Surveys

Evaluating the Potential of Aerial Infrared as a Lek Count Method for Prairie Grouse

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Abstract

Wildlife biologists use counts of birds attending traditional breeding grounds (i.e., leks) to develop indices of population trends in several grouse species. Standardized lek counts for sage-grouse *Centrocercus* spp. provide information about population trends by allowing comparison of counts across their range. In contrast, biologists lack a standard lek-count method for prairie grouse *Tympanuchus* spp. The lack of a standard lek-count method limits our ability to make rigorous spatial and temporal comparisons or to estimate population trends. Recent use of cooled infrared cameras in aerial surveys and their increased affordability make this technology attractive for monitoring prairie grouse populations. Our objective was to evaluate the efficacy of aerial infrared (AIR) technology for estimating abundance of prairie grouse by comparing AIR lek counts with ground-based lek counts of Columbian sharp-tailed grouse *T. phasianellus columbianus* in Idaho. We used both methods simultaneously to count sharp-tailed grouse at 25 leks to compare method consistency. We also used both methods to count sharp-tailed grouse at 88 other leks to quantify and compare the resources required for both methods. The average count obtained with the AIR method (12.3 ± 1.5 SE) and the ground-based method (12.9 ± 1.8 SE) was similar, and we were unable to detect a statistical difference between methods when conducting a negative binomial regression (z = 0.165, P = 0.87). Aerial infrared was twice the cost of the ground-based method, but AIR surveyed more leks in less time (88 leks during 4 d) compared with the ground-based method (88 leks during 29 d). Aerial infrared improves population monitoring by counting leks inaccessible by ground. The time efficiency of AIR and the ability to obtain counts consistent with ground-based methods suggests that AIR may be an effective and efficient lek-count method.

Keywords: aerial infrared; aerial surveys; Columbian sharp-tailed grouse; infrared camera; lek counts; management program; prairie grouse

Received: February 2, 2015; Accepted: June 5, 2015; Published Online Early: June 2015; Published: December 2015


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Aerial Infrared Lek Counts for Prairie Grouse

Introduction

Broad-scale loss and fragmentation of grassland and shrub ecosystems (Noss et al. 1995) have been a conservation concern for grouse (Phasianidae) that have evolved in diverse prairie and shrub landscapes. Emerging challenges including energy development and climate change exacerbate threats to these species (Sands and Pope 2010). Thus, it is important for wildlife managers to provide recommendations, informed by population monitoring programs, to guide population and habitat management. During early spring, grouse attend leks—communal display areas where breeding occurs. One common method of counting grouse at leks (i.e., lek counts) is to count grouse from a distance with the aid of binoculars or a spotting scope. Lek counts are a common method used for describing species distribution, population growth, population size, and population trends of lekking grouse (Schroeder et al. 1992; Aldridge and Brigham 2003; Connelly et al. 2004; Garton et al. 2011). In the early 2000s, a standard protocol was adopted for conducting lek counts of sage-grouse *Centrocercus* spp. (Connelly et al. 2003), which allowed comparison of population trends across their range (Garton et al. 2011).

A standard lek-count method is fundamental to understanding population trends and implementing effective management practices for prairie grouse *Tympanuchus* spp. (Ripley 1971; Schroeder et al. 1998; Applegate et al. 2004). Most prairie grouse population-monitoring programs lack a standard lek-count method that balances cost, time, and the ability to make statistical inferences. For example, various survey methodologies for monitoring sharp-tailed grouse *Tympanuchus phasianellus columbianus* obscured rather than informed the decision to list the species as threatened or endangered under the U.S. Endangered Species Act (ESA 1973, as amended; U.S. Fish and Wildlife Service 2006). The need for a standard lek-count method for prairie grouse has been recognized (Schroeder et al. 1992; Giesen 2000; Applegate et al. 2004; Hagen et al. 2004; Robel 2004) but not realized because prairie grouse lek-count methods vary in at least four ways: 1) the frequency of lek counts during a breeding season, 2) timing of counts, 3) gender counted, 4) technique (i.e., counting displaying prairie grouse from a blind versus flushing prairie grouse to obtain a count without distinguishing between sexes).

