INFLUENCES OF ELK BROWSE ON ASPEN STAND STRUCTURE AND LANDBIRDS AT THE NATIONAL ELK REFUGE, JACKSON HOLE, WYOMING

by

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ABSTRACT

Aspen stands in the Rocky Mountains are hot spots of biodiversity meeting the habitat needs of many species, including wintering ungulates. Ungulates have the potential to alter habitat composition and structure via browsing, especially near areas of concentrated use associated with winter feedgrounds. The National Elk Refuge, established in Jackson, Wyoming in 1912, has provided supplemental winter feed for elk during all but nine winters since its establishment. I conducted the current study to assess aspen stand structure, estimate the likelihood of aspen recruitment given current browse levels, and examine if existing bird communities are reflective of aspen stand structure.

I sampled 27 aspen stands at varying distances from feedgrounds during June 2014. I quantified aspen structure using five height class categories along 10 × 40 m belt transects. Twenty trees in height range of elk browse (i.e., 50–150 cm) were selected and measured within each belt to determine the Live-Dead Index, a quantification of browse intensity. I conducted two rounds of bird point counts to assess bird community composition in relation to aspen stand structure.

My results indicated current browse levels were largely precluding aspen recruitment. LD Index values indicated 89% of 27 stands sampled in the National Elk Refuge were experiencing high browse intensity and aspen ≤150 cm were being browsed back to ground level. A relationship between distance to feedgrounds and LD Index was not present, possibly resulting from intensive browsing throughout the refuge. In addition, bird communities were responding to the altered aspen stand structure. For example, Yellow Warblers were strong indicators of stands that had experienced recent aspen recruitment (i.e. greater mid-story canopy and structure). White-breasted Nuthatches were an indicator of a bird community group associated with larger aspen stands. Based on the current lack of recruitment on the refuge, large exclosures surrounding targeted aspen stands are recommended to protect juvenile aspen until they grow out of the browse zone.

INTRODUCTION

Aspen (*Populus tremuloides)* stands across the Rocky Mountains comprise a small percentage of the landscape but support a disproportionate diversity of wildlife (DeByle 1985). Invertebrates, amphibians, small mammals (Shepperd et al. 2006), and birds (Verner 1989, Heath and Richardson 2004) generally have greater species diversity within aspen stands compared to surrounding habitats, likely due to the greater structural diversity and more mesic microclimates associated with aspen (St. John 1995). In Northern Arizona, mean abundance and mean species richness of birds was higher in aspen stands compared to equivalent ponderosa pine forests (Griffis-Kyle and Beier 2002). Similarly, bird species richness and abundance was generally higher in aspen stands than surrounding habitats in the Greater Yellowstone Ecosystem (GYE; Turchi et al. 1995, Hollenbeck and Ripple 2007, Binkley 2008). Bird species respond to the composition and size of aspen stands. Aspen stands with high understory cover and multiple canopy layers increased bird species richness and diversity throughout the GYE (Dobkin et al. 1995). In Saskatchewan, there was a positive correlation between the area of an aspen stand and bird species diversity; the number of bird species observed (Johns 1993). In Rocky Mountain National Park, the amount of understory was correlated with bird species richness and aspen stand structure was the most important predictor of bird species richness (Turchi et al. 1995). In addition, Dobkin et al. (1995), pointed to high understory cover within aspen stands which increased bird species richness and large aspen trees were used more frequently for cavity nesting birds than other montane habitats. Landbirds respond to not only plant species composition within plant communities, but also to the plant structure of the community. For example, higher diversity of birds has been associated with multiple layers of a deciduous forest (Casey and Hein 1983).

Large-scale declines in aspen stands have been observed throughout the Rocky Mountains over the past 100 years (Bartos 2000, Kay and Bartos 2000, Barnett and Stohlgren 2001, Binkley 2007, Worral et al. 2013). Bartos (2000) compared photographs of aspen stands from the late 1800s to photographs from the late 1900s and discovered declines ranging from 49% to 60% across the Rocky Mountains. Coverage of aspen stands sampled in the GYE decreased 10% between 1956 and 2001, and stand area declined 4–10% within one year (Ripple et al. 2001, Brown et al. 2005, Wagner 2006, Kimble and Sowell 2013). The majority of aspen stands in the GYE are approaching their 150-year life expectancy for the region (Romme et al. 1995, Binkley 2008). When older trees die, they are generally replaced by clonal stems (i.e. suckers) (Bartos and Mueggler 1981, Kay and Bartos 2000), with most suckering stimulated by above-ground disturbances such as forest fires (Kay and Bartos 2000, Petrides and Petrides 2005). When a sucker grows above the browse zone, it is classified as a recently recruited tree (Keigley et.al. 2009). An aspen stand is maintained through recruitment, and if recruitment fails, the extent and density of the stand will decline and may be replaced by subalpine fir (*Abies lasiocarpa),* sagebrush (*Artemisia* spp.), or grasses (Kay 1990, Bartos 2000).

Multiple hypotheses have been posited for the decline in aspen across much of the western Rockies, including conifer encroachment, fire suppression, ungulate browsing, or combinations of these factors. For example, wildfires during 1879 reinvigorated growth of aspen stands by eliminating resource (i.e. sunlight) competition with conifer trees on the National Elk Refuge (NER) in western Wyoming (Smith et al. 2004). Fire suppression increases survival of young conifers, which can eventually overtop and inhibit the growth of shade-intolerant aspen (Bartos 2000, Brown et al. 2005). Only one third of aspen stands in Rocky Mountain National Park contained exclusively aspen trees, while the remaining stands experienced conifer encroachment (Kaye et al. 2002). Stam et al. (2008) found a negative impact of conifer encroachment on aspen understory.

