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Monitoring of Greater Sage-grouse Habitats and Populations

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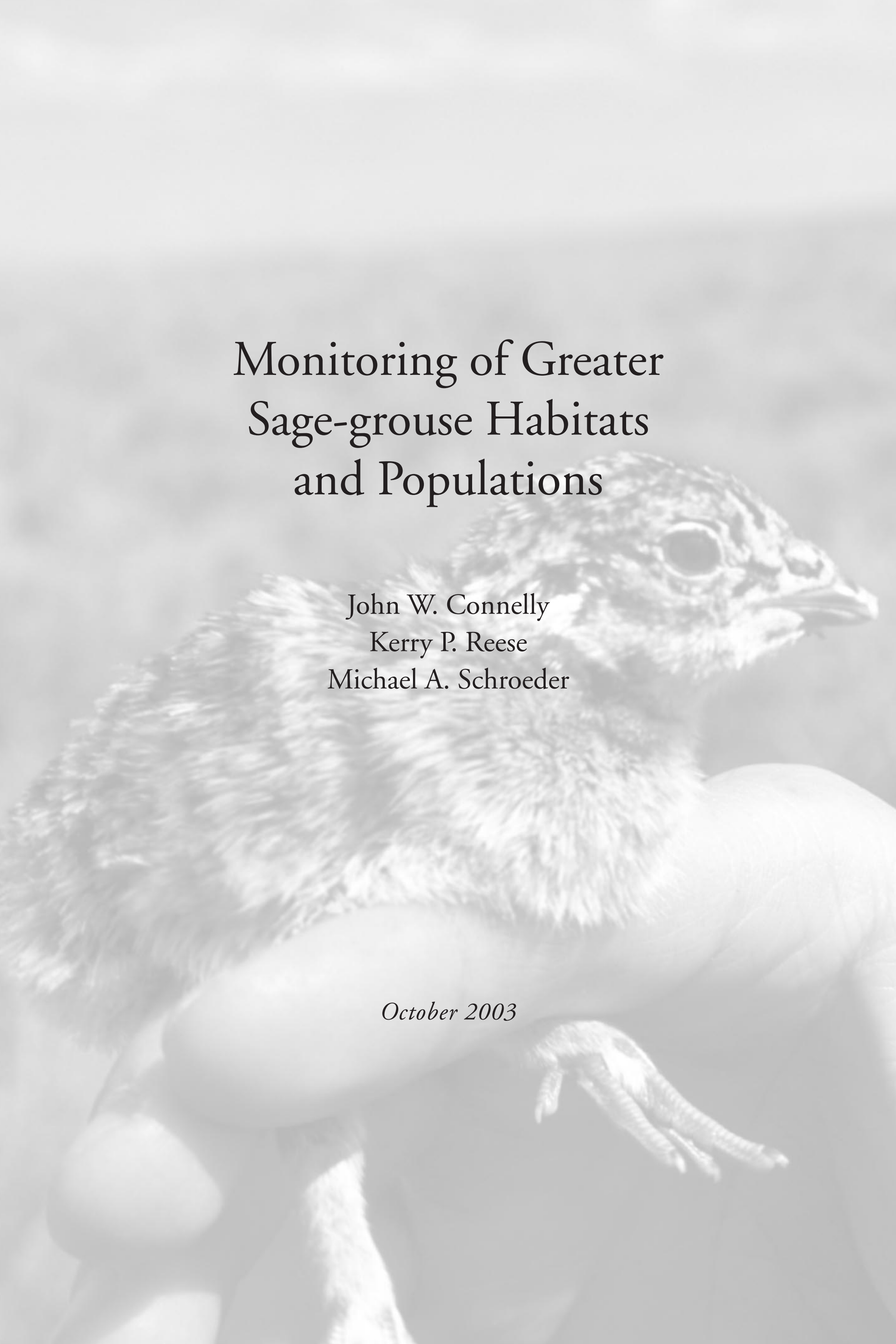

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Acknowledgments

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Introduction

Numerous studies have reported on characteristics of greater sage-grouse (*Centrocercus urophasianus*) populations and habitats throughout the species' range (Gregg et al. 1994, Fischer et al. 1996*a*, Schroeder 1997, Apa 1998, Sveum et al. 1998, Commons et al. 1999, Lyon 2000, Nelle et al. 2000, Smith 2003, and others). Additionally, Connelly et al. (2000*b*) provided guidelines for managing sage-grouse populations and habitats and identified monitoring as an important component of a sage-grouse management program.

Most studies of sage-grouse relied on published techniques for assessing range vegetation, monitoring, and trapping sage-grouse (Canfield 1941, Daubenmire 1959, Floyd and Anderson 1982, Giesen et al. 1982, Emmons and Braun 1984, Wakkinen et al. 1992, Burkepile et al. 2002, Connelly et al. 2000*a*, and others). However, published methods for assessing vegetation were not developed specifically for sage-grouse habitats. Some population monitoring techniques have not been described in detail while others were based on work done in a single area or over a relatively short time.

Because of declines in sage-grouse populations (Connelly and Braun 1997, Braun 1998) and continuing threats to this species and its habitats (Connelly and Braun 1997, Wambolt et al. 2002), standard techniques for monitoring populations and habitats are necessary to allow valid comparisons among areas and years and provide rigorous and consistent data sets. To date, no effort has been made to compile and standardize all major monitoring techniques useful for assessing sage-grouse habitats and populations. The purpose of this report is to describe various techniques suitable for assessing sage-grouse habitat characteristics, monitoring sage-grouse populations, and capturing and marking sage-grouse. We attempt to standardize techniques where variations may exist and make recommendations about the use of some techniques. We also provide a glossary at the end of this report to help standardize terms used in sage-grouse management. We intend this report to be used with the guidelines to manage sage-grouse populations and their habitats (Connelly et al. 2000*b*).

Habitat Assessment

Sagebrush (*Artemisia* spp.) habitats have changed markedly over the last 25 to 50 years and fire and agricultural development have played major roles in this change in many portions of the west (Knick and Rotenberry 1997, Connelly et al. 2000*a*, Wambolt et al. 2002). In other areas, energy development has impacted sagebrush rangeland (Braun 1998, Lyon 2000). Recently, revised guidelines for managing greater sage-grouse populations and habitats were published (Connelly et al. 2000*b*). These guidelines strongly suggest that management decisions should be based on the best available data. Therefore, the quality and quantity of sage-grouse habitats must be documented to make appropriate management decisions. There are four general reasons for assessing habitats: 1) to document current condition and trend of habitat; 2) to evaluate impacts of a land treatment; 3) to assess the success of a habitat restoration program; and 4) to evaluate the ability of habitat to support a reintroduced population. This section provides information on how sage-grouse habitat assessments may be made for any of these reasons and discusses techniques used to make these measurements.

In virtually all cases, habitat characterization should follow habitat selection processes described by Johnson (1980). Therefore, habitat assessment should initially reflect first-order selection or the geographic range of the sage-grouse population of interest. Within this range, second-order selection of habitat should be examined based on home ranges of individuals or subpopulations (e.g., birds associated with a lek or lek complex). Assessing the condition of various habitat components within the home range describes third-order selection and further refines the habitat assessment process (e.g., breeding habitat). Finally, if necessary, assessment can be made at the fourth-order selection level that involves the quality and quantity of food or cover at particular use sites.

LANDSCAPES

Many, if not most, sage-grouse populations are migratory, have large annual ranges, and use different habitats at different times of the year (Connelly et al. 1988, 2000*b*). For non-migratory populations these habitats may be well interspersed but for migratory populations they may be separated by many kilometers (Schroeder et al. 1999; Connelly et al. 1988, 2000*b*, Leonard et al. 2000). Before assessing habitats over a landscape, seasonal movements by grouse must be well understood. Once these data have been obtained, the size and quality of the available habitats can be measured. Aerial photos, satellite imagery, and digitized maps can be used to measure the size and juxtaposition of these habitats (Homer et al. 1993). Remote sensing technology will often form the basis for inventorying, evaluating, and monitoring rangeland resources (Tueller 1989, Anderson and Gutzwiller 1994). Landscape assessment corresponds to first-order habitat selection (Johnson1980). Landscape characteristics that should be measured include patch size, habitat quality, connectivity (availability of corridors connecting patches), amount of edge and distance between habitat patches. Hamerstrom et al. (1957) provided an early example of landscape assessment for managing greater prairie chickens (*Tympanuchus cupido*).

For non-migratory populations, seasonal habitats should be well interspersed with no major barriers (e.g., reservoirs, urban areas) between habitats. These areas (sagebrush uplands, mesic areas) can be identified by aerial photographs, satellite imagery, or field inspection and mapping. Generally, breeding habitats may be about 23 km^2 (Wallestad and Pyrah 1974), summer habitats may range from 0.4 to 0.9 km^2 in Montana (Wallestad 1971) to 28 km^2 in northeastern Colorado (Hausleitner 2003). Winter ranges may vary from 11 to 31 km^2 (Wallestad 1975).

For migratory populations, grouse may use an area the size of the state of Rhode Island on an annual basis, and these movements may vary depending on annual precipitation (Connelly 1982, Fischer et al. 1996*b*). However, within this large area there are specific seasonal habitats used by these birds each year. These habitats may be disjunct, but corridors dominated by sagebrush should connect adjacent seasonal ranges. These ranges may vary in size, but generally breeding habitats will be 150 to more than 600 km^2 (Leonard et al. 2000, J. W. Connelly unpublished data), summer range will be 0.5 to 7 km^2 (Connelly and Markham 1983) and winter range may exceed 400 km^2 (Leonard et al. 2000).

A study by Leonard et al. (2000) provides an example of the use of remote sensing for analyzing spatial components and juxtaposition of sage-grouse seasonal habitats for a migratory sage-grouse population. On a landscape scale, this study compared seasonal habitats available to sage-grouse in the 1970s with those available in the 1990s. Analysis was based on landsat imagery obtained from the U.S. Geological Survey's Earth Resources Observation Systems Data Center. Image processing software was used to classify habitats from this imagery. Land ownership was documented with Arc View software (ESRI, Inc., 380 New York St., Redlands, CA 92373-8100). This research indicated that agricultural lands within sage-grouse habitat in eastern Idaho increased by more than 70% over a 17 year period, and also showed an inverse relationship between development of cropland and sage-grouse population levels (Leonard 1998, Leonard et al. 2000).

Landscape analysis is becoming a relatively common approach for assessing sage-grouse habitat. Oyler-McCance et al. (2001) employed a landscape approach similar to that of Leonard et al. (2000) to assess changes in habitat for Gunnison sage-grouse (*C. minimus*) in Colorado. A Geographic Information System and low-level aerial photographs allowed researchers to document changes in sagebrush-dominated habitats between the 1950s and 1990s (Oyler-McCance et al. 2001). Smith (2003) also used a similar approach to investigate sage-grouse habitat in the Dakotas.

VEGETATION

The type and amount of vegetation data recorded usually depends on the goal of the habitat assessment or research project but may also be influenced by time, budget, and manpower limitations. Regardless of the goal of the study, an unbiased characterization of habitat will require random sampling and this approach will often be a stratified random sample. The strata will depend on vegetative and topographic characteristics of the area. Thus, involving a statistician in the early planning stages should result in a characterization that will withstand critical review.

Long-term studies (normally more than 3 years) often involve numerous personnel changes. Therefore, data collection techniques should be adequately described to all personnel, all field personnel should receive adequate training, and these techniques should generally not be modified during the study. This approach will result in consistent data collection among years and observers.

Most habitat assessments for sage-grouse include estimates of one or more of the following: cover, height, density, frequency, and visual obstruction for individual plant species or groups of species. Density is the number of individuals per unit area (e.g., plants/m^2) and can be used to assess the abundance of specific plants important to sage grouse. Frequency is the percentage of plots of uniform size, in a series of samples, in which a specified species or genus occurs (Daubenmire 1968). Frequency can be used to assess the relative abundance or distribution of specific plants. Visual obstruction reflects the relative density and height of a stand of vegetation. The term "cover" is generally used in vegetation field studies to describe ground cover (plant material, litter, rocks, or bare soil at the ground surface) or the canopy projection of a plant. Canopy cover is the attribute most often measured to characterize sage-grouse habitat.