A standard lek-count method similar to that used for sage-grouse (counts of males from a distance) has not been adopted for prairie grouse species. The potential reasons that a standard lek-count method that extends beyond state lines has not been adopted for prairie grouse include 1) prairie grouse species have moderate sexual dimorphism (Manweiler 1939; Henderson et al. 1967); 2) prairie grouse can occupy a greater diversity of habitats with higher horizontal obstruction during lek activity compared with sage-grouse (Klott and Lindzey 1989); and 3) prairie grouse often avoid open areas on leks (Ward 1984). These biological, ecological, and behavioral factors make both sightability of prairie grouse on leks and differentiation of sexes challenging. Moreover, remote prairie grouse leks within the Intermountain West pose access challenges (e.g., topographic roughness) different from those for prairie grouse occupying the plains of the Midwest. Hence, characteristics of prairie grouse may preclude the standard ground-based lek-count method used for sage-grouse.

Aerial lek counts, which are typically counts of flushing grouse, have been used in prairie grouse monitoring programs to count and search for new leks (Lehmann and Mauermann 1963; Martin and Knopf 1981; Schroeder et al. 1992; McRoberts et al. 2011; Timmer et al. 2013). Aerial methods are not biased by proximity to roads (Applegate 2000; Anderson 2001; Garton et al. 2007), are not limited by accessibility to survey areas (McRoberts et al. 2011), and do not require the personnel-hours that ground-based methods necessitate (Martin and Knopf 1981; Grensten 1987; Schroeder et al. 1992). Furthermore, the advent of long-range infrared (IR) cameras has increased the efficiency and reduced the impact of observers on displaying birds during aerial counts (Blackwell et al. 2006). An aerial infrared (AIR) lek-count method was recently found to be consistent with ground-based counts for sage-grouse and may increase confidence in lek count assumptions (Gillette et al. 2013).

Our goal was to evaluate the potential of AIR as a lek count method for sharp-tailed grouse. Our objectives were 1) to determine whether AIR cameras could detect sharp-tailed grouse on leks, 2) to compare AIR and ground-based sharp-tailed grouse lek counts conducted simultaneously, and 3) to compare the cost and effort required to count sharp-tailed grouse leks once using both AIR and ground-based methods within the context of a population monitoring program.

Study Site

We targeted active leks in five southeastern Idaho counties during 2012 and 2013 (Figure 1). In the valleys where most sharp-tailed grouse leks occur, mean annual precipitation was 32.8 cm, average annual minimum temperature was 2.2 °C and average annual maximum temperature was 16.1 °C (Western Regional Climate Center 2013). The mean number of birds at leks in the study was 8.5 grouse, based on ground-based lek counts conducted by the Idaho Department of Fish and Game (IDFG) for that year (range = 0–30). Eighty-five percent of leks in the study area (*n* = 113) occurred at low to mid elevations (1,500–1,800 m) where vegetation communities were characterized by dry-land grain and Conservation Reserve Program perennial grasses (crested wheatgrass *Agropyron cristatum*, intermediate wheatgrass *A. intermedium*, bulbous bluegrass *Poa bulbosa*, smooth brome *Bromus inermis*), big sagebrush *Artemisia tridentata*, rabbitbrush *Chrysothamnus* spp., and Utah juniper *Juniperus osteosperma*. Sharp-tailed grouse leks also occurred in mesic, higher elevation (1,800–2,000 m) mountain shrub communities consisting of antelope...
bitterbrush *Purshia tridentata*, serviceberry *Amelanchier alnifolia*, snowberry *Symphoricarpos* spp., and chokecherry *Prunus virginiana*.

With a trained field crew, we conducted simultaneous lek counts using an AIR method and a ground-based method on 11 April 2012 in the Rockland Valley \((n = 12)\) and 12 April 2012 in the Curlew Valley \((n = 13)\). The simultaneous lek count consisted of ground-based observers arriving at leks prior to the airplane and concluded when the ground-based observers flushed and counted grouse on the lek after the AIR count was finished and the airplane ceased circling the lek. The timing of all lek counts was between 0.5 h before sunrise and 1.5 h after sunrise (i.e., winds > 16 km/h or during precipitation).