Ungulates throughout the Rocky Mountains browse on aspen suckers and juveniles, particularly during winter months (elk [Romme et al. 1995, Kaye et al. 2002], moose [Schwartz et al. 1988], mule deer [Beck and Peek 2005]). High densities of ungulates impact aspen stand structure through browsing (Kay and Bartos 2000). Elk typically browse on young suckers between 50 cm and 150 cm in height, but may reach trees up to 250 cm tall (Baker et al. 2007, Keigley and Frisina 2011). Stands browsed primarily by elk in south-central Utah forests were dominated by old trees with limited or no recruitment, while stands where elk were excluded developed multiple height class layers and an extensive understory of shrubs and forbs (Kay and Bartos 2000). Fifty-six percent of aspen stands sampled within the GYE, including the National Elk Refuge (NER) had no recruitment, a consequence likely due to browsing by high-densities of wintering elk (Barnett and Stohlgren 2001). Although aspen have been observed to decline in areas with a long history of fire suppression (Bartos 2000, Brown et al. 2005), fire disturbance in areas of high-density ungulate populations fosters additional declines. For instance, the 1988 wildfires in the GYE stimulated aspen suckering, but growth was inhibited by ungulate browse (Romme et al. 1995). When areas were protected from ungulate browsing, aspen stands successfully recruited (Kay and Bartos 2000). Stands impacted by high densities of elk are characterized by low aspen numbers, a monoculture of large, old trees, and limited understory (Binkley 2008).

Objectives and Hypotheses

I undertook this investigation to examine the effects of ungulate browsing on aspen stand structure and recruitment within the National Elk Refuge. I also explored bird community response to existing aspen structure on the NER, after a legacy of supplemental elk feeding. The objectives of this study were to: 1) determine stand structure on the NER using height-based categories to classify aspen; 2) quantify patterns of browse intensity as a function of distance to feedground and stand area; and 3) examine variation in bird community composition and diversity as a function of aspen stand size and structure.

I tested three hypotheses and resultant predictions regarding elk browse, aspen structure, and bird community response. First, I hypothesized that stands closer to winter feedgrounds would be more frequently utilized by wintering elk, and therefore experience higher intensity of browsing both historically and currently. I expected stands browsed by elk would be structurally simplified, with height classes dominated by aspen suckers and juveniles (height class 1; ≤50 cm and height class 2; 51-250 cm). I hypothesized that stands closest to the feedgrounds would have the highest levels of browse and lowest number of recent aspen recruits based on Anderson’s (2002) prior studies. In addition, I expected larger stands would recruit more than smaller stands. I also anticipated bird community composition to reflect the simplified canopy structure of aspen stands, with more bird species preferring dense mid-story structure limited to stands that had experienced recent aspen recruitment.

METHODS

Study Area

The National Elk Refuge (NER) encompasses ≈10,000 ha within Jackson Hole, Wyoming, on the southern extent of the GYE (Fig. 1). The NER was established in 1912 and is one of more than 560 National Wildlife Refuges managed by the U. S. Fish and Wildlife Service (USFWS). Supplemental winter feeding of elk has occurred during all but nine winters on the NER since its establishment (USFWS unpubl. data).

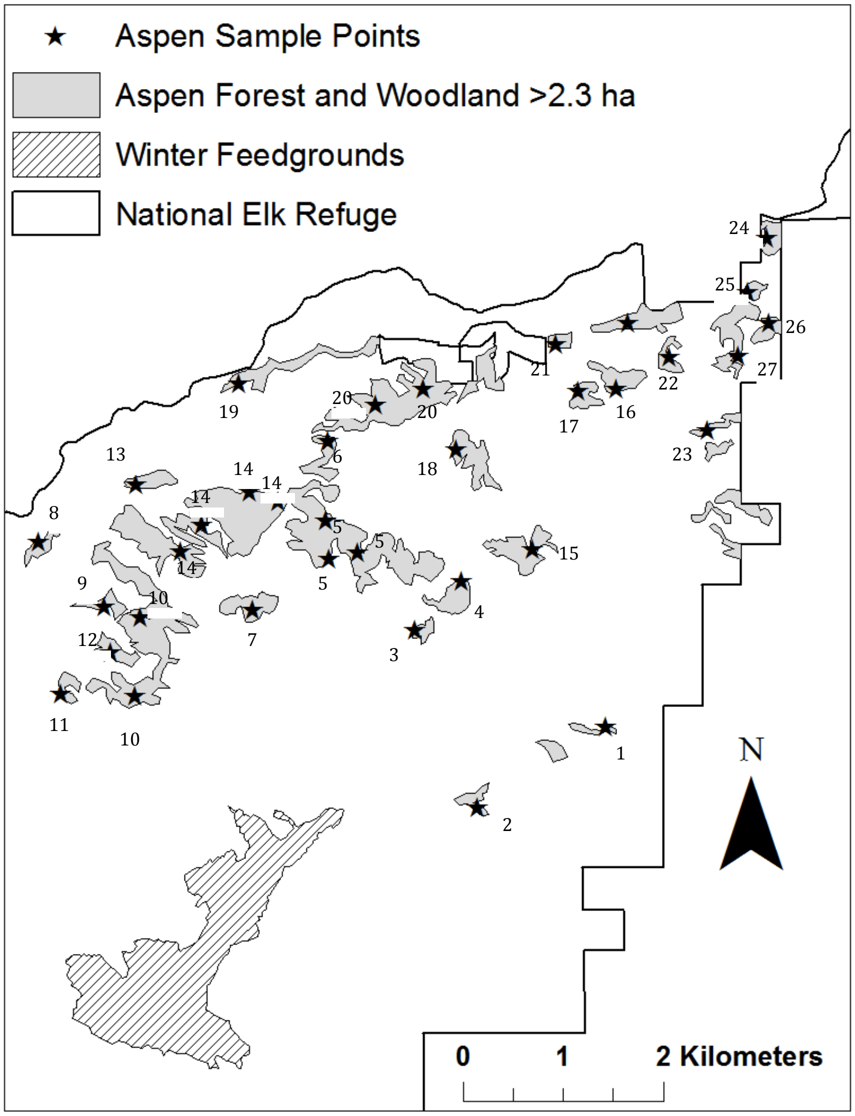

Figure 1. Location of aspen stand study points within the National Elk Refuge, Wyoming.

