Use of GIS and a modified habitat suitability index model to quantify Columbian sharp-tailed grouse habitats in the Upper Blackfoot Valley Montana

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USE OF GIS AND A MODIFIED HABITAT SUITABILITY INDEX MODEL TO QUANTIFY COLUMBIAN SHARP-TAILED GROUSE HABITATS IN THE UPPER BLACKFOOT VALLEY, MONTANA

Master’s Thesis

by

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Date
Columbian sharp-tailed grouse (*Tympanuchus phasinellus columbianus*) historically occupied much of the shrub-steppe habitat west of the Continental Divide. In western Montana, and across the Intermountain West, these areas were some of the first to be converted to agriculture. As a result of these changes and other impacts, CSTG populations have declined precipitously across their range. If a population of CSTG still survives in Montana, it is most likely to occur in the upper Blackfoot Valley, in the sagebrush and grassland areas surrounding the town of Helmville. Population supplementation may be the only way to restore and/or sustain CSTG populations in Montana.

A model to quantify CSTG habitat quality was developed using a modified version of an existing Columbian sharp-tailed grouse Habitat Suitability Index procedure in conjunction with a GIS to analyze Landsat TM data. The model estimated habitat suitability over a large area, and this output was used to identify areas most likely to benefit from conservation and restoration, to locate potential sites for reintroduction, and to determine if reintroduction of this species from stable populations from outside Montana is warranted.

The results suggest that there is ample high quality habitat available in the upper Blackfoot Valley to warrant reintroduction. However, due to uncertainties in the model, and an inability to considered fine-scale attributes of habitat, it is not recommended that CSTG be reintroduced at this time. Recommendations include field quantification of winter forage followed by any necessary restoration of existing habitats before reintroducing birds from stable populations elsewhere. Two areas with the highest potential for restoration and future reintroduction are identified.
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Numerous people provided support, assistance, and direction, without which this undertaking would not have been possible. I am indebted, and give my sincerest appreciation to my committee members Vicki Watson, Len Broberg, and Paul Wilson. Vicki deserves special mention for not only serving as my committee chair, but also for offering hours of patient advice, friendship, and knowledge to someone who was more often than not an irresolute student. Her efforts were beneficial on this project and throughout my entire graduate education.

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INTRODUCTION

The Columbian sharp-tailed grouse (CSTG) (*Tympanuchus phasianellus columbiae*) was once common throughout its native range: shrub-steppe habitats west of the continental divide. CSTG exist today only in a handful of highly scattered, remnant populations. In western Montana, the species is thought to have dwindled to a single, tiny population in the upper Blackfoot River Valley. Very few recent sightings suggest this population may be near extinction, or is already extirpated. This study estimates the quality of CSTG habitats in the upper Blackfoot Valley and provides recommendations for possible reintroduction of the species and for restoration of existing habitats.

CSTG are one of six recognized subspecies of sharp-tailed grouse presently found in North America (AOU 1957, Johnsgard 1973). Lewis and Clark originally discovered the species in 1805 on the bunchgrass (*Agropyron*) and sagebrush (*Artemisia*) plains of the Columbia River. Historically CSTG occupied British Columbia and most US states west of the Continental Divide, except Arizona and possibly New Mexico (Aldrich 1963). Today CSTG are considered the rarest of the six sharp-tail grouse subspecies, having lost about 90% of their former range in Montana, Utah, Washington, and Wyoming (Hays et al. 1998, Miller and Graul 1980) (Figure 1). This massive reduction in range and numbers occurred rapidly and coincided closely with the settlement of intermountain areas and the conversion of grasslands to agriculture in the early decades of the 20th century (Yocum 1952). CSTG have since been reintroduced in Oregon and Nevada (Federal Register 2000), where a precariously small population has been established in each state. Most remaining CSTG populations are small and fragmented (Miller and Graul 1980) except in parts of Idaho, where the largest US population of CSTG resides, estimated at 20,000 to 65,000 birds (Meints et al. 1992, Deeble 1996). Other remnant CSTG populations occur in the few remaining, highly-isolated, relatively undisturbed patches of shrub-steppe and bunchgrass prairie in eastern Washington, northwestern Colorado, and south-central British Columbia.

In western Montana, CSTG were once common in the sagebrush plains associated with large intermountain river valleys (Hand 1969). However, the same suite of factors
that diminished populations elsewhere have reduced to near or actual extinction what was once the most abundant native gallinaceous bird occurring in the shrub-steppe of western Montana (Deeble 1996). It is not known if any populations of CSTG remain in Montana. A few birds were reported as recently as autumn of 2002 on a Helmville ranch (Manley 2003). In the mid 1990's only 2, distantly-isolated populations were known to occur in Montana, one outside Eureka in the Tobacco Plains, and one near Helmville in the upper Blackfoot Valley (Deeble 1996). Counts around this time estimated population sizes of less than 10 birds in the Tobacco Plains (Young in Deeble 1996) and less than 30 in the upper Blackfoot (Deeble 1996). Today, all accounts decisively conclude the Tobacco Plains population is extinct (Mantas 2003), while recent anecdotal reports suggest the Blackfoot population has declined precipitously and is near extinction (Deeble 2003, Manley 2003).

The drastic, state-wide population declines prompted the Montana Natural Heritage Program and Montana Fish, Wildlife, and Parks (MTFWP) to list CSTG as an S1 species, indicating the population in Montana is “critically imperiled because of extreme rarity or because of some factor(s) of its biology making it especially vulnerable to extinction” (Carlson 2003). CSTG were proposed for threatened species listing under the Endangered Species Act, however a review by the US Fish and Wildlife Service (USFWS) determined CSTG were not warranted for such protection (Federal Register 2000).

Substantial range-wide declines have created a strong interest in the re-establishment of the species to its historic range (Rodgers 1992), placing intense pressure on Idaho to provide transplant stock (Meints et al. 1992). Partially in response to this pressure, Meints et al. (1992) developed a CSTG Habitat Suitability Index (HSI) procedure to evaluate and rank the quality of CSTG habitats. The CSTG HSI quantifies
the suitability of leks\(^1\) or breeding sites as a function of their surrounding landcover and can be used to determine if suitable habitat is available to warrant reintroductions to existing or potential leks.

Additionally, for purposes of recovery efforts in Washington and elsewhere, researchers have attempted to assess CSTG populations’ geographic structure and genetics (Warheit and Schroeder 2001). A closely related and morphologically-similar subspecies, the Plains sharp-tailed grouse \((T. \ p. \ jamesi)\), is locally abundant east of the continental divide in Montana (Deeble 1996), and researchers have questioned whether the Blackfoot sharp-tailed grouse population is \(T. \ p. \ columbianus\) or \(T. \ p. \ jamesi\).

Population supplementation of CSTG from the stable, viable populations in Idaho to the upper Blackfoot Valley would only be feasible and appropriate if two requirements are fulfilled, (1) if the upper Blackfoot population is not of the Plains subspecies and is truly \(T. \ p. \ columbianus\), and (2) if enough suitable habitat, as defined by Meints et al. (1992), is available to justify reintroduction.

The first requirement, concerning subspecies affinity, is difficult to satisfy completely as conclusive evidence may now be impossible to obtain. A preliminary genetic analysis comparing several sharp-tailed grouse populations throughout the Northwest and Alaska attempted to answer this standing question. The study by Warheit and Schroeder (2001) concluded that genetic samples drawn from the upper Blackfoot Valley population in 1999 were taken from CSTG rather than Plains sharp-tailed grouse. It should be noted that the conclusions of Warheit and Schroeder (2001) could be questioned because of the limited number of individuals found to test in western Montana. The study also found that there was little or no migration of individuals between all populations analyzed. This second finding is supported by natural history characteristics indicative of CSTG, which are likely to preclude the Blackfoot Valley

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1 A lek is the center of activity of the breeding complex for a grouse population or individual breeding unit. The breeding complex is an area where display, mating, nesting, brood rearing, foraging, and loafing occur and typically includes all land within 2 km (1 mi) of the lek (Giesen and Connelly 1993). The size of the dispersal area around a lek should represent a minimum habitat area required for the particular population centered on the lek (Prose 1987). Leks are typically characterized as an open and flat area, approximately 15 m\(^2\), and frequently located on elevated grounds, such as knolls and ridge tops, where little vegetation grows. These areas are used by males for breeding display dances. Distant travel from a home lek is rare.
grouse from being connected by gene flow to any other populations westward or
eastward over the Divide. These characteristics include no records of migration or
dispersals greater than 20 km (Meints 1991) for CSTG, no regular long-distance
migrations, and no described zones of introgression between T. p. columbianus and T. p.
\textit{jamesi}. Additional behavioral evidence also suggests the grouse in the upper Blackfoot
Valley are of the Columbian subspecies. A Blackfoot Valley grouse was documented on
video performing an exaggerated "flutter jump" during breeding displays (Deeble 1996),
a behavior not observed in plains sharp-tails (Youmans in Deeble 1996).

Deeble (1996) argued that even if the Blackfoot grouse population is instead
found to be of the Plains subspecies, "it would represent the first known population of
this race west of the continental divide", and as such, the population and its habitat would
also be of great conservation interest. However, in this case population supplementation
from Idaho stock would not be appropriate. Citing the evidence described above, this
study assumes that the population found in the upper Blackfoot Valley in 1999 was
CSTG. Unfortunately, all indications suggest that there is no longer a large enough
population in the upper Blackfoot to support a conclusive taxonomic assessment.

The second requirement for warranted CSTG reintroduction concerns habitat
quality and quantity. Resource managers believe that "only carefully planned efforts to
reintroduce CSTG into highly suitable habitats have a high probability of success"
(Meints et al. 1992). Most attempts to re-establish CSTG in the Pacific Northwest have
been unsuccessful, with a lack of detailed planning and habitat evaluation cited as
probable causes (Meints et al. 1992). This is the possible cause of failed reintroduction
efforts in the Tobacco Plains (see below).

In the region surrounding Helmville, where the last population of CSTG is
believed to occur, the quality of CSTG habitat is virtually unknown. Connelly and Sands
(1995) completed a non-quantitative assessment of CSTG habitat in western Montana,
based upon brief field visits, a literature review, and conversations with wildlife
biologists. This study found "fair to poor" breeding habitat and "poor" winter habitat in
the upper Blackfoot Valley. Connelly and Sands (1995) recommended a detailed habitat
evaluation using the CSTG HSI, yet such an evaluation is still lacking to date.
The use of remotely sensed data and GIS models to rapidly assess and map large regions of wildlife habitat has become prevalent in recent years. Yet there are no published reports of the CSTG HSI being applied in a GIS environment. Previous studies have attempted to quantify potential CSTG habitat using remotely sensed data and GIS software (Redmond et al. 1998, Black et al. 1999), but these studies relied on broad scale vegetation associations, excluding fine-scale vegetative attributes which are of great importance to CSTG nest success (Prose 1987). Studies have shown CSTG primarily choose habitat based on height and density of vegetation, and secondarily on species composition (Hays et al. 1998). Furthermore, Black et al. (1999) did not quantify CSTG habitat using a continuous range, but rather described potential habitat in only two discrete categories, zero potential (unsuitable) or optimum potential (suitable).

The main goal of this study was to quantify CSTG habitat quality in the upper Blackfoot Valley using a continuous ranking so that the relative quality of habitats could be distinguished at a scale large enough to locate regions for special management. In order to meet this goal, this study had the following specific objectives:

1. Utilize existing, remotely-sensed, Landsat TM data to describe landcover in the study region.

2. Modify the existing CSTG Habitat Suitability Index procedure to facilitate the estimation of habitat suitability over a very large area using a GIS model in conjunction with the Landsat TM landcover data.

3. Obtain required model inputs, including fine-scale vegetation height and density measurements, and correlate these fine-scale measurements collected in one region with the broad-scale, remotely-sensed landcover data across all regions.

4. Use model estimation of CSTG habitat quality to: (a) determine if reintroductions of CSTG to the upper Blackfoot Valley are warranted at present, (b) identify the most appropriate sites for reintroduction if reintroduction is found to be appropriate, and (c) locate areas worthy of special management, conservation, or restoration as CSTG habitat.
STUDY AREA SELECTION & DESCRIPTION

The study region was delineated by the overlap of 3 regions. These regions included:

1. Locales having the most consistent confirmed and anecdotal sighting reports of CSTG described by Deeble (1996 and 2000),
2. The statewide CSTG habitat distribution estimated by the Wildlife Spatial Analysis Laboratory (WSAL) using vegetation associations (Redmond et al. 1998),
3. The CSTG distribution defined by MTFWP based on data originally mapped in 1970 by MTFWP wildlife biologists and later digitized (MTFWP 2003).

The resulting study area contained 240,139 ha (927 mi²), 60% of which is privately owned (Figure 2).

The study area is located in the upper Blackfoot River watershed, encompassing the river valley and foothills surrounding the towns of Ovando and Helmville, Montana. It is roughly centered on Helmville, approximately 100 km northeast of Missoula. Small portions of the study area fall within Missoula, Granite, and Lewis and Clark counties, but the vast majority is within Powell County.

Elevations in the study region range from a minimum of 1,141 meters (3,743 ft) to a maximum of 2,576 meters (8,451 ft), with a mean elevation of 1,583 meters (5,194 ft). However, research focused primarily on the valley floor, where the elevation is approximately 1,300 meters (4,265 ft). Average annual precipitation in the upper Blackfoot Valley is 43 cm, while the annual mean minimum and maximum temperatures are −4 °C (25 °F) and 12 °C (54 °F) respectively (Western Regional Climate Center 2003).

The dominant native plant community within the study area is shrub-steppe. Shrub-steppe is a descriptive term for plant communities consisting of one or more layers of perennial grass with a conspicuous, but discontinuous, layer of shrubs above
(Daubenmire 1988). The shrub layer is composed mainly of Rocky Mountain Big Sagebrush (*Artemesia tridentate*). In open areas interspersed between *Artemesia* grow forb species, such as arrowleaf balsamroot (*Balsamorhiza sagittata*), yarrow (*Achillea millefolium*), and salsify (*Tragopogon dubius*), and grasses, such as fescues (*Festuca* spp.) and bunchgrasses (*Agropyron* spp.). Douglas Fir (*Pseudotsuga menziesii*) and Ponderosa Pine (*Pinus ponderosa*) have invaded some areas. Deeble (1996) concluded this was likely a result of fire suppression in the valley.

Streams and rivers bisecting the dominant shrub-steppe communities often support narrow riparian areas. Several permanent kettle lakes and numerous ephemeral wetlands are scattered across the bottomlands. Approximately 15% of the study area is comprised of riparian species, including Black cottonwood (*Populus trichocarpa*), quaking aspen (*Populus tremuloides*), birch (*Betula* spp.), hawthorn (*Crataegus douglasii*), rose (*Rosa* spp.), snowberry (*Symphoricarpos albus*), and willow (*Salix* spp.). Where the foothills rise from the valley floor, the landscape becomes increasingly forested by evergreen species, including Ponderosa Pine and Douglas Fir.

The human population within the study region is small and scattered. The two population centers include the towns of Helmville and Ovando, where less than a total of 600 inhabitants live (US Census 2003). The valley bottomlands contain the vegetative communities most closely associated with CSTG. Most of the valley floor is privately owned and used for agriculture with large areas modified by grazing or converted to exotic grass pastures and haylands. Given this large overlap of private lands and CSTG habitats, it is hopeful to see a growing number of conservation easements in the area.