**Methods**

**Simultaneous lek counts**

We counted sharp-tailed grouse leks simultaneously using an AIR method and a ground-based method on 11 April 2012 in the Rockland Valley \((n = 12)\) and 12 April 2012 in the Curlew Valley \((n = 13)\). The predominant private land use in the Rockland Valley was dry land row-crop agriculture with some irrigated grain and hay fields.
when one observer counted three leks. We trained observers to count leks in a standardized manner and instituted the following measures to minimize observer error. Ground-based observers arrived at their first lek of the morning 1 h before sunrise to avoid disturbing leks prior to AIR lek counts. Prior to the study, we placed a florescent flag (stake height: 61 cm; flag: 6.4-cm height × 8.9-cm width) 30–50 m from the lek to indicate where observers should park their vehicle to view their first lek while the AIR lek count was conducted. From their vehicle, observers recorded grouse behavior during the AIR lek count, the number of grouse, presence of female grouse on the lek, and lek vegetation type. As soon as the airplane ceased circling the lek, ground-based observers exited their vehicle and walked to the center of the lek, counting sharp-tailed grouse as they flushed. We also marked the center of lek activity prior to the study with a florescent flag for ground-based observer reference. Ground-based observers proceeded to their next lek, but parked their vehicles at marked locations 50–100 m from the lek to avoid disturbing the lek prior to AIR lek counts. Ground-based observers then repeated lek count procedures following the AIR count.

Statistical analysis. The ground-based observer flush count was paired with the AIR lek count on each day. We compared 12 paired lek-count surveys that were conducted on 11 April 2012 and 13 paired lek-count surveys conducted on 12 April 2012. We used a negative binomial regression model with a log link function in Program R (version 3.0.1) because our count data followed a Poisson distribution with an overdispersion parameter of 5.71 (e.g., overdispersion; Blevins et al. 2015). The number of grouse counted was modeled as a function of survey method. We included “survey method” as a fixed effect in the model because we were interested in differences in counts between AIR and ground-based methods. We planned a priori to only include “survey method” as a fixed effect in our model because we did not believe differences between days might influence simultaneous lek counts. However, ambient air temperatures reached a record high of 24°C (75°F) in southeastern Idaho on the first day of counts (11 April 2012), whereas the average maximum temperature is 14°C (57°F) on that day (Western Regional Climate Center 2013). Temperatures on the second day of simultaneous lek counts (12 April 2012) were average—10°C warmer than the first day. Hence, as a modeling precaution, we also included “day” and “lek” as random effects in the negative binomial regression to determine whether these factors influenced differences in counts between survey methods.

Single counts of sharp-tailed grouse leks using both methods
After understanding the capability of AIR lek counts by conducting simultaneous lek counts during 2012, we randomly selected a subset of leks within each of four counties for 100 total targeted leks in 2013 (Figure 1). We obtained leks from the IDFG sharp-tailed grouse lek database. Inability of ground-based observers to access some leks on private property or leks in remote locations prevented counting all 100 targeted leks. Hence, 88 sharp-tailed grouse leks were counted twice, once with the AIR method and once using the ground-based method; these leks were not counted on the same day during 2013. Counting the same leks using both methods within the context of a population monitoring program allowed us to compare the cost and effort in resources needed for each method. Active leks were defined as having a count of ≥3 sharp-tailed grouse at least once during the 3 previous years.

Owyhee Air Research personnel counted leks using the same AIR method described for simultaneous lek counts. Aerial IR counts were completed during the first 2 h of light on 17–19 and 24 April 2013. A population monitoring program was already in effect where IDFG personnel conducted ground-based lek counts according to annual assignments within Bannock, Caribou, Franklin, Oneida and Power counties in southeastern Idaho (Figure 1). The IDFG made minor adjustments to their population monitoring program to satisfy the following methods. Personnel with the IDFG conducted ground-based lek counts by the first 2 h of light during 27 March–29 April 2013. All ground-based observers were familiar with their assigned lek locations and most had counted their assigned leks in previous years. To minimize observer error, all ground-based observers were trained on methodology and given a 2013 sunrise calendar, a map of assigned leks, and datasheets that specified how and what data were to be collected. Ground-based observers recorded their start and end time, mileage of vehicles driven, and whether reconnaissance for other leks was conducted during each lek route. Observers recorded the count and type of vegetation at each lek (e.g., Conservation Reserve Program, row-crop agriculture, shrub-steppe).