Elevation of the refuge varies from 1,890–2,195 m above mean sea level. Mean maximum and minimum temperatures are 10.2 and -7.4 °C, respectively. Mean precipitation for the area is 77.1 cm, most of which falls as snow with a mean depth of 50.8 cm (1905-

2013; High Plains Climate Center). Vegetation on the refuge is predominately sagebrush shrublands and native grasslands. Common shrub species include big and three-tipped sagebrush (*Artemisia tridentate; A. tripartita*), and Antelope bitterbrush (*Purshia tridentata*). Grasses include needlegrasses (*Achnatherum* spp.), bluegrasses (*Poa* spp.), and wheatgrasses (*Elymus* spp.) (USFWS and USNPS 2007, Jacobs 2007). Conifers, such as lodgepole pine (*Pinus contorta)* and Douglas fir (*Pseudotsuga menziesii*), grow in pockets on north-facing slopes (USFWS and USNPS, 2007). Aspen stands occur in relatively mesic sites and commonly include willow (*Salix* spp.), Douglas-fir, pinegrass (*Calamagrostis rubescens*), snowberry (*Symphoricarpos albus*), wild rose (*Rosa* spp.) and bluegrasses (*Poa* spp.) (Kay and Bartos 2000, Jacobs 2007, USFWS and USNPS 2007).

Site Selection

Aspen stands on the NER delineated following National Vegetation Classification Standards protocol (U.S. National Vegetation Classification 2014) were merged to create a single spatial data layer representing aspen habitat on the NER using ArcGIS 10.0 (ESRI, Inc., Redlands, California) geographic information system (GIS) software. A simple random sample of 34 points within 27 aspen stands ≥ 2.3 ha, and no closer than 200 m apart, was selected using GIS software (Appendix A). The area represents the minimum approximate breeding territory size of Dusky Flycatchers (*Empidonax oberholseri*) in mixed conifer-aspen woodland (Dobbs 2005), a species of conservation concern on local and regional scales, due to recent population declines in response to reduced aspen extent (Nicholoff 2003).

Distance between each study point and the nearest feedground (±1 m) (DFG) was estimated using GIS software. Distance to feedground was standardized to have a mean = 0 and standard deviation = 1 to assist with model convergence due to the broad range of DFG values experienced (i.e., 1.3 km – 7.1 km).

Aspen Stand Structure and Browsing Intensity

I used a 10 × 40 m belt transect centered on a randomly selected point and oriented lengthwise along a random bearing to quantify aspen height structure. I classified aspen within each transect into the following height classes (Table 1) based on the height of individuals: 1) suckers (class 1; ≤50 cm), 2) juveniles (class 2; 51–250 cm), 3) recently recruited trees (class 3; >251cm – ≈75% of adult tree height), 4) adults (class 4; mature upper canopy layer), and 5) standing snags (class 5) (Strand et al. 2009). Class 2 through 5 aspen were quantified using 10 x 40 m transect belt. Suckers (class 1) were numerous; therefore I counted them within a 1 x 40 m belt. Exceptions occurred when I utilized a 10 x 40 m belt for all height classes at aspen stand one, and a 1 x 40 m belt was used to enumerate all height classes in stand 19, a very densely forested area.

Table 1. Aspen height class categories used to explore relationships, height, and transect area on the National Elk Refuge, Wyoming, 2014.

Class	Description	Height	Belt Dimensions (m)
1	Suckers	≤50 cm	1x40
2	Juveniles	51-250 cm	10x40
3	Recently Recruited Trees	>251 cm ~ 75% of adults	10x40
4	Adult Trees	Upper Canopy	10x40
5	Snags	Dead, standing trees	10x40

Current levels of browse intensity was quantified utilizing the Live-Dead (LD) Index, a comparison of growing portions and browsed portions of aspen within the browse zone (Keigley and Frisina 2011). Within transect belts, twenty trees ranging in height between 50 - 150 cm (most intense height of browsing), were randomly sampled (Appendix B). Height measurements (± 1cm) were taken at the base of these trees' current year's growth and the tallest portion browsed. The LD Index was calculated by determining the height difference between the base of current year's growth and the tallest stem browsed (Keigley and Frisina 2011), providing an objective and repeatable method for quantifying current browse levels. An LD Index value of 0 indicates all annual growth of a browsed plant is being consumed, while values < 0 cm indicate browsing is removing all new growth and a portion of prior year's growth. Continued browsing at these latter levels would result in plants being browsed to ground level, ultimately leading to plant death. Positive LD Index values (i.e., > 0 cm) provide evidence that browse levels are not removing all annual growth, which could lead to an individual plant growing through the browse zone and being recruited (Keigley and Frisina 2011).

<u>Bird Point Count Surveys</u>

Bird point count surveys were conducted at the center of each belt transect (Anderson 2002). Points were surveyed twice during the breeding season. Surveys were conducted from 30 minutes before sunrise until 1000 hrs. Surveys were 10 minutes in length and preceded by a one-minute settling period. Species, sex (when possible), number, distance (±1 m), and method of detection (i.e. song; call; territorial behavior; visual; flyover; or a combination of these) were recorded for each observation (Appendix C).

Data Analysis

I assessed whether variation in browse intensity was correlated with distance to feedground (DFG) and stand area, while accounting for repeated sampling, using general linear mixed effect models implemented in program R version 3.0.3 (R Development Core Team 2015) and package lme4 (Bates et al. 2014). I evaluated the strength of support for each model representing competing predictions of browse intensity by ranking models with Akaike's Information Criterion corrected for small sample size (AIC_c) (Burnham and Anderson 2002).

