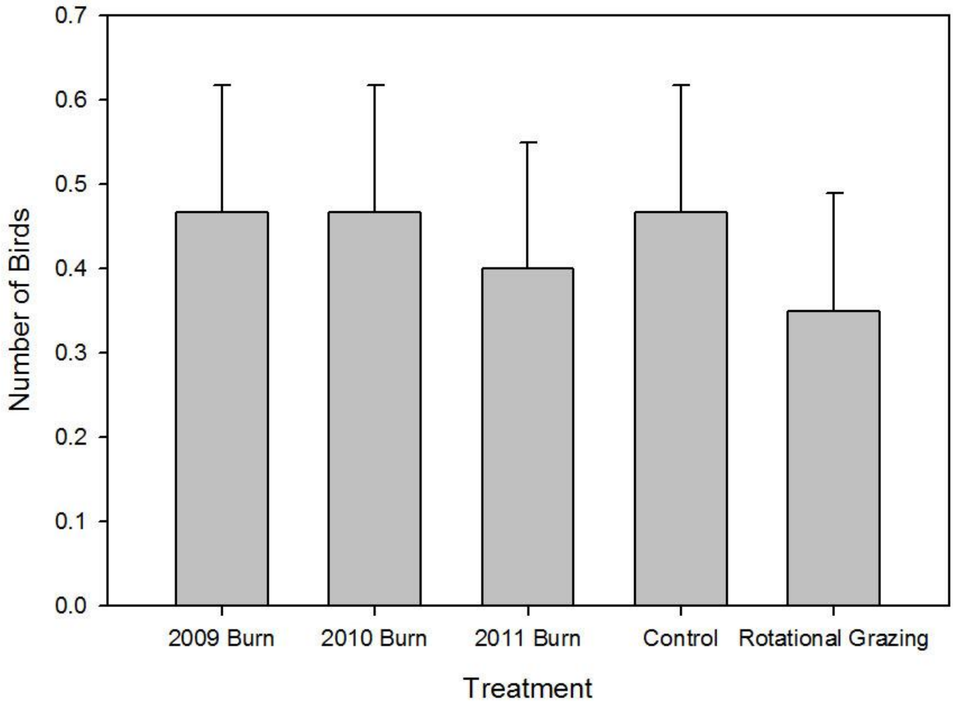

Figure 2.41. Comparison of average number of northern mocking birds per treatment in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

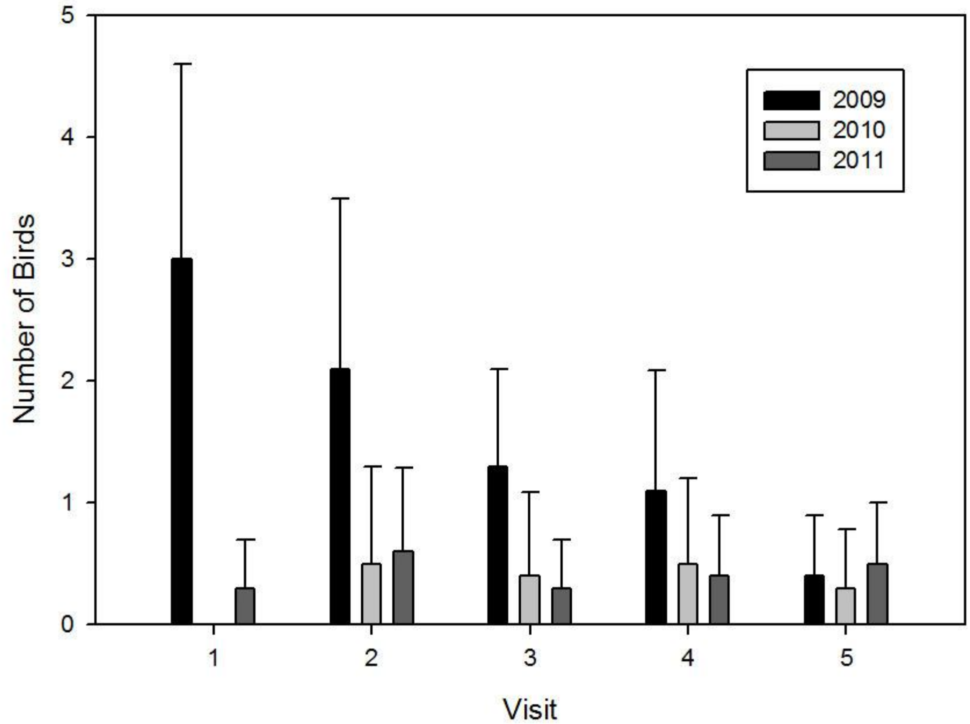

Figure 2.42. Comparison of average number of northern mocking birds per year within visits for all treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

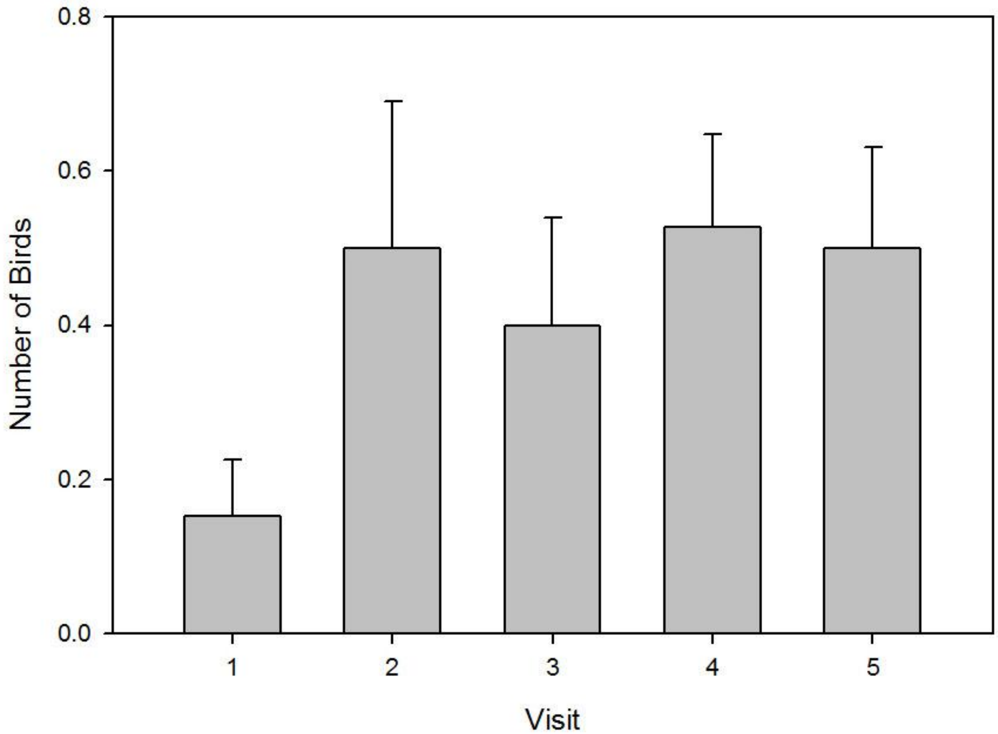

Figure 2.43. Comparison of average number of northern mocking birds per visit for treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

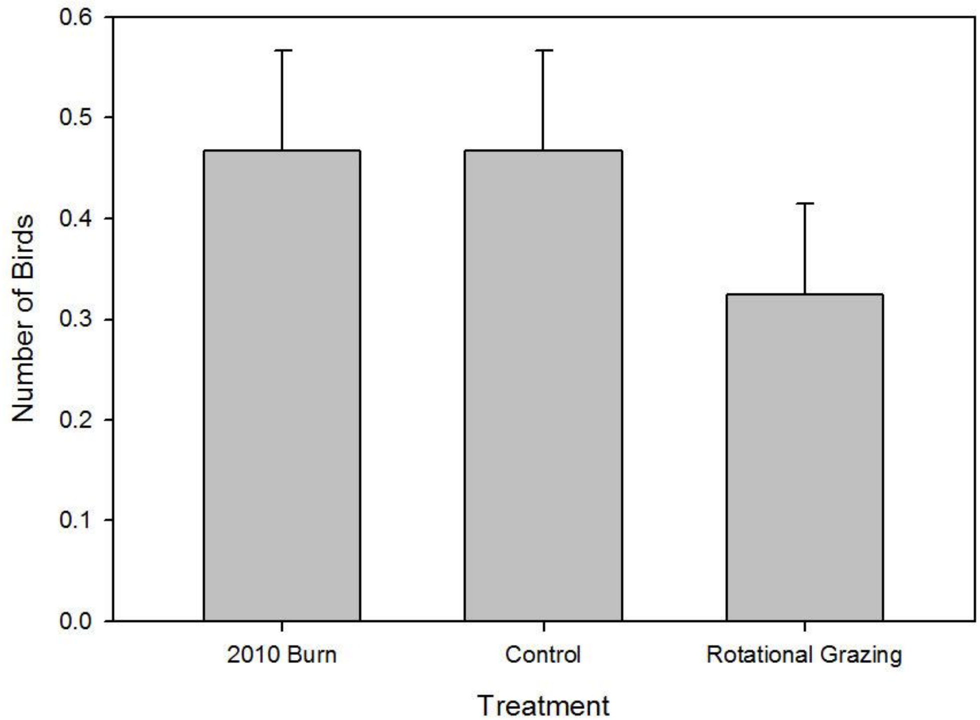

Figure 2.44. Comparison of average number of northern mocking birds per treatment for treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

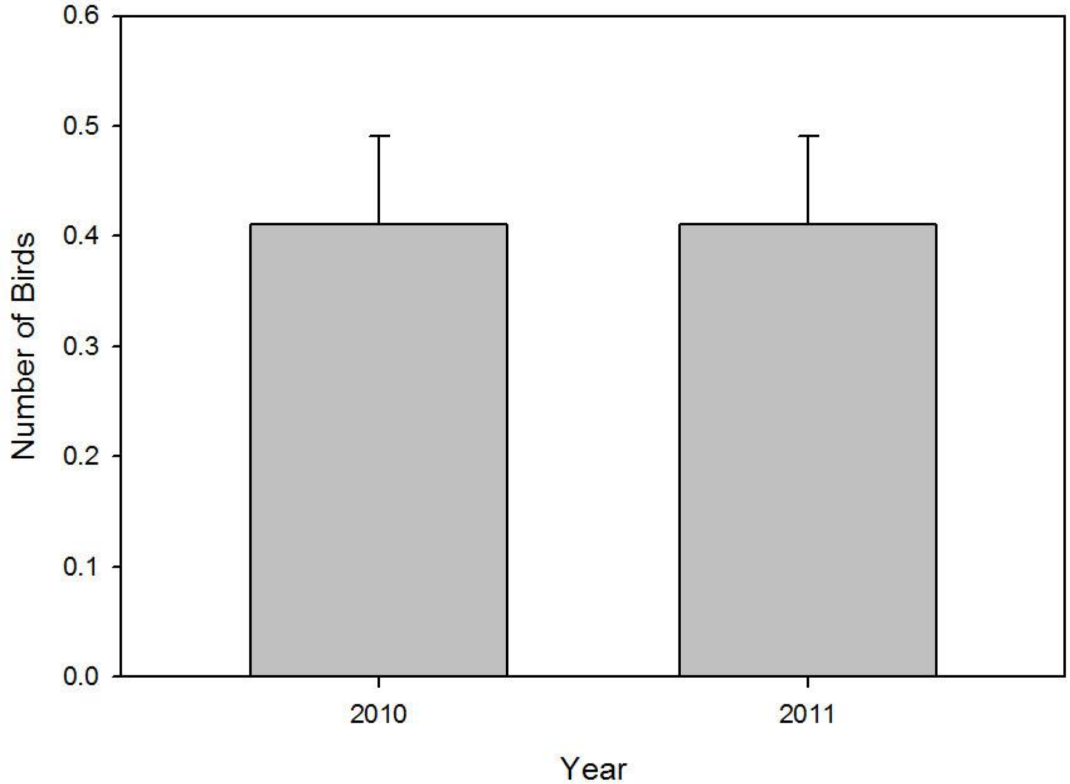

Figure 2.45. Comparison of average number of northern mocking birds per year for treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

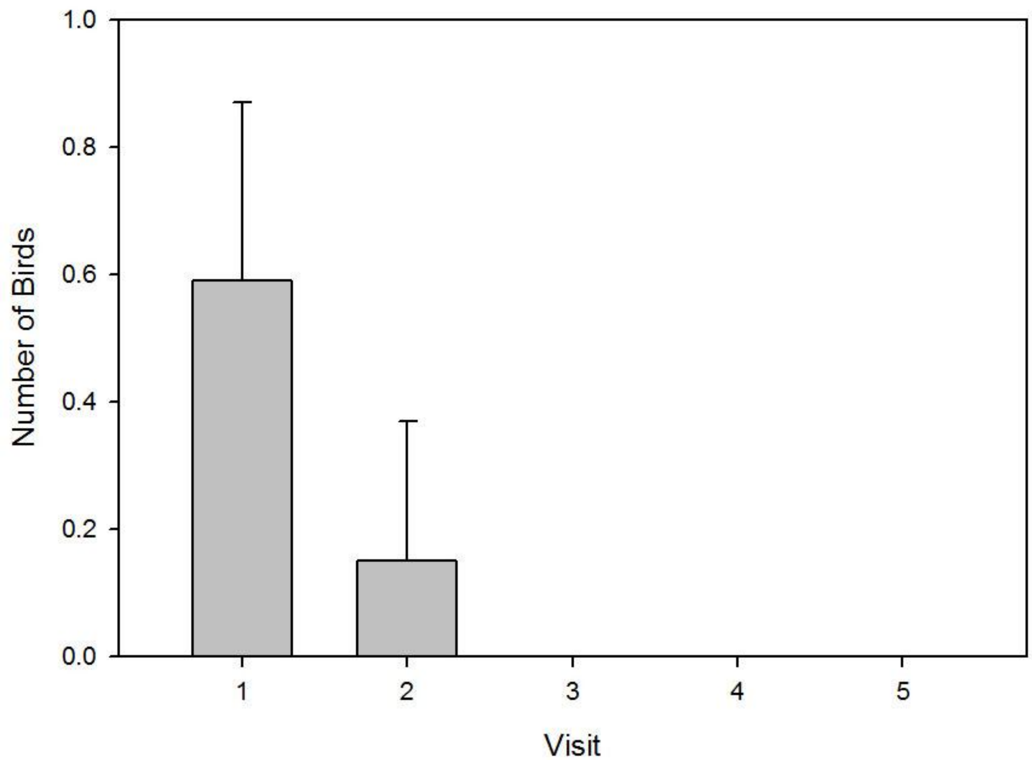

Figure 2.46. Comparison of average number of grasshopper sparrows per visit in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

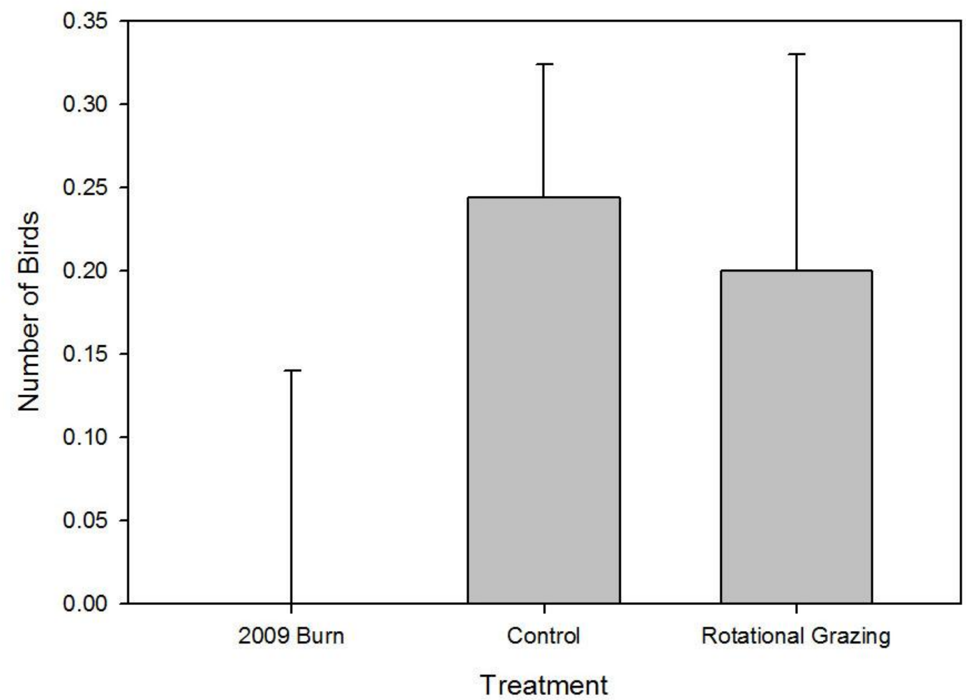

Figure 2.47. Comparison of average number of grasshopper sparrows per treatment in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

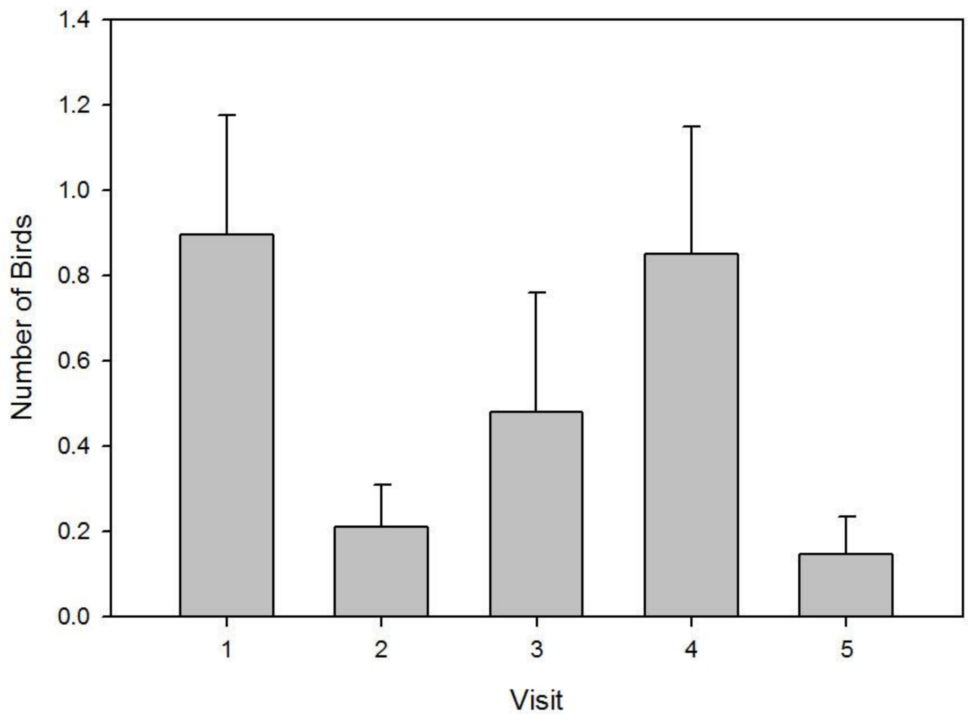

Figure 2.48. Comparison of average number of grasshopper sparrows per visit in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

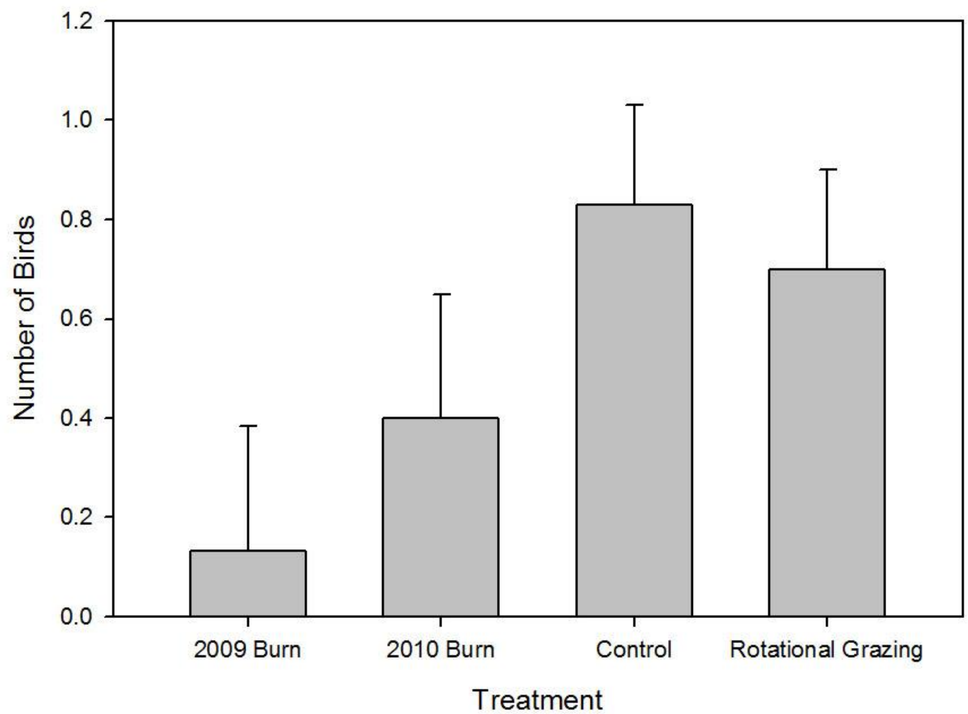

Figure 2.49. Comparison of average number of grasshopper sparrows per treatment in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

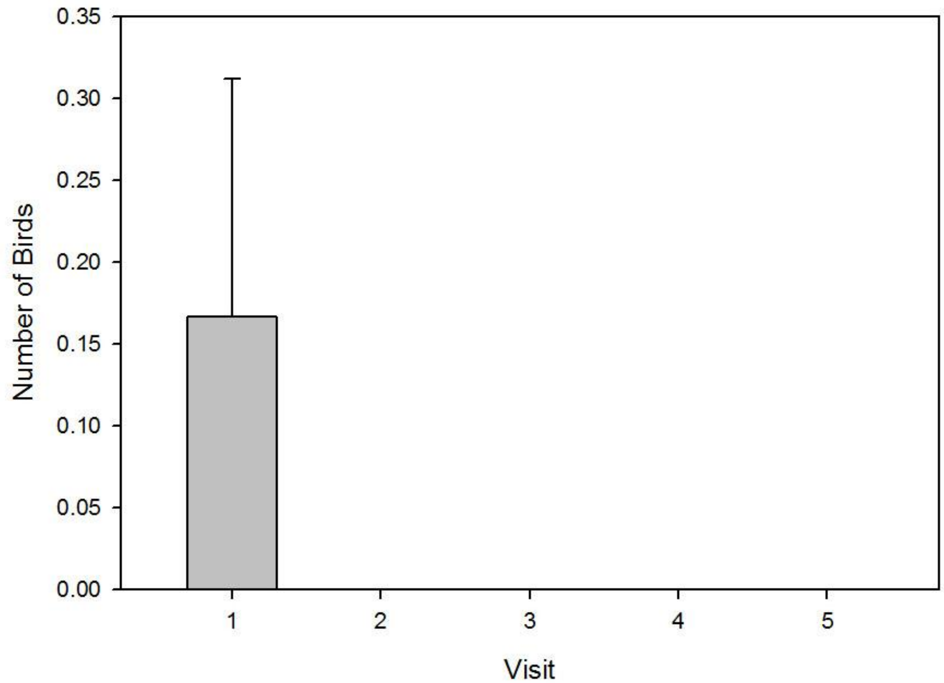

Figure 2.50. Comparison of average number of grasshopper sparrows per visit in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