Density, height, and frequency are direct counts or measurements, but a number of methods exist to estimate canopy cover (Table 1). Three general approaches are used to quantify shrub and herbaceous canopy cover in shrub steppe habitats: line transects, quadrats, and ocular estimates (Table 1). Line transect methods are generally more suitable for estimating shrub cover while quadrat methods have advantages in estimating herbaceous cover. Within each of these general categories several techniques have been developed. Often, different techniques will yield comparable results. Hanley (1978) reported that line interception and Daubenmire plots gave similar results for estimating canopy cover of sagebrush in northwestern Nevada. However, line intercepts are preferable to Daubenmire frames when high levels of precision and confidence are required (Hanley 1978). Common techniques for estimating canopy cover in sagebrush- dominated rangeland will be discussed under their respective vegetation types below.

Table 1. Attributes of methods used to estimate canopy cover in shrub-steppe habitats. Yes or no indicates suitability of the technique.

	Technique					
	Line Transect		Quadrat Methods			Ocular Estimate
Characteristic Attribute	Line Intercept	Point Intercept	Daubenmire Plot	Circular Plot	Point Intercept Frame	
Shrub Cover	Yes	Yes	Yes	Yes	Yes	
Time[a]	2	2	1	3	2	1
Precision[b]	3	2	1	2	2	1
Replication[c]	2	1	2	2	2	1
Other measures[d]	1,3,4	1,3,4	1,3,4	1,2,3,4		—
Herbaceous Cover	Yes	Yes	Yes	Yes	Yes	
Time[a]	2	2	1	NA[e]	1	1
Precision[b]	2	2	3	NA	3	1
Replication[c]	2	2	2	NA	2	1
Other measures[d]	1,3,4	1	1,2,3,4	NA	1,2,3,4	—
Reference	Canfield 1941	Evans and Love 1957	Daubenmire 1959	Connelly 1982	Floyd and Anderson 1982	Daubenmire 1968

[a]Approximate time needed to complete a plot, line, or area: 1 = less than 10 minutes; 2 = 11-30 minutes; 3 = 31-60 minutes for a 20 m transect, standard Daubenmire plot and point intercept frame and 1-m radius circular plot.

[b]1 = low; 2 = medium; 3 = high.

[c]An indication of the relative bias involved in repeating the process by other observers: 1 = not easily replicated, large differences may occur among different observers; 2 = easily replicated, few differences should occur among different observers.

[d]Other data that can be recorded while using this technique: 1 = height; 2 = density; 3 = frequency; 4 = species composition.

[e]NA = not applicable

Several methods are used to measure visual obstruction (Table 2). Unlike measurements of canopy cover, density and frequency, visual obstruction is not specific to individual species or genera of plants. Instead, these techniques provide a value that indicates the relative cover of all vegetation, alive and dead, at a given point. This value reflects both the density and height of vegetation. For sage-grouse, these data are most useful for assessing nesting cover. However, a visual obstruction value alone may have limited use in describing nesting habitat because the same value could be obtained for habitats dominated by sagebrush (i.e., potentially important for nesting sage-grouse) or dominated by other shrubs or grasses (i.e., not generally important for nesting grouse).

Table 2. Attributes of methods used to estimate visual obstruction in shrub and grass dominated habitats.

	Technique			
Attribute	Robel Pole	Cover Pole	Jones Cover Board	Profile Board
Time[a]	1	1	1	1
Precision[b]	2	2	1	2
Replication[c]	2	2	1	2
Other measures[d]	1	1	1	1
Reference	Robel et al. 1970	Griffith and Youtie 1988	Jones 1968	Nudds 1977

[a]Approximate time needed to complete a plot, line or area: 1 = less than 10 minutes; 2 = 11-30 minutes; 3 = 31-60 minutes.

[b]Estimated for use in sagebrush dominated habitats only: 1 = low; 2 = medium; 3 = high.

[c]An indication of the relative bias involved in repeating the process by other observers: 1 = not easily replicated, large differences may occur among different observers; 2 = easily replicated few differences should occur among different observers.

[d]Other data that can be recorded while using this technique: 1 = height; 2 = density; 3 = frequency; 4 = species composition.

Sometimes classification of dominant vegetation within an area is necessary (e.g., classifying the relative amount of sagebrush-dominated habitat within an area of rangeland). If so, Marcum and Loftsgaarden (1980) described a simple non-mapping technique for describing general habitats. This method involves selecting a number of random points within the area of interest, locating those points (easily accomplished from the ground or air with a GPS unit) and classifying the dominant vegetation at each point (e.g., sagebrush, annual grass, bare ground, etc.). Marcum and Loftsgaarden (1980) also provided an appropriate method of analyzing these data.

More recently, Rotenberry et al. (2002) described a model that predicts animal use based on a minimum combination of the species' requirements. They reported that this model functioned well for predicting habitat use by sage sparrows (*Amphispiza belli*) in an altered landscape.

Sather-Blair et al. (2000) described an approach to assessing sage-grouse habitats and making management decisions based on these assessments. Although numerous methods may be used to characterize sagebrush landscapes, Sather-Blair et al. (2000) presented a qualitative method and two quantitative methods for gathering data. Methods of habitat assessment may vary but all should be relatively objective and biologically defensible.

SHRUB VEGETATION

Prior to measuring characteristics of shrub vegetation, observers should be able to identify different species of shrubs as well as differentiate among the different species and subspecies of sagebrush. Several keys have been published to aid identification of sagebrush taxa (e.g., Atwood 1970; Winward and Tisdale 1969, 1977; Shultz 1984).

Cover

Shrub, specifically sagebrush, overstory is a vital component of sage-grouse habitat. Normally, shrub overstory is referred to as canopy cover and is defined as a projection of the crown or stems of the plant onto the ground surface (Higgins et al. 1994). It is the most commonly reported measurement in studies of sage-grouse habitat. Live shrub canopy cover allows an assessment (along with measurements of herbaceous vegetation) of the suitability of an area as sage-grouse nest habitat, early brood-rearing habitat, and winter habitat. In virtually all cases, the species and subspecies of shrub are noted and data for each are recorded separately.

Line intercept (Canfield 1941) is one of the most common techniques used to estimate shrub canopy cover (Figure 1). This technique involves stretching a tape out (usually for 15 to 50 m) and measuring the amount of the live shrub canopy intersected by an imaginary vertical plane that is bisected lengthwise by the tape (Appendix 1). Care should be taken to exclude large spaces (e.g., 5 cm and greater) between branches or foliage so that only live shrub cover intersecting the line is counted (Baker 1968). The amount of total shrub intersecting the line is tallied and then divided by the length of the line (example: 580 cm of sagebrush/2500 cm of total line = 23.2% canopy cover). Often, line intercepts are run in conjunction with the Daubenmire technique (Daubenmire 1959) to estimate herbaceous cover (see Herbaceous vegetation section).

Figure 1. The line intercept method is used to measure shrub canopy cover.

Line intercept may be somewhat more time consuming than other methods of estimating cover, but it is less subjective than other methods, generally has greater accuracy and precision than other methods (Higgins et al. 1994), and is widely accepted as a method for estimating shrub canopy cover. Use of line intercept also allows direct comparison with data from many other studies because this is a very common method of measuring sagebrush canopy cover (Wakkinen 1990, Connelly et al. 1991, Gregg et al. 1994, Fischer 1994, Holloran 1999, Lyon 2000).

Point intercept (Evans and Love 1957, Hanson et al. 1988, Sather-Blair et al. 2000) involves dropping a pin or small-diameter rod to the ground (or using a notch or point at the toe of a boot) and recording a hit each time the pin strikes a portion of the canopy. Canopy cover is calculated as the total number of hits divided by the total number of pin drops times 100. The diameter of the pin and the way in which the pin is dropped or lowered towards the ground can affect the accuracy of the estimate (Higgins et al. 1994). Very large numbers of samples are needed in areas with sparse shrub overstory. Thus, this may be a very inefficient method of sampling areas characterized by relatively few shrubs (Heady et al. 1959, Higgins et al. 1994). Hanson et al. (1988) evaluated three types of point methods for estimating cover: step-point, wheel-point, and point-frame. They reported that data obtained from step-point and wheel point methods differed from that obtained from the point-frame method. They also indicated that all methods were subject to operator bias. In most sagebrush stands, point methods will provide results comparable to those generated by line intercept, but the point intercept may often be faster (depending on the number of samples needed) and perhaps subject to greater observer bias than the line intercept.

Quadrat sampling has been used to estimate shrub canopy cover (Connelly 1982, Aldridge 2000). This technique involves estimating the amount of cover of individual species or groups of species occurring within a frame placed on or just above the ground. Quadrats can vary in size and shape, but are often square or rectangular. The Daubenmire frame (Daubenmire 1959) and variations of this frame (Leonard 1998) are some of the most common types of quadrat sampling frames. Some frames can be relatively bulky and awkward (e.g. point intercept frame [Floyd and Anderson 1982], but many can be easily constructed to be highly portable in the field (Neal et al. 1988)

The circular plot (Connelly 1982) is another form of quadrat sampling that is seldom used. It was originally developed to estimate cover on big game winter range (Lyon 1968, Peek et al. 1978) and was subsequently used to characterize sage-grouse winter habitat (Connelly 1982). This technique requires establishing circular plots (often 1-m radius) along a transect in the area of interest and measuring the width and length of sagebrush plants within these plots. The average crown area for plants can be estimated from these measurements and the percentage of the crowns covering the total area encompassed by plots provides an estimate of canopy cover.

One advantage of quadrat techniques is that they also allow a relatively quick estimate of shrub density. Unfortunately, the definition of canopy cover used for some quadrat sampling techniques (e.g., Daubenmire frame) differs somewhat from the definition used in the line intercept technique. Often in quadrat sampling, canopy cover is considered the surface area over which a plant has influence, thus root systems can be included and plant canopies are viewed as polygons. Because of this, quadrat sampling (using this definition of canopy cover) may over-estimate nesting cover for sage-grouse.

Ocular estimates are also used for estimating shrub cover (Leonard 1998). Although the Daubenmire frame may be considered an ocular estimate (Higgins et al. 1994), it involves the use of a sampling frame and cover classes that provide similar estimates regardless of the number of observers (Daubenmire 1959). True ocular estimates are simply characterizations of the canopy cover, sometimes by cover class, but without the aid of sampling frames or other standardized techniques. This approach may be useful for broad categorizations (Leonard 1998) but is subject to a great deal of observer bias and is difficult to standardize among observers. Thus, it should only be used to roughly characterize shrub cover in a stand.

Density

The number of shrubs per unit area is sometimes of interest in sage-grouse habitat studies. However, density by itself does not provide a sufficient characterization of shrub overstory for nesting or wintering birds. As an example, a relatively high density of shrubs could be produced following successful seedling establishment, but overall canopy cover would be low and plants would be very short because of their young age. This parameter may be most useful in assessing the success of an effort to reseed sagebrush or natural regeneration of sagebrush following a disturbance.

Density can be estimated by counting the number of shrubs occurring in plots established within the area of interest. These plots are often placed along transects randomly established within the study area.

Frequency

The frequency of shrub species or subspecies is not normally collected when assessing the shrub component of sage-grouse habitat. However, some species, subspecies, or plants of sagebrush are preferred over others by foraging sage-grouse (Remington and Braun 1985, Welch et al. 1988, Welch et al. 1991). Thus, frequency of preferred plants may provide an indicator of overall habitat quality, especially for sage-grouse winter range. Frequency may also help to minimize errors related to use of different observers and may help indicate trend over time (R. Miller, personal communication). Frequency of important shrubs can be assessed using quadrat-sampling procedures that employ relatively large frames or plots and allow counting individuals within a series of samples of uniform size (i.e., frames) contained in a single stand (Daubenmire 1968). Frequency can also be measured with points (Higgins et al. 1994). The point of a pin or small-diameter rod is dropped to the ground repeatedly (usually along a transect). The percentage of hits for each species encountered gives an estimate for the frequency of those species. If frequency information is needed, it is most efficiently collected while assessing shrub density.

Height

Most sage-grouse use breeding habitats characterized by sagebrush 40-80 cm tall (Connelly et al. 2000*b*). During winter, sage-grouse feed on relatively short sagebrush, at least with respect to its height above snow (Robertson 1991, Connelly et al. 2000*b*). Shrub height is normally measured in conjunction with estimating canopy cover. The tallest live part of shrubs occurring along a transect or within a plot is recorded (Figure 2). Normally the average height is reported. Time of year may affect height measurement and observers should indicate whether seed heads were included in their measurements.

