

HABITAT USE AND MOVEMENTS OF SYMPATRIC SAGE AND
COLUMBIAN SHARP-TAILED GROUSE IN SOUTHEASTERN IDAHO

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Anthony Dean Apa

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Major Professor: Kerry P. Reese, Ph.D.

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AUTHORIZATION TO SUBMIT DISSERTATION

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Major Professor Kerry Paul Reese Date 4-22-98
Kerry P. Reese

Committee Members John W. Connelly Date 3-27-98
John W. Connelly

Dale O. Everson Date 4/21/98
Dale O. Everson

M. Hironaka Date 4/22/98
Migoru Hironaka

J. Michael Scott Date 4/20/98
J. Michael Scott

Department Administrator George W. LaBar Date 4/22/98
George W. LaBar

College Dean Charles R. Hatch Date 4/23/98
Charles R. Hatch

Final Approval and Acceptance by the College of Graduate Studies

Jeanine M. Shreeve Date 5/6/98
Jean'ne M. Shreeve

ABSTRACT

I investigated the habitat use and movements of sympatric female sage (Centrocercus urophasianus) and Columbian sharp-tailed grouse (Tympanuchus phasianellus columbianus) during the breeding, nesting, and brood-rearing periods in the Curlew Valley region of southeastern Idaho. During March and April of 1988 through 1991, I captured 69 female sage and 75 female Columbian sharp-tailed grouse on or near strutting or dancing grounds, respectively. I radio-marked 85 (37 sage grouse, 48 Columbian sharp-tailed grouse) female grouse. I also experimentally tested predictions of the Male Avoidance (M-A) and Sentinel Decoy (S-D) theories of lek evolution through the construction of 551 artificial Columbian sharp-tailed grouse nests during April through June of 1990 (262 nests) and 1991 (289 nests). The nests were constructed and checked around 7 different active Columbian sharp-tailed grouse dancing grounds at 6 sequentially increasing distances (0.25, 0.50, 0.75, 1.00, 1.50, 2.00 km) from the center of the lek. The artificial nests were checked a 1, 3, 6, and 9 days following construction to determine fate.

Sage grouse nest success (44%) was lower than for gallinaceous birds generally and tetraoninae specifically. Sage grouse nest success in the Curlew Valley was lower than earlier reported in Idaho (61 and 52%). Hens that nested under shrubs other than sagebrush were not successful. Columbian sharp-tailed grouse nest success (51%) was similar to sharp-tailed grouse generally, but lower than previously reported in Idaho (72 and 56%). All Columbian sharp-tailed grouse hens that nested in native vegetation were successful, while 45% that nested in non-native vegetation were successful.

I rejected the hypothesis that sage and Columbian sharp-tailed grouse movements from the lek of capture to nest did not differ. Sage grouse moved over twice as far from the lek of capture to nest than did Columbian sharp-tailed grouse.

Sage grouse nested under taller sagebrush (*Artemisia* spp.) than was present in the near vicinity or at random, and taller (10 - 20 cm more) than has been previously reported. The height differences were due to study area location and the presence of a different sagebrush subspecies than was available in other studies. Female sage grouse nested under sagebrush crowns that were 2.1 times larger than those used by nesting Columbian sharp-tailed grouse. Total shrub canopy cover and forb height were variables in a predictive model for sage grouse nesting habitat. Understory measurements suggested that nests were unique from independent macro-habitat sites (third-order selection), but not different from dependent macro-habitat sites (fourth-order selection).

Columbian sharp-tailed grouse also nested in areas with high shrub canopy cover (62%). Columbian sharp-tailed grouse used less cover than was present at independent macro-habitat sites and less than has been reported in previous studies. Fifty-three percent of Columbian sharp-tailed grouse nests were under a forb or grass species. Columbian sharp-tailed grouse nests were unique from third-order habitats but were not unique from fourth-order. Grass and sagebrush height contributed significantly to a logistic regression model.

Sage and Columbian sharp-tailed grouse partitioned nesting habitat. Sage grouse nested in higher elevation sites, while Columbian sharp-tailed grouse nested in lower elevation sites. Sagebrush canopy cover and site slope were predictive in the segregation of nesting habitat. Sage and Columbian sharp-tailed grouse had different life history strategies that made sage grouse more specialized in nesting habitat, while Columbian sharp-tailed grouse were generalists.

Sage and Columbian sharp-tailed grouse brood movements did not follow plant desiccation changes based on elevation as previously reported. I rejected the hypothesis that sage and Columbian sharp-tailed grouse movements did not differ. Median daily movements of sage grouse were greater than those of Columbian sharp-tailed grouse.

Plant species richness was higher at sage grouse sites than Columbian sharp-tailed grouse sites. Grouse brood sites had twice as much forb cover (8%) than was present at independent macro-habitat sites. Sites with high forb cover were more predictive of sage grouse brood sites from independent macro-habitat sites, while sites with tall sagebrush and tall forbs were highly predictive of Columbian sharp-tailed grouse brood habitat.

Columbian sharp-tailed grouse appeared to have a narrower brood habitat niche than sage grouse. There appeared to be some niche separation with reduced overlap, but not to the extent that was exhibited with nest sites. Nesting habitat niche breadth for sage grouse was narrower than brood habitat niche breadth.

Artificial nests adequately simulated vegetation structure and placement of natural nests and provided a unique opportunity to evaluate predation rates or patterns. The primary avian predators were the common raven (Corvus corone) and black-billed magpie (Pica pica). After 9 days of exposure 92% and 91% of the nests were depredated during Trial II and I, respectively. This experiment supported the M-A theory and suggests that female Columbian sharp-tailed grouse may reduce nest predation by nesting relatively far from leks. My data do not support the S-D theory predictions. Distance of nest from the lek and density were interrelated aspects of nest survival.

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DEDICATION

I believe that life is meaningless, or at least mundane, without the challenges and personal growth following difficult times. During the writing of this dissertation I faced life's challenges through the death of my father and a very good friend, Craig Kvale. I have also faced the serious illness of many friends and colleagues. I also faced my own mortality through the diagnosis and treatment of cancer. Regardless of my treatment's outcome, I would like to dedicate this dissertation to Drs. P. Workman and G. Seville and the staff at the Southern Idaho Regional Cancer Center. Your professional, medical treatment and emotional support, through 4 biopsies, numerous tests, 2 surgeries, 8 weeks of radiation therapy and a subsequent recovery, has given me the time and opportunity to complete this very important portion of my life. I think we hit a "home run," Dr. Seville. Thank you!

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PREFACE

Although chapters in this dissertation will be submitted to different professional journals, I have written each chapter using The Journal of Wildlife Management style. The personal pronoun "I" is used throughout, however, multiple authorship of submitted papers will necessitate changing "I" to "we."

INTRODUCTION

Sage (Centrocercus urophasianus) and Columbian sharp-tailed (Tympanuchus phasianellus columbianus) grouse are native to the Intermountain West. The historic distribution of both species overlapped in eastern Washington and Oregon, southern Idaho, southwestern Montana, western Wyoming and Colorado, northern California and Nevada, north-central Utah, and south-central British Columbia (Aldrich 1963, Marks and Marks 1987). Today the imbricate nature of their ranges has been reduced to approximately 10% of the former range (Johnsgard 1983, Giesen and Connelly 1993). Both species coexist in southern Idaho, extreme northern Utah and western Colorado and Wyoming.

Columbian Sharp-tailed Grouse

The Columbian sharp-tailed grouse is the rarest of the 6 subspecies of sharp-tailed grouse (Miller and Graul 1980). Subspecies include the Columbian, Northern (T. p. phasianellus), Northwestern (T. p. kennicotti), Alaskan (T. p. caurus), Prairie (T. p. capestris), and Plains (T. p. jamesi), sharp-tailed grouse (Aldrich 1963, Johnsgard 1983). The Columbian subspecies is distinguished by its smaller size, relative to the other subspecies, and its associated habitat type which includes the sagebrush (Artemisia spp.)-grass and shrub-steppe habitat cover types.

Most research has focused on subspecies other than the Columbian sharp-tailed grouse. Therefore, reasons for the decline in populations of this subspecies are unclear, but coincided with western settlement, associated plowing of native rangeland for agriculture, and intensive livestock grazing (Hart et al. 1950, Yocum 1952, Buss and Dziedzic 1955, Hamerstrom and Hamerstrom 1961, Aldrich 1963, Rogers 1969, Parker 1970, Zeigler 1979).

Kessler and Bosch (1982) reported responses from western rangeland managers about Columbian sharp-tailed grouse population status. One respondent (1%) indicated an increase in Columbian sharp-tailed grouse populations, 30% reported stable populations,

22% reported decreasing populations and 5% reported fluctuating populations. Forty-two percent of the managers responding reported extirpated populations. Reasons respondents gave for decreases in populations included past and present livestock overgrazing, intensive agriculture, urban development, and absence of fire in Columbian sharp-tailed grouse habitat. More specifically, former Columbian sharp-tailed grouse habitat overgrazed by livestock had reduced native bunchgrasses and forbs, which are important components of nesting and brood-rearing habitat (Yocum 1952, Jewett et al. 1953, Evans 1968). Marks and Marks (1987) contended that Columbian sharp-tailed grouse select areas least modified by livestock grazing. They argued that Columbian sharp-tailed grouse could be a suitable indicator of range quality in Intermountain West mesic shrub-steppe habitats.

Other studies have suggested that through proper range management practices, livestock grazing need not be damaging to sharp-tailed grouse habitat (Hart et al. 1950, Brown 1966). Laycock (1967) found that fall grazing with sheep maintained seral sagebrush stands which created open areas where grass and forb production was similar to ungrazed areas. More recently, Columbian sharp-tailed grouse populations in Idaho have increased largely due to the Conservation Reserve Program (CRP), which was initiated in 1985 (Sirotnak et al. 1991, Meints et al. 1992).

Seasonal And Daily Movements.--Information dealing with seasonal and daily movements of Columbian sharp-tailed grouse is lacking. Most studies of sharp-tailed grouse movements have been conducted with subspecies other than the Columbian sharp-tailed grouse and have been concerned with movements on a monthly basis or during the nesting or brood-rearing stages (Artmann 1970, Christensen 1970, Pepper 1972, Schiller 1973, Kohn 1976, Ramharter 1976). Gratson (1988) evaluated spatial patterns and daily movement patterns of sharp-tailed grouse in Wisconsin. He found daily movements were reduced in the late-winter through spring and early-summer but increased through late-fall. Female grouse had larger home ranges than males during the pre-laying period. Gratson suggested that hens attempted to nest as far away from a lek as possible while still

remaining on their summer range. He hypothesized that hens nested away from leks because of the increased predatory activity around leks created by actively displaying males. Nesting close to a lek would pose a risk to the hen and/or nest. Fall daily movement patterns increased into late-October (Gratson 1988). Reasons for the increased movement patterns revolved around the hen's desertion of the brood and brood dispersal. Meints (1991) reported the mean nest to capture lek distance of 1.2 ± 0.9 km ($n = 16$), while the mean daily brood movements were 0.9 ± 0.2 km ($n = 42$).

Nesting Habitat.--Nesting habitat appears to be less restrictive than winter habitat. Besides nesting in native vegetation, Columbian sharp-tailed grouse have nested in alfalfa (Medicago spp.) (Meints 1991), wheat (Triticum spp.), and wheat stubble fields (Hart et al. 1950). Nests have been located under big sagebrush (Artemisia tridentata), antelope bitterbrush (Purshia tridentata) (Parker 1970, Meints 1991), snowberry (Symphoricarpos spp.) (Oedekoven 1985), arrowleaf balsamroot (Balsamorhiza sagittata) and bluebunch wheatgrass (Agropyron spicatum) (Marks and Marks 1987). Marks and Marks (1987) suggested that Columbian sharp-tailed grouse in Idaho choose nesting cover that is more dense than average, but a small sample size ($n = 4$ radio-tagged hens, $n = 5$ incidental nests) restricted conclusions. In another Idaho study, Meints (1991) found that Columbian sharp-tailed grouse nested in areas with higher than average canopy coverage of antelope bitterbrush and three-tipped sagebrush (Artemisia tripartita), and higher shrub densities than random locations. Geisen (1987) reported that Columbian sharp-tailed grouse in Colorado also selected relatively dense cover for nests ($n = 13$).

Summer/Brood Habitat.--Oedekoven (1985) described Columbian sharp-tailed grouse spring and summer habitat in Wyoming as mixed shrub communities with high forb densities. He indicated that brood habitat had a higher snowberry frequency than other habitats. Klott and Lindzey (1990) agreed, and found that brood habitat consisted of sagebrush-snowberry and mountain shrub habitat sites. Total shrub cover ranged from 13-40%. Brood sites were typically in areas with less shrub cover than habitat sites in

general. Like both Klott (1987) and Ammann (1957), McArdle (1977) found that Columbian sharp-tailed grouse preferred 20-40% shrub cover. Marks and Marks (1987) found that during the summer Columbian sharp-tailed grouse inhabited big sagebrush cover types more than in proportion to availability of 9 other cover types. The big sagebrush cover type had greater vegetation canopy cover, high shrub, forb, and grass species diversity, and structural diversity than other cover types (Marks and Marks 1987). Meints (1991) found that broods were located closer to habitat edges, leks, and riparian areas than were randomly located points.

Sage Grouse

In contrast to Columbian sharp-tailed grouse, a great deal of research has been conducted on sage grouse. Specific studies dealing with general diet and winter habitat use are numerous and span over 50 years (Girard 1937, Griner 1939, Patterson 1952, Klebenow and Gray 1968, Peterson 1970, Wallestad et al. 1974, Remington and Braun 1985, Hupp 1987). Breeding habitat has been described by Wallestad and Schladweiler (1974), Autenrieth (1981), Schoenberg (1982), Emmons and Braun (1984), and Eng and Schladweiler (1972). Nesting and brood habitat has been evaluated by Girard (1937), Patterson (1952), Trueblood (1954), Rogers (1964), Klebenow (1969), Peterson (1970), and Wallestad and Pyrah (1974). Information about all stages of sage grouse life history was summarized by Roberson (1986).

The historical distribution of sage grouse closely followed the historical distribution of sagebrush in the western United States (Beetle 1960, Braun 1985). As total sagebrush area was reduced from 58.7-109.3 million ha (Beetle 1960, Sturges 1973) to 2-10 million ha (Schneegas 1967, Braun et al. 1976), sage grouse populations declined drastically (Autenrieth et al. 1977). The primary reason for sagebrush eradication efforts was to increase forage production for livestock (Schneegas 1967, Wallestad 1975, Higby 1976) and to clear land for agricultural purposes. Due to the close association of sage grouse

with sagebrush throughout all portions of its life history (Patterson 1952, Eng and Schladweiler 1972, Wallestad et al. 1974), sage grouse populations have decreased from pre-sagebrush eradication levels.

Seasonal And Daily Movements.--Sage grouse seasonal movements differ depending on whether the population is migratory or non-migratory. The general trend is movement from summer and fall ranges to relatively dense sagebrush stands on winter areas in response to snow accumulation and lack of available food (Wallestad 1975, Beck 1977, Connelly et al. 1988).

Nesting Habitat.--Sage grouse hens usually nest under sagebrush and are more successful when nesting under sagebrush. Eighty to 90% of nests occur under sagebrush (Patterson 1952, Klebenow 1969, Gray 1967, Wallestad and Pyrah 1974, Connelly et al. 1991) and sage grouse hens choose individual sagebrush plants that are taller (40.4 - 79.3 cm) (Wallestad and Pyrah 1974, Autenreith 1981, Gregg 1991) than average and sagebrush canopy cover is rarely over 25% (Klebenow 1969, Wallestad and Pyrah 1974). Nesting habitat shrub canopy cover typically ranges from 20-40% (Patterson 1952, Klebenow 1969, Martin 1970, Jarvis 1974, Wallestad and Pyrah 1974, Autenrieth 1981).

Not only is the overstory important, the understory can also affect nesting habitat suitability. Klebenow (1969) commented that the percent basal area of grass affects the suitability of understory for nest site selection, and Autenrieth (1981) noted that the type of understory contributes to a warmer micro-climate but provided little supportive data. In Idaho, Wakkinen (1990) indicated the percent grass cover found at nests did not differ from random sites. In contrast, Gregg et al. (1994) found in Oregon that sage grouse hens select nest sites with greater grass cover when compared to random sites. Similar results were found when successful and unsuccessful nests were compared. Wakkinen (1990) found no difference in grass cover between successful and unsuccessful nests while Gregg et al. (1994) found greater grass cover at successful nests. However, Wakkinen (1990) reported taller grass (18.2 cm) at nest sites compared to random sites (15.3 cm). Connelly

et al. (1991) reported that grass height was lower at sagebrush nests compared to nests in non-sagebrush habitats, which further supports the idea that grass height is an important component of nest sites.

Other factors may influence nest site selection by females. Autenrieth (1981) suggested that proximity of the nest habitat to a strutting ground may determine the distance a hen moves from the breeding lek (Autenrieth 1981), although Wakkinen et al. (1992) found that nests are randomly located with respect to leks, that nest distribution may depend on other habitat components. Nest site fidelity is also an influence (Fischer et al. 1993) and 40 - 50% of females return to areas close to previous nest sites (Berry and Eng 1985).

Other habitat influences may also be considered, such as proximity of wetland (riparian) areas or availability of free water (Patterson 1952, Trueblood 1954, Carr 1967). However, more recent findings indicate no direct relationship with proximity of water or wetland areas to nest sites (Klebenow 1969, Wallestad 1975, Autenrieth 1981).

Summer/Brood Habitat.—Sage grouse brood-rearing habitat consists of the sagebrush-grass habitat (Rogers 1964, Klebenow 1969). Brood sites have less sagebrush canopy cover (Klebenow 1969, Martin 1970, Klott 1987) and low sagebrush densities (Klebenow 1969, Martin 1970, Autenrieth 1981). Sagebrush canopy cover at brood sites is similar to nest sites, but usually less than nesting areas and ranges from 6-20% (Klebenow 1969, Peterson 1970, Wallestad and Pyrah 1974, Wallestad 1971).

Sage grouse chicks forage on high protein foods such as forbs and insects (Klebenow and Gray 1968, Peterson 1970). Peterson (1970) found that forbs comprised 75% of the diet of 12-week-old sage grouse. He found that leaves and buds of common dandelion (Taraxacum officinale) and common salsify (Tragopogon dubius) were the most highly preferred. As broods matured, their diet shifted to shrubs and was similar to adults where only 39-47% of the diet consisted of forbs (Trueblood 1954, Peterson 1970, Drut et al. 1994b). Over the summer, broods tend to move in response to plant desiccation

(Autenrieth 1981, Fischer et al. 1996b). In early-summer, broods are associated with the sagebrush-grass type then move to more mesic situations as summer progresses (Klebenow 1969, Schlatterer and Pyrah 1970, Wallestad 1971, Drut et al. 1994a, Fischer et al. 1996b). These mesic situations can include movements up or down in elevation to wet meadow habitats (Gill 1965, Savage 1969, Drut et al. 1994a). Movement up in elevation follows the green food plant gradient (Klebenow 1969, Wallestad 1971), whereas movement down in elevation is in response to forage located in bottomland meadow habitats or agricultural fields (Wakkinen 1990).

Brood movements ranged from 0.4 to 0.8 km per day in response to food availability (Wallestad 1971). Movements increased with brood age (Autenrieth 1981) from about 7 weeks of age when birds leave early brood-rearing habitat (Bean 1941, Klebenow 1969).