We calculated the cost for AIR lek counts as the flight time required to count 88 leks at U.S. currency $800/h during flights on four mornings. Aerial IR contractors have not charged for reviewing IR videography to determine AIR counts, so there was no cost associated with reviewing IR videography. Calculating the cost of ground-based counts included the total number of IDFG personnel within hours spent traveling to and from leks, mileage charges for vehicles that were driven to and from lek counts, and respective daily rental rates for vehicles required to visit leks. We divided targeted leks into lek routes of 2–5 leks in close proximity (1.9–8.1 km), with the goal of counting all leks in a morning for each lek route. A ground-based lek route began when observers arrived at the Pocatello IDFG regional office to use an IDFG vehicle for conducting lek counts and ended when ground-based observers returned each morning. One exception to this occurred where an observer began and ended three lek routes from his residence in Franklin county because leks were located >70 km from the IDFG regional office in Pocatello (Figure 1).

Statistical analysis. We calculated the cost to pay ground-based observers for the total hours required to count 88 leks at the level of an IDFG senior wildlife
technician ($27.34/h including benefits) by using the simple formula: (hourly salary × total hours). We calculated vehicle expenses with the following formula: vehicle expense = ($0.55 × miles driven in trucks) + ($32.20/d truck rental × number of days used) + ($11.05/d all-terrain-vehicle rental × number of days used). The rental rate includes insurance costs, which cover accidents, flat tires, oil changes, or other costs potentially incurred while conducting lek counts. We did not include the time required for ground-based observers to contact private landowners to gain access to private lands. We did not compare counts between methods for the 88 leks counted in 2013 because leks were not counted on the same day from the air and ground. The 25 leks counted simultaneously during 2012 were separate from the 88 leks counted during 2013 (Figure 1).

Results
Simultaneous sharp-tailed grouse lek counts
Sharp-tailed grouse were distinguishable from a background of vegetation and abiotic matter when viewed with a cooled IR camera. Ambient air temperature was 7.2°C when surveys were started and 10.6°C when surveys ended on 11 April 2012, and 1.7°C at the start and 3.9°C when surveys ended on 12 April 2012. Using AIR, we detected sharp-tailed grouse at 24 of 25 leks targeted for simultaneous counts.

The average count of grouse attending leks for the AIR method was 12.3 grouse ± 1.5 standard error (SE) and for the ground-based method was 12.9 grouse ± 1.8 SE (n = 25). Negative binomial regression showed that the number of grouse counted between the AIR and ground-based method were not different (z = 0.165, P = 0.87) and the effect of day (z = −0.479, P = 0.63) or lek (z = −1.017, P = −0.31) was not significant. Identical lek counts using ground-based and AIR methods were obtained at 8 of 25 (32%) leks (Table 1). The average difference between paired counts was 0.6 ± 0.7. Individual differences within pairs (AIR minus ground) ranged from 7 to −11. The average absolute difference (lx − yl) in simultaneous counts between AIR and ground was 2.0 ± 0.5 grouse. During 9 of 25 (36%) paired sampling occasions, AIR counts resulted in lower numbers than did ground-based counts. A difference of ≥ 3 birds was observed during 6 (24%) paired sampling occasions. Observers identified species characteristics (e.g., large number of birds flushing simultaneously at leks R5 and R11), environmental variables (e.g., lek C3 was on a knoll with tall brush), observer variables

<table>
<thead>
<tr>
<th>Lek</th>
<th>AIR Count</th>
<th>Ground Count</th>
<th>Comments by Ground Observers</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>17</td>
<td>17</td>
<td>Four female grouse observed</td>
</tr>
<tr>
<td>R2</td>
<td>11</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>15</td>
<td>13</td>
<td>Approximate count</td>
</tr>
<tr>
<td>R4</td>
<td>4</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>14</td>
<td>18</td>
<td>Approximate count</td>
</tr>
<tr>
<td>R6</td>
<td>19</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td>16</td>
<td>22</td>
<td>Five grouse approx. 200 m from lek included in the ground count</td>
</tr>
<tr>
<td>R8</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>R9</td>
<td>0</td>
<td>2</td>
<td>Grouse observed were approx. 400 m from lek coordinates</td>
</tr>
<tr>
<td>R10</td>
<td>26</td>
<td>28</td>
<td>Approximate count</td>
</tr>
<tr>
<td>R11</td>
<td>29</td>
<td>40</td>
<td>Approximate count</td>
</tr>
<tr>
<td>R12</td>
<td>2</td>
<td>4</td>
<td>Goshawk Accipiter gentilis attacked grouse 3 min before plane arrives</td>
</tr>
<tr>
<td>C1</td>
<td>21</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>12</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>9</td>
<td>2</td>
<td>Inaccurate count; lek is on a knoll with tall brush</td>
</tr>
<tr>
<td>C4</td>
<td>10</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>11</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>19</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>C7</td>
<td>9</td>
<td>8</td>
<td>Approximate count</td>
</tr>
<tr>
<td>C8</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>C9</td>
<td>3</td>
<td>2</td>
<td>Grouse were 175–225 m from lek coordinates</td>
</tr>
<tr>
<td>C10</td>
<td>9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>C11</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>C12</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>C13</td>
<td>11</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Simultaneously conducted aerial infrared (AIR) and ground-based lek counts of Columbian sharp-tailed grouse Tympanuchus phasianellus columbianus in Idaho, USA. Lek counts were conducted in the Rockland Valley (R) on 11 April 2012 and the Curlew Valley (C) on 12 April 2012.
and unknown causes (leks C6 and R4) for the more substantial differences in simultaneous counts (Table 1). Aerial infrared counts were higher than ground counts during 8 of 25 occasions (32%). Average counts from a distance on the ground without flushing grouse (6.8 grouse ± 1.1 SE, n = 25) differed from average counts of flushing grouse (12.9 grouse ± 1.8 SE, n = 25).

