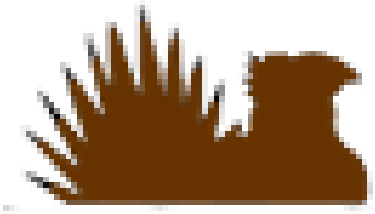
THE PARKER MOUNTAIN SAGA



Parker Mountain Adaptive Resource Management Local Working Group

Utah State University Extension

Community-Based Conservation Program

EXTENSION
UtahStateUniversity

A Brief Working History of the Parker Mountain Adaptive Resource Management (PARM) Local Working Group

The mission of the Parker Mountain Adaptive Resource Management (PARM) Local Working Group is to help reach the goal of maintaining and improving current abundance and viability of Greater Sage-grouse (Centrocercus urophasianus*; sage-grouse*) populations and their habitat in the Parker Mountain area while taking into consideration historical land uses and long term socioeconomic needs, especially for local communities.

In 1997, Terry Messmer, USU, Dean Mitchell and Leon Bogedahl, UDWR attended the winter meeting of the Parker Grazing Association. We were invited to the meeting by Verl Bagley, USU Extension to discuss what was going on with the sage-grouse population. The number of males counted on leks had declined from 300 in 1992 to less than 150 in 1996. After much discussion, it was concluded we really did not know what was going on. The population was declining even as the number of livestock grazing the Parker was at a historic low. All agreed we needed to do something, but we were not sure what.

We stepped out in the hallway, to allow the regular business meeting to proceed. About 15 minutes later, Andy Taft emerged and handed Terry Messmer a check for $3,000 to buy the first radio-collars ever deployed on sage-grouse on the Parker. The $3,000 was leveraged into $30,000 and Joel Flory was recruited as the first graduate student to study sage-grouse vital rates and habitat-use on the Parker. The PARM was formed in 1998, chaired by Andy Taft, and Gary Hallows, and facilitated by Terry Messmer and Verl Bagley. The PARM consists of state and federal agency personnel, representatives from local government, non-profit organizations, academic institutions, private industry, and private individuals. Since then PARM has worked consistently and cooperatively to learn more about both sage-grouse ecology and their management, while they were managing them. Although the leadership and membership of PARM has changed over time, the group has remained true to its mission. Other graduate students to follow Joel included Renee Chi, Dave Dahlgren, Michel Guttery, Danny Caudill, and now Nathan Dulfon. The PARM has been facilitated by Todd A. Black and now Dave Dahlgren. Both are members of the Utah's Community-Based Conservation Program (CBCP), a collaborative partnership between the UDWR and Utah State University Extension Services, with support from the Jack H. Berryman Institute. Sarah Lupis (CBCP) served as the technical writer and compiler of the PARM Plan, which was published in 2006. The Plan was the culmination of over eight years of research and management.

The PARM group spent many hours and much discussion analyzing threats currently or potentially affecting sage-grouse and sagebrush habitats in the Parker Mountain area. Plan implementation is conducted within an adaptive resource management framework; as relevant information from a local and rangewide perspective become available, it has been used to modify and refine management strategies, priorities, and general understanding of sage-grouse ecology in the area. This Plan will help meet these goals by providing local management solutions based on local or compatible data and research to the extent practical. In addition, PARM hopes to develop management solutions that will result in diverse and productive sagebrush habitat for sage-grouse while recognizing healthy sagebrush habitats are valuable to the existence of other species.

Assessment Goals:

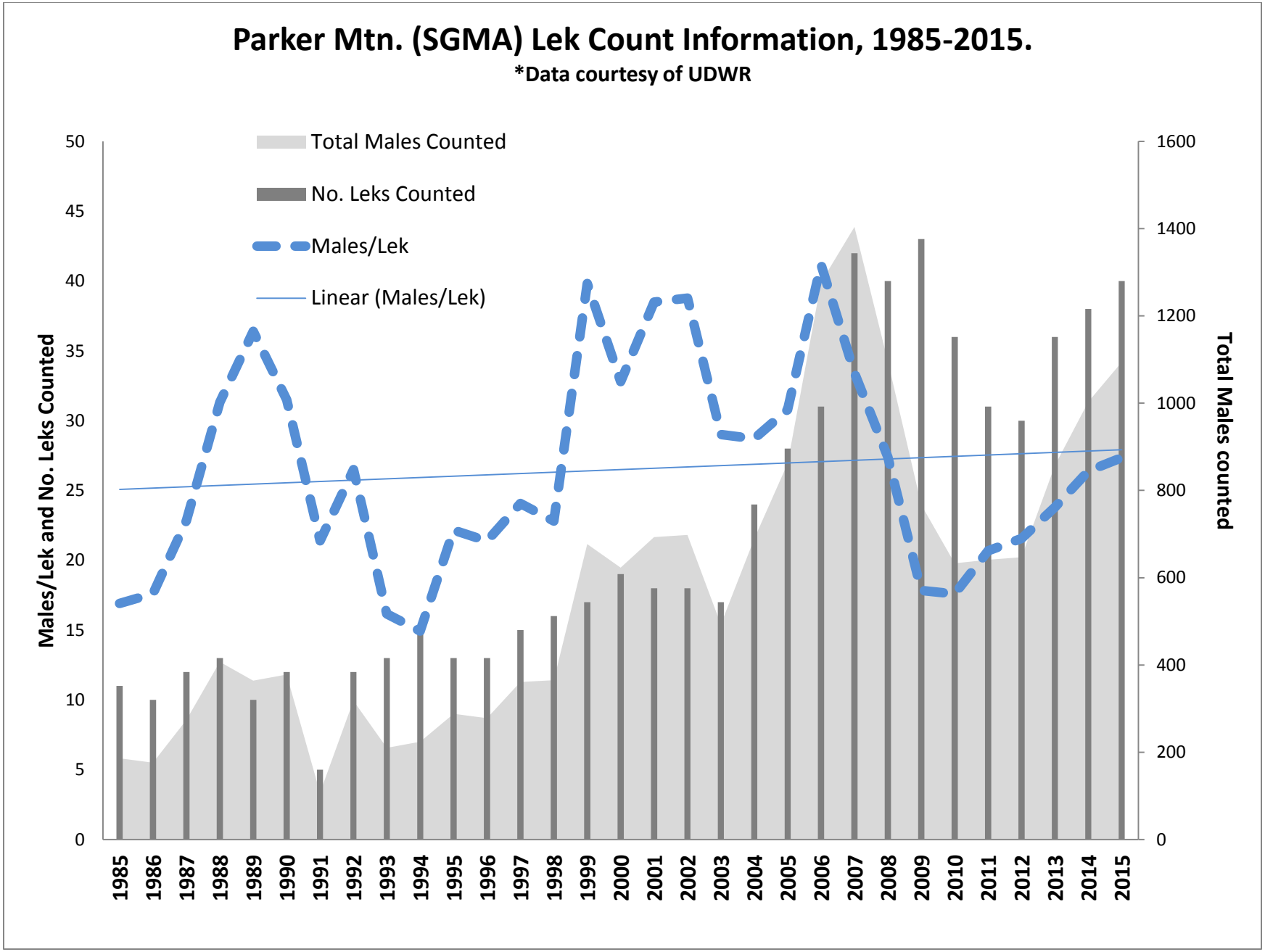
This Plan will provide an assessment of the status of the Parker Mountain area sage-grouse population by accomplishing the following goals:

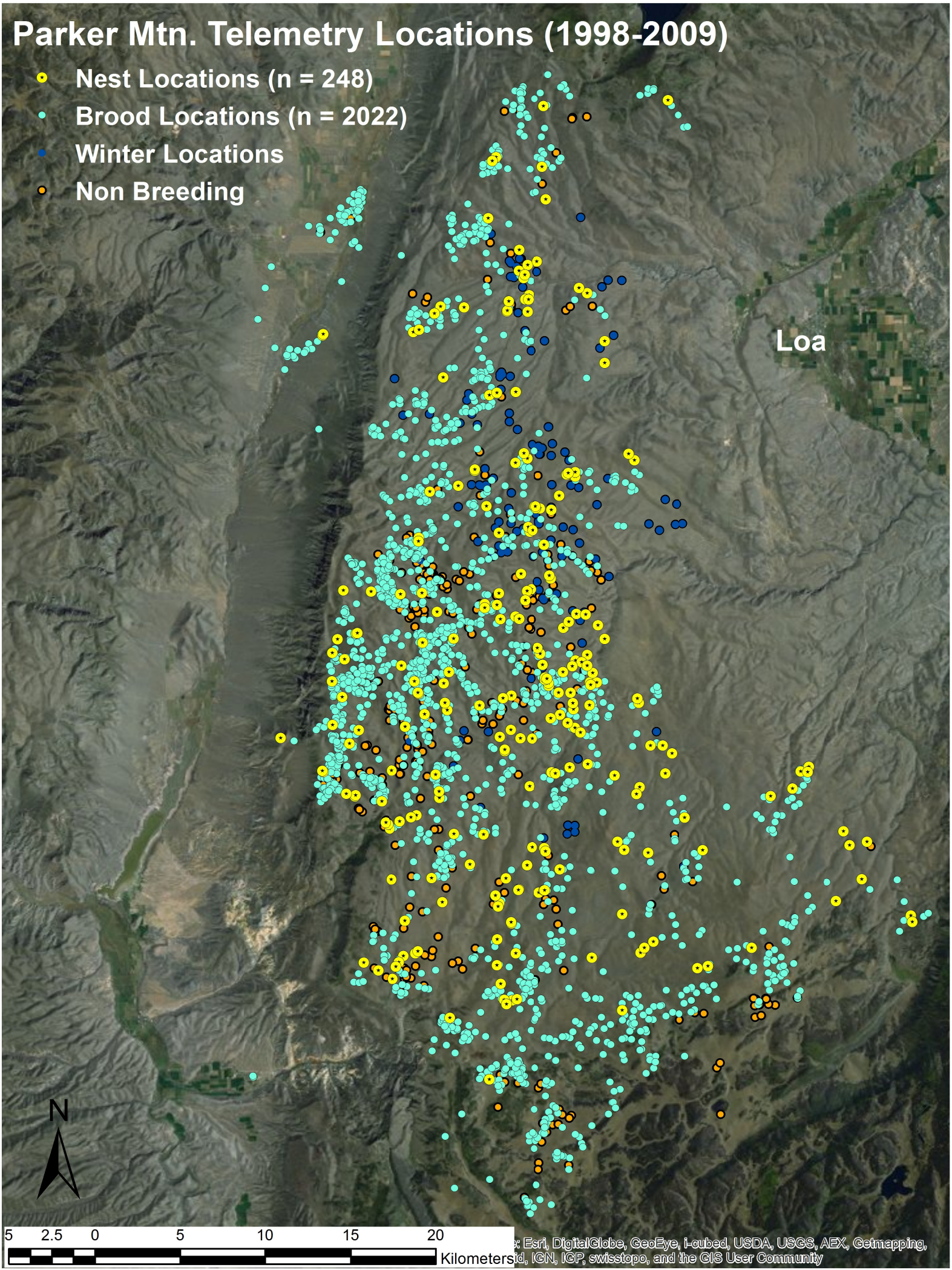
1. Estimate current population size and evaluate population trends; estimate the amount and condition of sage-grouse habitat,
2. Identify research needs and knowledge gaps,
3. Determine sage-grouse population and sage-grouse habitat needs for the future, and
4. Identify and discuss threats that could potentially impact sage-grouse.

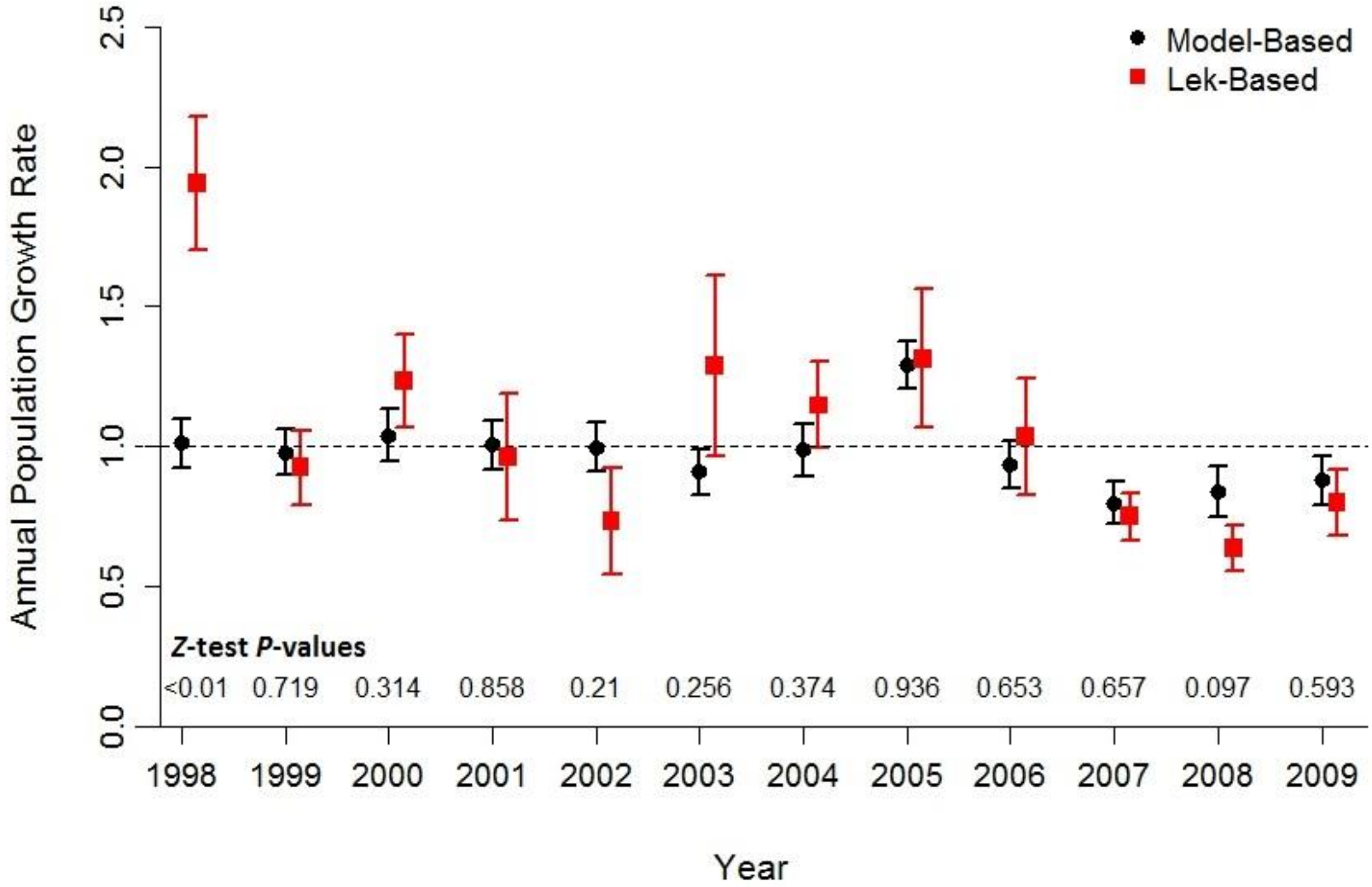
Strategy Goals:

1. Incorporate management strategies from state and federal agency partners, local governments, as they are applicable and practical,
2. Increase effective communication with all potential stakeholders,
3. Address and prioritize threats to aid in making informed management solutions, and
4. Identify and pursue funding sources, or support partners in their pursuance of funding for projects that will help achieve specific strategies and actions.