**METHODS**

*Study Approach*

I used the Meints et al. (1992) CSTG HSI procedure as the basis and methodology for estimating CSTG habitat quality. The CSTG HSI procedure is a revised version of a HSI developed by Prose (1987) for plains sharp-tailed grouse, but was modified by Meints et al. (1992), to reflect the specific habitat needs of CSTG. Both HSI’s were specifically created to evaluate sharp-tailed grouse habitats and potential release sites and
were developed for wildlife managers wishing to appraise a few leks using landcover maps and aerial photographs. Such efforts would produce discrete habitat suitability data for each lek evaluated. However, I wished to assess a very large region, wanted continuous data to determine how habitat suitability varied across the landscape, and was unable to practically locate existing or potential leks. Hence, the formal HSI was not workable for my purposes. This study’s approach differed from the formal CSTG HSI in that I used remotely sensed landcover data in conjunction with a GIS to model CSTG habitats. The original CSTG HSI allowed for such analyses once some modifications were made (see below).

The CSTG HSI has two main components, each component based on a life requisite of CSTG. These include (1) shrub and riparian habitats providing reliable winter food and cover from severe weather and (2) upland areas supplying food and vegetative cover during summer nesting and brood rearing (from here forward referred to as WFC and NBC respectively). To quantify the suitability of each life requisite, three inputs are required. The model assumes that WFC habitat quality can be estimated using landcover characteristics only, including distances between cover types and relative areas of cover types. The NBC component requires assessment of these same landcover relationships and additional vegetation height and density data. That is, the height and density of vegetation is more critical to NBC habitat suitability (given its use in nesting and brood rearing) than it is to WFC suitability. Measurements and calculations are “lek centered”, meaning all data are collected within a radius of either 2 km or 6.5 km from active or potential lek sites for NBC and WFC respectively. These distances are based upon home range sizes (habitat use in summer and winter) determined from observations of CSTG movements.

The landcover relationships and vegetation data are used along with a series of linear equations to quantify and relate interspersion of cover types and protective cover provided by residual vegetation to CSTG habitat suitability. The concept of “percent equivalent optimum area” is used to rate habitat quality on a continuous scale from zero (unsuitable) to one (optimum suitability). Prose (1987) stated percent equivalent optimum area.
...expresses field conditions (i.e. percent area providing a life requisite, quality level of the life requisite, and distance between cover types providing different life requisites) in terms of percent area of available habitat providing the life requisite at maximum quality and interspersion levels. Available habitat is defined as the total land area having the potential to support sharp-tailed grouse. For example, 100% actual area providing the life requisite at a 0.5 quality level is equivalent to 50% of the area providing the life requisite at a 1.0 quality level, i.e. 50% equivalent optimum area. Therefore, the equivalent optimum area concept assumes that a large area of low quality can have a habitat value equivalent to a smaller area of higher quality.”

The most significant modification to the original CSTG HSI was the use of the Spatial Analyst extension within ArcGIS 8.1 for Windows to rapidly analyze a raster-based landcover image instead of making hand calculations from maps or aerial photographs. This facilitated individual examination of over 5 million pixels in the landcover image, each of which was treated as a potential/existing lek and analyzed. This does not imply that I considered each pixel was a potential/existing lek per se, but rather that any given location (pixel) acted as a “center of analysis” around which I performed all necessary calculations. Therefore, the term “lek”, as used here, refers to a central point of calculation, not necessarily an actual or potential lek site. The habitat suitability of this point is a function of the physical characteristics in a radius of either 2 km for NBC, or 6.5 km for WFC, surrounding the point. The additional modifications necessary to permit this approach are outlined below. A copy of the Meints et al. (1992) CSTG HSI, which explains in greater detail the calculations, methodologies, and assumptions of the formal CSTG HSI procedure, can be found in Appendix D.

**Landcover Data**

The fundamental requirement of the CSTG HSI is knowledge of the landcover. Landcover data used in this study were based on a subset of a 30-m spatial resolution (each pixel covers a 30 x 30 m area) Landsat TM scene (Path 40, Row 27) acquired on
July 11, 1996. This image was selected because it overlapped the study area. The original Landsat image was cropped using the study area boundary.

In 1998 the WSAL classified the image into 19 landcover types. Each cover type was assigned a 4-digit code corresponding to a different plant community, vegetation density, or land use (e.g., cover code 6102 referred to riparian broadleaved species). The digital landcover data were especially useful for quantifying CSTG habitat because great effort was extended to divide cover types within and among sagebrush and grassland types, the vegetative communities most closely associated with CSTG. Sagebrush was delineated into 5 separate cover types; 4 density classes (thin, medium, thick, and very thick) and a fifth class describing sagebrush areas containing invading conifer species. I used a comprehensive literature review and the cover type descriptions from the Montana Landcover Atlas (Fisher et al. 1998) to delineate the 19 cover types into one of the two life requisite components, WFC or NBC. A few cover types, such as water, did not belong in either life requisite and were thus classified as “neither”. Although some cover types could potentially function as either NBC or WFC, I chose the more appropriate of the two, as a cover type could be classified as NBC or WFC, but not both. See Appendix A for a detailed description of the Landsat image dataset, its classification into landcover types, and the accuracy of its classification.

Field Characterization of Nesting and Brood Rearing Cover

I collected vegetation height and density measurements in 7 samples of each NBC cover type in order to quantify the ability of vegetation to provide nesting and brood rearing cover. Vegetation height and density were described in terms of vegetation visual obstruction readings (VOR) using a Robel pole (Robel 1970). Due to the timing of CSTG reproduction, I collected VOR measurements from late March to in early May 2003, before significant spring green-up. Residual vegetation from the previous year is the only cover available to nesting hens and is considered to be one of the factors characterizing NBC suitability (Prose 1987). The pole was constructed from a segment of PVC piping (1.8 x 200 cm), marked into half-decimeters. VOR measurements were taken every 5 m along a 25 m transect (5 VOR measurements per transect).
I located transects using ArcGIS and the WSAL landcover map by identifying several patches of each NBC cover type within reasonable walking distance of roads and on accessible lands (public or private with permission). I selected only large patches (greater than 2 pixels per side or 60 x 60 m) to ensure that any inaccuracies in the GPS unit would not cause a 25 m transect to extend into another cover type. I determined the approximate center of each patch, and loaded the UTM coordinates of the patch's center into a Magellan GPS 315/320 Revision 2.02 handheld GPS unit.

Once in the field, I navigated to the center coordinates of the patch using the GPS unit and examined the surrounding area to ensure the patch was not obviously misclassified from the landcover map (e.g. a patch was classified as sagebrush on the landcover map but in reality was grassland). If the patch was misclassified, it was not used for VOR measurement. I was able to visually identify patches as misclassified very rarely. More commonly, some low-lying areas were covered by spring melt water and were inaccessible. I chose a random starting point and direction for the transect, then I tied a 25-m nylon rope between two stakes, starting from the random point and continuing in the selected direction. VOR measurements (the number of decimeters visually obstructed on the pole by vegetation) were recorded at an observation height of 1 m, 4 m from the pole and at a distance of 20 cm to the right of the transect line.

VOR measurements were used to calculate a mean VOR value for each NBC cover type. All similarly classified patches of each NBC cover type across the study area were assigned the appropriate mean VOR (i.e. all patches classified as Sagebrush, Thin in the study area were assigned the same VOR value). I assumed that mean VOR values calculated from measurements taken in one area could be applied across the entire study region because similar patches, no matter the distance separating them, were originally classified as equivalent (i.e. having the same vegetative characteristics) from the Landsat TM dataset.

**Modeling Process, Assumptions, and Boundary Conditions**

Using ArcGIS Spatial Analyst, I analyzed the Landsat TM dataset to determine landcover characteristics in the home range radius (2 km for NBC and 6.5 km for WFC) around each pixel. The landcover characteristics of interest were the percent availability
of each NBC and WFC cover type and the mean distance from each individual NBC cover type to the nearest WFC habitat and vice versa. (For example, when determining mean distance from an individual NBC cover type, say Sagebrush, Thin, to any WFC cover type, WFC cover types were lumped into a single category, WFC, and the distances from Sagebrush, Thin patches to the nearest patch of WFC habitat was calculated.) I calculated percent availability as the total area of an individual NBC cover type relative to the total area of all cover types considered useable by CSTG (i.e. the total area of Sagebrush, Thin divided by the total area of all NBC and WFC cover types). I made analogous calculations for each WFC cover type.

The products of these analyses were two sets of raster images for every NBC and WFC cover type. Each pixel in the resulting rasters represented the product of the appropriate calculation, either percent availability or mean distance, using the values of all pixels within the home range radius (2 km for NBC and 6.5 km for WFC). The detailed methodology outlining the use of Spatial Analyst to perform these calculations can be found in Appendix B.

The original CSTG HSI called for distance measurements between cover types to be made at several random points within each cover type. The procedure required that for every lek being evaluated, one distance measurement be made at a random point for every 1% of a cover type’s availability. For instance, for a given lek, if a NBC cover type provided 23% of the total NBC habitat available, 23 total random points were to be selected in patches of that NBC cover type and the distance from those random points to the edge of the nearest WFC patch measured. Instead of following this methodology, I made use of the computational capabilities of Spatial Analyst to determine the shortest straight-line distance (center to center) from every patch of each individual NBC cover type to the nearest WFC patch of any cover type and vice versa. Using these distance data, I then calculated the mean minimum distance from each individual NBC cover type to WFC of any cover type and vice versa around each pixel using the appropriate home range radius.

I made a similar modification to the method of collecting vegetation data. Meints et al. (1992) required one VOR measurement be taken every 25 m in each NBC cover type
for every 1% of that cover type available. Instead, the method outlined above was used to determine VOR measurement locations and 7 VOR transects (with 5 readings per transect) were placed in each NBC cover type regardless of its availability relative to other NBC cover types.

As stated above, the original path 40, row 27 Landsat image was cropped to the study area boundary. Because the habitat model used adjacent pixels to determine the suitability of each location in the study area, analysis of pixels near the boundary included pixels outside the study region; areas for which there were no landcover data. Using these outside points in calculations causes “boundary effects” which can produce misleading results for locations close to the edge. In this analysis, any calculation involving cells 6.5 km or less from inside the study area edge suffered from such errors. The region where boundary errors occurred is between the "Analysis Boundary" and the "Study Area Boundary" (Figure 2).

To avoid erroneous results, I removed from the model output all data points within 6.5 km of the edge produced using the above calculations. Since landcover data extended 6.5 km beyond the intended analysis boundary, this action did not remove areas of interest within the study region, only those pixels suffering from boundary effects.

**Model Habitat Suitability Calculations**

All calculations using the equations described below were performed on every pixel considered CSTG habitat, i.e. classified as NBC or WFC. Around every pixel calculations were made using the landcover characteristics within 2 km for NBC and 6.5 km for WFC.

**Winter Food and Cover**

The landcover measurements for WFC cover types were related to habitat suitability using the following equations derived from the habitat suitability relationships provided in Meints et al. (1992).

\[
WFC_{	ext{Dist}} \text{ attempts to account for the mean distance between each individual WFC cover type and the nearest NBC habitat. } WFC_{	ext{Dist}} \text{ was calculated for each WFC cover type using Equation 1, with the following boundary conditions}
\]
\[ W_{FC_{Dist}} = -0.0024 \times W_w + 1.2195 \text{ for } 90 \leq W_w \leq 500 \] (Equation 1)

\[ W_{FC_{Dist}} = 1 \text{ for } W_w < 90 \text{ m} \]
\[ W_{FC_{Dist}} = 0 \text{ for } W_w > 500 \text{ m} \]

where \( W_w \) equaled the mean minimum distance from an individual WFC cover type to the nearest patch of NBC habitat in meters. If the mean minimum distance between a WFC cover type and NBC habitat is less than 90 m, distance is not considered a limiting factor in habitat suitability for that WFC cover type. If the mean minimum distance between a WFC cover type and NBC habitat is greater than 500 m, that WFC cover type is not useable CSTG WFC habitat.

Using the \( W_{FC_{Dist}} \) suitability values from Equation 1, the percent equivalent optimum area providing winter food and cover was calculated and was defined as

\[ PEOA_{WFC} = \sum_{i=1}^{n} (N_i)(W_{FC_{Dist,i}}) \] (Equation 2)

where \( PEOA_{WFC} \) equaled the percent equivalent optimum area providing winter food and cover, \( N_i \) equaled the percent availability of each WFC cover type (defined above), \( W_{FC_{Dist,i}} \) equaled the suitability index accounting for distances between WFC cover types and NBC habitat, and \( n \) equaled the total number of WFC cover types present (in this study \( n = 5 \)).

The final WFC habitat suitability index, \( SI_{WFC} \), was related to \( PEOA_{WFC} \) using Equation 3, where

\[ SI_{WFC} = 10 \times PEOA_{WFC} \text{ for } PEOA_{WFC} \leq 0.1 \] (Equation 3)

\[ SI_{WFC} = 1 \text{ for } PEOA_{WFC} \geq 0.1 \]
Thus, according to Equation 3, optimum WFC suitability occurs at percent equivalent optimum area values of 0.1 (10%) or greater.

If SIWFC was less than 0.1, the formal HSI procedure also accounted for the contribution of grain crops as a potential winter food source. Cultivated food supplies are considered to increase WFC suitability when available (Prose 1987, Meints et al. 1992). However, Giesen (1997), in a study of CSTG habitat use in Colorado, found that the use of wheat fields by CSTG was limited to a few weeks after harvest when waste grain was readily available prior to snow cover. Furthermore, only a fraction of the agriculture in the study area is in small grain crops (Green 2003). For these reasons, cultivated grain was not considered a winter food source significant enough to support CSTG in the upper Blackfoot Valley, and therefore, the contribution of cultivated grain to WFC habitat suitability was not considered in this study.

Nesting and Brood Rearing Cover

The calculation of NBC habitat suitability involved landcover characteristics (area and distance between NBC cover types and WFC habitat) and vegetation height and density data (in terms of VOR).

$NBC_{oist}$ attempts to account for the mean distance between each individual NBC cover type and the nearest WFC habitat. $NBC_{oist}$ was calculated using Equation 4, with the following boundary conditions

$$NBC_{oist} = -0.0005 \times W_s + 1.3298 \text{ for } 620 < W_s < 2500 \text{ (Equation 4)}$$

$$NBC_{oist} = 1 \text{ for } W_s < 620 \text{ m}$$
$$NBC_{oist} = 0 \text{ for } W_s > 2500 \text{ m}$$

where $W_s$ equaled the mean minimum distance from an individual NBC cover type to the nearest patch of WFC habitat in meters. If the mean minimum distance between a NBC cover type and WFC habitat is less than 620 m, distance itself is not considered a limiting factor in habitat suitability for that NBC cover type. If the mean minimum distance
between a NBC cover type and WFC habitat is greater than 2,500 m, that NBC cover type is not useable CSTG NBC habitat.