Sympatric Relationships

Division of resources by sympatric species within a community has been the primary focus in the study of interspecific competition. Analysis of the partitioning of those resources helps to determine the limits that interspecific competition places on the number of species that can coexist (Schoener 1974). Most of the quantitative evidence has been obtained from the study of closely related sympatric species (Emmel 1976). Emmel (1976:299) stated that evidence from such studies can be categorized in 2 ways: "(a) two sympatric species will vary inversely in population numbers, and (b) two sympatric species will occupy different parts of the same habitat for no clearly obvious reason associated with variations in the habitat features."

Schoener (1974) reviewed 81 studies involving resource partitioning in groups that included 3 or more species. The resource parameters found to be involved in ecological differences between sympatric species included micro-habitat, food, and food type (e.g. size, texture, etc.) and time of day or season of year involved in competitive interaction.

is from his literature review was that "...habitat dimensions are than food type dimensions, which are important more often (Schoener 1974:33).

Columbian sharp-tailed grouse habitat are similar or different to the species' life histories. At some point, both species are found in high-grass, mountain-shrub communities, and/or agricultural areas. Sympatric habitat use is unknown. Klott (1987) attempted to determine the relationship between sage and Columbian sharp-tailed grouse broods and found that both species inhabited sites that had less shrub canopy cover. Klott and Lindzey (1990) reported that sage and Columbian sharp-tailed grouse differed in shrub and understory composition. Sites where sage grouse broods were located typically contained snowberry, bulbous cholla, and sulfur buckwheat (Eriogonum umbellatum). Sage grouse broods were found on different sites characterized by needle-and-thread grass (Stipa arida), Alyssum desertorum, and did not have snowberry present. The area of southeastern Idaho is 1 of the few remaining areas where both species can be investigated simultaneously. Even though overall habitat characteristics are similar (i.e. shrub cover, shrub density), the composition of the understory of a specific shrub or forb species may have different effects on 1 and/or both species. Problems may arise for land management decisions are made regarding areas used by both species. The goal is to make an attempt at specific management practices to enhance a habitat suitable to maintain the other species. However, specific sagebrush management and grazing regimes may be designed to benefit both species. The next step is to test hypotheses about sympatric sage and Columbian sharp-tailed grouse brooding and providing scientific information to aid wildlife and habitat management decisions concerning these tetraonids.

STUDY AREA

My study area was in southeastern Idaho in Oneida County near Holbrook (Fig. 1). Elevations ranged from approximately 1,490 m in the valleys to 2,100 m in the adjacent mountains. Mean annual precipitation was 35.6 cm, half of which fell as snow during the winter. Average annual temperature was 8 C, with an average winter and summer temperature of -3 C and 19 C, respectively.

Soils were fine textured Aridisols that consist of wind-blown deposits of sand and silt, subject to extensive wind and water erosion. Most soils contained high deposits of calcium carbonate which can limit soil productivity and fertility (Davidson 1977).

My study area consisted of approximately 425,000 ha. Approximately 57% is federally owned and 41% is private land. The Curlew Valley, or lower elevations, consisted of 9% of the land base and was administered by the Caribou National Forest as the Curlew National Grasslands (CNG). The adjacent higher elevation foothills consisted of 40% of the land base and were administered by the Bureau of Land Management (BLM). Smaller portions of my study area were administered by other entities (10%),

Most of the area was characterized by sagebrush/grass and mountain shrub-steppe complex. The rangeland portion of the valley was characterized as basin big sagebrush (Artemisia tridentata tridentata)/bluebunch wheatgrass (Agropyron spicatum) and basin big sagebrush/needle-and-thread (Stipa comata) habitat types (Hironaka et al. 1983). Most of the lower elevations have been planted with crested wheatgrass (Agropyron cristatum). Cheatgrass brome (Bromus tectorum) was common throughout the study area. Green (Chrysothamnus nauseosus) and rubber (C. viscidiflorus) rabbitbrush were present and sometimes dominate smaller sites (Hironaka et al. 1983). The foothill habitat types include basin big sagebrush/bluebunch wheatgrass and mountain big sagebrush (A. L. vaseyana)/bluebunch wheatgrass (Hironaka et al. 1983)

Continuous stands of sagebrush\grass cover types have been fragmented by private agricultural land and the CNG and BLM using conventional rangeland management

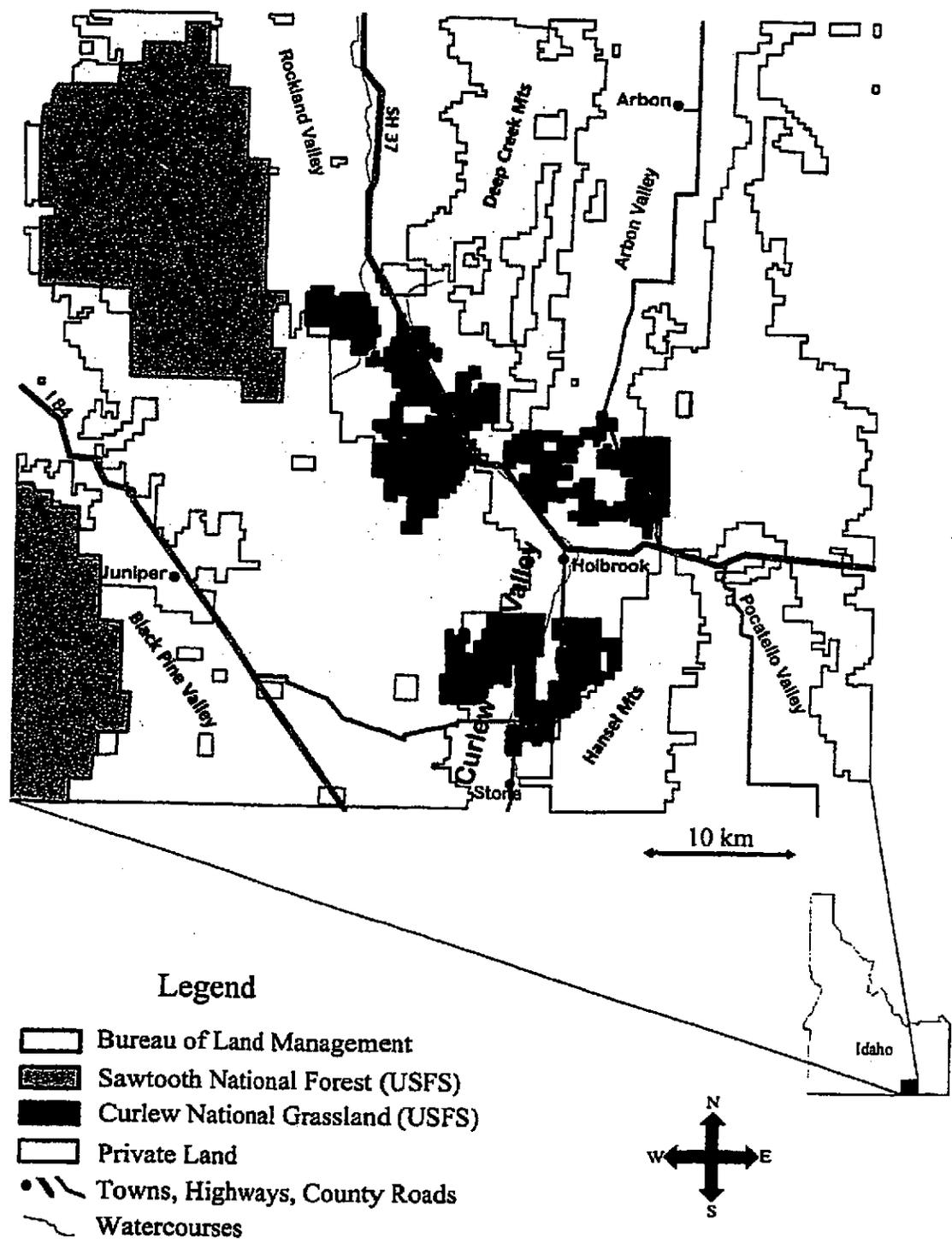


Figure 0.1. Sage and Columbian sharp-tailed grouse sympatry study area in the Curlew Valley region of southeastern Idaho, 1988-91.

practices. Chaining, strip and complete herbicide spraying, and prescribed fire were used to reduce sagebrush densities across the study area. The study area was grazed by cattle from mid-April through November.

CHAPTER I.

NESTING HABITAT USE, SUCCESS, AND MOVEMENTS OF SYMPATRIC FEMALE SAGE AND COLUMBIAN SHARP-TAILED GROUSE IN SOUTHEASTERN IDAHO

INTRODUCTION

Cody (1985) suggested that ecologically similar species, especially congeners, typically segregate through selection of habitat. He also suggested that different genera frequently overlap in habitat with some species having quite broad habitat ranges while others are relatively specific. Thus, natural selection might be expected to exert significant pressures on habitat selection patterns (Wiens 1985), resulting in observably optimal habitat selection.

Because species almost never occur alone in the environment, Wiens (1969) and Cody (1974, 1978) suggested that an ideal pattern of habitat selection is modified by competitive interactions with other community residents that would modify and mold patterns of habitat partitioning allowing the coexistence of ecologically similar species. In contrast, Wiens (1985:228) suggested that "in erratically varying environments, so the argument goes, selection favoring optimal habitat selection may not always be intense; habitats may not always be fully saturated; resources may not always be limiting; and changes in habitats or resources may not always be closely tracked."

The shrub-steppe region is an erratically varying environment (Wiens 1985) and has 2 coexisting tetraonid species, although non-congeners, that are ecologically similar and occur sympatrically, the eastern sage (Centrocercus urophasianus urophasianus) and the Columbian sharp-tailed (Tympanuchus phasianellus columbianus) grouse. Aldrich (1963) first reported that sage and sharp-tailed grouse distributions overlapped extensively in the

western United States, but only 1 study (Klott and Lindzey 1989, 1990) has attempted to evaluate the sympatric relationship of the 2 species.

Numerous observational studies have documented habitat use by each species individually. Sage grouse nesting habitat has been evaluated in Wyoming (Patterson 1952), Oregon (Nelson 1955, Gregg 1991), Montana (Wallestad and Pyrah 1974), Utah (Jarvis 1974), Colorado (Gill 1965), and Idaho (Dalke et al. 1963, Klebenow 1969, Connelly et al. 1991, Wakkinen et al. 1992, Fisher 1994). The Columbian sharp-tailed grouse has not been as extensively studied, although nesting habitat has been described in Wyoming (Oedekoven 1985), Colorado (Giesen 1987), Washington (Yocum 1952, Hofmann and Dobler 1988) and Idaho (Parker 1970, McArdle 1977, Kessler and Bosch 1982, Meints 1991, Saab and Marks 1992).

Sage grouse hens usually nest under sagebrush. Eighty to 90% of nests have been found under sagebrush (Patterson 1952, Klebenow 1969, Wallestad and Pyrah 1974). Connelly et al. (1991) reported that nest success was higher for sage grouse that nested under a sagebrush plant than for hens using non-sagebrush nest sites. Columbian sharp-tailed grouse nest in a variety of vegetation types including native and non-native shrub-steppe habitats (Marks and Marks 1987, Giesen 1987) and agricultural crops (Meints 1991).

Habitat studies are frequently focused on habitat loss and the continued existence of a single species. With sage and Columbian sharp-tailed grouse, habitat loss due to agricultural development is conspicuous and typically occurs on private lands. However, the influence of livestock grazing on public land is more prevalent and noticeable in the remaining sage and Columbian sharp-tailed grouse range (Marshall and Jensen 1937, Rogers 1969, Zeigler 1979). Unfortunately, many nesting habitat studies focused on an individual species (either sage or Columbian sharp-tailed grouse) and have not evaluated situations where both species exist. Therefore, the goals of my study were to investigate specific hypotheses about 2 shrub-steppe sympatric tetraonids, to provide knowledge about

sage and Columbian sharp-tailed grouse, and provide information to wildlife and habitat managers. The objectives of my study were to determine nesting habitat use at micro- and macro-habitat levels, determine movements from the lek of capture, determine nest and hen success, and determine nesting habitat niche breadth and overlap for sympatrically occurring sage and Columbian sharp-tailed grouse in a portion of their remaining imbricate range.

I hypothesized that: 1) reproductive success for sage and Columbian sharp-tailed grouse do not differ, 2) nest site selection at micro- and macro-habitat levels for sage and Columbian sharp-tailed grouse do not differ, 3) movements from the lek of capture for sage and Columbian sharp-tailed grouse do not differ, and 4) nesting habitat niche breadth and overlap between sage and Columbian sharp-tailed grouse do not differ.

METHODS

I captured sage and Columbian sharp-tailed grouse during the spring while birds attended leks. Sage grouse were captured on or near leks by spotlighting (Giesen et al. 1982, Wakkinen et al. 1992a) whereas Columbian sharp-tailed grouse were captured using funnel traps (Marks and Marks 1987). I radio-tagged 6, 18, 20, and 25 female sage grouse in 1988, 1989, 1990, and 1991, respectively. I also radio-tagged 12, 3, 19, and 22 female Columbian sharp-tailed grouse in 1988, 1989, 1990, and 1991, respectively. Females were fitted with poncho-mounted solar (all Columbian sharp-tailed grouse) or battery-powered radio transmitters (Amstrup 1980). Each sage grouse radio package weighed 20 g and was equipped with a 22 cm antenna and each Columbian sharp-tailed grouse radio package was 14 g with a 15 cm antenna. I determined the sex and age of sage grouse using wing characteristics (Dalke et al. 1963) and used crown and tail feathers (Henderson et al. 1967) and primary feather wear (Ammann 1944) to sex and age Columbian sharp-tailed grouse, respectively. I weighed all grouse using a Pesola scale, and banded each bird with a unique Idaho Department of Fish and Game (IDFG) leg band.

and-held Yagi antenna attached to a receiver/scanner (Mech
 . General locations of nesting hens were determined by
 that I was unable to locate from the ground were located using
 with a 4-element yagi and 2 H-antenni. Aerial locations were
 ed with an on-board personal computer interfaced with a dual
 Meints 1991).

st nest locations of hens using radio-telemetry and binoculars
 flush incubating hens. Nests were inconspicuously marked
 oughout the nesting bout. At the cessation of the nesting
 or unsuccessful) (Rearden 1951) was determined. A nest was
 east 1 egg hatched (Rearden 1951). I recorded the predator
 Rearden 1951) of unsuccessful nests. I plotted locations on
 maps and Universal Transverse Mercator (UTM) Coordinates

icro-habitat measurements at all nest sites. At each vegetation
 , 20-m transects (Canfield 1941) in the cardinal directions
 to determine canopy cover of shrub overstory. At 5 m
 eight and crown area of the nearest live or dead sagebrush
 ct was recorded. I also estimated cover obstruction at 0° and
 es 1968). Forb and grass species, bareground, and litter
 50 x 50 cm micro-plot (Daubenmire 1959, Mosley et al.
 d 20 m intervals along each transect. Canopy cover of
 timated using the following cover classes: 0-1%, 2-5%, 6-
 00%.

vegetation and physiographic measurements at dependent
 t macro-habitat locations that were collected at nest sites.
 sites were determined by moving in a random direction (0-

359⁰) and distance (50-100 m) from the nest site. Although vegetation measurements were the same, independent macro-habitat sites were selected differently for sage and Columbian sharp-tailed grouse. Sage grouse independent macro-habitat sites were determined by randomly choosing 2, 5-digit numbers representing the northing and easting UTM coordinates for the study area. Columbian sharp-tailed grouse independent macro-habitat sites were selected by first establishing a 2-km distance sampling area in the cardinal directions around the lek of capture. Random points were generated using the same technique as with sage grouse except using different boundaries.

Statistical Analyses

Data from 4 years of study were pooled into 3 years for statistical analyses. The years 1988 and 1989 were pooled due to low nest sample sizes for sage grouse in 1988 ($n = 2$) and for Columbian sharp-tailed grouse in 1989 ($n = 1$). Differences and/or homogeneity among years were evaluated in each statistical test. Years were pooled ($P \geq 0.05$) unless otherwise stated.

Movement From Capture Lek to Nest.—I used a Kruskal-Wallis ANOVA to evaluate the distance a sage or Columbian sharp-tailed grouse hen moved from the lek of capture to nest. I also compared the lek to nest movement with independent macro-habitat locations, and tested movement distances related to hen age and nest fate. In all cases when a non-parametric ANOVA was used, I reported the median and upper and lower quartiles.

Physiographic Variables.—Slope was partitioned into 4 categories ($\leq 9\%$, 10-19%, 20-29%, and $\geq 30\%$) for sage grouse and only 2 categories ($\leq 9\%$ and 10-19%) for Columbian sharp-tailed grouse. Aspect was also partitioned into 5 categories (0° (NO ASPECT), $315-45^{\circ}$ (NORTHERLY), $46-135^{\circ}$ (EASTERLY), $136-225^{\circ}$ (SOUTHERLY), and $226-314^{\circ}$ (WESTERLY)). Elevation was categorized as ($\leq 1,493$ m (VALLEY).

1,494-1,555 m (LOW), 1,556-1,707 m (MIDDLE) and 1,708-1,859 m (MED-HIGH), \geq 1,860 (HIGH)).

Possible differences in site selection for slope, aspect, and elevation were evaluated among years between sage and Columbian sharp-tailed grouse nests and between sage and Columbian sharp-tailed grouse nests and independent macro-habitat locations. I tested for year homogeneity using Chi-square tests (Zar 1984). A final Chi-square test of independence was conducted between sage and Columbian sharp-tailed grouse nests and between grouse nests and independent macro-habitat sites.

Nest Bush Use.—I analyzed the variables of nest shrub height (NESTHT) and nest shrub crown area (NESTAREA) and a sample of sagebrush heights (SHRUBHT) within a 20-m radius of the nest and sagebrush crowns (SHRUBAREA). NESTHT and SHRUBHT were highly correlated ($R = 0.6416$, $n = 140$, $P = 0.0001$) with NESTAREA and SHRUBAREA. Highly correlated variables included in a multivariate analysis of variance (MANOVA) can influence the power of the test through the influence of collinearity (Johnson and Wichern 1992). I used ANOVA, rather than a MANOVA, for each dependent variable.

Hens nested under a variety of plant species. The sample size of nests under each species was small. Therefore, a test of association between nest plant life form (shrub, grass, forb) and grouse species was conducted using Chi-square and G (William's correction) tests (Sokal and Rohlf 1981).

Plant Species Richness.—I used species richness (McIntosh 1967) to evaluate the number of plant species present at sage and Columbian sharp-tailed grouse nests and associated dependent micro-habitat and independent macro-habitat sites. Species richness for the total number of plant (TOTALRICH), shrub (SHRUBRICH), grass (GRASSRICH), forb (FORBRICH), and grass and forb (UNDERRICH) species were evaluated for normality. Variables were also evaluated for collinearity. TOTALRICH had a strong association ($R = 0.9386$, $n = 260$, $P = 0.0001$) with UNDERRICH and

FORBRICH and UNDERRICH were highly correlated ($R = 0.9502$, $n = 260$, $P = 0.0001$). Therefore, FORBRICH, and UNDERRICH were eliminated from analyses and a nonparametric Kruskal-Wallis ANOVA, rather than a MANOVA, was used to analyze TOTALRICH.