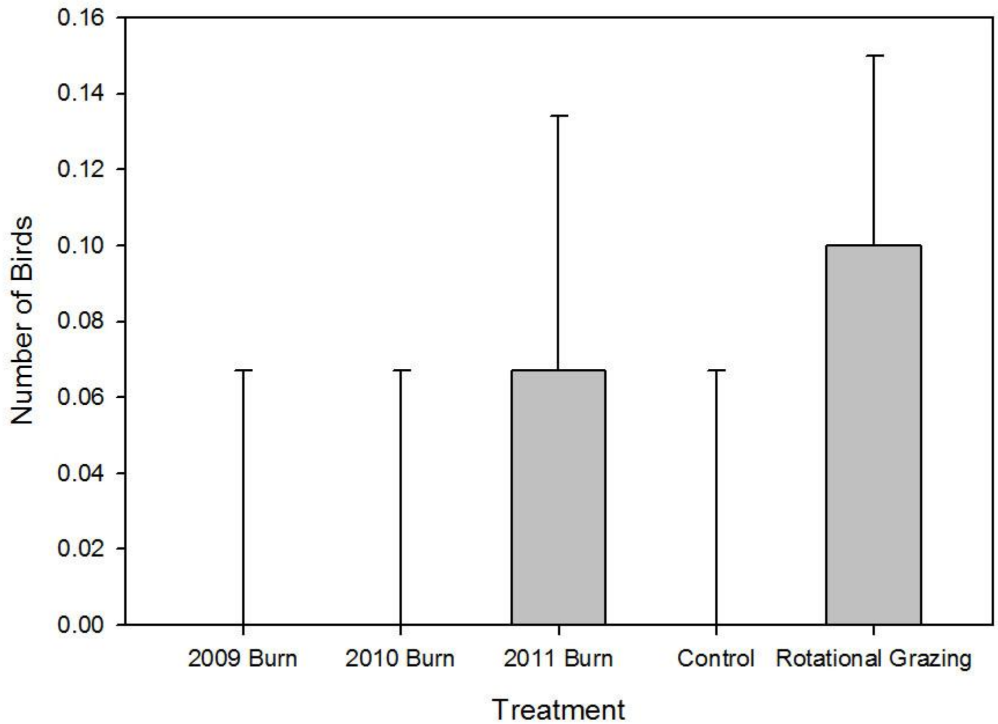

Figure 2.51. Comparison of average number of grasshopper sparrows per treatment in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

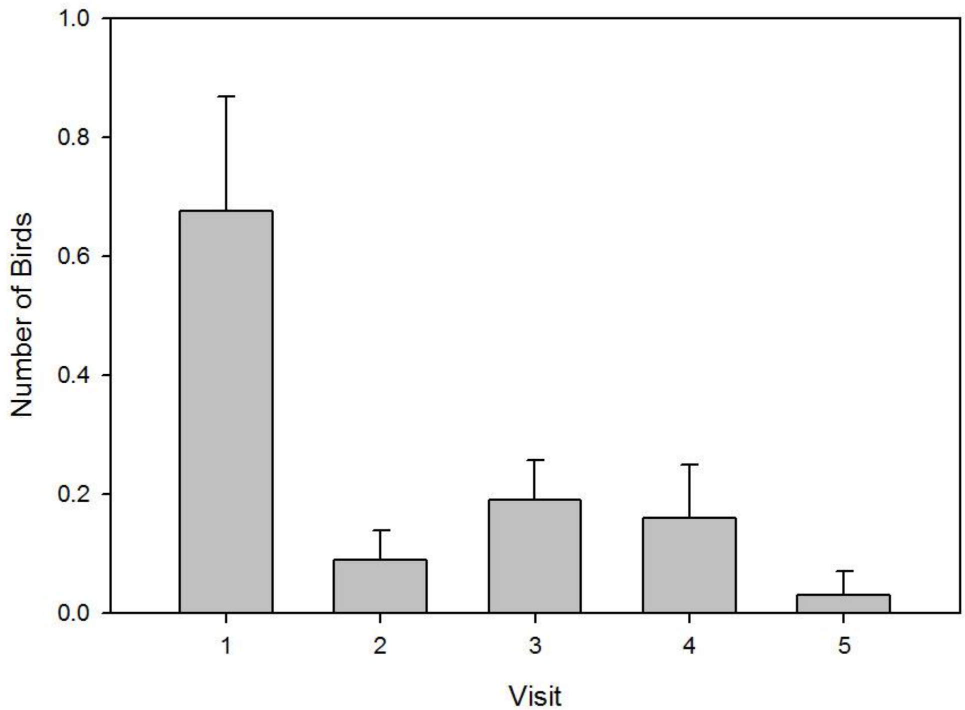

Figure 2.52. Comparison of average number of grasshopper sparrows per visit for treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

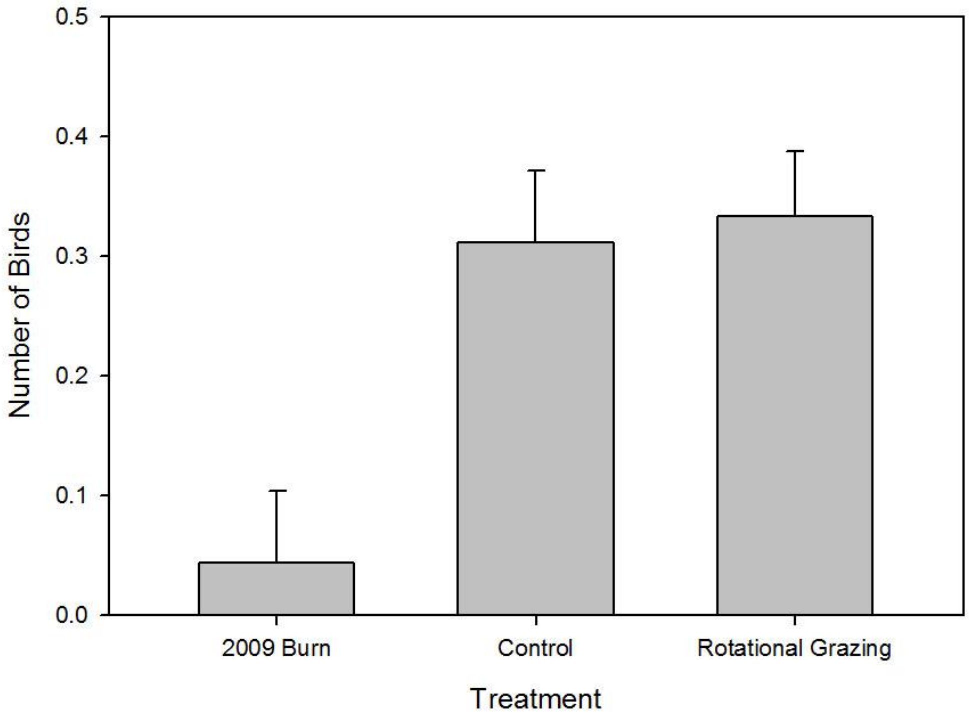

Figure 2.53. Comparison of average number of grasshopper sparrows per treatment for treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

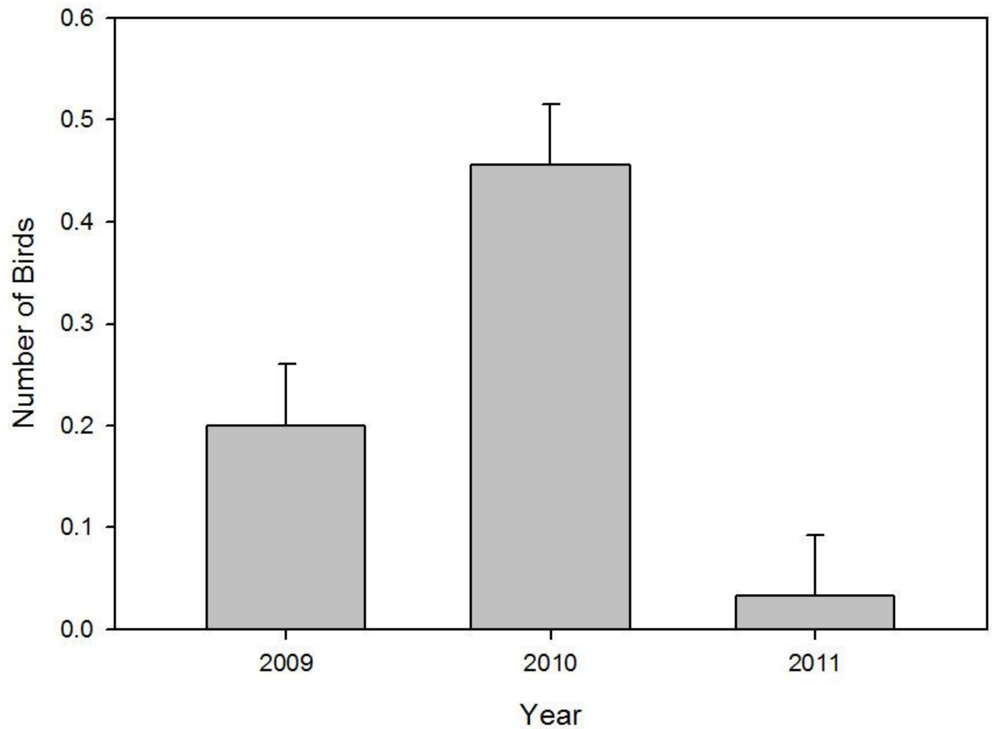

Figure 2.54. Comparison of average number of grasshopper sparrows per year for treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

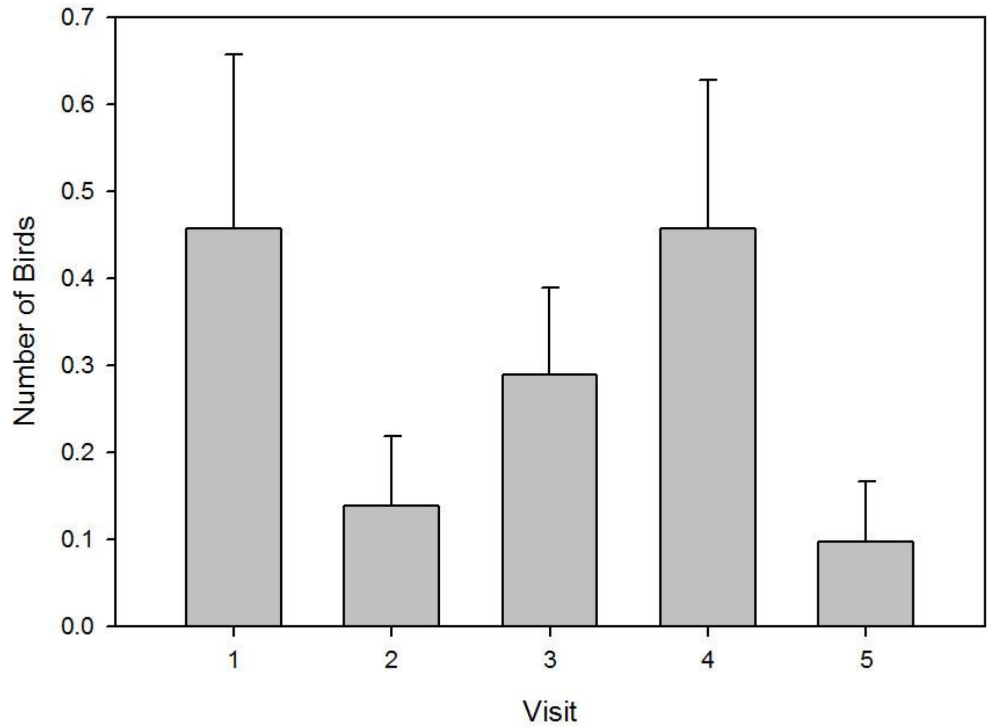

Figure 2.55. Comparison of average number of grasshopper sparrows per visit for treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

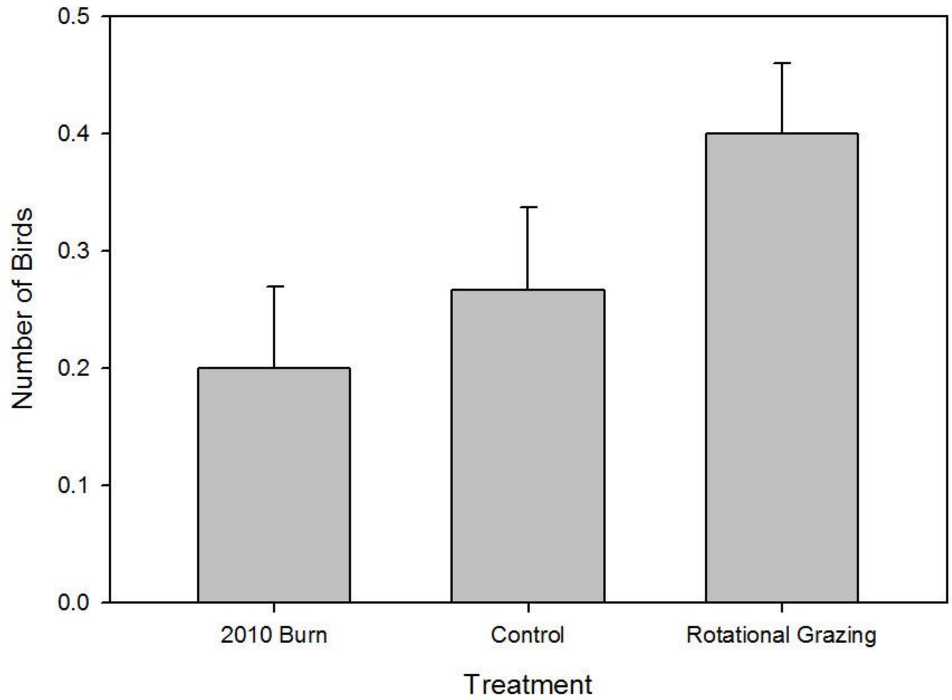

Figure 2.56. Comparison of average number of grasshopper sparrows per treatment for treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

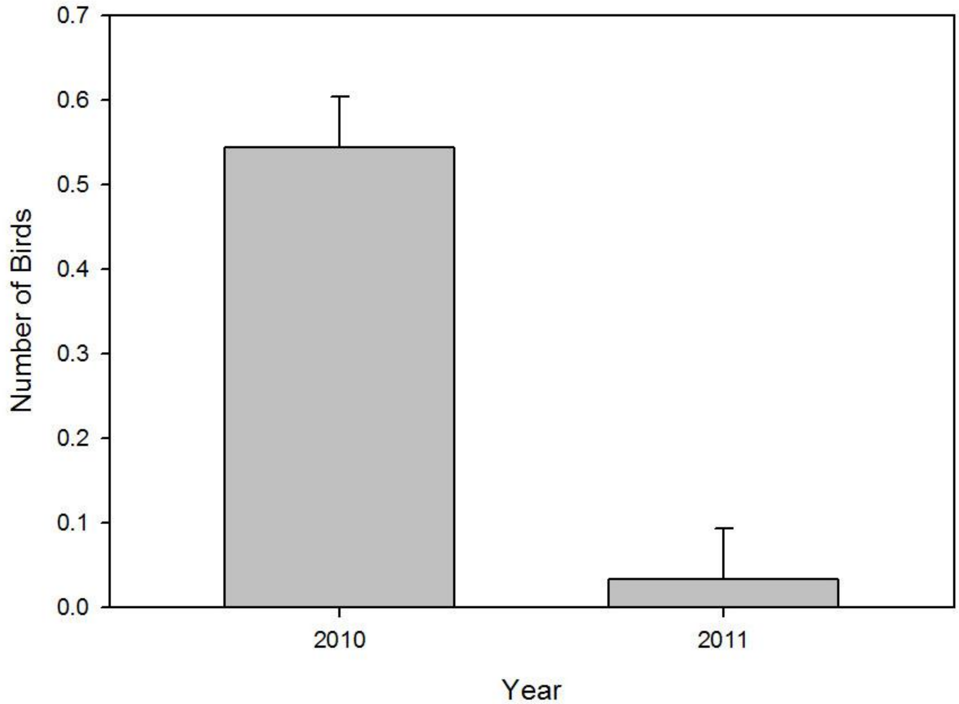

Figure 2.57. Comparison of average number of grasshopper sparrows per year for treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

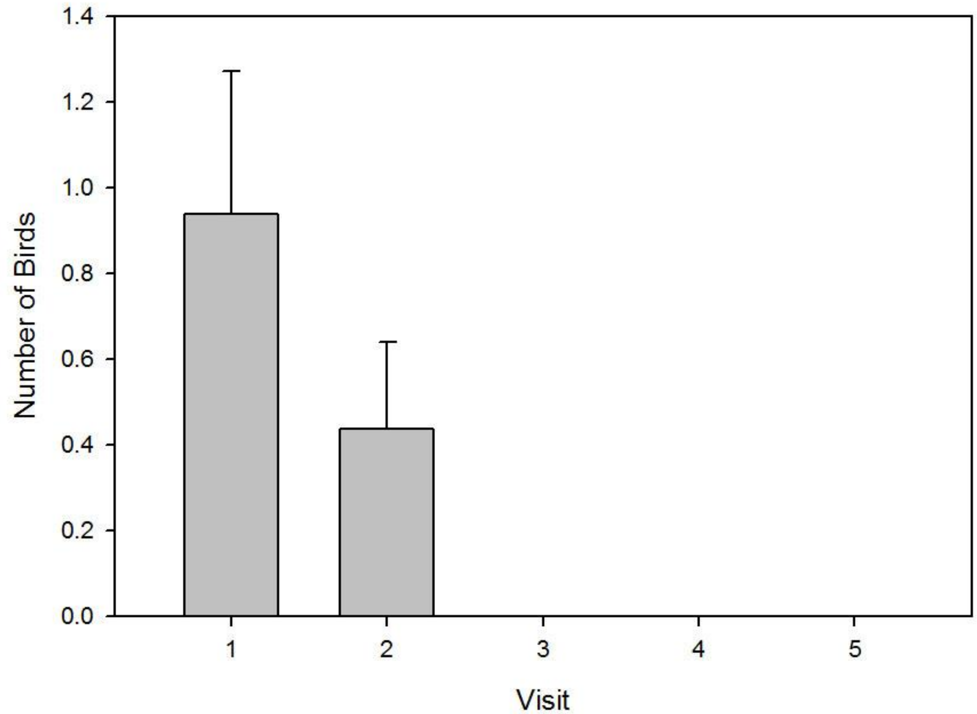

Figure 2.58. Comparison of average number of scissor-tailed flycatchers per visit in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

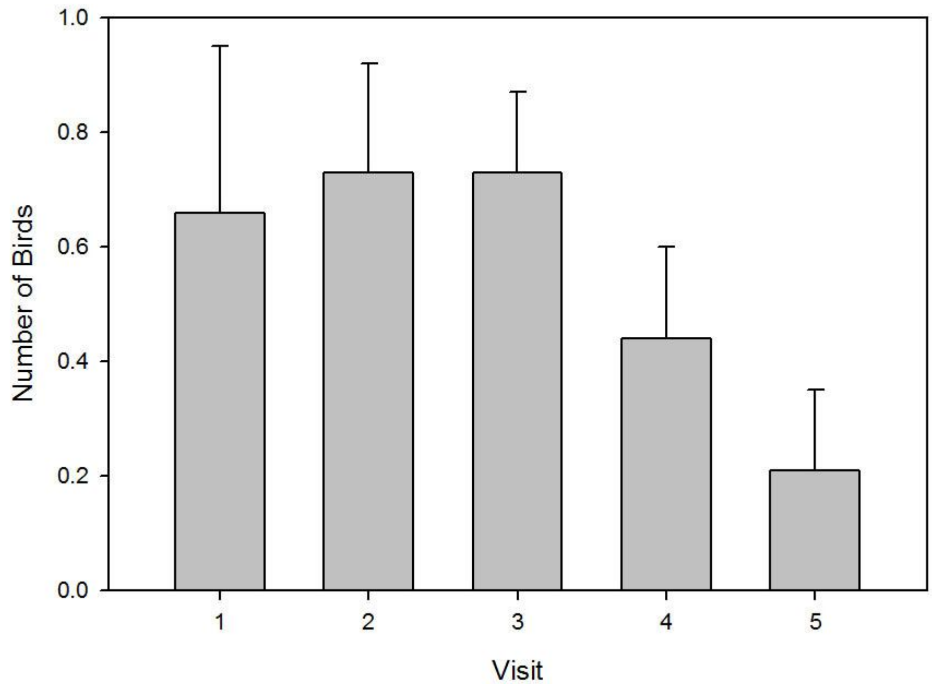

Figure 2.59. Comparison of average number of scissor-tailed flycatchers per visit in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

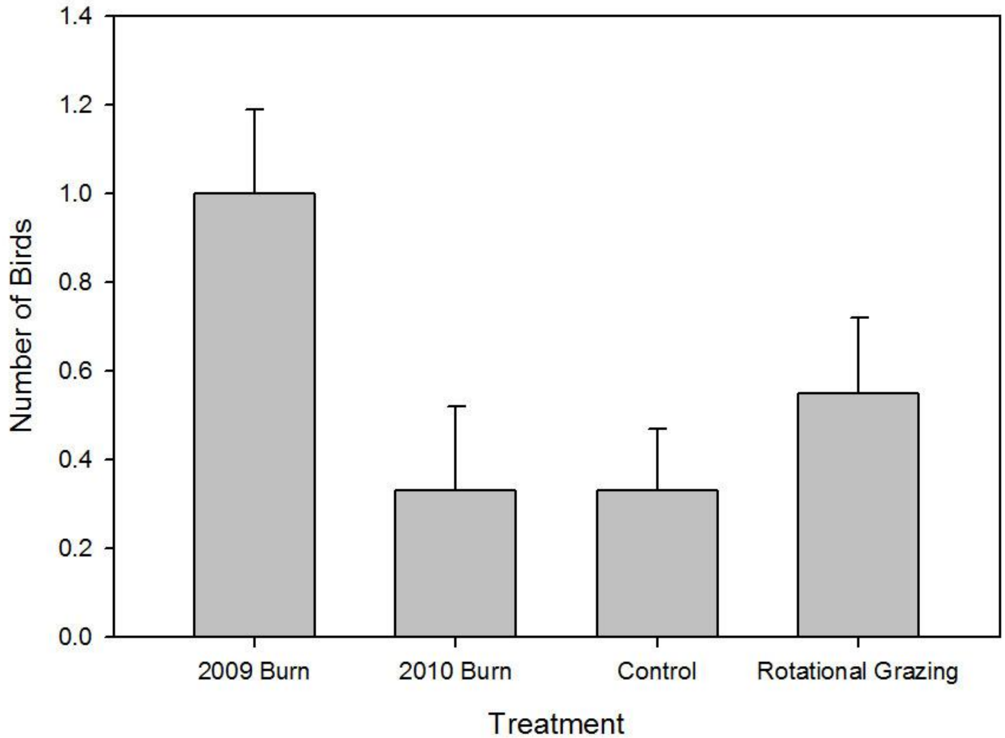

Figure 2.60. Comparison of average number of scissor-tailed flycatchers per treatment in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