PARM Partners - Local Grazing Associations Wayne, Piute, and Sevier County Commissions Utah Division of Wildlife Resources, USDA Forest Service (USFS) Utah School and Institutional Trust Lands Administration, Bureau of Land Management, U.S. Fish and Wildlife Service, USDA Wildlife Services, Farm Services Agency, Natural Resource Conservation Service, Utah State University Extension, Jack H. Berryman Institute, Utah Department of Natural Resources Utah Farm Bureau Federation, and local County Boards Fremont River Soil Conservation District


Parker Mtn. (SGMA) Lek Count Information, 1985-2015.
*Data courtesy of UDWR
Total Males Counted
No. Leks Counted
Males/Lek
Linear (Males/Lek)
Males/Lek and No. Leks Counted
Total Males counted
0
5
10
15
20
25
30
35
40
45
50
0
200
400
600
800
1000
1200
1400
1600
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015


Parker Mtn. Telemetry Locations (1998-2009)
Nest Locations (n = 248)
Brood Locations (n = 2022)
Winter Locations
Non Breeding
Loa
N
5 2.5 0 5 10 15 20
Kilometers
Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community


Model-Based
Lek-Based
Annual Population Growth Rate
0.0
0.5
1.0
1.5
2.0
2.5
Z-test P-values
<0.01
0.719
0.314
0.858
0.21
0.256
0.374
0.936
0.653
0.657
0.097
0.593
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

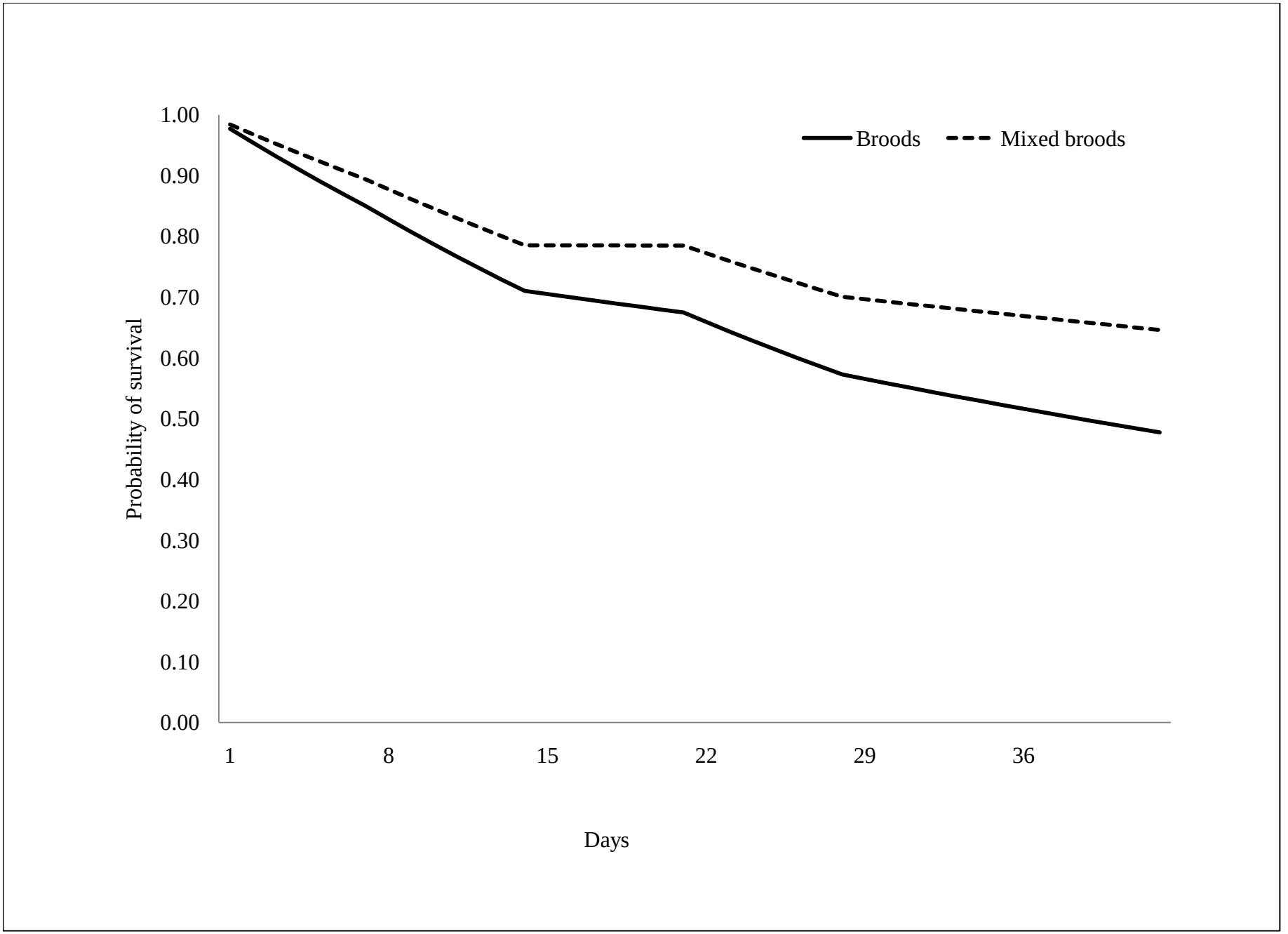

1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Probability of survival
Broods
Mixed broods
1
8
15
22
29
36
Days

Table 3. Characteristics of sagebrush rangeland needed for productive sage grouse habitat.

	Breeding		Brood-rearing		Winter[e]	
	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)
Mesic sites[a]						
Sagebrush	40–80	15–25	40–80	10–25	25–35	10–30
Grass–forb	>18[c]	≥25[d]	variable	>15	N/A	N/A
Arid sites[a]						
Sagebrush	30–80	15–25	40–80	10–25	25–35	10–30
Grass/forb	>18[c]	≥15	variable	>15	N/A	N/A
Area[b]	>80		>40		>80	

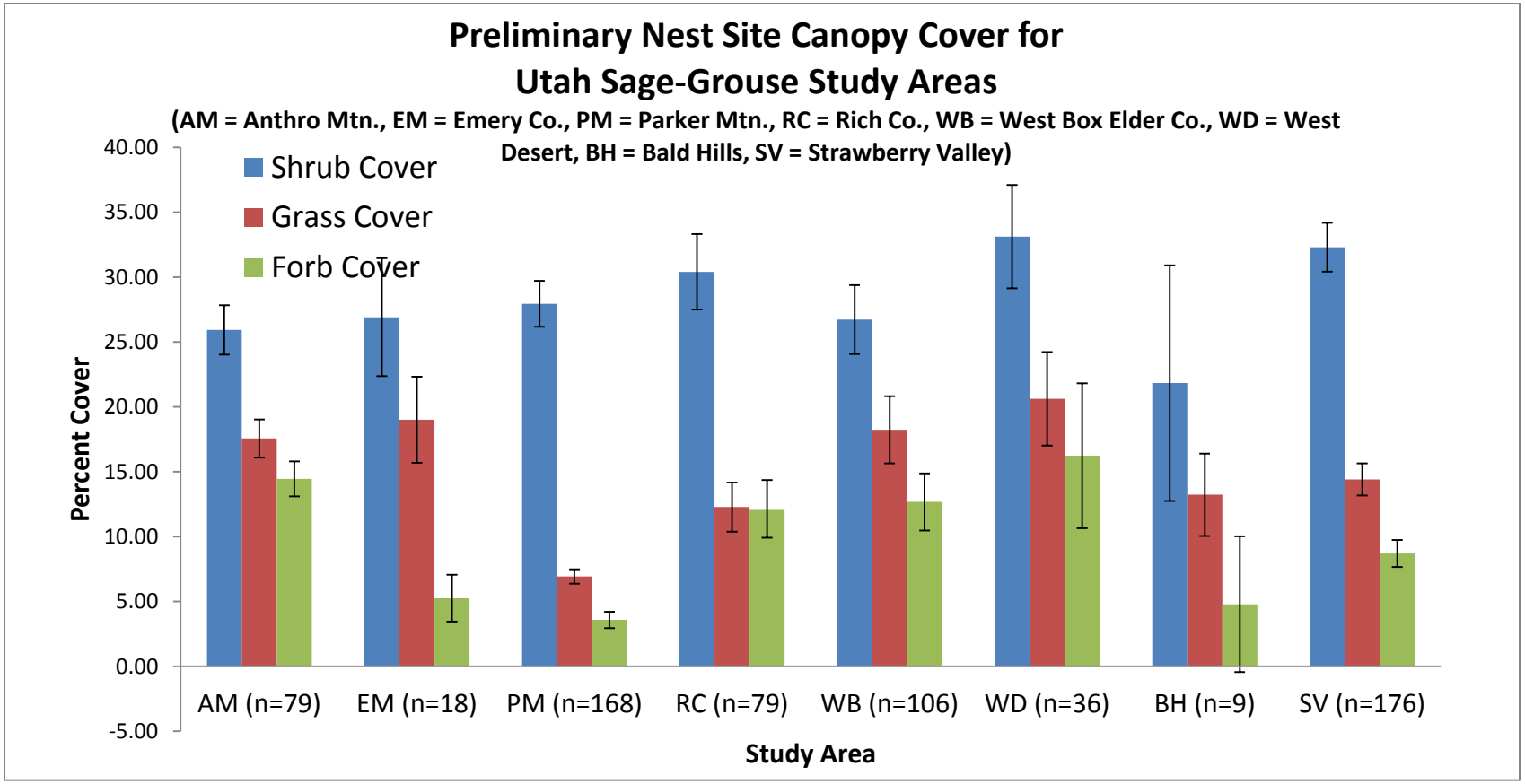
[a] Mesic and arid sites should be defined on a local basis; annual precipitation, herbaceous understory, and soils should be considered (Tisdale and Hironaka 1981, Hironaka et al. 1983).

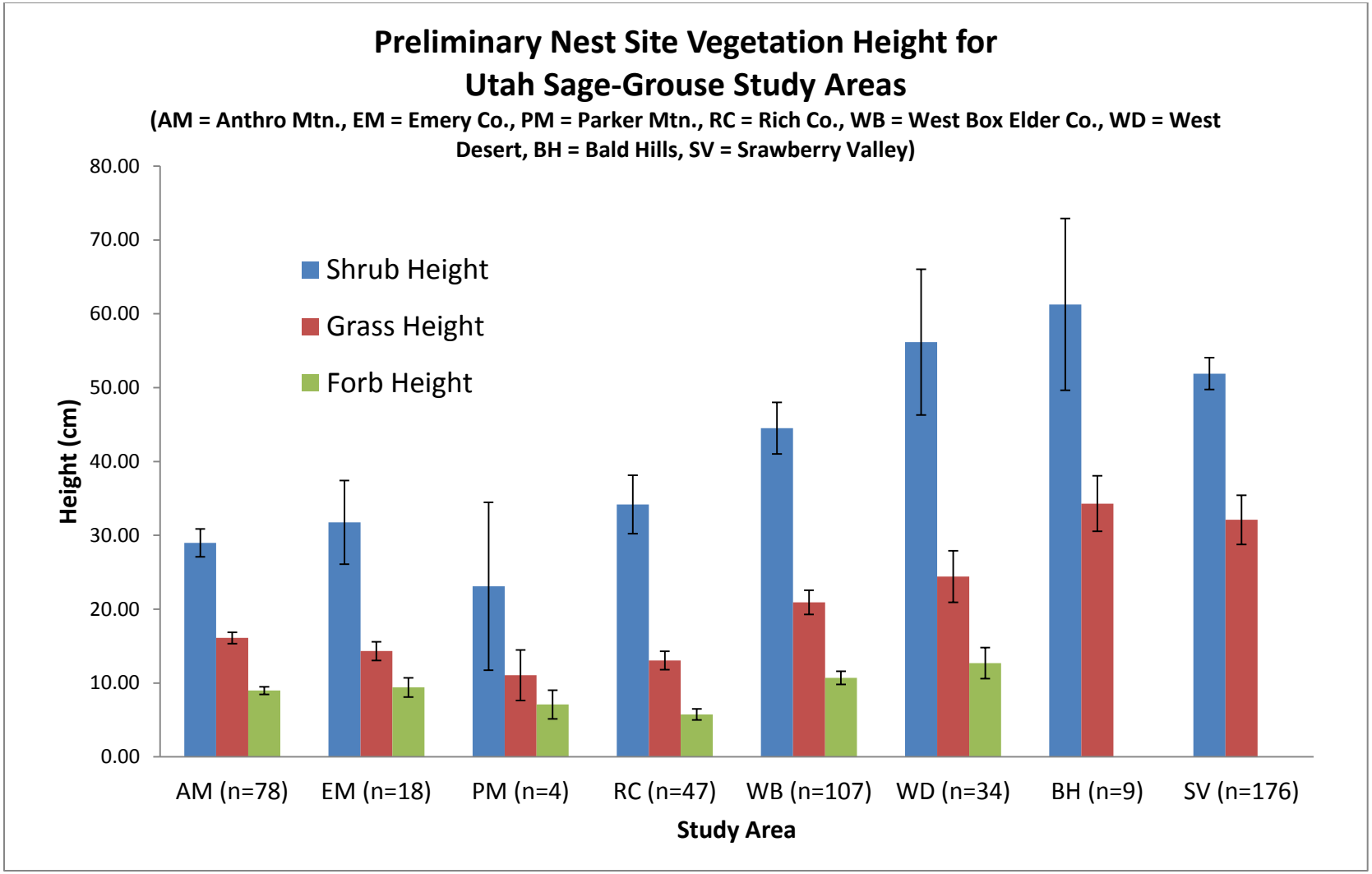
[b] Percentage of seasonal habitat needed with indicated conditions.