Plant species richness was also used to determine if a nest site was predominantly "native" or "non-native." I characterized a site as native if $\leq 10\%$ of the grass cover consisted of either intermediate or crested wheatgrass or bulbous bluegrass (Poa bulbosa) or if $\leq 30\%$ of the grass cover consisted of cheatgrass brome or domestic wheat; otherwise the site was considered non-native.

I used G-tests (William's correction) to compare grouse (also by species) nest success at native and non-native nest sites. I used a nonparametric Kruskal-Wallis ANOVA to evaluate potential differences in species richness at native and non-native sites. The dependent variable, species richness, was evaluated by grouse species (SPP) and native or non-native sites (SITE) main effects and the appropriate interactions.

Niche Breadth and Overlap.--Niche breadth was evaluated using program NICHE (Krebs 1989). Three measures of niche breadth were determined; Levins' measure (Levins 1968), later standardized by Hurlbert (1978), Shannon-Wiener measure, as suggested by Colwell and Futuyma (1971), and Smith's measure (Smith 1982). Twenty-five resource states were considered for niche breadth analysis. Niche breadth was calculated from the number of sage and Columbian sharp-tailed grouse nests present in each resource state grouping. There were 9 groups of resource states (Table 1.1). I tested the null hypothesis of equal niche breadth for each of the 3 estimates with a Mann-Whitney test.

The aforementioned resource states were used to calculate niche overlap. Five niche overlap estimates were generated. The niche overlap estimates were Pianka's measure (Pianka 1973), the Percentage Overlap (Renkonen 1938), Morisita's measure of similarity (Morisita 1959), the simplified Morisita index (Horn 1966), and Horn's Index of

used to calculate niche breadth and overlap.

<u>Source State^a</u>	<u>Group</u>	<u>Resource State^a</u>
shrub nest	6.	Forb height \leq 20 cm
nest		Forb height $>$ 20 cm
% shrub canopy cover	7.	Grass height \leq 30 cm
% shrub canopy cover		Grass height $>$ 30 cm
% shrub canopy cover	8.	0-9% grass cover
slope		10-19% grass cover
slope		20-29% grass cover
% slope		\geq 30% grass cover
plant \leq 40 cm	9.	0-4% forb cover
plant $>$ 40 cm		5-9% forb cover
litter cover		10-14% forb cover
% litter cover		\geq 15% forb cover
% litter cover		

^aas used to determine occurrence rate for each resource state.

Overlap (Horn 1966). A Wilcoxon rank-sum test (SAS 1988) was used to evaluate possible differences among resource state groupings.

Comparisons Of Independent Macro-habitat Locations.--I simplified a potentially complex model to simultaneously evaluate possible differences between shrub-nesting sage and Columbian sharp-tailed grouse nest sites with several dependent vegetal variables. Columbian sharp-tailed grouse that nested in areas where no shrubs were present in the sampling area were considered non-shrub nesters and excluded from the analyses. Thirteen variables were initially considered and 9 were included in the MANOVA due to collinearity concerns. The complexity of a potential MANOVA model became evident when I attempted to evaluate 9 dependent variables for 2 SPECIES (sage and Columbian sharp-tailed grouse), 3 YEARS (1989, 1990, and 1991), and 3 sampling SITES (nests, dependent micro-habitat sites, independent macro-habitat sites). A complete MANOVA model of main effects and interactions would consist of:

9 Dependent Variables = SPECIES SITE SPECIES*SITE YEAR SITE*YEAR
SPECIES*YEAR SPECIES*SITE*YEAR

I took advantage of the paired nature of the sampling design for model reduction: corresponding dependent micro-habitat and independent macro-habitat sites were paired which eliminated the SITE main effect by incorporating it into a new set of dependent variable vectors. The new set of vectors were the calculated value difference at each nest site between the nest site and the dependent micro-habitat site by the following formulas/matrix:

$$\begin{array}{l}
 X_{11j} = \text{variable 1 under treatment 1, observation } j \\
 X_{12j} = \text{variable 2 under treatment 1, observation } j \\
 \vdots \\
 \vdots \\
 X_{1pj} = \text{variable } p \text{ under treatment 1, observation } j \\
 \hline
 X_{21j} = \text{variable 1 under treatment 2, observation } j \\
 X_{22j} = \text{variable 2 under treatment 2, observation } j \\
 \vdots \\
 \vdots \\
 X_{2pj} = \text{variable } p \text{ under treatment 2, observation } j,
 \end{array}$$

and then the paired difference (DIFFERENCE) was calculated as:

$$\begin{array}{l}
 D_{1j} = X_{11j} - X_{21j} \\
 D_{2j} = X_{12j} - X_{22j} \\
 \vdots \\
 \vdots \\
 D_{pj} = X_{1pj} - X_{2pj}
 \end{array}$$

I used a similar approach to reduce the independent variable main effect by taking advantage of the paired nature of the nest sites and dependent micro-habitat sites. An additional treatment is included as:

$$X_{31j} = \text{variable 1 under treatment 3, observation } j.$$

resulting in the DIFFERENCE formulae:

$$\begin{array}{l}
 D_{1j} = \frac{X_{11j} + X_{21j}}{2} - X_{31j} \\
 D_{2j} = \frac{X_{12j} + X_{22j}}{2} - X_{32j} \\
 \vdots \\
 \vdots \\
 D_{pj} = \frac{X_{1pj} + X_{2pj}}{2} - X_{3pj}
 \end{array}$$

therefore the main effect of SITE is incorporated into 9 variable vectors and the MANOVA model is reduced to:

9 Dependent Variables Differences = SPECIES YEAR SPECIES * YEAR.

The assumption of $\Sigma_1 = \Sigma_2 = \Sigma_3 \dots \Sigma_9$ (covariance homogeneity) was considered and occasionally violated. Covariance homogeneity is difficult to achieve and consistently occurs in natural resource data sets. Johnson and Wichern (1992) suggested that the equal covariance assumption is needed when sample sizes are "small." Unfortunately, the authors did not define a "small sample size." Therefore, the results of my study analyses should be viewed cautiously because my sample sizes may be considered "small."

While there may have been a significant main effect or interaction in some cases, there may not have been a statistical or mathematical difference in the DIFFERENCE (nest value minus the corresponding dependent micro-habitat or independent macro-habitat site value) variable. However, there may have been a predominantly positive or negative trend between nests and dependent micro-habitat sites that was masked. I used individual t-tests to determine if each variable DIFFERENCE was different from zero, but maintained overall protection ($\alpha \leq 0.05$) provided by combining probabilities from the independent tests of significance (Sokal and Rohlf 1981).

Comparisons Of Understory Grasses And Forbs.--Throughout the aforementioned analyses, the herbaceous understory was evaluated by pooling all the grass and forb species. Inasmuch as any micro-habitat use study would not be complete without a thorough evaluation of each species in the understory, it is unrealistic to evaluate each species due to the propensity of nonoccurrences of each plant species within each observation. Therefore, I used a qualitative data reduction approach. Grass species were pooled into their respective taxonomic tribe (Hitchcock 1971) and forbs were pooled into their respective tribe/subfamily (Hitchcock and Cronquist 1973). If a tribe/subfamily was not present in the taxonomic family, the family was used to pool species. A stepwise

(forward) discriminant analysis was used as a quantitative data reduction technique for the understory groupings, although the assumptions of multivariate normality and variance homogeneity were violated ($P \leq 0.20$).

Knowing that the aforementioned assumptions were violated, and my attempts to normalize the data were futile, I used non-parametric discriminate analysis (SAS 1988) and classification, rather than MANOVA, to determine if years could be pooled. I pooled years if the expected actual error rate (\hat{e} (AER)) was ≥ 0.30 . I used non-parametric discriminant analysis as a separatory procedure for grouse species nest sites and their associated dependent micro-habitat and independent macro-habitat sites and used crossvalidation to test the performance of the discriminant model through classification. I selected the \hat{e} (AER) over an apparent error rate (APER) because it provides, for modest samples, a nearly unbiased estimate of the \hat{e} (AER) and the APER requires large samples sizes (Johnson and Wichern 1992).

Stepwise Logistic Regression And Nest Type.—Stepwise logistic regression (maximum likelihood method) was used because of the binary response data (SAS 1990), which consisted of grouse nest or non-grouse nest (independent macro-habitat site) and a sage or Columbian sharp-tailed grouse nest. Logistic regression provided a level of predictive value to various micro-habitat variables. The stepwise option was used and significant variables ($P \leq 0.10$) entered the model. Variables with non-normal distributions were transformed.

RESULTS

Bird Capture

I captured 238 sage grouse (Table 1.2, Appendix A) on 11 different strutting grounds. Birds were trapped on 4, 8, 7, and 7 leks in 1988, 1989, 1990, and 1991, respectively. One lek was trapped every year and the same 5 leks were trapped the last 2 years. The number of strutting males on each lek ranged from 15 to 60. Four, 3, and 4

Table 1.2. Age and sex of sage and Columbian sharp-tailed grouse captured and marked in the Curlew Valley region of southeastern Idaho, 1988-91.

Age and Sex	Grouse Species		Mark	
	Sage	Columbian sharp-tailed	Band Only ^a	Transmitter
Adult Female				
1988	0	16	0/8	0/8
1989	10	3	0/0	10/3
1990	11	12	0/3	11/9
1991	9	9	0/0	9/9
Yearling Female				
1988	6	9	0/2	6/4
1989	8	0	0/0	8/0
1990	9	11	0/1	9/10
1991	16	14	0/1	16/13
Unknown Female				
1988	0	1	0/1	0/0
1989	0	0	0/0	0/0
1990	0	1	0/0	0/1
1991	0	1	0/1	0/0
Adult Male				
1988	11	19	11/19	0/0
1989	52	2	52/2	0/0
1990	42	10	42/10	0/0
1991	26	17	26/17	0/0

Table 1.2 con't. Age and sex of sage and Columbian sharp-tailed grouse captured and marked in the Curlew Valley region of southeastern Idaho, 1988-91.

Age and Sex	Grouse Species		Mark	
	Sage	Columbian sharp-tailed	Band Only ^a	Transmitter
Yearling Male				
1988	3	8	3/8	0/0
1989	8	1	8/1	0/0
1990	15	10	15/10	0/0
1991	12	15	12/15	0/0
Unknown Male				
1988	0	3	0/3	0/0
1989	0	1	0/1	0/0
1990	0	1	0/1	0/0
1991	0	0	0/0	0/0
Total	238	161	169/104	69/57

^aSage grouse/Columbian sharp-tailed grouse

leks were located on BLM, CNG, and private lands, respectively. Sixty-nine females were captured; thirty (44%) were adults and 39 (56%) were yearlings. More adult than yearling males were captured, 131 (78%) and 38 (22%), respectively.

I captured 162 Columbian sharp-tailed grouse (Table 1.2, Appendix A) on 13 different dancing grounds. Birds were trapped on 5, 3, 6, and 8 leks in 1988, 1989, 1990, and 1991, respectively. Only 2 leks were trapped every year. The number of dancing males on each lek ranged from 6 to 40. Four, 7, and 2 leks were located on BLM, CNG, and private lands, respectively. Seventy-five females were captured. Of the females classified by age, 42 (58%) were adults and 30 (42%) were yearlings. Three (4%) females were not classified by age. Eighty-seven males were captured. Of the males classified by age, 47 (57%) were adults and 35 (43%) were yearlings. Five (6%) were not classified by age. Not all birds captured were successfully weighed and/or classified by age, resulting in sample size differences throughout the analyses.

Bird Weight.--Female sage grouse weights varied among years ($F = 5.07$, 2, 125 df, $P = 0.0076$). Female sage grouse captured in 1991 weighed more ($P = 0.0001$) (Table 1.3) than females captured in 1990, but were not more ($P = 0.0670$) than females captured in 1989. Females captured in 1989 also weighed more ($P = 0.0047$) than females in 1990. Weights of female sage grouse also varied with age ($F = 17.69$, 1, 125 df, $P = 0.0001$); adults weighed more ($P = 0.0001$) (Table 1.3) than yearlings. In contrast, weight of female Columbian sharp-tailed grouse did not differ ($P = 0.4147$) with grouse age (Table 1.3). Overall (males and females) Columbian sharp-tailed grouse weight varied temporally ($F = 5.81$, 2, 135 df, $P = 0.0290$), with grouse captured in 1989 weighing more ($P = 0.0009$) (Table 1.3) than those captured in 1990. Columbian sharp-tailed grouse captured in 1991 weighed the same as captured in 1989 ($P = 0.0827$) and 1990 ($P = 0.0668$).

Table 1.3. Mean weight (g) \pm SE of sage and Columbian sharp-tailed grouse captured in the Curlew Valley region of southeastern Idaho, 1988-91.

<u>Sage Grouse</u>				
<u>YEAR^d</u>	<u>n</u>	<u>Weight (g)</u>	<u>SE</u>	<u>P</u>
1989	24	1,457.9	22.2	0.0047 ^a
1990	19	1,414.7	25.9	0.0670 ^b
1991	25	1,484.8	19.0	0.0001 ^c
<u>AGE^d</u>				
Adult	30	1,514.0	19.0	
Yearling	38	1,409.7	14.0	0.0001
<u>Columbian Sharp-tailed Grouse</u>				
<u>YEAR</u>	<u>n</u>	<u>Weight (g)</u>	<u>SE</u>	<u>P</u>
1989	53	729.5	5.6	0.0009 ^a
1990	42	695.8	6.3	0.0827 ^b
1991	52	715.4	5.7	0.0668 ^c
<u>AGE^d</u>				
Adult	40	691.4	6.5	
Yearling	29	674.1	6.5	0.4147
<u>SEX</u>				
Males	78	742.1	3.5	
Females	69	684.1	3.7	0.00017

^a1989 versus 1990

^b1989 versus 1991

^c1990 versus 1991

^dfemale weights only

Male Columbian sharp-tailed grouse weighed more ($F = 71.25$, 1, 141 df, $P = 0.0001$) than females (Table 1.3). Male and female weights within age classes were also similar ($F = 0.00$, 1, 135 df, $P = 0.9469$). In addition, sage and Columbian sharp-tailed grouse weights did not differ regardless of nest fate ($F = 0.25$, 1, 53 df, $P = 0.6157$).

Nest and Hen Success and Nesting Attempts.—I documented 38 sage grouse nests (1 incidental nest located) of which 37 were from radio-tagged hens. Ninety-five percent (35) of the nests were first nesting attempts, while 5% (2) were renests. Of 51 Columbian sharp-tailed grouse nests documented (3 incidental nests were located), 48 were from radio-tagged hens. Eighty-five percent (41) were initial nesting attempts, 12% (6) were first renesting attempts and 3% (1) was a second renesting attempt. Sage and Columbian sharp-tailed grouse nesting and renesting rates were similar ($G = 2.51$, 2 df, $P = 0.2870$).

Sage grouse nest success was 44% (18/41), while hen success was 46% (17/37). These values included 3 sage grouse that were successful but a nest was not located. Columbian sharp-tailed grouse nest success was 51% (24/47) while hen success was 58% (22/38). The aforementioned values do not include 1 Columbian sharp-tailed grouse that had a successful initial nesting attempt, the brood perished, and she had a successful renest.

Sage grouse nest and hen success was 0% and 0% in 1988, 54% and 54% in 1989, 60% and 67% in 1990 and 33% and 35% in 1991, respectively (Table 1.4). Columbian sharp-tailed grouse nest and hen success was 28% and 33% in 1988, 0% and 0% in 1989, 67% and 82% in 1990, and 44% and 47% in 1991, respectively (Table 1.4).

Sage grouse adult hen nest success was 50% while yearling nest success was 33%. Adult sage grouse hen success was 54% while yearling hen success was 33% (Table 1.4). Columbian sharp-tailed grouse adult hen nest success was 47% and yearling nest success was 59%. In addition, adult Columbian sharp-tailed grouse hen success was 54% and yearling hen success was 59% (Table 1.4). Nest success, hen age and grouse species were mutually independent of nest success ($X^2 = 2.16$, 4 df, $P = 0.7130$) and hen success ($X^2 = 2.73$, 4 df, $P = 0.6100$).

Table 1.4. Number of nests and female grouse and their nest fate in the Curlew Valley region of southeastern Idaho, 1988-91.

<u>NESTS</u>				
	<u>Sage Grouse</u>		<u>Columbian Sharp-tailed Grouse</u>	
	<u>Successful</u>	<u>Unsuccessful</u>	<u>Successful</u>	<u>Unsuccessful</u>
1988	0	2	2	5
1989	6	5	0	1
1990	6	4	14	7
1991	6	12	8	10
Total	18	23	24	23

<u>NESTS</u>				
	<u>Sage Grouse</u>		<u>Columbian Sharp-tailed Grouse</u>	
	<u>Successful</u>	<u>Unsuccessful</u>	<u>Successful</u>	<u>Unsuccessful</u>
Adult	13	13	14	16
Yearling	5	10	10	7
Total	18	23	24	23

<u>FEMALES</u>				
	<u>Sage Grouse</u>		<u>Columbian Sharp-tailed Grouse</u>	
	<u>Successful</u>	<u>Unsuccessful</u>	<u>Successful</u>	<u>Unsuccessful</u>
Adult	12	10	12	9
Yearling	5	10	10	7
Total	17	20	22	16

Movement From Capture Lek To Nest

Sage Grouse Versus Columbian Sharp-tailed Grouse.--Sage grouse moved a median of 4,920 m from the lek of capture to nest. This distance was 3.5 times larger than movements from the lek of capture to nest for Columbian sharp-tailed grouse (1,417 m) ($H = 38.58$, 1, 79 df, $P = 0.0001$) (Fig. 1.1)

Sage and Columbian Sharp-tailed Grouse Versus Independent Macro-habitat Locations.--Sage grouse did not move as far from the lek of capture as independently placed macro-habitat sites located throughout the study area ($H = 11.91$, 1, 68 df, $P = 0.0010$) (Fig. 1.1), although there were differences ($H = 7.84$, 2, 68 df, $P = 0.0009$) in movements among years. Sage grouse and independent macro-habitat sites were located farther from the lek of capture in 1991 (median = 9,860 m [4,690; 17,847] $n = 36$) than the previous years, 1990 (median = 8,640 m [5,829; 13,059] $n = 20$) and 1989 (median = 4,413 m [2,721; 6,188] $n = 18$). I could not evaluate the specific years by site interaction due to a non-significant result ($H = 2.17$, 2, 68 df, $P = 0.1226$). Columbian sharp-tailed grouse did not place nests as far ($H = 7.85$, 1, 83 df, $P = 0.0063$) from the lek of capture as independently placed macro-habitat locations throughout my study area (Fig. 1.1).

Sage grouse moved similar distances from the lek of capture to nest regardless of hen age ($H = 1.59$, 1, 25 df, $P = 0.2188$) or nest fate ($H = 0.50$, 1, 25 df, $P = 0.4866$). Hen age did not significantly affect the distance Columbian sharp-tailed grouse moved from the lek of capture to nest ($H = 0.09$, 1, 36 df, $P = 0.7722$), nor did nest fate ($H = 1.04$; 1, 36 df; $P = 0.3139$).