I used LD Index values, summarized at the stand level, to deterministically predict aspen recruitment in NER aspen stands, assuming current conditions do not change. The LD Index of each stand was also graphically summarized.

I examined bird community response to aspen stand structure using a suite of multivariate techniques. First, I created a Sørensen dissimilarity matrix of values based on bird species observed at each point. Next, I conducted a hierarchical agglomerative group analysis with a flexible beta of -0.25 based on the Sørensen dissimilarity matrix (Abella 2012). Third, the optimal number of groups, i.e., bird community groups, was selected using Indicator Species Analysis (ISA) metrics (Dufrêne and Legendre 1997). ISA provides indicator species values, *d*, for each species within a group. I used the top indicator species, i.e., the species with the greatest specificity to a group, to graphically explore and describe relationships between bird community groups and aspen stand attributes. All analyses were conducted in program R version 3.0.3.

RESULTS

Aspen transect data were collected 5 June – 24 June 2014. Nearly half (41%) of the aspen stands included in the study were <10 ha in area, with the largest stand 71.1 ha. Juvenile aspen (i.e. class 2: 51–250 cm in height) were the most abundant and variable aspen height class observed on the NER (Fig. 2). Adults and snags were proportionately low in aspen stands sampled. The combination of a high proportion of juveniles and low proportion of adults appears to indicate that aspen stands within NER were attempting to replace a diminishing canopy of old trees (Kay and Bartos 2000).

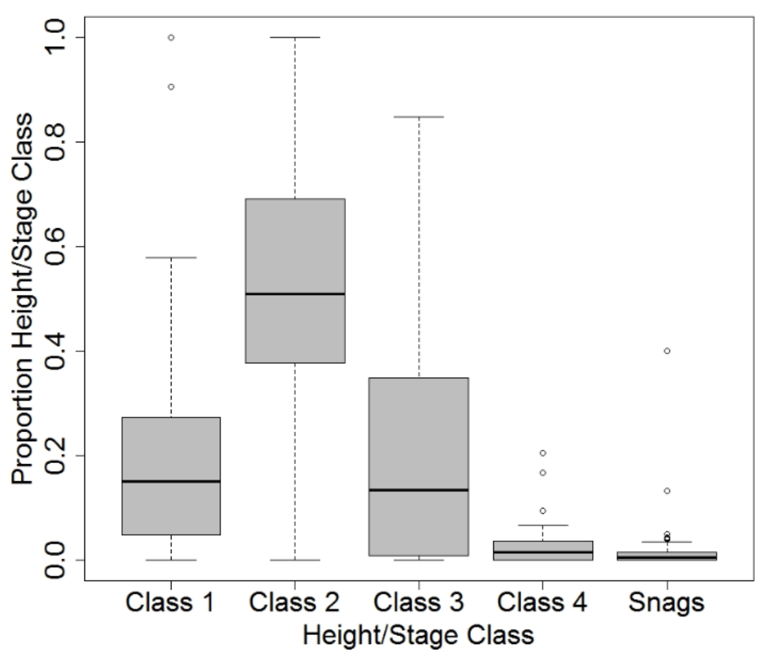

Figure 2. Proportion of aspen height/stage class categories from aspen stands sampled on the National Elk Refuge, Wyoming, 2014. Height/stage class definitions: Class 1, Suckers; Class

2, Juveniles; Class 3, Recent Recruits; Class 4, Adults; and Snags. See Table 1 for more thorough definitions.

Results from the LD Index indicated approximately 89% (n = 24) of the stands were browsed at levels that are resulting in aspen browsed to ground level (Fig. 3). Stand 1 had a median LD Index of -19.0, the lowest of all stands surveyed. Annual aspen growth in these stands is completely consumed by ungulates, and in addition some prior years' growth is also consumed. Current browse levels will preclude aspen recruitment, which, over an extended period, will lead to stand losses. Aspen within the browse zone could remain the same height for many years (Fig. 4); but if browse levels remain high, these individuals will eventually die. However, three stands (stands 17, 19, and 20) had median LD Indexes greater than zero, indicating these juvenile aspen may grow through the browse zone. For example, juvenile aspen in stand 19 would be predicted to grow through the browse zone within nine years based on the difference between the 1) mean juvenile aspen height (97.3 cm) within the stand, 2) height of the elk browse zone (150 cm; Keigley and Frisina 2011), and 3) the median LD Index of 6.0 cm. Assuming juvenile aspen annual survival of 0.94 (Romme et al. 2005), 58% of juvenile aspen will survive to recruit.