Unlike WFC habitats, the suitability of an area for nesting and brood rearing is also a function of the amount, height, and density of vegetation, especially forbs and grasses from the previous year (residual vegetation) (Meints et al. 1992). The vegetation measurements (VOR) were related to NBC habitat suitability via Equation 5.

\[
\text{VEG} = 0.6667 \times \text{VOR} - 0.6667 \text{ for } 1 \leq \text{VOR} \leq 2.5 \quad (\text{Equation 5})
\]

\[
\text{VEG} = 0 \text{ for } \text{VOR} < 1 \text{ dm}
\]

\[
\text{VEG} = 1 \text{ for } \text{VOR} > 2.5 \text{ dm}
\]

where VOR equaled the mean visual obstruction reading in decimeters for each NBC cover type. An NBC cover type cannot provide any useful vegetative cover if its mean VOR is less than 1 dm and is considered to provide optimum cover if its mean VOR is greater than 2.5 dm.

The NBC\text{Dist} values for each NBC cover type from Equation 4 were used in conjunction with each NBC VEG value from Equation 5 to determine the percent equivalent optimum area providing nest/brood cover (PEOA\text{NBC}). PEOA\text{NBC} was defined as

\[
\text{PEOA}_{\text{NBC}} = \sum_{i=1}^{n} (\text{VEG}_i)(N_i)(\text{NBC}_{\text{Dist}_i}) \quad (\text{Equation 6})
\]

where PEOA\text{NBC} equaled the percent equivalent optimum area providing nesting and brood rearing cover, N\text{t} equaled the percent availability of each NBC cover type, VEG\text{i} equaled the suitability index accounting for vegetation height and density, and n equaled total number of NBC types present (in this study n = 8).

The final NBC habitat suitability index, SINBC, was related to PEOA\text{NBC} using Equation 7, where
\[ \text{SINBC} = 2.222 \times \text{PEOA}_{\text{NBC}} - 0.111 \text{ for } 0.05 \leq \text{PEOA}_{\text{NBC}} \leq 0.5 \] (Equation 7)

\[ \text{SINBC} = 0 \text{ for } \text{PEOA}_{\text{NBC}} < 0.05 \]
\[ \text{SINBC} = 1 \text{ for } \text{PEOA}_{\text{NBC}} > 0.5 \]

Maximum NBC suitability occurs when the percent equivalent optimum area providing nesting and brood rearing cover is greater than 0.5 (50%) and reduces to 0 suitability at values less than 0.05 (5%) (Meints et al. 1992).

**Final Habitat Suitability Determination**

The final CSTG HSI value for each location (pixel) was determined by choosing the lesser of the SINBC and SIWFC values.

**RESULTS**

**Delineation of Landcover Types into Life Requisite Functions**

The 19 landcover types classified by WSAL were delineated into the life requisite functions using known habitat associations, seasonal habitat preferences, and home ranges of CSTG as documented from numerous studies across many regions (e.g. Swenson 1985, Marks and Marks 1987, Meints 1991, Stralser 1991, Cope 1992, Meints et al. 1992, Giesen and Connelly 1993, Giesen 1997). Although CSTG habitat use varies in different regions, all CSTG generally make use of two distinct seasonal habitats, and migration has been documented between these habitat types.

In summer, grasslands and sagebrush habitats that provide relatively dense cover are most often used for nesting and brood rearing. Giesen and Connelly (1993) characterized summer habitats of CSTG as shrub-steppe vegetation with a diversity of forbs and bunchgrasses. In west-central Idaho, Marks and Marks (1987) found two species of sagebrush were the most important species for nesting cover and that nesting cover often included arrowleaf balsamroot and bluebunch wheatgrass. These findings were supported by Meints (1991), who, in his own study in Idaho, found 74% of nests were placed in shrub habitats. In one of the only published studies of CSTG habitat use
in Montana, Cope (1992) determined hens with broods were located in dense vegetation consisting primarily of native grasses (rough fescue, bluebunch wheatgrass, or blue grass) or shrubs.

In winter, a distinct habitat shift occurs, and CSTG make greater use of riparian and deciduous broadleaved areas which provide critical food and shelter (Giesen and Connelly 1993). In southeastern Idaho, CSTG were closely associated with chokecherry, serviceberry, hawthorn, willow, birch, or aspen in winter (Meints 1991). In another study of CSTG winter habitat use in Idaho, Marks and Marks (1987) observed that all grouse decreased their use of sagebrush and grassland areas and increased their use of mountain shrub and riparian cover types, with hawthorn, serviceberry, and common chokecherry providing the main winter foods.

Based on these findings and the landcover code/plant species composition descriptions from the Montana Landcover Atlas (Fisher et al. 1998), 8 of the 19 cover types were most likely to provide nesting and brood rearing cover. These were (cover type name, cover code): Upland Grassland (3101), Mesic Grassland (3105), Altered Herbaceous (3102), and all five Sagebrush cover types: Sagebrush, Thin (3301), Sagebrush, Medium (3302), Sagebrush, Thick (3303), Sagebrush, Very Thick (3304), and Sagebrush, Invading Conifer (3306). Five of the 19 cover types were most likely to provide winter food and cover. These included: Mixed Mesic Shrub (3210), Upland Broadleaf (4102), Riparian Broadleaf (6102), Riparian Herbaceous (6201), and Riparian Shrub (6202). Six of the cover types were unlikely to support either life requisite function, including Dry and Irrigated Agriculture (2010 and 2020 respectively), Conifer Forests (4200), Water (5000), Barren Areas (7500), and Snow Fields (9100).

All told, 128,591 ha were considered usable as CSTG habitat, 82,987 ha (65%) of which were considered NBC cover types. WFC cover types comprised the remaining 45,604 ha or 35% of usable CSTG habitat. 111,549 ha, or 46% of the total study area, were not considered CSTG habitats. These results are summarized in Table 1.

**Nesting and Brood Rearing Cover Density from Field Observations**

Seven transects were placed in each NBC cover type and five VOR measurements were taken per transect, resulting in a total of 35 VOR data points per NBC cover type.
Mean VOR values for each NBC cover type were calculated from these measurements. VOR data for the 8 NBC cover types are summarized in Table 1, while detailed measurement data and locations are provided in Table 4 (Appendix C).

Two of the 8 NBC cover types, Altered Herbaceous and Upland Grassland, did not provide the minimum residual cover of 1.0 dm required to be considered suitable habitat (VEG > 0). Therefore all patches of these cover types were classified as unsuitable (SINBC = 0). Altered Herbaceous had the lowest mean VOR value (0.53 dm) and was often associated with areas severely disturbed by grazing and/or agriculture.

Four of the sagebrush cover types: Medium, Thick, Very Thick, and Invading Conifer, provided greater than the mean 2.5 dm of residual vegetative cover required for optimum suitability. Mesic Grassland and Sagebrush, Thin provided less than optimum residual vegetation, with mean VOR values of 1.2 dm and 1.64 dm respectively.

**Habitat Suitability Based on Model Output**

**Winter Food and Cover**

The modified CSTG HSI estimated WFC habitats as at or near optimum suitability throughout most of the study region (Figure 4). Consequently, a significant portion of the study area had SIWFC values greater than the minimum suitability value of 0.75 recommended by Meints et al. (1992) to warrant reintroduction of CSTG. SIWFC values were greater than 0.75 across approximately 90% (115,732 ha) of areas usable as CSTG habitat, while 79% (101,587 ha) of CSTG habitat was characterized as having optimum suitability (SIWFC = 1). The minimum and mean SIWFC values were 0.32 and 0.95 respectively (Table 2).

One large conspicuous area in the northeast corner of the study area exhibited lower than average WFC habitat suitability. Lower values in this region can be attributed to few and distant WFC cover types scattered along the periphery of very large patches of NBC habitat (in this case extensive grassland pastures) and agricultural fields (Figure 3). As a result, WFC percent availability in this region was small, and mean minimum distances from WFC cover types to NBC habitat were large, both contributing to low PEOA\textsubscript{WFC} and consequently low SIWFC values (Equations 2 and 3).
Results indicate that although much of the WFC habitat occurred in very small patches or narrow riparian corridors, WFC cover types were well distributed throughout the study area. Thus, the majority of locations had WFC$_{Dist}$ values near optimum (WFC$_{Dist} = 1$, Equation 1) and low percent availability. However, a PEOA$_{WFC}$ value of only 0.1 is required for optimum suitability (SIWFC = 1). Even though patches of WFC habitat were relatively small/narrow, PEOA$_{WFC}$ was large enough in most areas (due to high values of WFC$_{Dist}$) to translate into high overall WFC suitability.

**Nest & Brood Rearing Cover**

Unlike the results from the WFC model, NBC habitat suitability was quantified as less than optimum across much of the study area (Figure 5). Four percent (5,144 ha) of habitats available to CSTG had optimum NBC habitat suitability (SINBC = 1, Equation 7), while 10% (12,851 ha) met the minimum suitability value of 0.75 to support reintroduced CSTG. The mean SINBC value was 0.30, considerably lower than the mean SIWFC value of 0.95. The minimum SINBC value was 0.0 (Table 2).

Two patches of highly suitable NBC habitat were predicted, the largest of which occurred approximately 7.5 km southwest of Helmville. A smaller patch, west of Brown’s Lake and south of Kleinschmidt Lake also had much greater than average SINBC values. Regions exhibiting high NBC suitability were characterized by relatively large patches of NBC cover types (high percent availability) with optimum VEG indexes (Equation 5) and were interspersed with WFC habitats (high NBC$_{Dist}$ suitability, Equation 4).

The most limiting factor in NBC habitat quality was the small amount of NBC habitats offering optimum vegetation height and density. Only 20% of NBC habitats provided the requisite 2.5 dm of residual vegetation. Approximately 42% of NBC habitats provided less than optimum residual vegetation, while a full 38% of all NBC habitats offered less than the minimum VOR measurement of 1.0 dm considered necessary to support CSTG.
Final Habitat Suitability

The final HSI value for each location was the minimum value of SIWFC or SINBC at that location (Figure 6). Clearly, NBC habitat suitability was the most limiting across nearly all of the study area (Figure 7). Also, because some of the poorest WFC habitats overlapped with some of the highly suitable NBC habitats (particularly in the region directly east and southeast of Kleinschmidt Lake), the total area of CSTG habitat predicted to have optimum suitability dropped to 3% (3,858 ha). The amount of CSTG habitat with a suitability index greater than 0.75 did not change appreciably. The mean overall HSI value was 0.29.

When interpreting the total amount of suitable habitat predicted by the model, one must consider the fact that the suitability of each location is a function of its surrounding area, or 13,273 ha, the area of a 6.5-km radius circle. If a pixel is found to have a suitability of 0.75, this indicates that the surrounding 13,273 ha are considered capable of supporting a population of CSTG centered on that location (a maximum value which assumes all habitats within 6.5 km are usable by CSTG). The model found approximately 143,000 pixels with an HSI value greater than 0.75. The sum of all non-overlapping areas usable by CSTG within 6.5 km of each of these points is 56,223 ha. This area represents the total amount of habitat calculated to be capable of supporting reintroduced CSTG.

DISCUSSION

Comparison of Model Predictions to Previous Studies

The modified CSTG HSI model, used in conjunction with a GIS to examine a Landsat TM dataset was able to quantify CSTG habitat suitability in an efficient and effective manner over a very large area. Continuous habitat suitability data were produced, highlighting areas of high and low habitat quality throughout the study region. Those regions identified as likely to contain the best CSTG habitat based on broad-scale field observations made by the author and others (e.g. Connelly and Sands 1995, Deeble 2003) were predicted by the model to contain the best remaining habitat. Furthermore,
historically active leks sites, including the most recently known active lek site, are situated directly adjacent to large areas of the most suitable habitat.

The results from the modified CSTG HSI model contradict, in part, the findings of Connelly and Sands (1995) who, from brief field visits, qualitatively estimated CSTG habitat suitability in the upper Blackfoot Valley as generally poor. They cited a lack of quality winter range as the most significant limiting factor for CSTG in the upper Blackfoot Valley. Those conclusions directly contradict the predictions of the model presented here, which suggested a lack of nesting habitats as the limiting factor, and predicted optimum suitability for winter habitats throughout most of the study area. However, Connelly and Sands (1995) considered species composition and food availability in winter habitat types, both of which were not directly accounted for in the GIS model (see below).

Model predictions were similar to the findings of Connelly and Sands (1995) in regards to the suitability of NBC habitat. They attributed a low amount of dense nesting vegetation as the overall limiting factor in breeding habitat suitability, a conclusion the model supports. Furthermore, Connelly and Sands (1995) cited 3 areas (locations not given) that should provide adequate nesting and brood rearing cover, one being described as “dominated by sagebrush and bunch grass and not grazed by domestic livestock.” This study predicted two areas of high NBC habitat suitability, one of which overlaps with the Kleinschmidt Waterfowl Production Area (WPA), one of the few remaining areas in the upper Blackfoot Valley dominated by sagebrush and bunchgrasses and not recently grazed by domestic livestock. It is possible that the Kleinschmidt WPA is one of the areas alluded to by Connelly and Sands (1995).

Model Uncertainties

Assessing the “accuracy” of the habitat suitability predictions is impossible as there is no standard to which the output can be compared, unless the results are judged against the output from the formal CSTG HSI procedure. However, such information currently does not exist for the upper Blackfoot Valley, and time and funding constraints made it impractical to do so for this study. Nevertheless, uncertainties in model output can be addressed and were introduced by two main factors: (1) the age and classification
accuracy of the Landsat TM dataset and (2) an inability to directly associate information collected at broad scales (Landsat TM dataset) with the fine-scale attributes of habitat suitability, such as species composition of WFC habitats (i.e. abundance and food value of riparian species) and the association by cover type of VOR measurements collected in one area to mean vegetation height and density in another area.

**Landsat Classification Uncertainty**

The Landsat TM dataset was nearly 7 years old at the time of its use in this study. Development, changes in agricultural practices or land use, and a prolonged drought during this elapsed period may have all significantly altered portions of the landcover in the study area. Because of funding constraints, these changes were not quantified. However, it is likely the ability of the land to support CSTG has decreased during this time due to increased development, conversion to agriculture, and drought.

The 1998 upper Blackfoot Valley landcover map, based on Landsat TM data collected in 1996 and produced by the WSAL, is the most detailed and most recent landcover information available for the study region. Yet unquestionably uncertainty exists due to the inaccuracies of the original landcover classification. Thornton (1998) stated there was unavoidable spectral confusion among landcover types, especially within and among sagebrush and grassland types, within riparian cover types and with Mesic Grassland and other riparian cover. These cover types represent the vegetative communities most closely associated with CSTG and had some of the lowest classification accuracies of all cover types (as low as 22% for Sagebrush, Medium). Misclassification of landcover would introduce error, especially with the dismal classification accuracies of the sagebrush and riparian cover types. See Appendix A for a detailed review of classification accuracies.

**Scaling Concerns**

Without question, CSTG perceive the landscape at a scale much finer than that of the Landsat TM data (30 m² resolution). Thus, the fine-scale structural and composition attributes of habitat must play a significant role in determining the ability of an area to support CSTG in addition to the relationships assessed by the modified CSTG HSI. A
noteworthy limitation of this study was an inability to directly address the abundances and food values of riparian and other WFC species.