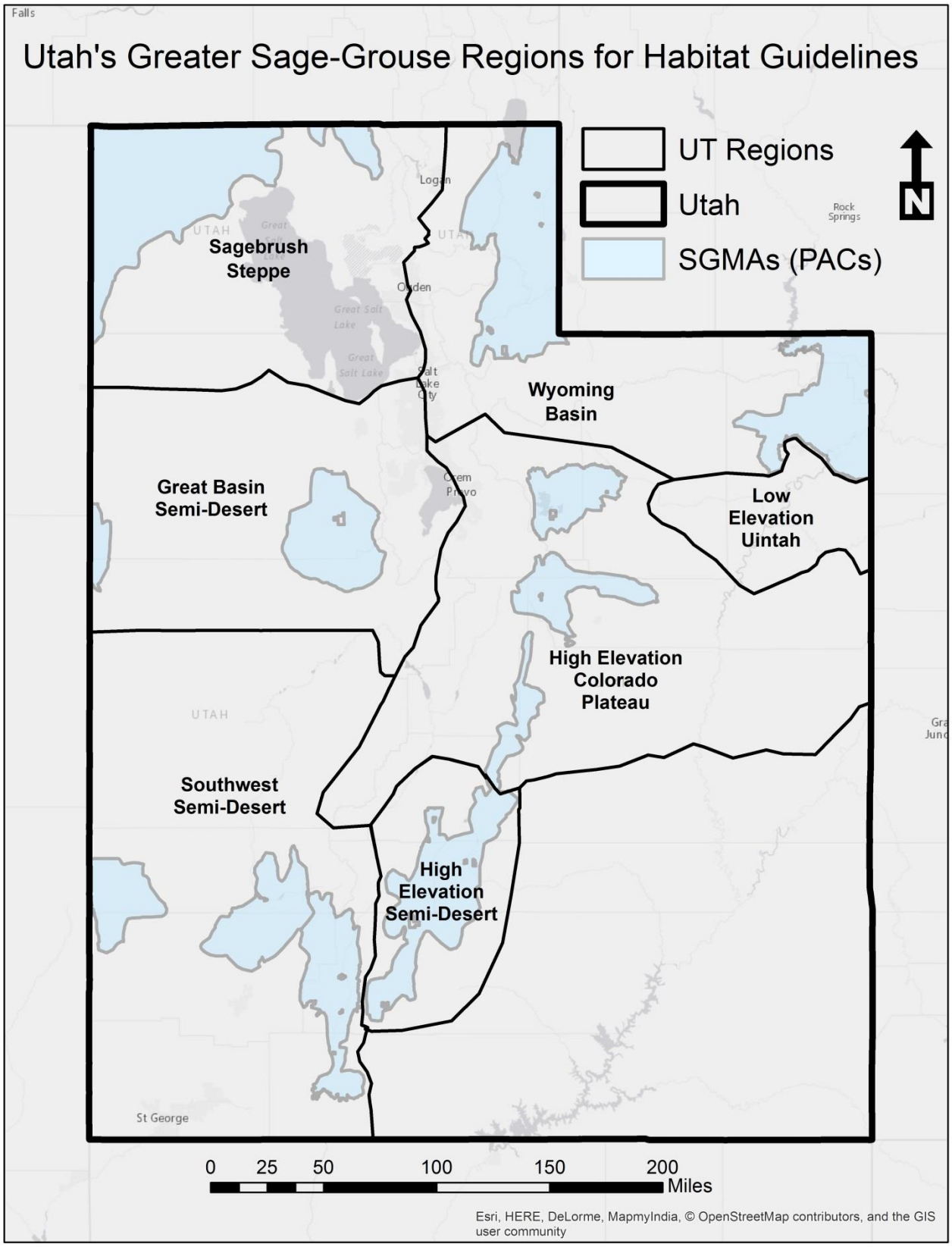
[c] Measured as "droop height"; the highest naturally growing portion of the plant.

[d] Coverage should exceed 15% for perennial grasses and 10% for forbs; values should be substantially greater if most sagebrush has a growth form that provides little lateral cover (Schroeder 1995)

[e] Values for height and canopy coverage are for shrubs exposed above snow.1


Preliminary Nest Site Canopy Cover for
Utah Sage-Grouse Study Areas
(AM = Anthro Mtn., EM = Emery Co., PM = Parker Mtn., RC = Rich Co., WB = West Box Elder Co., WD = West Desert, BH = Bald Hills, SV = Strawberry Valley)
Shrub Cover
Grass Cover
Forb Cover
Percent Cover
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
AM (n=79)
EM (n=18)
PM (n=168)
RC (n=79)
WB (n=106)
WD (n=36)
BH (n=9)
SV (n=176)
Study Area


Preliminary Nest Site Vegetation Height for
Utah Sage-Grouse Study Areas
(AM = Anthro Mtn., EM = Emery Co., PM = Parker Mtn., RC = Rich Co., WB = West Box Elder Co., WD = West Desert, BH = Bald Hills, SV = Srawberry Valley)
Height (cm)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Shrub Height
Grass Height
Forb Height
AM (n=78)
EM (n=18)
PM (n=4)
RC (n=47)
WB (n=107)
WD (n=34)
BH (n=9)
SV (n=176)
Study Area


Falls
Utah's Greater Sage-Grouse Regions for Habitat Guidelines
UT Regions
Utah
SGMAs (PACs)
N
Rock Springs
Logan
UTAH
Great Salt Lake
Ogden
Salt Lake City
Provo
Sagebrush Steppe
Wyoming Basin
Great Basin Semi-Desert
Low Elevation Uintah
High Elevation Colorado Plateau
Southwest Semi-Desert
High Elevation Semi-Desert
St George
0 25 50 100 150 200
Miles
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Preliminary Draft Eco-Regional Habitat Guidelines for Sage-Grouse in Utah

Eco-Region	Vegetation Type	Breeding (Nest)		Brood-Rearing		Winter	
		Height (cm)	Canopy (%)	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)
Sagebrush Steppe	Shrub/sagebrush	30-80	15-30	30-80	10-25	25-80	10-30
	grass	>18	>15	>18	>10	NA	NA
	forb	>10	>10	>10	>5	NA	NA
Wyoming Basin	shrub/sagebrush	25-80	15-35	25-80	10-25	25-80	10-30
	grass	>10	>10	>10	>10	NA	NA
	forb	>5	>10	>5	>5	NA	NA
High Elevation Colorado Plateau	shrub/sagebrush	25-80	15-35	25-60	10-30	25-80	10-30
	grass	>12	>10	>12	>10	NA	NA
	forb	>8	>5	>8	>5	NA	NA
High Elevation Semi-Desert	shrub/sagebrush	20-60	15-30	20-60	10-25	25-80	10-30
	grass	>8	>5	>8	>10	NA	NA
	forb	>5	>3	>5	>5	NA	NA
Southwest Semi-Desert	shrub/sagebrush	30-80	15-30	30-80	10-25	25-80	10-30
	grass	>18	>10	>18	>8	NA	NA
	forb	>10	>5	>10	>10	NA	NA
Great Basin Semi-Desert*	shrub/sagebrush	30-80	15-35	30-80	10-30	25-80	10-30
	grass	>15	>10	>15	>10	NA	NA
	forb	>8	>5	>8	>5	NA	NA
Low Elevation Uintah Basin	shrub/sagebrush	20-60	15-30	20-60	10-25	25-80	10-30
	grass	>8	>5	>8	>10	NA	NA
	forb	>5	>3	>5	>5	NA	NA

Sagebrush Steppe = West Box Elder study area; Wyoming Basin = Rich County and Diamond Mtn. study areas; High Elevation Colorado Plateau = Anthro Mtn., Strawberry Valley, and Horn and Wildcat Knolls study areas; High Elevation Semi-Desert = Parker Mtn.; Southwest Semi-Desert = Bald Hills and Hamlin Valley study areas; Great Basin Semi-Desert = West Desert (Sheeprock Mtns. and Ibapah) study areas; Low Elevation Uintah Basin = East Bench, Deadman's Bench study areas (see Map below). *Data from West Desert in 2005 was excluded when developing the guidelines for the Great Basin Semi-Desert region because of the extremely high precipitation and resulting vegetation measurements (see Robinson and Messmer 2013).

PARKER MOUNTAIN FUNDING SUPPORT

2000-2001 NRCS WHIP Grant (PLP Sagebrush Management Experiment) - $527,000

1998 – 2009 USU Extension Sage-Grouse Research Projects - $1.2 million (multiple funding partners)

2005-2014 SITLA ~$75,000 in range management

Utah Dept. of Agriculture and Food Grazing Improvement Program (GIP) Funding Support

Year	Activity	Metric		Funding
FY 11	Fence Maintenance	155601	ft	$36,562
FY12	Fence Maintenance	10792	ft	$2,754
	Pond Maintenance	2	ea	$5,700
	Spike	2172	acre	$12,236
FY13	Fence Maintenance	44576	ft	$10,865
	Pond Maintenance	2	ea	$5,700
	Spike	2500	acre	$15,375
FY14	Fence Maintenance	40646	ft	$9,907
	Pond Maintenance	6	ea	$17,300
FY15	Fence Maintenance	39586	ft	$14,850
			Total	$131,249

Other Funding and In Kind Support –

- SITLA - Nicks and Chicken Springs Spike Treatments (NRCS EQIP)
- UDWR Pond Maintenance
- NRCS Pond Maintenance with Parker Mountain Grazing Association
- USFS Housing (in kind)
- UDWR Vehicles (in kind)
- WRI/BLM/UDWR PJ Removal

Partners include: Local Grazing Associations Wayne, Piute, and Sevier County Commissions, Utah Division of Wildlife Resources (UDWR) USDA Forest Service (USFS) Utah School and Institutional Trust Lands Administration (SITLA) Bureau of Land Management (BLM) U.S. Fish and Wildlife Service (USFWS) USDA Wildlife Services (WS) Farm Services Agency (FSA) Natural Resource Conservation Service (NRCS) Utah State University Extension (USU/EXT) Jack H. Berryman Institute Utah Department of Natural Resources, Utah Farm Bureau Federation and local County Boards, Fremont Conservation District, Utah Chukar and Wildlife Foundation, Sage-grouse Restoration Project

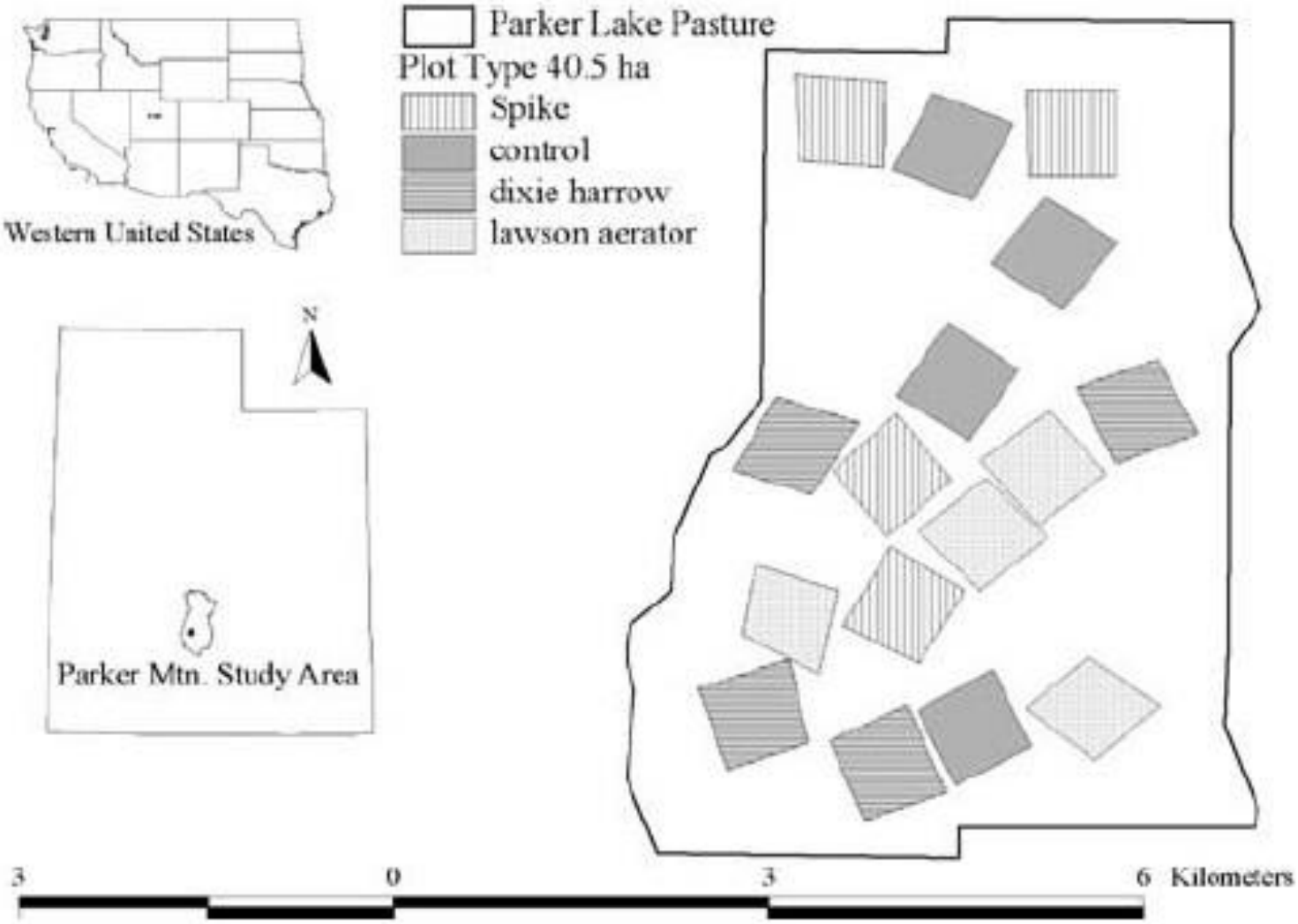


Figure 1. Parker Mountain study area and Parker Lake Pasture plots, Utah, USA, 2004.

Short Term Results 2001 to 2004

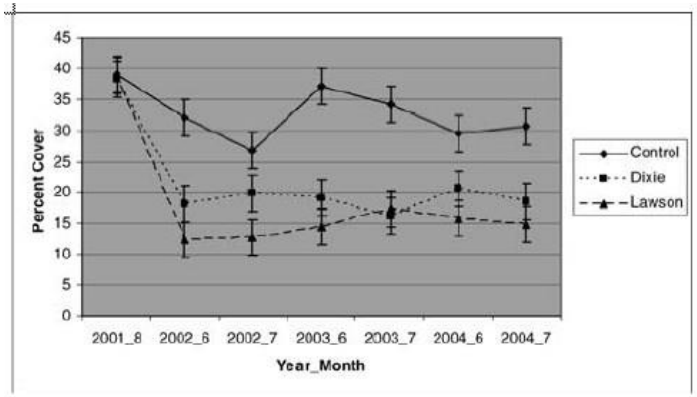


Figure 6. Shrub cover response to mechanical treatment, Parker Mountain, Utah, USA, 2001–2004.

