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Research Note

Assessing Greater Sage-Grouse Breeding Habitat With Aerial and Ground Imagery

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Abstract

Anthropogenic disturbances, wildfires, and weedy-plant invasions have destroyed and fragmented many sagebrush (*Artemisia* L. spp.) habitats. Sagebrush-dependent species like greater sage-grouse (*Centrocercus urophasianus*) are vulnerable to these changes, making habitat monitoring essential to effective management. Conventional ground inventory methods are time consuming (expensive) and have lower data collection potentials than remote sensing. Our study evaluated the feasibility of ground (0.3-mm ground surface distance [GSD]) and aerial imagery (primarily, 1-mm GSD) to assess ground cover for big sagebrush (*Artemisia tridentata* Nutt.) and other vegetation functional groups important in sage-grouse breeding habitat (lekking, nesting, and brood rearing). We surveyed ~ 526 km^2 of the upper Powder River watershed in Natrona County, Wyoming, USA, a region dominated by Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) communities interspersed with narrow riparian corridors. Our study area was used year-round by sage-grouse and included 16 leks. In June 2010, we acquired aerial images (1-mm resolution) for 3 228 systematic sampling locations; additional images were acquired as rapid-succession bursts where aerial transects crossed riparian areas and for 39 riparian and 39 upland ground locations (0.3-mm resolution) within 3.2-km of leks. We used SamplePoint software to quantify cover for plant taxa and functional groups using all ground images and a systematic sampling of aerial images. Canopy cover of sage-grouse food forbs—as averaged across aerial and ground imagery around all leks—was 1.8% and 7.8% in riparian and 0.5% and 4.0% in upland areas, respectively. Big sagebrush cover was 8.7% from upland aerial images and 9.4% from upland ground images. Aerial and ground imagery provided similar values for bare ground and shrubs in riparian and upland areas, whereas ground imagery provided finer-scale herbaceous-cover data that complemented the aerial imagery. These and other image-derived archival data provide a practical basis for landscape-scale management and are a cost-effective means for monitoring extensive sagebrush habitats.

Key Words: big sagebrush, *Centrocercus urophasianus*, rangeland monitoring and assessment, sampling costs, very large scale aerial imagery

INTRODUCTION

Although greater sage-grouse (*Centrocercus urophasianus*) are found in 11 western states and two Canadian provinces, their historical habitat has been reduced 50–60% (Schroeder et al. 2004). Agricultural expansion, housing and energy developments, weedy plant invasions, and wildfires have led to loss and fragmentation of sagebrush (*Artemisia* L. spp.) habitats within the Intermountain West (Knick et al. 2003; Naugle et al. 2011). These changes to remaining habitats make sagebrush-dependent species like sage-grouse more vulnerable to declines, thus emphasizing the importance of habitat monitoring to population management.

In March 2010, the US Fish and Wildlife Service concluded that greater sage-grouse were warranted for protection under the Endangered Species Act of 1973, but the listing was precluded to other species under severe threat of extinction (US Department of the Interior, Fish and Wildlife Service [USDI–FWS] 2010). Furthermore, information compiled in the 2010 listing decision suggested a lack of consistent assessment and monitoring information for sage-grouse habitats and populations (USDI–FWS 2010).

Many current assessment methods have focused on modeling habitat characteristics selected at the microhabitat scale at locations used by grouse for various life stages, including nesting and brood rearing (e.g., Connelly et al. 2011; Kirol et al. 2012), whereas others have focused on habitat selection at multiple scales (e.g., Doherty et al. 2010). Connelly et al. (2003) also described standardized procedures to use in assessing habitat characteristics on the ground. However, these common methods for sage-grouse habitat inventory are expensive, thus limiting data collection to support management decisions. Assessments designed to answer specific conservation questions about sage-grouse across large landscapes using remotely sensed data are becoming increasingly common (e.g., Homer et al. 1993; Oyler-McCance et al. 2001; Aldridge et al. 2012). For instance, low-level (1:20 000–1:30 000) aerial photographs were used to assess changes in sagebrush habitats used by Gunnison sage-grouse (*C. minimus*) in southwestern Colorado between the 1950s and 1990s (Oyler-McCance et al. 2001). Geographic data were recently

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developed for Wyoming using Landsat and Quickbird imagery to provide information on eight habitat attributes, including sagebrush cover, shrub height, bare ground, and litter (Homer et al. 2012). Here, we report landscape-scale habitat measurements based on image resolutions of 0.3- and 1-mm ground surface distance (GSD).