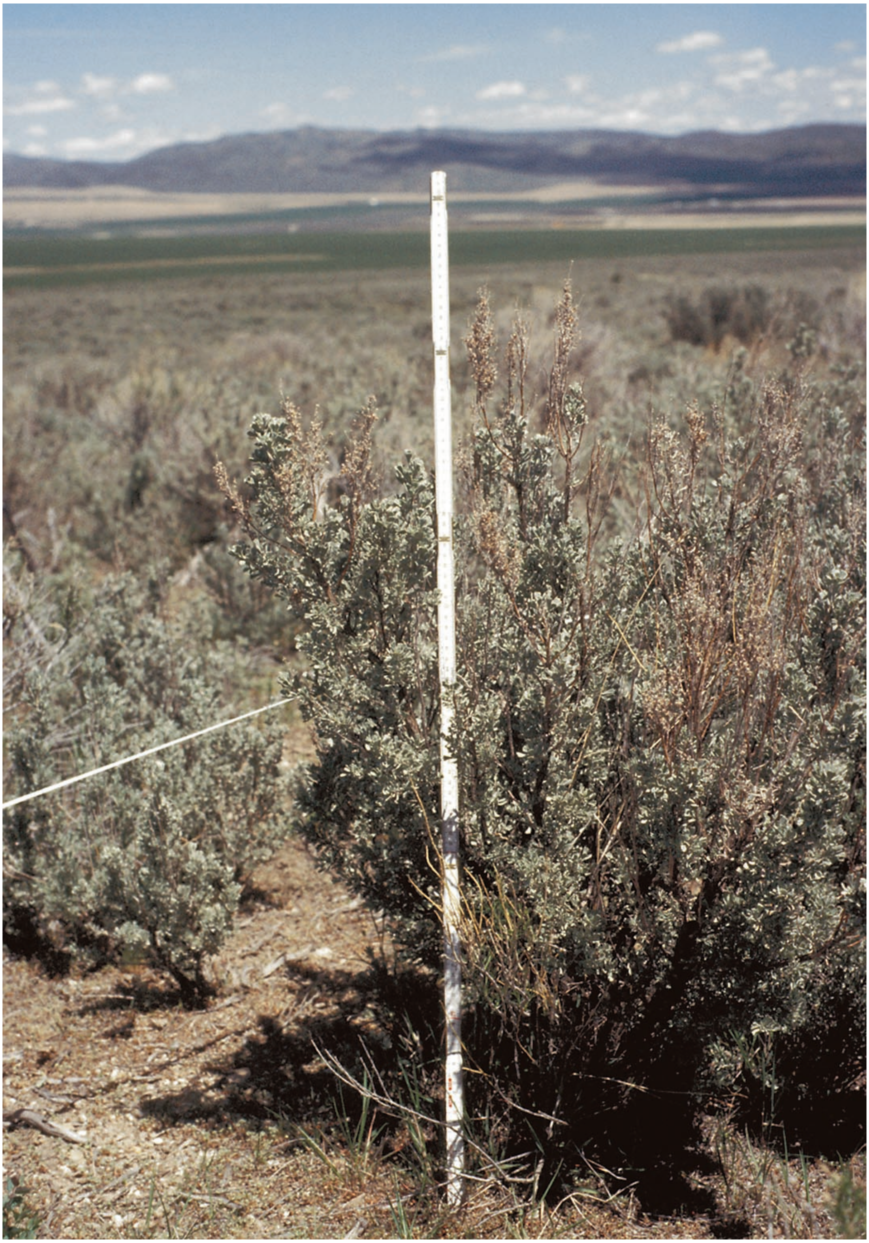


Figure 2. Shrub and grass heights are measured with a meter stick.

HERBACEOUS VEGETATION

Cover

Herbaceous understory is a critical component of sage-grouse breeding, early brood-rearing, and summer range. One of the most common methods for assessing the condition of this vegetation is by estimating canopy cover (Fischer 1994, Gregg et al. 1994, Hanf et al. 1994, Apa 1998, Lyon 2000). Canopy cover of herbaceous vegetation can be estimated using the same techniques described for estimating shrub canopy cover. However, quadrat and point intercept sampling are generally faster than line intercept. The Daubenmire technique (Figure 3) is one of the most common methods of estimating herbaceous cover (also litter and bare ground) in sagebrush steppe habitats (Daubenmire 1959). Regardless of method used, cover for both grasses and forbs should be recorded by species, and measurements are normally recorded in late May and early June to coincide with hatching.

Except in a very general way (e.g., classifying herbaceous cover as relatively dense or sparse), ocular estimates should be avoided because shrub overstory can block much of the understory from view. Moreover, shrubs and grasses may obscure the forb component.

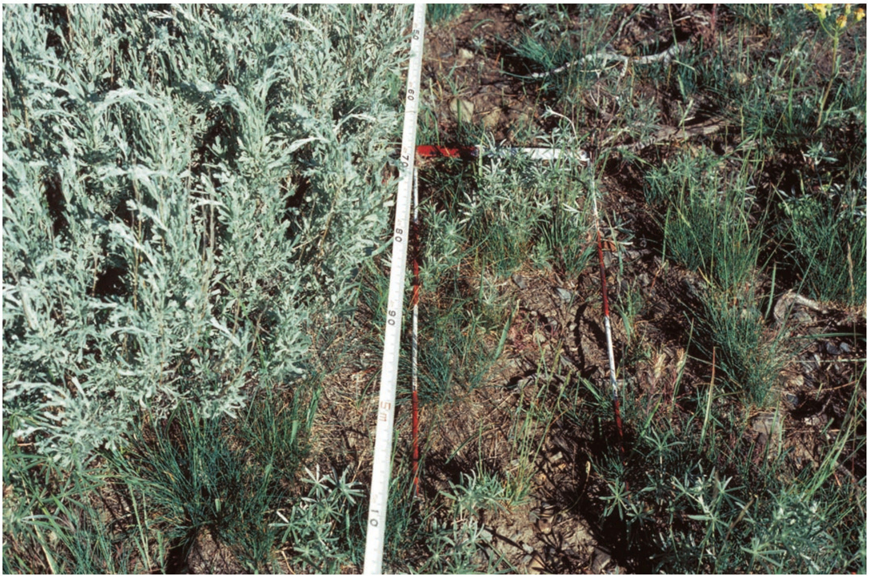


Figure 3. Daubenmire frame placed along a 50-m tape for estimation of herbaceous cover.

Density

The density of important forbs can provide an indication of habitat quality for pre-laying hens (Barnett and Crawford 1994) and early brood-rearing. Density can be estimated by counting the number of individual plants in circular, square or rectangular quadrats. The quadrat should be large enough so that the species of interest occurs in a majority of quadrats examined, yet small enough to allow counting of individuals in an efficient manner.

Frequency

Assessing the quality of breeding and brood-rearing habitat often involves identifying and quantifying forbs available for pre-breeding hens and, following hatch, chicks (Barnett and Crawford 1994, Drut et al. 1994). Frequency of important forbs can be assessed using any of the quadrat sampling procedures that allow counting individuals within a series of samples of uniform size (i.e., frames) contained in a single vegetative stand (Daubenmire 1968). Hyder et al. (1963) suggested that a quadrat 230 to 645 cm^2 was appropriate for frequency sampling in a sagebrush habitat in eastern Oregon. If frequency information is needed, it can be collected while assessing herbaceous cover or density.

Height

Herbaceous cover averaging 18 cm and greater in height has been identified as an important characteristic of sage-grouse nest sites (Wakkinen 1990, Gregg et al. 1994). This was supported by an experiment with artificial nests in Oregon (Delong et al. 1995). Height of grasses and forbs (both residual and new growth) can be easily obtained along transects or within quadrats established for estimating cover. When mature, most grasses and many forbs tend to bend or droop somewhat near the top of the plant, often because of the weight of the seed head. Normally, the natural or droop height of the plant should be recorded, rather than total length. This will provide a better indication of the lateral cover afforded by the herbaceous vegetation than would a measurement of total length. Height measurements for sage-grouse studies have normally been made in late May and early June, and coincide with hatching. Windy conditions may affect the accuracy of height measurements and if wind is a problem, measurements should be deferred until winds decrease. A modified, sample data sheet used in research on sage-grouse habitat in southern Idaho is presented in Appendix 2.

VISUAL OBSTRUCTION

The Robel pole (Robel et al. 1970), cover pole (Griffith and Youtie 1988) and Jones cover board (Jones 1968) can be used to assess visual obstruction (cover) in sagebrush-dominated rangeland (Wakkinen 1990, Fischer 1994, Gardner 1997). Nudds (1977) also described a cover board that may have application in sagebrush rangeland. Although a Robel pole provided some useful data for analyzing nest sites, the Jones cover board (3-sided or 4-sided) did not appear sensitive enough to detect differences that might have occurred among areas and may not be easily repeated by different observers (Wakkinen 1990, Fischer 1994). The Jones cover board is shorter than a Robel pole and, because of its height, most of the readings from this cover board tend to be grouped near 100% in some sagebrush habitats (Wakkinen 1990). However, Fischer (1994) and Apa (1998) successfully used the Jones cover board to help differentiate sage-grouse nest sites from dependent random sites. The Robel pole (Figure 4) was developed to assess habitat characteristics for greater prairie chickens in grassland habitat (Robel et al. 1970). Its use is now generally widespread and it appears applicable for numerous species and habitats, unless vegetation is very sparse (Higgins et al. 1994). The cover pole (Griffith and Youtie 1988) was developed to assess deer hiding cover in a variety of habitats including sagebrush-dominated rangeland. It has not been widely used to assess sage-grouse habitat and its application for these habitats should be investigated. Given the lack of data on cover poles in sage-grouse habitat and the concern expressed over the use of the Jones cover board, we generally recommend the Robel pole for assessing visual obstruction in sage-grouse habitat.

INSECTS

Insects are an important component of early brood-rearing habitat (Patterson 1952, Klebenow and Gray 1968, Johnson and Boyce 1990). A complete assessment of early brood-rearing habitat should include an evaluation of insect abundance. Several methods exist for estimating insect numbers including sweep nets, beating sheets, and pitfall traps (Fischer 1994). Ants and beetles are often the most important groups of insects for young sage-grouse chicks (Johnson and Boyce 1990, Fischer et al. 1996*a*), and their abundance can easily be assessed with pitfall traps. Pitfall traps can vary in size and shape. A common method of using this technique in sage-grouse habitat is to place test tubes so that they are flush with the ground in a grid arrangement (e.g., a 4x4 grid with tubes placed 50 cm apart) (Nelle 1998). Tubes are filled with a 1:1 solution of water and ethylene glycol and then sealed with a cork or rubber stopper until sampling begins. We suggest sampling over at least one 24-hour period from late May to mid-June (a time coinciding with the early brood-rearing period).

Figure 4. Robel pole showing amount of visual obstruction at a successful sage-grouse nest.

Population Monitoring and Assessment

Sage-grouse populations in various parts of western North America have been monitored for well over 50 years (Patterson 1952, Dalke et al. 1963). Unfortunately, even within a given state, monitoring techniques have varied among areas and years. This variation complicates attempts to understand grouse population trends and make comparisons among areas. Incomplete information on sage-grouse seasonal movements and the juxtaposition of various seasonal habitats also inhibits a manager's ability to understand population trends and effects of habitat changes. Thus far, only Autenrieth et al. (1982) attempted to standardize population data collection techniques and describe methods available for documenting sage-grouse population characteristics. The sage-grouse guidelines (Connelly et al. 2000*b*) stress the importance of population monitoring and collecting quality data in sage-grouse management programs. This section describes methods for routine monitoring as well as techniques for capturing and marking sage-grouse if more detailed information is necessary.

MONITORING

BREEDING POPULATIONS

Because sage-grouse gather on traditional display areas (leks) each spring, wildlife biologists are afforded relatively easy methods for tracking breeding populations. These methods include lek censuses (annually counting the number of male sage-grouse attending leks in a given area), lek routes (annually counting the number of male sage-grouse on a group of leks that are relatively close and represent part or all of a single breeding population or deme), and lek surveys (annually counting the number of active leks in a given area). All monitoring procedures are conducted during early morning (1/2 hour before to 1 hour after sunrise), with reasonably good weather (light or no wind, partly cloudy to clear) from early March to early May. Timing is dependent on elevation of leks and persistence of winter conditions. Sage-grouse will begin displaying in late February at lower elevations with milder climates and in years with mild winter weather (e.g., southern Washington). Lek attendance will persist into early or mid-May at higher elevations.

Locating Leks

Before a monitoring program for sage-grouse breeding populations can be designed, lek locations must be documented. Leks can be located by searching from the ground or air from early March to early May.