Other researchers have noted a marked lack of quality winter forage in the upper Blackfoot Valley (Connelly and Sands 1995, Deeble 1996). An abundance of non-preferred forage species, such as willow (*Salix* spp.), in riparian areas, and wintering areas highly disturbed by grazing and agriculture were cited as major limiting factors for CSTG in the region. Marks and Marks (1987) considered the forage value of winter habitat to be the single most important factor determining if an area will or will not support CSTG.

The model developed for this study only accounted for the relative areas of winter habitats and the distance to nesting and brood rearing habitats. Consequently, a large, highly disturbed area, comprised mostly of non-preferred food species would be quantified as highly suitable as long as it was proximate to summer habitats. Yet, the area would be unlikely to provide suitable forage or cover. If many areas identified as WFC cover types are indeed incapable of providing sufficient winter forage, due to species composition, grazing impacts (see below), or other reasons, then the modified CSTG HSI grossly overestimated WFC suitability.

In regards to NBC habitats, CSTG have been shown to select primarily for the height and density of vegetation and secondly for species composition (Hays et al. 1998). The classification of the Landsat TM dataset relied almost entirely on the broad-scale association of plant species compositions to cover types and did a poor job of delineating cover types by height and/or density (Table 3). Other studies have successfully associated Landsat TM data to fine-scale structural and composition attributes of shrub-steppe habitat and to sage grouse (*Centrocercus urophasianus*) habitat selection (Homer et al. 1993). However, by applying mean VOR values based on measurements taken at one location to all NBC patches across the entire study region, significant errors may have been introduced because I assumed VOR measurement locations on the ground were taken in correctly classified patches, unless it was obvious the patch was misclassified. These errors may have occurred even though similar, but distant, patches were classified as analogous from the Landsat TM data. In some instances I could
discern misclassified areas, yet it was often impossible to visually ascertain whether a measurement was being taken in a correctly classified patch. This was especially true for the sagebrush density cover types where visual inspection alone rarely could discriminate between thin and medium, medium and thick, or thick and very thick sagebrush.

The errors introduced due to classification inaccuracies in the sagebrush cover types are diminished when one considers that 3 of the 4 density classes had mean VOR values much greater than the optimum value of 2.5 dm. Thus, using Equation 5 above, these cover types would all have an optimum VEG value of 1.0. Nonetheless, this does not account for the fact that mean VOR values could have been calculated from measurements taken in misclassified patches. Finally, the majority VOR measurements were taken in the Kleinschmidt WPA, an area that has not been subjected to livestock grazing in several years. Most of the lands in the study area have been grazed by livestock and therefore the Kleinschmidt WPA may not be a representative sample of other NBC habitats in the study area.

**Reintroduction Potential & Detriments to Habitat Suitability**

**Reintroduction Potential**

Assuming the modified CSTG HSI does indeed evaluate the ability of an area to support reintroduced CSTG, and assuming that habitat must have a suitability of 0.75 or greater to support reintroduced birds, this modeling exercise suggests there exists 56,223 ha of habitat available to support reintroduced CSTG populations in the upper Blackfoot Valley. It is likely that 56,000 ha is also enough habitat to support any currently or historically viable CSTG populations. Either the model predictions are truly an accurate assessment of the ability of an area to support a self-sustaining CSTG population and other factors are causing CSTG population declines in the upper Blackfoot Valley, or habitat degradation is in fact the mechanism driving population decline and the uncertainties in the model lead to a gross overestimation of habitat suitability.

Although a suite of factors are likely responsible for reducing CSTG populations, the latter explanation seems more probable given that (1) habitat degradation is the most often cited cause of CSTG declines and (2) modeling uncertainties. Therefore, due to
misclassifications of the landcover and an inability to reconcile fine-scale attributes critical to habitat suitability with broad-scale landcover relationships, model predictions are best suited to locate general areas in which to focus conservation efforts, not to make final decisions regarding the reintroduction of CSTG. Final management decisions concerning reintroduction should also consider thorough field studies (see below).

**Detriments to Habitat Suitability**

One of the primary land uses in the upper Blackfoot valley is livestock grazing. Nearly all lands overlapping with CSTG habitats receive at least some grazing. Several studies have cited overgrazing as a primary cause of CSTG population declines and of decreased habitat quality range-wide (Miller and Graul 1980, Marks and Marks 1987, Klott and Lindzey 1990, Federal Register 2000) and in the Blackfoot Valley (Connelly and Sands 1995, Deeble 1996). As stated above, two primary features are considered to limit the ability of habitat to support CSTG. Residual vegetation must provide adequate cover to protect nesting hens and broods during the reproductive season. Deciduous shrubs that retain critical fruits and buds during severe weather when herbaceous vegetation desiccates must provide a reliable source of winter food. Detrimental effects of excessive grazing include the reduction of the grass and forb component of upland areas, habitats typically selected by CSTG for nesting and brood rearing, and severe damage to riparian areas which provide critical winter forage and escape cover (Giesen and Connelly 1993). Although CSTG are not associated with free water (Marks and Marks 1987), riparian areas are considered important sources of food not only in fall and winter, but also during drought years when herbaceous vegetation may be lacking.

Kessler and Bosch (1982) surveyed CSTG management practices and concluded that grazing and the resulting habitat loss are the most serious threats to CSTG survival. Hays et al. (1998) also noted increases in grazing pressure on currently occupied CSTG habitat as a principal threat to the continued existence of populations. Mark and Marks (1987) found CSTG appear to select areas least modified by livestock grazing, while Cope (1992) found reintroduced, radio-equipped CSTG were relocated more often in areas where cattle were not present. Yet grazing itself may not be the problem, but rather poor grazing practices which reduce the vigor of the rangeland and riparian areas.
Kessler and Bosch (1982), in their survey of states and provinces with past or present CSTG populations, found biologists regarded low intensity grazing as beneficial and high intensity grazing as negative in its effects.

Deeble (1996) also cited several other factors possibly responsible for CSTG population decline in the study area. These included conversion of shrub-steppe habitat to cultivation, fire suppression (which can degrade habitat as pioneering conifer species invade shrub-steppe communities), and direct and indirect impacts of agricultural chemicals. Certainly these factors also reduce habitat suitability, but were not directly considered in this study. Of these however, conversion of habitats to cultivated land is likely the second most detrimental impact in the valley after overgrazing.

**Recommendations**

Although the modified CSTG HSI model predicted a significant quantity of suitable habitat exists in the upper Blackfoot Valley, it is not advisable to reintroduce CSTG at this time for the reasons stated above. Yet, considering CSTG population trends, the scarcity of recent sightings, and a small population size (and the genetic problems encountered in small populations), the only promising measure to ensure the long-term establishment of a viable CSTG population in the upper Blackfoot Valley may be several future reintroductions. Before reintroduction occurs however, a comprehensive, on-the-ground review of those areas identified as highly suitable should be completed (Figure 8). Efforts in these areas should focus first and foremost on quantifying abundances and forage quality of riparian and mountain shrub species, attributes not addressed by the model, and secondly on determining locally the height and density of nesting and brood rearing vegetation. Once the fine-scale attributes of habitat suitability have been considered and merged with the results from this study, a habitat conservation and restoration program should be implemented as required. Translocation of CSTG from stable populations would be appropriate after these measures have been completed.

The success of such a program would hinge on the involvement of private landowners in the valley, as the vast majority of CSTG habitats, including the bulk of the best remaining habitats and all historically active lek sites, are privately held. Proper
planning and landowner participation could spare the wasted expense and effort of premature reintroductions into unsuitable habitat. Perhaps the most expensive, in terms of continued interest in conserving CSTG populations in Montana, would be several failed reintroductions leading to an abandonment of re-establishment programs. Previous efforts to reintroduce CSTG to the Dancing Prairie Preserve in northwestern Montana began in 1987 and continued through the early 1990’s. Enough time has passed to confidently state these efforts were unsuccessful (Mantas 2003). No future reintroductions are planned for Dancing Prairie at the time of this writing.

To ensure the highest probability of success, all subsequent habitat restoration efforts and conservation practices should follow the CSTG habitat management guidelines suggested by Giesen and Connelly (1993), including focusing management practices around breeding complexes (all lands within a 2-km radius of lek sites). Areas selected for conservation efforts should meet three criteria, including:

1. Because CSTG, including translocated birds, have a reported and inexplicable propensity to establish leks at historically active lek sites, areas proximate to previously-used lek sites should be considered first and foremost to reduce the possibility of birds dispersing from release areas.

2. Areas identified by the model to have an HSI value greater than 0.75 and all lands within a 2-km radius of these areas.

3. Lands held publicly, private lands under conservation easements, or lands held privately by landowners with a strong interest in conservation and restoration of CSTG populations.

Two areas currently meet all three of these criteria; foremost, the Kleinschmidt WPA and surrounding private lands under conservation easements, and secondly, several parcels of land southwest of Helmville, closest to the most recently active leks and highest quality habitat, and owned by the state of Montana and Bureau of Land Management (BLM) (Figure 8).
Although the Kleinschmidt WPA (525 ha) does not contain the largest block of high quality habitat in the valley, it is not grazed by livestock and is surrounded by large parcels of private land currently under conservation easement with the USFWS and others (at least 4,000 ha). Also, since a majority of VOR measurements were collected on lands within and adjacent to the Kleinschmidt WPA, predicted habitat suitability in this region should be the most representative estimate overall, especially in regards to NBC habitat suitability. Finally, and perhaps most importantly, a historically active lek site was located just to the south and west of the Kleinschmidt WPA. Therefore, initial field studies and habitat restoration efforts should focus on this area.

The Kleinschmidt WPA and neighboring areas offer some of the least impacted shrub-steppe habitats in the study region. If a detailed review of winter forage quality is completed and reveals insufficient food resources as anticipated, riparian corridors and mountain shrub communities should be rehabilitated with native shrubs that provide excellent winter forage. These include hawthorn (Crataegus douglasii), choke cherry (Prunus virginiana), serviceberry (Amelanchier alnifolia), and birch (Betula glandulosa and B. occidentalis). NBC habitats should be managed to maintain optimum residual vegetative cover of 2.5 dm, and any livestock use of riparian areas should be closely managed or eliminated to minimize damage to associated shrubs and trees. Invading conifer species, which reduce shrub-steppe cover, have impacted this area as well. An active management program to remove conifer species by cutting or prescribed burns would also be beneficial. With improved riparian areas and a modest increase in nesting and brood rearing cover, the Kleinschmidt WPA offers an excellent chance of supporting future CSTG populations.

A second, larger region of highly suitable habitat occurs southwest of Helmville and is proximate to the most recently known active lek sites. Within this area are two disjunct blocks of state land (390 ha total) and a few small parcels owned by the BLM (115 ha total). These areas alone are not of a sufficient size to support a population of CSTG and therefore the surrounding private lands would need to be utilized for conservation purposes. The private lands neighboring these sites are heavily grazed, with currently no land under conservation easement. However, at least one land owner in the
area (who owns the last known active leks) has shown some interest in conservation of CSTG (Ertle 2003). Habitat restoration efforts in this area of the valley should focus on providing more winter forage and cover via improved riparian and upland deciduous areas, making use of the species listed above. Unless funding for land acquisition becomes available, and/or a strong conservation interest can be kindled amongst private landowners, this area should be considered as “phase 2” of any CSTG habitat restoration plans, to be implemented after improvement of the Kleinschmidt WPA and surrounding acreage.

Maximum benefit may be derived from any of the above recommendations if future CSTG conservation efforts are coordinated with the Blackfoot Challenge. The Blackfoot Challenge is, by their own definition, “a 'grass roots' group which has organized to coordinate management of the Blackfoot River, its tributaries, and adjacent lands” (USFWS 2003). This group is organized through a series of committees and has no formal membership. Members include private landowners in the valley, federal and state agency representatives, local government officials and several corporate landowners.

One of the Blackfoot Challenge’s goals is habitat restoration and protection, which initially focused on the preservation of the Blackfoot River fishery via riparian area restoration, but has since expanded to include restoration at the landscape level. Any efforts designed to improve the narrow riparian corridors of smaller tributaries are likely to provide benefits to fish species as well as CSTG. It is likely that this group’s previous riparian restoration projects have improved existing, or even provided additional, CSTG habitat.

It would be cost effective to identify and design restoration projects intended to create or restore critical CSTG habitats while simultaneously improving fish habitat. Any such efforts, to be fully effective, should include the planting of highly favored food species, such as hawthorn, in preference to willow. Such endeavors, which take a holistic approach to conservation and coordinate efforts between parties with diverse and sometimes conflicting interests, will be crucial to the restoration and/or continued existence of CSTG in the Blackfoot Valley and Montana.
CONCLUSIONS

This study quantified CSTG habitat suitability utilizing a GIS to analyze Landsat TM data and a modified version of the CSTG HSI procedure. The most significant findings are:

1. Although the model predicted habitat of sufficient quality to support reintroduced CSTG, the reintroduction of CSTG to the upper Blackfoot Valley is not recommended at this time pending more detailed field review of winter forage quality and nesting and brood rearing cover.

2. CSTG habitats have been most impacted by grazing, which has removed necessary upland vegetative cover required for successful nesting and brood rearing and degraded riparian areas (winter habitat).

3. Restoration efforts should focus on the areas and guidelines identified above, with the most significant improvement opportunities to be had in improving winter forage and cover.

4. The two areas with the highest potential are, foremost, the public and private lands directly adjacent to Kleinschmidt Lake, and secondly, if an interest in conservation of CSTG can be fostered and sustained through land easements, the region southwest of Helmville identified in Figure 8.
LITERATURE CITED


Federal Register. 2000. Endangered and threatened wildlife and plants; 12-Month finding for a petition to list the Columbian sharp-tailed grouse as threatened. 65:197.


Figure 1. Approximate Original and Present Distributions of Columbian Sharp-tailed Grouse.¹

¹ Adapted from Aldrich 1963, with updated distribution information from Federal Register 2000, Mantas 2003, and Montana Department of Fish, Wildlife, and Parks 2003. Montana Population may be extinct.
Figure 2. Study Area.\textsuperscript{1}

\textsuperscript{1}Columbian Sharp-tailed Grouse distribution data layers adapted from Montana Department of Fish, Wildlife, and Parks 2003 and Redmond et al. 1998. All other data layers adapted from the Montana Natural Resources Information System 2003.
Table 1. Upper Blackfoot Valley Landcover Types, Areas, Habitat Life Requisite Functions, and VOR\(^1\).