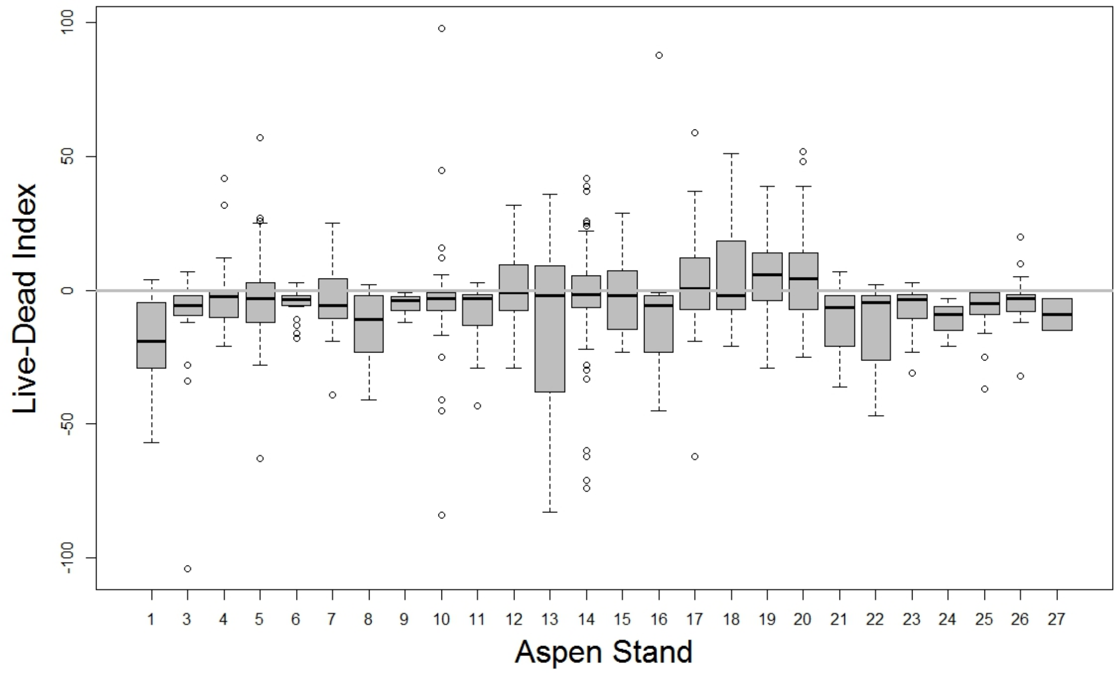

Figure 3. Boxplot summaries of live-dead index for aspen stands (*n* = 27) within the National Elk Refuge, Wyoming, 2014. Gray boxes represent 25th and 75th percentile values, black lines are medians, whiskers are maximum/minimum values or, if outliers are present (open circles),

are 1.5 × interquartile range. Points 2 and 35 lacked aspen within the browse zone and are not

shown.

Figure 4. Aspen sucker with a negative LD Index at the National Elk Refuge in Wyoming 2014. Height at the base of current year's growth is 13 cm, while height of dead is 114 cm, indicating this tree is dying back to ground level from high browse levels.

I did not find support for the hypothesized relationship between browse level and distance to feedground. The distance to feedground model received the least support based on ΔAIC_c ranking, and the stand area and distance to feedground model was within 0.05 AIC_c units of the null model (Table 2). Modest support for an influence of stand area on browse levels was evident, although this model and the stand area and distance to feedground model contained uninformative parameters (*sensu* Arnold 2010). The best model, taking into account uninformative parameters (Arnold 2010), indicated browse levels were constant across the NER (i.e., the null model) (Table 2). Mean browse level on the NER, as quantified using LD Index, was -5.3 (SE = 1.31), indicating browse levels currently preclude aspen recruitment and result in negative net growth.

Table 2. AIC ranking (highest to lowest) of best fit for competing browse models, Wyoming, 2014.

	df	AICc	ΔAICc
Stand area	4	4963.77	0.00
Distance + Stand area	5	4965.40	1.64
Null	3	4965.46	1.69
Distance * area	4	4965.62	1.86
Distance to feedground	4	4967.48	3.72

Bird Community Groups

I observed 54 bird species during 68 point count surveys conducted between 9 June – July 4 (Appendix D). The five most common species were House Wren (*Troglodytes aedon*; *n* = 104 individuals), Red-shafted Flicker (*Colaptes auratus cafer*; 63), Mountain Bluebird (*Sialia currucoides*; 60), Dark-eyed Junco (*Junco hyemalis*; 52), and American Robin (*Turdus migratorius*; 46). House Wrens were found in 94% (*n* = 32) of points, and Red-shafted Flickers were found in 85% (*n* = 29) of points. Eighteen species were only recorded once throughout the study. The Dusky Flycatcher, a species of concern used to define stand area criteria for sampling, was not observed during the study. Points 9, 27, and 32 had the highest species diversity, with 17 species each. Lowest bird diversity, eight species, was observed at points 8 and 26. Mean bird species per point was 12.57 (SE = 0.43).

Indicator species analysis initially indicated six bird community groups as optimal. However, two of the groups had Black-capped Chickadee as an indicator species, and were subsequently combined. Indicator species for the five groups were Tree Swallow (*Tachycineta bicolor)*, Black-capped Chickadee (*Poecile atricapillus)*, Black-billed Magpie (*Pica hudsonia)*, White-breasted Nuthatch (*Sitta carolinensis)*, and Yellow Warbler (*Setophaga petechial)*, with three of the five groups containing a strong indicator species (i.e., indicator value ≥0.50) (Table 3).

Table 3. Aspen stand bird community groups, indicator species, and indicator species value (*d*; Dufrêne and Legendre 1997).

Group	Species Name	*d*
1	Tree Swallow (*Tachycineta bicolor)*	0.571
2	Black-capped Chickadee (*Poecile atricapillus)*	0.366
3	Black-billed Magpie (*Pica hudsonia)*	0.545
4	White-breasted Nuthatch (*Sitta carolinensis)*	0.981
5	Yellow Warbler (*Setophaga petechial)*	0.707

Yellow Warblers were associated with aspen stands with high numbers of recent recruits (height class 3 trees) and low numbers of suckers (height class 1 trees; Fig. 5). White-breasted Nuthatches were strong indicators for the group associated with large aspen stands (Fig. 6), with a median area ≈ 45 ha. Other attributes of stand structure did not generally impact bird community groups.