Neither IR videography nor observations by personnel on the ground indicated that sharp-tailed grouse flushed from leks as a result of the airplane during AIR lek counts. The AIR method of circular flight patterns around the lek at low altitude (150–190 m above ground level) did not decrease sightability of birds on leks because sharp-tailed grouse did not flush from leks. Ground-based observers generally noted that sharp-tailed grouse initially oriented on the plane for 5–10 s and then resumed normal lekking behavior during aerial counts. Moreover, male sharp-tailed grouse territorial face-offs were observed on IR videography at 18 of 25 (72%) AIR lek counts (Figure 2). Other species-specific behavior, including aerial leaps with wing-fluttering, foot-drumming locomotion, and grouse chasing each other, were also observed on IR videography. During one lek count, an observer on the ground noted four females attending a lek; otherwise, no females were observed on leks by personnel on the ground during simultaneous counts.

Figure 2. Top image is a frame from infrared videography at a lek in the Curlew Valley, Idaho, USA, during April 2012. Columbian sharp-tailed grouse *Tympanuchus phasianellus columbianus* appear white against the background of a Conservation Reserve Program grass field. Three territorial face-offs between males (circled in red) are observed among 12 sharp-tailed grouse in the infrared image. Bottom image is a digital photograph (taken by T. Torell) of a territorial face-off among male sharp-tailed grouse.
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generally not in remote, difficult-to-access areas. From a two-track road (range = 25–1,115 m) and were ground-based observers were above the pay grade of 9 pickups, and 3 all-terrain vehicles. Seven of eight included 8 ground-based observers, 29 observer mornings, resources required by the ground-based method in- contractors for AIR are not widely available. The ferry cost in the estimate because it will likely be incurred by most agencies replicating this type of work because contractors for AIR are not widely available. The resources required by the ground-based method included 8 ground-based observers, 29 observer mornings, 9 pickups, and 3 all-terrain vehicles. Seven of eight ground-based observers were above the pay grade of a senior wildlife technician. On average, leks were 297 m from a two-track road (range = 25–1,115 m) and were generally not in remote, difficult-to-access areas.

**Table 2.** Cost ($ U.S. currency) to count 88 leks of Columbian sharp-tailed grouse *Tymanuchus phasianellus columbianus* once using both aerial infrared (AIR) and ground-based methods during March and April 2013 in southeast Idaho, USA. See text for cost calculations.

<table>
<thead>
<tr>
<th></th>
<th>AIR</th>
<th>Ground-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight time (h)</td>
<td>19.5 ($15,600)</td>
<td>—</td>
</tr>
<tr>
<td>Personnel-hours</td>
<td>—</td>
<td>151 ($4,128)</td>
</tr>
<tr>
<td>km driven</td>
<td>—</td>
<td>4,093 ($1,399)</td>
</tr>
<tr>
<td># of days vehicles rented</td>
<td>—</td>
<td>29 ($852)</td>
</tr>
<tr>
<td>Total cost</td>
<td>$15,600</td>
<td>$6,379</td>
</tr>
</tbody>
</table>