Knowledge of habitat conditions is essential to understanding the effects of management activities and disturbances on the status of sagebrush-dependent species and their habitats (Connelly et al. 2000). New technologies, such as the high-resolution photography used in our study, are providing relatively inexpensive inventory methods (Seefeldt and Booth 2006; Cagney et al. 2011) and may result in more frequent data collection than is common using nonimaging methods. More frequent, landscape-scale data collection may display trends in wildlife habitat conditions not detected by nonimaging inventory methods (Booth and Cox 2008). Our study evaluated the feasibility of using ground and aerial imagery to assess plant taxa and functional groups used by sage-grouse for breeding habitat (lekking, nesting, and brood rearing) in an area inhabited by sage-grouse year-round (Mandich 2011). Our primary objective was to compare the use of high-resolution aerial and ground imagery to identify habitat conditions in upland and riparian habitats within a 3.2-km radius of 16 sage-grouse leks. Our secondary objective was to provide estimates of cost to better inform practitioners about the utility of employing imagery to assess sage-grouse habitats.

STUDY AREA

Our study area included approximately 526 km^2 of the upper Powder River watershed in Natrona County, Wyoming, USA (lat 42°53′20.034″N, long 107°04′42.784″W), administered by the Bureau of Land Management (BLM)–Casper Field Office. The study area encompassed Casper Creek and Wallace Creek with their tributaries and associated streams arising in the Rattlesnake Range on either side of 2 613-m Garfield Peak. Elevations ranged from 1 744 to 2 467 m, and the study area was situated within Major Land Resource Area 34A, High Plains Southeast (10–14 SE; US Department of Agriculture, Natural Resources Conservation Service [USDA–NRCS] 2012). The area was dominated by Wyoming big sagebrush (*A. tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) uplands interspersed with narrow riparian corridors. Greasewood (*Sarcobatus vermiculatus* [Hook.] Torr.) occurred in low-lying depressions, and rabbitbrush (*Chrysothamnus* Nutt. spp.) and winterfat (*Krascheninnikovia lanata* [Pursh] A. Meeuse & Smit) were found intermittently in the study area. Native grasses in the upland areas included Indian ricegrass (*Achnatherum hymenoides* [Roem. & Schult.] Barkworth), needle and thread (*Hesperostipa comata* [Trin. & Rupr.] Barkworth), prairie Junegrass (*Koeleria macrantha* [Ledeb.] Schult.), Sandberg bluegrass (*Poa secunda* J. Presl), and western wheatgrass (*Pascopyrum smithii* [Rydb.] Á. Löve; Mandich 2011). The study area included 16 sage-grouse leks where peak lek attendance averaged 33.2 males from 2005 through 2009 (Wyoming Game and Fish Department lek database).

METHODS

Using ARCGIS 10.0 (Environmental Systems Research Institute, Redlands, CA), we placed a 3.2-km (radii) analysis zone around each of the 16 leks (Figs. 1A and 1B). Our radii were based on a management protection zone suggested by Connelly et al. (2000); also, Holloran and Anderson (2005) found that 45% of sage-grouse nests in central and western Wyoming occurred within 3 km of a lek, indicating the importance of habitat to sage-grouse within our analysis zone. We used ArcGIS 10.0 to develop a study-area sampling plan using aerial-image locations falling within lek zones.

Image Acquisition

We conducted a landscape aerial survey in June 2010 using 34 north-to-south aerial transects at 800-m intervals from east to west across our study area. To facilitate accurate identification of species, we conducted aerial and ground surveys to correspond with peak herbaceous growth. Sample locations along transects were at 200-m intervals. We acquired nested, 1-, 8-, and 20-mm GSD images (red, green, and blue [RGB]) at each sample location along each transect from a Dragonfly light sport airplane (LSA) flying at 100-m above ground level (AGL) using the methods of Booth and Cox (2008, 2009). Each 1-mm GSD aerial image sampled 12 m^2 of ground (i.e., the field of view). There were 3 228 planned sample locations for the LSA, but the pilot was instructed to acquire bursts of images where aerial transects intersected riparian habitat. This resulted in a total of 11 703 images acquired for 3 901 locations.