Helicopters or fixed-wing airplanes can be used for air searches. In either case, suspected breeding habitat should be flown on north - south transects with lines about one km apart. Transects should be flown 100 to 150 meters above ground level. Whenever possible, two observers should be used in addition to the pilot so that one observer is always looking away from the sun regardless of the direction the aircraft is flying. Special attention should be paid to old lakebeds, stock-watering areas, and other relatively open sites largely surrounded by sagebrush of 15 to 25% canopy cover. Lek searches from an aircraft should be conducted from $^1/_2$ hour before to one hour after sunrise, although during peak attendance the time can be stretched to $1^1/_2$ hours after sunrise.

Lek searches can be conducted from the ground by driving along roads in suspected or known breeding habitat and stopping every kilometer to listen for sounds of displaying grouse. Ground searches can be started an hour before sunrise. In less accessible areas, searches can be made from a mountain bike, trail bike, 4-wheel all terrain vehicle (ATV), horseback, or on foot. On a calm morning, breeding sage-grouse may be heard at a distance of 1.5 km. All openings in big sagebrush and stands of low sagebrush and black sagebrush should be searched for breeding birds with binoculars or a spotting scope.

A variation of the ground survey can be used following snowfall during the night or early morning. Although lek activity is minimal during stormy weather and the birds may flush at the first sign of an intruder, some male sage-grouse will attend leks on virtually every morning during the spring, regardless of weather. Areas that are suspected of being leks can be searched immediately following a snowfall. If grouse use the area, tracks will be evident in the snow, and the number of tracks may give some indication of the relative size of the lek. This technique is particularly useful for locating relatively small leks at higher elevations where spring weather is often severe. During a one-week period in southwestern Idaho, three new leks were found using this technique in an area that had been previously searched from the air (J. W. Connelly, unpublished data). The air search failed to locate these leks, likely because they were quite small (less than 12 males).

Lek Counts

Lek counts are a relatively common means of monitoring sage-grouse populations. In a lek count, male sage-grouse attending some or perhaps most of the leks in a given area are counted using accepted techniques (Jenni and Hartzler 1978, Emmons and Braun 1984). However, leks may be widely separated and no assumption is made that the census samples a single breeding population. Because some sage-grouse may use several leks in a given breeding season (Dalke et al. 1960, 1963), changes in lek attendance observed during a lek census may be due to some birds shifting to other leks rather than actual changes in the grouse population. Unless all leks are counted during a lek count, there would be no way to assess observed changes. As an example, a lek censused in the Big Desert of southeastern Idaho generally had few or no males attending after about 15 April. The first census usually reported 20 to 30 males, but the second and third replicate counts indicated few or no males. After some of the grouse were marked, researchers discovered that most males moved to another lek that was previously unknown, about three km away. The abandoned lek was relatively close (less than 300 m) to a cabin that was the center for ranching activities during spring. Apparently grouse abandoned this lek in response to human and livestock disturbance that occurred around 15 April each year as cattle were brought to that grazing allotment.

Although lek counts are widely used, concern over their usefulness has been expressed (Beck and Braun 1980). However, techniques for correctly conducting lek counts have been described (Jenni and Hartzler 1978, Emmons and Braun 1984) and problems generally seem to be related to disregarding accepted techniques. A recent review of raw data recorded while conducting lek counts in Idaho indicated that leks were sometimes counted when conditions were windy, ceiling was overcast, and during rainstorms; in some cases counts were begun greater than 1.5 hours after sunrise (M. L. Commons-Kemner, unpublished data).

Lek Routes

A lek route is a type of lek count with an important distinction—an attempt is made to census a group of leks that are relatively close and represent part or all of a single breeding population (i.e., deme). Lek routes have some of the same problems as lek counts (Beck and Braun 1980) but problems are usually related to disregarding accepted techniques (Jenni and Hartzler 1978, Emmons and Braun 1984). Whenever possible, leks should be counted along routes to facilitate repetition by other observers, increase the likelihood of recording satellite leks, and account for shifts in breeding birds if they occur. Lek routes should be established so that all leks along the route can be counted within 1.5 hours. Lek routes should be run from 0.5 hour before sunrise to one hour after sunrise and each route should be run at least four times during the spring. Normally, lek routes are conducted in late March or early April (i.e., March

20-April 7), mid-April (i.e., April 10-20), and late April (i.e., April 22-30). Counts can start a week earlier at lower elevations in relatively mild climates (e.g., southern Washington) and can be extended by a week for higher elevations or areas with relatively harsh climates (e.g., North Park, Colorado). The four counts will roughly coincide with peak hen attendance (early count), and maximum male attendance (middle or late counts).

Lek routes should only be conducted when weather conditions are characterized by clear to partly cloudy skies and winds less than 15 kph. Routes should never be conducted during rain or snowstorms. If weather degenerates after a route has begun, the route should be run again. If a lek is not occupied (and it had been in previous weeks or years), the observer should leave his/her vehicle and (with the engine off) listen for sounds of displaying grouse. Leks will move if birds are subject to continuing disturbance. Grouse may also be flushed from a lek by a predator and, if it is still reasonably early in the morning, may display nearby once the predator leaves the area.

Individual leks within lek routes should be counted at least three times. Subdominant males are often less active than more dominant males occupying the center of the lek and may be easily missed with a single count. A lek may be effectively counted in the following manner:

1. Locate a spot that provides good visibility of the entire lek. If the lek is very large (100 or more birds) it may be necessary to select two or more vantage points. Be careful not to get so close that an observer's presence disturbs the grouse.
2. Record the time that the lek count begins.
3. Count the birds from left to right (or vice versa).
4. Wait one to two minutes, then count from right to left.
5. Wait one to two more minutes, then again count from left to right.
6. Record the highest number of males and females separately, and then move to the next lek.

Before establishing lek routes in a given area, thought should be given to personnel available for conducting routes. It is much better to have a few routes with high quality data than many routes with questionable or missing data.

Lek Surveys

Lek surveys require less manpower and time than lek censuses. They can also be conducted from fixed-wing aircraft or helicopter. The major drawback of this technique is that it is not sensitive to a change in sage-grouse population size unless the change is very large. As an example, a group of five leks could have a total of 50 males during one spring and a total of 75 males two years later (a 50% increase). A lek survey would only indicate that all five leks were active each year (a stable population).

Some sage-grouse breeding habitat is inaccessible during spring because of mud and snow, or so remote that leks cannot be routinely counted. In these cases, lek surveys are the only reliable means of monitoring these populations. To provide the most useful information on population trends, lek surveys should be conducted in the same manner each year. For example, they should not be conducted from a fixed-wing aircraft one year and a helicopter the next year. The date and beginning and ending times should be recorded for each survey. UTM coordinates for each lek encountered should also be noted, as well as any other information that observers might consider important. Although it is difficult to get an accurate count of birds from an aircraft, it is usually possible to classify the number of birds observed into groups (e.g., 1-10, 11-50, and so on). Whenever possible, these data should be recorded to further refine monitoring efforts.

Data Analysis

Prior to analysis, field forms (i.e., raw data) should be reviewed to ensure that information was collected properly. Lek routes conducted during stormy weather, high winds or late in the morning (i.e., routes completed more than 1.5 hours after sunrise) should not be included in the analysis.

To assess breeding population trends, the minimum amount of information needed is a record of the number of active leks in a given area over a period of years. This information can be obtained from lek surveys and lek routes, but these data will only reflect gross changes in the population and may provide misleading results. For example, Connelly et al. (2000*a*) documented an 88-93% decline in a sage-grouse breeding population in southeastern Idaho following a prescribed burn and long-term drought, while the number of active leks in this area only decreased by 58% (Connelly et al. 1994). Connelly et al. (1994, 2000a) tracked changes in active leks, males per lek, males per major lek (a lek with 50 or more males) and maximum counts of males per route to assess changes in a sage-grouse breeding population in southeastern Idaho.

Lek route data that have been correctly collected are more useful for assessing population trends than information on the number of active leks. Lek routes provide the following data: active leks/route; average number of males/route; maximum number of males/route; average number males/lek; maximum number of males/lek; males/area (all males counted on a group of lek routes). The maximum number of males per lek and males per route are normally recorded.

Sometimes the number of leks along a route changes because the route has changed, the habitat has changed or satellite leks have developed or disappeared. If this occurs, then the most effective means of tracking populations and analyzing changes will be by examining the number of males per lek. If the number of leks does not change over a period of years or only the number of satellite leks change, the number of males per route should form the basis of breeding population assessment.

Female sage-grouse are usually counted along lek routes, but because of their secretive nature and cryptic appearance they are difficult to detect. Although the number of females counted may provide some information on peak of breeding, these data should not be used to assess population change.

Occasionally, lek data are used to estimate breeding populations but this is not a common practice among agencies. This procedure often consists of summing the maximum counts of males on leks representing the population of interest and dividing the number by 0.75 to estimate number of males (to adjust for unseen males). This value is then multiplied by 2 (assuming a 2:1 sex ratio of females to males) to estimate number of females. To our knowledge, this method has never been experimentally validated or recommended as a population estimator. Because of uncertainty associated with lek attendance patterns (Beck and Braun 1980, Emmons and Braun 1984, Walsh 2002), possible differences in sex ratios among years and areas (Swenson 1986), and some lack of uniformity in counting procedures, these efforts can only provide very crude estimates of minimum populations and are not generally useful for making comparisons among areas or years. However, Walsh (2002) identified a procedure using Bowden's estimator (Bowden and Kufeld 1995) that may be useful for estimating sage-grouse populations in relatively small, discrete areas.

PRODUCTION

Brood observations, brood routes, and wing surveys have been used to assess sage-grouse production (Autenrieth et al. 1982). Brood observations, sometimes called random brood routes, are simply records of all sage-grouse broods observed in a given area by any field personnel that find themselves in that area. This information provides some idea of the juvenile to adult ratio and percent of hens observed with broods. Thus, it is somewhat better than anecdotal data. However, it is not easily replicated and comparisons among years can be difficult to interpret.

Brood routes were commonly conducted in many states during the 1960's and 1970's (Autenrieth 1981) and are still used in some areas (Willis et al. 1993, Danvir 2002). Routes are usually driven at speeds less than 32 kph in the morning (sunrise to about 0900) and evening (1800 to sunset) during late June, July, and early August. Routes may also be walked or conducted from horseback, trail bike, mountain bike or ATV. Brood routes are normally established in areas known to have concentrations of sage-grouse (Autenrieth et al. 1982). These areas are often in or adjacent to wet meadows, riparian zones and agricultural fields. Each brood is recorded separately and the presence of a hen is also recorded. Groups of unsuccessful females and males are also normally tallied. Because chicks are quite secretive it is usually necessary to flush the brood to obtain an accurate count. A trained bird dog can increase the efficiency of this procedure. If sufficient numbers of grouse are observed such that the sample size is adequate, this technique can provide a reliable indication of trends in production. Brood routes provide the following information: birds/km, broods/km, average brood size, and chick:adult hen ratio. For non-hunted populations or populations subject to very light hunting where relatively few wings can be collected, brood routes are the only method available for assessing production, short of using radiotelemetry.

A sage-grouse wing collected in September and sometimes early October can be used to determine age, gender, and for females, reproductive status. For hunted populations, wing surveys are the most useful technique for assessing sage-grouse production. However, sample sizes should be 100 or more wings for adult and yearling hens, and could be considerably larger depending on the size of the area and population being sampled (Autenrieth et al. 1982). Wings are normally collected at wing barrels (Figure 5, Hoffman and Braun 1975) or hunter check stations. Several keys have been developed to aid in classifying sage-grouse wings (Eng 1955, Crunden 1963, Dalke et al. 1963, Beck et al. 1975, Braun personal communication). Some differences exist among the keys and this may reflect regional variation in breeding activities and molts. Some of the earliest work on sage-grouse molt and age and gender classification using known-age birds was conducted in Idaho (Pyrah 1963). A simple key currently used in Idaho to classify wings of greater sage-grouse is presented in Appendix 3.

In addition to primary replacement and length, the general size and color helps to classify wings to age and gender. Wings of males are larger than wings of females and juvenile females consistently have the smallest wings. Wings of females tend to have more white speckling along the leading edge than do wings of males.

Wing analyses and brood routes allow an assessment of trends in production and a comparison of production among areas (Autenrieth 1981). However, these data may not reflect population trends. For example, a portion of a population's winter habitat may be lost but the breeding range could remain intact. Production (juvenile:adult ratio) may be stable but the overall population may decline because of increased mortality on winter range. Thus, it is best to use this information in conjunction with data on breeding populations to make inferences on population trends.