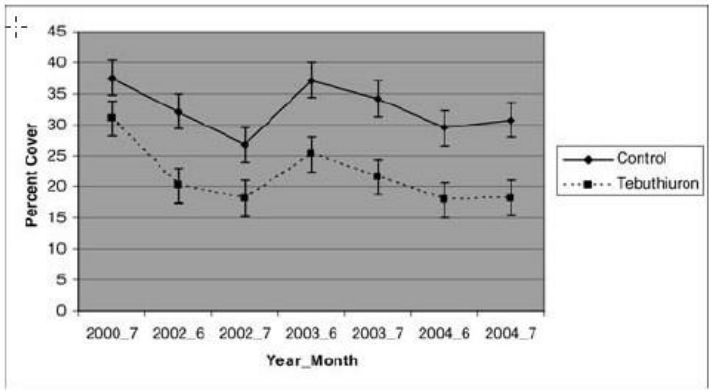


Figure 9. Shrub cover response to Tebuthiuron treatment, Parker Mountain, Utah, USA, 2000–2004.

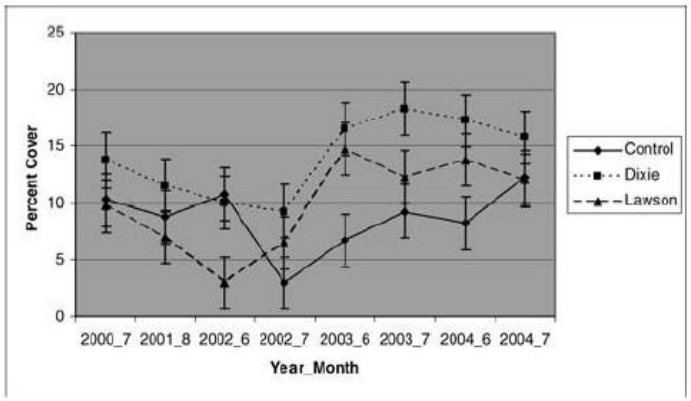


Figure 4. Grass cover response to mechanical treatment, Parker Mountain, Utah, USA, 2000–2004.

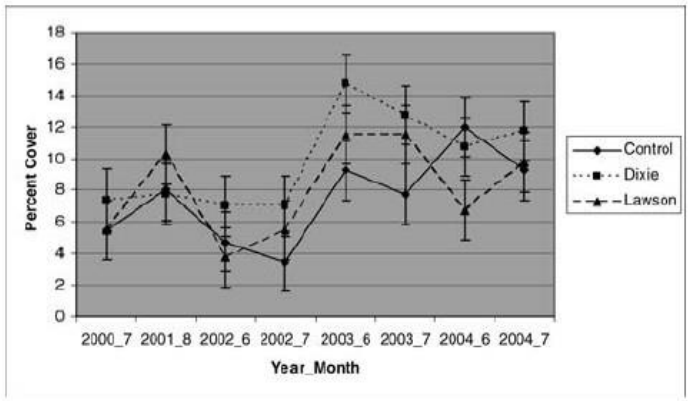


Figure 5. Forb cover response to mechanical treatment, Parker Mountain, Utah, USA, 2000–2004.

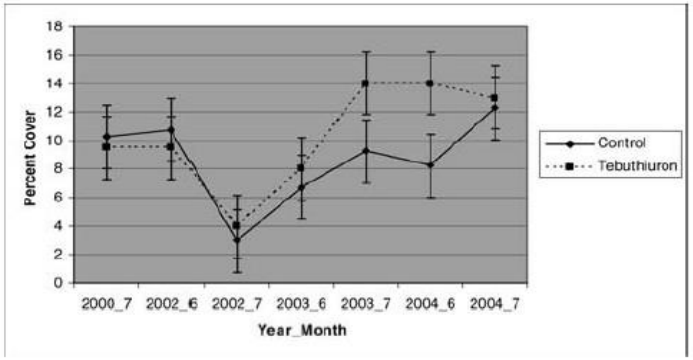


Figure 7. Grass cover response to Tebuthiuron treatment, Parker Mountain, Utah, USA, 2000–2004.

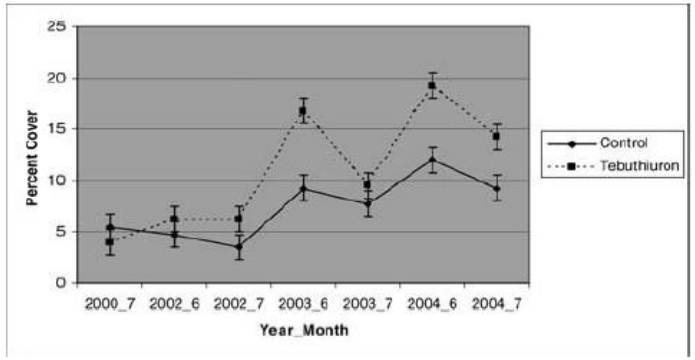
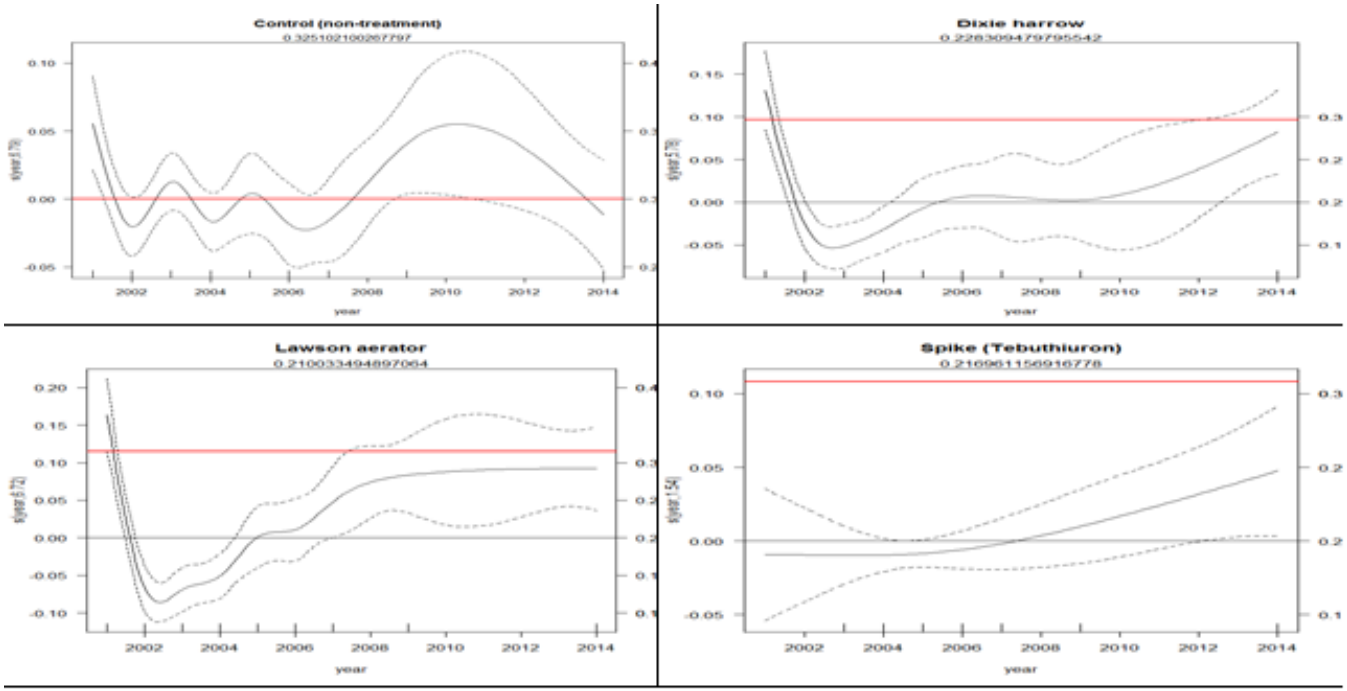
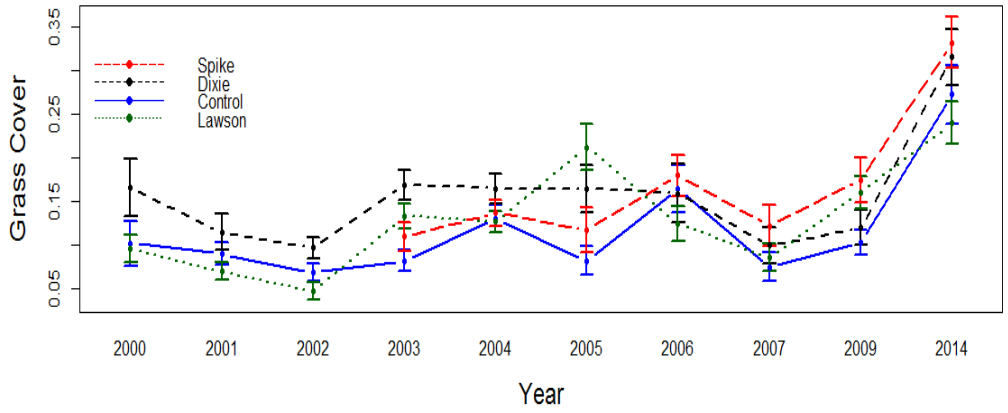
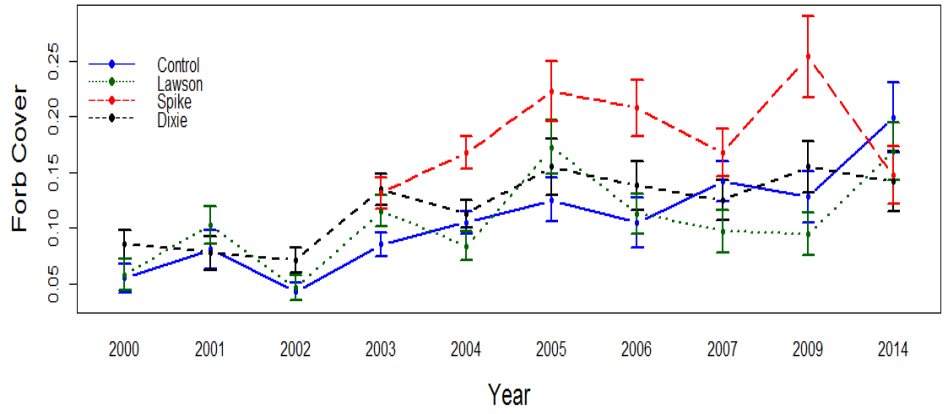


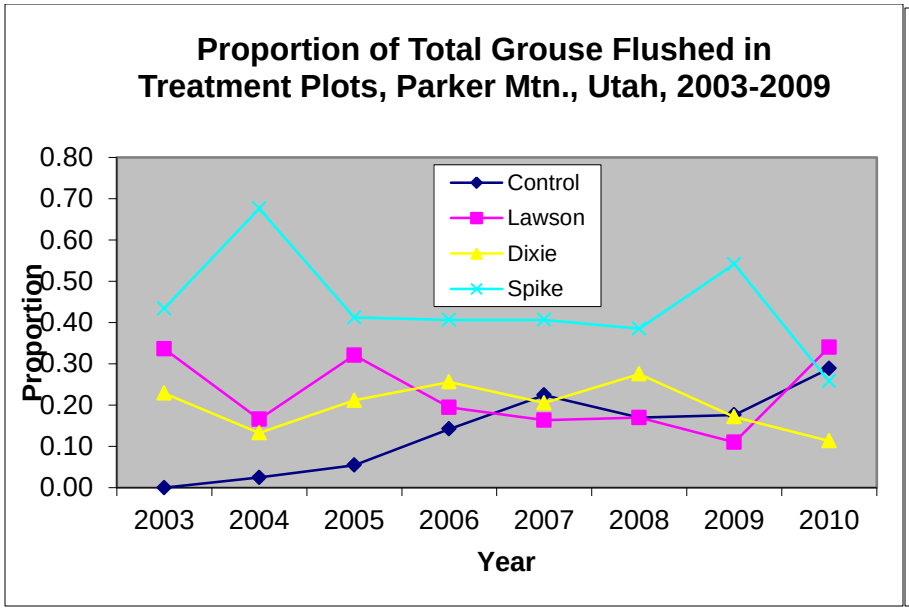
Figure 8. Forb cover response to Tebuthiuron treatment, Parker Mountain, Utah, USA, 2000–2004.