<table>
<thead>
<tr>
<th>Cover Code</th>
<th>Landcover</th>
<th>Area (ha)</th>
<th>Percent</th>
<th>Life Requisite Function(^{2,3})</th>
<th>Mean VOR (dm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Dry Agriculture</td>
<td>862.38</td>
<td>0.36%</td>
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</tr>
<tr>
<td>2020</td>
<td>Irrigated Agriculture</td>
<td>1883.79</td>
<td>0.78%</td>
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<tr>
<td>3101</td>
<td>Upland Grassland</td>
<td>18687.96</td>
<td>7.78%</td>
<td>NBC</td>
<td>0.77</td>
</tr>
<tr>
<td>3102</td>
<td>Altered Herbaceous</td>
<td>12829.23</td>
<td>5.34%</td>
<td>NBC</td>
<td>0.53</td>
</tr>
<tr>
<td>3105</td>
<td>Mesic Grassland</td>
<td>31620.06</td>
<td>13.17%</td>
<td>NBC</td>
<td>1.20</td>
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<tr>
<td>3210</td>
<td>Upland Mesic Shrub</td>
<td>7390.71</td>
<td>3.08%</td>
<td>WFC</td>
<td>---</td>
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<td>Sagebrush, Thin</td>
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<td>1.47%</td>
<td>NBC</td>
<td>1.64</td>
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<td>7010.01</td>
<td>2.92%</td>
<td>NBC</td>
<td>3.07</td>
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<td>5156.91</td>
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<td>NBC</td>
<td>3.10</td>
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<td>3304</td>
<td>Sagebrush, Very Thick</td>
<td>2802.6</td>
<td>1.17%</td>
<td>NBC</td>
<td>4.39</td>
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<td>3306</td>
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<td>1340.73</td>
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<td>NBC</td>
<td>3.61</td>
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<tr>
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<td>Upland Broadleaf</td>
<td>7960.32</td>
<td>3.31%</td>
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</tr>
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<td>4200</td>
<td>Conifer Forest</td>
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<tr>
<td>5000</td>
<td>Water</td>
<td>2250.36</td>
<td>0.94%</td>
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<td>---</td>
</tr>
<tr>
<td>6102</td>
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<td>6043.5</td>
<td>2.52%</td>
<td>WFC</td>
<td>---</td>
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<td>17175.87</td>
<td>7.15%</td>
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<td>---</td>
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<td>7033.23</td>
<td>2.93%</td>
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<td>---</td>
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<tr>
<td>7500</td>
<td>Barren</td>
<td>575.82</td>
<td>0.24%</td>
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<td>---</td>
</tr>
<tr>
<td>9100</td>
<td>Snow</td>
<td>196.47</td>
<td>0.08%</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

| Total of CSTG Habitats | 128581.83 | 53.4% |
| Total of all Areas     | 240130.35 | 100%  |

\(^1\) VOR = Vegetation Visual Obstruction Reading (Measurement required for NBC habitats only).
\(^2\) NBC = Nesting and Brood Rearing Cover.
\(^3\) WFC = Winter Food and Cover.
Table 2. Summary of Columbian Sharp-tailed Grouse Habitat Suitability Indexes in the Upper Blackfoot Valley as Estimated from Habitat Model and Landsat Thematic Mapper Data.

<table>
<thead>
<tr>
<th></th>
<th>Maximum</th>
<th>Minimum</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Food and Cover</td>
<td>1.00</td>
<td>0.32</td>
<td>0.95</td>
<td>0.13</td>
</tr>
<tr>
<td>Nesting and Brood Rearing Cover</td>
<td>1.00</td>
<td>0.00</td>
<td>0.30</td>
<td>0.28</td>
</tr>
<tr>
<td>Final Habitat Suitability¹</td>
<td>1.00</td>
<td>0.00</td>
<td>0.29</td>
<td>0.28</td>
</tr>
</tbody>
</table>

¹ Final Habitat Suitability value is the minimum value of either Winter Food and Cover suitability or Nesting and Brood Rearing Cover suitability at each location.
Figure 3. Landcover Map of upper Blackfoot Valley Study Area.

Figure 4. Columbian Sharp-tailed Grouse Winter Food & Cover Habitat Suitability.¹

Figure 5. Columbian Sharp-tailed Grouse Nesting & Brood Rearing Cover Habitat Suitability.¹

Figure 6. Columbian Sharp-tailed Grouse Final Habitat Suitability.¹

Figure 7. Comparison Summary of Columbian Sharp-tailed Grouse Habitat Suitability.
Figure 8. Areas Identified for Potential Columbian Sharp-tailed Grouse Reintroduction & Habitat Restoration.¹

¹ Lek site locations from Deeble 1996 & 2000. Town locations, roadways, and cadastral data from the Montana Natural Resources Information System 2003
APPENDIX A – CLASSIFICATION OF LANDCOVER DATA

Landcover data in this study were based on a Landsat Thematic Mapper (TM) scene (Path 40, Row 27) acquired on July 11, 1996. Landsat TM imagery has a 30-m spatial resolution (each pixel covers a 30 x 30 m area on the ground). The imagery is produced from data collected by sensors aboard satellites. The sensors record electromagnetic reflectance from the earth in several wavelengths. Reflectance is measured in each of 7 spectral bands and the value for each band is stored using 8 bits. A pixel’s value can thus range from 0 to 255. An image is created when the values from 0 (no reflectance) to 255 (maximum reflectance or saturation) are assigned 1 of 265 distinct shades of gray.

The original path 40, row 27 Landsat TM image in this study was subset to a smaller region encompassing the upper Blackfoot valley. This larger map was again subset to an area of 240,130 ha using the study area boundary defined above and then related to landcover via a two-step process by the Wildlife Spatial Analysis Laboratory (WSAL) and described by Thorton (1998). In the first step, the reflectance values were grouped by spectral signature only into similar cover types in a process called unsupervised classification. The second step involved associating these groupings of similar pixels with vegetation or landcover types using a supervised classification procedure, each group of analogous pixels potentially representing forest stands, grasslands, water bodies, etc.

The supervised classification process relied on the use of 732 ground-truth plots, or training samples. These training samples were areas of known cover type, as determined from field observations. The training samples were used to generate statistics about the cover types. These statistics were then used to predict the rest of the region’s landcover, as created during the unsupervised classification process. The supervised classification procedure was repeated 6 times to eliminate obvious misclassifications. Particular attention was paid to divide spectral cover types within and among sagebrush and grassland types, the vegetative communities most closely associated with CSTG.
The final classified image contained 19 cover types. Sagebrush was delineated into 5 cover types. An accuracy analysis performed on the final landcover classification revealed 86.7% of the map was considered to be classified to an acceptable level of accuracy. However, individual user accuracies, i.e. the percentage of the time an area visited on the ground will perfectly match the classification from the Landsat TM data, are provided in Table 3. See Lillesand and Kiefer (2000) for an excellent review of classification accuracy assessments.

Table 3. User Accuracies for Blackfoot Valley Landcover Classification.

<table>
<thead>
<tr>
<th>Cover Code</th>
<th>Landcover</th>
<th>User Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3101</td>
<td>Upland Grassland</td>
<td>61.65</td>
</tr>
<tr>
<td>3102</td>
<td>Altered Herbaceous</td>
<td>62.08</td>
</tr>
<tr>
<td>3105</td>
<td>Mesic Grassland</td>
<td>57.50</td>
</tr>
<tr>
<td>3301</td>
<td>Sagebrush, Thin</td>
<td>43.28</td>
</tr>
<tr>
<td>3302</td>
<td>Sagebrush, Medium</td>
<td>22.20</td>
</tr>
<tr>
<td>3303</td>
<td>Sagebrush, Thick</td>
<td>32.15</td>
</tr>
<tr>
<td>3304</td>
<td>Sagebrush, Very Thick</td>
<td>26.35</td>
</tr>
<tr>
<td>3306</td>
<td>Sagebrush, Invading Conifer</td>
<td>37.68</td>
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<tr>
<td>4200</td>
<td>Conifer Forest</td>
<td>84.69</td>
</tr>
<tr>
<td>5000</td>
<td>Water</td>
<td>100.00</td>
</tr>
<tr>
<td>6102</td>
<td>Riparian Broadleaf</td>
<td>39.22</td>
</tr>
<tr>
<td>6201</td>
<td>Riparian Herbaceous</td>
<td>43.29</td>
</tr>
<tr>
<td>6202</td>
<td>Riparian Shrub</td>
<td>37.75</td>
</tr>
<tr>
<td>7500</td>
<td>Barren</td>
<td>84.97</td>
</tr>
</tbody>
</table>
APPENDIX B – SPATIAL ANALYST CALCULATIONS

Spatial Analyst, an extension of ArcGIS 8.1 for Windows, was used to perform all “map algebra” calculations required to quantify CSTG habitat suitability. These calculations can be grouped into two general categories: (1) quantification of landcover characteristics (relative area and distance between cover types) and (2) model calculations. These are dealt with in turn below.

Background

Raster images can be thought of as a grid made of equally sized cells. Each cell in the grid can contain a numerical value or be empty, in which case the cell is assigned a value of “No Data”. Mathematical operations can be performed on the cells individually, such as multiplication, subtraction, etc to produce a new raster. Also, “focal” or “neighborhood functions” can be used to produce a new raster. A neighborhood function, as described by McCoy and Johnston (2002)

“...will produce an output raster in which the output value at each location is a function of the input value at a location and the values of the cells in a specified neighborhood around that location.”

Rasters can also be reclassified, where all cells containing the same value are assigned a new value. All three types of these operations were used in this study.

Quantification of Landcover Characteristics

Percent Availability Calculation

Mesic Grassland, a NBC cover type with cover code 3105, is used as an example (Figure 9). Recall WFC calculations used a 6.5 km “neighborhood” radius.

In the first step to calculate Mesic Grassland percent availability, the original WSAL landcover raster with 19 cover types was reclassified so that all cover types considered usable by CSTG (NBC and WFC cover types) were assigned a value of 1 and all cover types categorized as “neither” were assigned a value of “No Data”. All non-
empty pixels in the resulting raster were analyzed using a neighborhood function that summed all pixels in a 2 km radius. The value of each pixel in the raster produced from this operation was the number of cells classified as CSTG habitat in its 2-km neighborhood.

The second step began by once again reclassifying the original WSAL landcover raster containing all 19 cover types. This time however, all cover types were reclassified to “No Data”, except Mesic Grassland, which was assigned a value of 1. Each non-empty pixel in this new raster was analyzed using a neighborhood function that summed all pixels in a 2 km radius. The value of each pixel in the resulting raster was the number of cells classified as Mesic Grassland, in its 2 km neighborhood.

When the raster in step two (total area of Mesic Grasslands) was divided by the raster produced in step one (total area of CSTG habitat), the result was the percent of CSTG habitats in a 2 km radius that were Mesic Grassland. This process was repeated for all NBC cover types.

**Mean Minimum Distance Calculation**

The purpose of the mean minimum distance calculation was to quantify the interspersion of NBC habitats with WFC habitats and vice versa by determining the mean minimum distance from each NBC (or WFC) cover type to the nearest WFC (or NBC) habitat. Mesic Grassland is again used as an example (Figure 10). Recall WFC calculations used a 6.5 km “neighborhood” radius.

First, the original WSAL landcover raster with 19 cover types was reclassified so that all cover types except Mesic Grassland, were assigned a value of “No Data”. Mesic Grassland was assigned a value of 1. Using the Straight Line Distance function in Spatial Analyst, a “distance” raster was generated. Each pixel in this distance raster is assigned the magnitude of the distance from the center of the pixel at that location to the nearest patch of Mesic Grassland.

At this point a difficulty was encountered because only those pixel locations corresponding to WFC patches needed to be used for the mean minimum distance calculation, but the distance raster cells contained the values to Mesic Grassland from
every location. All other pixels corresponding to NBC or “neither” cover types had to be “masked out” or removed from consideration. Otherwise, pixels corresponding to NBC cover types would have been included in the mean minimum distance calculation. The information of interest was the distance from Mesic Grassland patches to the nearest WFC habitat, not to the nearest patch of NBC of WFC habitat.

For instance, if a patch of Mesic Grassland was completely surrounded by another NBC cover type and the shortest distance to every Mesic Grassland patch was determined, even those pixels located in the surrounding NBC cover type would be assigned a distance value. As stated above, what was of interest was the distance from Mesic Grassland patches to the nearest WFC habitat, not to all locations. If the pixels located in the surrounding NBC cover type were used in the mean minimum distance calculation, the calculated value would be incorrect because distances other than those to WFC habitats would be included.

This error was avoided by multiplying the distance raster by a “WFC mask” raster. The WFC mask was a raster in which all WFC cover codes were reclassified to 1 and all other cover codes were reclassified as “No Data”. When the distance raster was multiplied by the mask raster all pixels except those corresponding to WFC patch locations were assigned a value of “No Data”. The WFC patch locations retained their original distance value because they were multiplied by 1.

In the final step, a neighborhood function calculated the mean value of all non-empty pixels in a 2 km radius. The value of each pixel in the resulting raster was the mean minimum distance from Mesic Grassland patches to the nearest WFC habitat in its 2 km neighborhood. This process was repeated for all NBC cover types.

**Habitat Suitability Calculations**

The results from the above procedures were a collection of rasters. Each of the WFC and NBC cover types had two associated rasters, percent availability and mean minimum distance. An additional VOR data raster was created by reclassifying the original landcover raster. The NBC cover types were reclassified to their corresponding mean VOR value.
Equation 1 was applied to each WFC distance raster to produce a WFC_{Dist} raster for each WFC cover type. SIWFC was then calculated for each WFC cover type using Equations 2 and 3. The resulting rasters from this calculation were then summed to produce a final WFC habitat suitability raster.

In a similar manner, using Equations 4, 5, 6, and 7, SINBC was calculated for each NBC cover type. All SINBC rasters were then summed to produce a final NBC habitat suitability raster.

The final habitat suitability value for each location was the lesser of the WFC or NBC habitat suitability indexes.
Figure 9. Process for Calculating Percent Availability of One Nesting and Brood Rearing Cover Type (Illustrated with Mesic Grassland).  

1 “Warmer” colors in the non-landcover rasters above represent higher values.
Figure 10. Process for Calculating Mean Minimum Distance Between One Nesting and Brood Rearing Cover Type and all Winter Habitats (Illustrated with Mesic Grassland).

1 "Warmer" colors in the non-landcover rasters above represent higher values.
### Table 4. Vegetation Visual Obstruction Readings (VOR) in Nesting and Brood Rearing Cover types in the upper Blackfoot Valley, March – May 2003. (Includes UTM coordinates and directions of each of 7 25-m transects, with readings every 5 m).

<table>
<thead>
<tr>
<th>Direction &amp; UTM</th>
<th>3301-Sagebrush, Thin VOR (dm)</th>
<th>3302-Sagebrush, Medium VOR (dm)</th>
<th>3303-Sagebrush, Thick VOR (dm)</th>
<th>3304-Sagebrush, Very Thick VOR (dm)</th>
<th>3306-Sagebrush, Invading Conifer VOR (dm)</th>
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<tbody>
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<td>12342234 1.0</td>
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APPENDIX D – MEINTS ET AL. (1992) HABITAT SUITABILITY INDEX PROCEDURE FOR COLUMBIAN SHARP-TAILED GROUSE
Habitat Suitability
Index Procedure
for
Columbian Sharp-tailed Grouse

by Daryl R. Meints
John W. Connelly
Kerry P. Reese
Alan R. Sands
Thomas P. Hemker
Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbia*us) occupy <10 percent of their historic range. Because of recent increases in some sharp-tailed grouse populations, improved range condition, and the Conservation Reserve Program (CRP), interest in transplanting Columbian sharp-tailed grouse into historic range within the state of Idaho and surrounding Western States has increased. Unfortunately, a habitat suitability index (HSI) to systematically evaluate and rank potential release sites for the Columbian subspecies is not available. Therefore, after evaluating the HSI for the plains sharp-tailed grouse (*T. p. jamesil*), we developed an index more applicable to the Columbian subspecies. Four areas in southeastern Idaho, all known to support viable populations of sharp-tailed grouse, were chosen to develop the procedure.