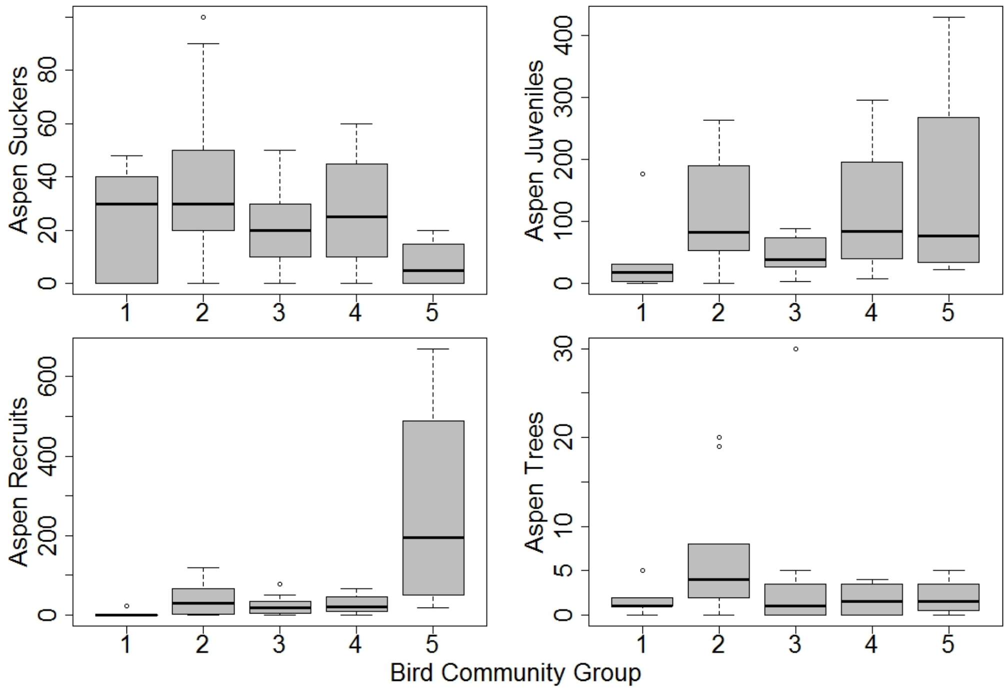

Figure 5. Aspen height class counts by bird community groups observed on the National Elk Refuge, 2014.

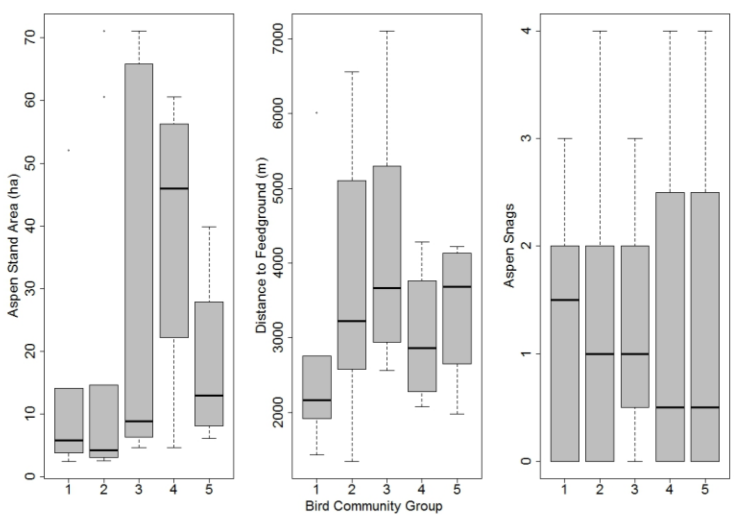

Figure 6. Indicator bird species groups by aspen stand attributes observed at the National Elk Refuge, 2014.

DISCUSSION

Contrary to my hypothesis, browse intensity did not vary with distant to feed ground. Browse levels were uniformly high in stands on the NER, with complete consumption of current year's aspen growth in 89% of stands sampled. Thus the results of this study do not agree with the results of Anderson's (2002) study, which found browse levels declined with increasing distance from NER feedgrounds. However, Anderson included aspen stands well beyond the NER boundary, while stands I sampled within the refuge were no further than 7.1 km from a feedground. Moreover, the number of elk wintering on the NER has increased since the completion of Anderson's work (USFWS unpubl. data) in 2002, which could also lead to greater, and more consistent, browse levels across aspen stands on the refuge. I also found higher browse levels than reported in the more recent work of Cole and Keigley (2009), although they sampled the northern half of the refuge where recent aspen recruitment had been observed.

Although I observed evidence of recent aspen recruitment, recruitment within aspen stands on the NER in the near future is unlikely given the consistent and high levels of browse intensity recorded during this study. Recruitment was limited throughout the NER, similar to Barnett and Stohlgren's (2001) results, which indicated that over half of aspen stands in the GYE had no recruitment. Of the 34 points sampled, eight points (24%) contained zero recently recruited trees, 2 points had a single recruit, and 2 points had a couple recruits. The combination of these twelve points suggest essentially 38% of sampled points functionally have no recruitment. Other points' number of recent recruits ranged between 8 and 670 trees.

The aspen stands in the area are old, reaching the end of their life expectancy and respond by; opening the canopy, increasing sunlight, and suckering (Mueggler 1989). Current browse levels will preclude the vast majority of these stands from recruiting age class 2 individuals.

The most common age class in NER aspen stands was juveniles, indicating stands were attempting to fill canopy openings, likely the result of older trees dying (Bartos, Meuggler and Campbell 1991). Anderson (2002) also discovered a high proportion of juveniles (tress ≤ 250 cm) in high elk density areas. When ungulate browse is absent, in areas such as exclosures, stands develop diverse, multiple-age class layers (Kay and Bartos 2000), a characteristic generally not observed on the NER during this study (Fig. 7).

Figure 7. Photograph of stand 14 depicting simplified layering of canopies National Elk Refuge (Iverson) 2014.

Bird communities in the NER responded to structural differences among stands. For example, Yellow Warblers were associated with stands with a greater proportion of recent aspen recruits. Yellow Warbler females prefer understory vegetation, and both sexes typically forage in the midstory (height class 3; recent recruits) between one to three meters in height (Morse 1985). Yellow Warblers were found in 26% of stands and were found in two of three stands with a positive LD Index (stand 19 and 20). No Dusky Flycatchers were observed during this study, although they have previously been recorded on the refuge (Anderson 2002, Nicholoff 2003). This may be a result of the general lack of aspen recent recruit canopy structure in stands sampled. Dobbs (2005) found 78% of Dusky Flycatcher nests in Utah were located in aspen trees at an average height of 1.72 m.