Renesting and Movement from Lek of Capture.--Sage grouse hen movements ranged from 485 - 30,339 m (median = 4,702, $n = 35$) for initial nesting attempts and 7,226 - 30,579 m (median = 18,902, $n = 2$) for renesting attempts. Columbian sharp-tailed grouse movements ranged from 200 - 12,749 m (median = 1,414, $n = 41$) for first nesting attempts, 388 - 8,492 (median = 3,182, $n = 6$) for first renesting attempts and 1

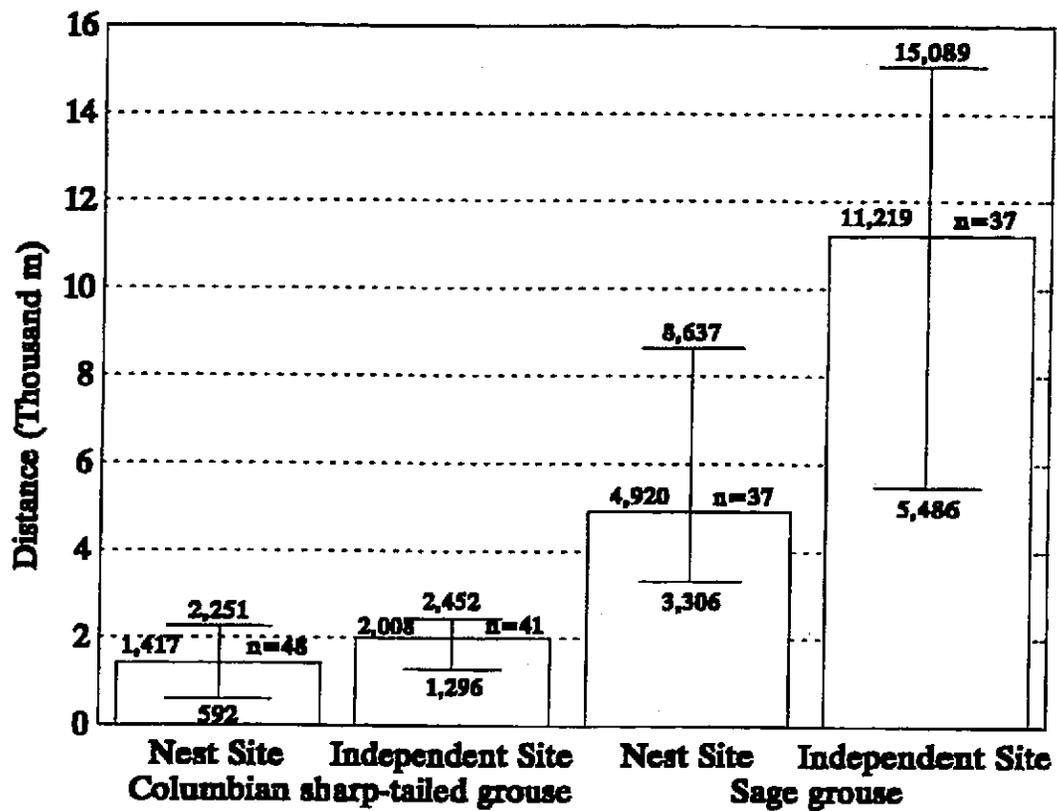


Figure 1.1. Median distance moved, and upper and lower quartiles, from the lek of capture to nest for sage and Columbian sharp-tailed grouse hens in the Curlew Valley region of southeastern Idaho, 1988-91.

female moved 876 m from the lek of capture for a second re-nesting attempt.

Nest Physiographic Habitat Variables

Slope.--Sage grouse nested on sites with slopes that were similar ($X^2 = 5.61$, 3 df, $P = 0.132$) as the slopes of sites sampled at independent macro-habitat locations. A similar result was found with Columbian sharp-tailed grouse nest sites and independent macro-habitat locations ($X^2 = 0.39$, 1 df, $P = 0.532$). A greater proportion of Columbian sharp-tailed grouse nest sites were located in the sites with $\leq 9\%$ slope than sage grouse nest sites (44 vs 15 nests) ($X^2 = 23.38$, 3 df, $P = 0.000$). In contrast, a larger proportion of sage grouse nested on sites with greater slope than Columbian sharp-tailed grouse (10-19% slope, (16 vs 7 nests), 20-29% slope (5 vs 0 nests), and $\geq 30\%$ slope (2 vs 0 nests).

Elevation.--Sage grouse exhibited no relationship ($X^2 = 2.52$, 4 df, $P = 0.641$) with nest site location and elevation when compared to independent macro-habitat locations. Columbian sharp-tailed also exhibited no relationship ($X^2 = 3.13$, 4 df, $P = 0.536$) with regard to elevation and macro-habitat location. Columbian sharp-tailed grouse used nest sites in proportion to sage grouse nest sites located at VALLEY (27 vs 10), LOW (5 vs 5), MIDDLE (11 vs 9), MED-HIGH (7 vs 12) and HIGH (1 vs 2) elevations ($X^2 = 7.93$, 4 df, $P = 0.094$).

Lek and Nest Elevation.--Thirty-seven percent (19) of the Columbian sharp-tailed grouse nests were located at or above the mean dancing ground elevation ($\bar{x} = 1,562 \pm 34$ m, $n = 12$) and 63% (32) were found below. In contrast, 60% (23) of sage grouse nests were found above the mean strutting ground elevation ($\bar{x} = 1,541 \pm 32$, $n = 10$) and 40% (15) were found below. More ($G = 4.77$, 1 df, $P = 0.0290$) sage grouse nests were found at or above the capture lek (23 vs 18 nests) while fewer than expected (15 vs 20 nests) were found below the mean strutting ground elevation. The reverse was found with Columbian sharp-tailed grouse. Fewer nests (19 vs 24 nests) were found above the mean dancing ground elevation and more nests were found below (32 vs 27 nests). The mean

sage grouse nest elevation was above 1,600 m ($\bar{x} = 1,625 \pm 26$ m, $n = 38$) while the mean Columbian sharp-tailed grouse mean nest elevation was below 1,600 m ($\bar{x} = 1,559 \pm 18$ m, $n = 51$).

Aspect.--Sage grouse exhibited no relationship ($X^2 = 5.62$, 4 df, $P = 0.230$) with regard to aspect of nest sites and independent macro-habitat locations. Columbian sharp-tailed grouse also exhibited no relationship ($X^2 = 2.390$, 4 df, $P = 0.664$) with aspect. Sage and Columbian sharp-tailed grouse selected nest sites in equal proportion at all nest site aspects ($X^2 = 5.40$, 4 df, $P = 0.248$).

Nest Site Vegetation

Nest Plant Use.--Sage and Columbian sharp-tailed grouse nested under 7 and 16 different plant species, respectively (Table 1.5). Twenty-five, 14, and 12 Columbian sharp-tailed grouse nests were located under shrubs, grasses, and forbs, respectively. Nest vegetation used by sage grouse was less diverse; 37 nests were located under shrubs, 1 in grass, and 0 in forbs. More specifically, 87% (33/37) of sage grouse nested under sagebrush. Sage grouse nested under shrubs (37 vs 26) more often and under forbs (0 vs 5) and grasses (1 vs 6) less often than Columbian sharp-tailed grouse ($G = 29.34$, 2 df, $P = 0.000$). In addition, Columbian sharp-tailed grouse nested under shrubs less often than expected (25 vs 35), more often under grass (14 vs 9) and forbs (12 vs 7) than expected. Sagebrush was also used extensively by Columbian sharp-tailed grouse. Of the shrub nesting hens, 64% (16/25) nested under sagebrush.

Nest Site and Success.--Sage grouse nested under only 2 plant life forms (shrubs and grass), therefore use of plant nest-bush use was categorized into sagebrush or non-sagebrush (including 1 nest in grass) nesters. Sage grouse nest success under sagebrush plants was 46% (15/33) while nest success for non-sagebrush nesting hens was 0% (0/5). More successful nests were located under sagebrush than would be expected (15 vs 13), and fewer unsuccessful nests (18) were observed than would be expected (20) under

Table 1.5. Plant species used by female sage and Columbian sharp-tailed grouse hens as nest sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Plant Species	Columbian Sharp-tailed Grouse		Sage Grouse	
		n		n
<u>Shrubs</u>				
<i>Amelanchier utahensis</i>		1		-
<i>Artemisia tridentata tridentata</i>		9		17
<i>A. t. vaseyana</i>		7		15
<i>A. tripartita</i>		-		1
<i>Chrysothamnus nauseosus</i>		5		1
<i>C. viscidiflorus</i>		1		-
<i>Purshia tridentata</i>		-		1
<i>Symphoricarpus oreophilus</i>		2		2
Total		25		37
<u>Grasses</u>				
<i>Agropyron cristatum</i>		9		1
<i>A. intermedium</i>		1		-
<i>Bromus tectorum</i>		2		-
<i>Elymus cinereus</i>		1		-
<i>Triticum aestivum</i>		1		-
Total		14		1
<u>Forbs</u>				
<i>Balsamorhiza sagittata</i>		1		-
<i>Descuraninia pinnata</i>		1		-
<i>Lupinus argenteus</i>		5		-
<i>Medicago sativa</i>		4		-
<i>M. officinalis</i>		1		-
Total		12		0

sagebrush. Non-sagebrush-nesting hens also had fewer successful nests (0) than would be expected (2) and more nests were unsuccessful (5) than would be expected (3) ($G = 4.97$, 1 df, $P = 0.028$).

Nest fate for Columbian sharp-tailed grouse was not related to plant life form ($G = 0.02$, 2 df, $P = 0.989$). In addition, there was no relationship detected for sagebrush versus non-sagebrush nesting Columbian sharp-tailed grouse and nest fate ($G = 0.30$, 1 df, $P = 0.581$).

I evaluated nest success as it relates to native and non-native vegetation. Sage grouse nest success was 36% (4/11) at native sites and 40% (10/25) in non-native sites. Only 36 nests were used in the analyses rather than 38 reported earlier. One nest was documented as unsuccessful but the nest could not be relocated for vegetation analyses. Columbian sharp-tailed grouse nest success was 100% (6/6) in native situations and 45% (19/42) in non-native vegetation sites. There was no relationship between nest success and whether a site was native or non-native for sage grouse ($G = 0.79$, 1 df, $P = 0.412$) grouse. More ($G = 7.941$, 1 df, $P = 0.006$) Columbian sharp-tailed grouse were successful in native sites (6) than were expected (3), while there were fewer (0) unsuccessful nests in native sites than expected (3). There were also fewer (19) successful nests located in non-native sites than expected (22) and more (23) unsuccessful nests in non-native sites than expected (20).

Nest Bush versus Surrounding Area.--Of the birds that nested under a shrub, 64% (16) of Columbian sharp-tailed grouse and 87% (33) of sage grouse nested under sagebrush. I compared the specific sagebrush plant a bird nested under with a sample of sagebrush plants within a 20 m radius of the nest. Separate ANOVAS, rather than MANOVA, were conducted for dependent variables of nest plant height and nest plant crown area due to collinearity ($R = 0.5557$, $P = 0.0001$, $n = 98$). Sage grouse nested under taller ($F = 5.29$, 1, 94 df, $P = 0.0236$) sagebrush plants and in areas with taller sagebrush plants than Columbian sharp-tailed grouse (Fig. 1.2). In addition, regardless of

grouse species, hens nested under sagebrush plants that were 22 cm taller (89 vs 67 cm) than the mean height of sagebrush plants within a 20 m radius ($F = 31.81$, 1, 94 df, $P = 0.0001$) (Fig. 1.3). Differences in nest plant height at and around the nest by grouse species could not be detected ($F = 1.41$, 1, 94 df, $P = 0.2384$).

When I evaluated sagebrush crown area, years could not be pooled ($F = 13.59$, 2, 92, $P = 0.0017$). Sage grouse nested in areas with larger ($F = 13.59$, 1, 92 df, $P = 0.0004$) sagebrush crowns than Columbian sharp-tailed grouse (Fig. 1.4), although sagebrush crown area increased with time ($F = 13.59$, 2, 92 df, $P = 0.0017$) (Fig. 1.5). Sagebrush crown area was nearly twice as large in 1991 than it was in 1989. Sagebrush crown area at either sage or Columbian sharp-tailed grouse nests was similar ($F = 1.14$, 1, 92 df, $P = 0.2891$) to sagebrush crowns in the near vicinity (grouse species and sagebrush crown location [at the nest and 20-m distance] interaction) (Fig. 1.6).

Grass/Forb At Nests Versus Surrounding Area.--Grass and forb heights were measured at the nest site and in the immediate vicinity (20-m radius) for non-shrub nesting birds. There was only 1 sage grouse that nested under a grass plant and this datum was pooled with the remaining Columbian sharp-tailed grouse nests. Hens nested under taller ($F = 11.58$; 1, 48 df; $P = 0.0014$) grass and forb plants than were in a 20-m radius (Fig. 1.7).

Nest Bush And Grouse Age And Nest Fate.--I evaluated nest plant use with regard to nest fate (successful or unsuccessful) and hen age (adult or yearling). To eliminate interactions and avoid small sample sizes I conducted separate ANOVAs for each variable. I also sacrificed a reduced P -value based on the increased number of ANOVA'S.

No relationship was exhibited in sagebrush-nesting grouse age and nest fate ($F = 1.82$, 3, 42 df, $P = 0.1588$). Nest fate was also not related to nest plant height ($F = 0.30$, 3, 45 df, $P = 0.8231$). I also evaluated the relationship of grass and forb nesting hens between hen age and nest fate. No relationship was found with nest plant height between hen ages ($F = 0.26$, 1, 24 df, $P = 0.6140$) or nest fate ($F = 1.25$, 1, 25 df, $P =$

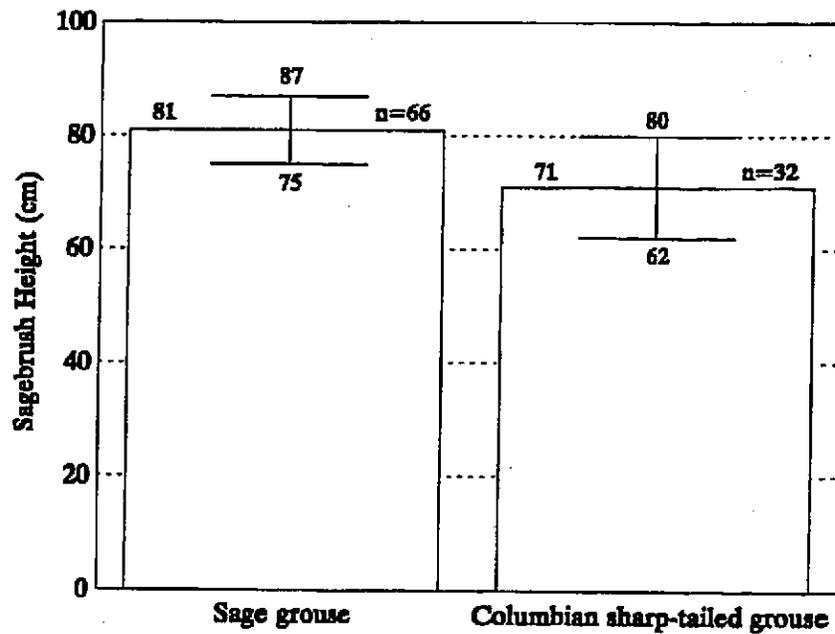


Figure 1.2. The combined (nest and 20-m radius) mean sagebrush height and 95% confidence limits for sage and Columbian sharp-tailed grouse nest sites in the Curlew Valley region of southeastern Idaho, 1988-91.

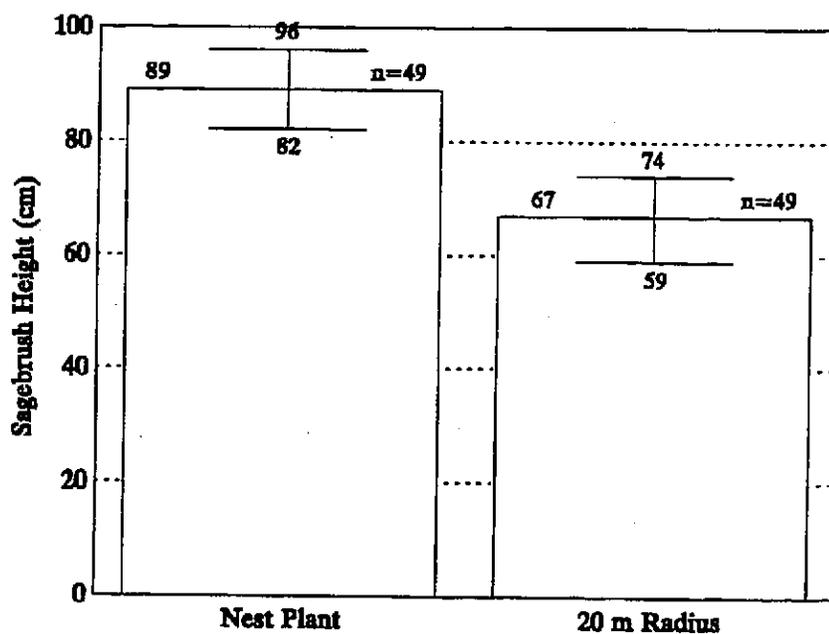


Figure 1.3. Mean sagebrush height and 95% confidence limits of combined (sage and Columbian sharp-tailed grouse) grouse nests and in a 20-m radius of the nest in the Curlew Valley region of southeastern Idaho, 1988-91.

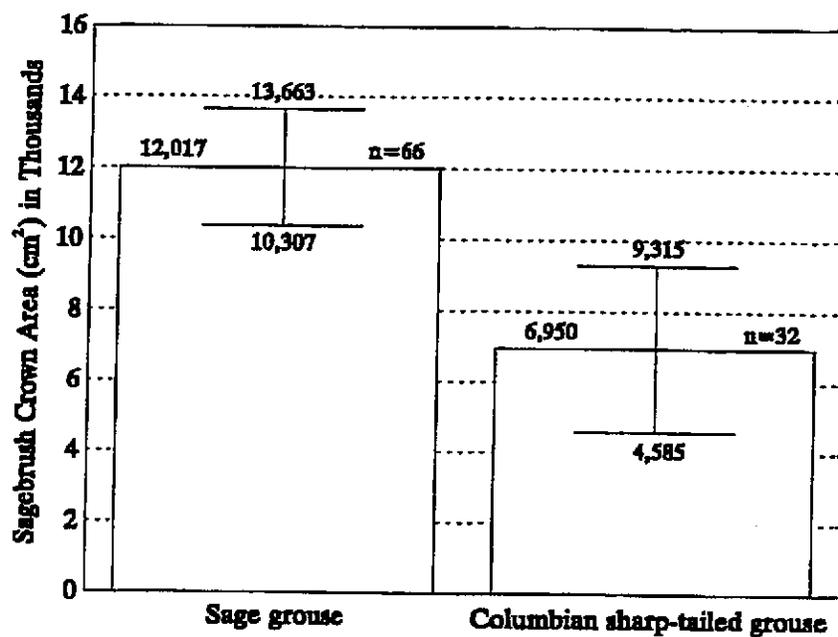


Figure 1.4. Mean sagebrush crown area and 95% confidence limits at combined (nest and 20-m radius) sage and Columbian sharp-tailed grouse nests in the Curlew Valley region of southeastern Idaho, 1988-91.