We identified ground-sample locations using stratified random selection among the aerial photo locations that were within 3.2 km of a lek (Fig. 1B). Riparian ground-sample locations were moved, in the field, to the nearest riparian community if the identified aerial-photo ground location did not fall within a riparian community. To avoid road effects, no location was used for ground photography that was ≤ 50 m from a road. We collected ground images in June 2010 using the Johnson staff (Louhaichi et al. 2010). Images were 1-m AGL from a 10-megapixel digital color (RGB) camera, giving an image pixel GSD of 0.3 mm and an image field of view of 0.5 m. We recorded species present inside the photo plots at the time the images were acquired. We collected 12 ground images at each of 39 upland and 39 riparian locations within 3.2 km of leks (Fig. 1B). Images were obtained as three rows of four images with 5 m between rows and images at upland sites. Riparian sampling was linear with 5-m spacing between images.

Image Analysis

From the 3 901 aerial-image locations, we identified 500 by systematically selecting approximately every eighth location; 339 of these occurred within lek-analysis zones and were classified as riparian or upland, resulting in 65 riparian and 274 upland aerial-image locations. Selected aerial images from riparian-image bursts that did not show a riparian plant community were replaced by image substitutes chosen by proximity to the location being replaced.

We measured ground cover from the 1-mm aerial GSD images and 0.3-mm ground images with SamplePoint software

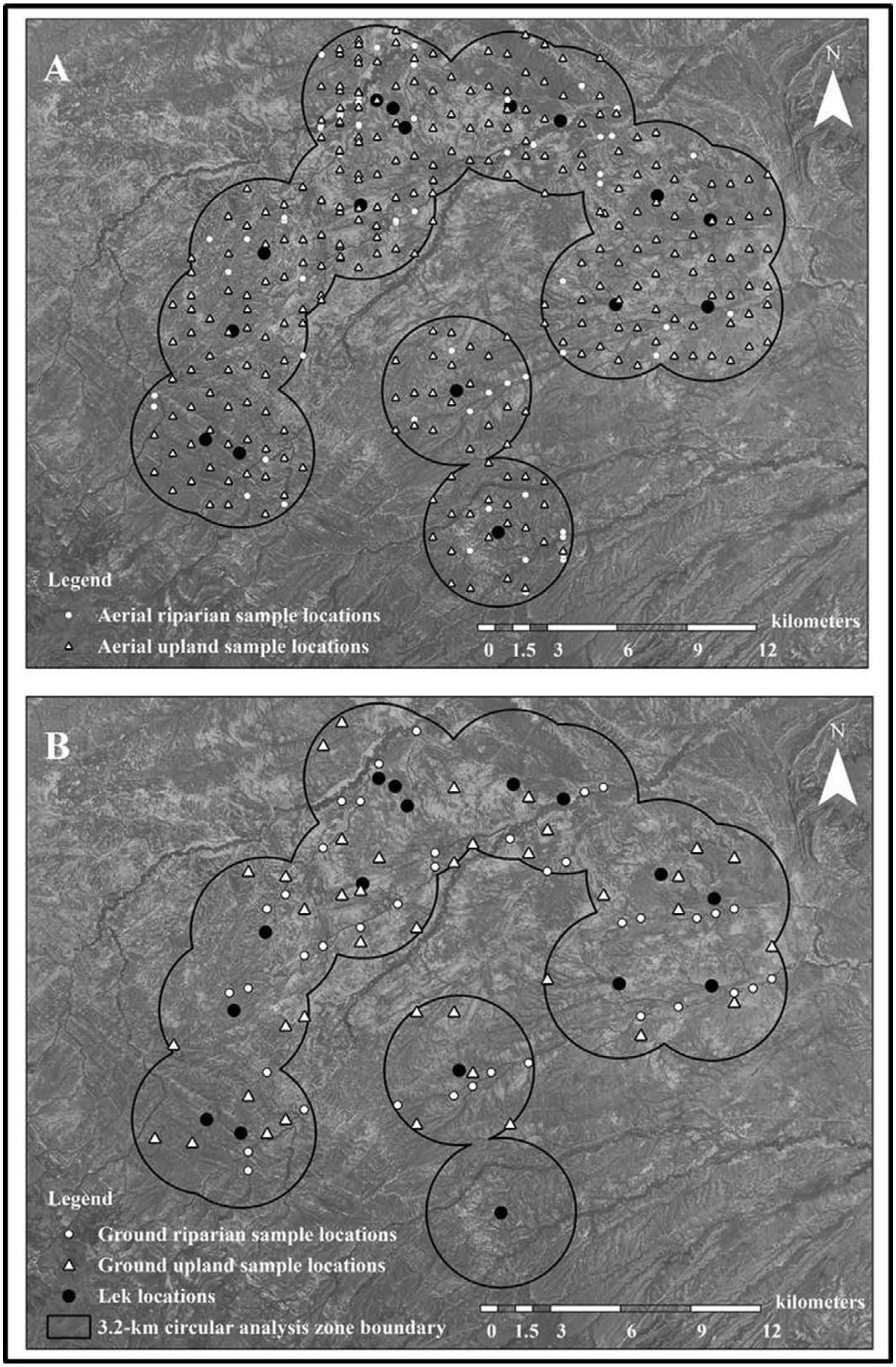

Figure 1. Project area and 3.2-km lek analysis zones on 1-m GSD National Agriculture Imagery Program aerial photography (Natural Resources Conservation Service Datagateway), central Wyoming, USA, June 2010. **A,** aerial image locations and **B,** ground image locations. We did not average cover separately by lek because some images occurred in more than one lek zone.