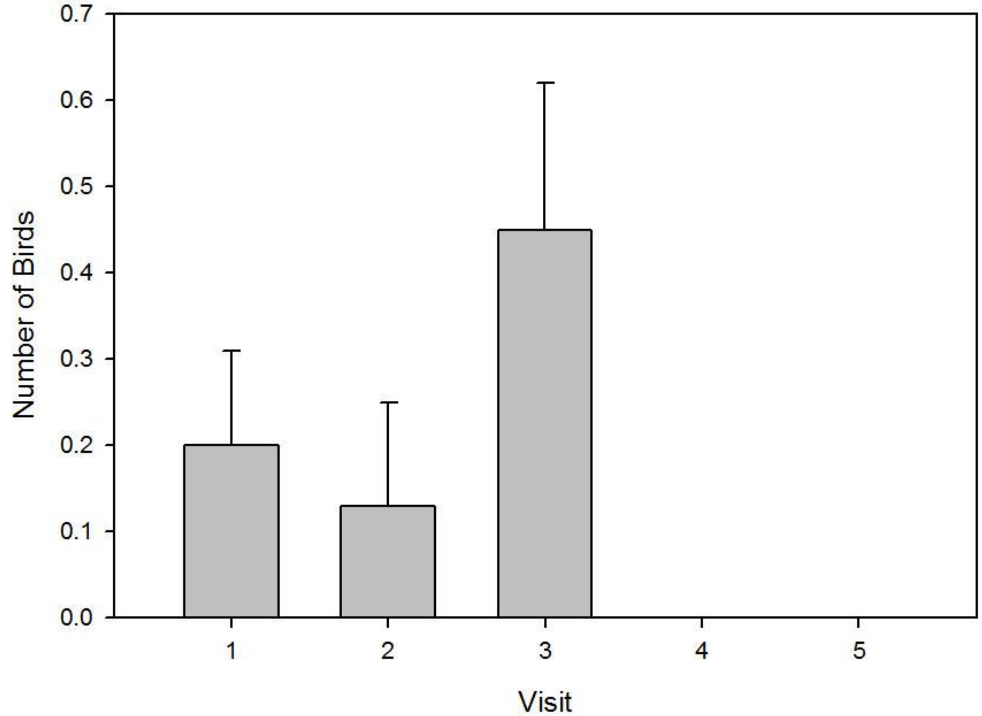

Figure 2.61. Comparison of average number of scissor-tailed flycatchers per visit in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

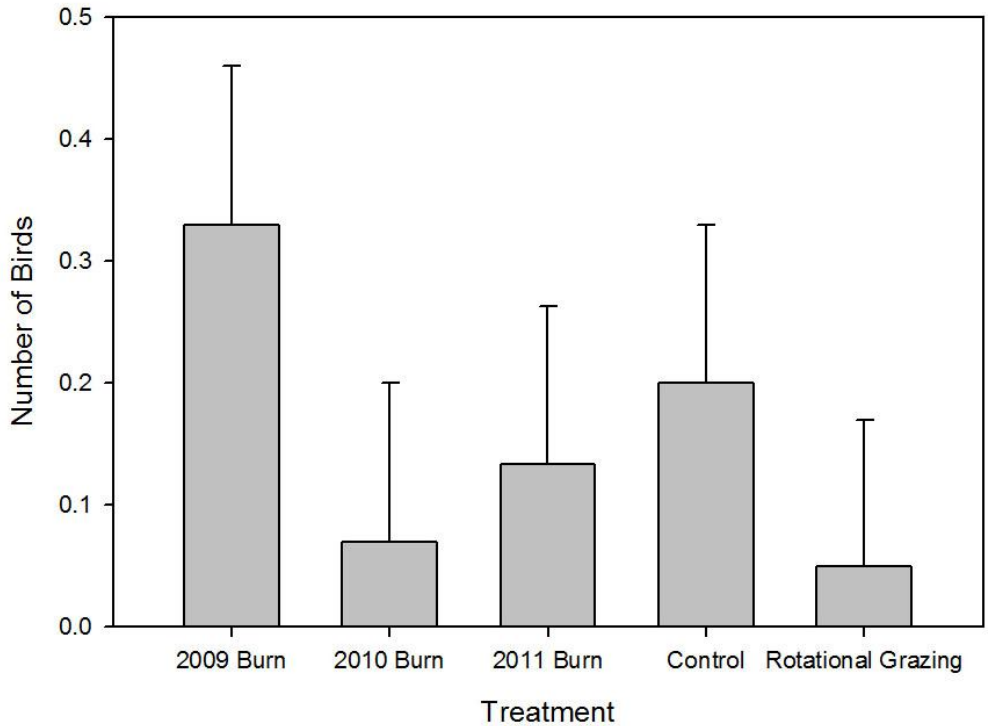

Figure 2.62. Comparison of average number of scissor-tailed flycatchers per treatment in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

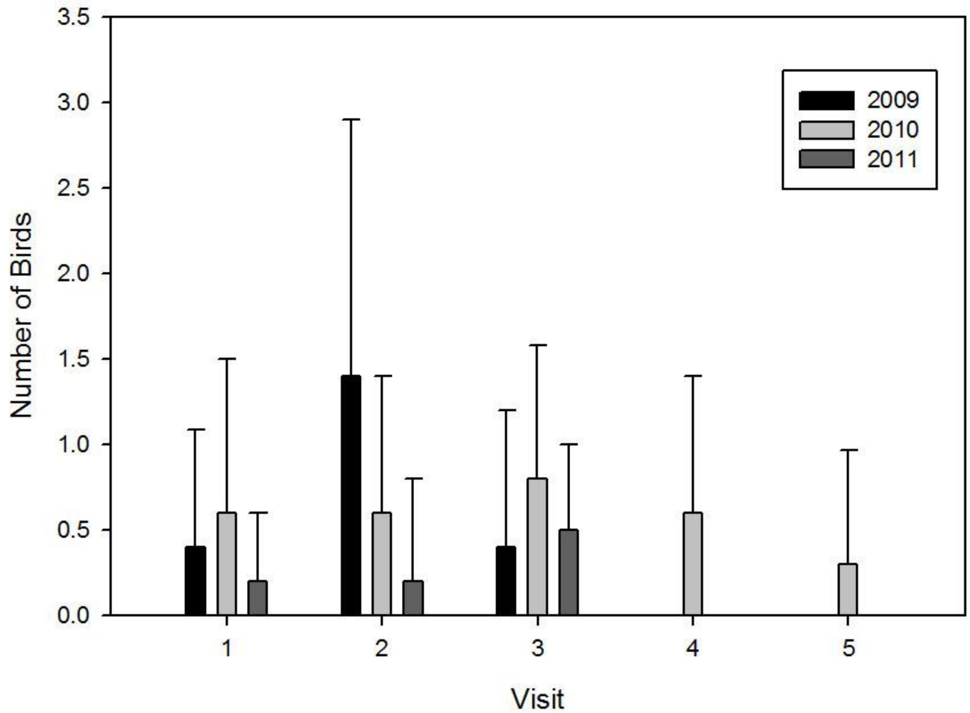

Figure 2.63. Comparison of average number of scissor-tailed flycatcher per year within visits for all treatments applied in 2009 for patch burn-grazing and rotational grazing (Mean±SE).

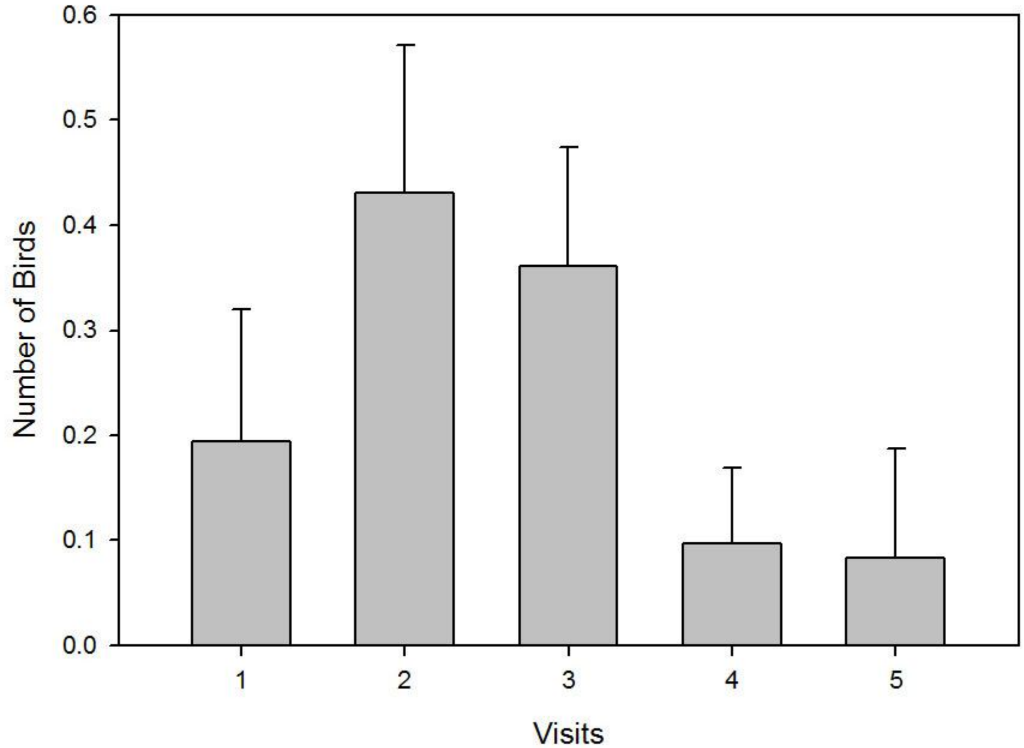

Figure 2.64. Comparison of average number of scissor-tailed flycatcher per visit for treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

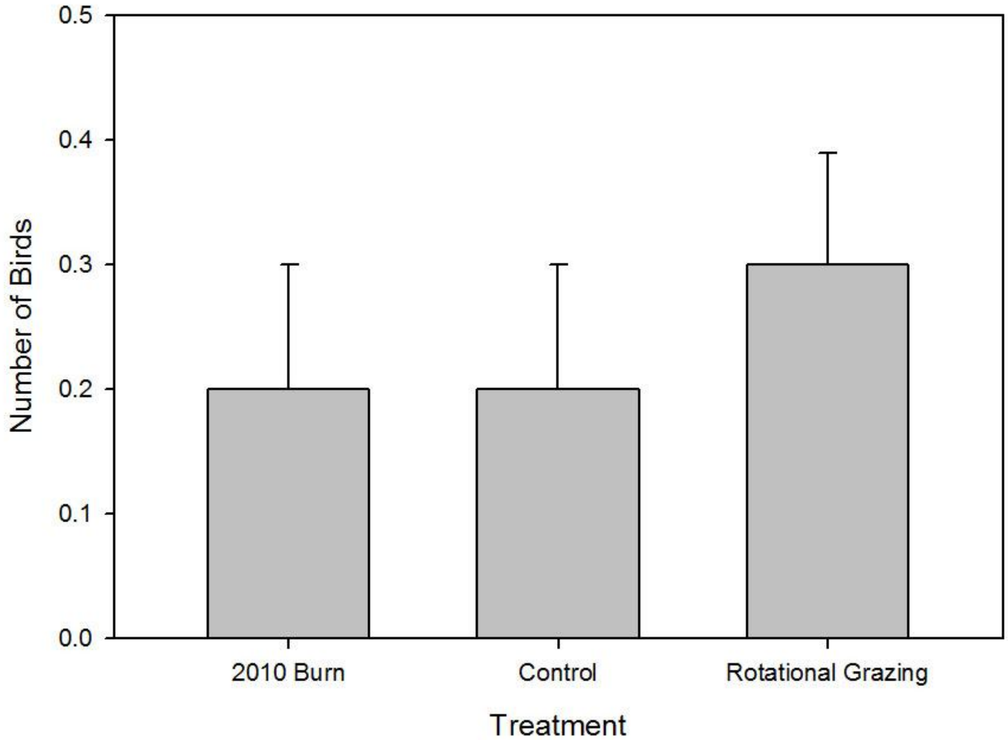

Figure 2.65. Comparison of average number of scissor-tailed flycatcher per treatment for treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

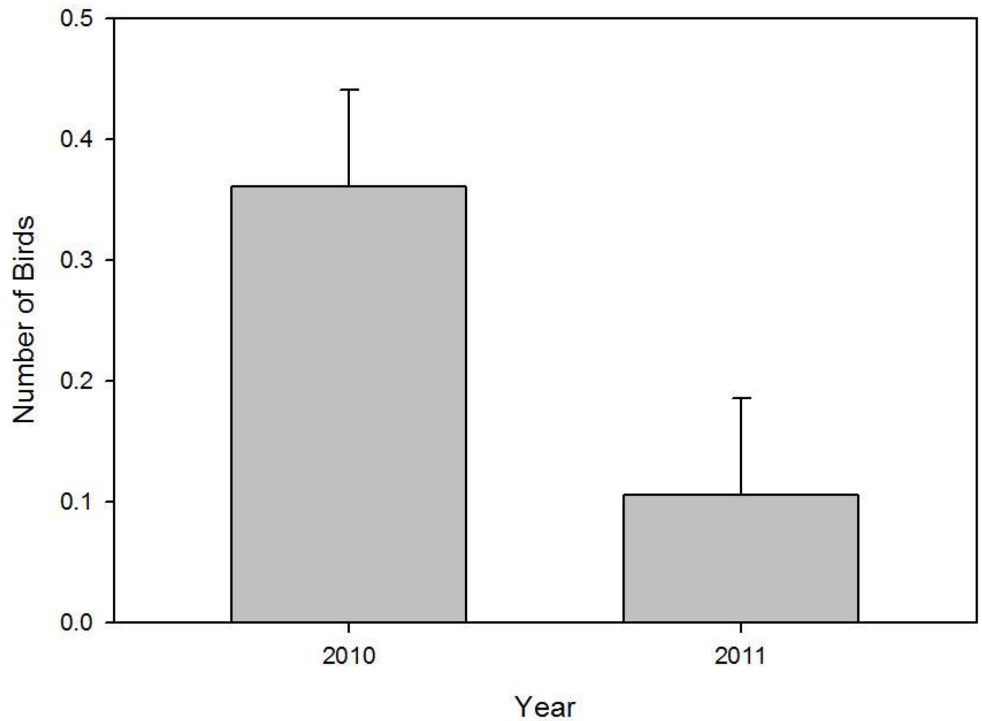

Figure 2.66. Comparison of average number of scissor-tailed flycatcher per year for treatments applied in 2010 for patch burn-grazing and rotational grazing (Mean±SE).

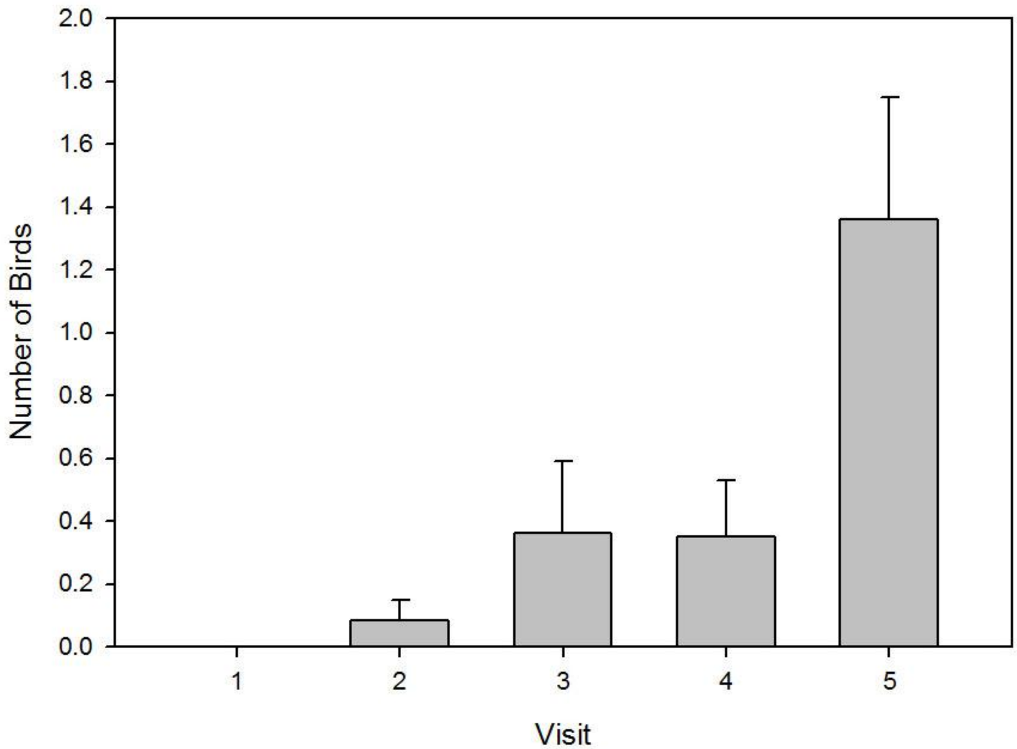

Figure 2.67. Comparison of average number of painted buntings per visit in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

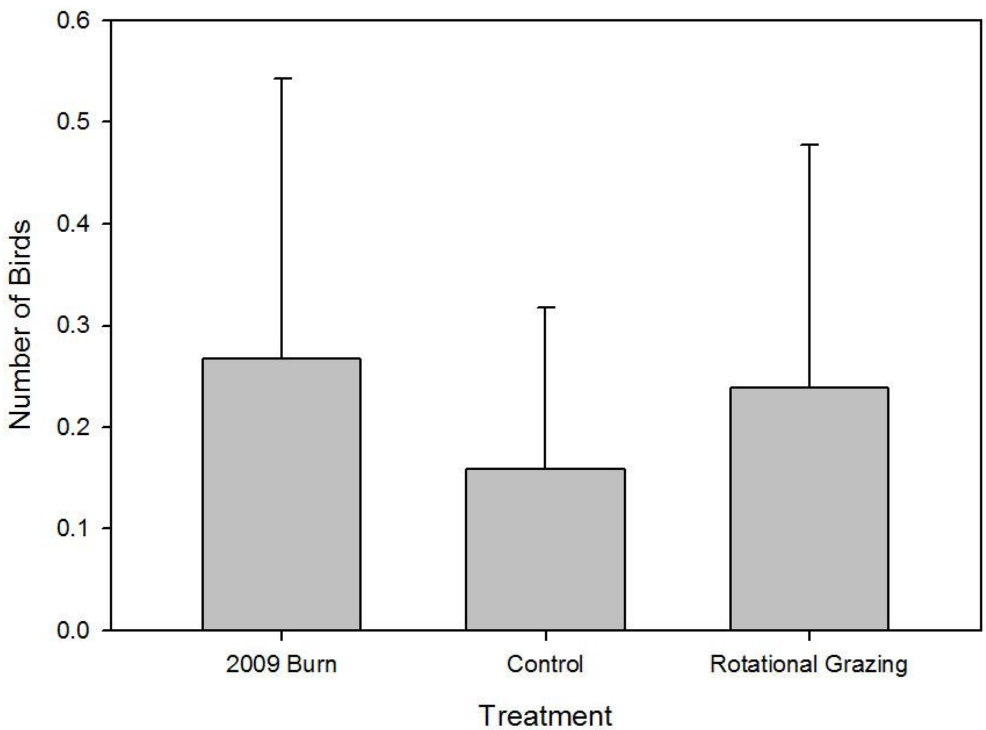

Figure 2.68. Comparison of average number of painted buntings per treatment in patch burn-grazing and rotational grazing in 2009 (Mean±SE).

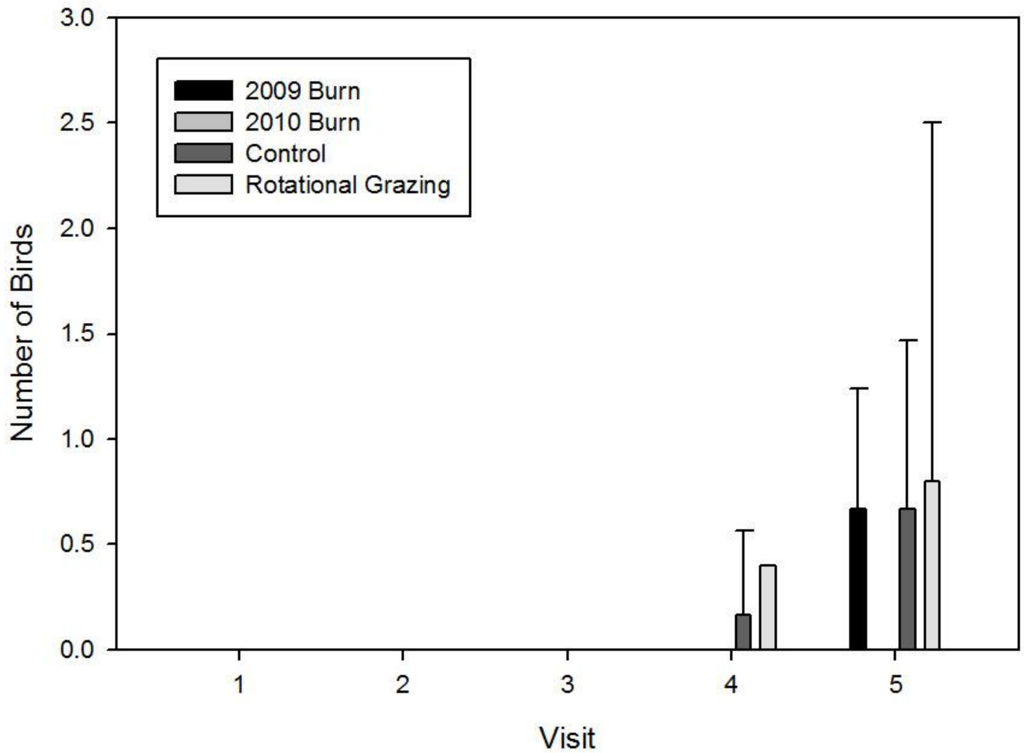

Figure 2.69. Comparison of average number of painted buntings per treatment within visits in patch burn-grazing and rotational grazing in 2010 (Mean±SE).