**Single counts of sharp-tailed grouse leks using both methods**

We counted 88 leks once using both AIR and ground-based methods. The AIR counts cost $177/lek, 2.5 times that of the ground-based method at $72/lek (Table 2). Aerial IR required no IDFG personnel or vehicles compared with ground-based counts (Table 2). The total flight time for AIR counts was 19.5 h during four mornings. The total cost of AIR included a 4-h ferry of the airplane to and from the study area. We retained the ferry cost in the estimate because it will likely be incurred by most agencies replicating this type of work because contractors for AIR are not widely available. The resources required by the ground-based method included 8 ground-based observers, 29 observer mornings, 9 pickups, and 3 all-terrain vehicles. Seven of eight ground-based observers were above the pay grade of a senior wildlife technician. On average, leks were 297 m from a two-track road (range = 25–1,115 m) and were generally not in remote, difficult-to-access areas.

**Discussion**

We detected sharp-tailed grouse attending leks using AIR and obtained AIR lek counts that were consistent with simultaneously conducted ground-based counts. The consistency of AIR and ground-based lek counts suggests AIR has great potential as a standard lek-count method for use throughout the range of sharp-tailed grouse and other prairie grouse species. Infrared technology has only recently become more affordable and available to wildlife biologists. Although still costly in comparison to ground-based counts, opportunity exists to refine AIR lek-count methods to reduce costs and to determine whether the technology can differentiate sex of prairie grouse.

Aerial methods, including helicopter lek surveys, may also have potential as a standard approach to monitoring populations of lesser prairie-chickens *T. pallidicinctus* (McDonald et al. 2014) and other prairie grouse; however, costs, resource requirements, and safety concerns should be addressed before these aerial methods are employed in a long-term population-monitoring strategy. Schroeder et al. (1992) estimated that aerial lek counts conducted by helicopter were four times the cost of ground-based lek counts. Counting 88 leks once using AIR was approximately 2.5 times the cost of the ground-based method. The cost of AIR in our study was exact, whereas we used the minimum estimate of the cost of ground-based counts (i.e., seven of eight ground-based observers were various levels of pay grade higher than a senior wildlife technician). Costs of lek counts, especially by ground, will vary by the number of leks counted, distance between leks, the number of repeat counts of leks, the pay grade of lek observers, participation by volunteers, the level of training lek observers require, spring weather conditions, and equipment available. Although costs of AIR and ground-based counts may vary, ground-based methods were less expensive than AIR methods in our study.

Aerial infrared and ground-based counts should not be conducted during inclement weather (i.e., precipitation or winds > 24 km/h) because weather may prevent prairie grouse from attending leks and may negatively bias counts. Inclement weather during morning lek counts influences methods similarly; however, the protocol to avoid conducting sage-grouse lek counts during inclement weather for ground-based methods has occasionally been disregarded (Connelly et al. 2003). Disregarding protocol to avoid counts during inclement weather for AIR is unlikely because of flight safety concerns. General spring weather conditions (e.g., a wet spring) can delay ground-based efforts by preventing access to leks when males are actively displaying, whereas AIR methods are unaffected by mud or snow on roads. We experienced mild spring conditions during our 2013 study when costs were compared between methods; weather did not increase cost or the time required to conduct lek counts for either method.

Probability sampling of leks requires that all leks are known or, at least, that locations of all leks within an area can be determined. Most leks in our study were found by ground-based efforts of field biologists in accord with IDFG translocation and population monitoring efforts for sharp-tailed grouse the past 20 y. However, some areas where prairie grouse occur do not have a history of intensive restoration, management, and monitoring activities where all or the majority of leks in an area are known. Aerial IR provides an efficient way to search for leks and count leks that are inaccessible to ground-based observers (e.g., private property, sites with poor or no road access), which allows for probability sampling across the range of ecological and environmental conditions available to the population of interest recommended by researchers (Anderson 2001; Garton et al. 2007, 2011). Additionally, AIR lek counts allow more of the landscape to be covered in less time. In this context, AIR lek counts are valuable auxiliary information for use in statistical population reconstruction at large scales (Broms et al. 2010) and satisfy recent suggestions for population monitoring programs to prioritize “a larger sample of individual leks” over “multiple counts of a smaller sample of leks” (Fed 2011). Counting more leks using AIR during the 2-h lek-count survey may decrease the likelihood of violating the assumption that sharp-tailed grouse do not change leks, and minimizes the limitation that all leks are not counted because of convenience sampling (Dalke et al. 1963; Johnson and Rowland 2007; Sedinger 2007).
Aerial infrared lek counts required no IDFG employees, vehicles, or agency time and ground-based counts required over seven times the number of mornings (29) that AIR required (4) to count 88 leks one time. Ground-based lek counts may be cost-effective for wildlife agencies if a lek count protocol has been adopted. However, spring data collection is a demanding time, especially for biologists managing sympatric species of lekking grouse. If challenging spring weather conditions (limiting access to leks during the breeding season) are coupled with the responsibility to monitor multiple lekking species of grouse, then wildlife managers in the Intermountain West can be faced with an impracticable task of monitoring populations in a rigorous manner using ground-based methods. For example, 67% of the active 88 leks counted in our 2013 study were visited ≤ 1 time from 2008 to 2012 using a ground-based method, which is likely insufficient for documenting population trends based on lek count data alone. Hence, it is not surprising that the validity of lek counts as an index to population size has been questioned (Applegate 2000; Walsh et al. 2004; Johnson and Rowland 2007).