The HSI is divided into 2 components, each representing a seasonal habitat of Columbian sharp-tailed grouse. Both winter food/cover habitat and nest/brood cover habitat were evaluated using the concept of percent equivalent optimum area. The equivalent optimum area concept assumes that a large area of low quality can have a habitat value equivalent to a smaller area of higher quality.

Our HSI provides a systematic method to evaluate habitat quality for Columbian sharp-tailed grouse. It can also provide values which are compatible with the U.S. Fish and Wildlife Services' Habitat Evaluation Procedure (HEP). The HSI can also be used to determine the amount of mitigation crediting a particular site may provide and be used by biologists without considerable experience in sharp-tailed grouse biology.
ACKNOWLEDGMENTS

This project was funded by the Bureau of Land Management (BLM) and Idaho Department of Fish and Game (IDFG). The IDFG provided a vehicle and miscellaneous equipment while the BLM and United States Forest Service (USFS) provided maps. The USFS also provided a trailer which served as a field station. We thank Kenneth Giesen and Michael Gratson for providing helpful reviews. The art work and figures were done by Amber Hanson and the manuscript was typed by Cheryl Hardy. A special thanks to landowners Grant Weeks and Calvin Dredge for allowing us to survey leks on their property.
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Habitat Suitability Index
Procedure for Columbian Sharp-tailed Grouse

Daryl R. Meints
John W. Connelly
Kerry P. Reese
Alan R. Sands
Thomas P. Hemker

Introduction

Columbian sharp-tailed grouse are one of six sharp-tailed grouse subspecies currently found in North America (Johnsgard 1973) and are the only subspecies native to the Pacific Northwest (Starkey and Schnoes 1976). This subspecies appears to have declined the greatest in terms of range and numbers (Hamerstrom and Hamerstrom 1961). Isolated populations remain in Colorado, Idaho, Montana, Utah, Washington, Wyoming and British Columbia (Marks and Marks 1987) (Fig. 1). Outside British Columbia, Idaho has the largest remaining population of Columbian sharp-tailed grouse. British Columbia may have the largest population, but little is known about sharp-tailed grouse in that area (Miller and Graul 1980). This subspecies no longer occurs in California, Nevada, and Oregon, but efforts are underway to reintroduce the subspecies to Oregon (Starkey and Schnoes 1976, Crawford 1986).

The Columbian subspecies was first discovered by Lewis and Clark in 1805 on the bunchgrass (Agropyron) and sagebrush (Artemisia) plains of the Columbia River. From the early 1900's, sharp-tailed grouse populations drastically declined; this coincided with the period in which the grasslands of the Pacific Northwest and intermountain area were settled, converted to agriculture, and heavily grazed by livestock (Yocom 1952). Today, as in the past, increased agricultural development of sharp-tailed grouse habitat has caused a decrease in their range and numbers (Yocom 1952, Buss and Dziedzic 1955, Olsen 1976).

Livestock grazing is also a major factor influencing abundance and distribution of sharp-tailed grouse (Hart et al. 1950, Hamerstrom and Hamerstrom 1961, Aldrich 1963, Rogers 1969, Parker 1970, Zeigler 1979). Grazing has or may have 2 major impacts on grouse habitat: 1) reduction of nesting and brood cover (Yocom 1952, Evans 1968), and 2) reduction of deciduous trees and shrubs, important for sharptail wintering habitat, by trampling, rubbing, and browsing (Marshall and Jensen 1937, Rogers 1969, Zeigler 1979). Livestock grazing is the dominant land use in the remaining Columbian sharp-tailed grouse habitat (Kessler and Bosch 1982). Current range management practices within grouse habitat include seasonal, deferred, and rotation grazing; prescribed burning; mechanical and chemical treatments; and reseeding of native and non-native forage plants. These practices affect the composition of grasses, forbs, and shrubs upon which sharptail populations depend (Sisson 1976).

Most of Idaho's Columbian sharp-tailed grouse occur in the southeastern portion of the state in Oneida, Power, Bannock, Bingham, Caribou, Franklin, Bear Lake, Bonneville, Fremont and Clark counties (Meints 1991). A small population also exists in west-central Idaho (Washington and Adams counties) (Marks and Marks 1987) (Fig. 2).

Improved grazing practices and CRP have recently resulted in increased sharptail habitat and, therefore, sharptail numbers in parts of southern Idaho (Meints 1991). However, some areas that have improved habitat are disjunct from existing sharptail populations and thus do not support sharptailed grouse. Translocation of Columbian sharp-tailed grouse into these areas could expand the range of this species in Idaho. Translocations may also allow future opportunities for expanding this species' range in other parts of the Northwest that may now, or soon will, provide suitable sharptail habitat.

Interest in receiving transplant stock from Idaho for release in other western states is intense. Idaho has received requests from Nevada, Oregon, Montana, Utah, Washington and California. Unfortunately, an HSI to systematically evaluate and rank potential release sites is not available.

A number of grouse species have been successfully translocated, including ruffed grouse (Bonasa umbellus) (Hanson 1985, White and Dimmick 1978) and sharp-tailed grouse (Ammann 1957, Rogers 1990, Rogers 1992). Recently, the Idaho Department of Fish and Game successfully translocated sage grouse (Centrocercus urophasianus) to central Idaho to augment a very low population (Musil 1989). Oregon is currently in its second year (spring 1992) of reintroducing sharp-tailed grouse. Unfortunately, most attempts to re-establish Columbian sharp-tailed grouse in the Pacific Northwest have failed, probably because of a lack of detailed planning and habitat evaluation. Therefore, we believe that only carefully planned
Figure 1. Past and present distribution of Columbian sharp-tailed grouse (modified by Miller and Graul 1980, from Marks and Marks 1987).
Figure 2. Past (left) and present (right) distribution of Columbian sharp-tailed grouse in Idaho (modified by Parker 1970, from Marks and Marks 1987).
efforts to translocate Columbian sharptails into suitable habitats have a high chance of success.

The objective of this study was to develop an HSI for the Columbian sharp-tailed grouse similar to that which was developed for the plains subspecies (Prose 1987). We urge readers to familiarize themselves with the plains HSI (Prose 1987) so they may obtain a more thorough understanding of the philosophy behind it and our HSI. What we present here is not a new HSI but a revision of the plains HSI to reflect the habitat needs of the Columbian subspecies.

■Study Areas

The study areas were the Sand Creek Wildlife Management Area (SCWMA) located on the Upper Snake River Plain in Fremont County, approximately 9.5 km west of St. Anthony, Idaho; the Tex Creek Wildlife Management Area (TCWMA) located in Bonneville County, approximately 24 km southeast of Ririe, Idaho; the Malad area located in Oneida County approximately 6.5 km north of Malad City, Idaho; and the Curlew Valley, also in Oneida County approximately 33.5 km west of Malad City (Fig. 3). Each area provides a unique complex of cover types that presently support stable to increasing populations of Columbian sharp-tailed grouse.

The SCWMA, about 1500 m in elevation, is comprised of level plains and low, rolling hills. Soil depth varies from less than a few centimeters to several meters. Vegetation is dominated by basin big sagebrush (*Artemisia tridentata tridentata*), antelope bitterbrush (*Purshia tridentata*), and chokecherry (*Prunus virginiana*). Moving sand dunes cover several thousand hectares. The area has low precipitation (the annual mean is 31.6 cm), hot summers (the July mean is 30°C), and cold winters (the January mean is -15°C).

The TCWMA ranges in elevation from 1400 to 2200 m and is comprised of table benchlands used for agriculture dissected by steep-sloped canyons. Benchland vegetation is dominated primarily by basin big sagebrush and bitterbrush, while Utah juniper (*Juniperus osteosperma*), aspen (*Populus tremuloides*), and willow (*Salix spp.*) are common in the canyons. Temperatures range from -16°C in winter to 42°C during summer. Annual precipitation ranges from 30.0 cm to 46.0 cm.

The Malad area ranges in elevation from 1357 to 1658 m and is comprised of private agricultural land, much of which has been enrolled in the CRP program, and land administered by the USFS which is used for grazing. The USDA Forest Service land is dominated primarily by sagebrush, Utah juniper and maple (*Acer spp.*) with a mixture of Douglas-fir (Pseudotsuga menziesii), aspen, chokecherry and serviceberry (*Amelanchier alnifolia*) located at the higher elevations.

The Curlew Valley area is semiarid and ranges in elevation from 1390 m to 2086 m. The upper elevations are administered by the BLM, while the Curlew National Grassland is managed by the USFS. Private land used for cropland and grazing is interspersed throughout the area. The valleys are dominated by sagebrush and crested wheatgrass (*Agropyron cristatum*), while the foothills are dominated by sagebrush and Utah juniper. Maple-, bitterbrush-, chokecherry-, serviceberry-, and aspen-dominated draws are common within the foothills.

■Methods

We first reviewed the current HSI procedure for the plains subspecies (Prose 1987). The only change we made before data collection occurred was the amount of area evaluated around each lek. The plains model considered only an area within a 1.3-km radius of each lek for nest/brood and winter habitat. We increased this distance to 2.0 km for nest/brood habitat and to 6.5 km for winter habitat, based on recent information on movements and habitat use (Rogers 1969, Oedekoven 1985, Giesen 1987, Marks and Marks 1987, Marks and Marks 1988, Klett and Lindsell 1990, Apa 1991, Meints 1991) of Columbian sharp-tailed grouse. Because nest cover and brood cover are intermixed, we combined these components. These changes were tested on 4 areas in southeastern Idaho known to support Columbian sharp-tailed grouse: SCWMA, TCWMA, the Malad City area, and the Curlew Valley. In each area, 3 leks were chosen and winter and nest/brood habitats were measured around each lek. Data were collected in the following manner.

Winter Habitat

Within a 6.5-km radius of each lek, the percent of each winter cover type was determined from color aerial photos and mapped on 1:24,000 orthophotoquads. After ground truthing, a dot count method (Bryant 1943) was used to estimate area. On 2 study areas, the TCWMA and the Malad City area, all 3 leks in each area could be encompassed by one 6.5-km radius circle. Thus, in each of these areas we surveyed only one 6.5-km radius circle (around the center lek) to eliminate bias from double sampling. We randomly selected a point within each stand of winter cover on orthophotoquads and measured the distance to the nearest nest/brood cover.

Nest/Brood Habitat

Within a 2.0-km radius of each lek (referred to as the lek site), the percent of each nest/brood
Figure 3. Study areas in Idaho used to develop Columbian sharp-tailed grouse Habitat Suitability Index (HSI) procedure.
cover type was determined from colored aerial photos and mapped on 1:24,000 orthophotoquads. After ground truthing, a dot count method (Bryant 1943) was used to estimate area of cover types. During June, we chose a random point and direction within each stand of nest/brood cover. From the nearest identifiable landmark, the distance and direction to the random point were determined. By starting at the landmark, we used the direction and distance to move to the random point. From this point, Robel pole (Robel et al. 1970) measurements were taken every 25 m along the predetermined direction to evaluate the quality of nest/brood cover. One Robel pole measurement was taken for every 1 percent of the lek site occupied by nestÆrood habitat. If we moved outside the cover type and more Robel pole measurements were needed, we then selected another random point and direction and proceeded until we obtained the needed number of measurements. We read the pole from a distance of 4 m at 1 m above the ground. From each random point within each cover type, the distance to the nearest winter cover type was measured to the nearest 20 m on orthophotoquads.

Analysis
We used the Bartlett test to assess homogeneity of variance. If data proved to be non-normal, they were log transformed. Student t-tests (Ott 1984) and ANOVA (Conover 1980) were used to test for differences between and within study areas. The Tukey test (Hays 1988) was used to isolate differences when P ^ 0.05.

This HSI is divided into 2 components, each representing a seasonal habitat of Columbian sharp-tailed grouse. Both habitats (winter food/cover and nest/brood cover) were evaluated using the concept of percent equivalent optimum area (Prose 1987). The equivalent optimum area concept assumes that a large area of low-quality habitat can have a habitat value equivalent to a smaller area of higher quality habitat.

Appropriate variables (Appendix I) were entered into the plains HSI and the model was used to calculate habitat suitability with no modifications. The HSI was then modified based on the data we collected. The suitability index for an optimal (i.e., 1.0) mean visual obstruction reading was increased from 2.0 to 2.5 dm based on our data, and the suitability index for an optimal distance between cover types was halved. The scale used for the plains HSI did not adequately represent distance measurements found in the Columbian sharp-tailed grouse literature. Therefore, we used a separate suitability index for distances from nest/brood to winter cover types and for distances from winter to nest/brood cover types. We then compared the results of our HSI to those of the plains HSI (Prose 1987).

Results
Habitat Characteristics
Winter cover types at each location varied from 0.1 - 14.0 percent (Table 1). Sand Creek (x = 4.7 + 1.5) had less (P < 0.05) total winter cover than all other locations (Tex Creek, x = 20.0 ± 0.0; Malad Area, 18.0 ± 0.0; and Curlew Valley, 16.3 ± 5.0) (Table 2). The overall mean for all locations was 12.6 ± 7.3 percent.

The mean distance from random points within each winter cover type to the nearest nest/brood cover type was less (P < 0.05) on Sand Creek (x = 0 ± 20 m) than on all other locations (Tex Creek x = 80 ± 80 m; Malad Area 160 ± 220 m; Curlew Valley 120 ± 120 m) (Table 3). The overall mean for all locations was 90 ± 110 m.

The mean number of birds (males) present during spring lek counts on leks that we surveyed for the HSI varied from 8 to 26 (Table 4). Lek counts not only varied yearly but also daily depending on weather conditions, female attendance and disturbance (e.g., predators, livestock, photographers).

The amount of nest/brood cover available by location at these lek sites ranged from 2 to 58 percent (Table 5). However, the amount of nest/brood habitat was similar (P > 0.05) among study areas (Table 6). The mean nest/brood cover available for all 4 study areas was 80.8 ± 11.9 percent.

Robel pole measurements within nest/brood cover types ranged from 1.9 - 5.7 dm (Table 7). Horizontal visual cover associated with nest/brood habitats differed among study areas (Table 8). Robel pole measurements taken in nest/brood cover types indicated that Sand Creek (x = 1.9 ± 1.5 dm and Curlew Valley (x = 2.3 ± 1.2 dm) differed (P < 0.05) from each other and all other locations (Tex Creek, x = 2.7 ± 1.2 dm and Malad City Area, x = 3.3 ± 1.9 dm) (Table 8). The overall Robel pole measurement for all 4 locations was 2.5 ± 1.6 dm.

The mean distance from random points within each nest/brood cover type to the nearest winter cover type was less (P < 0.05) on Tex Creek (x = 200 ± 180 m) than those found in the Malad City Area (x = 660 ± 840 m) and Curlew Valley (x = 1260 ± 680 m) (Table 9). The overall mean distance from nest/brood cover to winter cover for all locations was 620 ± 500 m.
Table 1. Mean (± SD) available winter cover types by location.