The Bison and Elk Management Plan (USWFS 2007), a document created to guide management decisions on the NER, selected a habitat conservation goal to "provide secure, sustainable ungulate grazing habitat that is characterized primarily by native composition and structure within and among plant communities and that also provides for the needs of other native species." My work indicated that high densities of elk were impacting aspen stand structure and composition. Elk winter use of the NER is increasing, with >8,500 elk of the Jackson Elk Herd observed on the NER during winter 2015. This is ≈1,500 more elk than the running five-year average (USFWS unpubl.data). My results indicate that if this level of winter elk use continues on the NER aspen recruitment is unlikely to occur. Aspen stands within the area are largely past their 150-year life expectancy (Romme et al. 1995, Binkley 2008), likely explaining the preponderance of suckers observed in this study (Mueggler 1989). However, juveniles are prevented from recruiting via current ungulate browse levels. Stands simplified by historical browse levels may not meet needs of certain bird species, such as the Dusky Flycatcher, and further stand simplification and losses will exacerbate this. To meet the habitat conservation goal of the NER, it will be necessary to take management actions that will facilitate aspen recruitment in aging stands. For example, building large ungulate exclosures around targeted stands will enable trees to release and recruit into adults (Mueggler 1989, UWFWS unpubl. 2007).

VALUES

I am so fortunate to have had the opportunity to complete this project. I have grown personally and professionally throughout this entire experience. I became a seeker of evidence, a woman not afraid to hike alone, an observer, and a critic of information. I will remember this experience with fondness. I can hardly wait to share the skills I have learned with my students.

I appreciate the tenacity required of a scientist. Oftentimes, I wondered if I should have been a field biologist rather than a teacher. This project justified my career choice: I love science, but even more, I love teaching science. I realized I appreciate the problem solving process and I like learning about a wide array of topics. It required patience and determination to undertake this task, the answering of an ecological question. After I got through the fun part of data collection, I was ready to move on to a different topic. The scientists, namely Jeff Warren, I have met throughout my project continually impressed me through their enthusiasm, persistence, and downright doggedness to find solutions.

I believe my students will directly benefit from my experience. As an educator passionate about scientific inquiry, authenticity, and ecology, I am confident in my skills to guide students through their own ecological studies. I improved developing attainable research questions, researching, and finding data collection techniques to answer ecological questions. I am eager to pass this learning on to my students next year.

There are certain intrinsic rewards obtained from spending time alone in a forest. I was continually awed by howling wolves nearby, surprised by moose laying in the shadows, and entertained by the antics of birds going about their busy lives. I gained self-reliance (do not forget extra pencils) and self-confidence. Mostly, I was overcome with an incredible sense of peace interrupted by occasional shots of adrenaline just to keep things interesting.

Wyoming is known for its wildness and vastness due to a low population density. Many people in my community rely on the habitat for food, pleasure, and careers. Despite this reliance, I see an ignorance of ecological issues in my students, my colleagues, my newspaper, and my social media. I am not claiming to know all the answers, but I hope that I can inspire my community, via my students, to think critically and deeply about the science when making ecological decisions. This place is special, and I want it to persist for many generations.

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APPENDICES

APPENDIX A

ASPEN STAND AND POINT ATTRIBUTES

Stand	Point	Easting *	Northing *	Bearing ° N	Perimeter (m)	Area (ha)	**dist.fg (m)
1	1	530660	4825283	308	1100	2.5	2756
2	2	529379	4824482	104	1333	4.3	1346
3	3	528774	4826256	104	875	3	1944
4	4	529223	4826741	16	1470	8.7	2582
5	5	527895	4826958	265	8195	60.6	2481
5	6	528184	4827023	100	8195	60.6	2560
5	7	527860	4827340	215	8195	60.6	2864
6	8	527886	4828138	209	2074	7.3	3661
7	9	527132	4826456	209	1689	10.1	1978
8	10	524992	4827131	348	1244	4.7	3239
9	11	525649	4826482	316	1504	4.9	2335
10	12	525957	4825592	161	8817	52.1	1430
10	13	526009	4826383	13	8817	52.1	2077
11	14	525216	4825618	350	1142	3.8	2002
12	15	525719	4826024	331	1530	6.6	1916
13	16	525972	4827697	23	1217	6.1	3327
14	17	526416	4827038	88	9643	71.1	2584
14	18	527390	4827528	306	9643	71.1	3076
14	19	526630	4827295	8	9643	71.1	2811
14	20	527106	4827626	285	9643	71.1	3139
15	21	529929	4827060	302	2741	14.6	3226
16	22	530760	4828658	21	1550	8.8	5015
17	23	530380	4828632	168	1303	5.7	4796
18	24	529168	4828048	281	2650	13.4	3770
19	25	526994	4828710	316	4048	15.9	4217
20	26	528839	4828658	154	6230	39.9	4279
20	27	528355	4828493	41	6230	39.9	4040
21	28	530155	4829094	317	730	3.1	5106
22	30	531293	4828967	285	1337	4.7	5571
23	31	531676	4828244	160	1431	3.5	5261
24	32	532268	4830156	287	1180	5.4	7106
25	33	532077	4829612	18	676	2.6	6559
26	34	532284	4829306	274	1064	4.7	6455
27	35	531979	4828986	89	3268	14.1	6012

* NAD 1983 Map Zone 12.
**dist.fg (m): Distance between stand and feedground.