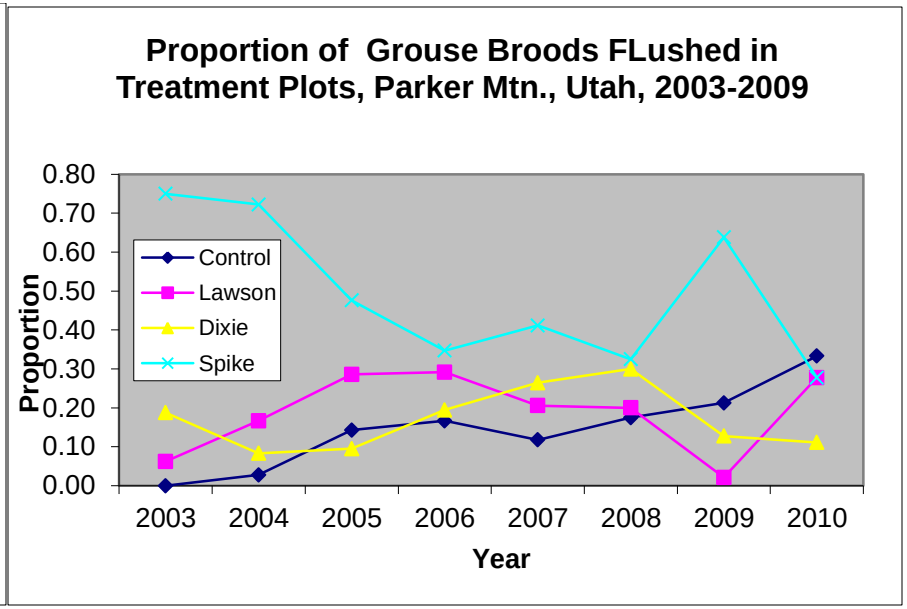
Long Term Results 2001 to 2014

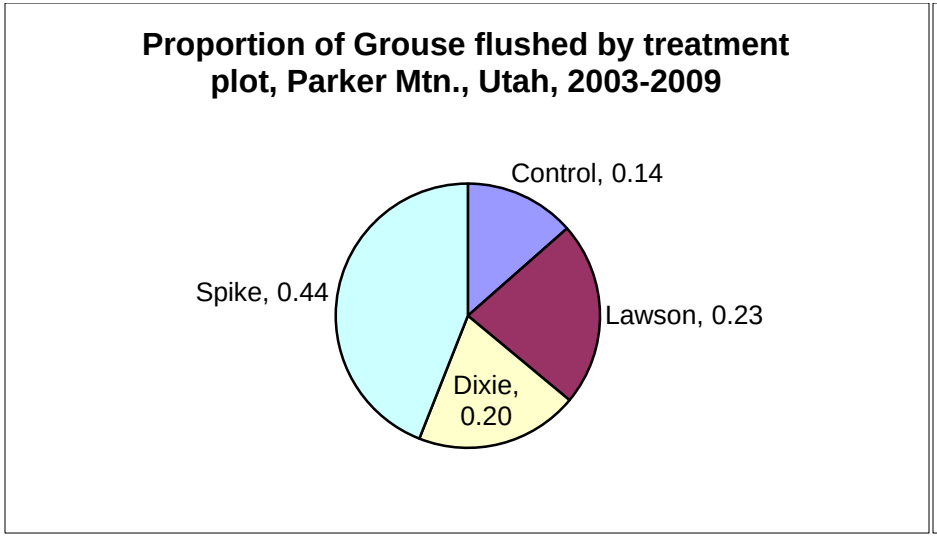


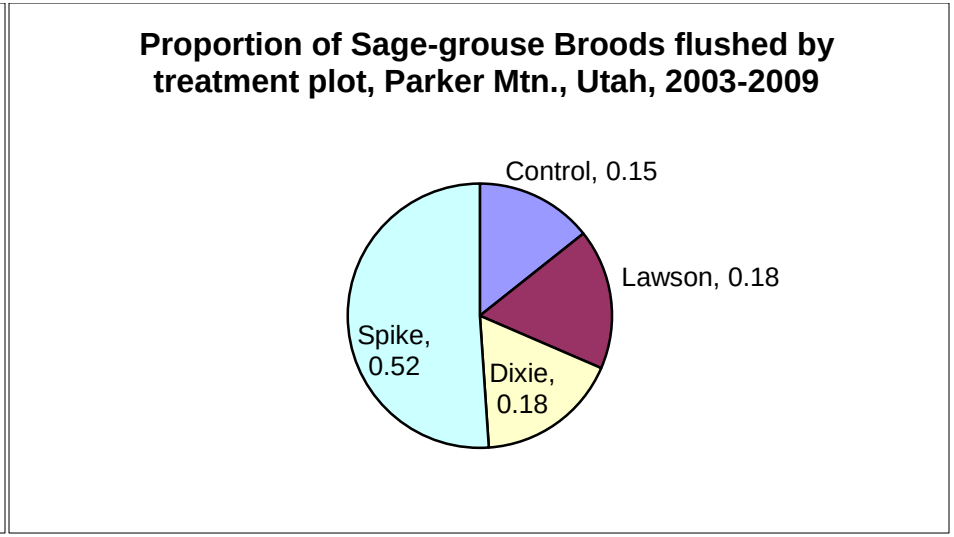


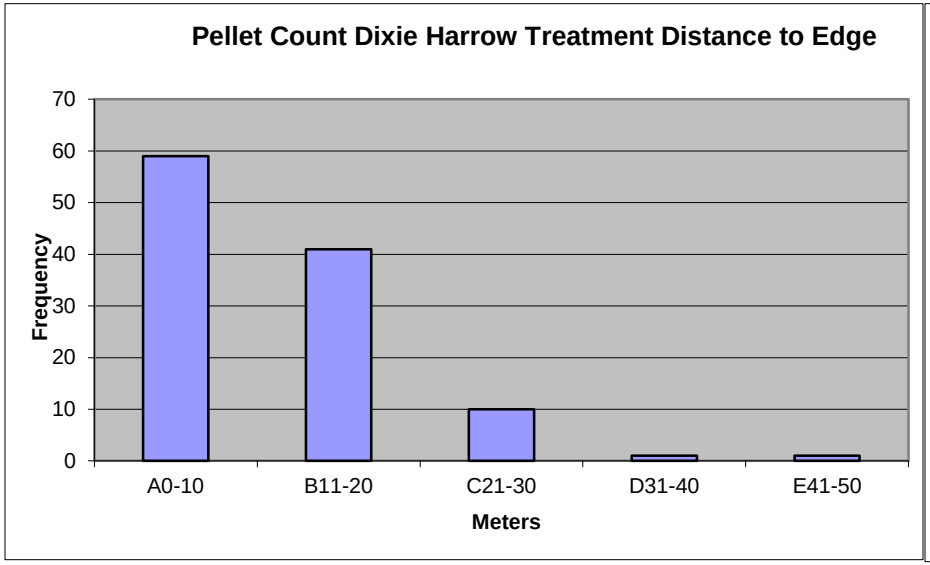


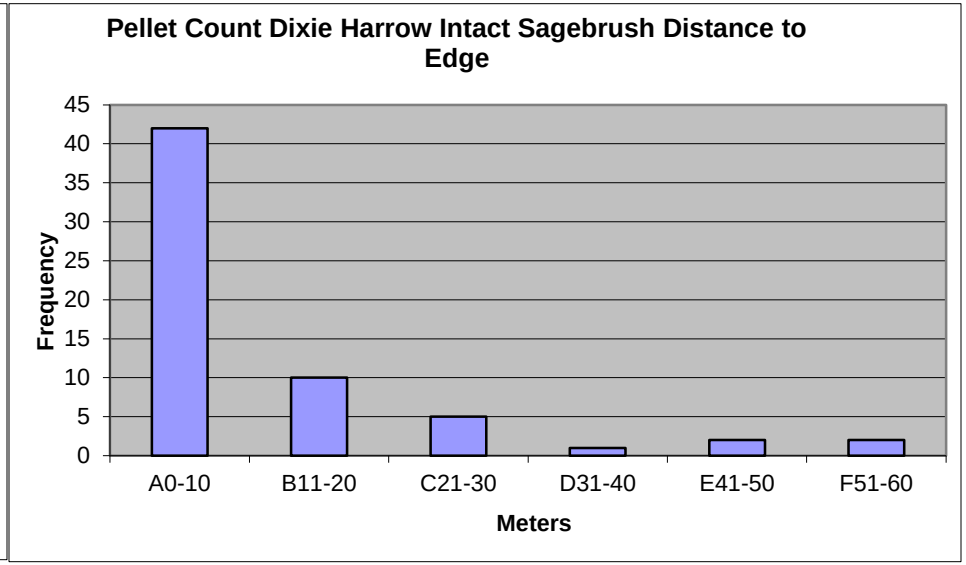

Proportion of Total Grouse Flushed in Treatment Plots, Parker Mtn., Utah, 2003-2009
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Proportion
Control
Lawson
Dixie
Spike
2003
2004
2005
2006
2007
2008
2009
2010
Year

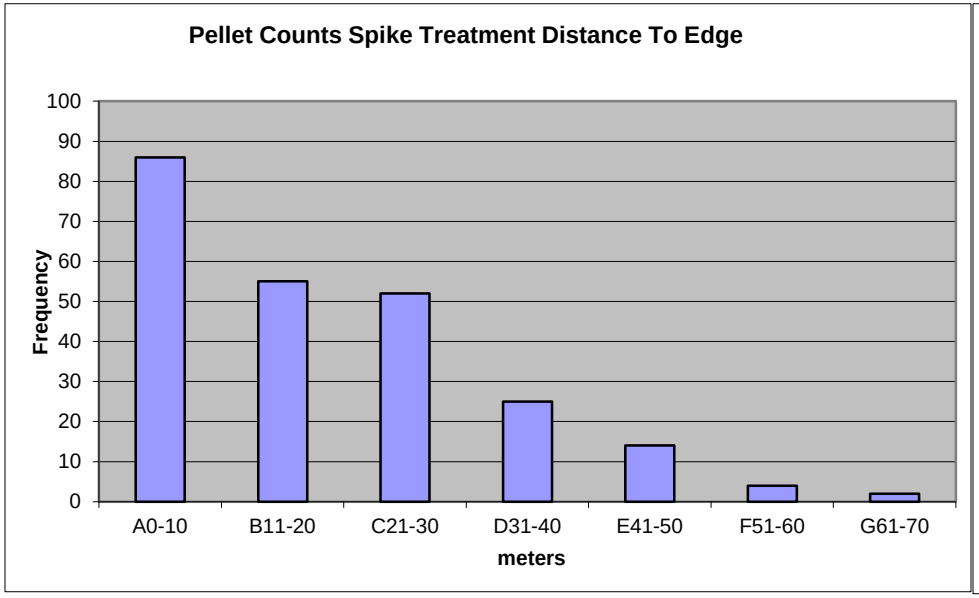

Proportion of Grouse Broods FLushed in Treatment Plots, Parker Mtn., Utah, 2003-2009
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Proportion
Control
Lawson
Dixie
Spike
2003
2004
2005
2006
2007
2008
2009
2010
Year

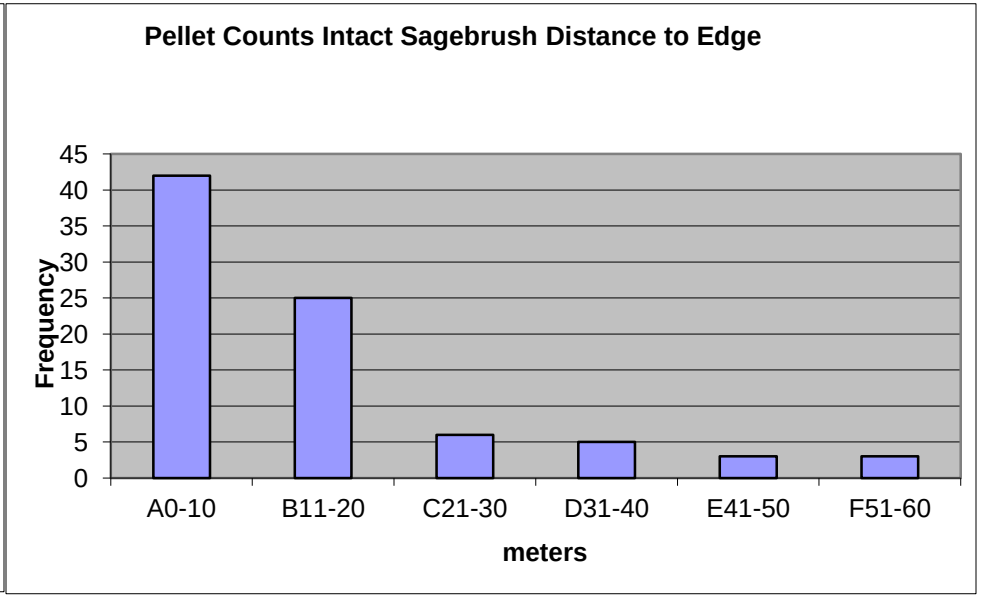

Proportion of Grouse flushed by treatment plot, Parker Mtn., Utah, 2003-2009
Control, 0.14
Lawson, 0.23
Dixie, 0.20
Spike, 0.44


Proportion of Sage-grouse Broods flushed by treatment plot, Parker Mtn., Utah, 2003-2009
Control, 0.15
Lawson, 0.18
Dixie, 0.18
Spike, 0.52


Pellet Count Dixie Harrow Treatment Distance to Edge
70
60
50
40
30
20
10
0
Frequency
A0-10
B11-20
C21-30
D31-40
E41-50
Meters


Pellet Count Dixie Harrow Intact Sagebrush Distance to Edge
45
40
35
30
25
20
15
10
5
0
Frequency
A0-10
B11-20
C21-30
D31-40
E41-50
F51-60
Meters


Pellet Counts Spike Treatment Distance To Edge
100
90
80
70
60
50
40
30
20
10
0
Frequency
A0-10
B11-20
C21-30
D31-40
E41-50
F51-60
G61-70
meters

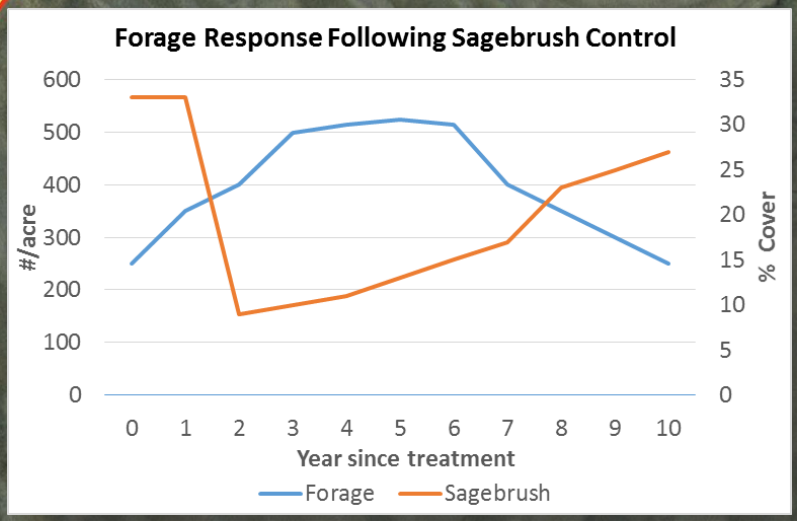

Pellet Counts Intact Sagebrush Distance to Edge
45
40
35
30
25
20
15
10
5
0
Frequency
A0-10
B11-20
C21-30
D31-40
E41-50
F51-60
meters

Upper Elevation Spiked Pastures

N

- Dog Transects
- Veg Transects
- ChickenSprings
- Nick's Pasture
- Forshea Pasture
- Butte Pasture
- South Pasture
- Reference Areas