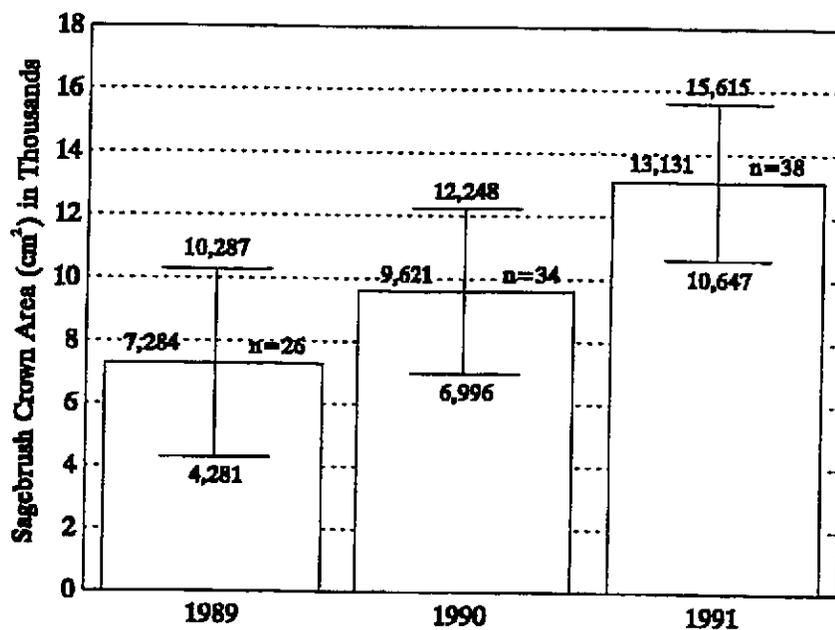


Figure 1.5. Mean sagebrush crown area and 95% confidence limits at combined (sage and Columbian sharp-tailed grouse nests and in a 20-m radius) grouse nests in 1989, 1990, and 1991 in the Curlew Valley region of southeastern Idaho, 1988-91

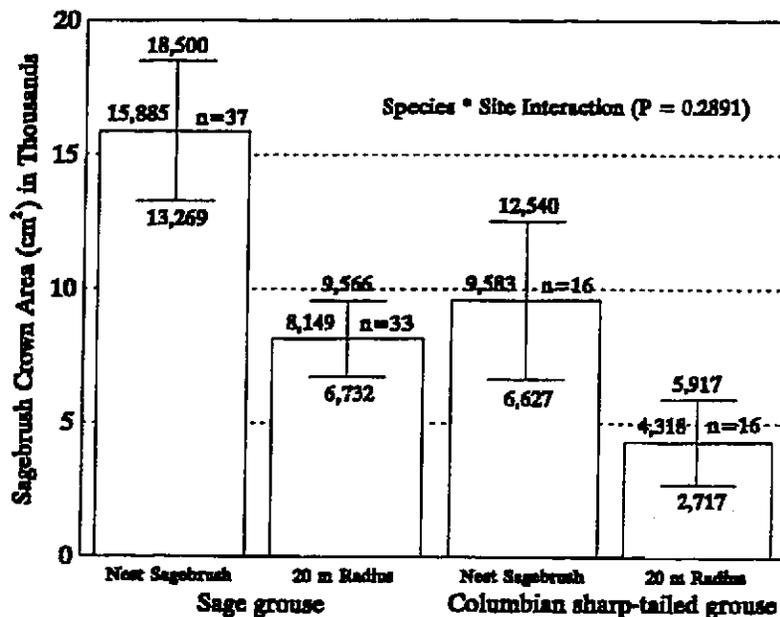


Figure 1.6. Mean sagebrush crown area at sage and Columbian sharp-tailed grouse nest sites and in a 20-m radius around the nest in the Curlew Valley Region of southeastern Idaho, 1988-91.

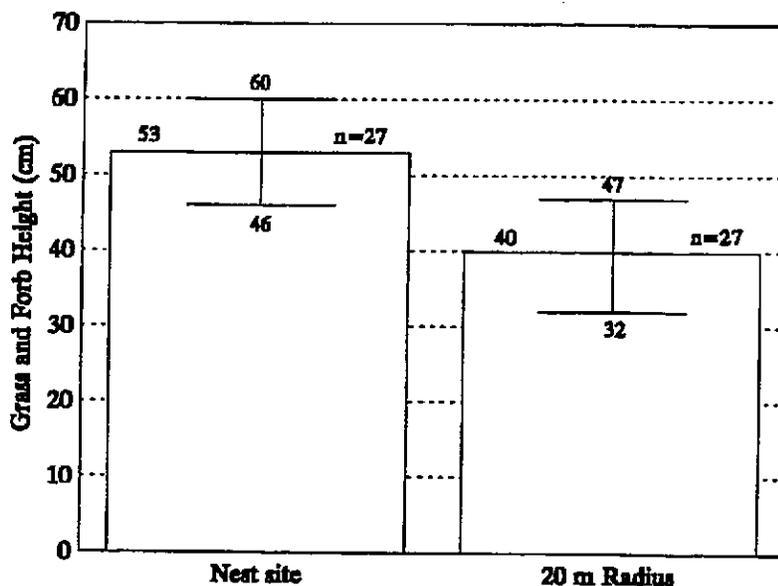


Figure 1.7. Mean grass and forb height and 95% confidence intervals at combined (sage and Columbian sharp-tailed grouse) grouse nests and in a 20-m radius of the nest in the Curlew Valley region of southeastern Idaho, 1988-91.

0.2743).

I also evaluated sagebrush crown area of nest plants with regard to grouse age and nest fate. Sagebrush crown area for adult and yearling sage or Columbian sharp-tailed grouse was similar ($F = 1.37$, 1, 42 df, $P = 0.2489$). Nest plant sagebrush crown area was also similar ($F = 0.05$, 1, 45 df, $P = 0.8303$) between successful and unsuccessful sage or Columbian sharp-tailed grouse.

Plant Species Richness

Plant species richness by year could not be pooled ($H = 8.98$, 2, 237 df, $P = 0.0002$). There was higher ($H = 15.54$, 1, 237 df, $P = 0.0001$) species richness at combined sage grouse nest, dependent micro-habitat, and independent macro-habitat locations when compared to the same Columbian sharp-tailed grouse sites (Fig. 1.8). Species richness also differed among years ($H = 8.98$, 2, 237 df, $P = 0.0002$) at the 3 aforementioned sampling locations. There was less species richness in 1991 than in 1989 ($P = 0.0177$) and 1990 ($P = 0.0001$) (Fig. 1.9).

Species richness was evaluated in relation to native or non-native vegetation. Species richness was higher ($H = 58.08$, 1, 248 df, $P = 0.0001$) at native sites versus non-native sites (Fig 1.10).

Niche Breadth And Overlap

Levins' measure produced niche breadth estimates for sage grouse that ranged from 0.000 - 0.915, while the Shannon-Wiener measure ranged from 0.000 - 0.968, and Smith's measure ranged from 0.707 - 0.994 (Table 1.6). Columbian sharp-tailed grouse niche breadth for Levins', Shannon-Wiener, and Smith's measures ranged from 0.144 - 0.999, and 0.400 - 1.000, and 0.814 - 1.000, respectively. Niche breadth did not differ between sage and Columbian sharp-tailed grouse for Levins' ($Z = 0.53$, 1 df, $P = 0.5962$), Shannon-Wiener ($Z = 0.66$, 1 df, $P = 0.5076$), or Smith's ($Z = 0.71$, 1 df, $P = 0.4799$)

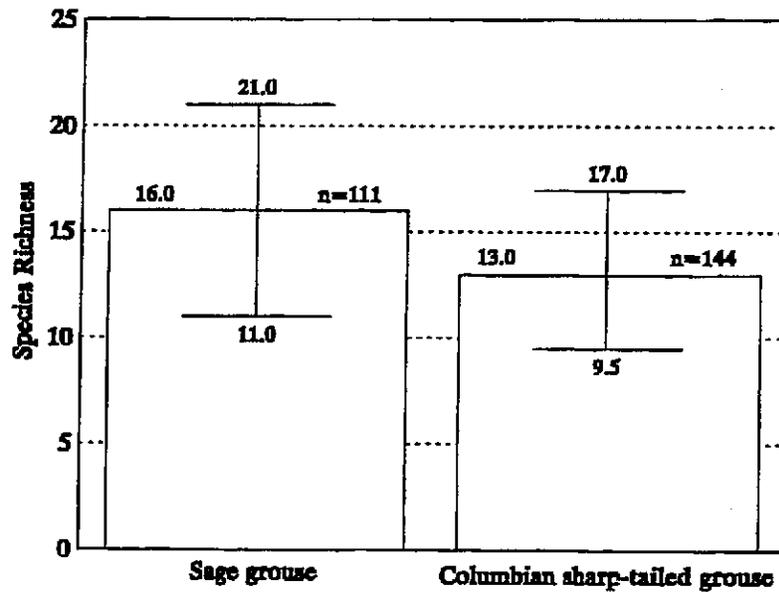


Figure 1.8. Median plant species richness and upper and lower quartiles at combined sage grouse nest, dependent micro-habitat, independent macro-habitat sites compared to the same Columbian sharp-tailed grouse sites in the Curlew Valley region of southeastern Idaho, 1988-91.

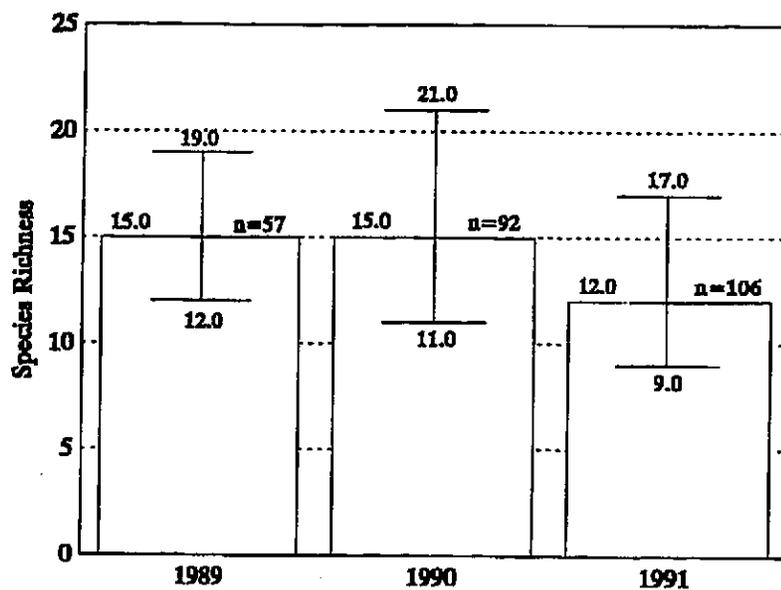


Figure 1.9. Median plant species richness and upper and lower quartiles by year at all sampling locations in the Curlew Valley region of southeastern Idaho, 1988-91.

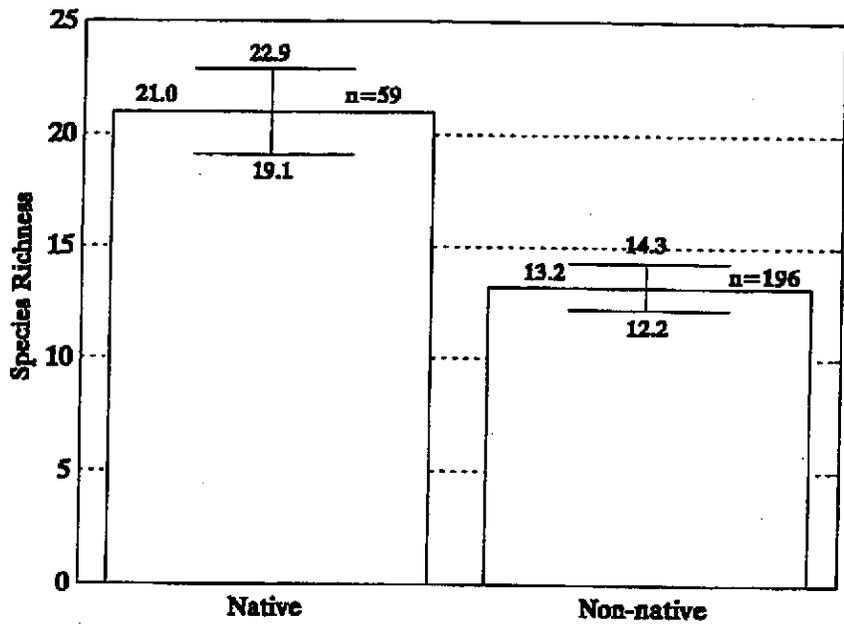


Figure 1.10. Median plant species richness and upper and lower quartiles at all grouse native and non-native sampling sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Table 1.6. Niche breadth estimates for Levins', Shannon-Wiener, and Smith's measures of 9 resource states at sage (SG) and Columbian sharp-tailed grouse (CSTG) nest sites in the Curlew Valley of southeastern Idaho, 1988-91.

<u>Resource Grouping^a</u>	<u>Niche Breadth Estimate</u>					
	<u>Levins' Measure</u>		<u>Shannon-Wiener Measure</u>		<u>Smith's Measure</u>	
	<u>SG</u>	<u>CSTG</u>	<u>SG</u>	<u>CSTG</u>	<u>SG</u>	<u>CSTG</u>
Shrub Nesting	0.054	0.999	0.176	1.000	0.812	1.000
Shrub Canopy Cover	0.364	0.810	0.686	0.937	0.912	0.983
Slope	0.883	0.144	0.960	0.400	0.989	0.814
Nest Plant Height	0.000	0.215	0.000	0.463	0.707	0.893
Litter Cover	0.699	0.660	0.865	0.876	0.958	0.967
Forb Height	0.915	0.987	0.968	0.995	0.994	0.999
Grass Height	0.870	0.710	0.949	0.874	0.991	0.978
Grass Cover	0.612	0.777	0.819	0.916	0.922	0.968
Forb Cover	0.736	0.667	0.916	0.891	0.971	0.963

^aRefer to Table 1.1 for detailed resource state descriptions.

measures (Fig. 1.11).

Five measures of niche overlap were evaluated for each of the 9 categories of resource states. The niche overlap for resource categories of shrub versus non-shrub nests, shrub canopy cover and slope was lower ($Z = -5.31$, 1 df, $P = 0.0001$) than the measurements of niche overlap for nest plant height, litter cover, forb height, grass height, grass cover, and forb cover (Table 1.7).

Dependent Micro- and Independent Macro-Habitat Comparisons

Nest versus Dependent Micro-Habitat Site.--I detected differences in the 9 dependent variables (litter, forb and grass cover, grass, sagebrush and forb height, sagebrush and shrub canopy cover and visual obstruction at 45°) between grouse species (MANOVA; Wilks' $\lambda = 0.69$; $F = 3.00$; 9, 61 df; $P = 0.0050$) and among years (MANOVA; Wilks' $\lambda = 0.62$; $F = 1.81$; 18, 122 df; $P = 0.0313$). No differences were detected in the species by year interaction (MANOVA; Wilks' $\lambda = 0.90$; $F = 0.38$; 18, 122 df; $P = 0.9893$).

There was a greater difference in litter cover at sage grouse nests, between nests and dependent micro-habitat sites than at Columbian sharp-tailed grouse nests ($F = 6.15$, 1, 69 df, $P = 0.0156$). Sage grouse nest sites had 7% more litter than was present at the dependent micro-habitat sites, whereas Columbian sharp-tailed grouse nest sites had lower litter cover than was present in dependent micro-habitat sites (Table 1.8). Sage grouse nest sites had more ($F = 9.84$, 1, 69 df, $P = 0.0025$) sagebrush canopy cover than at dependent micro-habitat sites whereas Columbian sharp-tailed grouse nested at sites with less sagebrush than at dependent micro-habitat sites (Table 1.8).

No additional significant differences were found with the 7 remaining variables analyzed, although differences between sage and Columbian sharp-tailed grouse may not be extreme enough to be detected by the MANOVA and positive or negative trends may be present. One variable that exhibited a trend was visual obstruction (JO45). Sage grouse

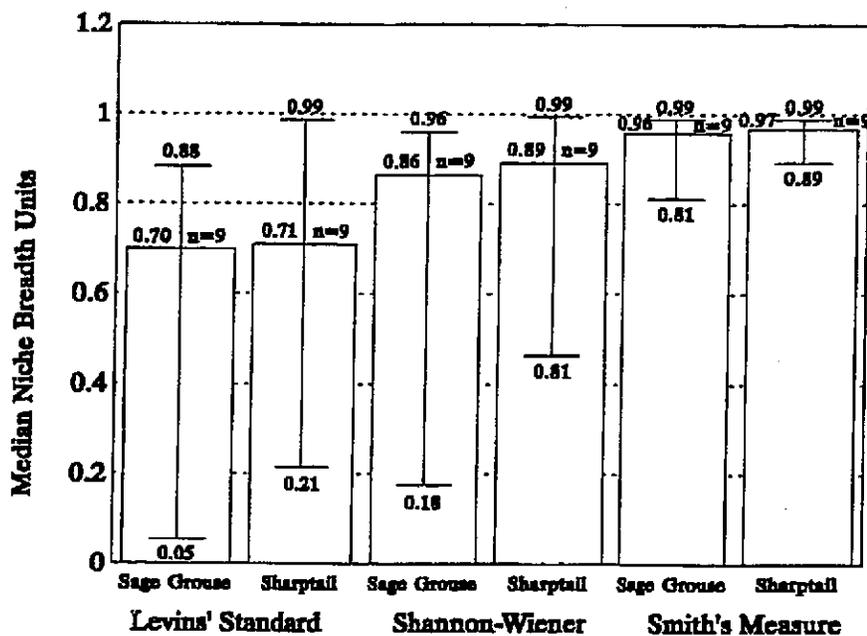


Figure 1.11. Median and upper and lower quartiles for Levins', Shannon-Wiener, and Smith's measurements of niche breadth for sage and Columbian sharp-tailed (Sharptail) grouse in the Curlew Valley region of southeastern Idaho, 1988-91.

Table 1.7. Niche overlap estimates for Pianka's Measure (PM), Percentage Overlap Measure (POM), Morisita's Measure (MM), Simplified Morisita's Measure (SMM), and Horn's Index Measure (HIM) of 9 resource states for sage and Columbian sharp-tailed grouse in the Curlew Valley of southeastern Idaho, 1988-91.

<u>Resource Grouping^a</u>	<u>Niche Overlap Estimate</u>				
	<u>PM</u>	<u>POM</u>	<u>MM</u>	<u>SMM</u>	<u>HIM</u>
Shrub Nest	0.712	51.7	0.683	0.677	0.749
Shrub Canopy Cover	0.544	49.7	0.546	0.533	0.775
Slope	0.626	46.7	0.595	0.583	0.733
Nest Plant Height	0.994	90.2	0.991	0.989	0.949
Litter Cover	0.943	82.1	0.974	0.943	0.968
Forb Height	0.992	93.5	1.000	0.992	0.997
Grass Height	0.991	92.6	1.000	0.990	0.995
Grass Cover	0.825	70.7	0.860	0.820	0.820
Forb Cover	0.956	85.3	1.000	0.955	0.974

^aRefer to Table 1.1 for resource state descriptions.