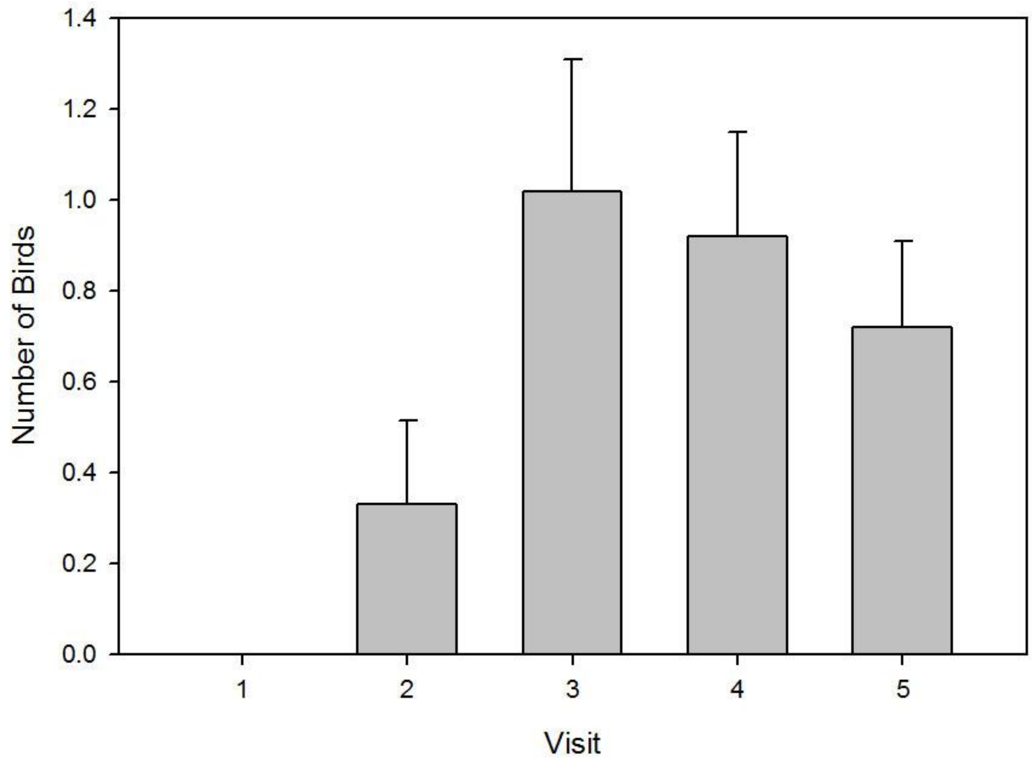

Figure 2.70. Comparison of average number of painted buntings per visit in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

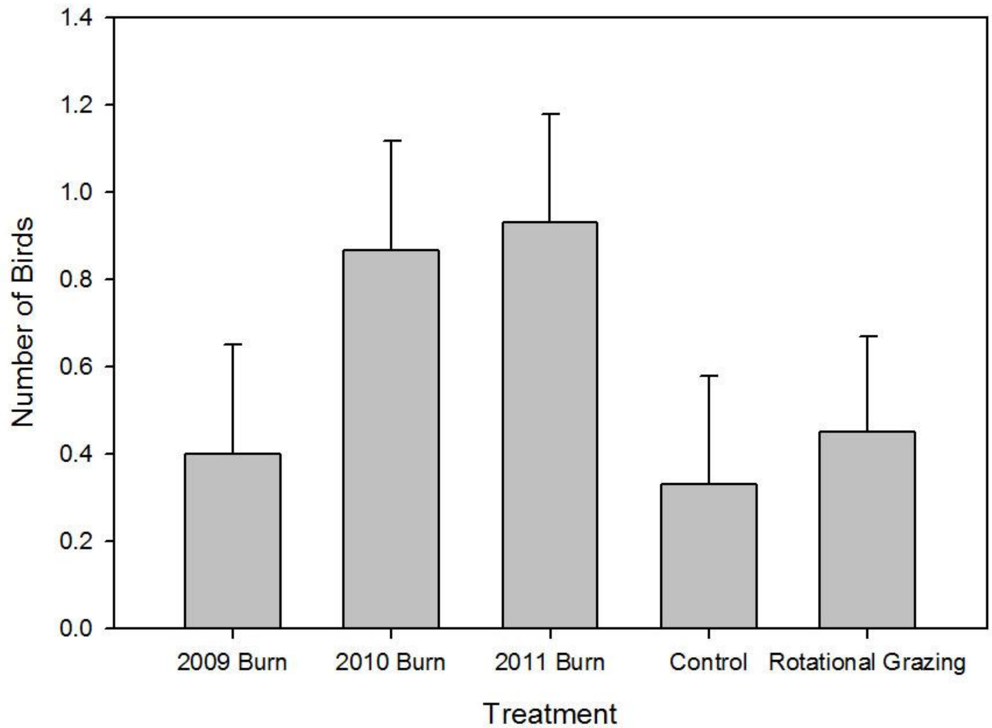

Figure 2.71. Comparison of average number of painted buntings per treatment in patch burn-grazing and rotational grazing in 2011 (Mean±SE).

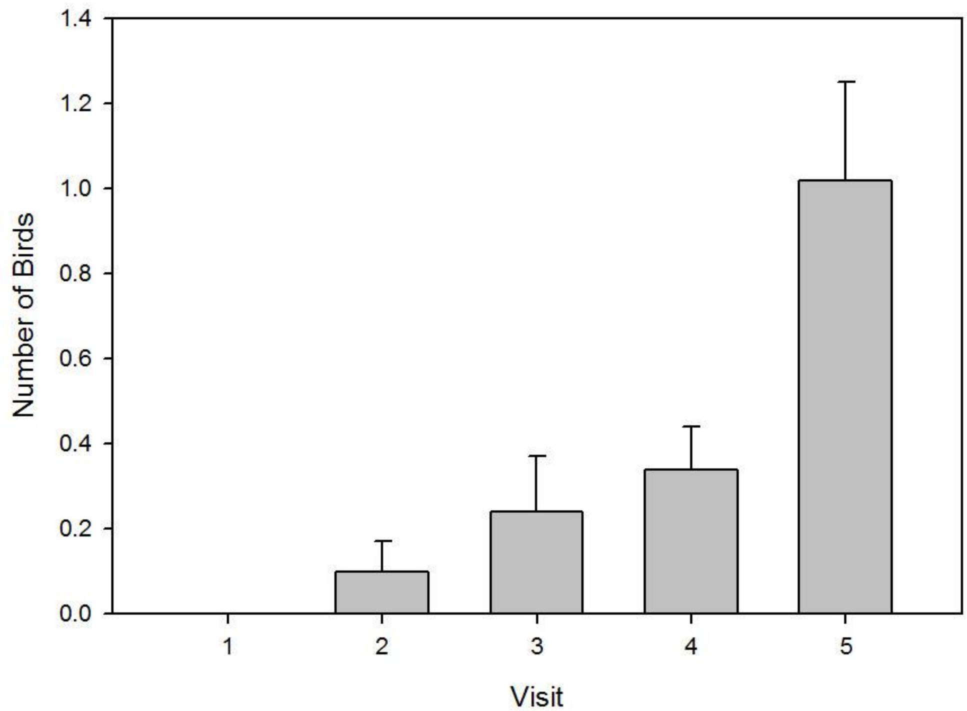

Figure 2.72. Comparison of average number of painted buntings per visit for treatments applied in 2009 in patch burn-grazing and rotational grazing (Mean±SE).

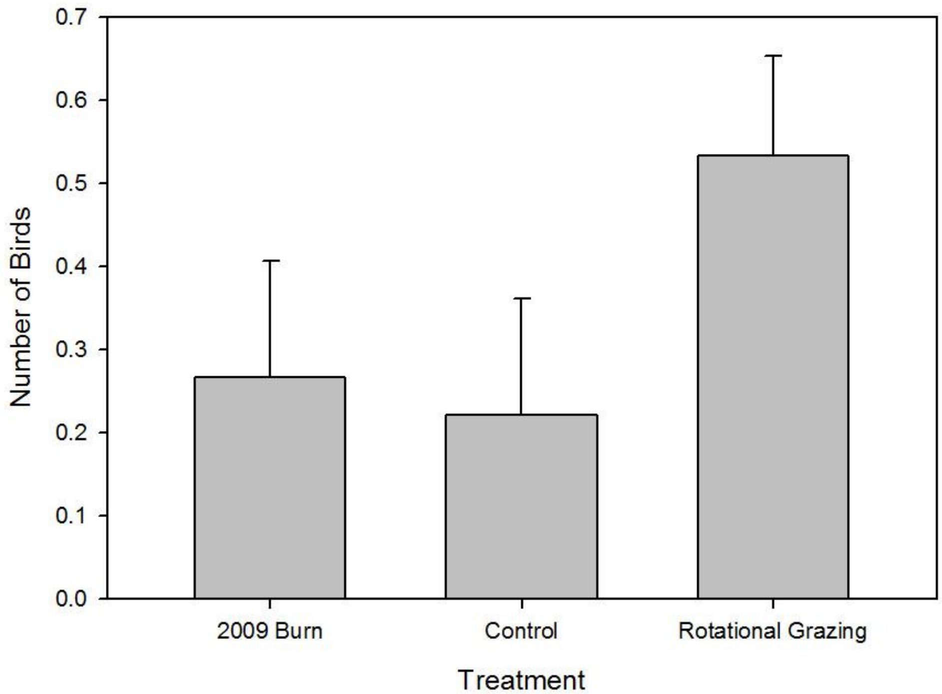

Figure 2.73. Comparison of average number of painted buntings per treatment for treatments applied in 2009 in patch burn-grazing and rotational grazing (Mean±SE).

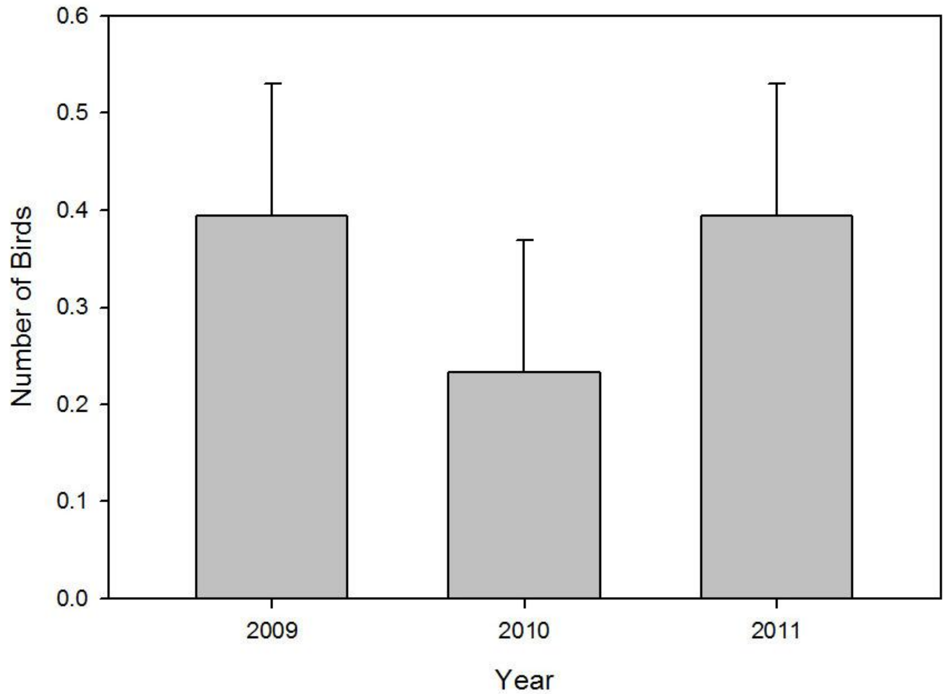

Figure 2.74. Comparison of average number of painted buntings per year for treatments applied in 2009 in patch burn-grazing and rotational grazing (Mean±SE).

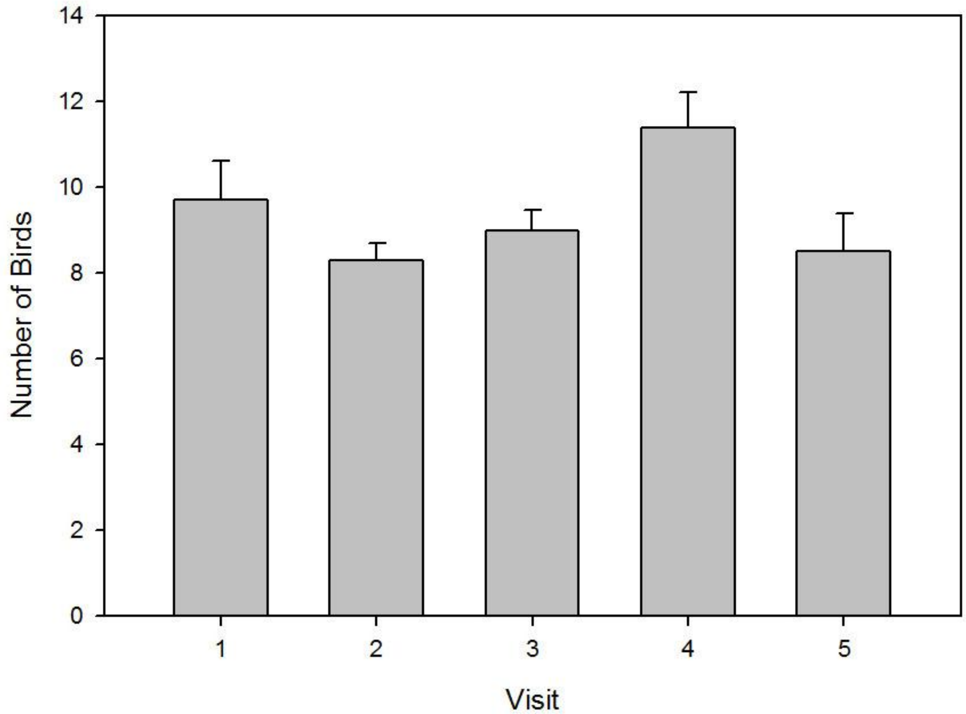

Figure 2.75. Comparison of average number of painted buntings per visit for treatments applied in 2010 in patch burn-grazing and rotational grazing (Mean±SE).

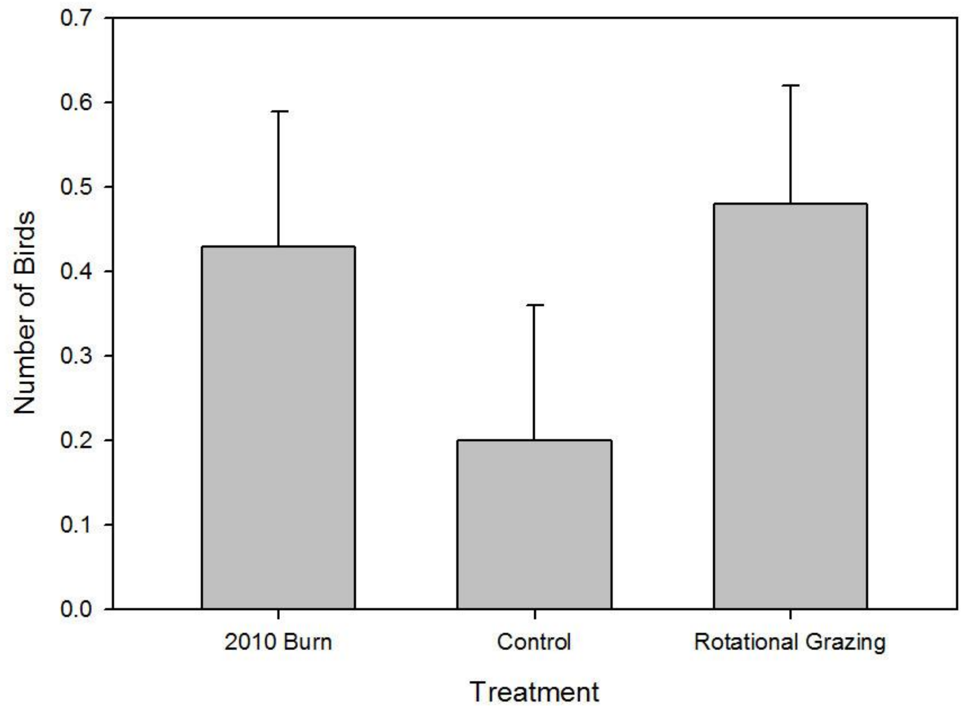

Figure 2.76. Comparison of average number of painted buntings per treatment for treatments applied in 2010 in patch burn-grazing and rotational grazing (Mean±SE).

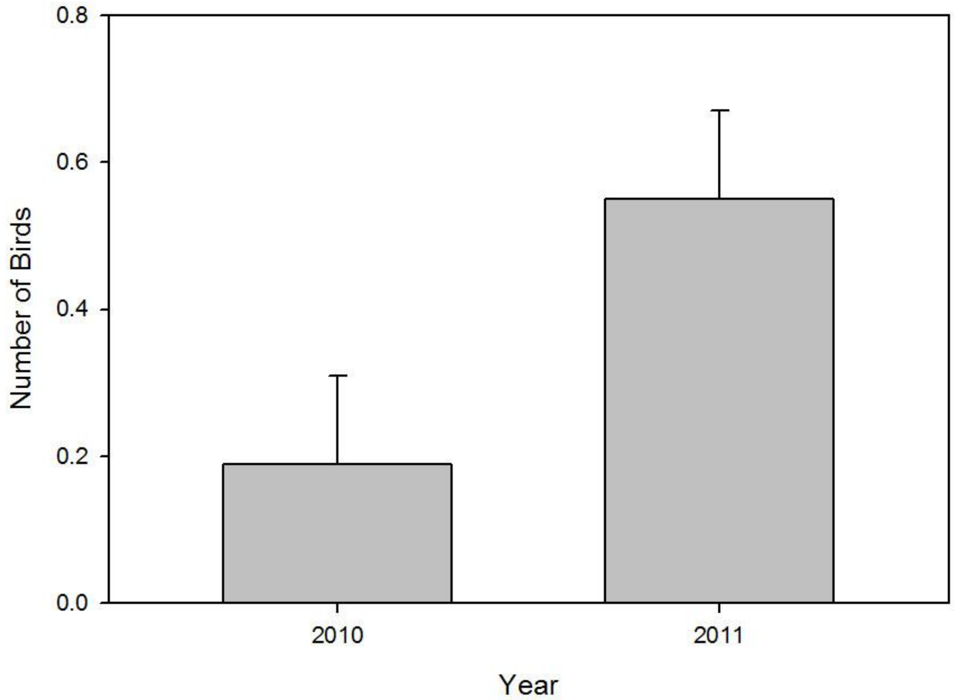

Figure 2.77. Comparison of average number of painted buntings per year for treatments applied in 2010 in patch burn-grazing and rotational grazing (Mean±SE).

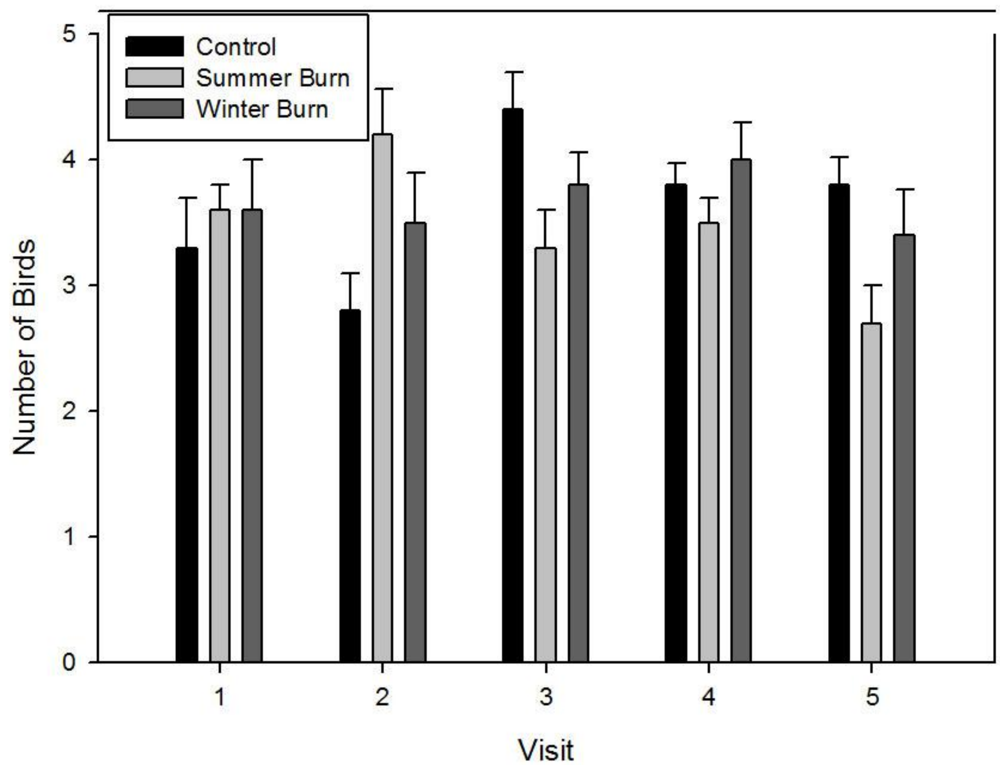

Figure 2.78. Comparison of average number of species per treatment within visit for patch burn-without grazing (Mean±SE).

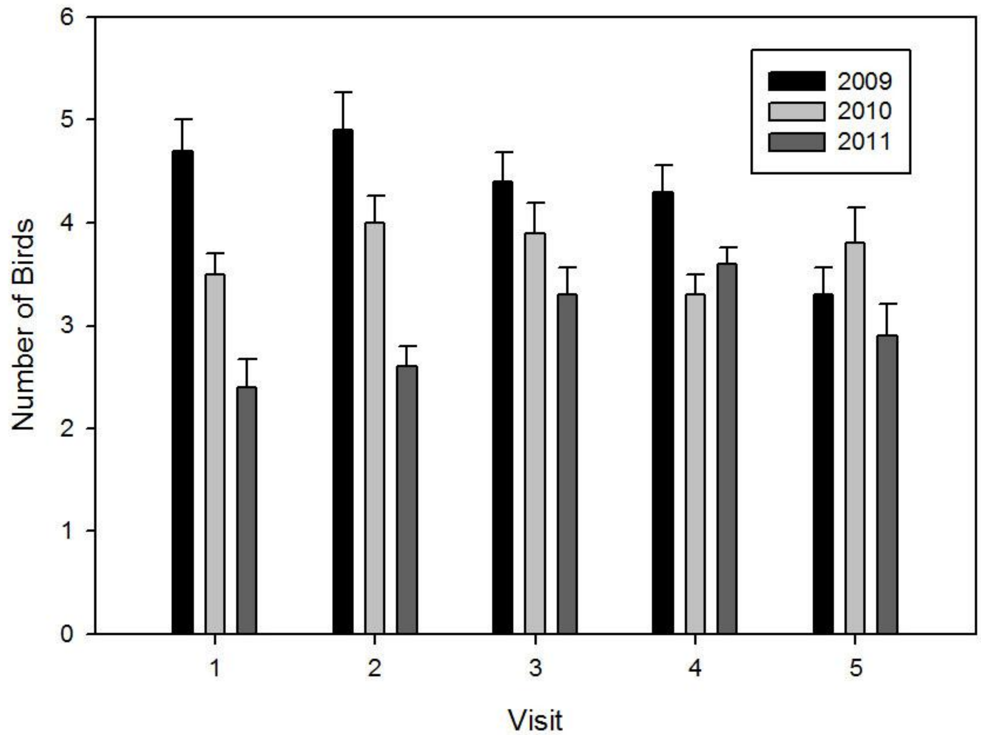

Figure 2.79. Comparison of average number of species per year within patch burn-without grazing (Mean±SE).