WINTER POPULATIONS

Unlike breeding populations and production, there are no widely accepted methods for assessing winter populations. In part, this is because birds may be spread out over large areas during mild winters but clumped in less than 10% of the available habitat in severe winters (Beck 1977).

Beck (1977) searched probable winter use areas in Colorado by 4-wheel drive vehicles, snowmobiles, and snowshoes to document sage-grouse winter habitat. Similarly, Connelly (1982) used survey routes traversed by 4-wheel drive truck or snowmobile, depending on conditions, to document winter habitat use of sage-grouse in southeastern Idaho. Flock size, location, cover type, snow depth, and temperature were recorded along these routes (Connelly 1982).

Aerial surveys using either a fixed-wing aircraft or helicopter may be effective in identifying sage-grouse winter habitats and can often be done in conjunction with surveys for pronghorn (*Antilocapra americana*; Patterson 1952). If aerial surveys are used, data should be acquired over a series of years with different snow conditions to give a more complete picture of sage-grouse distribution in winter.

TRAPPING AND MARKING

TRAPPING

The capture and subsequent marking of sage-grouse has been employed as a method of assessing and delineating populations for well over 50 years (Patterson 1952). Over the years, techniques have been modified and the quality of radio transmitters has improved considerably. Nevertheless, there remains two main periods for effectively capturing sage-grouse, spring and late summer, although Colorado biologists have had success trapping grouse during winter (A. D. Apa, personal communication). Techniques used will vary depending on terrain, access, weather, and population size.

Figure 5. Wing barrel used to collect gamebird wings.

Night-lighting

During March and much of April, male and female sage-grouse will often roost on or near leks at night. This is especially common during peak hen attendance, usually the last week of March and first week of April, but occurs in mid-April in some high elevation areas. At this time, birds are quite vulnerable to being captured by night-lighting (Giesen et al. 1982, Wakkinen et al. 1992). One of the common difficulties encountered with this technique is that males are much easier to see than females. Consequently, more males are captured, often at the expense of missing a female. Moreover, males will tend to roost in the center of the lek while females are found near the edges, sometimes in rocky areas. These sites may be more difficult to traverse with a 4-wheel drive truck. To overcome these difficulties, researchers in Idaho made two modifications to the standard night-lighting technique: binoculars and rock and roll music (i.e., an entertaining form of "white noise").

Before beginning night grouse trapping, the research leader should make assignments and brief the trapping crew about general trapping procedures. An ideal crew will consist of four people: driver, spotter, primary netter and secondary netter. If possible, people should switch jobs during the night to keep everyone fresh.

To start, binoculars are used with a 1-million candlepower spotlight (more powerful spotlights may be available) to search the lek area as the crew approaches using a 4-wheel drive truck (Wakkinen et al. 1992). The spotlight should be equipped with a shroud to help narrow the beam (Figure 6). A coffee can or plastic container for garden plants will work well as a shroud. As the crew moves around the lek the driver should stop about every 100-200 m or whenever signaled by the spotter and the spotter will search the lek and area immediately surrounding it with the binoculars and spotlight. If possible, driving to higher ground adjacent to the lek will increase search efficiency and afford a better opportunity for spotting birds roosting in heavier cover.

Sage-grouse eyes resemble sparkling emeralds in the glare of a spotlight and can be seen for over 200 m, depending on terrain and vegetation. Depending on distance, it may not be possible to distinguish males from females. Normally, males, when viewed from less than 100 m, can be identified by their white breast feathers. Location of the bird with respect to the lek also provides a clue to the gender of the observed bird. Males tend to roost singly in the relative open area of the lek and sometimes on sparsely vegetated ridges adjacent to the lek. Females are often more secretive, roosting closer to sagebrush at the perimeter of the lek, sometimes in small groups.

Figure 6. Night-lighting sage-grouse.

Once a bird has been spotted and a decision made to try to capture it, the music previously mentioned comes into play. Trapping trucks are equipped with tape players or compact disc players with external speakers or tape player with reasonably powerful speakers. As the approach begins, loud rock music is played which, together with the sound of the vehicle's engine, covers the footsteps of approaching trappers and tends to disorient the roosting bird. Tape recordings of snowmobiles, generators, and other white noise will also serve the same function, but music tends to improve spirits and generally make cold spring nights more tolerable. When making an approach, two netters dressed in dark clothing are walking along the driver's side of the truck. All netting should be done from the driver's side to facilitate communication between the driver and netters and allow the driver an awareness of the netter's location relative to the truck for safety. As the truck approaches the bird, the spotlighter will eventually be able to easily see the bird without binoculars. At this point, the spotter begins to shimmy the light rapidly, to produce a strobe effect, but keeps the light on the bird to further confuse the roosting grouse. Netters on the ground will likely not be able to see the bird at this point but when they notice the rapidly moving light, they move 5-10 m from the truck, careful to stay out of the spotlight. Even though they may not be able to see the bird, the netter has to concentrate on the center of the light. Eventually, the netter will see the bird. As the truck's fender is about to pass the grouse, the trapper should be placing the net on the bird. The movement of the net should be relatively low and parallel to the ground. It should not be swung down on the bird from the shoulder like a butterfly-net; to do so increases the possibility of injuring the grouse. If the netters are somewhat slow, the driver should begin to circle the bird at a distance of about 5 m. Throughout all of this activity, the spotter continually shines the spotlight directly on the bird's eyes, continuing the shimmy movement to help mesmerize the bird. Once the bird is in the net, the netter should restrain the bird by holding its wings next to its body, not allow it to struggle in the net, and wait for help to remove it from the net. This reduces both chance of injury to the bird and chance of escape. However, an experienced netter will be able to remove the grouse from the net and safely handle it without additional help. As soon as the spotter sees that the captured grouse is under control, he or she should search the immediate area (out to about 100 m) for other grouse. If another bird is found, the trapping crew can move off after it. If trapping crew waits until after processing the captured bird, any nearby birds will likely flush before another approach can be made. The second netter has two purposes. The first is to replace the primary netter if he/she should stumble or fall on an approach to the bird. The second is to aid in a rapid second capture.

Although most sage-grouse captured with this technique are caught within a few meters of the truck, some grouse may be captured up to 20 m from the truck. The only time the long distance captures should be attempted is when a grouse is roosting in a rock pile or muddy area where driving is unsafe. The same procedure is used as described above, but the netter must move quite rapidly and take special care to stay out of the light. The loud music is especially helpful in concealing footsteps in this kind of effort.

If the soil is very muddy or otherwise difficult to traverse in a truck, procedures used for night-lighting from a truck can be employed from a 4-wheel ATV. Birds may be more difficult to spot from an ATV because the observer does not have the high vantage point afforded by the truck. Normally, only two or three trappers are used with an ATV.

Sage-grouse can also be captured by night-lighting on foot. This technique can be especially useful when birds' roosting areas are known and search time is minimal. It also has the advantage of only requiring two people, although three are optimum, and it can be used in rough terrain that cannot be traversed by a vehicle. With this type of night-lighting, one person is equipped with a rechargeable power-pack (normally used to jump start engines and available at most auto supply and hardware stores) carried in a backpack, a portable spotlight connected to the power-pack, and a tape recorder or compact disc player with loud rock music. Binoculars are also useful because trappers can stop on high points and glass for sage-grouse. The other trapper carries a long-handled net and the marking supplies in a backpack. When a grouse is found the approach should be swift, although running often results in one or more of the trappers falling and the bird escaping. The netter should stay even with, but a few meters to the side of, the person with the spotlight. If the grouse begins to walk (usually a prelude to flushing), the netter may have to sprint ahead to make the capture. We recommend entering the GPS coordinates of the vehicle as a waypoint before leaving it to night-light on foot. This assures that the trapping crew can return to the vehicle later that night.

When trapping from a truck we often carry a portable power-pack in case we find grouse roosting in inaccessible areas. We also night-light on foot when capturing birds associated with a radio-marked bird (normally a hen and her brood) and when trying to capture a grouse to replace a radio. In these cases, the individual with the spotlight also has an antenna and telemetry receiver connected to headphones. Without headphones, the transmitter signal cannot be heard over the rock music.

Night-lighting is normally used to capture sage-grouse during spring, summer, and early fall. It may be less effective during winter when grouse often roost in large flocks, snow cover allows trappers to be seen at long distances, and deep or crusty snow impedes the netters' movements. However, recent information from Colorado (A. D. Apa, personal communication) indicates night-lighting during winter can be very effective. Colorado biologists captured 40 hens during the 2001 winter. They reported that this technique worked well until snow was shin deep or became very crusty.

Night-lighting is also not very effective on bright, moon-lit nights because birds can easily see approaching trappers before being confused by the lights and music. Normally, we avoid night-lighting within three days of a full moon unless the sky is heavily overcast.

Walk-in Traps

Walk-in traps (Gill 1965, Schroeder and Braun 1991) can be used to capture sage-grouse on leks (Schroeder 1997, Leonard et al. 2000, Aldridge and Brigham 2002) and on summer foraging areas (Connelly 1982). These traps can be round, square, or rectangular (Figure 7). They are about 50 cm high, and 100 to 150 cm deep (a round trap would have a 100-150 cm diameter). Funnel openings are used that allow birds unobstructed entrance but hinder their escape. Normally, several traps (pods) are connected by leads (wings) which the sage-grouse walk along as they move into the trap entrances. Trap leads should be set to intersect hens walking onto a lek or grouse walking onto a feeding area. Leads are generally 25 to 75 meters long and about 35 cm high. Traps should be made from nylon or cotton netting; never from poultry netting because it can inflict deep cuts on grouse trying to escape. A door can be fashioned into the side or roof to allow removal of birds. Traps should be constantly tended when set. Otherwise, there is a risk that a captured bird may injure itself when trying to escape or be killed by a predator that detects it in the trap.

Mist Nets

Mist nets have been used to capture sage-grouse on summer range (Connelly 1982, Browers and Connelly 1986). We have also used mist nets on leks but could only catch one or two males each morning. As soon as males were caught we had to remove them to prevent their injury and this disrupted breeding activities for the remainder of the morning. Mist nests can be an effective way of capturing broods foraging on summer range. We have also used them in conjunction with walk-in traps. We placed mist nests behind walk-in traps to catch birds that would flush at the funnel entrance to the trap. Like walk-in traps, mist nets must be constantly monitored to prevent injury to captured birds.

Drop Nets

Drop nets can be used to capture sage-grouse on leks (Leonard et al. 2000). However, drop nets are infrequently used because their use tends to disrupt lek activities and they are not as efficient as other trapping techniques.

Cannon and Rocket Nets

Cannon and rocket nets have been used to capture sage-grouse for many years and were commonly used for this purpose. Research personnel in Colorado have recently used a relatively new type of cannon net (CODA Netlauncher) to capture a number of hens on leks (Hausleitner 2003, A. D. Apa, personal communication). However, their use also tends to disrupt lek activities and they may not be as efficient as other trapping techniques.

Pointing Dogs

Well-trained pointing dogs can be used to capture sage-grouse chicks up to about four weeks of age. We used pointing dogs to capture the chicks of radio-marked hens by first locating and flushing the hen. We then let the dog search an area within about a 200 m radius of the site where the hen flushed. The dog will normally go on point within 50 cm of the chick and then it is a matter of reaching down and picking up the chick. For older chicks (more than two weeks old) a long-handled net can be used to capture the bird. Experienced, steady dogs are necessary for this technique to be successful.

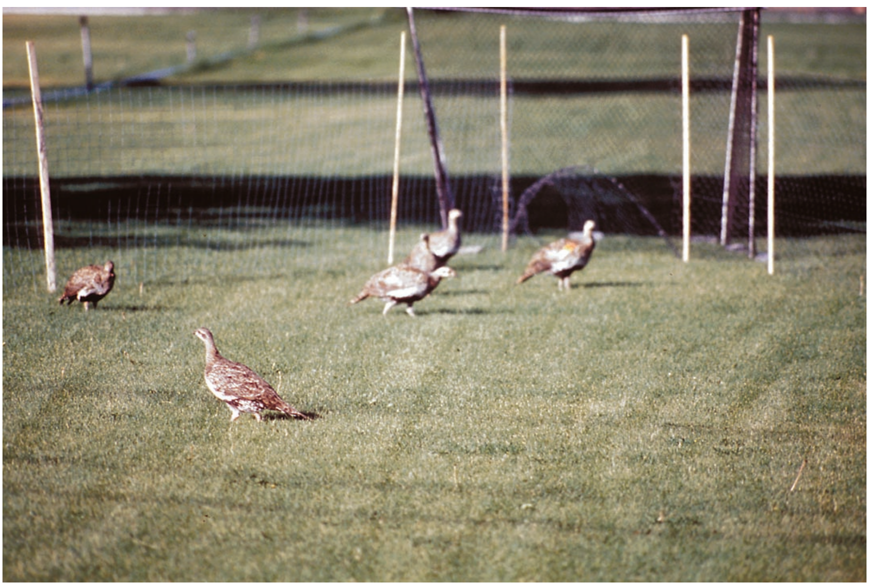


Figure 7. Walk-in trap for sage-grouse on atypical summer range (lawn at the Idaho National Engineering and Environmental Laboratory).