The criticism of lek counts as a population index has centered on lek count assumptions (Sedinger 2007) because violating assumptions creates bias in estimates. Statistical deficiencies in lek counts will arise regardless of the method used, but standardization has improved the consistency of lek counts in general (Johnson and Rowland 2007). Increasing the standardization of lek counts can improve the statistical rigor of lek counts (Walsh et al. 2004; Johnson and Rowland 2007; Sedinger 2007). Observer bias may be a major source of variation in lek counts and can arise as a function of observer experience, training, counting effort, fatigue, memory, visual acuity, and the distance from the observer to the lek (Bibby et al. 1992; Anderson 2001; Drummer et al. 2011). Aerial IR either eliminates or decreases the likelihood of these sources of observer bias by counting more leks in less time per observer and by allowing review of IR videography in more suitable conditions (i.e., lab, office). Without standard lek-count methods for prairie grouse species, lek counts will continue to have limited utility in prairie grouse management.

Few studies can provide context for interpreting the results of our study because visibility bias associated with lek counts is rarely measured. The apparent visibility bias in our study was similar, if not lower, than sightability estimated for ground-based lek counts of greater sage-grouse; Baumgardt (2011) found that average differences between simultaneously conducted ground-based lek counts were 3.4 sage-grouse/lek. We observed a difference of 2.0 sharp-tailed grouse/lek comparing an AIR and ground-based method conducted simultaneously. Visibility bias is believed to be caused by observer variables, species characteristics, and environmental characteristics (Anderson 2001; Baumgardt 2011). In our study, we identified all of these variables as influencing sightability when differences in counts were ≥ 3 (Lek R5, R7, R11, and C3), but two causes of differences in counts were unknown (Lek R4 and C6). Furthermore, observer bias likely interacts with species and environmental characteristics to influence sightability of grouse attending leks. An observer’s knowledge and experience, or lack thereof, with grouse behavior (a species characteristic) or a lek on a knoll with tall brush (environmental characteristics) will influence to what degree visibility bias occurs for a given lek count. For example, a knowledgeable and experienced observer can approach a lek with many birds (i.e., lek R5 or R11) or a lek on a knoll with tall brush (i.e., lek C3) in multiple ways to reduce visibility bias caused by those characteristics (Table 1).

We did not have sufficient sample sizes or resources to test factors influencing sightability of sharp-tailed grouse attending leks. Research is needed that investigates the magnitude of effect that observer variables, environmental characteristics, and species characteristics have on sightability during AIR and ground-based lek counts of prairie grouse species. For example, environmental characteristics that influence visual obstruction of grouse on leks (e.g., percent cover or height of grass and shrubs) could influence sightability of grouse using AIR. Similarly, prairie grouse attending leks with greater concealment cover may be less likely to flush and less likely to be counted by ground-based observers. It is unknown which lek count method is more likely to detect a lek associated with inaccurate coordinates or a lek that has moved > 200 m. Research regarding AIR should also focus on technology that is capable of interfacing with IR cameras. For example, IR cameras can be equipped with a laser that provides coordinates of where the camera is pointing to on the ground as well as the distance to the center of the camera field of view. Because the exact distance to the target lek from the camera is currently unknown and can vary during AIR counts, this information will help increase standardization of AIR counts, decrease observer bias, and increase the likelihood of successfully using AIR to differentiate sex as a function of behavioral and thermal characteristics. We expect a difference in thermal emissivity of male and female sharp-tailed grouse on leks because energy expenditure during male display behavior is costly and can be as much as 17 times basal metabolic rates (Vehrencamp et al. 1989). The ground-based observer at lek R1 (Table 1) identified at least four female sharp-tailed grouse during the ground-based count. During the AIR count of lek R1, a difference in thermal emissivity of five sharp-tailed grouse was visually observed in comparison with other thermal signatures of grouse attending the lek (Figure 3). If the distance from the camera to the target is known, then using metrics in ExaminIR software to identify an expected thermal emissivity of male and female prairie grouse and distinguish between sexes is more likely to occur. Observation of male display characteristics coupled with apparent differences in thermal emissivity of grouse during AIR lek counts may allow analysts to distinguish sexes of prairie grouse with Examin IR software during AIR counts.