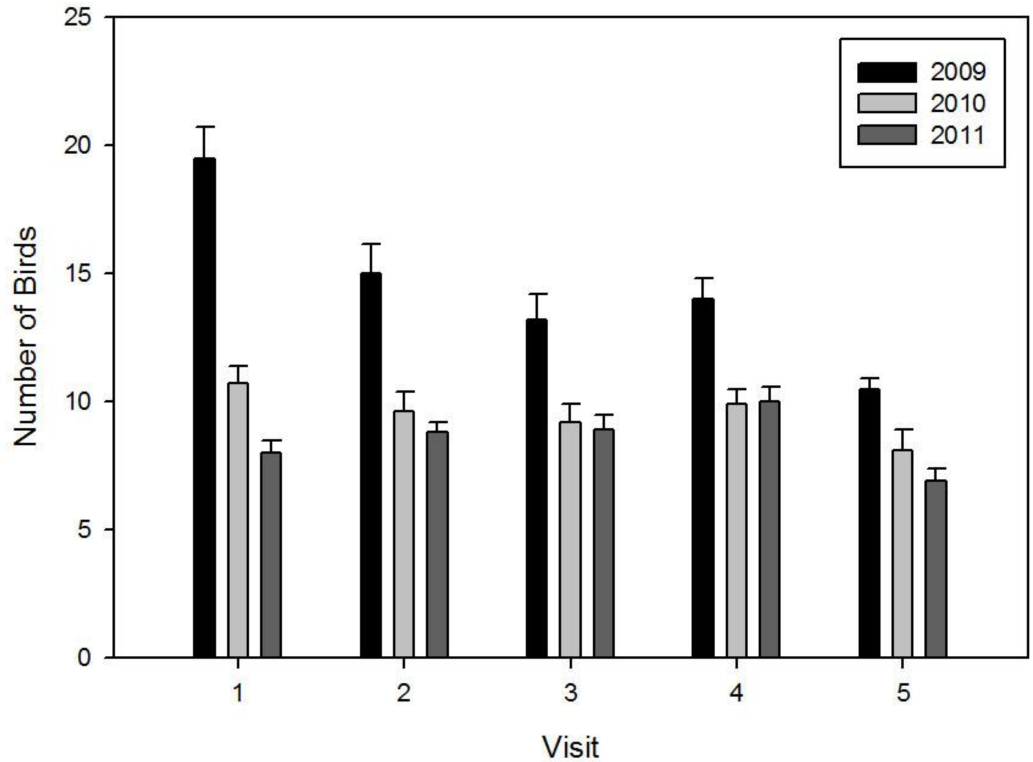

Figure 2.80. Comparison of average total number of birds per year within visit for patch burn-without grazing (Mean±SE).

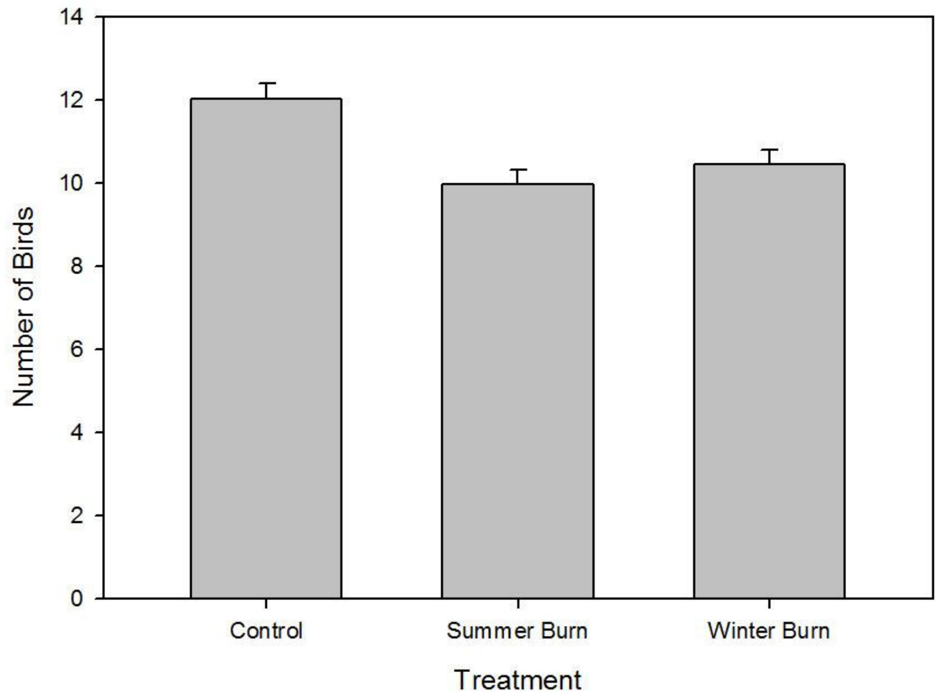

Figure 2.81. Comparison of average total number of birds per treatment for patch burn-without grazing (Mean±SE).

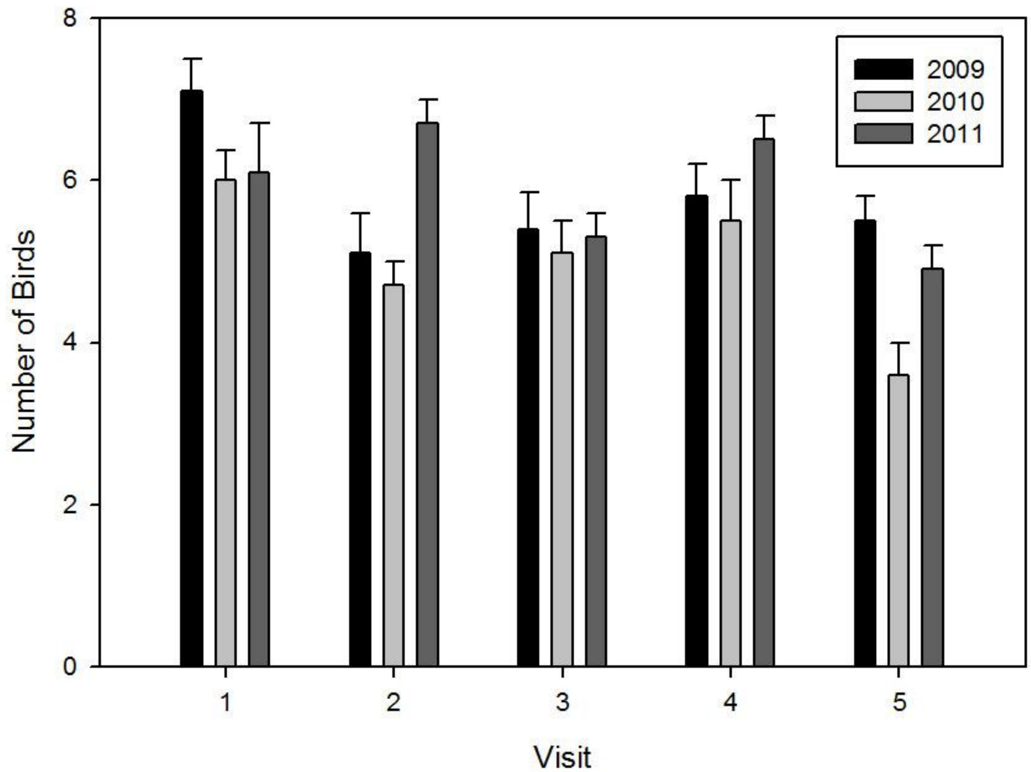

Figure 2.82. Comparison of average number of Cassin's sparrows per year within visit for patch burn-without grazing (Mean±SE).

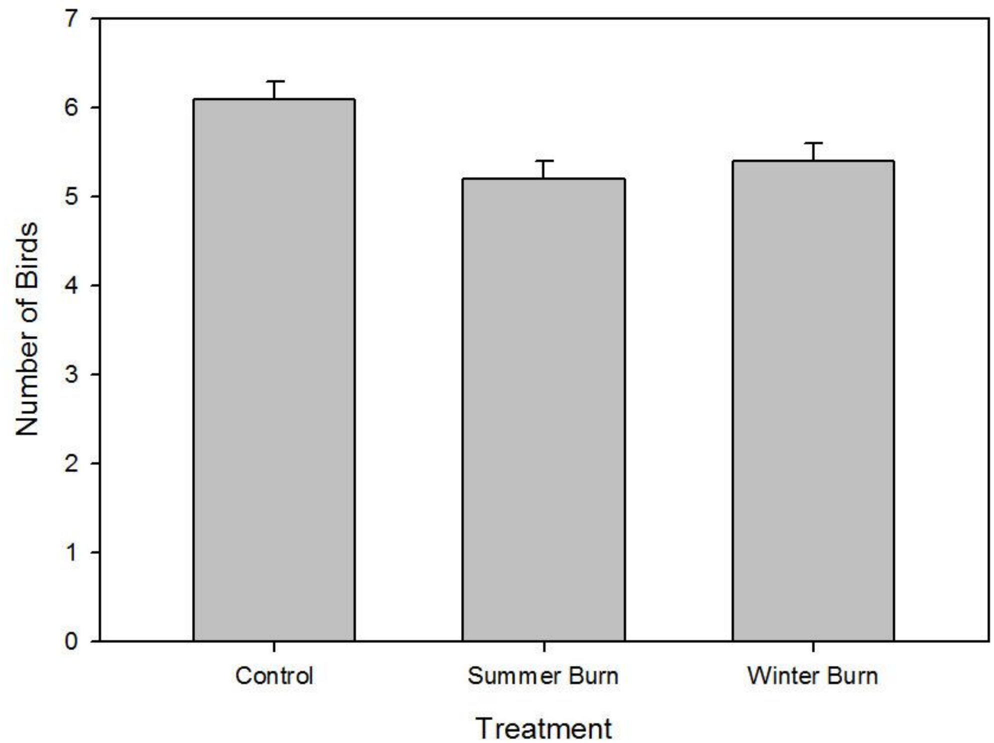

Figure 2.83. Comparison of average number of Cassin's sparrows per treatment for patch burn-without grazing (Mean±SE).

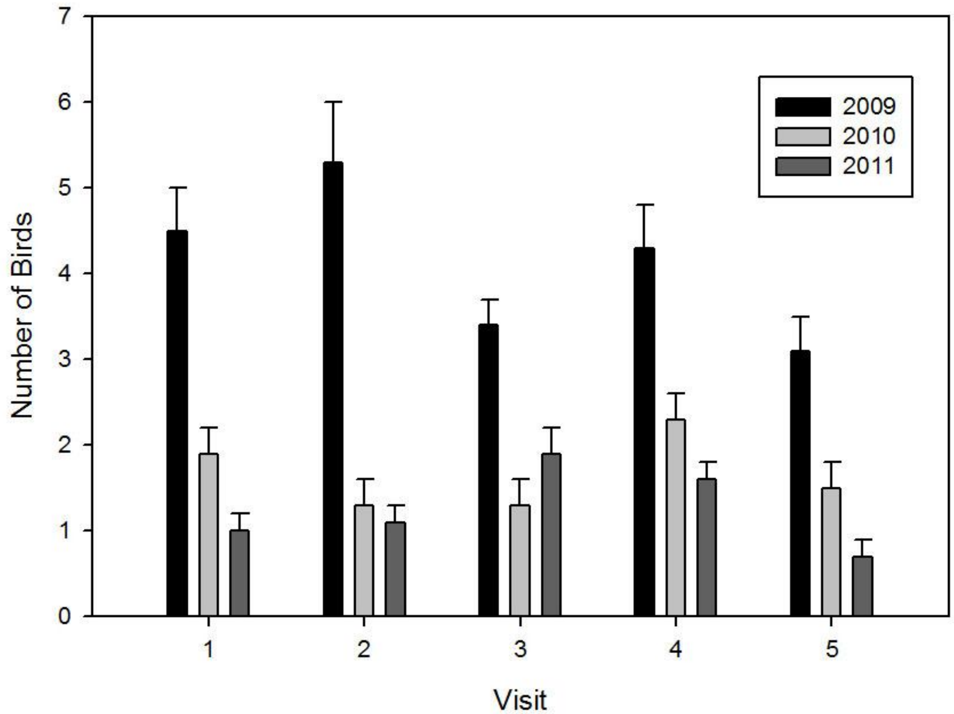

Figure 2.84. Comparison of average number of northern bobwhite per year within visit for patch burn-without grazing (Mean±SE).

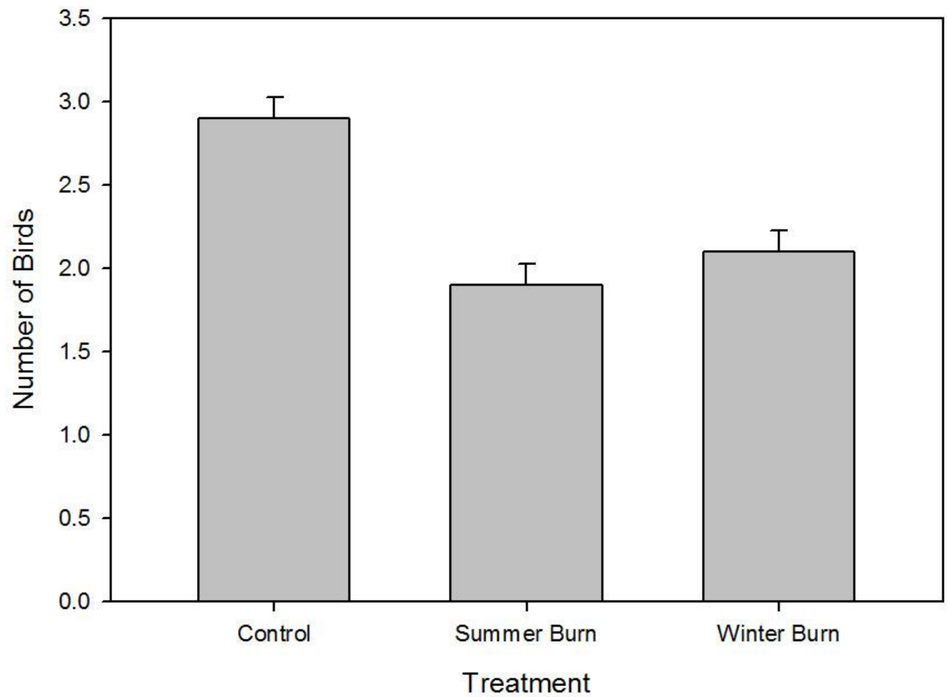

Figure 2.85. Comparison of average number of northern bobwhite per treatment for patch burn-without grazing (Mean±SE).

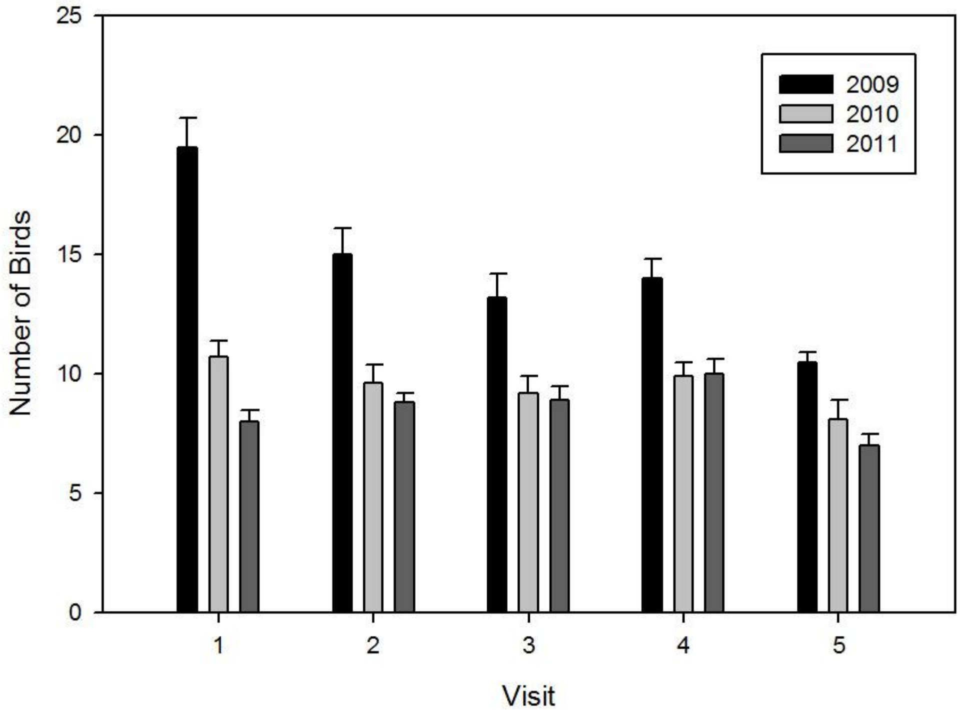

Figure 2.86. Comparison of average number of northern mocking birds per year within visit for patch burn-without grazing (Mean±SE).

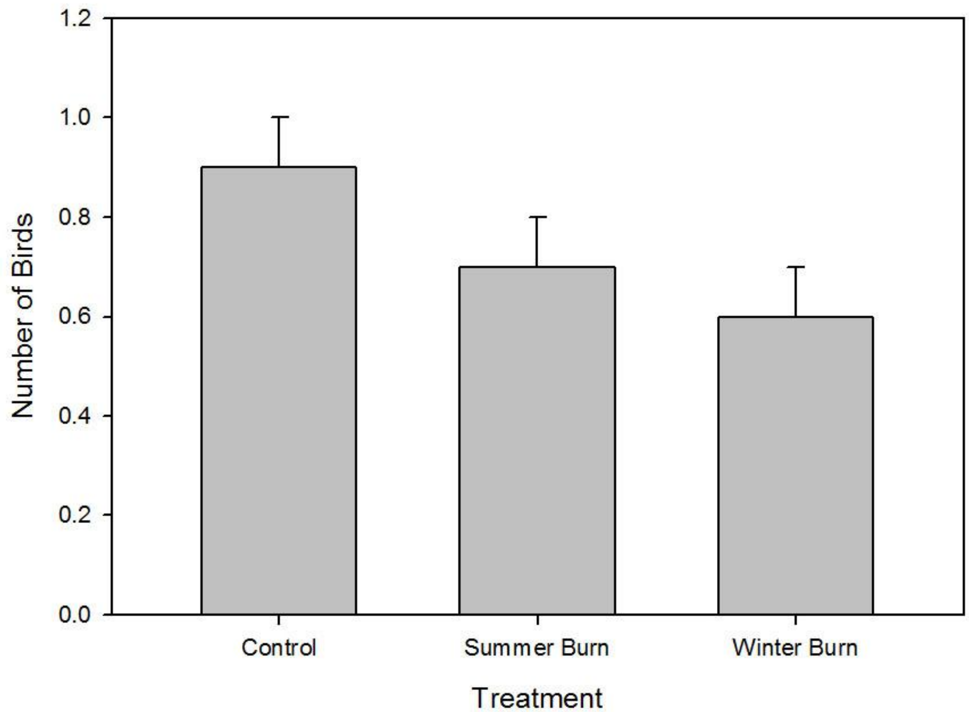

Figure 2.87. Comparison of average number of northern mocking birds per treatment for patch burn-without grazing (Mean±SE).

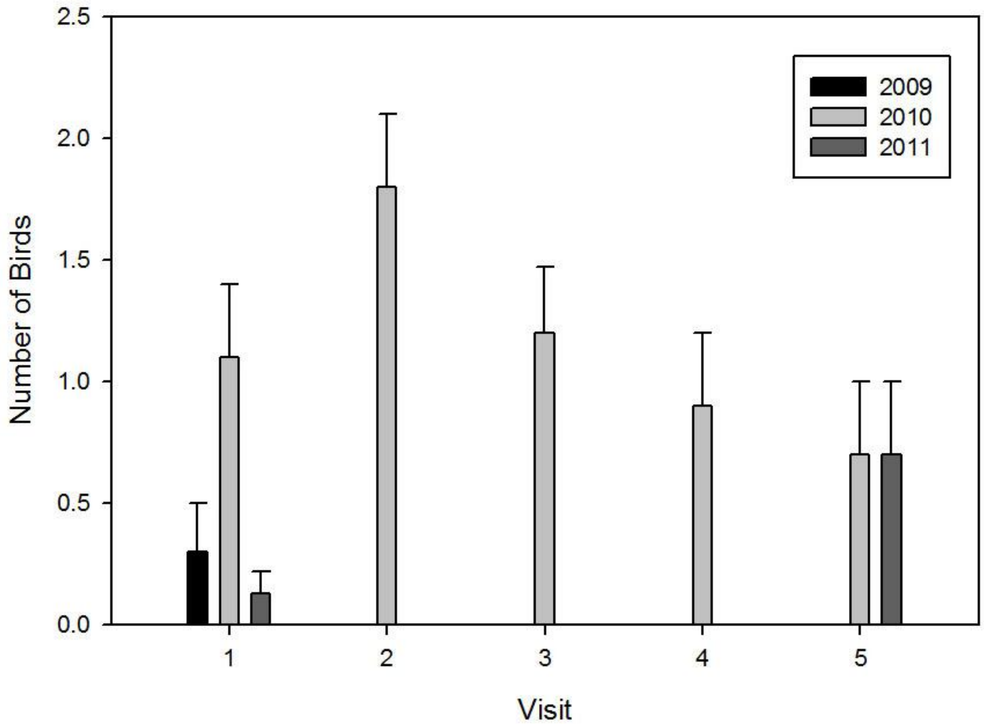

Figure 2.88. Comparison of average number of grasshopper sparrows per year within visit for patch burn-without grazing (Mean±SE).

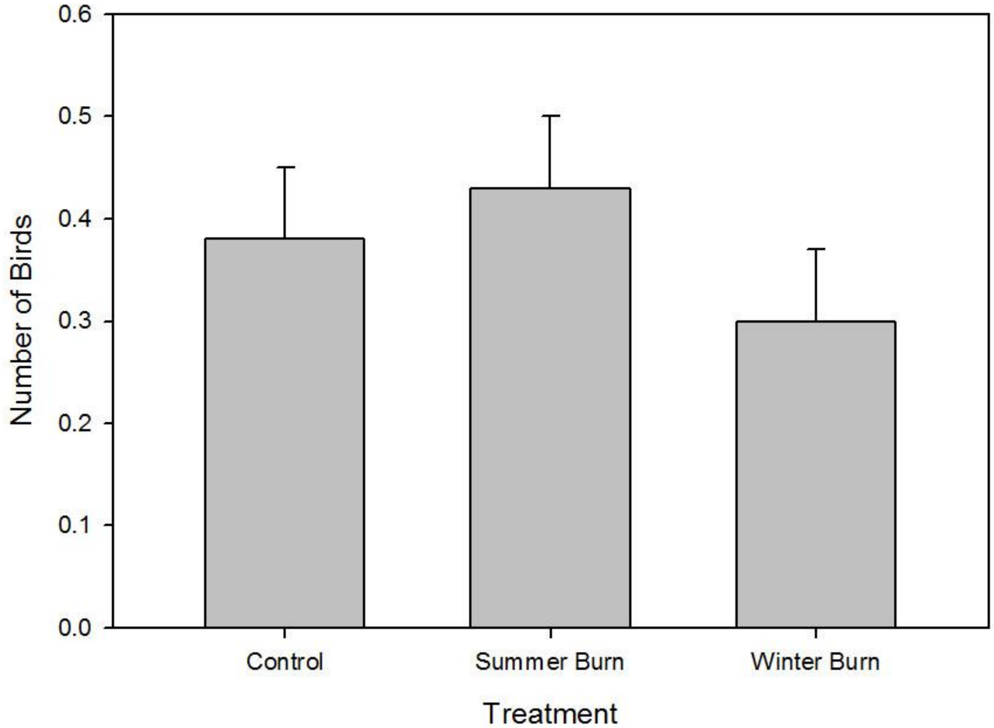

Figure 2.89. Comparison of average number of grasshopper sparrows per treatment for patch burn-without grazing (Mean±SE).