MARKING

A variety of techniques have been used to identify individual sage-grouse including numbers and patterns of tail feathers (Wiley 1973), leg-bands (Patterson 1952, Dalke et al. 1963), wing markers (Connelly 1982), ponchos (Wallestad 1975), colored back-tags (Autenrieth 1981), and radio-transmitters (Wallestad 1975, Autenrieth 1981). Two researchers even resorted to shooting off tips of tail feathers of displaying males as a means of identifying individual birds (Hartzler and Jenni 1988). Generally leg bands and radio-transmitters are the most common methods currently used for marking grouse. Patagial tags may also have some value in providing movement and distribution data at a relatively low cost.

Banding

Virtually all captured sage-grouse are marked with serially numbered leg bands, very young chicks (less than 10 weeks of age) being the only exception. In most cases, the bands contain a unique identifying number and an address for reporting a recovered band. It is also wise to use identifying letters in addition to the number (e.g., sgm [sage-grouse, male], sgf [sage-grouse, female]) in case other game birds are being marked in the state or province. With a letter prefix, the species being reported can be immediately ascertained. In some studies, grouse (especially males) have been marked with a series of color-coded leg bands to allow identification of individuals in the field. This works well if re-observations are made on leks or other reasonably open areas, but much of the time grouse are in relatively heavy cover and viewing markers on legs may be difficult. Band return data provide information on harvest rates, survival, and seasonal movements (Zablan et al. 2003). If a sufficient number of grouse are marked and subsequently recaptured, population size may be estimated. The actual number of captures and recaptures needed for this estimate depends on the number of birds available and the size of the area occupied by the sage-grouse population of interest.

Wing-markers

Wing-markers or patagial tags have also been used to identify individual birds (Connelly 1982, Musil et al. 1993). These tags are often modified cattle ear markers with an identifying letter or number, although Wallestad (1975) used numbered metal clips to mark wings of young chicks. Patagial tags may be more easily seen than colored bands and their use should result in more re-observation data than use of colored leg bands. Thus, they provide a relatively inexpensive means of obtaining information on local and seasonal movements.

However, because of their visibility, they may result in greater losses to predators, so their use should be restricted to males and applied only if other marking methods are ineffective.

Radio-telemetry

Radio-transmitters provide the most common and most useful means of documenting sage-grouse seasonal habitat selection and movements. Radio-telemetry also allows an estimate of daily, seasonal, and annual survival rates. Biologists have been marking sage-grouse with radio-transmitters since at least 1965 (Autenrieth 1981). Unfortunately, early transmitters weighed more than 70 g (five percent or more of an adult female's mass) and had relatively short battery lives. Thus, information collected during these early studies should be considered with the utmost care. By the mid- to late 1970s, transmitter weights had been reduced to about 25 g (two percent or less of an adult female's mass) and these transmitters would generally last for six months or more. Throughout the 1970s and early 1980s, transmitters were attached to sage-grouse using variations of a backpack harness (Brander 1968). During the early 1980s, we learned that backpack harnesses increased the vulnerability of sage-grouse to predation and thus switched to a poncho-mounted transmitter (Amstrup 1980).

Poncho-mounted transmitters were used on sage-grouse throughout much of the 1980s and early 1990s. Both battery-powered and solar powered transmitters were mounted on ponchos. The opening in the poncho was custom fit to individual birds, then the opening was pulled over the bird's head and feathers were preened around the poncho material. The transmitter was fixed to the poncho so that it would lie against the bird's crop. Although the method provided a quick, reliable way to mark a sage-grouse with a radio-transmitter, problems were identified when solar transmitters were mounted in this fashion. During summer, sage-grouse often feed on succulent forbs including dandelion (*Taraxacum officianale*), salsify (*Tragopogon dubius*), lettuce (*Lactuca* spp.) and hawksbeard (*Crepis acuminata*). These plants contain a milky substance that will run down the bird's bill onto their breast feathers. In doing so, the substance collects and hardens on radio-transmitters and in the case of solar transmitters reduces the light to the solar panel so that the transmitter stops functioning.

By the mid 1990s, most research biologists had settled on a battery-powered transmitter attached around the bird's neck by a necklace usually made of plastic-coated cable. This radio-harness was somewhat lighter than a poncho, but could be attached just as quickly. It had an added advantage because a transmitter could be more quickly fixed to a necklace than to a poncho. When using this attachment technique care must be taken to leave the cable loose enough to avoid crop impaction and thus harm the grouse. Normally, a finger's width of room between the throat and cable will result in sufficient space to allow birds to forage normally but still retain the transmitter.

Although a great deal of information has been obtained from radio-marked sage-grouse, virtually all of the birds marked were older than 10 weeks of age. Few, if any attempts, were made to radio-mark sage-grouse chicks less than 10 weeks old until 1998. A major concern involved the attachment of a transmitter to a day-old chick weighing about 30 grams. The technique should pose a low risk to grouse chicks but still result in an attachment that lasted at least two weeks. A simple attachment arrangement has been developed for a sage-grouse chick that involves piercing the skin just in front and behind the transmitter with a 20-gauge hypodermic syringe. Sutures are then threaded through the syringe and through holes in the 1-gm transmitter and tied off (Figure 8). Cyanoacrylic glue is applied to the knots to enhance security of the attachment (Burkepile et al. 2002).

Figure 8. Three-week old sage-grouse with 1-gm radio transmitter. Note antenna extends posteriorly.

Glossary

Adult—A sage-grouse that is at least 15 months of age and has entered or is about to enter its second breeding season.

Breeding habitat—Habitat used by sage-grouse for breeding, nesting, and early brood rearing; generally occupied from early March to mid-June.

Breeding population—A group of sage-grouse associated with 1 or more occupied leks in the same geographic area separated from other leks by more than 20 km.

Canopy cover—a) The percentage of the ground included in a vertical projection of imaginary polygons drawn about the total natural spread of foliage of the individuals of a species (usually used for herbaceous plants); or b) The percentage of the ground covered by a projection of the crown, stems, and leaves of the plant onto the ground surface (usually used for shrubs).

Canon nets—A net attached to cylindrical projectiles that are shot from tubes and quickly carry the net over the animal(s) to be trapped. At one time commonly used to capture sage-grouse on leks, but have been largely replaced by rocket nets.

Chick—A sage-grouse up to 10 weeks of age.

Climax—A state reached by a plant community characterized by a fluctuation of its vegetative populations rather than a unidirectional change. A climax community will remain in a self-perpetuating state as long as climatic, edaphic, and biotic conditions remain relatively constant.

Cover—An indication of the relative amount of shelter or protection of all vegetation at a given point; normally used to assess nesting habitat.

Daubenmire frame—Normally a 20 x 50 cm wooden, metal or PVC frame used to estimate canopy cover. The frame has a painted pattern that allows reference for visual estimates of 5, 25, 50, 75, and 95 percent of the frame.

Deme—A local population of closely related plants or animals.

Density— The number of plants, animals, or other items in a defined area (e.g., number of plants/m^2).

Droop height—The height of a grass or forb measured from the ground to the point where the plant naturally bends. There may be no droop to some plants with relatively short stature.

Drop net—A net that is elevated above an area commonly used by animals (e.g., a lek) and designed to fall and trap the target animals when a trigger is mechanically or electronically activated.

Forb—An herbaceous plant other than a grass, sedge, or other plant with similar foliage.

Frequency—The percent occurrence of a species in a series of samples of uniform size contained in a single stand.

Habitat type—A collective term for all parts of a land surface supporting or capable of supporting the same kind of climax vegetation.

Herbaceous vegetation (herbs)—Plants that die back to the ground surface each year, normally with soft, non-woody stems.

Juvenile—A sage-grouse that is more then 10 weeks of age but has not entered into its first breeding season.

Lek—A traditional display area where two or more male sage-grouse have attended in two or more of the previous five years. The area is normally located in a very open site in or adjacent to sagebrush-dominated habitats.

Lek surveys—A classification of leks as active or inactive, often done from an aircraft.

Lek census—A count of male sage-grouse on a lek or group of leks.

Lek routes—A count of male sage-grouse on a group of leks that are relatively close and represent part or all of a single breeding population.

Line intercept—A technique for measuring canopy cover that involves placing a tape between 2 points and measuring the amount of plant (crown, stems, leaves) that intersects a vertical projection of this line. Normally used for shrubs.

Mist net—A finely constructed net that is difficult for birds to see. When a net is stretched between two poles, birds fly into the net and become entangled.

Night-lighting—The use of powerful spotlights (usually 750,000 or more candlepower) and long-handled nets to capture sage-grouse. This technique usually involves the use of binoculars to spot birds at a distance and "white noise" (often loud rock and roll music) to cover approaching footsteps and further disorient the birds.

Non-migratory population—Sage-grouse that do not move more than 10 km between seasonal ranges.

One-stage migratory population—Sage-grouse that move more than 10 km between two distinct seasonal ranges.

Patagial tag—A type of marker for birds that is attached to the wing(s) through the patagium.

Patch— A habitat unit of variable size that contains a homogeneous set of characteristics.

Production—The number of juvenile birds recruited to the fall population, often reported as a ratio of juveniles to adult females (including yearlings).

Renesting—A nesting attempt that follows the loss of an initial nest.

Rocket net—A net attached to cylindrical projectiles that are powered by propellant in the base of the cylinder and quickly carry the net over the animal(s) to be trapped. Normally used to capture breeding sage-grouse on leks.

Satellite lek—A relatively small lek (usually less than 15 males) that develops near a large lek during years with relatively high grouse populations.

Shrub-steppe—Temperate zone vegetation with the understory dominated by grasses and a conspicuous shrub element providing a relatively open overstory above the grass layer.

Summer population—A group of sage-grouse associated with one or more summer habitats (usually moist, forb-rich areas) in the same geographic area.

Two-stage migratory population—Sage-grouse that migrate among three distinct seasonal ranges; each range is separated from the others by more than 10 km.

Visual obstruction—An index of the relative density and height of a stand of vegetation.

Walk-in traps—Cages (usually made of netting or welded wire) with wings or leads (usually made of chicken wire) extending from funnel entrances. Birds are captured when they walk along the leads, enter the funnel opening, and cannot find their way out.

Winter population—A group of sage-grouse associated with a single winter range, normally separated from other winter ranges by more than 20 km.

Wing barrel—A barrel or other container placed in areas frequented by bird hunters and used as a collection site for wings from hunter-harvested birds.

Wing survey—A collection and classification of wings by age and sex. Wings are normally collected at hunter check stations, wing barrels, or through mail solicitation.

Yearling—A sage-grouse that has entered its first breeding season but not completed its second summer molt, normally between 10 and 17 months of age.

Literature Cited

Aldridge, C. L. 2000. Reproduction and habitat use by sage grouse (*Centrocercus urophasianus*) in a northern fringe population. M.S. thesis, University of Regina, Regina, Saskatchewan, Canada.

Aldridge, C. L., and R. M. Brigham. 2002. Sage-grouse nesting and brood habitat use in southern Canada. Journal of Wildlife Management 66:433-444.

Amstrup, S. C. 1980. A radio-collar for game birds. Journal of Wildlife Management 44:214-217.

Anderson, S. H., and K. J. Gutzwiller. 1994. Habitat evaluation methods. Pages 592-606 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland.

Apa, A. D. 1998. Habitat use and movements of sympatric sage and Columbian sharp-tailed grouse in southeastern Idaho. Ph.D. dissertation, University of Idaho, Moscow.

Atwood, N. D. 1970. Flora of the National Reactor Testing Station. Brigham Young University Science Bulletin Biological Series 9(4):1-46.

Autenrieth, R. E. 1981. Sage grouse management in Idaho. Wildlife Bulletin No. 9. Idaho Department of Fish and Game, Boise.

Autenrieth, R. E., W. A. Molini, and C. E. Braun. 1982. Sage grouse management practices. Western States Sage-grouse Committee Technical Bulletin Number 1. Idaho Department of Fish and Game, Twin Falls, ID.