Table 1.8. Mean and standard error (SE) percent cover of litter (LITTER), grass (GRASSHT) and forb heights (FORBHT), percent cover of forbs (FORBCC), sagebrush height (SAGEHT), and canopy cover (SAGECC), non-sagebrush shrubs (SHRUBCC), grass cover (GRASSCC), and visual obstruction at 45° (JO45) analyzed in a MANOVA for sage and Columbian sharp-tailed grouse nests (NEST), dependent micro-habitat sites (DEPT) and the mean difference (DIFF) between NEST and DEPT sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Variable	Sage Grouse						Columbian Sharp-tailed Grouse						P
	NEST	SE	DEPT	SE	DIFF	SE	NEST	SE	DEPT	SE	DIFF	SE	
LITTER	43.3	2.4	36.5	2.5	7.3	2.9	37.2	2.2	38.7	2.2	-1.6	1.8	0.0156
GRASSHT	34.4	1.7	32.3	2.0	2.5	1.7	36.3	1.9	35.7	2.1	0.6	1.1	0.3121
FORBHT ^a	26.2	2.7	19.2	2.0	7.0	3.4	20.1	2.0	19.7	2.2	0.4	1.1	0.1206
FORBCC ^a	9.5	1.5	9.0	1.2	0.4	1.8	7.2	1.3	7.4	1.6	-0.2	0.9	0.8549
SAGEHT	69.0	2.6	64.2	3.0	4.5	2.6	59.4	3.5	57.0	2.6	2.4	2.9	0.4267
SAGECC ^a	18.6	1.4	14.6	1.6	3.6	1.4	9.6	1.4	9.7	1.5	-0.1	0.9	0.0025
SHRUBCC ^a	16.8	2.0	14.3	2.0	2.3	2.2	9.5	1.5	9.4	1.5	0.2	1.1	0.3062
GRASSCC	15.1	1.1	13.7	1.3	1.1	1.4	20.6	1.2	21.2	1.9	-0.6	1.6	0.3226
JO45 ^a	94.6	1.4	79.3	4.1	15.3	4.1	89.6	1.5	77.0	3.8	12.7	3.5	0.2265

^aArcSin Transformation used in MANOVA, mean and SE reported.

nest sites had higher ($P = 0.0005$) JO45 ($\bar{x} = 94.6 \pm 1.4\%$ [S.E.], $n = 38$) than corresponding dependent micro-habitat sites ($\bar{x} = 79.3 \pm 4.1\%$ [S.E.], $n = 38$).

A yearly difference was observed ($F = 6.28$, 2, 69 df, $P = 0.0031$) in visual obstruction between nests and dependent micro-habitat sites (Table 1.9). The difference in JO45 was greater in 1989 than in 1991 ($P = 0.0012$) and in 1990 than 1991 ($P = 0.0187$), although the difference was not significant between 1989 and 1990 ($P = 0.2514$). The difference between nests and dependent micro-habitat sites decreased with time in 1989, 1990 and 1991, 28.3, 16.2, and 3.4%, respectively. Mean visual obstruction (JO45) at nests, dependent micro-habitat, and independent macro-habitat sites increased through time (Fig. 1.12).

Mean grass height increased through time at nests, dependent micro-habitat and independent macro-habitat sites (Fig. 1.13). Mean forb (Fig. 1.14) height also increased through time at dependent micro-habitat and independent macro-habitat sites, although at nest sites there was a slight decrease from 1989 to 1990 and an increase in 1991. Mean monthly precipitation increased from 1989 to 1990 and decreased in 1991, but there was a general trend of increased precipitation over 1989 levels (Fig. 1.15).

Nest Versus Independent Macro-habitat.--Differences in dependent variables did not vary between sage and Columbian sharp-tailed grouse (MANOVA; Wilks' $\lambda = 0.92$; $F = 0.56$; 9, 56 df; $P = 0.8215$) (Table 1.10) or on a yearly basis (MANOVA; Wilks' $\lambda = 0.68$; $F = 1.42$; 18, 112 df; $P = 0.2058$). However, there were differences (MANOVA; Wilks' $\lambda = 0.59$; $F = 1.90$; 18, 112 df; $P = 0.0223$) between grouse species by year.

Grass cover was the only dependent variable of the 9 evaluated that illustrated a difference ($F = 4.16$, 2, 64 df, $P = 0.0200$) in the grouse species by year interaction (Table 1.11). In 1991, there was more ($\bar{x} = -11.0 \pm 3.7\%$ [S.E.], $n = 18$) ($P = 0.0039$) grass cover at sage grouse independent macro-habitat sites than at the average of the nests and dependent micro-habitat sites versus Columbian sharp-tailed grouse sites. The opposite was true at Columbian sharp-tailed grouse sites; the average nest and dependent

Table 1.9. Mean and standard error (SE) percent cover of litter (LITTER), grass (GRASSHT) and forb heights (FORBHT), percent cover of forbs (FORBCC), sagebrush height (SAGEHT), and canopy cover (SAGECC), non-sagebrush shrubs (SHRUBCC), grass cover (GRASSCC), and visual obstruction at 45° (JO45) analyzed in a MANOVA for each study year (1989, 1990, 1991) at combined sage and Columbian sharp-tailed grouse nests (NEST), dependent micro-habitat sites (DEPT) and the mean difference (DIFF) between NEST and DEPT sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Variable	1989						1990					
	NEST	SE	DEPT	SE	DIFF	SE	NEST	SE	DEPT	SE	DIFF	SE
LITTER	35.5	2.7	36.5	2.5	-0.4	3.1	35.5	2.6	32.4	2.5	3.1	2.6
GRASSHT	26.5	2.0	25.6	2.1	1.2	1.3	32.0	1.7	29.2	1.7	2.8	1.4
FORBHT ^a	21.7	3.5	15.4	1.8	5.8	3.6	17.7	1.5	16.4	1.5	1.2	1.4
FORBCC ^a	7.8	1.4	7.4	1.7	0.2	1.7	9.1	1.5	9.4	1.9	-0.3	0.8
SAGEHT	54.3	3.3	54.8	2.5	-1.9	2.9	63.9	4.2	57.0	4.0	6.8	3.5
SAGECC ^a	16.1	2.7	11.7	2.8	3.4	2.1	12.5	1.7	12.5	1.9	0.0	1.4
SHRUBCC ^a	11.2	2.5	8.1	1.8	2.5	2.3	14.0	2.3	12.0	1.9	2.1	2.4
GRASSCC	19.7	2.2	17.8	2.3	1.4	1.6	17.1	1.1	16.4	1.4	0.7	1.3
JO45 ^{ac}	86.2	2.5	57.5	6.5	28.3 ^l	6.4	92.9	1.7	76.7	4.5	16.2 ^l	4.7

Table 1.9 con't. Mean and standard error (SE) percent cover of litter (LITTER), grass (GRASSHT) and forb heights (FORBHT), percent cover of forbs (FORBCC), sagebrush height (SAGEHT), and canopy cover (SAGECC), non-sagebrush shrubs (SHRUBCC), grass cover (GRASSCC), and visual obstruction at 45° (JO45) analyzed in a MANOVA for each study year (1989, 1990, 1991) at combined sage and Columbian sharp-tailed grouse nests (NEST), dependent micro-habitat sites (DEPT) and the mean difference (DIFF) between NEST and DEPT sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Variable	1991						P ^b
	NEST	SE	DEPT	SE	DIFF	SE	
LITTER	47.5	2.7	43.0	3.0	4.5	3.2	0.6070
GRASSHT	44.0	1.4	43.4	2.1	0.6	2.0	0.5368
FORBHT ^a	29.0	3.2	24.5	3.0	4.5	3.7	0.7364
FORBCC ^a	8.0	2.0	7.6	1.5	0.4	2.2	0.9472
SAGEHT	70.8	3.4	67.1	2.8	3.7	3.2	0.1851
SAGECC ^a	14.3	1.6	12.0	1.6	2.3	1.0	0.0991
SHRUBCC ^a	13.6	2.1	13.9	2.4	-0.3	1.8	0.5267
GRASSCC	17.4	1.4	18.2	2.4	-0.8	2.2	0.6359
JO45 ^a	95.2	1.2	91.8	1.9	3.4 ²	2.3	0.0031

^aArcSin Transformation used in MANOVA, mean ± SE reported.

^bANOVA p-value

^clike numbers are not significantly different

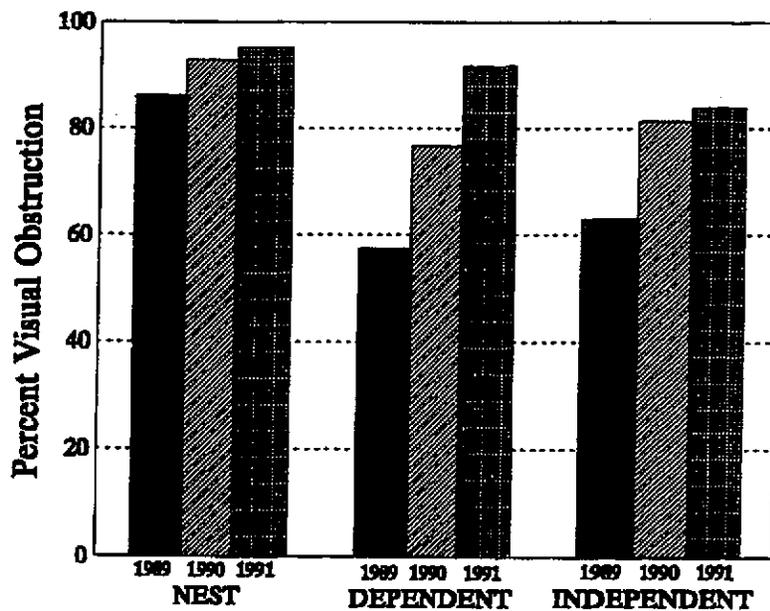


Figure 1.12. Visual obstruction at sage and Columbian sharp-tailed grouse nests (NEST), dependent micro-habitat (DEPENDENT), and independent macro-habitat (INDEPENDENT) locations in the Curlew Valley region of southeastern Idaho, 1988-91.

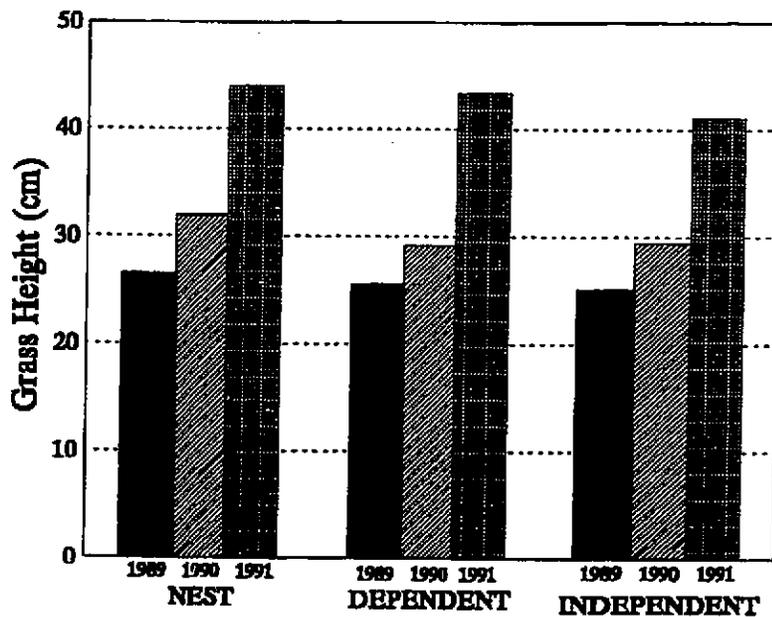


Figure 1.13. Mean grass height at sage and Columbian sharp-tailed grouse nests (NEST) dependent micro-habitat (DEPENDENT), and independent macro-habitat (INDEPENDENT) locations in the Curlew Valley region of southeastern Idaho, 1988-91.

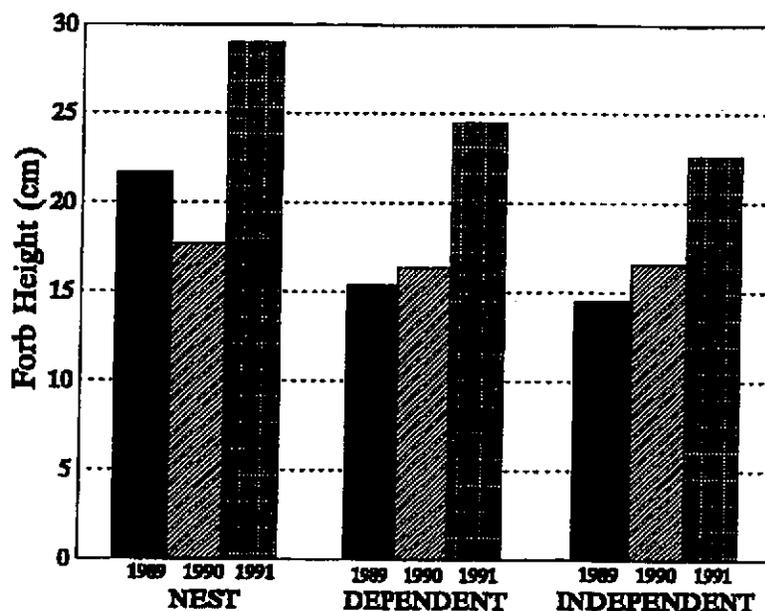


Figure 1.14. Mean forb height (arcsin squareroot transformation used in analyses) at sage and Columbian sharp-tailed grouse nests (NEST), dependent micro-habitat (DEPENDENT), and independent macro-habitat (INDEPENDENT) locations in the Curlew Valley region of southeastern Idaho, 1988-91.

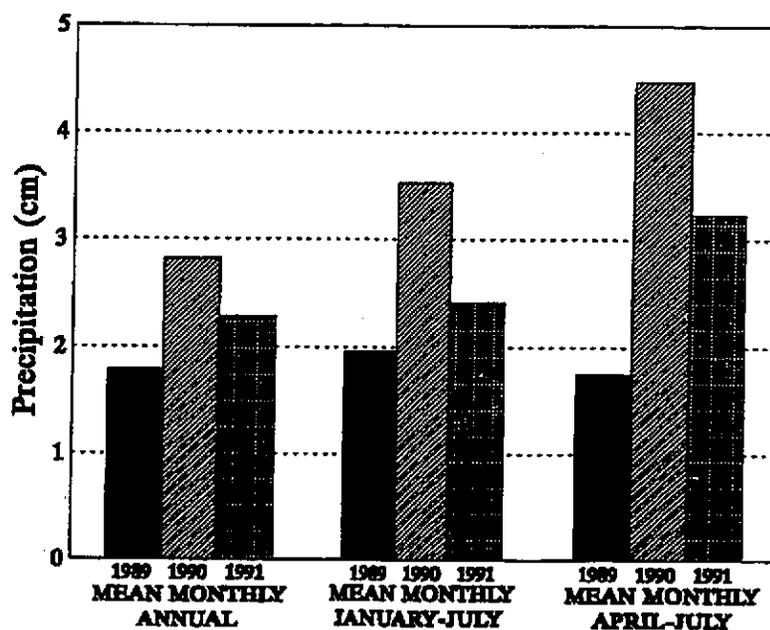


Figure 1.15. Mean monthly precipitation for January through December (ANNUAL), January through July (JANUARY-JULY), and summer months (APRIL-JULY) (data from Agricultural Engineering Dept., Univ. Idaho, Moscow) Snowville, UT, 1988-91.

Table 1.10. Mean and standard error (SE) percent cover of litter (LITTER), grass (GRASSHT) and forb heights (FORBHT), percent cover of forbs (FORBCC), sagebrush height (SAGEHT), and canopy cover (SAGECC), non-sagebrush shrubs (SHRUBCC), grass cover (GRASSCC), and visual obstruction at 45° (JO45) analyzed in a MANOVA for sage and Columbian sharp-tailed grouse nests (NEST), dependent (DEPT) micro-habitat, and independent macro-habitat (INDT) sites and the mean difference (DIFF) between NEST and DEPT and INDT sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Variable	Sage Grouse								Columbian Sharp-tailed Grouse								P
	NEST	SE	DEPT	SE	INDT	SE	DIFF ^a	SE	NEST	SE	DEPT	SE	INDT	SE	DIFF ^a	SE	
LITTER	43.3	2.4	36.5	2.5	37.7	2.9	2.7	3.2	37.2	2.2	38.7	2.2	38.5	2.7	0.3	3.3	0.7357
GRASSHT	34.4	1.7	32.3	2.0	33.4	2.3	0.8	1.8	36.3	1.9	35.7	2.1	33.9	2.1	3.1	2.5	0.6003
FORBHT ^b	26.2	2.7	19.2	2.0	18.7	1.7	3.8	2.6	20.1	2.0	19.7	2.2	18.8	2.0	1.8	2.9	0.5592
FORBCC ^b	9.5	1.5	9.0	1.2	8.6	1.2	-0.1	1.6	7.2	1.3	7.4	1.6	4.3	0.9	3.2	1.9	0.6971
SAGEHT	69.0	2.6	64.2	3.0	62.6	3.5	5.4	4.2	59.4	3.5	57.0	2.6	66.3	3.6	-7.1	4.4	0.1930
SAGECC ^b	18.6	1.4	14.6	1.6	17.0	2.3	-1.1	2.7	9.6	1.4	9.7	1.5	12.6	2.0	-3.4	2.4	0.7134
SHRUBCC ^b	16.8	2.0	14.3	2.0	8.5	1.7	7.0	1.9	9.5	1.5	9.4	1.5	11.7	2.4	-2.0	2.8	0.0130
GRASSCC	15.1	1.1	13.7	1.3	17.9	2.2	-3.4	2.6	20.6	1.2	21.2	1.9	17.4	2.4	3.3	2.3	0.3803
JO45 ^b	94.6	1.4	79.3	4.1	79.3	2.8	9.0	3.5	89.6	1.5	77.0	3.8	78.4	3.8	6.7	3.5	0.7173

^aDIFFERENCE = (NEST + DEPENDENT)/2 - INDEPENDENT

^bArcSin Transformation used in MANOVA, mean and SE reported.

Table 1.11. Mean and standard error (SE) percent cover of litter (LITTER), grass (GRASSHT) and forb heights (FORBHT), percent cover of forbs (FORBCC), sagebrush height (SAGEHT), and canopy cover (SAGECC), non-sagebrush shrubs (SHRUBCC), grass cover (GRASSCC), and visual obstruction at 45° (JO45) analyzed in a MANOVA for 1989, 1990, and 1991 for sage and Columbian sharp-tailed grouse nests (NEST), dependent micro-habitat (DEPT), and independent macro-habitat (INDT) sites and the mean difference (DIFF) between NEST and DEPT and INDT sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Variable	1989															
	Sage Grouse								Columbian Sharp-tailed Grouse							
	NEST	SE	DEPT	SE	INDT	SE	DIFF ^a	SE	NEST	SE	DEPT	SE	INDT	SE	DIFF ^a	SE
LITTER	35.0	2.7	32.5	3.8	37.6	6.5	-2.9	6.0	35.9	5.2	40.6	2.9	31.2	3.1	12.4	3.5
GRASSHT	23.0	1.5	21.2	2.0	23.2	2.1	0.8	1.8	30.5	3.6	29.9	3.2	29.0	3.6	4.0	4.4
FORBHT ^b	25.3	6.2	15.7	3.2	14.1	1.9	5.6	6.2	17.6	2.4	15.2	2.0	15.0	3.9	3.8	3.9
FORBCC ^b	11.5	1.7	10.2	2.5	2.3	0.5	6.4	1.2	3.6	1.3	4.6	2.0	3.7	1.4	0.1	1.6
SAGEHT	57.9	3.9	55.1	3.9	69.6	6.2	-10.6	7.7	50.2	5.5	54.5	3.4	48.3	4.7	6.8	7.6
SAGECC ^b	22.0	3.8	13.8	4.7	16.8	6.3	-2.2	7.2	9.6	2.4	9.7	3.4	5.8	3.2	1.5	4.3
SHRUBCC ^b	15.5	4.0	10.5	2.8	4.3	1.8	8.0	2.8	6.5	2.0	5.8	2.1	6.9	3.9	-0.8	4.4
GRASSCC	16.2	3.0	11.8	2.0	12.3	4.4	3.1	5.8	23.4	2.7	23.9	2.9	29.7	7.0	-5.9	6.6
JO45 ^b	89.0	4.2	59.7	11.4	66.7	3.2	12.5	7.8	83.0	2.4	55.3	6.8	58.1	8.3	14.8	4.5

^aDIFFERENCE = (NEST + DEPENDENT)/2 - INDEPENDENT

^bArcSin Transformation used in MANOVA, mean and SE reported.