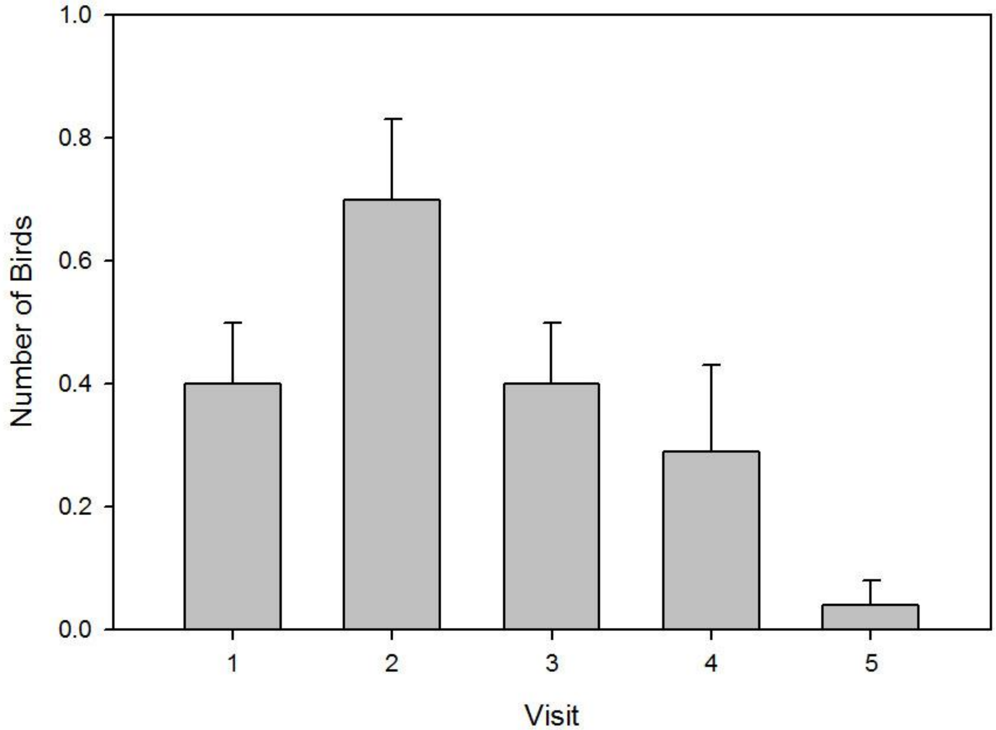

Figure 2.90. Comparison of average number of scissor-tailed flycatcher per visit for patch burn-without grazing (Mean±SE).

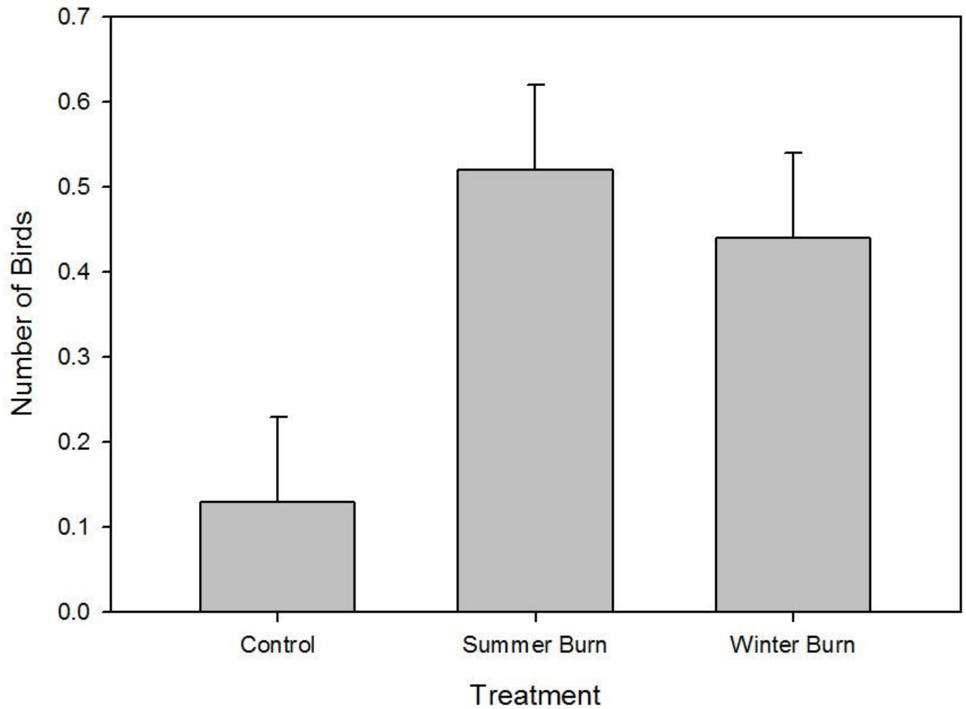

Figure 2.91. Comparison of average number of scissor-tailed flycatcher per treatment for patch burn-without grazing (Mean±SE).

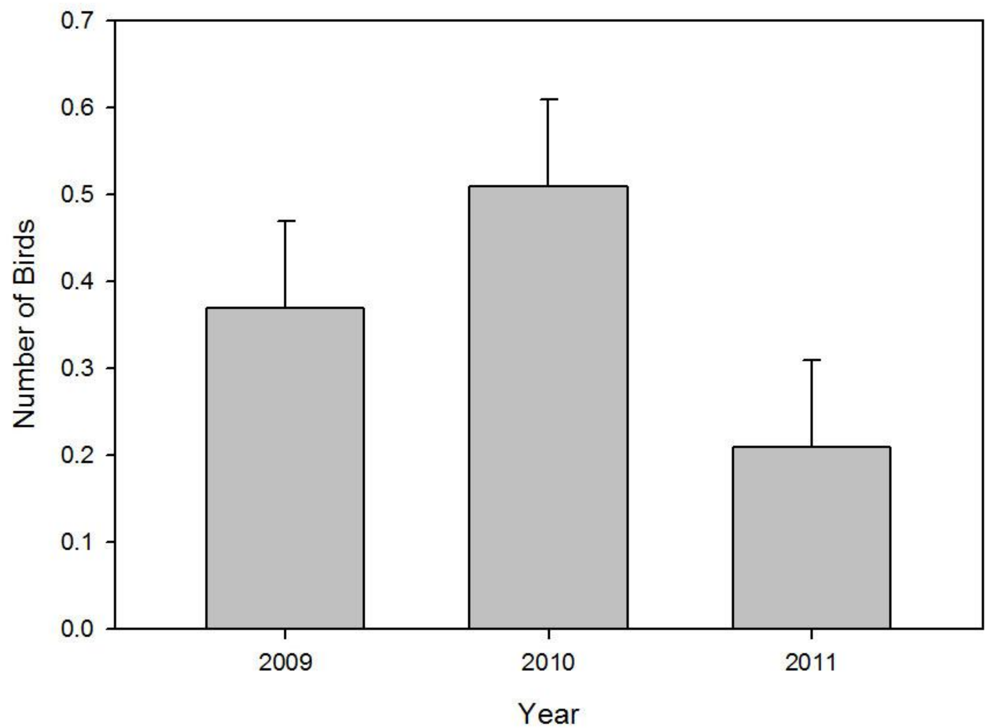

Figure 2.92. Comparison of average number of scissor-tailed flycatcher per year for patch burn-without grazing (Mean±SE).

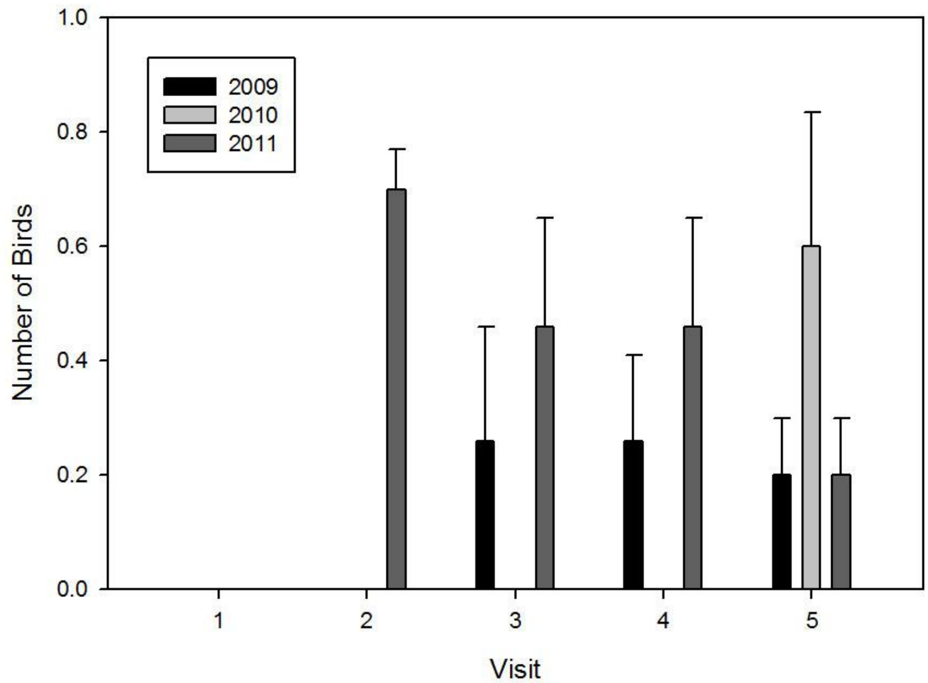

Figure 2.93. Comparison of average number of painted buntings per year within visit for patch burn-without grazing (Mean±SE).

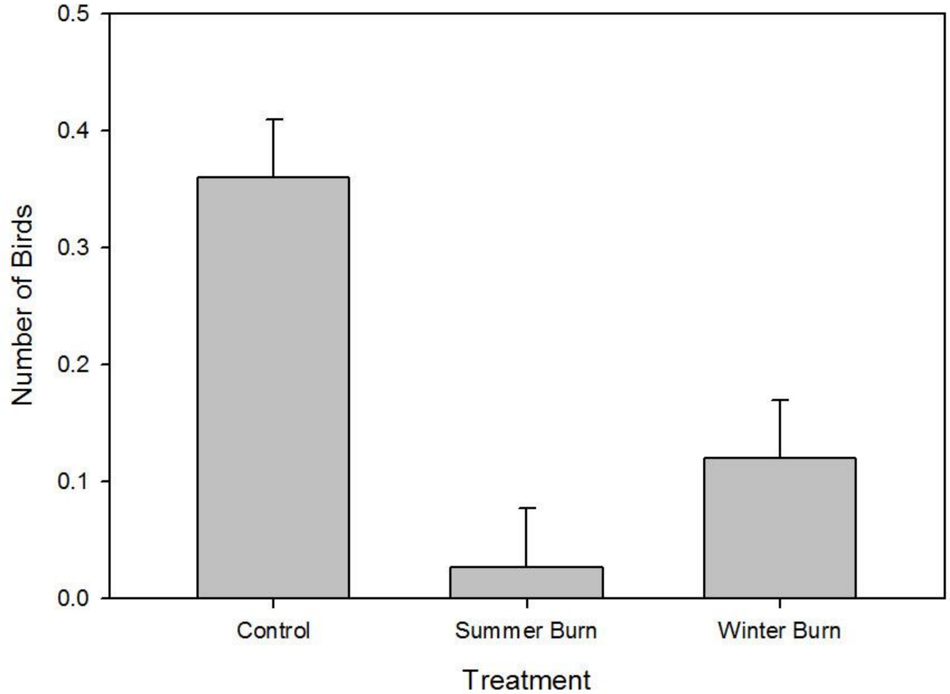

Figure 2.94. Comparison of average number of painted buntings per treatment for patch burn-without grazing (Mean±SE).

CHAPTER III

PATCH BURNING AND GRAZING EFFECTS ON NORTHERN BOBWHITE QUAIL IN A SAND SAGEBRUSH-HONEY MESQUITE RANGELAND

INTRODUCTION

The Rolling Plains ecoregion of Texas historically contained a diverse mixture of habitats that supported a large and diverse group of avifauna. This ecoregion evolved with fire and bison grazing that created a shifting mosaic of patches within the landscape, varying in time and space since their last disturbance (Fuhlendorf and Engle 2004). Prior to human involvement, lightning strikes were the primary natural source of ignition of vegetation (Komarek 1966). Following European settlement in the Great Plains there was an increase in fire suppression as well as a change in grazing practices that have contributed to a change in the vegetative dynamics of the Great Plains (Archer et al. 1988). The early culture of fire suppression in this region has allowed livestock to disperse seeds that have allowed the encroachment of many woody species, namely honey mesquite (*Prosopis glandulosa*) (Wright 1974, Archer et al. 1988). Most grazing and burning practices currently used focus on homogenous habitats designed for efficient grazing. Heterogeneity needed for the ecosystems to function is lost (Briske et al. 2003; Fuhlendorf and Engle 2001). A large scale homogenous habitat does not benefit multiple species that require differing levels of succession in their habitat (Weir et al. 2007).

Patch burning and grazing is a new emerging technique that can provide heterogeneity through varying disturbance temporally and spatially. This technique of patch burn-grazing mimics the interaction of fire and grazing that occurred prior to settlement of the Great Plains. Patch burning has been described as the purposeful grazing of a section of a landscape or management unit that has been prescribed burned, and then burning another section to refocus the grazing pressure to the newly disturbed unit, creating a shifting mosaic on the landscape (Weir et al. 2007). In the Great Plains it is suggested that a new patch be burned every 6-12 months to shift the grazing focus (Weir et al. 2007). This allows for the previously burned unit to receive less grazing pressure and transition through different levels of standing biomass and litter accumulation to where it can be burned again in 2.5 to 3 years. With the improved heterogeneity in the vegetation, and the varying levels of succession that this system provides, many habitat types are available (Fuhlendorf et al. 2006).

Patch-burn grazing could potentially be beneficial for wildlife, because many species are adapted to these varying levels of disturbance. Northern bobwhites (*Colinus virginianus*) use habitats with varying levels of disturbance and are a species of current management concern with extensive range within the Rolling Plains of Texas (Link et al. 2008). With Northern Bobwhites at a historic population low in the Rolling Plains of Texas (Texas Parks and Wildlife 2012), it is imperative managers increase the acreage of habitat available for northern bobwhites. The patch burning grazing system may provide superior habitat characteristics for northern bobwhites as compared to traditional range management practices that use large homogenous burns and continuous or rotational grazing. The objectives of my study were to compare the effects of a patch-burn grazing system on northern bobwhite survival, nest success, and habitat use as compared to traditional range management practices used in a sand sagebrush – honey mesquite rangeland.

STUDY AREA

Matador Wildlife Management Area

This study was conducted within the Matador Wildlife Management Area (WMA), located in Cottle County, Texas approximately 10 km North of the town of Paducah, Texas. The Matador WMA is 11,410-ha located in the Rolling Plains ecoregion of Texas for the purposes of wildlife research and management as well as public use. Matador WMA was purchased by the state of Texas in 1959 using Pittsman-Robertson funds and serves as a research and demonstration area that is managed by Texas Parks and Wildlife. Climate is described as subtropical with dry winters and hot, humid summers with an average annual rainfall of 56.2 cm (Richardson et al. 1974). Rainfall is quite variable monthly to yearly and occurs most frequently as a result of thunderstorms (Richardson et al. 1974). Months of greatest average rainfall are May (9 cm) and June (8.8 cm; Richardson et al. 1974; Table 8). Topography ranges from nearly level to very steep (Richardson et al. 1974). The predominant soil association is Miles – Springer consisting of soils nearly level to strongly sloping, deep, coarse textured and moderately coarse textured soils on outwash plains. In particular, the soils contained within my unique study area within Matador WMA consist of Miles (fine-loamy, mixed, thermic, alfisols), and Springer (coarse-loamy, mixed, thermic, alfisols; Richardson et al. 1974).

Predominant woody vegetation occurring within the Matador WMA included honey mesquite (*Prosopis glandulosa*), redberry juniper (*Juniperus pinchotii*), netleaf hackberry (*Celtis reticulata*), eastern cottonwood (*Populus deltoides*), salt cedar (*Tamarix gallica*), Chickasaw plum (*Prunus angustifolia*), and sand sagebrush (*Artemisia* *filifolia*). Predominant grass species found on the area included little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), sideoats grama (*Bouteloua curtipendula*), purple threeawn (*Aristida purpurea*), Japanese brome (*Bromus japonicus*) and plains bristlegrass (*Setaria leucopila*). Predominant forb species on the area included western ragweed (*Ambrosia psilostachya*), woolly plantain (*Plantago insularis*), annual sunflower (*Helianthus annus*), and lamb's quarters (*Chenopodium album*, Hall 2005).

METHODS

Burning and Experimental Design

My study site consisted of 619-ha of contiguous sand sagebrush-mesquite rangeland in the Entrance and Headquarters pastures of the Matador Wildlife Management Area (34.117721, -100.356536). I compared patch-burning grazing treatment, rotational grazing treatment, summer and winter burn without grazing, and control or undisturbed areas within this study. Space and timing constraints prevented one experimental design incorporating a combination of all these possible treatments of interest within a single grid.

Patch burning-grazing treatments consisted of 12 plots approximately 17-ha in size (Figure 3.1) located within the Entrance pasture. The 12 plots were randomly assigned one of four treatments; control (unburned), 2009 winter burn, 2010 winter burn, and 2011 winter burn. Hence, in 2009 the plots designated for 2010 winter burn and 2011 winter burn were treated as controls since they were scheduled for burn in following years. Further, plots designated for a 2011 burn treatment were used as controls during

2010. These plots were compared to rotational grazing only treatments consisting of 4, 18-ha plots separated by fencing (Figure 3.1) also located in the entrance pasture. These comparisons between patch burning-grazing, rotational grazing, and control treatments were analyzed using 3 separate repeated measures analysis of variance restricted to single years. Analyses were restricted to single years (2009, 2010, and 2011), because the number of replicates changed through the duration of the study as additional plots were burned in 2010 and 2011. Comparison of changes across years was accomplished using 2 separate repeated measures analysis of variance. The first analysis compared metrics (cover, frequency, and density data) that could be followed for 3 years; from 2009 to 2011. Likewise, a second analysis was used to compare metrics from treatments that became available during 2010 and could be followed for only 2 years (2010 to 2011).

The patch burning-grazing and rotational grazing plots were grazed at the NRCS recommended stocking rate, which was approximately one animal unit per 14-ha. Water facilities were installed so that at any position within the study area cattle were within 0.8 km (1/2 mile) of water.

In the Headquarters pasture plots were not subjected to grazing and consisted of 15, 18-ha burn plots. The pasture was divided into a 3 x 5 grid containing 5 blocks with three treatments randomly assigned to the three plots located within each block. Using a randomized block design, the three plots within each block were randomly assigned the treatments control (non-burned), summer burn, and winter burn. The summer burns were conducted in August 2008 and winter burns were conducted in February 2009.

Quail Capture-Monitoring-Analysis

Northern bobwhite hens were captured using funnel traps (Stoddard 1931) that were baited with grain from February-April in the years 2009-2011. Upon capture, hens were weighed, aged, and banded with each bird receiving a leg band containing a unique identification number. Females weighing 150 grams or more were outfitted with a 5 gram necklace-style radio transmitter (Wildlife Enterprises, Monticello, Florida). Bird location and survival status were obtained using a homing technique at least every other day using radio telemetry. Radiomarked bobwhites dying within 7 days of the initial trapping event were excluded from the study because of concern for capture myopathy-related bias (Kurzejeski et al. 1987). Survival was estimated using the nest survival model in ProgramMARK. GPS locations were obtained from the time of capture through nesting season (February-July). Once a nest was determined the nest was checked daily. If the females were present on the nest it was assumed to still be active and left undisturbed. Once a female was not present when the nest was visited then the nest was inspected to determine if the nest was still active, successful, or had been predated. In all cases the clutch size was determined by counting eggs present. Once a nest was deemed inactive (abandoned, successful, or predated), nest site characteristics were measured to determine characteristics that contributed to nest fate.

Cover measurements at nest sites were obtained using a 1x1 meter frame (Daubenmire 1959). The nest location was used as the center for the placement of the frame. Percentage cover was estimated for the categories of residual plant material, bare ground, forb cover, grass cover, and shrub cover. Maximum vegetation height was obtained from the tallest plant rooted within the frame. Nearest shrub and the nearest edge were also measured with the nest location used as the origin for these measures. Nearest edge was classified as closest distance to a disturbance such as a road or fence line. Visual obstruction at the nest site was quantified using a cover board (Nudds 1977, Pleasant et al. 2006). Alternating black and white bands marked 25-cm intervals on the 2-m high, 25-cm wide board. Proportion of each 0.25-m interval was recorded as a single value (1-5) corresponding to percentage of the interval obstructed by vegetation (i.e., 1 corresponded to 1-20% obstruction, 2 corresponded to 21-40% obstruction, etc.). A 2-tailed t-test for the equality of means for successful and unsuccessful nests of these covariates was produced.

Quail home ranges were calculated using the GPS locations for inputs into ArcGIS (ESRI Co., Redland, CA, USA) in conjunction with Geospatial Modeling Environment (Beyer 2012) and R (R Development Core Team 2008) to obtain a 95% fixed kernel density with least squares cross validation for estimate of home range. Using ArcGIS, home ranges were clipped to available treatments to obtain what portions of home ranges were within each treatment. Habitat use was analyzed by using a chi-square test comparing use versus availability of treatments (Rogers and White 2007). Adult quail survival was calculated for the months of February through July using ProgramMARK. Due to small sample size, nest data were compiled for all three years. Nest survival was calculated using ProgramMARK and individual covariates that were measured at the nest site were also used to look for competing models in order to determine if specific covariates were influencing nest survival. Variables measured at the nest site were also compared to nest success using a paired t-test.

RESULTS

Adult Survival

Hen survival pooled across the three seasons of the study for the months of February through July was 0.18, 95%CI (0.13:0.25). Survival for the year 2009 for the months of February through July was 0.19, 95%CI (0.11:0.32). Survival for the year 2010 for the months of February through July was 0.05, 95%CI (0.02:0.13). Survival for the year 2011 for the months of February through July was 0.36, 95%CI (0.22:0.52).

Home Range

Mean home range size did not differ among years (F=1.248, P=0.298, Figure 3.2). Bobwhites did not use any habitat type more than expected during 2009 ($\chi 2$=5.901, P=0.207, Table 3.1), 2010 ($\chi 2$=4.345, P=0.501, Table 2), or 2011 ($\chi 2$=10.397, P=0.109, Table 3.3).

Nest Survival

Daily nest survival rate pooled for the years 2009-2011 was 0.95, 95%CI (0.92:0.97). Nest survival rate for the 24 day incubation period was 0.29. Survival models that implemented covariates produced in ProgramMark produced four single competing covariate models. The model encompassing percentage of residual plant matter at the nest site to the original S(.) model had a ΔAICc=0.4185, Table 3.4. The model incorporating total percentage of shrub at the nest site to the original S(.) model had a ΔAICc=0.5547, Table 3.4. The model incorporating nearest edge at the nest site to the original S(.) model had a ΔAICc=0.8821, Table 3.4. The combined model incorporating all 3 competing covariates produced ΔAICc=0.0000, Table 3.4. Percentage of residual plant matter mean for successful nests 38.0 and unsuccessful nests was 62.0 (P=0.068, Figure 3.3). Percentage of shrub mean for successful nests was 51.0 and unsuccessful nests was 21.7 (P=0.027, Figure 3.4). Distance to nearest edge (m) for successful nests was 32.5 and unsuccessful nest was 64.4 (P=0.049, Figure 3.5). Other parameters tested for equality of means for successful, unsuccessful nests respectively; percentage bare ground means (1.5, 2.3, P=0.491, Figure 3.6), percentage of forb means (8.5, 7.3, P=0.798, Figure 3.7), percentage of grass means (42.0, 34.3, P=0.572, Figure 3.8), maximum vegetation height means (m) (0.7, 0.8, P=0.205, Figure 3.9), nearest shrub distance (m) (0.2, 1.7, P=0.036, Figure 3.10), visual obstruction score of square 1 (4.5, 4.5, P=0.918, Figure 3.11), visual obstruction score of square 2 (3.0, 2.2, P=0.231, Figure 3.12), visual obstruction score of square 3 (1.9, 1.2, P=0.298, Figure 3.13), visual obstruction score of square 4 (0.2, 0.7, P=0.121, Figure 3.14), visual obstruction score of square 5 (0.1, 0.3, P=0.491, Figure 3.15).