<table>
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<th>Location</th>
<th>Cover Type</th>
<th>N¹</th>
<th>¯% Available/Location</th>
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<tr>
<td>Sand Creek</td>
<td>Chokecherry</td>
<td>3</td>
<td>3 ± 1</td>
</tr>
<tr>
<td></td>
<td>Juniper</td>
<td>3</td>
<td>2 ± 1</td>
</tr>
<tr>
<td>Tex Creek</td>
<td>Aspen</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Conifer²</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Riparian³</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Malad</td>
<td>Conifer</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Juniper</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Riparian</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Curlew</td>
<td>Juniper</td>
<td>3</td>
<td>8 ± 6</td>
</tr>
<tr>
<td></td>
<td>Mt. Shrub Mix⁴</td>
<td>3</td>
<td>5 ± 4</td>
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<tr>
<td></td>
<td>Serviceberry</td>
<td>1</td>
<td>2</td>
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<tr>
<td></td>
<td>Russian Olive</td>
<td>1</td>
<td>0.1</td>
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¹N = number of areas with a 6.5-km radius within which the cover type occurred.
²Douglas-fir and lodgepole pine (Pinus contorta).
³Willow and chokecherry.
⁴Chokecherry, serviceberry, aspen, snowberry (Symphoricarpos vaccinioides).
Table 2. Winter habitat available within a 6.5-km radius of each lek at each location and overall mean.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lek</th>
<th>N(^1)</th>
<th>% Available Per Lek</th>
<th>(\bar{x}) % Available Per Location(^2)</th>
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<tr>
<td>Sand Creek</td>
<td>Upper Grassy</td>
<td>2</td>
<td>6.0</td>
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</tr>
<tr>
<td></td>
<td>Chokecherry</td>
<td>2</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Miller's Corral</td>
<td>2</td>
<td>5.0</td>
<td>4.7 ± 1.5(^\text{a})</td>
</tr>
<tr>
<td>Tex Creek</td>
<td>Headquarters</td>
<td>3</td>
<td>20.0</td>
<td>20.0(^\text{b})</td>
</tr>
<tr>
<td>Malad Area</td>
<td>Grant Weeks</td>
<td>3</td>
<td>18.0</td>
<td>18.0(^\text{b})</td>
</tr>
<tr>
<td>Curlew Valley</td>
<td>West Jacobson</td>
<td>3</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Badger</td>
<td>2</td>
<td>21.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vanderhoff</td>
<td>3</td>
<td>17.0</td>
<td>16.3 ± 5.0(^\text{b})</td>
</tr>
</tbody>
</table>

Overall \(\bar{x} = 12.6 ± 7.3\)

\(^1\)N = number of different winter cover types available.

\(^2\)Means followed by same letter are similar (P > 0.05).
Table 3. Distance\(^1\) (\(\bar{x} \pm SD\)) from random points within each winter cover type to the nearest nest/brood cover.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lek</th>
<th>N</th>
<th>(\bar{x}/\text{Lek})</th>
<th>(\bar{x}/\text{Location})(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Creek</td>
<td>Upper Grassy</td>
<td>31</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chokecherry</td>
<td>3</td>
<td>60 (\pm) 60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Miller's Corral</td>
<td>11</td>
<td>0</td>
<td>0(^a)</td>
</tr>
<tr>
<td>Tex Creek</td>
<td>Red Granary</td>
<td>96</td>
<td>80 (\pm) 80</td>
<td>80 (\pm) 80(^b)</td>
</tr>
<tr>
<td></td>
<td>Headquarters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indian Fork</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malad Area</td>
<td>Lookout</td>
<td>31</td>
<td>160 (\pm) 220</td>
<td>160 (\pm) 220(^b)</td>
</tr>
<tr>
<td></td>
<td>Grant Week</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calvin Dredge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curlew Valley</td>
<td>West Jacobson</td>
<td>23</td>
<td>100 (\pm) 60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Badger</td>
<td>25</td>
<td>160 (\pm) 160</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vanderhoff</td>
<td>32</td>
<td>100 (\pm) 140</td>
<td>120 (\pm) 120(^b)</td>
</tr>
</tbody>
</table>

Overall \(\bar{x} = 90 \pm 110\)

\(^1\) Measured in meters.

\(^2\) Means followed by same letter are similar (\(P > 0.05\)).
Table 4. Spring lek counts from leks that were surveyed to develop the Columbian sharp-tailed grouse HSI.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lek</th>
<th>N&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Creek&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Upper Grassy</td>
<td>14</td>
<td>15</td>
<td>1-26</td>
</tr>
<tr>
<td></td>
<td>Chokecherry</td>
<td>8</td>
<td>10</td>
<td>4-20</td>
</tr>
<tr>
<td></td>
<td>Miller's Corral</td>
<td>10</td>
<td>8</td>
<td>3-10</td>
</tr>
<tr>
<td>Tex Creek&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Red Granary</td>
<td>8</td>
<td>11</td>
<td>10-14</td>
</tr>
<tr>
<td></td>
<td>Headquarters</td>
<td>30</td>
<td>21</td>
<td>7-43</td>
</tr>
<tr>
<td></td>
<td>Indian Fork</td>
<td>19</td>
<td>7</td>
<td>1-12</td>
</tr>
<tr>
<td>Malad Area&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Lookout</td>
<td>7</td>
<td>20</td>
<td>17-22</td>
</tr>
<tr>
<td></td>
<td>Grant Weeks</td>
<td>6</td>
<td>26</td>
<td>22-31</td>
</tr>
<tr>
<td></td>
<td>Calvin Dredge</td>
<td>10</td>
<td>12</td>
<td>10-16</td>
</tr>
<tr>
<td>Curlew Valley&lt;sup&gt;c&lt;/sup&gt;</td>
<td>West Jacobson</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Badger</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vanderhoff</td>
<td>23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Censused over two breeding seasons, 1988-89.
<sup>b</sup>Censused during the 1991 breeding season.
<sup>c</sup>Estimated maximum number of birds attending over 4 breeding seasons, 1988-91 (pers. commun. A. Apa).
<sup>d</sup>Number of censuses.
Table 5. Mean (+ SD) nest/brood cover types by location.

<table>
<thead>
<tr>
<th>Location</th>
<th>Cover Type</th>
<th>N⁴</th>
<th>(\bar{x} %) Available/Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Creek</td>
<td>Antelope Bitterbrush</td>
<td>3</td>
<td>49 ± 32</td>
</tr>
<tr>
<td></td>
<td>Big Sagebrush</td>
<td>3</td>
<td>37 ± 32</td>
</tr>
<tr>
<td>Tex Creek</td>
<td>CRP</td>
<td>3</td>
<td>29 ± 8</td>
</tr>
<tr>
<td></td>
<td>Big Sagebrush</td>
<td>3</td>
<td>22 ± 12</td>
</tr>
<tr>
<td></td>
<td>Three-tip Sagebrush</td>
<td>2</td>
<td>22 ± 28</td>
</tr>
<tr>
<td></td>
<td>Snowberry</td>
<td>1</td>
<td>2 ± 0</td>
</tr>
<tr>
<td>Malad</td>
<td>CRP</td>
<td>3</td>
<td>35 ± 6</td>
</tr>
<tr>
<td></td>
<td>Big Sagebrush</td>
<td>3</td>
<td>34 ± 12</td>
</tr>
<tr>
<td></td>
<td>Alfalfa</td>
<td>2</td>
<td>7 ± 9</td>
</tr>
<tr>
<td>Curlew</td>
<td>Big Sagebrush</td>
<td>3</td>
<td>58 ± 9</td>
</tr>
<tr>
<td></td>
<td>Crested Wheatgrass</td>
<td>3</td>
<td>31 ± 13</td>
</tr>
</tbody>
</table>

¹Number of times nest/brood cover type occurred per location.
²Three-tip sagebrush (Artemisia tripartita).
Table 6. Nest/brood habitat within a 2.0-km radius of each lek at each location and overall mean.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lek</th>
<th>N$^1$</th>
<th>% Available Per Lek</th>
<th>$\bar{%}$ Available Per Location$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Creek</td>
<td>Upper Grassy</td>
<td>2</td>
<td>96.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chokecherry</td>
<td>2</td>
<td>93.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Miller’s Corral</td>
<td>2</td>
<td>67.0</td>
<td>85.3 ± 15.9</td>
</tr>
<tr>
<td>Tex Creek</td>
<td>Red Granary</td>
<td>3</td>
<td>74.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Headquarters</td>
<td>4</td>
<td>69.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indian Fork</td>
<td>2</td>
<td>63.0</td>
<td>68.7 ± 5.5</td>
</tr>
<tr>
<td>Malad Area</td>
<td>Lookout</td>
<td>2</td>
<td>73.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grant Weeks</td>
<td>3</td>
<td>80.0</td>
<td>76.7 ± 3.5</td>
</tr>
<tr>
<td></td>
<td>Calvin Dredge</td>
<td>3</td>
<td>77.0</td>
<td></td>
</tr>
<tr>
<td>Curlew Valley</td>
<td>West Jacobson</td>
<td>2</td>
<td>90.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Badger</td>
<td>2</td>
<td>94.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vanderhoff</td>
<td>2</td>
<td>93.0</td>
<td>89.0 ± 5.6</td>
</tr>
</tbody>
</table>

Overall $\bar{\%} = 80.8 ± 11.91$

$^1$N = number of different nest/brood cover types available.

$^2$No differences occurred in nest/brood habitat availability between locations.
Table 7. Robel pole values (dm, $\bar{x} \pm SD$) within each nest/brood cover type.

<table>
<thead>
<tr>
<th>Cover Type</th>
<th>N</th>
<th>$\bar{x} \pm SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>20</td>
<td>5.7 $\pm$ 0.6</td>
</tr>
<tr>
<td>CRP</td>
<td>201</td>
<td>3.9 $\pm$ 1.2</td>
</tr>
<tr>
<td>Snowberry</td>
<td>7</td>
<td>3.6 $\pm$ 2.9</td>
</tr>
<tr>
<td>Three-tip Sagebrush</td>
<td>46</td>
<td>3.0 $\pm$ 1.3</td>
</tr>
<tr>
<td>Crested Wheatgrass</td>
<td>61</td>
<td>2.4 $\pm$ 1.1</td>
</tr>
<tr>
<td>Big Sagebrush</td>
<td>478</td>
<td>2.0 $\pm$ 1.2</td>
</tr>
<tr>
<td>Antelope Bitterbrush</td>
<td>146</td>
<td>1.9 $\pm$ 1.4</td>
</tr>
</tbody>
</table>
Table 8. Robel pole values (dm) in nest/brood cover ($\bar{x} \pm SD$) for each lek, location and overall mean.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lek</th>
<th>N</th>
<th>$\bar{x}$/Lek</th>
<th>$\bar{x}$/Location$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Creek</td>
<td>Upper Grassy</td>
<td>96</td>
<td>2.0 ± 1.6</td>
<td>1.9 ± 1.5$^a$</td>
</tr>
<tr>
<td></td>
<td>Chokecherry</td>
<td>93</td>
<td>2.2 ± 1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Miller's Corral</td>
<td>67</td>
<td>1.4 ± 1.1</td>
<td></td>
</tr>
<tr>
<td>Tex Creek</td>
<td>Red Granary</td>
<td>74</td>
<td>3.0 ± 1.2</td>
<td>2.7 ± 1.2$^b$</td>
</tr>
<tr>
<td></td>
<td>Headquarters</td>
<td>70</td>
<td>2.7 ± 1.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indian Fork</td>
<td>63</td>
<td>2.5 ± 1.1</td>
<td></td>
</tr>
<tr>
<td>Malad Area</td>
<td>Lookout</td>
<td>73</td>
<td>2.7 ± 1.7</td>
<td>3.3 ± 1.9$^b$</td>
</tr>
<tr>
<td></td>
<td>Grant Week</td>
<td>80</td>
<td>3.4 ± 1.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calvin Dredge</td>
<td>76</td>
<td>3.9 ± 2.0</td>
<td></td>
</tr>
<tr>
<td>Curlew Valley</td>
<td>West Jacobson</td>
<td>90</td>
<td>2.5 ± 1.1</td>
<td>2.3 ± 1.2$^c$</td>
</tr>
<tr>
<td></td>
<td>Lower Badger</td>
<td>94</td>
<td>2.2 ± 1.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vanderhoff</td>
<td>83</td>
<td>2.1 ± 1.3</td>
<td></td>
</tr>
</tbody>
</table>

Overall $\bar{x} = 2.5 \pm 1.6$

$^1$Means followed by same letter are similar (P > 0.05).
Table 9. Distance\(^1\) (\(\bar{x} \pm SD\)) from random points within each nest/brood cover type to the nearest winter cover type.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lek</th>
<th>N</th>
<th>(\bar{x}/\text{Lek})</th>
<th>(\bar{x}/\text{Location}^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Creek</td>
<td>Upper Grassy</td>
<td>5</td>
<td>240 (\pm) 100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chokecherry</td>
<td>4</td>
<td>400 (\pm) 180</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Miller’s Corral</td>
<td>5</td>
<td>460 (\pm) 480</td>
<td>360 (\pm) 300(^{ab})</td>
</tr>
<tr>
<td>Tex Creek</td>
<td>Red Granary</td>
<td>12</td>
<td>240 (\pm) 180</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Headquarters</td>
<td>23</td>
<td>240 (\pm) 200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indian Fork</td>
<td>16</td>
<td>140 (\pm) 160</td>
<td>200 (\pm) 180(^a)</td>
</tr>
<tr>
<td>Malad Area</td>
<td>Lookout</td>
<td>18</td>
<td>200 (\pm) 100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grant Weeks</td>
<td>24</td>
<td>220 (\pm) 180</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calvin Dredge</td>
<td>19</td>
<td>1620 (\pm) 940</td>
<td>660 (\pm) 840(^b)</td>
</tr>
<tr>
<td>Curlew Valley</td>
<td>West Jacobson</td>
<td>8</td>
<td>1000 (\pm) 700</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Badger</td>
<td>8</td>
<td>1500 (\pm) 800</td>
<td>1260 (\pm) 680(^b)</td>
</tr>
<tr>
<td></td>
<td>Vanderhoff</td>
<td>12</td>
<td>1280 (\pm) 540</td>
<td></td>
</tr>
</tbody>
</table>

Overall \(\bar{x} = 620 \pm 500\)

\(^1\)Measured in meters.
\(^2\)Means followed by same letter are similar (P > 0.05).
Model Assumptions - (Prose 1987)

1. Winter food/cover and nest/brood cover are the most limiting habitat factors for stable populations of Columbian sharp-tailed grouse.

2. Winter food/cover suitability is a function of relative area of winter cover and availability of supplementary grain.

3. Nest/brood cover suitability is a function of the relative area of cover types used for nesting and brood rearing and the height and density of residual herbaceous vegetation.

4. Interspersion of cover types providing different life history requirements can be characterized by the distance between them.

5. A large area of low quality can have an overall habitat value equivalent to a small area of high quality (i.e., area can compensate for quality and quality can compensate for area).

6. The presence of available cultivated grains increases the winter food/cover value of an area by providing a supplemental food source and reducing the dependency of sharp-tailed grouse on woody cover.

7. Habitats lacking shrubs cannot have a suitability index for winter/food cover > 0.5.

8. Residual vegetation within cover types providing potential nesting and brood-rearing cover exists in a variety of heights and densities.