(Booth et al. 2006; Booth and Cox 2008, 2009) using 100 points per image. Ground-cover analysis categories were annual grass (primarily cheatgrass [*Bromus tectorum* L.]), perennial graminoids, sage-grouse food forbs (see Kirol et al. 2012 for a species list), nonfood forbs, litter, bare ground, shadow, big sagebrush (*Artemisia tridentata* Nutt.), other shrub (nonsagebrush shrub species), and unknown (i.e., vegetation not discernible to taxa or functional group). During processing,

Table 1. Mean percentage (1 SD) cover by attribute determined from 0.3- and 1-mm GSD ground and aerial images within a 3.2-km radius of $n=16$ leks, central Wyoming, USA. Aerial and ground images were collected in June 2010, and ground cover was quantified with SamplePoint (Booth and Cox 2008; Booth et al. 2006). Cover for aerial and ground images were averaged separately for riparian and upland images across a 345-km^2 lek analysis study area.

	Riparian		Upland	
Attribute	Aerial[1]	Ground[2]	Aerial	Ground
Ground cover				
Bare ground	18.7 (15.5)	19.0 (11.3)	35.7 (22.1)	36.8 (19.6)
Litter	10.8 (8.9)	32.1 (10.5)	17.1 (13.0)	27.5 (10.6)
Understory				
Annual grass	0.0 (0.0)	2.0 (4.2)	0.0 (0.0)	2.2 (8.2)
Food forbs	1.8 (8.7)	7.8 (5.9)	0.5 (2.4)	4.0 (2.9)
Total forbs	13.4 (18.1)	8.6 (6.2)	12.3 (14.0)	4.7 (3.2)
Perennial graminoids	44.2 (19.7)	35.3 (13.2)	21.4 (16.1)	14.5 (6.4)
Shrub overstory				
Big sagebrush	6.8 (8.0)	2.0 (6.1)	8.7 (10.6)	9.4 (9.3)
Other shrubs	2.4 (6.1)	0.4 (0.9)	1.1 (3.1)	3.5 (4.8)

[1]Five-hundred aerial images (one sample per location) were selected systematically from among 3 901 images acquired. There were 103 riparian (65 inside and 38 outside 3.2-km radii lek analysis zones) and 395 upland aerial samples (274 inside and 121 outside 3.2-km radii lek analysis zones). Two aerial images fell outside of our ~526-km^2 study area and were not classified.

[2]Results for ground imagery were computed from $n=12$ images at each sample location.

we verified taxa and functional groups by examining photos of plant species identified while acquiring ground imagery. To further our analysis, we compared ground cover, as measured from aerial and ground images, to corresponding values for big sagebrush, bare ground, and litter obtained from a 30-m sagebrush mapping product for Wyoming that used multiscale remotely sensed imagery and field sampling (Homer et al. 2012). We intersected pixels from this map within 3.2 km of leks and averaged the values within each pixel across the 345-km^2 area formed around 16 lek-analysis zones. Cover from aerial images was averaged across the 345-km^2 area for riparian and upland images separately (Fig. 1A), and cover from ground images was computed by averaging mean values (from 12 images averaged per sample location) separately for riparian and upland sample locations across our 345-km^2 study area (Fig 1B). We did not average cover separately by lek because some images occurred in more than one lek zone. We report means and 1 standard deviation (SD) for all cover values.