DISCUSSION

Adult survival has been extensively reported throughout the literature, allowing comparisons with my study in regards to habitat as well as relative time frame. In western Oklahoma a study spanning 1991-2002 reported a survival of northern bobwhites in the time frame of February through July of 25.6% (Cox et al. 2004). Approximately 96 km south of my study site, summer survival for northern bobwhites in 2011 was observed at 59% and 55% in 2012 (Buckley 2013). With the exception of survival rate in 2010

(5.3%), my results are comparable to the survival rates observed in western Oklahoma for the appropriate time range. Lower survival in my study compared to (Buckley 2013) was likely due to my monitoring period incorporating the spring raptor migration. Patch burn-grazing did not appear to influence survival when compared to studies that were in a similar ecoregion (Cox et al. 2004).

Northern bobwhite home range can be variable across its range and throughout time. An example of this variability in size is shown when comparing an average home range size of 16.77 ha for bobwhites observed in Georgia (Terhune et al. 2006) to 47.6 ha which was observed in the Rolling Plains ecoregion of Texas (Buckley 2013). In my study, home ranges were more comparable to those observed in Buckley (2013), however, they are slightly larger. Home range size did not differ among years in my study, a result also observed in Terhune et al. (2006). Throughout the duration of my study, as successional heterogeneity increased, it was expected that as more habitat types become available in a smaller area home ranges might decrease in size. Home ranges did not significantly change in the two years of observation, but extreme drought conditions likely could have influenced behavior. While patch burn-grazing did not statistically show differences in home range across years, the home range size when compared to home ranges in similar locations and time frames (Buckley 2013), were roughly 20-30 hectares larger. This could indicate that quail home range size is expanded in a patch burn-grazing system, however, drought effects may have also influenced home range size. Larger home ranges resulting in increased movement could increase susceptibility to predation or increased energy expenditure. Extreme drought conditions could have likely contributed to this response.

Northern bobwhite select habitat based on a variety of characteristics. In south Texas northern bobwhites selected for dense, herbaceous cover (Wilson and Crawford 1987). In short duration grazing systems northern bobwhites select for increased species richness, forb cover, bare ground, and decreased plant height and litter accumulations against what was available (Wilkins and Swank 1992). In the Texas panhandle from 2000-2003 bobwhites selected a mixed-shrub cover association consisting of sand plum (Prunus angustifolia) and fragrant sumac (Rhus aromatic) as compared to what was available (Hiller et al. 2007). Brooding habitat can generally differ from other habitat and hens with broods in south Texas selected areas that had higher moisture content in the vegetation, as well as selecting for areas with higher canopy cover during midday loafing areas compared to evening feeding areas (Taylor and Guthery 1994). Bobwhites in my study did not exhibit a preference for one treatment over another. As my study progressed each year, and another level of disturbance was added there was still no treatment selected by bobwhites across the years 2009, 2010, or 2011. Patch burn-grazing provides multiple patches varying in time and disturbance which provides many necessary cover types for quail to utilize throughout the year as cover needs shift. As all treatments were utilized and quail were not selecting for a specific treatment, it is difficult to quantify whether this system is beneficial. In my study it did not appear to benefit survival or home range size.

Northern bobwhite nesting success is variable across its range for numerous reasons such as annual precipitation and available vegetation characteristics for nesting cover to name a few. The nest survival rate for this study was 0.28 which is lower than what was observed in some other studies. In Missouri bobwhites exhibited a nesting success of 43.7% (Burger et al. 1995), which is higher than what was observed in this study. For nests located in grass in west-central Texas nest success was 38% (Carter et al. 2002). In south Texas, a daily nest survival rate of 0.9593 was achieved by bobwhites (Rader et al. 2007), which is comparable to 0.9494 which was observed in my study. It is difficult to assess patch burn-grazing effects on nesting success for bobwhites, however, lower nesting success may have been influence by drought effects. With lack of plant production due to the drought, the drought effects could have played a significant role in the low nest survival.

Northern bobwhites in other studies select areas for nesting based on certain vegetation characteristics and these studies show similar selective tendencies for certain variables. In the tallgrass prairies vegetation characteristics selected included taller vegetation, greater visual obstruction, and more litter cover (Taylor et al. 1999), and in the panhandle of Texas these same selective tendencies were exhibited as well (Lusk et al. 2006). The models produced in the nesting survival function of ProgramMARK for the variables measured in my study provided similar results. The 4 models with the lowest ΔAICc for single covariates for nest survival were; percent residual (ΔAICc =0.4185), percent shrub (ΔAICc =0.5547), distance to nearest edge (ΔAICc =0.8821), and vegetation height (ΔAICc =1.8056). These vegetation characteristics were selected as most important in determining nest success in these models. By combining models of percentage of residual, percentage of shrub, and nearest edge a combined model stating these covariates in combination proved to be most important in nest success in my study (ΔAICc =0.0000). I compared means of these variables between successful and unsuccessful nests to illustrate these relationships. Nests were more successful with lower percentage of residual matter at the nest site. Higher percentage of shrub cover at the nest site resulted in higher nest success which was also confirmed by Lusk et al. (2006), but contradicted by results from the tallgrass prairie (Taylor et al. 1999). Being closer to an edge proved to increase success rate for nests, which seems to be counter intuitive considering, edge is hypothesized to provide corridors for predator travel. Upon further examination of distance to edge, mean for successful nests was 32.5 meters and distance to edge for unsuccessful nests was 64.4. This low differential could possibly overstate the effect of this variable since 32.5 meters in its self seems an ample distance from possible predator travel areas. Distance to edge effects on ground nesting birds has shown to be insignificant in other study (Batari and Baldi 2004). Lower bare ground resulted in higher nesting success, which is contradictory to what was found by Lusk et al. (2006), that found higher success rates a more bare ground at the nest site. In regards to nesting, a patch burn grazing system that allows the recovery of patches by shifting grazing focus, will create heterogeneous habitat, and possibly provide essential vegetative nesting components that can possibly improve nest success, but this was not observed in my study.

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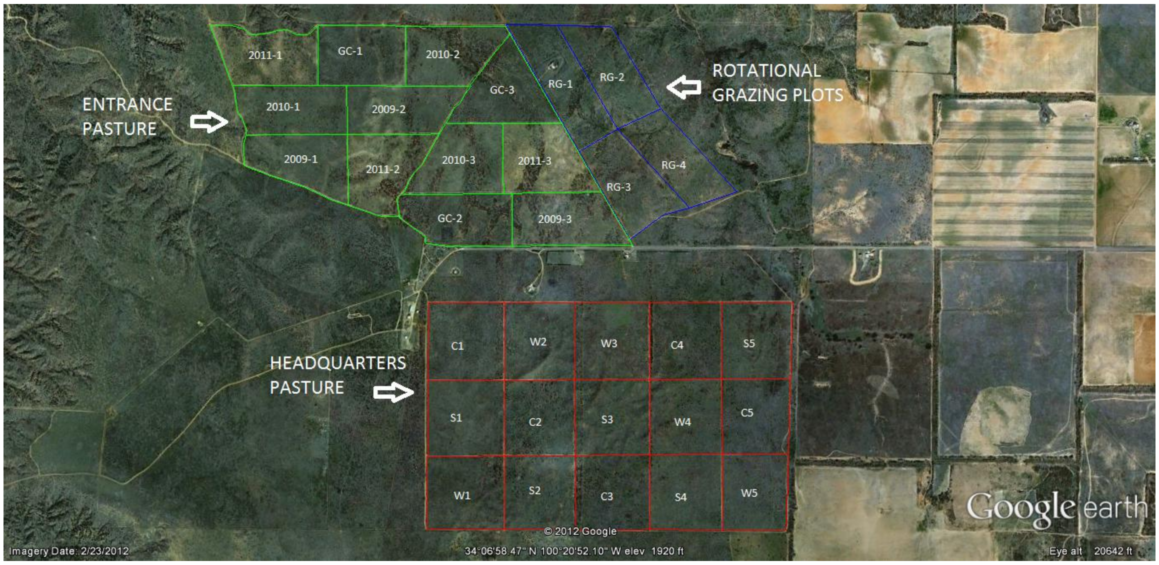

Figure 3.1. Diagrammatic representation of plots located within Entrance and Headquarters pastures at Matador Wildlife Management Area. Headquarters pasture was divided into a 3 x 5 grid with each of 5 blocks containing 3 plots approximately 18 ha in size. Utilizing a randomized block design, each block was randomly assigned 3 treatments consisting of summer burn, winter burn, and control. Entrance pasture was divided into 16 plots approximately 17 ha in size that were subjected to patch burn-grazing and rotational grazing. Due to area constraints, 12 plots were randomly assigned 3 replicates of treatments 2009 burn, 2010 burn, 2011 burn, and control. Additionally 4 plots were subjected to rotational grazing treatment only.

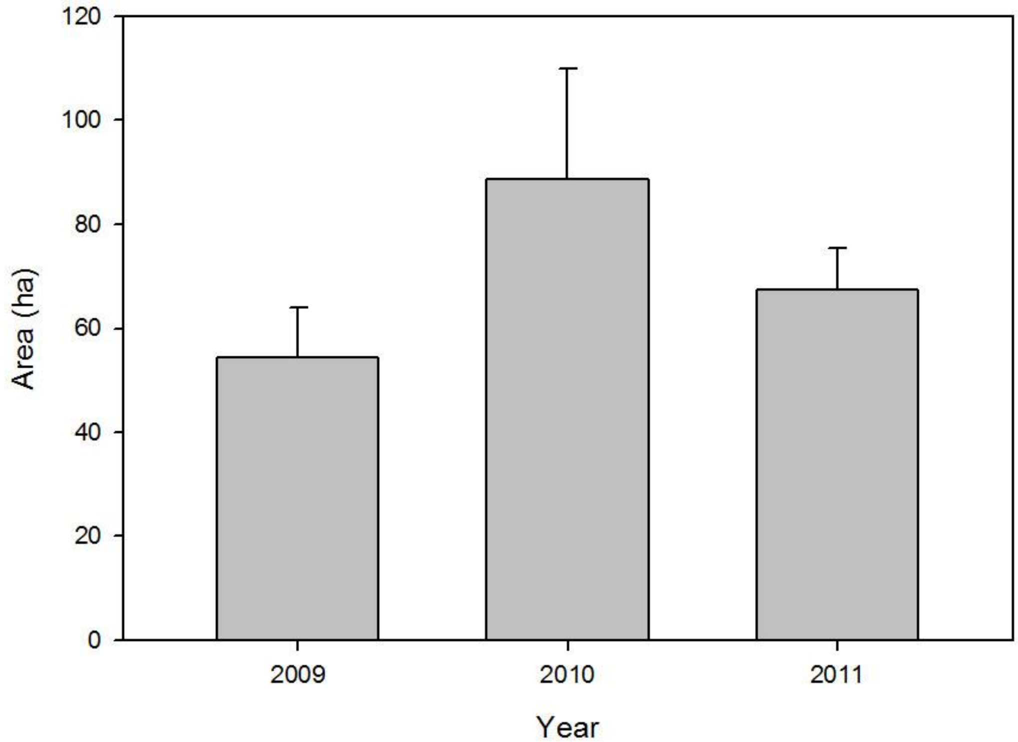

Figure 3.2. Average home range for northern bobwhites for years 2009 through 2011 (Mean±SE).

Table 3.1. 2009 available area (hectares) of each available treatment compared to average area of home range (hectares) encompassed in each individual treatment.

	Control	2009 Burn	Rotational Grazing	Summer Burn	Winter Burn
Available	250.55	53.16	71.73	88.78	86.45
Used	24.50	2.90	1.11	7.91	8.88

Table 3.2. 2010 available area (hectares) of each available treatment compared to average area of home range (hectares) encompassed in each individual treatment.

	Control	2009 Burn	2010 Burn	Rotational Grazing	Summer Burn	Winter Burn
Available	196.91	53.16	53.16	71.73	88.78	86.45
Used	22.54	3.15	2.80	4.37	9.97	7.01

Table 3.3. 2011 available area (hectares) of each available treatment compared to average area of home range (hectares) encompassed in each individual treatment.

	Control	2009 Burn	2010 Burn	2011 Burn	Rotational Grazing	Summer Burn	Winter Burn
Available	145.23	53.16	53.16	51.68	71.73	88.78	86.45
Used	15.56	1.17	4.63	2.22	0.52	8.63	8.22

Table 3.4. Models and AIC criteria produced using nest survival model in ProgramMARK. S.=base survival model without covariates. Covariates (res=percent residual; sh=percent shrub; ne=nearest edge; vh=maximum vegetation height; vs1=visual obstruction score of 1st frame; vs2=visual obstruction score of second frame; vs3=visual obstruction score for 3rd frame; gr=percent grass; bg=percent bare ground; fb=percent forb).

Model	AICc	ΔAICc	AICc Weight	Model Likelihood	Parameters	Deviance
S.	120.8134	2.9054	0.03334	0.2339	1	118.7998
S. x res x sh x ne	117.9080	0.0000	0.14252	1.0000	4	109.7710
S. x res x sh	118.1918	0.2838	0.12366	0.8677	3	112.1099
S. x res	118.3265	0.4185	0.11561	0.8112	2	114.2857
S. x res x ne	118.4493	0.5413	0.10872	0.7629	3	112.3674
S. x sh	118.4627	0.5547	0.10800	0.7578	2	114.4219
S. x ne	118.7901	0.8821	0.09169	0.6434	2	114.7493
S. x res x vh	118.8456	0.9376	0.08918	0.6257	3	112.7637
S. x vh	119.7136	1.8056	0.05778	0.4054	2	115.6728
S. x vs1 x vs 2	119.8687	1.9607	0.05347	0.3752	3	113.7868
S. x vs1 x vs2 x vs3	121.9234	4.0154	0.01914	0.1343	4	113.7865
S. x gr	122.2047	4.2967	0.01663	0.1167	2	118.1639
S. x bg	122.3903	4.4823	0.01515	0.1063	2	118.3495
S. x fb	122.6979	4.7899	0.01299	0.0911	2	118.6570
S. vs1	122.8388	4.9308	0.01211	0.0850	2	118.7980

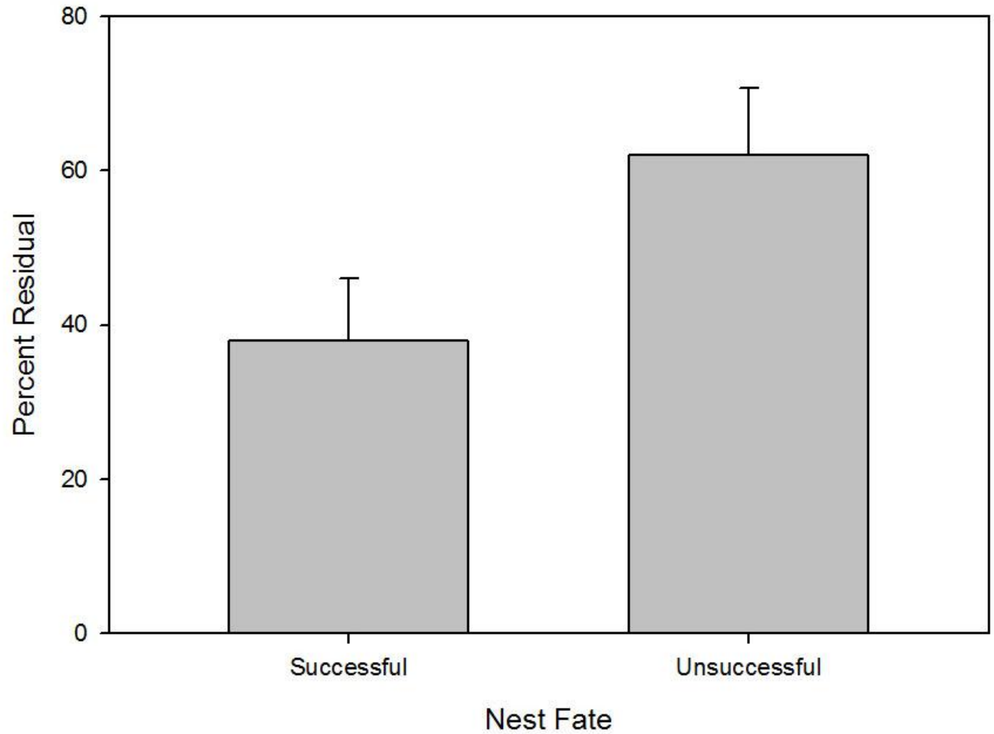

Figure 3.3. Percent residual matter cover for successful and unsuccessful nests (Mean±SE).

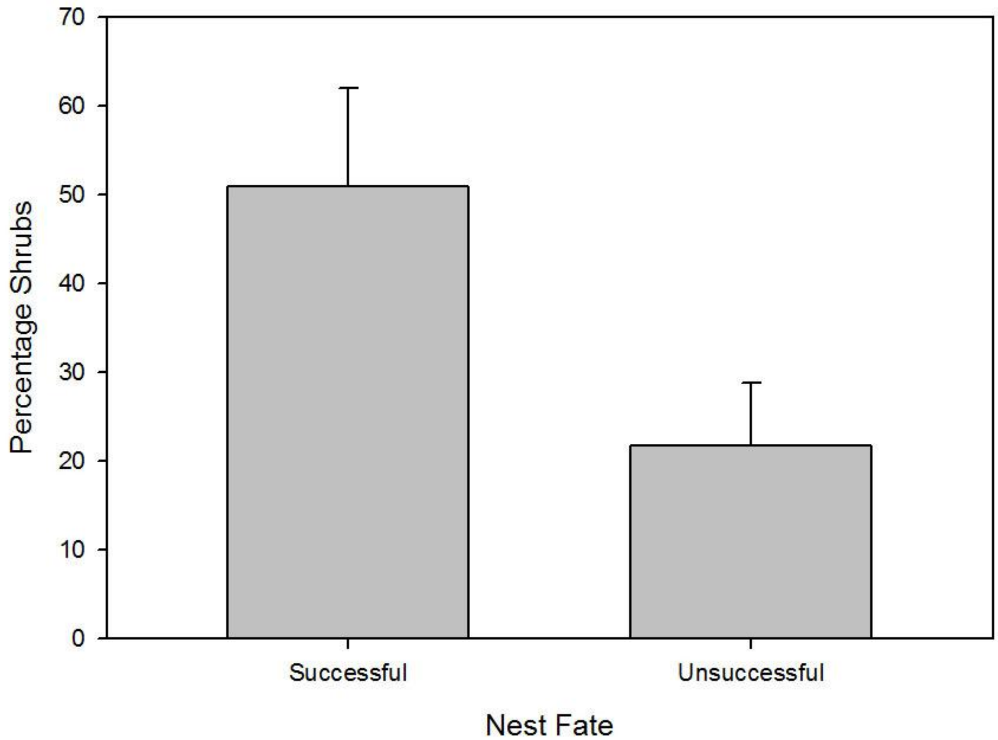

Figure 3.4. Percent of shrub cover for successful and unsuccessful nests (Mean±SE).

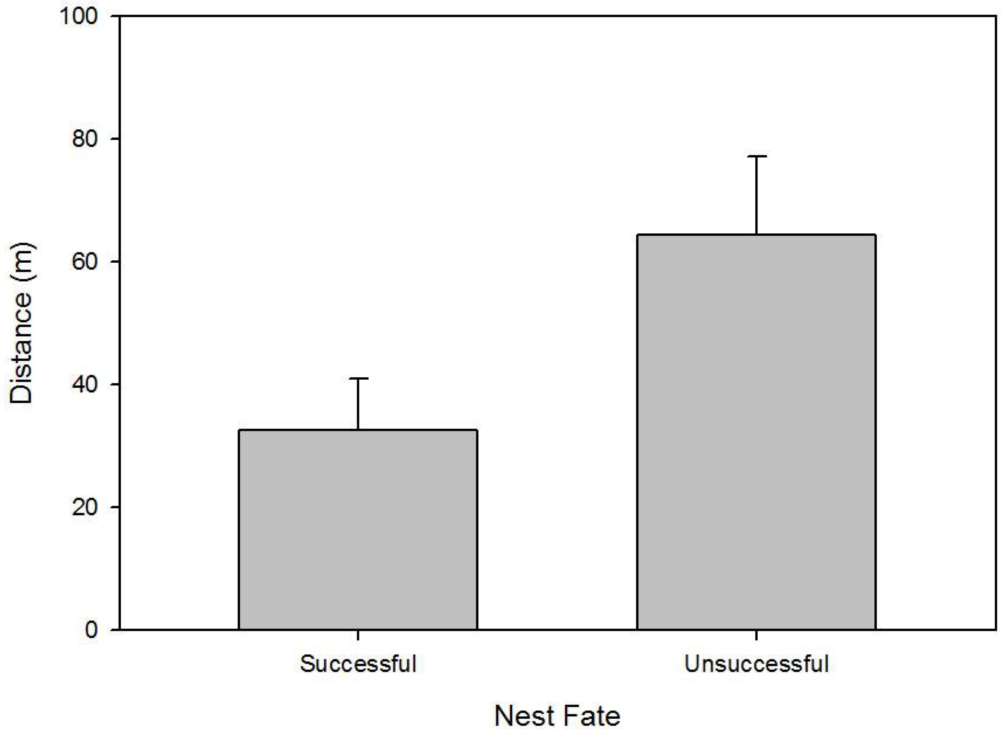

Figure 3.5. Distance to nearest edge (m) for successful and unsuccessful nests (Mean±SE).

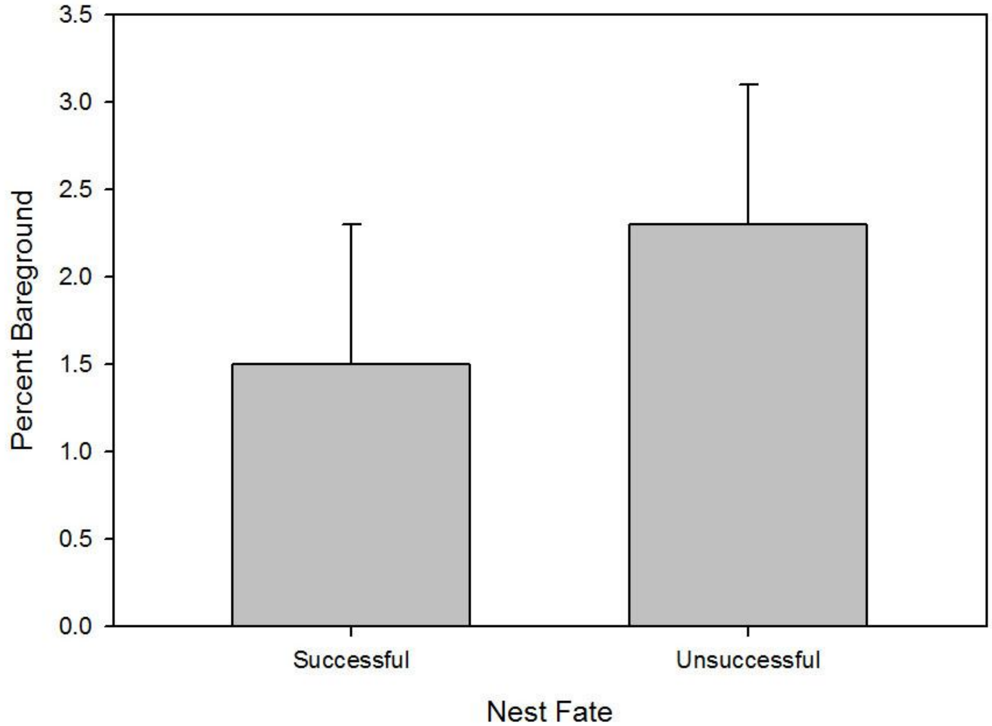

Figure 3.6. Percentage of bare ground for successful and unsuccessful nests (Mean±SE).