Aerial IR surveys do not require disturbing grouse by flushing birds from leks as ground-based methods require. Aerial IR allows a spatial evaluation of leks in addition to evaluating the size of leks by providing a spatial map of the location of grouse on the lek—
something that a ground-based method does not easily provide. Changes in the spatial footprint of a lek may provide insight into territorial behavior or other lek dynamics that are difficult to quantify.

Management Implications

Results suggest AIR has potential as a standardized method for monitoring prairie grouse, especially when leks are inaccessible by ground. We caution against AIR lek counts if ambient air temperature is $> 15^\circ$C. The AIR lek-count method using fixed-wing aircraft can be half the cost of using helicopters. Aerial IR lek counts can mitigate nonfiscal resource constraints in population monitoring programs because a high number of leks (approx. 100) can be counted during a short time frame (four mornings) and without requiring wildlife agency personnel or vehicles. Some wildlife agencies have sought to decrease employee time in low-flying aircraft during wildlife surveys as a safety precaution. In our study, IDFG employees were not present in aircraft during AIR lek counts because the contractors were experienced in aerial wildlife surveys, especially AIR lek counts. Ground-based lek counts without flushing grouse were inaccurate in our study. Until a standard lek count is adopted for prairie grouse, lek count databases are more likely to be compatible across a species’ range and inform conservation decisions if non-AIR lek counts always consist of a flush count.

Supplemental Material

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Found at DOI: http://dx.doi.org/10.3996/022015-JFWM-008.S2; also available at http://sagemap.wr.usgs.gov/docs/Greater_Sagegrouse_Conservation_Assessment_060404.pdf (15.9 MB PDF).

Reference S3. The following references are all contained in Reese KP, Bowyer RT. 2007. Monitoring populations of sage-grouse. Moscow, Idaho: University of Idaho. College of Natural Resources Experiment Station Bulletin 88.


Figure 3. Infrared image of 17 Columbian sharp-tailed grouse *Typanuchus phasianellus columbianus* on a lek (R1) against a background of sagebrush, rabbitbrush, and crested wheatgrass during April 2012 in Rockland Valley, Idaho, USA. A ground-based observer noted $\geq 4$ females attending this lek during the aerial infrared count. Five thermal signatures of sharp-tailed grouse (circled in yellow) appear $\geq 1^\circ$C lower compared with other sharp-tailed grouse thermal signatures in red.
sampling approach to estimate greater sage-grouse population characteristics. Pages 31–41.


Found at DOI: http://dx.doi.org/10.3996/022015-JFWM-008.54; also available at https://archive.org/details/locatingsharptail00gren (8427 KB PDF).


Found at DOI: http://dx.doi.org/10.3996/022015-JFWM-008.55; also available at http://noss.cos.ucf.edu/papers/Noss%20et%20al%201995.pdf (2249 KB PDF).


Acknowledgments

This research was funded by the Idaho Department of Fish and Game (IDFG), U.S. Forest Service (USFS), the National Wild Turkey Federation, and a Conservation Innovation Grant awarded by the Idaho Natural Resources Conservation Service.

We thank J. Romero, D. Gotsch, M. Wackenhut, and Z. Lockyer for their coordination efforts. We thank Owyhee Air Research, USFS, and IDFG employees for lek count efforts. We thank the private landowners of the Rockland and Curlew valleys for access to their lands. We thank J. Maselko, D. Leptich, and two anonymous reviewers for comments that improved early drafts of this manuscript. This is a contribution from Idaho Federal Aid in Wildlife Restoration Project W-160-R.

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