RESULTS AND DISCUSSION

We acquired images for 3 901 aerial and 960 ground locations. We computed cover from 65 riparian and 274 upland, 1-mm GSD, aerial images and from 936 ground images (12 photos each at 39 riparian and 39 upland locations) within our 345-km^2 analysis area (Figs. 1A and 1B). It required 182.8 h to obtain the 960 ground-location photos. Travel time to transects was 163.9 h, and 18.9 h were used by the technician at the transect locations. The cost for ground-image acquisition was $4 731.40 ($4.93 per image) plus vehicle costs. The cost to obtain the aerial images was $11 000 and included 16.1 h of airtime at $160 per hour. The remaining acquisition costs were for ground time, ground support, lodging, and per diem. Because of weather delays, these costs were greater than expected. Aerial-image-acquisition costs were $0.94 per image (all resolutions), or $2.82 per imaged location. Image-analysis costs—as distinct from aerial-image acquisition costs—were $2 527.20 for the 936 ground images ($2.70 per image) and $857.67 for the 339 aerial images ($2.53 per image).

The largest savings realized from aerial imaging relative to conventional ground monitoring are usually the labor costs of ground travel time and fuel and maintenance for the ground vehicle (Seefeldt and Booth 2006; Booth et al. 2008). Similarly, in this study, aerial-image-acquisition costs were about half those of the ground-image acquisition costs ($2.82 per imaged location versus $4.93 per image plus vehicle costs). There can also be important labor savings even with ground imaging, as reported by Seefeldt and Booth (2006) and Cagney et al. (2011). The former found that point-frame sampling required 6–10 min per sample compared to 2–4 min for either ground imaging or visual estimates. Similarly, Cagney et al. (2011) reported that ground imaging and analysis took only a third as long as the conventional line-point intercept technique.

Bare ground measured from aerial and ground imagery was similar at riparian and upland sites, whereas measurements of litter were approximately three times higher from ground images compared to aerial images at riparian sites and 1.6 times higher from ground images compared to aerial images at upland sites (Table 1). Perennial graminoids dominated understory cover and had the highest amount of cover as measured from aerial images taken at riparian sites (Table 1). Cover of sage-grouse food forbs within 3.2 km of leks, which, as measured from aerial and ground imagery, was 1.8% and 7.8%, respectively, in riparian habitat and 0.5% and 4.0% as measured by aerial and ground imagery, respectively, in upland habitat (Table 1). At the overstory level, big sagebrush cover was 8.7% (SD=10.6%) from upland aerial images, 9.4% (SD=9.3%) from upland ground images (Table 1), and 8.9% (SD=4.6%) from the Homer et al. (2012) data. Data from the Homer et al. (2012) analysis was higher for bare ground (mean=54.3%, SD=13.4%) and lower for litter (mean - 15.8%, SD=6.1%) compared to data from our upland images (Table 1). We detected annual grasses using ground images in riparian and upland habitats but not with aerial images (Table 1), suggesting that resolution and motion blur were factors in the difference.

The difference in herbaceous-cover values from aerial and ground imaging illustrate the importance of obtaining ground and aerial images concurrently (e.g., food-forb values had a fivefold difference between aerial and ground methods in riparian habitat and an eightfold difference in uplands). Again, we attribute the difference to greater resolution of ground imaging and to motion blur in the aerial images. The differences between aerial- and ground-image-derived values should be considered in the context of findings by Booth et al. (2008). They reported 1) that bare-ground values from different methods were more closely associated than were other ground-cover variables and 2) that vegetation-cover values were the least correlated ground-cover parameter among methods, suggesting a problem in consistently measuring vegetation cover. Ground-method associations in their study were no better correlated than ground-to-air associations, adding to evidence that high variability in vegetation-cover measurements exists among the conventional ground methods. Bare ground usually has high spectral reflectance and high contrast. The shades of greens and browns reflected by vegetation are more difficult to interpret. Still, images—despite the difficulties of differentiating among the many spectra reflected by vegetation—are a tangible entity for storage, reanalysis, and potential verification of ground conditions at given points in time and space. Most important, image acquisition is a practical means for acquiring large amounts of data across vast areas—a basic requirement for a defendable statistical evaluation of data from landscape-scale management units.

IMPLICATIONS

We recommend that land managers consider the use of aerial and ground imagery as a means to inventory sage-grouse breeding habitat across large landscapes. Using imagery for this type of inventory provides a cost-efficient medium allowing for comparisons with future conditions. Aerial and ground imagery provided fine-scale data—including food forbs and annual grasses (ground images only)—that may be more difficult to obtain with other remotely sensed products (e.g., Homer et al. 2012) and was a direct measure of on-the-ground conditions as opposed to an interpolation from space-based remote-sensing scenes where ground conditions may differ in elevation, aspect, and micrometeorological conditions. Different remote-sensing products offer different advantages. In our study, aerial methods allowed for landscape-scale sampling, but ground imaging provided evidence that aerially derived herbaceous-layer values should be adjusted—probably to compensate for motion blur and lower resolution.

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