Parker Lake

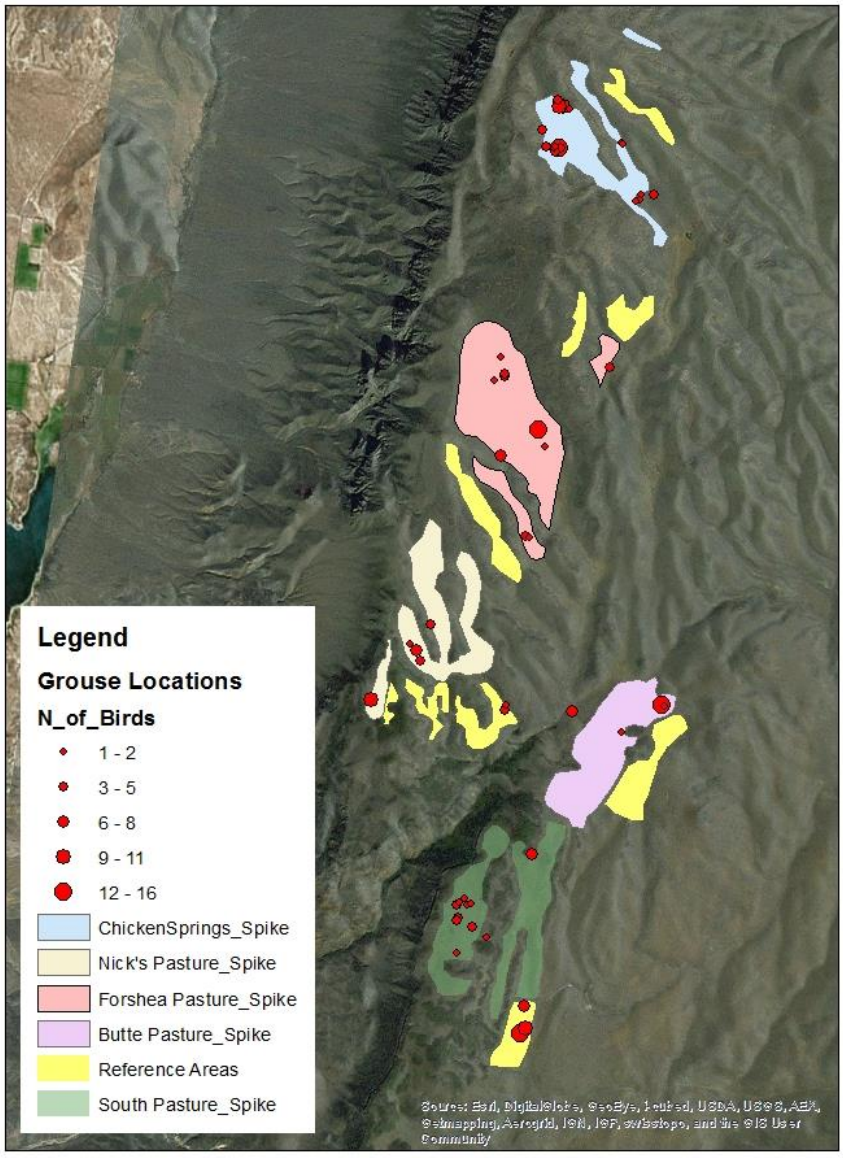


0 0.5 1 2 3 4 Miles

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Table 1. Greater sage-grouse use of spiked (Tebuthiuron) high elevation pastures, Parker Mountain, Utah, 2014. Pastures were treated with spike in various years, and portions of pastures were treated. Cattle were grazed in Buttes and South pastures June-August in 2014, while Chicken Springs, Nick's, and Forshea pastures were not grazed until September. In late July and early August pointing dogs were used to search transects (5 per pasture and 6 in untreated reference areas throughout pastures) which were placed in treated sagebrush for all but reference areas.

Pasture	Spike Year	Grazed (summer)	Total Transect Length (mi)	Total Grouse	Grouse/mi	Total Broods	Broods/mi	Total Chicks	Chick/mi
Buttes	2012	Yes	4.8	17	3.54	0	0.00	0	0.00
Chicken	2007	No	4.5	71	15.78	7	1.56	19	4.22
Forshea	2011	No	4.9	40	8.16	8	1.63	27	5.51
Nicks	2005	No	4.7	103	21.91	7	1.49	14	2.98
South	2009	Yes	4.3	27	6.28	2	0.47	4	0.93
Reference	NA	Yes/No	5.3	29	5.47	2	0.38	17	3.21
Total			28.5	287	10.07	26	0.91	81	2.84



Peer Reviewed

Greater Sage-Grouse Response to Sagebrush Management in Utah

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Abstract

*Greater sage-grouse (*Centrocercus urophasianus*) populations throughout much of their range have been declining. These declines have largely been attributed to the loss or deterioration of sagebrush (*Artemisia *spp.) habitat. In response government agencies such as the United States Department of Agriculture, Natural Resources Conservation Service are cost-sharing on management practices designed to improve habitat conditions for sage-grouse. Little is known regarding sage-grouse response to various sagebrush management techniques. We studied the effects of reducing sagebrush canopy cover using 2 mechanical (Dixie harrow and Lawson aerator) treatments and 1 chemical (Tebuthiuron) treatment on greater sage-grouse use of brood-rearing habitats on Parker Mountain, Utah, USA. To conduct this experiment, we identified 19 40.5-ha plots that exhibited >40% mountain big sagebrush (*A. tridentata vaseyana*) canopy cover and randomly assigned 16 as treatment or controls (4 replicates each). Tebuthiuron and Dixie-harrow-treated plots had more forb cover than did control plots (*$P = 0.01$ *and 0.02, respectively) in post-treatment periods. Greater sage-grouse brood use was higher in Tebuthiuron than control plots (*$P = 0.01$*). We believe this was attributed to increased herbaceous cover, particularly forb cover. However, in all plots, sage-grouse use was greatest within 10 m of the edge of the treatments where adjacent sagebrush cover was still available. Although the treatments we studied resulted in the plots achieving sage-grouse brooding-rearing habitat guidelines, caution should be exercised in applying these observations at lower elevations, on sites with less annual precipitation, or on a different subspecies of big sagebrush. Prior to using these techniques to implement large-scale sagebrush treatments, the specific rationale for conducting them should be clearly identified. Large-scale projects using the techniques we studied would not be appropriate within sage-grouse wintering or nesting habitat.*
(WILDLIFE SOCIETY BULLETIN 34(4):975–985; 2006)

Key words

2002 Farm Bill, Artemisia *spp., brood-rearing,* Centrocercus urophasianus*, Dixie harrow, greater sage-grouse, habitat management, Lawson aerator, sagebrush, Tebuthiuron, Utah.*

Greater sage-grouse (*Centrocercus urophasianus*) are sagebrush (*Artemisia* spp.) obligates that inhabit sagebrush areas throughout the western United States (Patterson 1952, Schroeder et al. 2004). Sage-grouse populations throughout much of this range have been declining (Connelly et al. 2004). These declines have largely been attributed to the loss or deterioration of sagebrush habitat (Braun et al. 1977, Connelly and Braun 1997, Braun 1998, Connelly et al. 2004). Additionally, in some sagebrush communities canopy cover has increased to such densities that it is reducing or eliminating herbaceous understory cover and diversity (West 1983). Reduced herbaceous understory cover and diversity also may impact sage-grouse productivity (Connelly et al. 2000).

Sage-grouse prefer a more open shrub canopy cover (Martin 1970, Wallestad 1971) that exhibits a high grass and forb component (~15% cover) for brood-rearing habitat (Sveum et al. 1998, Connelly et al. 2000). These areas typically provide the forb and insect abundance and diversity that are important components of brood-rearing habitat (Dunn and Braun 1986, Apa 1998). Connelly et al. (2000) and Beck and Mitchell (2000) suggested that sagebrush canopy cover should be reduced to 10–25% in brood-rearing habitats that exhibit a low grass and forb component.

The Western Association of Fish and Wildlife Agencies (WAFWA) identified a need to conduct experiments of sufficient scale to demonstrate the effect of various management practices in stabilizing and enhancing sage-grouse populations and sagebrush ecosystems (WAFWA 1999). The scientific literature clearly indicates that sage-grouse are dependent on large expanses of sagebrush-dominated landscapes. However, more information is required regarding the appropriate management techniques and scale of management activity within these areas to improve seasonal habitats for sage-grouse.

Approximately 30% of the sagebrush lands in the western United States are privately owned (Connelly et al. 2004). The greatest percentages of privately owned sagebrush lands occur in Montana, Colorado, Washington, and South Dakota. Of states containing the largest total area of sagebrush, the states with the greatest percentage in private ownership are Wyoming (38%), Oregon (27%), Nevada (17%), and Colorado (17%). The Utah Division of Wildlife Resources (UDWR) estimates that in Utah over 50% of the remaining sage-grouse populations in the state occur on private or state land (UDWR 2002). Box Elder, Garfield, Rich, Uintah, and Wayne Counties, all with an estimated

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GREATER SAGE-GROUSE SELECT NEST SITES TO AVOID VISUAL PREDATORS BUT NOT OLFACTORY PREDATORS

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Abstract. Birds can hide from visual predators by locating nests where there is cover and from olfactory predators where habitat features create updrafts, high winds, and atmospheric turbulence, but sites optimal for hiding from visual and olfactory predators often differ. We examined how Greater Sage-Grouse (*Centrocercus urophasianus*) balance the dual needs of hiding from both visual and olfactory predators on Parker Mountain, Utah, where the Common Raven (*Corvus corax*) is the main visual predator and the striped skunk (*Mephitis mephitis*) and American badger (*Taxidea taxus*) are the main olfactory predators. By comparing nest sites to random sites during 2005 and 2006, we found that sage-grouse nest at sites where their nests were obscured from visual predators but were exposed to olfactory predators. To validate these findings, we replicated the study in southwest Wyoming during 2008. Again, we found that visual obscurity at nest sites was greater than at control sites but olfactory obscurity was less. Our results indicate that Greater Sage-Grouse select nest sites where they will be concealed from visual predators but at the cost of locating nests where they are exposed to olfactory predators. In southwest Wyoming, we found that olfactory predators (mammals) and visual predators (birds) depredated an equal number of nests. By selecting nest sites with visual obscurity, Greater Sage-Grouse have reduced the threat from visual predators to where it was similar to the threat posed by olfactory predators.

Key words: Centrocercus urophasianus, *nest depredation*, *nest-site characteristics*, *olfactory predators*, *sage-grouse*, *visual predators*.

Centrocercus urophasianus Selecciona Sitios de Anidación para Evitar Depredadores Visuales pero no Depredadores Olfatorios

Resumen. Las aves pueden esconder sus nidos de depredadores visuales localizándolos en sitios con cobertura y de depredados olfatorios donde las características del hábitat crean corrientes de aire, vientos fuertes o turbulencia atmosférica, pero los sitios con características óptimas para esconder los nidos de cada tipo de depredador generalmente son diferentes. Examinamos como *Centrocercus urophasianus* evalúa las necesidades de esconder sus nidos ante depredadores visuales y olfatorios en las montañas Parker, estado de Utah, donde el cuervo *Corvus corax* es el principal depredador visual mientras que los mamíferos *Mephitis mephitis* y *Taxidea taxus* son los principales depredadores olfatorios. Al comparar las características de los sitios de anidación con las de sitios al azar durante 2005 y 2006, encontramos que los nidos de *C. urophasianus* se encontraban escondidos de depredadores visuales pero que estaban expuestos a depredadores olfatorios. Para validar estos hallazgos, replicamos el estudio en el sudoeste de Wyoming en 2008. Nuevamente encontramos que la cobertura visual en los nidos era mayor que para sitios al azar, pero que la cobertura olfatoria era menor. Nuestros resultados indican que *C. urophasianus* selecciona los sitios de anidación con características que esconden los nidos de depredadores visuales pero a costa de localizar los nidos en sitios expuestos a depredadores olfatorios. En el sudoeste de Wyoming, encontramos que los depredadores olfatorios (mamíferos) y visuales (aves) depredaron la misma cantidad de nidos. Al seleccionar sitios de anidación con cobertura visual, *C. urophasianus* ha reducido el riesgo de depredación por depredadores visuales a un nivel similar al del riesgo impuesto por los depredadores olfatorios.

INTRODUCTION

Nest depredation is the main reason why Greater Sage-Grouse (*Centrocercus urophasianus*) nests fail (Gregg et al. 1994, Schroeder and Baydack 2001, Holloran et al. 2005). Sage-grouse nest success depends upon the hen's ability to place its nest where predators will not find it, but nest predators use different modalities to locate nests. Many nest predators use vision to locate nests (hereafter called visual predators), while others use odor cues to locate nests when atmospheric conditions favor the use of this modality (hereafter called olfactory predators). Olfactory predators include many mammals, such as the feral hog (*Sus scrofa*), striped skunk (*Mephitis mephitis*), and American badger (*Taxidea taxus*) (Conover 2007).

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Management and Conservation Article

Achieving Better Estimates of Greater Sage-Grouse Chick Survival in Utah

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ABSTRACT Declining sage-grouse (*Centrocercus urophasianus*) populations may be characterized by poor recruitment largely attributed to low chick survival. However, few published studies have explicitly examined factors that influence chick survival. We used a suture method to radiomark 1–2-day-old sage-grouse chicks (n = 150) in 2005–2006 on Parker Mountain in south-central Utah, USA, and monitored their survival to 42 days. We modeled effects of year, hatch date, chick age, brood-female age, brood-mixing, and arthropod abundance on chick survival. Our best model revealed an average survival estimate of 0.50 days to 42 days, which is the highest level ever documented for this long-lived species. Brood-mixing occurred in 21% (31/146) of chicks and 43% (18/42) of broods we studied. Moreover, yearling females had more chicks leave their broods than did adults. We found that survival may be higher among chicks that switch broods compared to those that stayed with their natal mother until fledging. Thus, brood-mixing may be an adaptive strategy leading to increased sage-grouse chick survival and higher productivity, especially among chicks born to yearling females. Our findings also indicate that arthropod abundance may be an important driver of chick survival, particularly during the early brood-rearing period and, therefore, sage-grouse populations may benefit from a management strategy that attempts to increase arthropod abundance via brood habitat management.

KEY WORDS brood-mixing, *Centrocercus urophasianus*, chick survival, greater sage-grouse, productivity, radiotelemetry, suture method, Utah.

Range-wide, greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) population declines have been attributed to environmental factors affecting production (Connelly and Braun 1997; J. W. Connelly, Western Association of Fish and Wildlife Agencies, unpublished report). Recruitment, a key and highly variable component of production in North American grouse species (Tetraoninae), largely depends on chick survival (Bergerud 1988, Gotelli 2001). The quality of brooding-rearing habitat is an important component of sage-grouse recruitment (Drut et al. 1994, Connelly et al. 2000, Aldridge and Boyce 2007, Gregg et al. 2007).

Arthropod abundance is also critical for survival of young chicks (<21 days old; Klebenow and Gray 1968, Peterson 1970, Johnson and Boyce 1990). Thompson et al. (2006) found sage-grouse productivity (measured by harvested wing samples and F with broods) was positively associated with arthropods (medium-sized Hymenoptera and Coleoptera) and herbaceous components of sagebrush habitats. Insect abundance may be related to plant diversity within sagebrush systems (especially intact sagebrush communities) but may be more highly associated with annual productivity (moisture dependent) within specific habitats (Wenninger and Inouye 2008). However, the direct relationship between insect availability and sage-grouse chick survival in a natural setting is poorly understood.

In addition to habitat quality and arthropod abundance, the age and experience of brood females may also influence chick survival and productivity (Newton 1998). Curio (1982) found that young birds (avian species in general) reproduce more poorly than older birds. In general, adult sage-grouse females have a higher probability of nesting and may have higher chick survival than yearling females (Connelly et al. 1993, Gregg 2006).