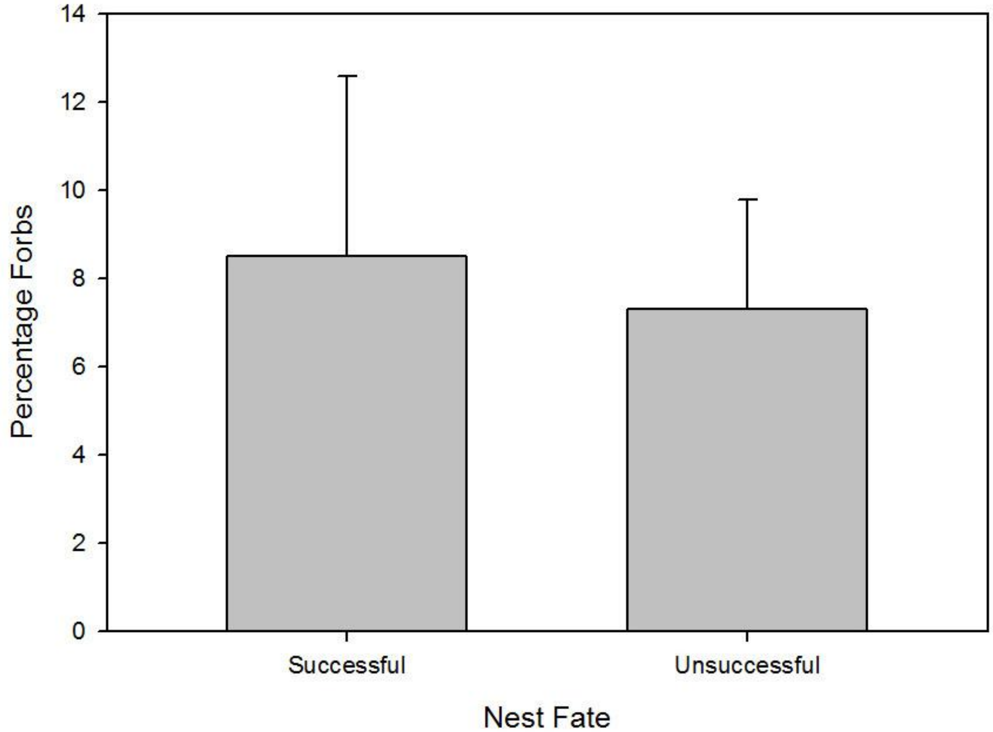

Figure 3.7. Percentage of forb cover for successful and unsuccessful nests (Mean±SE).

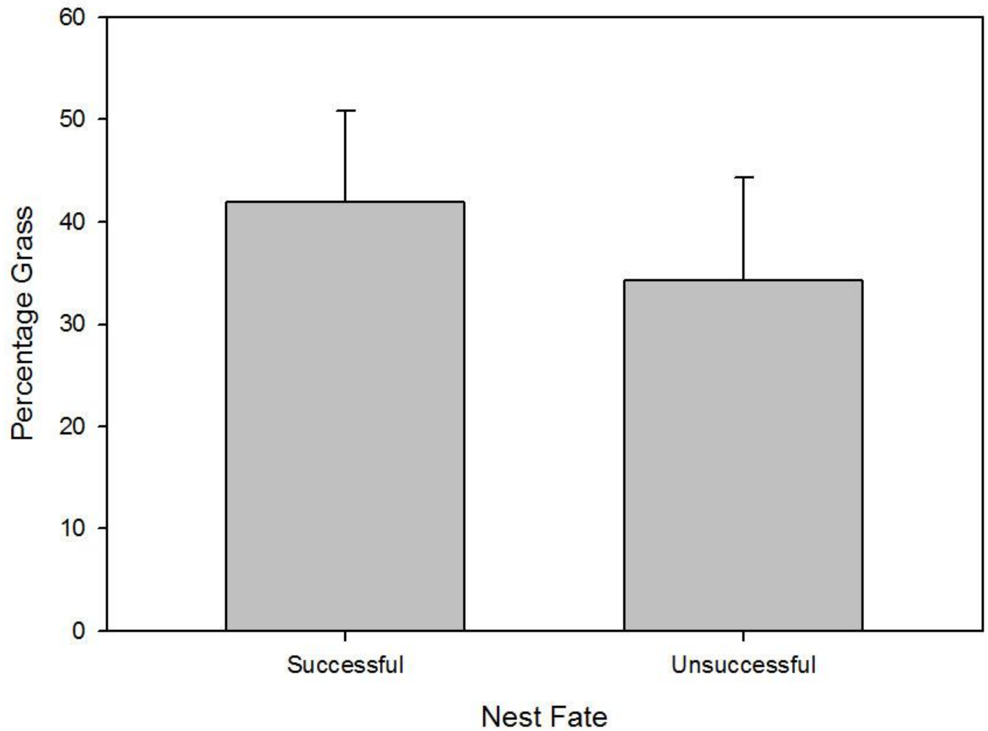

Figure 3.8. Percentage of grass cover for successful and unsuccessful nests (Mean±SE).

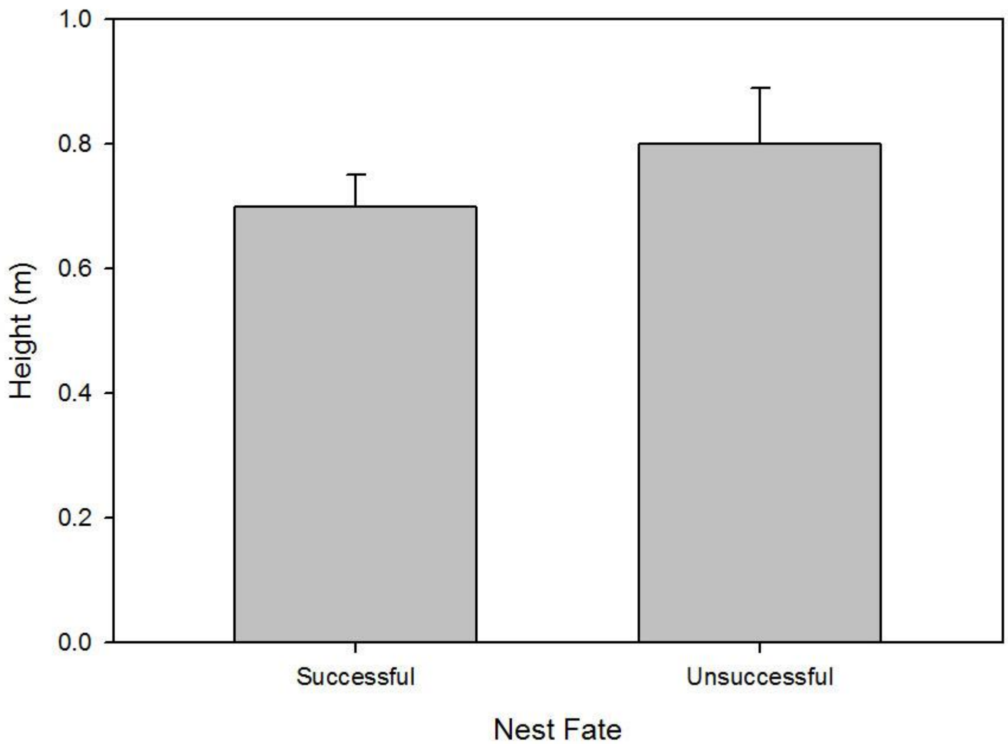

Figure 3.9. Maximum vegetation height (m) for successful and unsuccessful nests (Mean±SE).

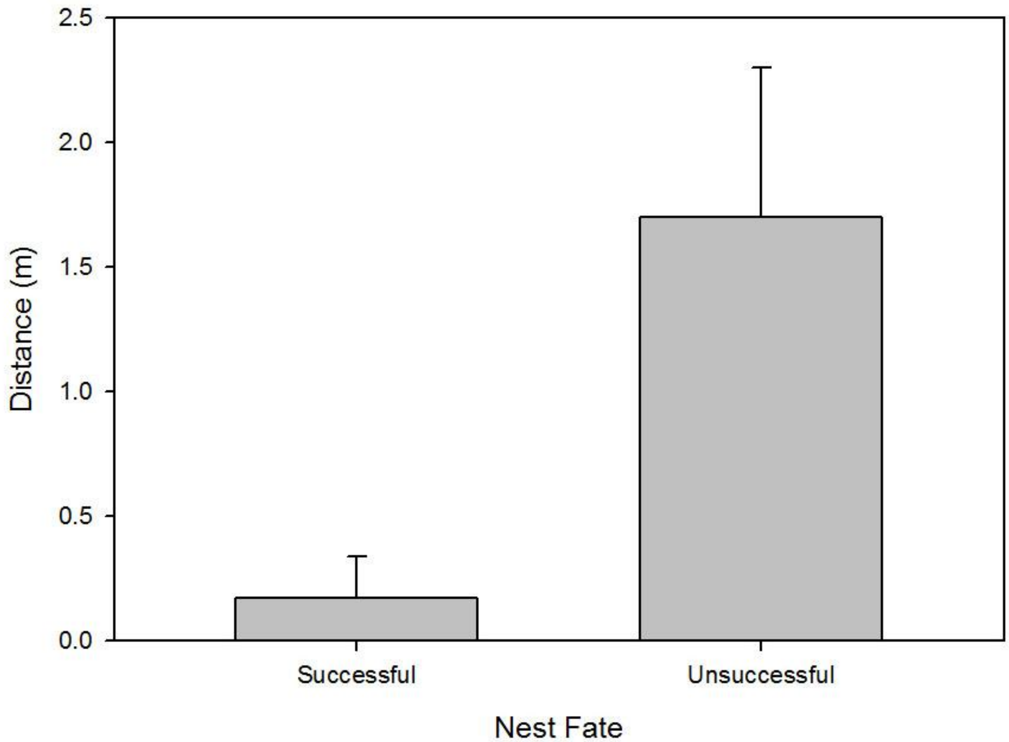

Figure 3.10. Distance to nearest shrub (m) for successful and unsuccessful nests (Mean±SE).

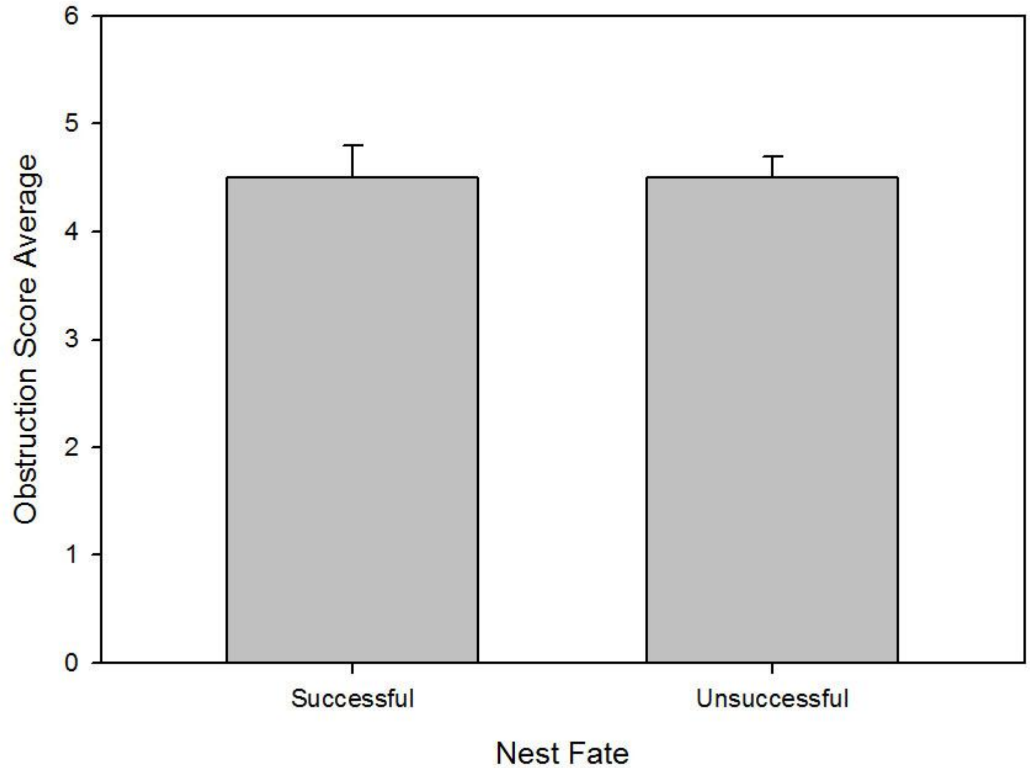

Figure 3.11. Average visual obstruction score for frame 1 of cover board for successful and unsuccessful nests (Mean±SE).

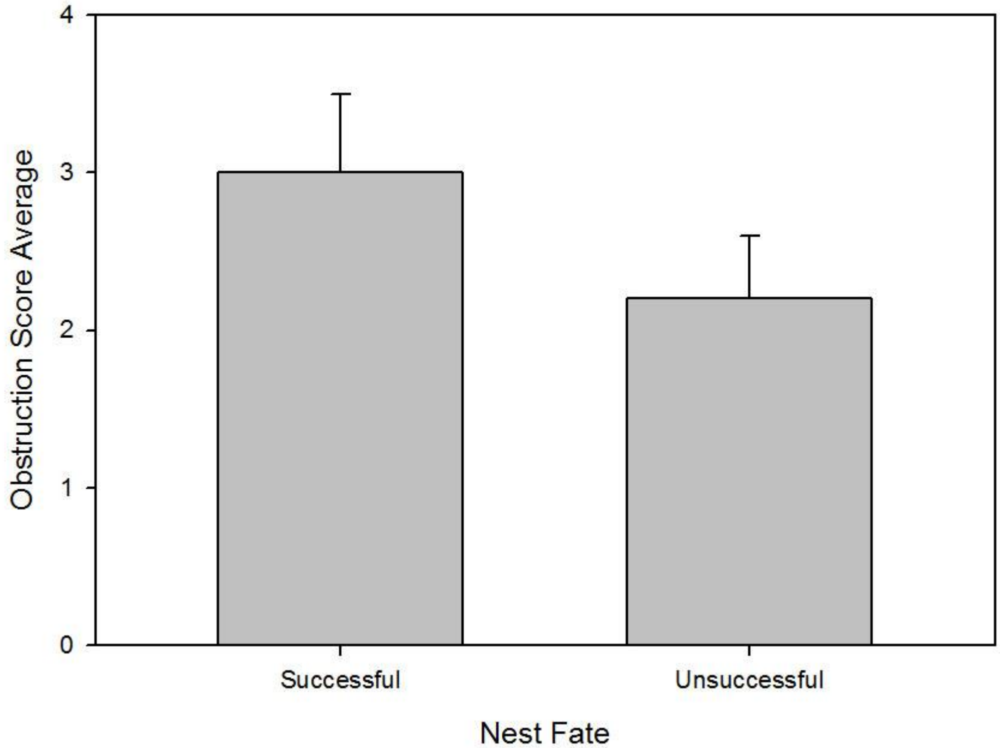

Figure 3.12. Average visual obstruction score for frame 2 of cover board for successful and unsuccessful nests (Mean±SE).

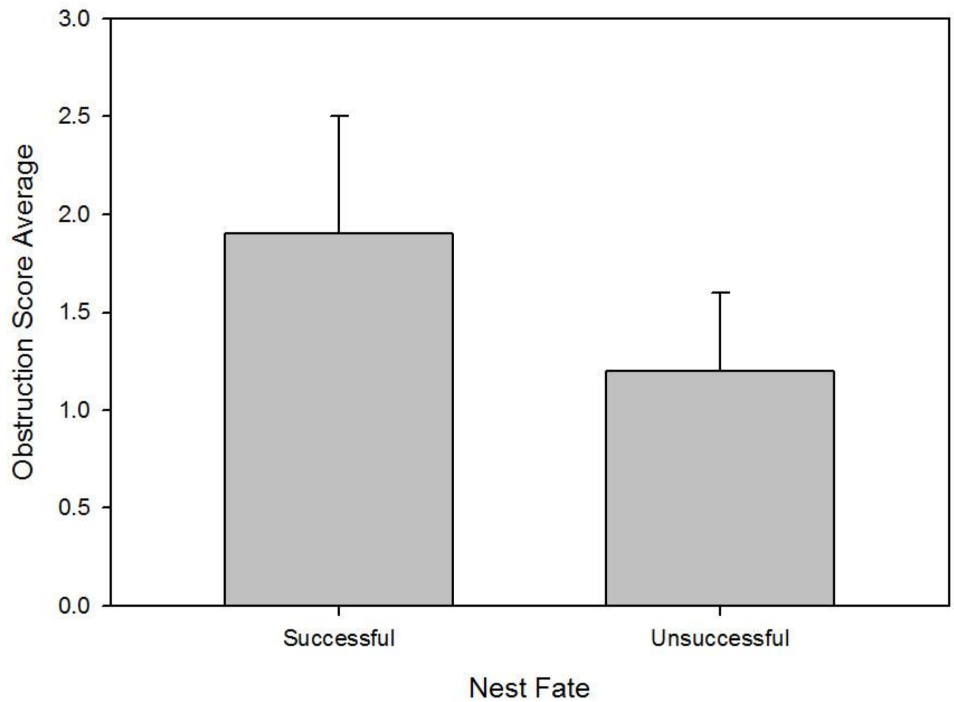

Figure 3.13. Average visual obstruction score for frame 3 of cover board for successful and unsuccessful nests (Mean±SE).

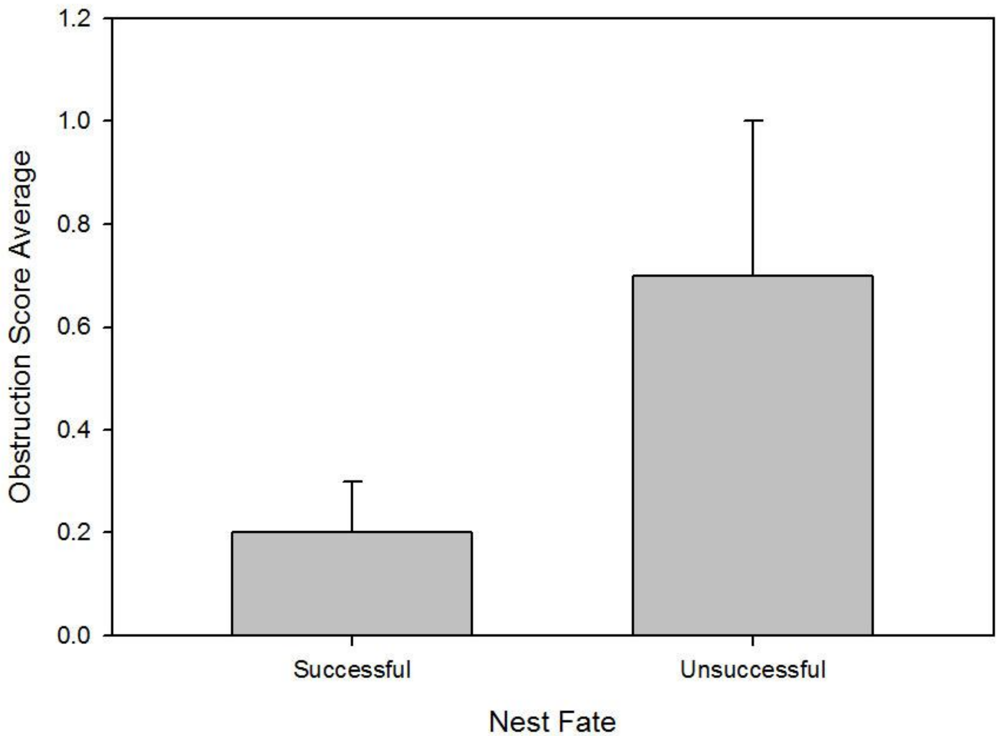

Figure 3.14. Average visual obstruction score for frame 4 of cover board for successful and unsuccessful nests (Mean±SE).

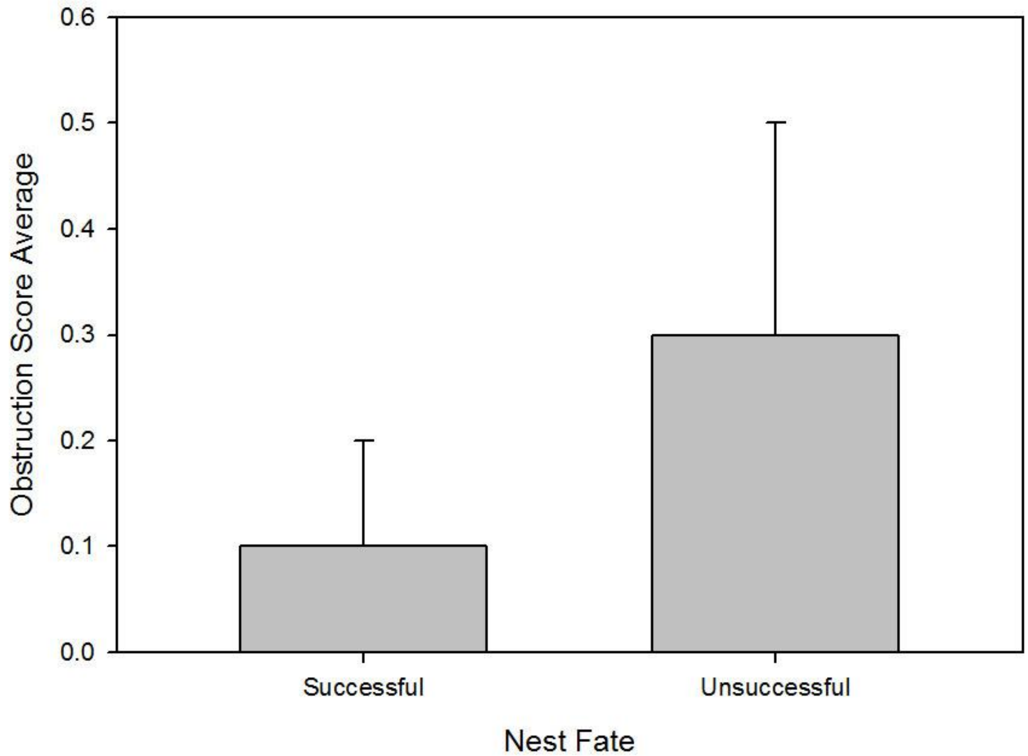

Figure 3.15. Average visual obstruction score for frame 5 of cover board for successful and unsuccessful nests (Mean±SE).