Baker, B. D. 1968. Techniques for measuring shrub crown intercept when employing the line intercept method of sampling range vegetation. Colorado Outdoor Facts Number 64. Colorado Division of Wildlife, Fort Collins.

Barnett, J. K., and J. A. Crawford. 1994. Pre-laying nutrition of sage grouse hens in Oregon. Journal of Range Management 47:114-118.

Beck, T. D. I. 1977. Sage grouse flock characteristics and habitat selection during winter. Journal of Wildlife Management 41:18-26.

Beck, T. D. I., and C. E. Braun. 1980. The strutting ground count: variation, traditionalism, management needs. Proceedings of the Western Association of Fish and Wildlife Agencies 60:558-566.

Beck, T. D. I., R. B. Gill, and C. E. Braun. 1975. Sex and age determination of sage grouse from wing characteristics. Colorado Division of Game, Fish and Parks, Game Information Leaflet Number 49. Fort Collins, CO.

Brander, R. B. 1968. A radio-package harness for gamebirds. Journal of Wildlife Management 32:630-632.

Braun, C. E. 1998. Sage grouse declines in western North America: what are the problems? Proceedings of the Western Association of Fish and Wildlife Agencies 78:139-156.

Browers, H. W., and J. W. Connelly. 1986. Capturing sage grouse with mist nets. Prairie Naturalist 18:185-188.

Bowden, D. C., and R. C. Kufeld. 1995. Generalized mark-sight population size estimation applied to Colorado moose. Journal of Wildlife Management 59: 840-851.

Burkepile, N. J., J. W. Connelly, D. W. Stanley, and K. P. Reese. 2002. Attaching radio transmitters to day-old sage-grouse chicks. Wildlife Society Bulletin 30:93-96.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry 39:388-394.

Commons, M. L., R. K. Baydack, and C. E. Braun. 1997. Sage grouse response to pinyon-juniper management. Pages 238-239 *in* S. B. Monsen and R. Stevens, compilers. Proceedings: ecology and management of pinyon-juniper communities. USDA Forest Service RMRS-P9, Fort Collins, CO.

Connelly, J. W., Jr. 1982. An ecological study of sage grouse in southeastern Idaho. Ph.D. thesis, Washington State University, Pullman. 84pp.

Connelly, J. W., and C. E. Braun. 1997. Long-term changes in sage grouse *Centrocercus urophasianus* populations in western North America. Wildlife Biology 3:229-234.

Connelly, J. W., and O. D. Markham. 1983. Movements and radionuclide concentrations of sage grouse in southeastern Idaho. Journal of Wildlife Management 47:169-177.

Connelly, J. W., H. W. Browers, and R. J. Gates. 1988. Seasonal movements of sage grouse in southeastern Idaho. Journal of Wildlife Management 52:116-122.

Connelly, J. W., K. P. Reese, R. A. Fischer, and W. L. Wakkinen. 2000*a*. Response of a sage grouse breeding population to fire in southeastern Idaho. Wildlife Society Bulletin 28:90-96.

Connelly, J. W., K. P. Reese, W. L. Wakkinen, M. D. Robertson, and R. A. Fischer. 1994. Sage grouse ecology final report. Idaho Department of Fish and Game Job Completion Report. W-160-R-19. Subproject 9.

Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000*b*. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28: 967-985.

Connelly, J. W., W. L. Wakkinen, A. D. Apa, and K. P. Reese. 1991. Sage grouse use of nest sites in southeastern Idaho. Journal of Wildlife Management 55:521-524.

Crunden, C. W. 1963. Age and sex of sage grouse from wings. Journal of Wildlife Management 27:846-849.

Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford, and E. F. Schlatterer. 1960. Seasonal movements and breeding behavior of sage grouse in Idaho. Transactions of the North American Wildlife Conference 25:396-407.

Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford, and E. F. Schlatterer. 1963. Ecology, productivity, and management of sage grouse in Idaho. Journal of Wildlife Management 27:811-841.

Danvir, R. E. 2002. Sage-grouse ecology and management in northern Utah sagebrush-steppe. Deseret Land and Livestock Wildlife Research Report, Woodruff, UT.

Daubenmire, R. F. 1959. A canopy-coverage method of vegetation analysis. Northwest Science 33:43-64.

Daubenmire R. F. 1968. Plant communities: a textbook of plant synecology. Harper and Rowe, Publishers, New York, New York.

DeLong, A. K., J. A. Crawford, and D. C. DeLong. 1995. Relationship between vegetational structure and predation of artificial sage grouse nests. Journal of Wildlife Management 59:88-92.

Drut, M. S., J. A. Crawford, and M. A. Gregg. 1994. Brood habitat use by sage grouse in Oregon. Great Basin Naturalist 54:170-176.

Emmons, S. R., and C. E. Braun. 1984. Lek attendance of male sage grouse. Journal of Wildlife Management 48:1023-1028.

Eng, R. L. 1955. A method for obtaining sage grouse age and sex ratios from wings. Journal of Wildlife Management 19:267-272.

Evans, R. A., and R. M. Love. 1957. The step-point method of sampling—a practical tool in range research. Journal of Range Management 10:208-212.

Fischer, R. A. 1994. The effects of prescribed fire on the ecology of migratory sage grouse in southeastern Idaho. Ph.D. dissertation, University of Idaho, Moscow.

Fischer, R. A., K. P. Reese, and J. W. Connelly. 1996*a*. An investigation on fire effects within xeric sage-grouse habitat. Journal of Range Management 49:194-198.

Fischer, R. A., K. P. Reese, and J. W. Connelly. 1996*b*. Influence of vegetal moisture content and nest fate on timing of female sage grouse migration. Condor 98: 868-872.

Floyd, D. A., and J. E. Anderson. 1982. A new point frame for estimating cover of vegetation. Vegetatio 50:185-186.

Gardner, S. C. 1997. Movements, survival, productivity, and test of a habitat suitability index model for reintroduced Columbian sharp-tailed grouse. M.S. thesis, University of Idaho. Moscow.

Giesen, K. M., T. J. Schoenberg, and C. E. Braun. 1982. Methods for trapping sage grouse in Colorado. Wildlife Society Bulletin 10:224-231.

Gill, R. B. 1965. Distribution and abundance of a population of sage grouse in North Park, Colorado. M.S. thesis, Colorado State University, Fort Collins, Colorado.

Gregg M. A., J. A. Crawford, M. S. Drut, and A. K. DeLong. 1994. Vegetative cover and predation of sage grouse nests in Oregon. Journal of Wildlife Management 58:162-166.

Griffith, B., and B. A. Youtie. 1988. Two devices for estimating foliage density and deer hiding cover. Wildlife Society Bulletin 16:206-210.

Hamerstrom, F. N., Jr., O. E. Mattson, and F. Hamerstrom. 1957. A guide to prairie chicken management. Technical Wildlife Bulletin Number 15, Wisconsin Conservation Department, Madison, WI.

Hanf, J. M., P. A. Schmidt, and E. B. Groshens. 1994. Sage grouse in the high desert of central Oregon: results of a study, 1988-1993. United States Department of Interior, Bureau of Land Management, Series P-SG-01, Prineville, OR.

Hanley, T. A. 1978. A comparison of the line-interception and quadrat estimation methods of determining shrub canopy coverage. Journal of Range Management 31:60-62.

Hanson, C. L., J. R. Wight, and C. W. Johnson. 1988. Measuring cover using the step-point, wheel-point, and point-frame methods. Bureau of Land Management Technical Bulletin 88-3. Idaho State Office, Boise, Idaho.

Hartzler, J. E., and D. A. Jenni. 1988. Mate choice by female sage grouse. Pages 240- 269 *in* A. T. Bergerud and M. W. Gratson, editors. Adaptive strategies and population ecology of northern grouse. University of Minnesota Press, Minneapolis.

Hausleitner, D. 2003. Population dynamics, habitat use and movements of greater sage-sage-grouse in Moffat County, Colorado. M.S. thesis, University of Idaho, Moscow.

Heady, H. F., R. P. Gibbens, and R. W. Powell. 1959. A comparison of the charting, line intercept, and line point methods of sampling shrub types of vegetation. Journal of Range Management 12:180-188.

Higgins, K. F., J. L. Oldemeyer, K. J. Jenkins, G. K. Clambey, and R. F. Harlow. 1994. Vegetation sampling and measurement. Pages 567-591 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland.

Hoffman, R. W., and C. E. Braun. 1975. A volunteer wing collection station. Colorado Division of Wildlife, Game Information Leaflet 101.

Holloran, M. J. 1999. Sage grouse (*Centrocercus urophasianus*) seasonal habitat use near Casper, Wyoming. M.S. thesis, University of Wyoming, Laramie.

Homer, C. G., T. C. Edwards, Jr., R. D. Ramsey, and K. P. Price. 1993. Use of remote sensing methods in modeling sage grouse winter habitat. Journal of Wildlife Management 57:78-84.

Hyder, D. N., C. E. Conrad, P. T. Tueller, L. D. Calvin, C. E. Poulton, and F. A. Sneva. 1963. Frequency sampling in sagebrush-bunchgrass vegetation. Ecology 44:740-746.

Jenni, D. A., and J. E. Hartzler. 1978. Attendance at a sage grouse lek: implications for spring census. Journal of Wildlife Management 42:46-52.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Johnson, G. D., and M. S. Boyce. 1990. Feeding trials with insects in the diet of sage grouse chicks. Journal of Wildlife Management 54:89-91.

Jones, R. E. 1968. A board to measure cover used by prairie grouse. Journal of Wildlife Management 32:28-31.

Klebenow, D. A., and G. M. Gray. 1968. Food habits of juvenile sage grouse. Journal of Range Management 21:80-83.

Knick, S. T., and J. T. Rotenberry. 1997. Landscape characteristics of disturbed shrubsteppe habitats in southwestern Idaho (U.S.A.). Landscape Ecology 12:287-297.

Leonard, K. M. 1998. Distribution, movements, and habitats of sage grouse on the Upper Snake River Plain: changes from the 1950's to the 1990's. M.S. thesis, University of Idaho, Moscow.

Leonard, K. M., K. P. Reese, and J. W. Connelly. 2000. Distribution, movements, and habitats of sage grouse *Centrocercus urophasianus* on the Upper Snake River Plain of Idaho: changes from the 1950's to the 1990's. Wildlife Biology 6:265-270.

Lyon, A. G. 2000. The potential effects of natural gas development on sage grouse (*Centrocercus urophasianus*) near Pinedale, Wyoming. M.S. thesis, University of Wyoming, Laramie.

Lyon, L. J. 1968. Estimating twig production of serviceberry from crown volumes. Journal of Wildlife Management 32:115-118.

Marcum, C. L., and D. O. Loftsgaarden. 1980. A nonmapping technique for studying habitat preferences. Journal of Wildlife Management 44:963-968.

Musil, D. D., J. W. Connelly, and K. P. Reese. 1993. Movements, survival, and reproduction of sage grouse translocated into central Idaho. Journal of Wildlife Management 57:85-91.

Neal, D. L., R. D. Ratliff, and S. E. Westfall. 1988. A quadrat frame for backcountry vegetation sampling. Journal of Range Management 41:353-355.

Nelle, P. J. 1998. The long-term effect of fire on sage grouse nesting and brood-rearing habitats on the Upper Snake River Plain. M.S. thesis, University of Idaho, Moscow.

Nelle, P. J., K. P. Reese, and J. W. Connelly. 2000. The long-term effect of fire on sage grouse nesting and brood-rearing habitat on the Upper Snake River Plain. Journal of Range Management 53:586-591.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113-117.

Oyler-McCance, S. J., K. P. Burnham, and C. E. Braun. 2001. Influence of changes in sagebrush on Gunnison sage grouse in southwestern Colorado. The Southwestern Naturalist 46:323-331.

Patterson, R. L. 1952. The sage grouse in Wyoming. Sage Books, Inc. Denver.

Peek, J. M., F. D. Johnson, and N. N. Pence. 1978. Successional trends in a ponderosa pine/bitterbrush community related to grazing by livestock, wildlife, and to fire. Journal of Range Management 31:49-53.

Pyrah, D. 1963. Sage grouse investigations. Idaho Department of Fish and Game, Job Completion Report W-125-R-2. Boise, ID.

Remington, T. E., and C. E. Braun. 1985. Sage grouse food selection in winter, North Park, Colorado. Journal of Wildlife Management 49:1055-1061.