Chick survival in sage-grouse has been difficult to study. Estimates reported from field studies have been low, even among studies where chicks were individually radiomarked (12–22% for the first few weeks of survival; Aldridge and Boyce 2007, Gregg et al. 2007). Additionally, posthatch brood amalgamation (termed brood-mixing in precocial species), as a form of alloparental care, may confound survival estimates from studies that did not include both radiomarked brood females and chicks (Flint et al. 1995). Sage-grouse, compared to other gallinaceous species, are long-lived with lower reproductive output (Patterson 1952, Schroeder et al. 1999). Thus, sage-grouse share life strategy characteristics with other species that brood-mix. However, this phenomenon has rarely been discussed in the sage-grouse literature. Brood-mixing may afford adoptive parents several selective advantages, including increased survival of their progeny by earlier detection of predators and dilution of predation on natal offspring because of increased brood sizes (Riedman 1982). Concomitantly, younger, inexperienced mothers may improve their offspring's chances of survival by giving them up to older, more experienced mothers (Eadie and Lumsden 1985, Eadie et al. 1988).

We monitored radiomarked sage-grouse brood females and approximately 1-day-old sage-grouse chicks to evaluate temporal effects of hatch date, chick age, brood-female age, brood-mixing, year, and arthropod abundance on chick survival. We hypothesized that yearling females are more likely to lose offspring via brood-mixing events and that offspring that leave their natal broods experience higher survival. Additionally, we hypothesized that arthropod abundance is associated with higher chick survival during the early brood-rearing period (<21 days), when chicks are

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EVALUATION OF BROOD DETECTION TECHNIQUES: RECOMMENDATIONS FOR ESTIMATING GREATER SAGE-GROUSE PRODUCTIVITY

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ABSTRACT.—Obtaining timely and accurate assessment of sage-grouse (*Centrocercus* spp.) chick survival and recruitment is an important component of species management and conservation. We compared the effectiveness of walking, spotlight, and pointing-dog surveys to detect radio-marked and unmarked chicks within broods of radio-marked hens in Utah. Walking surveys detected 72% of marked chicks, while spotlight and pointing-dog surveys detected 100% and 96%, respectively. We found no difference between spotlight and pointing-dog counts in number of marked and unmarked chicks detected ($P = 0.57$). Spotlight counts were slightly more time efficient than pointing-dog surveys. However, spotlight surveys were nocturnal searches and perceived to be more technically arduous than diurnal pointing-dog surveys. Pointing-dog surveys may offer greater utility in terms of area searched per unit effort and an increased ability to detect unmarked hens and broods.

Key words: brood counts, Centrocercus urophasianus, *Greater Sage-Grouse, pointing dogs, spotlighting, walking surveys, Utah.*

Recent declines in Greater Sage-Grouse (*Centrocercus urophasianus,* hereafter sage-grouse) populations have been attributed to low productivity and poor recruitment caused by declining habitat quantity and quality (Connelly and Braun 1997, Connelly et al. 2004). Concomitantly, obtaining reliable and cost-effective estimates of productivity and recruitment has been identified as an important sage-grouse conservation strategy (Connelly et al. 2004, Crawford et al. 2004).

Multiple studies have reported uncertainty in locating all sage-grouse chicks around a radio-marked brood hen during walking flush counts and also have noted that this technique may underestimate juvenile survival (Schroeder 1997, Aldridge and Brigham 2001, Aldridge 2005). Burkepile et al. (2002) and Gregg et al. (2007) devised methods for radio-marking sage-grouse chicks, and these methods likely yielded more-reliable estimates of chick survival than traditional walking flush counts. However, radio-marking chicks is expensive and labor-intensive, and not all research projects have sufficient funding to use the technique. Moreover, most managers interested in monitoring production do not have the resources required to monitor radio-marked hens or broods, especially at large-population or statewide scales. Clearly, from both research and management perspectives, better methods are needed for assessing productivity within sage-grouse populations.

The use of nocturnal brood surveys with spotlights may provide improved chick detection (Walker et al. 2006) over walking flush counts. Using dogs to locate individual chicks within a brood may also improve detection rates (Zwickel 1980). In North America, pointing dogs have been used specifically for sage-grouse research (Autenrieth 1981, Connelly et al. 2000b, 2003, Dahlgren et al. 2006). Connelly et al. (2003) recommended using pointing dogs for sage-grouse brood surveys. Nevertheless, in spite of all the North American and European grouse research studies that have used pointing dogs, we could not find any publications evaluating the effectiveness of pointing dogs for detecting grouse. The objectives of this study were (1) to determine if walking, spotlight, and pointing-dog surveys differed in their ability to detect chicks within radio-marked broods and (2) to evaluate the relative efficiency of walking, spotlight, and pointing-dog surveys in detecting chicks.

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Management and Conservation

Using Gas Chromatography to Determine Winter Diets of Greater Sage-Grouse in Utah

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ABSTRACT Sagebrush (*Artemisia* spp.) constitutes the majority (>99%) of sage-grouse (*Centrocercus* spp.) winter diets. Thus, identification and protection of important winter habitats is a conservation priority. However, not all sagebrush may be alike. More information is needed regarding sage-grouse sagebrush winter dietary preferences for application to management. The objective of our research was to determine if chemical analysis of fecal pellets could be used to characterize winter sage-grouse diets as a substitute for more invasive methods. We collected and analyzed fecal pellets and sagebrush samples from 29 different sage-grouse flock locations in northwestern and southcentral Utah. Using gas chromatography, we were able to identify crude terpene profiles that were unique to Wyoming sagebrush (*A. tridentata wyomingensis*) and black sagebrush (*A. nova*). We subsequently used the profiles to determine sagebrush composition of sage-grouse fecal pellets, thus reflecting sage-grouse winter diets. This technique provides managers with a tool to determine which species or subspecies of sagebrush may be important in the winter diets of sage-grouse populations. © 2011 The Wildlife Society.

KEY WORDS *Artemisia*, black sagebrush, *Centrocercus urophasianus*, gas chromatography, Utah, winter diet, Wyoming sagebrush.

Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations have been declining over the last 5 decades (Connelly et al. 2004, Garton et al. 2011). On 4 March 2010, the United States Fish and Wildlife Service (USFWS) designated greater sage-grouse as a candidate species for protection under the Endangered Species Act of 1973 (USFWS 2010). The USFWS cited continued loss and/or fragmentation of important sage-grouse habitats as a major conservation concern (USFWS 2010).

Sage-grouse are sagebrush (*Artemisia* spp.) obligates, thus sagebrush is the most dominant feature of sage-grouse winter habitats (Gullion 1966). Sagebrush constitutes >99% of their winter forage (Patterson 1952, Dalke et al. 1963, Gullion 1966, Wallestad et al. 1975) and is used exclusively for escape and protective cover (Eng and Schlandweiler 1972, Beck 1977, Hupp and Braun 1989, Robertson 1991, Battazzo 2007). Previous research reported that sage-grouse exhibit forage preferences for certain sagebrush species or subspecies during the winter (Remington and Braun 1985, Welch et al. 1989, Welch et al. 1991, Rosentreter 2005). Preferences may be explained by protein levels in sagebrush leaves (Remington and Braun 1985). Other studies suggested that factors such as availability and secondary compounds influenced sagebrush selection (Welch et al. 1989, 1991). Sage-grouse dietary preferences likely vary among populations (Remington and Braun 1985, Welch et al. 1991). Sage-grouse use a variety of sagebrush habitats across the population range, therefore it is imperative for managers to be able to identify what types of sagebrush are being used as forage as part of their winter habitat assessment (Dalke et al. 1963, Remington and Braun 1985, Welch et al. 1989, Connelly et al. 2004, Thacker 2010).

Previously, sage-grouse diets have been determined using crop analysis or observational methods (Wallestad et al. 1975, Remington and Braun 1985, Barnett and Crawford 1994, Gregg et al. 2008). Crop sampling is accurate but requires grouse to be harvested in order to examine crop contents. This sampling technique may not be a viable option in small or declining populations and may not be a widely accepted practice for a candidate species. Observational studies can be effective, but have logistical limitations. Approaching winter sage-grouse flocks without disturbing or influencing foraging behavior is difficult (Thacker 2010). Indirect observations (identifying evidence of herbivory) can be used but lacks specificity to quantify grouse abundance in a foraging area, time of foraging, or composition of the diet. Likewise, captive studies have limited applicability to populations at landscape levels, because observations are made in artificial settings (Welch et al. 1991). Given the limitations of these methods, a simple, reliable, and accurate way to classify sage-grouse winter diets is needed.

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Winter habitat use by juvenile greater sage-grouse on Parker Mountain, Utah: implications for sagebrush management

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***Abstract*:** Greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) are entirely dependent on sagebrush (*Artemisia* spp.) for food and cover during winter. Loss or fragmentation of important wintering areas could have a disproportionate affect on population size. We radio-marked and monitored 91 juvenile sage-grouse in south-central Utah from 2008 to 2010. Thirty-four individuals survived to winter (January to March) and were used to evaluate winter habitat use. Resource use was calculated using kernel density estimation of radio-marked individuals and compared to available habitat using a G-test. We found that juvenile sage-grouse used winter habitats characterized by 0 to 5% slopes regardless of aspect and slopes 5 to 15% with south-to-west facing aspects. The importance of high slope (5 to 15%) wintering habitats has not been previously documented in sage-grouse. Most winter use was on a small proportion (3%; 2,910 ha) of available habitat. Important wintering habitats may not be readily identifiable in typical years, and consequently, due to their elevation, may be more susceptible to land management treatments focused on increasing early season livestock or big game winter forage, rendering them unsuitable for winter use by sage-grouse. Prior to implementing land management treatments in lower elevation sagebrush sites with slopes ≤5% regardless of aspect and slopes 5 to 15% south to west in aspect, managers should consider the potential effects of such treatments on the availability of suitable winter habitat to mitigate against winters with above-normal snowfall.

***Key words*:** *Centrocercus urophasianus*, Geographic Information System, GIS, greater sage-grouse, habitat, human–wildlife conflicts, topography, Utah, winter

The historic range of greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) has declined in area by >55% (Connelly et al. 2004, Schroeder et al. 2004). Sage-grouse are completely dependent on sagebrush (*Artemisia* sp.) for forage during the winter (Patterson 1952, Dalke et al. 1963, Wallestad et al. 1975) and exhibit some degree of site fidelity to wintering areas (Eng and Schladweiler 1972, Berry and Eng 1985, Connelly et al. 1988). Doherty et al. (2008) concluded that impacts to wintering habitats could disproportionately affect population size. Lower elevation sagebrush habitat used by sage-grouse may constitute important winter areas for big game and early spring forage areas for domestic livestock (Connelly et al. 2004). Land management treatments on lower elevation sagebrush areas to increase big game or livestock forage at the expense of sagebrush cover could have long-term consequences for sage-grouse if treatment areas constitute important, winter habitat during winters with above normal snowfall.

Burke et al. (1989) reported that the distribution of vegetation in a mountain big sagebrush (*A. tridentata vaseyana*) steppe community was dependent upon wind exposure and topography. Similarly, sage-grouse habitat selection during winter has been shown to be related to exposure and topography, with grouse typically using south to west aspects (Beck 1977) with slopes <5%, and avoiding slopes >5 to 10% (Eng and Schladweiler 1972, Beck 1977). Further, Doherty et al. (2008) reported that slope was an important topographic predictor of whether sage-grouse

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PLOS ONE

Effects of Landscape-Scale Environmental Variation on Greater Sage-Grouse Chick Survival

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Abstract

Effective long-term wildlife conservation planning for a species must be guided by information about population vital rates at multiple scales. Greater sage-grouse (*Centrocercus urophasianus*) populations declined substantially during the twentieth century, largely as a result of habitat loss and fragmentation. In addition to the importance of conserving large tracts of suitable habitat, successful conservation of this species will require detailed information about factors affecting vital rates at both the population and range-wide scales. Research has shown that sage-grouse population growth rates are particularly sensitive to hen and chick survival rates. While considerable information on hen survival exists, there is limited information about chick survival at the population level, and currently there are no published reports of factors affecting chick survival across large spatial and temporal scales. We analyzed greater sage-grouse chick survival rates from 2 geographically distinct populations across 9 years. The effects of 3 groups of related landscape-scale covariates (climate, drought, and phenology of vegetation greenness) were evaluated. Models with phenological change in greenness (NDVI) performed poorly, possibly due to highly variable production of forbs and grasses being masked by sagebrush canopy. The top drought model resulted in substantial improvement in model fit relative to the base model and indicated that chick survival was negatively associated with winter drought. Our overall top model included effects of chick age, hen age, minimum temperature in May, and precipitation in July. Our results provide important insights into the possible effects of climate variability on sage-grouse chick survival.

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Introduction

Selective pressures result in the evolution of a life history conducive to species persistence under the environmental conditions encountered throughout the species' evolutionary history. Environmental conditions are not static, but rather experience climatic, geological, and successional changes through time. While such changes continue to occur naturally, anthropogenic disturbances have critically altered many of these processes, resulting in environments changing at rates that exceed the ability of some species to adapt [1]. The impact of rapidly changing environments may be particularly severe for species with limited dispersal opportunities (i.e., those existing in highly fragmented habitats; [2]). Efforts to conserve such species must focus on identifying the key demographic rates that are limiting population growth and the environmental factors that affect these rates [3].

During the 20th century, greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations experienced precipitous declines as a result of anthropogenic habitat destruction, degradation, conversion, and fragmentation [4,5]. In response to declining populations and increasing threats to remaining habitat, the Canadian Committee on the Status of Endangered Wildlife in Canada declared sage-grouse to be an endangered species in 1998 [6]. The United States Fish and Wildlife Service (USFWS) designated the sage-grouse as a candidate for protection under the Endangered Species Act in 2010 [7].

Sage-grouse are endemic to sagebrush (*Artemisia* sp.) dominated habitats of western North America, which have historically been very stable given that sagebrush is a long-lived and persistent plant. As such, sage-grouse evolved to use sagebrush for food and cover throughout the majority of their annual cycle. However, sage-grouse chicks do not consume sagebrush during their early development but instead require forbs and their associated arthropod communities. These components of the sagebrush ecosystem are highly dependent upon precipitation levels and therefore may exhibit high interannual variability. Thus, sage-grouse evolved a life history characterized by high annual adult survival but relatively low and variable reproductive rates compared to most other tetronids [8,9].

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Population Ecology

Greater Sage-Grouse Sex Ratios in Utah: Implications for Reporting Population Trends

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ABSTRACT Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) are a species of conservation concern throughout western North America. Obtaining valid population estimates is essential to understanding population trajectories and the effects of management. Counts of male sage-grouse attending leks during the breeding season are used directly as a population index or to estimate the breeding population size by assuming a detection probability and sex ratio. In the latter case, managers often assume a 2:1 female-biased ratio. However, this sex ratio has not been validated and may result in biased population estimates. We evaluated sex ratios at hatch, 42 days of age, and at harvest to determine if sex ratios were biased for sage-grouse in Utah. Sex ratios at hatch and at 42 days of age did not differ from parity. Harvest data suggested that sage-grouse may exhibit a slight female-biased sex ratio (1.458:1) in the fall. Wildlife management agencies should use caution when using lek count data to estimate population size if sex ratios have not been validated.