APPENDIX B

ASPEN TRANSECT DATA SHEET

ASPEN TRANSECT DATA SHEET

Date:____/____/____ Observer:________

Point:________ Start:________ End:________ Bearing:________

Class I (≤50cm):_______ Class II (>50–250cm):________

Class III (>250cm–75% adult ht):________ Class IV (adult): ________

Snags (adult only): ________

	HBCYG	HD
1		
2		
3		
4		
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6		
7		
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10		
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14		
15		
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17		
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19		
20		

Comments:

APPENDIX C

BIRD POINT COUNT SURVEY DATA SHEET

Point ID	**DATE** (mm/dd/yy)	**OBS**	**VISIT # (1-2)**
Conditions:			
Cloud cover (0-4)	Precip (0-5)	Wind (0-6)	Temp (°F)
Fill in the following information below:			

DIS (m) **1** = 0-5; **2** = >5-10; **3** = >10-20; **4** = >20-35; **5** = >35-50; **6** = >50-75	**ACT**(activity): D = during survey; **B** = before survey; **A** = after survey; **T** = travel b/t points
DET (Detection): **S** = song; **C** = call; **T** = territorial; **V** = visual; **VS** = visual and song; **VC** = visual and call; **F** = flyover	**SEX: M; F; J** = juvenile; **U**=unknown

Time	Spp	DIS	ACT	SEX	DET	NUM	Stand?	Comments

APPENDIX D

OBSERVED BIRD SPECIES LIST RANKED BY NUMBER OF INDIVIDUALS

Bird Species Code	Species Name	Scientific Name	# of Individuals
HOWR	House Wren	*Troglodytes aedon*	104
RSFL	Red-shafted Flicker	*Sphyrapicus nuchalis*	63
MOBL	Mountain Bluebird	*Sialia currucoides*	60
DEJU	Dark-eyed Junco	*Junco hyemalis*	52
AMRO	American Robin	*Turdus migratorius*	46
WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*	39
CHSP	Chipping Sparrow	*Spizella passerina*	27
GTTO	Green-tailed Towhee	*Pipilo chlorurus*	25
BCCH	Black-capped Chickadee	*Poecile atricapillus*	24
TRES	Tree Swallow	*Tachycineta bicolor*	23
RCKI	Ruby-crowned Kinglet	*Regulus calendula*	22
BHCO	Brown-headed Cowbird	*Molothrus ater*	19
VESP	Vesper Sparrow	*Pooecetes gramineus*	17
WEWP	Western Wood Pewee	*Contopus sordidulus*	16
BBMA	Black-billed Magpie	*Pica hudsonia*	14
RBNU	Red-breasted Nuthatch	*Carduelis pinus*	14
YEWA	Yellow Warbler	*Setophaga petechia*	14
LISP	Lincoln's Sparrow	*Melospiza lincolnii*	13
BRSP	Brewer's Sparrow	*Spizella breweri*	12
WEME	Western Meadowlark	*Sturnella neglecta*	12
RTHA	Red-Tailed Hawk	*Buteo jamaicensis*	11
OCWA	Orange-crowned Kinglet	*Contopus cooperi*	7
WBNU	White-breasted Nuthatch	*Sitta carolinensis*	7
MODO	Mourning Dove	*Zenaida macroura*	6
WIFL	Willow Flycatcher	*Empidonax traillii*	6
RUGR	Ruffed Grouse	*Bonasa umbellus*	5
CAFI	Cassin's Finch	*Haemorhous cassinii*	4
MOCH	Mountain Chickadee	*Poecile gambeli*	4
PIGR	Pine Grosbeak	*Regulus calendula*	4
WETA	Western Tanager	*Piranga ludoviciana*	4
AMCR	American Crow	*Corvus brachyrhynchos*	3
MALL	Mallard	*Anas platyrhynchos*	3
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*	3
WAVI	Warbling Vireo	*Vireo gilvus*	3
CEDW	Cedar Waxwing	*Bombycilla cedrorum*	2
RNSA	Red-naped Sapsucker	*Sitta canadensis*	2
RUHU	Rufous Hummingbird	*Selasphorus rufus*	2
ALFL	Alder Flycatcher	*Empidonax Alnorum*	1

MAKE	American Kestrel	*Falco sparverius*	1
BAEA	Bald Eagle	*Haliaeetus leucocephalus*	1
CANG	Canada Goose	*Branta canadensis*	1
CLNU	Clark's Nutcracker	*Nucifraga columbiana*	1
CORA	Common Raven	*Corvus corax*	1
COYE	Common Yellowthroat	*Geothlypis trichas*	1
DOWO	Downy Woodpecker	*Picoides pubescens*	1
KILL	Killdeer	*Charadrius vociferus*	1
LAZB	Lazuli Bunting	*Passerina amoena*	1
MGWA	MacGillivray's Warbler	*Geothlypis tolmiei*	1
OSFL	Olive-sided Flycatcher	*Colaptes auratus cafer*	1
PISI	Pine Siskin	*Pinicola enucleator*	1
VATH	Varied Thrush	*Ixoreus naevius*	1
VEER	Veery	*Catharus fuscescens*	1
WEKI	Western Kingbird	*Tyrannus verticalis*	1
WESJ	Western Scrub Jay	*Aphelocoma californica*	1

* Alder Flycatcher, American Kestrel, Bald Eagle, Canada Goose, Clark's Nutcracker, Common Raven, Common Yellowthroat, Downy Woodpecker, Killdeer, Lazuli Bunting, MacGillivray's Warbler, Olive-sided Flycatcher, Pine Siskin, Varied Thrush, Veery, Western Kingbird, Western Scrub Jay were only observed once throughout the study.

APPENDIX E

TOTAL NUMBER OF UNIQUE BIRD SPECIES OBSERVED AT EACH SITE RANKED HIGHEST TO LOWEST

Point	Total number of unique bird species
Site 9	17
Site27	17
Site 32	17
Site 4	16
Site 15	16
Site 16	16
Site 11	15
Site 21	15
Site 20	14
Site 24	14
Site 30	14
Site 35	14
Site 6	13
Site 10	13
Site 25	13
Site 31	13
Site 34	13
Site 1	12
Site 12	12
Site 18	12
Site 23	12
Site 28	12
Site 3	11
Site 5	11
Site 7	11
Site 19	11
Site 22	11
Site 33	11
Site 2	10
Site 8	10
Site 14	9
Site 17	9
Site 13	8
Site 26	8