Robel R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Robertson, M. D. 1991. Winter ecology of migratory sage grouse and associated effects of prescribed fire in southeastern Idaho. M.S. thesis, University of Idaho, Moscow.

Rotenberry, J. T., S. T. Knick, and J. E. Dunn. 2002. A minimalist approach to mapping species' habitat: Pearson's planes of closest fit. Pages 281-289 *in* J. M. Scott, P. J. Heglund, M. L. Morrison, J. B. Haufler, M. G. Raphael, W. A. Wall, and F. B. Samson, editors. Predicting species occurrences, issues of accuracy and scale. Island Press, Washington, DC.

Sather-Blair, S., P. Makela, T. Carrigan, and L. Anderson. 2000. A framework to assist in making sensitive species habitat assessments for BLM-administered public lands in Idaho. U.S. Bureau of Land Management, Draft Document, Idaho State Office, Boise.

Schroeder, M. A. 1997. Unusually high reproductive effort by sage grouse in a fragmented habitat in north-central Washington. Condor 99:933-941.

Schroeder, M. A., and C. E. Braun. 1991. Walk-in traps for capturing greater prairie-chickens on leks. Journal of Field Ornithology 62:378-385.

Schroeder, M. A., J. R. Young, and C. E. Braun. 1999. Sage grouse (*Centrocercus urophasianus*). Pages 1-28 *in* A. Poole and F. Gill, editors. The birds of North America, Number 425. The Birds of North America, Philadelphia, Pennsylvania.

Shultz, L. M. 1984. Taxonomic and geographic limits of *Artemisia* subgenus Tridentatae (Beetle). Pages 20-28 *in* E. D. McArthur and B. L. Welch, editors. Proceedings—symposium on the biology of *Artemisia* and *Chrysothamnus*. U.S. Forest Service Intermountain Research Station, Ogden, UT.

Smith, J. T. 2003. Greater sage-grouse on the edge of their range: leks and surrounding landscapes in the Dakotas. M.S. thesis, South Dakota State University, Brookings.

Sveum, C. M., W. D. Edge, and J. A. Crawford. 1998. Nesting habitat selection by sage grouse in south-central Washington. Journal of Range Management 51:265-269.

Swenson, J. E. 1986. Differential survival by sex in juvenile sage grouse and gray partridge. Ornis Scandinavica 17:14-17.

Tueller, P. T. 1989. Remote sensing technology for rangeland management applications. Journal of Range Management 42:442-453.

Wakkinen, W. L. 1990. Nest site characteristics and spring-summer movements of migratory sage grouse in southeastern Idaho. M.S. thesis, University of Idaho, Moscow.

Wakkinen, W. L., K. P. Reese, J. W. Connelly, and R. A. Fischer. 1992. An improved spotlighting technique for capturing sage grouse. Wildlife Society Bulletin 20:425-426.

Wallestad, R. O. 1971. Summer movements and habitat use by sage grouse broods in central Montana. Journal of Wildlife Management 35:129-136.

Wallestad, R. O. 1975. Life history and habitat requirements of sage grouse in central Montana. Montana Fish and Game Department Technical Bulletin. Helena, MT.

Wallestad, R. O., and D. B. Pyrah. 1974. Movement and nesting of sage grouse hens in central Montana. Journal of Wildlife Management 38:630-633.

Walsh, D. P. 2002. Population estimation techniques for greater sage-grouse. M.S. thesis, Colorado State University, Fort Collins.

Wambolt, C. L., A. J. Harp, B. L. Welch, N. Shaw, J. W. Connelly, K. P. Reese, C. E. Braun, D. A. Klebenow, E. D. McArthur, J. G. Thompson, L. A. Torrell, and J. A.Tanaka. 2002. Conservation of greater sage-grouse on public lands in the Western U.S.: implications of recovery and management policies. Policy Analysis Center for Western Public Lands Policy Paper SG-02-02. Caldwell, ID.

Welch, B. L., F. J. Wagstaff, and J. A. Roberson. 1991. Preference of wintering sage grouse for big sagebrush. Journal of Range Management 44:462-465.

Welch, B. L., J. C. Pederson, and R. L. Rodriquez. 1988. Selection of big sagebrush by sage grouse. Great Basin Naturalist 48:274-279.

Wiley, R. H. 1973. Territoriality and non-random mating in sage grouse, *Centrocercus urophasianus.* Animal Behavior Monographs 6:87-169.

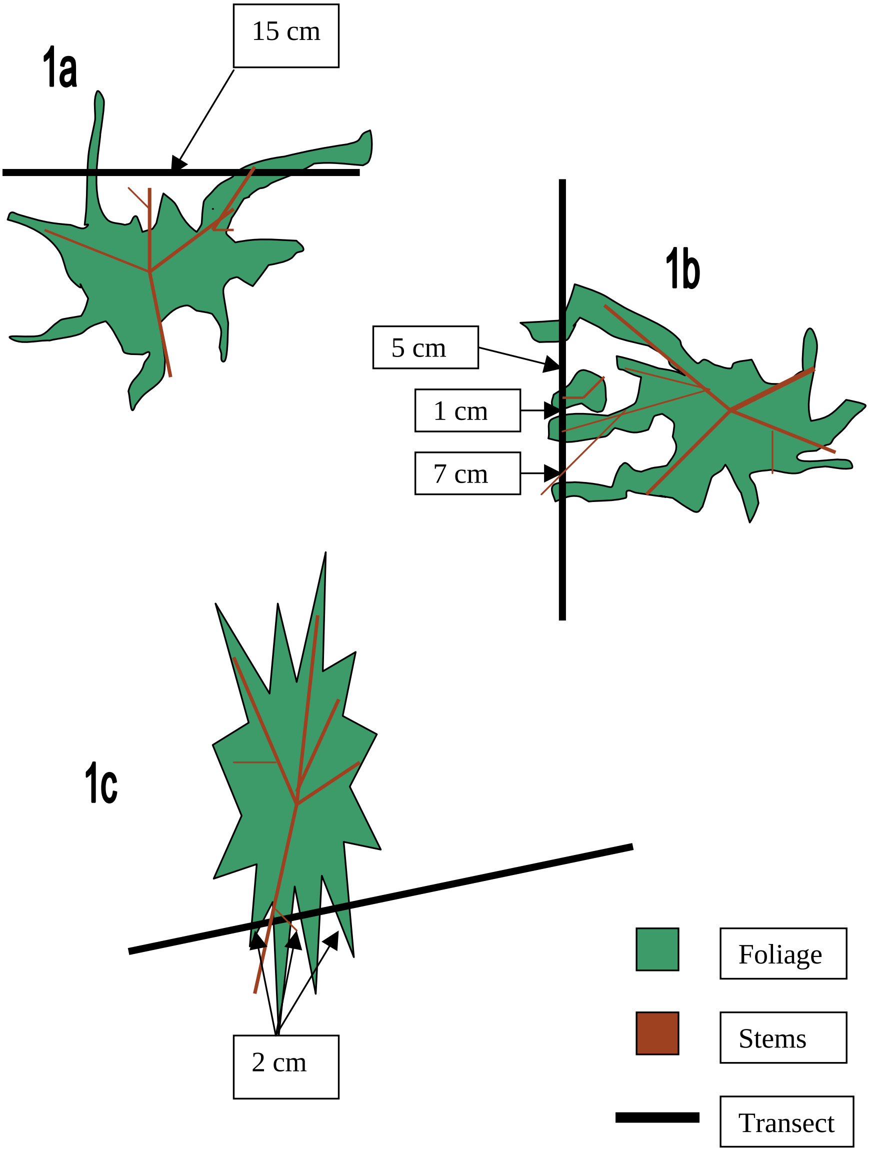
Willis, M. J., G. P. Keister, Jr., D. A. Immell, D. M. Jones, R. M. Powell, and K. R. Durbin. 1993. Sage grouse in Oregon. Oregon Department of Fish and Wildlife, Wildlife Research Report 15, Portland, OR.

Winward, A. H., and E. W. Tisdale. 1969. A simplified chemical method for sagebrush identification. University of Idaho Forest, Wildlife and Range Experiment Station Bulletin 11.

Winward, A. H., and E. W. Tisdale. 1977. Taxonomy of the *Artemisia tridentata* complex in Idaho. University of Idaho Forest, Wildlife and Range Experiment Station Note 19.

Zablan, M. A., C. E. Braun, and G. C. White. 2003. Estimation of greater sage-grouse survival in North Park, Colorado. Journal of Wildlife Management 67:144-154.

Appendix 1. Illustrations of Canfield (1941) line intercept technique showing gaps in foliage from overhead. Figure 1a, the gap should be excluded from the measurement. Figure 1b, the 1 cm gap should be included while the 5 and 7 cm gaps are excluded. Figure 1c, the 2 cm gaps are included in the measurement.



Appendix 2. A general procedure for assessing sage-grouse breeding habitat with an example of a data sheet (one side only) used for habitat monitoring in southern Idaho.

Before going into the field:

1. Acquire the necessary equipment.
   a. 50 meter tape
   b. Meter stick
   c. Daubenmire frame
   d. Field forms
   e. Pens/pencils
   f. Camera/film
   g. GPS unit
2. Select an appropriate number of random points. The actual number of points (or points within strata) will depend on the size and homogeneity of the area to be assessed.

Collecting field data at random points:

1. Be certain the random point is located in sagebrush steppe (seedings and CRP could be included in this definition) and not in a non-habitat area such as a livestock pond or wheat field. If the point is not acceptable select another.
2. Select the sagebrush plant closest to the random point. A sagebrush plant can also be randomly selected by having one of the field crew toss an object (stake, rock, etc) over their shoulder and select the sagebrush plant closest to the object.
3. Run a tape at a random bearing (0-359 degrees) the distance of the transect (normally 20 to 50 meters).
4. Take a photo of the line from one or both ends (optional).
5. Measure intercept of shrub crowns (by species) along the tape, careful to work along only one side of the tape. Measurements should be made with a meter stick and not by trying to use measurements on the transect tape.
6. Work back along the opposite side of the tape from which the canopy measurements were taken and place a Daubenmire frame at 1-meter intervals (i.e., a 50-m transect would yield 50 Daubenmire plots).
   a. For every frame estimate cover of forbs (by species), grasses, annual grasses, litter, and bare ground.
   b. Measure the height of the sagebrush plant or other shrub nearest the outside right (or left) corner of the frame.
   c. Measure the droop height of the grass plant nearest the outside right (or left) corner of the frame. This can be done separately for annuals and perennials or just perennials.
   7. Move to the next random point.

50-mTransect: Location ________________________________

Photo numbers ________________ Date ________________

Elevation ________________ Slope ________________

Aspect ________________ Crew ________________

Line Intercept – Shrubs

Artemisia tridentata wyomingensis ________________

____

Art. tripartita ________________________________

____

Other ________________________________

Daubenmire – 1=0-1%, 2=1.1-5%, 3=5.1-25%, 4=25.1-50%, 5=50.1-75%, 6=75.1-100%

Shrub ht (cm)	Grass ht (cm)	Grass	Bare	Litter	Minor forbs	Cheat-grass	Major forbs by species: abundant or eaten by sage-grouse

1. ________________________________
2. ________________________________
3. ________________________________
4. ________________________________
5. ________________________________
6. ________________________________
7. ________________________________
8. ________________________________
9. ________________________________
10. ________________________________
11. ________________________________
12. ________________________________
13. ________________________________
14. ________________________________
15. ________________________________
16. ________________________________
17. ________________________________
18. ________________________________
19. ________________________________
20. ________________________________

Appendix 3. Key to sage-grouse wings in Idaho.

Molting primaries 10 or 9 .... Adult

  Primary 1 less than 150 mm .... Female

  Primary 1 greater than 149 mm .... Male

    Molting primary 9 with worn, pointed primary 10 .... Yearling

    Molting primary 9 with rounded primary 10 .... Adult

Molting primaries 8, 7 or 6:

  Primaries 10 and 9 pointed and in good condition .... Juvenile

    Primary 1 less than 126 mm .... Female

    Primary 1 greater than 126 mm .... Male

  Primaries 10 and 9 pointed, worn and faded .... Yearling

    Primary 1 less than 150 mm .... Female

    Primary 1 greater than 149 mm .... Male

  Primaries 10 and 9 rounded, somewhat faded .... Adult

    Primary 1 less than 150 mm .... Female

    Primary 1 greater than 149 mm .... Male

Note: A yearling or adult female molting primary 6, 7 or 8 (rarely) can be classified as having brought off a brood, although it should not be implied that any chicks survived to fall.

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