KEY WORDS candidate species, *Centrocercus urophasianus*, greater sage-grouse, population estimation, sex ratio, Utah.

Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) are a large, sexually dimorphic tetraonid endemic to the sagebrush-steppe habitats of western North America (Schroeder et al. 1999). Recent estimates indicate that sage-grouse populations declined at an average rate of 2% between 1965 and 2003 (Connelly et al. 2004, Garton et al. 2011). Currently, sage-grouse occupy <60% of their former range (Schroeder et al. 2004). In response to declining populations and increasing threats to remaining habitat, the Canadian Committee on the Status of Endangered Wildlife in Canada declared sage-grouse to be an endangered species in 1998 (Harris et al. 2001). The United States Fish and Wildlife Service (USFWS) designated sage-grouse as a candidate for protection under the Endangered Species Act in 2010 (USFWS 2010).

Sage-grouse population status and trends are primarily monitored by counting displaying males on leks (Connelly et al. 2003, Garton et al. 2011). These counts are often used as a population index and counts are compared over time to assess population trends. Alternatively, lek counts are occasionally used to estimate the breeding population by assuming a constant male detection probability and population sex ratio (Utah Division of Wildlife Resources [UDWR] 2009). Sage-grouse biologists have generally assumed that sage-grouse populations exhibit a 2:1 female-biased sex ratio (UDWR 2009, Atamian and Sedinger 2010, USFWS 2010, Garton et al. 2011), although other ratios have been proposed (Hagen 2005). This assumption is based on sex ratios observed during hunter harvest surveys in the fall. Although harvest data are convenient and inexpensive to collect, these data may yield biased results if hunters preferentially harvest 1 sex or if 1 sex is more susceptible to harvest than the other. Sex-biased harvest probabilities have been reported in Idaho where Connelly et al. (2000) found that 42% of adult female sage-grouse mortalities were attributable to hunter harvest, compared to only 15% of adult male mortalities. Unfortunately, few efforts have been made to determine if sage-grouse exhibit biased breeding season sex ratios (Atamian and Sedinger 2010). Additionally, the use of sex ratios observed during the fall harvest season to estimate breeding season populations assumes that wing barrel data are representative of the harvest and the population and that any bias in sex ratio is constant from fall to spring.

Seasonally skewed sex ratios can arise as a function of differential production of the sexes (biased primary sex ratio) or as a result of various factors occurring after birth or hatching (biased secondary sex ratio; Girondot and Pieau 1993). Fisher (1958) posited that the sexes should be produced with equal investment of resources by parents. Therefore, biased primary sex ratios could occur if 1 sex were

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Research Article

Greater Sage-Grouse Juvenile Survival in Utah

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ABSTRACT Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) adult hen and juvenile survival have been shown to have significant influence on population growth rates. However, assessing the sensitivity of population growth rates to variability in juvenile survival has proven difficult because of limited information concerning the potentially important demographic rate. Sage-grouse survival rates are commonly assessed using necklace-type radio transmitters. Recent technological advances have lead to increased interest in the deployment of dorsally mounted global positioning system (GPS) transmitters for studying sage-grouse ecology. However, the use of dorsally mounted transmitters has not been thoroughly evaluated for sage-grouse, leading to concern that birds fitted with these transmitters may experience differential mortality rates. We evaluated the effect of transmitter positioning (dorsal vs. necklace) on juvenile sage-grouse survival using a controlled experimental design with necklace-style and suture-backpack very high frequency (VHF) transmitters. To evaluate the effects of temporal variation, sex, and transmitter type on juvenile sage-grouse survival, we monitored 91 juveniles captured in south-central Utah from 2008 to 2010. We instrumented 19 females with backpacks, 14 males with backpacks, 39 females with necklaces, and 19 males with necklaces. We used Program MARK to analyze juvenile survival data. Although effects were only marginally significant from a statistical perspective, sex ($P = 0.103$) and transmitter type ($P = 0.09$) were deemed to have biologically meaningful impacts on survival. Dorsally mounted transmitters appeared to negatively affected daily survival ($\beta_{\text{transmitter type}} = -0.55$, SE $= 0.32$). Temporal variation in juvenile sage-grouse daily survival was best described by a quadratic trend in time, where daily survival was lowest in late September and was high overwinter. An interaction between the quadratic trend in time and year resulted in the low point of daily survival shifting within the season between years (27 vs. 17 Sep for 2008 and 2009, respectively). Overall (15 Aug–31 Mar) derived survival ranged 0.42–0.62 for females and 0.23–0.44 for males. For all years pooled, the probability death was due to predation was 0.73, reported harvest was 0.16, unreported harvest was 0.09, and other undetermined factors was 0.02. We observed 0% and 6.8% crippling loss (from hunting) in 2008 and 2009, respectively. We recommend the adoption of harvest management strategies that attempt to shift harvest away from juveniles and incorporate crippling rates. In addition, future survival studies on juvenile sage-grouse should use caution if implementing dorsally mounted transmitters because of the potential for experimental bias.

KEY WORDS *Centrocercus urophasianus*, crippling, greater sage-grouse, harvest, juvenile, radio-telemetry, survival, unreported harvest.

Wildlife managers require better information regarding the factors affecting greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) population growth to optimize the effect of management actions on species conservation. Taylor et al. (2012) argued that in the absence of quantitative data regarding population-specific mortality factors, management actions should focus ultimately on increasing hen and chick survival. However, they recognized that the lack of reliable estimates of juvenile survival may have resulted in the importance of this demographic rate being under emphasized in their analysis. Johnson and Braun (1999) previously concluded that both adult and juvenile survival were the demographic parameters most limiting to population growth for sage-grouse. Although a substantial amount of information is available concerning population dynamics of adults (Crawford et al. 2004), a gap remains range-wide regarding the dynamics of juvenile sage-grouse (e.g., survival, dispersal, predation, recruitment; Crawford et al. 2004, Beck et al. 2006, Taylor et al. 2012).

Stakeholders have expressed concern regarding the possible impacts of harvest on sage-grouse populations (Connelly et al. 2004) despite the lack of evidence to suggest that current hunting regulations pose a long-term risk to sage-grouse conservation (Reese and Connelly 2011). However, few studies have examined the effects of hunting on sage-grouse populations (Connelly et al. 2000, 2003, 2004; Reese and Connelly 2011). Reese and Connelly (2011) concluded

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ECOSPHERE

Effects of climatic variation and reproductive trade-offs vary by measure of reproductive effort in greater sage-grouse

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Abstract. Research on long-lived iteroparous species has shown that reproductive success may increase with age, until the onset of senescence, and that prior reproductive success may influence current reproductive success. Such complex reproductive dynamics can complicate conservation strategies, especially for harvested species. Further complicating the matter is the fact that most studies of reproductive costs are only able to evaluate a single measure of reproductive effort. We systematically evaluated the effects of climatic variation and reproductive trade-offs on multiple reproductive vital rates for greater sage-grouse (*Centrocercus urophasianus*; sage-grouse), a relatively long-lived galliforme of conservation concern throughout western North America. Based on over a decade of field observations, we hypothesized that reproduction is influenced by previous reproductive success. We monitored hen reproductive activity from 1998 to 2010, and used generalized linear mixed models to assess effects of climate and previous reproductive success on subsequent reproductive success. Reproductive trade-offs manifested as chronic effects on subsequent reproduction and were not apparent in all measures of subsequent reproduction. Neither nest initiation nor clutch size were found to be affected by climatic variables (either year $t - 1$ or t) or previous reproductive success. However, both nest and brood success were affected by climatic variation and previous reproductive success. Nest success was highest in years with high spring snowpack, and was negatively related to previous brood success. Brood success was positively influenced by moisture in April, negatively associated with previous nest success, and positively influenced by previous brood success. Both positive and negative effects of previous reproduction on current year reproduction were observed, possibly indicating high levels of individual heterogeneity in female reproductive output. Our results support previous research in indicating that climatic variability may have significant negative impacts on reproductive rates.

Key words: *Centrocercus urophasianus*; climate; cost of reproduction; generalized linear mixed model; greater sage-grouse; trade-offs; Utah.

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Seasonal Movements of Greater Sage-Grouse Populations in Utah: Implications for Species Conservation

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ABSTRACT: Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) are currently a candidate species for listing under the Endangered Species Act (1973). Understanding seasonal movements for at-risk species is critical to species conservation. We analyzed sage-grouse radio-telemetry location data from 13 study areas in Utah collected from 1998 to 2013 to determine seasonal movements across populations for conservation planning purposes. Maximum distances from nearest lek to nesting, summer, and winter locations across all radio-marked grouse averaged 2.20 km (90^{th} percentile = 5.06 km), 3.93 km (90^{th} percentile = 8.45 km), and 3.76 km (90^{th} percentile = 7.15 km), respectively. Maximum seasonal movements from nest to summer, nest to winter, and between summer and winter locations across all radio-marked grouse averaged 5.77 km (90^{th} percentile = 13.60 km), 11.77 km (90^{th} percentile = 26.36 km), and 14.75 km (90^{th} percentile = 30.77 km), respectively. Maximum distance from lek of capture to summer locations was greater for males than females, while females moved father than males from lek to winter and between summer and winter locations. There was no difference in movements by male age class. Adult females moved farther than yearlings from lek to nest and summer to winter areas. Utah sage-grouse seasonal movement distances were generally shorter than those reported in other states where populations inhabited larger and more contiguous habitats. Our results suggest that the more usable habitat space available during summer the farther sage-grouse, especially broods, will move within that space. Utah's sage-grouse management areas, delineated by the state's sage-grouse conservation plan, included approximately 85% of the radio-telemetry seasonal locations and > 95% when weighted by lek counts.

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Declining populations of greater sage-grouse: hunter motivations when numbers are low

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greater sage-grouse; endangered species act; anthropogenic allee effect; hunter survey; hunting; motivations; rarity.

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Abstract

As a hunted species becomes increasingly rare, the effort required to locate and harvest an individual tends to increase. As rarity increases, governmental oversight, including changes in hunting regulations and protection of habitats and individuals using mechanisms such as the US Endangered Species Act (ESA), can be used to mitigate extinction risks. However, recent research has demonstrated the existence of a feedback mechanism through which increased rarity may increase hunter demand for opportunities to pursue rare species before the opportunity is lost. This phenomenon, referred to as the anthropogenic Allee effect, may exacerbate exploitation, thereby resulting in disproportionally large effects of harvest on vulnerable species. In 2010, the US Fish and Wildlife Service designated greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) as a candidate for listing under the ESA. Although sage-grouse are a candidate for ESA listing, they are still hunted throughout much of their current range. In 2008, the demand for sage-grouse hunting permits in Utah exceeded their availability, raising questions about why hunters choose to pursue this species. We hypothesized that the pending ESA listing decision increased hunter demand for permits. We surveyed randomly selected hunters who obtained permits to hunt sage-grouse in Utah in 2008–2010 ($n = 838$) to determine their motivations for hunting sage-grouse and determinants of hunter satisfaction. The most commonly reported reasons for hunting sage-grouse were to spend time with family, for tradition and meat. Although the potential ESA listing was not a major motivational factor in 2009 or 2010, the percentage of respondents selecting this option did increase by 7%. Hunter awareness of the ESA listing petition also increased by 18% during this period. Our results provide new insights on the sociological importance and potential threats of hunting rare species.

Introduction

'When a wildlife population is threatened, deliberately killing individuals from it may seem perverse' (Loveridge, Reynolds & Milner-Gulland, 2007). Following the overexploitation of various wildlife species during the 19th century, conservation-minded sportsmen in the late 19th and early 20th centuries advocated for regulated hunting as a means of protecting wildlife populations (Trefethan, 1975). Subsequently, sport hunting of free-ranging wildlife has played a fundamental role in the evolution of wildlife conservation in North America. Pivotal legislation in the US, such as the Pittman-Robertson (PR) Federal Aid in Wildlife Restoration Act of 1937, established critical linkages between hunting and conservation funding (Smith, 1976; Mangun & Shaw, 1984) and most state wildlife management agencies currently depend upon PR funding to provide revenues for wildlife conservation. However, as populations of some game species decline, largely as a result of habitat loss and fragmentation, society has increasingly questioned the role hunting should play in contemporary wildlife management (Manfredo, Teel & Bright, 2003).

Regulated harvest has traditionally been believed to pose a minor threat of causing species extinction because of the 'law of diminishing returns' [i.e. hunters stop pursuing game if numbers decline to the point that harvest is unlikely (Strickland *et al.*, 1996, although see Connelly, Gammonley & Peek, 2005)]. However, recent research in bio-economic theory has shown that increased rarity may result in increased demand for hunting opportunities by hunters who fear that the opportunity to pursue the species may be lost because of heightened governmental regulations aimed at protecting the species (Courchamp *et al.*, 2006; Gault, Meinard & Courchamp, 2008; Hall, Milner-Gulland &

Evaluating Vital-Rate Contributions to Greater Sage-Grouse Population Dynamics to Inform Conservation

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Abstract

Efforts to recover the distribution and abundance of species often suffer from haphazard collections of short-term studies that are not able to identify the vital rates that contribute most to the growth of any particular population. Although proposed as a candidate for protective listing under the U.S. Endangered Species Act, and sometimes referred to as an umbrella species in the sagebrush (*Artemisia* spp.) biome of western North America, the conservation of greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) unfortunately suffers from the abovementioned syndrome. To provide a direction for better optimization of conservation efforts, we performed both prospective and retrospective perturbation analyses of a life cycle model based on a 12-year study that encompassed nearly the entire repertoire of sage-grouse vital rates. To help validate our population models, we compared estimates of annual finite population growth rates (λ) from our female-based life cycle models to those attained from male-based lek counts. Post-fledging (i.e., after second year, second year, and juvenile) female survival parameters contributed most to past variation in modeled λ during our study and had the greatest potential to change λ in the future, indicating these vital rates can be important determinants of sage-grouse population dynamics. In addition, annual estimates of λ from female-based life cycle models and male-based lek data were similar in all but 1 year, providing the most rigorous evidence to date that spring lek counts of males can serve as a valid index of sage-grouse population growth rates. Results from our perturbation analyses suggest that contemporary sage-grouse conservation efforts, which tend to focus on nesting habitat and nesting success, may need reevaluation. Our findings indicate that greater attention should be paid to those factors affecting post-fledging juvenile and adult survival. Our approach demonstrates the need for greater focus on long-term studies of vital rates across the life cycle. Such studies should address the decoupling of sampling variation from underlying process (co)variation in vital rates, identification of how such variation drives population dynamics, and how managers can use this information to better direct conservation efforts at the most limiting points in the life cycle for a given population.