Winter Food/Cover Component

Equation 1 is used to calculate the contribution of shrubby cover to the percent equivalent optimum area of winter food/cover.

\[ PAWS = \sum_{i=1}^{n} S_i (SIV_1)_i \]  

where \( PAWS = \) percent equivalent optimum area providing winter food/cover contributed by shrubby cover types

\( n = \) total number of shrubby cover types present

\( S_i = \) percent of available habitat in shrubby cover type \( i \)

\( SIV_1)_i = \) mean suitability index for distance between winter cover type \( i \) and the nearest cover type providing nest/brood cover (Fig. 4)

Separate scales were used to evaluate the distances between winter cover types to nest/brood cover types and nest/brood cover types to winter cover types for the Columbian sharp-tailed grouse HSI. None (0/20) of the winter-to-nest/brood distance measurements exceeded 1.6 km, the optimal distance reported by Prose (1987). Therefore, we decreased the optimal distance measurement to 90 m (Fig. 4), which was the overall mean distance measurement from winter to nest/brood cover for Columbian sharp-tailed grouse (Table 3).

Columbian sharp-tailed grouse do not require cultivated grain, but grain can be a preferred winter food when available. Available grain crops in the plains subspecies HSI were those within 750 m of woody cover and \(< 50 \) m from cropland's edge. Because grain crops may be unavailable to sharp-taileds during periods of heavy snow cover, the percent equivalent optimum area of winter food/cover provided by grain crops (Equation 2) cannot exceed 5 percent (the percent corresponding to a suitability index of 0.5) (Fig. 5) for its contribution to the total percent equivalent optimum area for the study area (Equation 3).

\[ PAWC = \sum_{j=1}^{n} C_j (SIV_1)_j \]  

where \( PAWC = \) percent equivalent optimum area providing winter food/cover contributed by grain crop cover types

\( n = \) total number of available grain crop cover types

\( C_j = \) percent of available habitat in available grain crop cover type \( j \)

\( SIV_1)_j = \) average suitability index for distance between available grain/crop cover type \( j \) and the nearest cover type providing nest/brood cover (Fig. 4)

Note: If PAWC exceeds 5 percent, it should be set to 5 percent for further calculations.
Figure 4. The relationship between distance from winter cover to nest/brood cover and suitability for Columbian sharp-tailed grouse.

Figure 5. The relationship between percent equivalent optimum area providing winter food/cover and suitability of winter food/cover for Columbian sharp-tailed grouse.
The overall percent equivalent optimum area providing winter food/cover is equal to the sum of that provided by both shrubby cover (PAWS) and grain crops (PAWC) (Equation 3). Maximum winter food/cover suitability in this HSI is reached at 10 percent equivalent optimum area (Fig. 5). Shrubs are the primary source of native winter foods and are a critical food source during periods of heavy snow cover. The presence of grain crops need not be considered on study areas having > 10 percent equivalent optimum area in winter food/cover that is provided by shrubby cover.

Percent Equivalent Optimum Area Providing Winter Food/Cover
= PAWS + PAWC (3)

The suitability index for the winter food/cover requirement is equal to the suitability index for equivalent optimum area providing winter food/cover.

The Sand Creek leks were the only leks we studied where the area within a 6.5-km radius of each lek contained < 10 percent winter cover; all other locations exceed 10 percent winter cover, which is equivalent to a 1.0 optimum habitat suitability index. Moreover, the Sand Creek leks were the only ones in which no grain crop occurred within a 6.5-km radius. Therefore, the percent equivalent optimum area providing winter food/cover contributed by grain crop cover types for all leks in all locations was zero.

Nest/Brood Cover Component
We assumed that Robel pole readings (VOR) taken in spring (i.e., early nesting season) reflect factors affecting availability of nest/brood cover (Prose 1987). For the plains HSI, residual vegetation with a Robel pole mean ≥ 2.0 dm over the entire area represented optimal nesting and brood rearing conditions. When we analyzed nest/brood cover for Columbian sharp-tailed grouse, we found that only 34 percent (10/29) of Robel pole means fell below the 2.0 dm optimal measurement used in the plains sharp-tailed grouse model (Prose 1987). Therefore, we increased the optimal measurement to 2.5 dm (Fig. 6), which was our overall mean Robel pole measurement (Table 8). We also observed that only 7 percent (2/29) of the mean measurements taken from nest/brood cover to winter cover exceeded the optimal distance of 1.6 km. Thus, we decreased the optimal distance measurement to 620 m (Fig. 7), which was our overall mean distance measurement from nest/brood cover to winter cover (Table 9).

Nest/brood cover suitability in both the plains and Columbian sharp-tailed grouse HSI's is a function of height and density of vegetation in spring, relative size of nest/brood cover types, and relationship between distance from nest/brood cover to winter cover. This relationship is expressed as percent equivalent optimum area providing nest/brood cover and is derived with Equation 4.

Percent Equivalent Optimum Area
= \sum_{i=1}^{n} (SIV3_i)(N_i)(SIV4_i) (4)

where
n = total number of nest/brood cover types
SIV3_i = the suitability index for cover in cover type i (Fig. 6)
N_i = percent of study area in cover type i (Fig. 6)
SIV4_i = mean suitability index for distance between nest/brood cover type i and the nearest cover type providing winter food/cover (including available cropland) (Fig. 7)

The maximum nest/brood cover suitability in the HSI exists when the equivalent optimum area providing nest/brood cover is ≥ 50 percent (Fig. 8) and decreases as the percent equivalent optimum area decreases until zero suitability is reached at 5.0 percent. The suitability index for nest/brood cover is equal to the suitability index for percent equivalent optimum area providing nest/brood cover.

HSI Determination
The HSI is equal to the lower of the life requirement values for winter food/cover (SIV2) or nest/brood cover (SIV5).

After the Columbian sharp-tailed grouse data were entered into the plains sharp-tailed grouse HSI before modifications took place, the 12 study leks were ranked from most optimal (West Jacobson, HSI = 1.0) to least optimal (Chokecherry, HSI = 0.30) (Table 10).

We then modified the plains HSI to include new optimal measurements and distances and re-analyzed the Columbian sharp-tail data. The 12 study leks were ranked from most optimal (Red Granary, West Jacobson, Headquarters, and Grant Weeks HSI = 1.00) to least optimal (Chokecherry, HSI = 0.30) (Table 11). Using our modifications, 75 percent (9/12) of the habitat suitability indices for our study leks changed and the rankings of 92 percent (11/12) of the leks changed. The mean HS generated by the plains method was 0.70. However, after our modifications, this value increased to 0.75.
Figure 6. The relationship between mean visual obstruction of residual vegetation and nest/brood cover suitability for Columbian sharp-tailed grouse.

Figure 7. The relationship between distance from nest/brood cover to winter cover and suitability for Columbian sharp-tailed grouse.
Figure 8. The relationship between percent equivalent optimum area providing nest/brood cover and suitability of nest/brood cover for Columbian sharp-tailed grouse.
Table 10. Habitat suitability index values and lek rankings using the plains sharp-tailed grouse method.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lek</th>
<th>Habitat Suitability Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nest/Brood</td>
<td>Winter</td>
</tr>
<tr>
<td>Sand Creek</td>
<td>Upper Grassy</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>Chokecherry</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Miller’s Corral</td>
<td>0.35</td>
</tr>
<tr>
<td>Tex Creek</td>
<td>Red Granary</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Headquarters</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>Indian Fork</td>
<td>0.60</td>
</tr>
<tr>
<td>Malad Area</td>
<td>Lookout</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>Grant Weeks</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>Calvin Dredge</td>
<td>0.80</td>
</tr>
<tr>
<td>Curlew Valley</td>
<td>West Jacobson</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Lower Badger</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Vanderhoff</td>
<td>0.90</td>
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Ranking

<table>
<thead>
<tr>
<th>Lek</th>
<th>HSI</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Vanderhoff</td>
<td>0.90</td>
</tr>
<tr>
<td>Red Granary</td>
<td>0.80</td>
</tr>
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</tr>
<tr>
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<td>0.35</td>
</tr>
<tr>
<td>Chokecherry</td>
<td>0.30</td>
</tr>
</tbody>
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Table 11. Habitat suitability index values and lek rankings using the Columbian sharp-tailed grouse method.

<table>
<thead>
<tr>
<th>Location</th>
<th>Lek</th>
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<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Creek</td>
<td>Upper Grassy</td>
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<td>0.55</td>
</tr>
<tr>
<td></td>
<td>Chokecherry</td>
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<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Miller's Corral</td>
<td>0.35</td>
<td>0.50</td>
</tr>
<tr>
<td>Tex Creek</td>
<td>Red Granary</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Headquarters</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Indian Fork</td>
<td>0.85</td>
<td>1.00</td>
</tr>
<tr>
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<td>Lookout</td>
<td>0.95</td>
<td>1.00</td>
</tr>
<tr>
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<td>Grant Weeks</td>
<td>1.00</td>
<td>1.00</td>
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<td>1.00</td>
</tr>
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<td></td>
<td>Vanderhoff</td>
<td>0.80</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Ranking**

<table>
<thead>
<tr>
<th>Lek</th>
<th>HSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Red Granary</td>
<td>1.00</td>
</tr>
<tr>
<td>1. West Jacobson</td>
<td>1.00</td>
</tr>
<tr>
<td>1. Headquarters</td>
<td>1.00</td>
</tr>
<tr>
<td>1. Grant Weeks</td>
<td>1.00</td>
</tr>
<tr>
<td>2. Lookout</td>
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<tr>
<td>3. Indian Fork</td>
<td>0.85</td>
</tr>
<tr>
<td>4. Vanderhoff</td>
<td>0.80</td>
</tr>
<tr>
<td>5. Calvin Dredge</td>
<td>0.60</td>
</tr>
<tr>
<td>6. Lower Badger</td>
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</tr>
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<td>7. Upper Grassy</td>
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<td>8. Miller's Corral</td>
<td>0.35</td>
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<tr>
<td>9. Chokecherry</td>
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</tr>
</tbody>
</table>
DISCUSSION

The greatest change made from the plains to the Columbian sharp-tailed grouse HSI was the distance measurements between the 2 components (nest/brood and winter habitat). Columbian sharp-tailed grouse habitat occurs in areas with great diversity where these two components are intermixed and usually occur in proximity. The plains sharptail uses areas with large expanses of brushy grasslands with limited diversity and, therefore, larger distances between the two components.

The greater Robel pole measurements associated with the Columbian sharptail nest/brood habitat are most likely because they were taken during June (late nesting) and not in April (prior to nesting), as they were for the plains HSI. We urge HSI users to take this into consideration when collecting Robel pole data. We collected data during June because of funding and time constraints for this project and not for any biological reasons.

We advise HSI users to refrain from reintroducing Columbian sharp-tailed grouse into areas where the HSI is < 0.75. In areas where the HSI is < 0.75, one or both of the habitat components may be limited to the point that introduced birds could not locate needed habitat to survive and reproduce. Introduced birds may disperse to find suitable habitat, food or cover, and never establish a lek and also suffer relatively high mortality rates (Musil 1989). Therefore, even though all 12 of the leks that were used to revise this procedure held viable populations, we would advise reintroducing birds into habitats that were similar to only 7 of these leks. The remaining leks may not provide adequate habitat components for a translocated population to become established.

There may not be a direct relationship between lek attendance (Table 4) and HSI values (Table 11). However, the number of leks in a given unit of habitat may vary, and this density of leks should reflect habitat quality.

This HSI provides a systematic method to evaluate habitat quality for Columbian sharp-tailed grouse. This method assesses the two key components for sharp-tailed grouse: nest/brood and winter habitat. This procedure can provide HSI values which are compatible with the HEP of the U.S. Fish and Wildlife Service. It can be used to determine the amount of mitigation crediting a particular site may provide and can also be used by biologists lacking considerable experience with sharp-tailed grouse biology.

This procedure could be further improved by collecting habitat data in other parts of the current range of Columbian sharp-tailed grouse as well as in areas that were once known to support Columbian sharp-tailed grouse, but due to habitat modifications are now abandoned. The results can then be compared to relationships in our HSI to determine if any further modifications to the procedure are needed.

LITERATURE CITED


APPENDIX I. Guidelines for Implementing the Columbian Sharp-tailed Grouse Habitat Suitability Index.

I. Determine location of existing or artificial (release site) leks.

A. This is commonly done by systematically searching areas from a vehicle during the early morning (i.e., 0.5 hours before sunrise to 1 hour after sunrise). Stops are made at 1-km intervals and observers listen for displaying birds as well as search relatively open areas with binoculars or a spotting scope.

II. Data Collection.

Determine percent availability of each winter cover type (including grain) within a 6.5-km radius of each lek or release site.

When determining availability of winter (or nest/brood) cover, several techniques can be used depending on the availability of resources. To determine availability for this project we used color aerial photos along with orthophotoquads. In some cases, only 1:24,000 topographic maps may be available, depending on the area examined. Each block of cover type that is ≥ 1% of the area defined by a 6.5-km radius should be included. Cover types can be delineated by dominant species and/or structure.

1. Select a random point within each winter cover type (select 1 random point for each 1 percent of winter cover type available) and determine the distance to the nearest nest/brood cover.

Determine percent of each nest/brood cover type within a 2.0-km radius of each lek or release site.

1. Select a random point and direction within each cover type.

   a. Use these as starting points in taking Robel pole measurements (take 1 measurement every 25 m for every 1 percent of nest/brood cover available). The pole is read from 4 m at 1 m above the ground.

      If a point falls outside the cover type and more Robel pole measurements are needed, select another random point and direction and proceed until the needed number of measurements are obtained.

   b. From each of these points, use a topographic map or orthophotoquad to determine the distance to the nearest wintering cover.

III. Calculating Winter Food/Cover Component.

1. Determine total percent availability of each winter cover type for each lek.

2. Determine mean distance between winter cover types and the nearest nest/brood cover for each lek.

3. Enter distance means into Fig. 4 to determine suitability for each winter cover type for each lek.

4. Enter values into Equation 1 (keeping leks separate) to determine percent equivalent optimum area providing winter food/cover available by shrubby cover.
5. Calculate percent equivalent optimum area providing winter food/cover contributed by grain if shrubby cover provides < 10 percent suitability (Fig. 5).

6. Determine suitability index (Fig. 5) for the winter food/cover life requisite.

IV. Calculating Nest/Brood Cover Component.

1. Determine total percent availability of each nest/brood cover type for each lek.

2. Determine mean distance between nest/brood cover types and the nearest winter cover for each lek.

3. Enter distance means into Fig. 7 to determine suitability for each nest/brood cover type for each lek.

4. Determine mean Robel pole measurements for each nest/brood cover type for each lek.

5. Enter mean measurements into Fig. 6 to determine suitability for each nest/brood cover type for each lek.

6. Enter values into Equation 4 (keeping leks separate) to determine percent equivalent optimum area providing nest/brood cover.

7. Determine suitability index (Fig. 8) for the nest/brood cover life requisite.

V. (HSI) Determination.

1. List each lek and its corresponding winter food/cover and nest/brood cover index values (Table 11).

2. Rank leks using the lower of the 2 index values.

3. We do not recommend introducing birds into an area with an HSI lower than 0.75.