Table 1.11 con't. Mean and standard error (SE) percent cover of litter (LITTER), grass (GRASSHT) and forb heights (FORBHT), percent cover of forbs (FORBCC), sagebrush height (SAGEHT), and canopy cover (SAGECC), non-sagebrush shrubs (SHRUBCC), grass cover (GRASSCC), and visual obstruction at 45° (JO45) analyzed in a MANOVA for 1989, 1990, and 1991 for sage and Columbian sharp-tailed grouse nests (NEST), dependent micro-habitat (DEPT), and independent macro-habitat (INDT) sites and the mean difference (DIFF) between NEST and DEPT and INDT sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Variable	1990															
	Sage Grouse								Columbian Sharp-tailed Grouse							
	NEST	SE	DEPT	SE	INDT	SE	DIFF ^a	SE	NEST	SE	DEPT	SE	INDT	SE	DIFF ^a	SE
LITTER	35.6	4.7	28.3	2.9	31.8	3.5	0.1	4.0	35.5	3.2	34.8	3.4	40.2	4.6	-5.1	5.6
GRASSHT	32.4	1.9	28.3	2.1	28.1	3.6	2.3	3.6	31.7	2.5	29.7	2.5	30.3	1.8	0.4	2.6
FORBHT ^b	17.7	2.0	15.7	2.3	22.1	3.6	-5.4	3.3	17.7	2.1	16.9	2.0	13.4	0.7	3.9	2.0
FORBCC ^b	9.0	1.6	10.5	2.2	11.2	2.6	-1.5	3.1	9.1	2.3	8.8	2.8	2.8	0.5	6.1	2.7
SAGEHT	75.5	4.9	64.0	6.9	65.2	7.8	4.6	9.4	57.0	5.4	52.9	4.9	72.9	5.2	-17.9	6.0
SAGECC ^b	18.8	2.0	17.8	2.8	19.4	4.2	-1.1	4.8	8.8	2.0	9.4	2.4	15.7	2.7	-6.6	3.8
SHRUBCC ^b	16.8	4.9	12.0	3.1	10.7	4.2	3.7	3.8	12.4	2.4	11.9	2.4	11.2	2.4	-0.9	3.7
GRASSCC	17.0	1.9	15.4	1.9	10.4	2.0	5.8	2.4	17.2	1.4	16.9	2.0	11.3	1.2	5.8	1.6
JO45 ^b	97.7	1.2	80.0	8.0	87.8	5.0	1.0	6.5	90.0	2.3	74.7	5.6	77.7	6.1	4.7	7.0

^aDIFFERENCE = (NEST + DEPENDENT)/2 - INDEPENDENT

^bArcSin Transformation used in MANOVA, mean and SE reported.

Table 1.11 con't. Mean and standard error (SE) percent cover of litter (LITTER), grass (GRASSHT) and forb heights (FORBHT), percent cover of forbs (FORBCC), sagebrush height (SAGEHT), and canopy cover (SAGECC), non-sagebrush shrubs (SHRUBCC), grass cover (GRASSCC), and visual obstruction at 45° (JO45) analyzed in a MANOVA for 1989, 1990, and 1991 for sage and Columbian sharp-tailed grouse nests (NEST), dependent micro-habitat (DEPT), and independent macro-habitat (INDT) sites and the mean difference (DIFF) between NEST and DEPT and INDT sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Variable	1991																P ^c
	Sage Grouse								Columbian Sharp-tailed Grouse								
	NEST	SE	DEPT	SE	INDT	SE	DIFF ^a	SE	NEST	SE	DEPT	SE	INDT	SE	DIFF ^a	SE	
LITTER	52.1	3.2	43.0	4.1	41.2	4.6	6.3	5.3	40.5	4.0	42.9	4.2	39.8	4.0	1.9	4.6	0.2414
GRASSHT	41.9	1.8	40.0	2.7	41.0	3.3	-0.0	2.8	47.2	1.9	48.5	2.7	41.4	4.8	6.5	6.0	0.5015
FORBHT ^b	31.4	4.0	22.8	3.4	18.8	2.5	8.3	3.7	25.5	5.2	27.0	5.6	28.2	4.3	-2.0	8.0	0.1062
FORBCC ^b	8.6	3.0	7.6	1.8	9.9	1.6	-1.8	2.5	7.0	2.2	7.6	2.9	6.8	2.3	0.5	3.7	0.0751
SAGEHT	71.6	3.8	68.8	4.1	58.0	4.8	12.2	5.1	69.7	6.3	64.6	3.4	66.0	5.8	1.2	7.5	0.0616
SAGECC ^b	16.7	1.8	13.3	1.9	15.7	3.1	-0.7	3.8	10.7	2.8	10.1	2.8	11.6	3.7	-1.2	4.9	0.3737
SHRUBCC ^b	17.5	2.6	17.5	3.3	9.1	2.3	8.3	2.9	7.8	2.6	8.5	2.8	14.9	5.7	-6.7	5.9	0.0940
GRASSCC	13.5	1.2	13.6	2.1	24.5	3.3	-11.0	3.7	23.2	2.3	25.2	4.5	20.0	5.1	4.2	5.3	0.0200
JO45 ^b	96.0	1.3	88.7	2.9	80.2	4.0	12.1	4.8	94.0	2.2	96.3	1.4	89.5	2.7	5.6	2.4	0.7714

^aDIFFERENCE = (NEST + DEPENDENT)/2 - INDEPENDENT

^bArcSin Transformation used in MANOVA, mean and SE reported.

^cSpecies by Year Interaction P-value

micro-habitat sites had more grass cover present than was present at independent macro-habitat sites. In addition, there was more ($P = 0.0233$) grass cover ($\bar{x} = 3.1 \pm 5.8\%$ [S.E.], $n = 10$) at sage grouse nest and dependent micro-habitat sites than at independent macro-habitat sites in 1989 versus 1991 and grass cover ($\bar{x} = 5.8 \pm 2.4\%$ [S.E.], $n = 10$) was also higher in 1990 ($P = 0.0027$) versus 1991.

Although there was an overall significant MANOVA in the species by year interaction, there were no differences detected with the 8 remaining dependent variable difference vectors. Upon further evaluation for positive and negative trends from zero (Students t-test with overall alpha protection of $\alpha = 0.05$) trends were found. In 1989, there was more ($P = 0.0122$) forb cover at the average of sage grouse nests and dependent micro-habitat versus independent macro-habitat sites. In 1991, there was taller ($P = 0.0303$) sagebrush at the average of sage grouse nests and dependent micro-habitat than at independent macro-habitat sites and higher ($P = 0.0006$) visual obstruction. No trends were found for Columbian sharp-tailed grouse in 1989 or 1991, but in 1990 there was more ($P = 0.0495$) forb cover, lower ($P = 0.0498$) sagebrush canopy cover, and shorter sagebrush ($\bar{x} = 17.9 \pm 6.0$ cm [S.E.], $n = 17$) at the average of Columbian sharp-tailed grouse nests and dependent micro-habitat sites when compared to the independent macro-habitat sites.

Understory (Grass and Forb) Nest Versus Dependent Micro-Habitat And Independent Micro-Habitat Sites.--I identified 154 species of grasses and forbs at or near nests of sage and Columbian sharp-tailed grouse, dependent micro-habitat and/or independent macro-habitat sites (Appendix B). A majority of samples were identified to species, although some could only be identified to genera and only 9 samples (6.1%) were unidentified. More specifically, 27 species of grasses (or grass-like) were identified, with some samples only identified to genera and there were no unknowns (Appendix B). There were 32 taxonomic families and 12 tribes/subfamilies represented by the forbs, and 3

families and 4 tribes were represented by the grasses. An additional 11 forb species were identified but did not occur at vegetation sampling sites.

I pooled 125 species of forbs into 41 tribes/subfamilies or families. When tribes/subfamilies were not present for categorization, species were grouped into the next highest taxonomic category (Family). The 29 species of grasses were reduced to 5 tribes. I used stepwise discriminant analysis as a data reduction technique to reduce 46 variables to 8 variables (30 species) that successfully discriminated between class variables of nest (regardless of grouse species), dependent micro-habitat and independent macro-habitat locations. The variables included the grass tribe *Hordeae* (HORD) from Gramineae, Group I (LEGU1) of Leguminosae the family of Leguminosae (LEGU), Group I (CHEN1) of Chenopodiaceae, Group VI (CRUC6) of Cruciferae, subfamily *Inuleae* (INUL) of Compositae, and the families of Linaceae (LINA) and Santalaceae (SANT).

Dependent micro-habitat and sage and Columbian sharp-tailed grouse nests could not be differentiated based upon the understory groupings. Understory vegetation at sage grouse nests was similar to dependent micro-habitat locations ($\hat{\epsilon}$ (AER) = 0.5600), as were Columbian sharp-tailed grouse nests ($\hat{\epsilon}$ (AER) = 0.5098).

Similar results were found when independent macro-habitat locations were compared to sage grouse nests. There were no predominant discriminating characteristics between sage grouse nests and independent macro-habitat sites ($\hat{\epsilon}$ (AER) = 0.4079). Seventy-one percent of sage grouse nests were correctly classified but independent macro-habitat sites were not as successfully classified. Only 47% of the independent macro-habitat sites were correctly classified (Table 1.12). Columbian sharp-tailed grouse nest and independent macro-habitat locations illustrated some differentiation ($\hat{\epsilon}$ (AER) = 0.3012). Eighty-six percent of the Columbian sharp-tailed grouse nests were correctly classified, although independent macro-habitat sites were not as successfully classified and were

Table 1.12. Classification of predicted and actual sage grouse nests and independent macro-habitat sites in the Curlew Valley region of southeastern Idaho (1988-91) using the forb and grass vegetation variables of HORD, LEGU1, LINA, INUL, CRUC6, CHEN1, SANT, and LEGU.

		Predicted Group Membership		
		<u>Nest</u>	<u>Independent Site</u>	<u>Total</u>
<u>Group</u> <u>Membership</u>	Nest	27	11	38
	Percent	71	29	100
	Independent Site	20	18	38
	Percent	53	47	100
	Totals	47	29	76
	Percent	62	38	100
	Priors	50	50	

essentially equally divided (Table 1.13); as many independent macro-habitat sites were incorrectly (51%) classified as were correctly classified (49%).

Sage and Columbian sharp-tailed grouse nests could not technically be successfully discriminated and classified ($\hat{\epsilon}$ (AER) = 0.4270). Ninety-five percent (36 of 38) of sage grouse nests were mis-classified as Columbian sharp-tailed grouse nests (Table 1.14). In contrast, only 4% (2 of 51) of Columbian sharp-tailed grouse nests were misclassified as sage grouse nests. As a result, 96% of the Columbian sharp-tailed grouse nests were correctly classified.

Stepwise Logistic Regression And Nest Type

I selected 9 variables for the stepwise procedure. The variables included litter cover (LITTER), forb height (FORBHT), grass height (GRASSHT), forb cover (FORBCC), grass cover (GRASSCC), total shrub canopy cover (TOTALCC), slope (SLOPE), sagebrush height (SAGEHT), and sagebrush canopy cover (SAGECC). A tenth variable, nest plant height (NESTHT), was included when sage and Columbian sharp-tailed grouse nests were compared.

Nest Versus Independent Macro-habitat.—Two of the 9 variables that entered the Columbian sharp-tailed grouse versus macro-habitat site analysis were identified as significant contributors to the logistic regression model resulting in 58% of the nests being correctly classified. GRASSCC (Wald $\chi^2 = 4.95$, 7 df, $p = 0.0260$) (Fig. 1.16) and SAGEHT (Wald $\chi^2 = 6.38$, 8 df, $p = 0.0115$) (Fig. 1.17) were selected. By substituting the transformed value for GRASSCC and untransformed value of SAGEHT the following model results:

$$\text{SHARPTAIL NEST (P)} = -0.2330 + (3.3761)(\text{GRASSCC}) + (-0.0211)(\text{SAGEHT}).$$

Table 1.13. Classification of predicted and actual Columbian sharp-tailed grouse nests and independent macro-habitat sites in the Curlew Valley region of southeastern Idaho (1988-91) using the forb and grass vegetation variables of HÖRD, LEGU1, LINA, INUL, CRUC6, CHEN1, SANT, and LEGU.

		Predicted Group Membership		
		<u>Nest</u>	<u>Independent Site</u>	<u>Total</u>
<u>Group</u> <u>Membership</u>	Nest	44	7	51
	Percent	86	14	100
	Independent Site	22	23	45
	Percent	49	51	100
	Totals	66	30	96
	Percent	69	31	100
	Priors	53	47	

Table 1.14. Classification of predicted and actual grouse species (sage versus Columbian sharp-tailed (Sharptail) grouse) nests in the Curlew Valley region of southeastern Idaho (1988-91) using the forb and grass vegetation variables of HÖRD, LEGU1, LINA, INUL, CRUC6, CHEN1, SANT, and LEGU.

		Predicted Group Membership		
		<u>Sage Grouse</u>	<u>Sharptail</u>	<u>Total</u>
<u>Group</u> <u>Membership</u>	Sage Grouse	2	36	38
	Percent	5	95	100
	Sharptail	2	49	51
	Percent	4	96	100
	Totals	4	85	89
	Percent	5	95	100
	Priors	43	43	

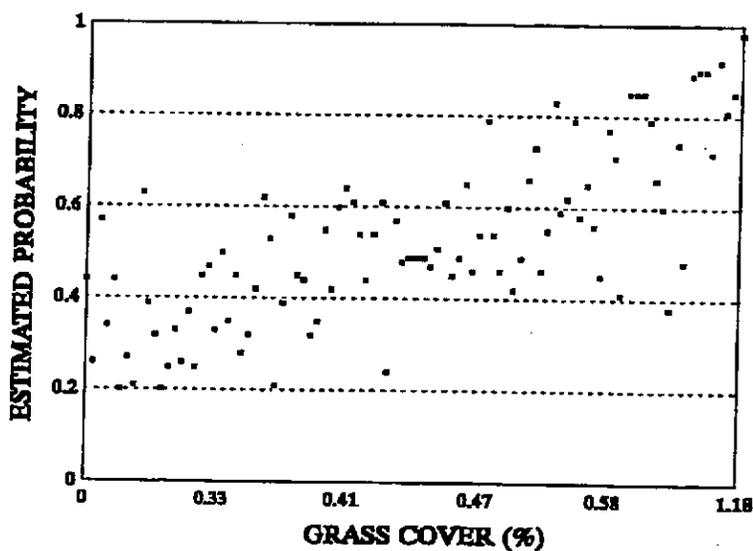


Figure 1.16. The estimated probability of a Columbian sharp-tailed grouse nest, versus an independent macro-habitat site, when transformed grass cover is entered into the logistic regression in the Curlew Valley of southeastern Idaho, 1988-91.

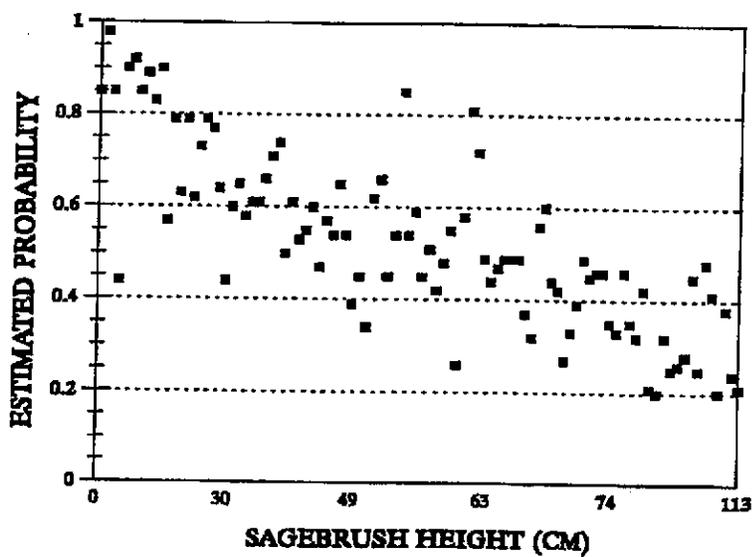


Figure 1.17. The estimated probability of a Columbian sharp-tailed grouse nest, versus a independent macro-habitat site when sagebrush height is entered into the logistic regression in the Curlew Valley of southeastern Idaho, 1988-91.

Then by substituting

$$p = e^{(\text{SHARPTAIL NEST (P)})}$$

the estimated probability that the site is a Columbian sharp-tailed grouse nest site is determined.

Two of the 9 variables entered into the sage grouse versus macro-habitat site were identified as significant contributors to the logistic regression model and correctly classified 59% of the nests. TOTALCC (Wald $\chi^2 = 4.63$, 7 df, $p = 0.0315$) (Fig. 1.18) and FORBHT (Wald $\chi^2 = 5.16$, 8 df, $p = 0.0231$) (Fig. 1.19) were selected. Given the transformed value for FORBHT and the untransformed value of TOTALCC the following model results:

$$\text{SAGE GROUSE NEST (P)} = -2.6235 + (3.2431)(\text{FORBHT}) + (3.5453)(\text{TOTALCC}).$$

Then by substituting

$$p = e^{(\text{SAGE GROUSE NEST (P)})}$$

the estimated probability that a possible site is a sage grouse nest site is determined.

Sage versus Columbian Sharp-tailed Grouse Nests.--Two of the 10 variables entered into the sage versus Columbian sharp-tailed grouse nest sites analysis were identified as significant contributors to the logistic regression model resulting in 75% of the sage grouse nests being correctly classified. SLOPE (Wald $\chi^2 = 8.11$, 8 df, $p = 0.0044$) (Fig. 1.20) and SAGECC (Wald $\chi^2 = 13.12$, 9 df, $p = 0.0003$) (Fig. 1.21) were selected. Given the untransformed values for SLOPE and SAGECC the following model results:

$$\text{SAGE GROUSE NEST (P)} = -2.6277 + (0.1512)(\text{SLOPE}) + (11.3745)(\text{SAGECC}).$$

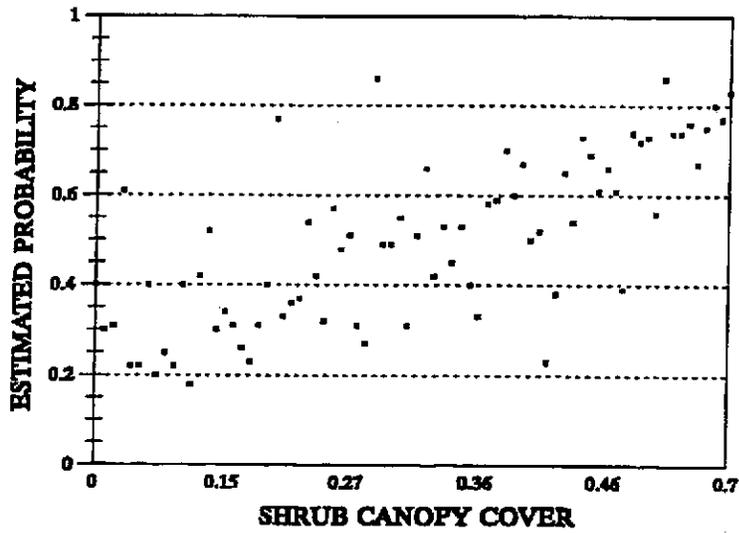


Figure 1.18. The estimated probability of a sage grouse nest, versus an macro-habitat independent site, when total shrub canopy cover is entered into the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

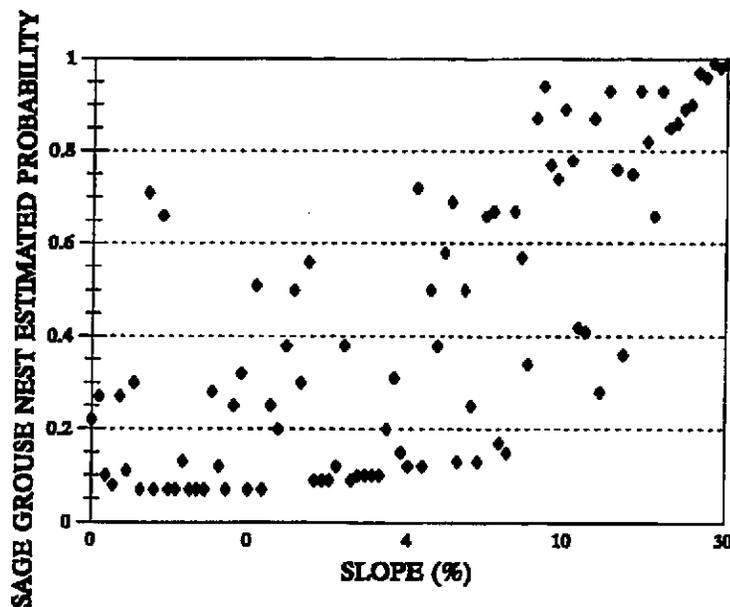


Figure 1.20. The estimated probability of a sage grouse nest, versus a Columbian sharp-tailed grouse nest, when slope is entered into the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

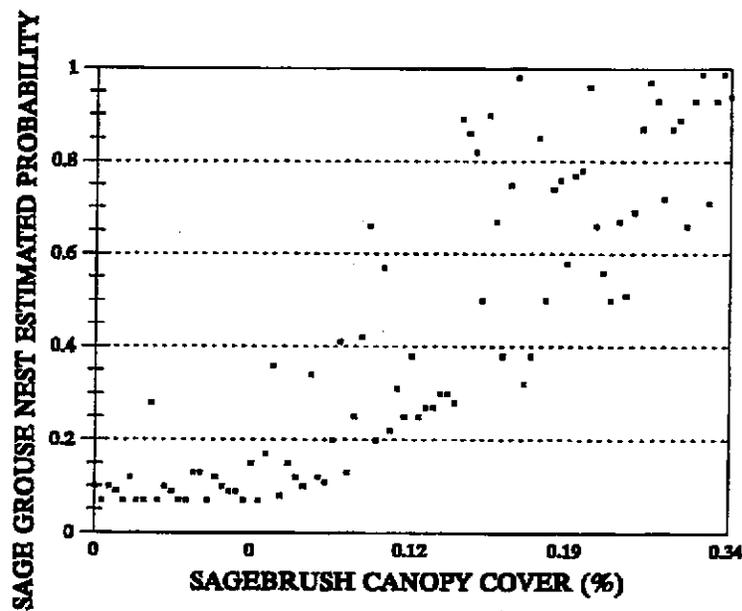


Figure 1.21. The estimated probability of a sage grouse nest, versus a Columbian sharp-tailed grouse nest, when sagebrush canopy cover is entered into the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

Then by substituting

$$p = e^{(\text{SAGE GROUSE NEST (P)})}$$

the estimated probability that the site is a sage grouse nest site is determined given the untransformed values for SLOPE and SAGECC.

DISCUSSION

Female sage grouse in the Curlew Valley varied in weight by age and among years. Similar results were reported by Autenrieth (1981) who suggested that sage grouse weights vary by sex, age, time of year, and by differing populations. My female sage grouse weights were within the range of other studies (Patterson 1952, Dalke et al. 1963, Wallestad 1975, Beck and Braun 1978, Autenrieth 1981) that ranged from 1,310 - 1,700 g. Yearling female sage grouse weights were also within earlier reported weight ranges: 1,220 - 1,600 g (Dalke et al. 1963, Beck and Braun 1978, Autenrieth 1981).

Adult sage grouse hens averaged 100 g more than yearlings which has also been reported (Dalke et al. 1963, Beck and Braun 1978, Autenrieth 1981) with adult hens weighing from 90 - 180 g more than yearlings. The lower weights in yearlings is due to the lack of reproductive tract development and fewer fatty deposits than in adults (Dalke et al. 1963). Female sage grouse weights were the lowest in 1990. The yearly difference found in my study is not explained by the adult:yearling ratio. More adults than yearlings were captured in 1990. Although there is no obvious reason for yearly weight differences in my study, Beck and Braun (1978) found differences in sage grouse weight between different populations. They suggested that the weight differences may be due to habitat quality. Habitat quality may also explain the yearly differences in my study (i.e. habitat quality, annual range condition, etc.), although habitat quality in relation to hen weight was not evaluated in my research.

Female Columbian sharp-tailed grouse weights did not vary by age or among years. Curlew Valley female Columbian sharp-tailed grouse weighed slightly more (16 - 27 g) than Meints (1991) reported in eastern Idaho. Following my study, Schneider (1994) collected birds during 2 winters in the Hansel Mountains adjacent to the Curlew Valley and these birds weighed less (46 - 79 g) than the birds attending dancing grounds captured during my study. Schneider (1994) and my results suggest that Columbian sharp-tailed grouse weights varied through the winter (Fig. 1.22) and then increased by 9% (males) and 13% (females) in April over the mean winter weight. Columbian sharp-tailed grouse do not gain weight throughout the winter as reported by Hupp (1987) with sage grouse.

Sage grouse nesting success in the Curlew Valley (44%) was lower than gallinaceous birds generally and tetraoninae specifically. Nest success for phasianinae and tetraoninae is approximately 55% (Nice 1942), while general grouse nest success is 58% (Hickey 1955). More recently, Bergerud (1988) reviewed 12 sage grouse studies and reported 38% nesting success. Sage grouse nest success in the Curlew Valley (38%) was lower than other grouse species but higher than in Bergerud's review. In contrast, sage grouse nest success (my study) was much lower than reported in other Idaho studies; 61% (Wakkinen 1990) and 52% (Connelly et al. 1991), but higher than Gregg (1991) reported in Oregon (12 and 24% in 2 study areas). The 44% nest success in the Curlew Valley was influenced by the complete failure of hens nesting under non-sagebrush plants. My results agree with (and were a part of) Connelly et al. (1991). They found that sage grouse nesting success was higher under sagebrush than under non-sagebrush shrubs.

Curlew Valley Columbian sharp-tailed grouse nest success (51%) was essentially equal to earlier reports of sharp-tailed grouse nest success (54%) (Bergerud 1988). It was much lower than the 72% reported in another eastern Idaho study (Meints 1991). Meints (1991) acknowledged that the nest success rate in his study was very high, and higher than reported in western Idaho (56%) (Marks and Marks 1987). Hen success (58%) in the Curlew Valley was 30% lower than reported by Meints (1991). In addition, the

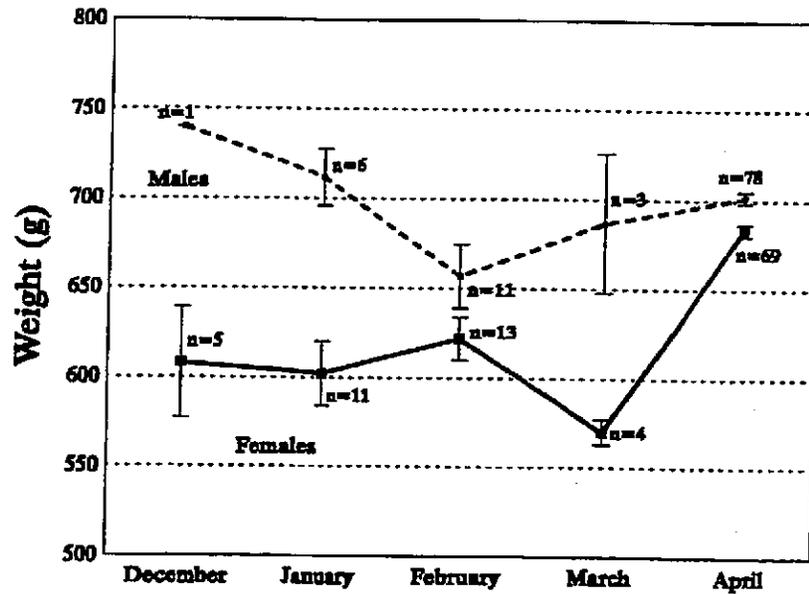


Figure 1.22. Mean weight and 95% confidence limits for Columbian sharp-tailed grouse collected through the winter in the Hansel Mountains (January 1992 - February 1992 and December 1992 - March 1993 (Schneider 1994)) and during the spring (April) on dancing grounds in the Curlew Valley region of southeastern Idaho 1988-91.

re-nesting rate for hens in the Curlew Valley was 15%, while Meints (1991) reported 86%. The discrepancy in our studies may be attributed to different study objectives. Meints (1991) reported solely on Columbian sharp-tailed grouse productivity and habitat use. He also radio-located each bird more intensively, and therefore, was more likely to discover re-nests, and a higher re-nesting rate, whereas my results may have underestimated the re-nesting rate of Columbian sharp-tailed grouse.

I failed to reject the hypothesis that sage and Columbian sharp-tailed grouse nest success was not different. In fact, both grouse species in the Curlew Valley had lower nest success than has been reported previously in other Idaho studies. This would indicate that the reduced nest success is consistently low for both grouse species across my study area.

Gregg et al. (1994) found a direct relationship between vegetation cover and predation of sage grouse nests, whereas Wakkinen (1990) did not. Grass and sagebrush height and cover have been reported as important variables related to nest success (Gregg et al. 1994), although additional factors combined with the aforementioned variables may contribute to nest fate. The presence of native vegetation may be an additional measure of habitat quality and may be related to nest fate. Although similar results were not present with sage grouse, all of the Columbian sharp-tailed grouse nests that were present in native habitats were successful, while 45% of the nests were successful at non-native sites. This resulted in a 120% increase in nest success in native habitat, which can substantially influence productivity.

Sage grouse in the Curlew Valley moved a similar distance from the lek of capture to nest (4.9 km) as reported in other Idaho studies. Fischer (1994) and Wakkinen (1990) reported such movements to be 3.4 and 4.6 km, respectively. Sage grouse also nested closer to the lek of capture than independently placed locations throughout my study area. Similarly, Columbian sharp-tailed grouse nested closer to the lek of capture than independently located points placed around the lek.

Further, I rejected the hypothesis that sage and Columbian sharp-tailed grouse movements from the lek of capture to nest did not differ. Columbian sharp-tailed grouse did not have as specific nesting habitat requirements as sage grouse, and as a result, found adequate nesting habitat closer to the lek of capture. Sage grouse also nested at sites that had greater slope than Columbian sharp-tailed grouse. A concomitant increase in elevation with slope would also be expected, but there was no statistical relationship discovered. Even though a statistical relationship was not detected, a trend of 2 times more Columbian sharp-tailed grouse nests were located at VALLEY and LOW elevations and 1.7 times more sage grouse nests were located at MED-HIGH and HIGH elevations than Columbian sharp-tailed grouse. In addition, Columbian sharp-tailed grouse nested at elevations that were lower than the lek of capture, while 60% of sage grouse nested higher than the lek of capture.

Numerous studies have described fourth-order (Johnson 1980) nest site selection in sage grouse (Patterson 1952, Gray 1967, Klebenow 1969, Wallestad and Pyrah 1974, Peterson 1980, Autenrieth 1981, Wakkinen 1990, Gregg 1991, Fischer 1994). Many authors have found that sage grouse hens place nests under the tallest sagebrush plants in the sagebrush stand, and the mean height of the nest sagebrush varied from 25 cm (Patterson 1952) to 71 cm (Fischer 1994). Sage grouse in the Curlew Valley also nested under the tallest sagebrush within a sagebrush stand, and in 1991, used taller sagebrush than was present at random sites sampled throughout my study area. Although sage grouse nesting habitat in the Curlew Valley illustrated similar results to earlier studies, sagebrush plants averaged 81 cm tall, 10 - 20 cm taller than previously reported. The discrepancy in sagebrush heights is an artifact of sagebrush subspecies and study area location. All of the aforementioned studies occurred in Wyoming big sagebrush habitat types, while the Curlew Valley is dominated by taller, basin, and mountain big sagebrush.

Wakkinen (1990) found that sage grouse hens used sagebrush bushes with larger crowns than sagebrush crowns measured at random locations. My results do not provide

such a decisive separation statistically, but it appeared that sage grouse had a tenacity to use sagebrush plants with larger crowns compared to sagebrush plants in the same sagebrush stand. My failure to detect a significant difference is explained by the yearly changes that occurred in the size of sagebrush crown area: sagebrush crown area increased throughout the duration of my study. This result is not biologically meaningful because sagebrush grows slowly and this magnitude of increase over the duration of my study (4 years), was not detectable in mature sagebrush plants, but was more likely due to the increase in sage grouse nest sample sizes and the use of larger bushes by sage grouse.

Autenrieth (1981) suggested that sagebrush plants provide an umbrella effect that improves security from predation. More specifically, a larger bird would require more horizontal cover than a smaller bird. Female sage grouse are 2.1 times larger than female Columbian sharp-tailed grouse, and I detected a 1.7 times increase in sagebrush crown area (horizontal structure) by female sage grouse over Columbian sharp-tailed grouse. Vertical structure (sagebrush height) did not illustrate a concomitant increase and was 0.8 times larger for sage grouse when compared to Columbian sharp-tailed grouse.

Previous researchers indicated that sagebrush canopy cover (horizontal) is important to nesting hens (Gray 1967, Klebenow 1969, Wallestad and Pyrah 1974, Peterson 1970). Horizontal sagebrush cover was also important to sage grouse in the Curlew Valley. Sage grouse hens nested in areas with higher sagebrush horizontal cover than was present in the adjacent sagebrush stands (14.6%).

Wakkinen (1990) used stepwise logistic regression to develop a predictive model for sage grouse habitat on the Big Desert of Idaho. He found that his classification rate was incorrect 33.6% of the time and concluded that the high misclassification rate was due to the small amount of variation between nest and independent random sites: which suggested that there was a sufficient number of nests sites available on his study area. I found a higher (41%) misclassification rate, but a 59% correct classification rate. If only the misclassification rate is evaluated, the model could appear to have little value, but if nest

site estimated probability is also considered for the variables entered into the model. (total shrub canopy cover and forb height) the model becomes more meaningful. Although there was not a distinct threshold in the relationship between shrub canopy cover and the estimated probability of a sage grouse nest, it is clear that as shrub canopy cover increases, the probability that a site is a sage grouse nest increases. While total shrub canopy cover of 40 - 70% would result in a 0.7 - 0.8 sage grouse nest probability, 0% shrub canopy cover would result in a 0.2 sage grouse nest probability. In addition, sites with forb heights of approximately 15 cm (> 0.40 cm, transformed value) would have a sage grouse nest probability of > 0.6 . More precise probabilities, when both variables are considered, can be determined from previously presented model formulas.

Columbian sharp-tailed grouse nested in areas with higher cover when compared to random locations (Meints 1991). Meints (1991) also reported that antelope bitterbrush (19%) and sagebrush (20%) had higher canopy coverages at nest sites than independent random sites, 5 and 3%, respectively. Marks and Marks (1987) found that female Columbian sharp-tailed grouse nested in areas with higher shrub canopy coverage (62%) than random sites (55%), and Giesen (1987) found that shorter shrubs (< 1.0 m) were 5 times more dense at nest sites than at sites 10 m from the nests or random points. Columbian sharp-tailed grouse in the Curlew Valley nested under sagebrush plants that were taller (89 cm) and appeared to be larger in circumference (9.583 cm²) than plants in the immediate vicinity (20-m radius), 67 cm and 4.318 cm², respectively. My data also suggests that Columbian sharp-tailed grouse nested in areas of lower (9.6%) sagebrush canopy cover than was present within the adjacent sagebrush stand (9.7%), although this value is statistically different, a difference of 0.1% is not biologically meaningful.

Columbian sharp-tailed grouse also used less cover in the Curlew Valley, when compared to independent macro-habitat sites, than reported in previous studies (Giesen 1987, Marks and Marks 1987, Meints 1991). In 1990, Columbian sharp-tailed grouse nest sites were located in sites with less (8.8 versus 15.7%) sagebrush canopy cover and shorter

(57 versus 72.9 cm) sagebrush, but in 1991 the results were similar to previous studies: Columbian sharp-tailed grouse nested in taller (69.7 versus 66.0 cm) sagebrush than was present at independent macro-habitat sites.

More than half (53%) of the Columbian sharp-tailed grouse in my study nested under a grass or forb plant whereas in eastern Idaho, Meints (1991) reported that only 27% of the Columbian sharp-tailed grouse in his study nested in non-shrub areas. More specifically, the herbaceous plants Columbian sharp-tailed grouse nested under in my study were 32% taller (53 versus 40 cm) than the herbaceous plants in the near vicinity (20-m radius). Grass height at shrub nesting hen nests were 35% taller (36.3 versus 26.8) and non-shrub grass heights were 9% shorter (39.8 cm) than reported by Meints (1991). I found no detectable difference between successful and unsuccessful sage or Columbian sharp-tailed grouse nests, although height of the understory vegetation has been shown to influence nest fate (Gregg et al. 1994, Riley et al. 1992). Similar results were found by Meints (1991) with Columbian sharp-tailed grouse in Idaho.

Understory grasses and forbs, with a sagebrush overstory, provide more suitable nesting habitat than a similar sagebrush site with less understory (Rasmussen and Griner 1938). While other sage grouse researchers (Gray 1967, Klebenow 1969, Hulet et al. 1986, Wakkinen 1990, Gregg 1991) have reported about herbaceous cover, only Klebenow (1969), Wakkinen (1990), and Gregg (1991) found more grass cover at nest sites when compared to random sites. In contrast to earlier research, in 1991, sage grouse in the Curlew Valley nested at sites with less grass cover (13.5%) than independent macro-habitat sites (24.5%), although the reverse was true in 1989 (16.2 versus 12.3%) and 1990 (17.0 versus 10.4%).

In a more detailed evaluation of understory grass and forb cover using discriminant analyses, sage grouse nests were uniquely classified at third-order selection (macro-habitat) levels but not at fourth-order (micro-habitat). The great deal of similarity (a large number of misclassifications) between nest sites and dependent micro-habitat sites suggests that

understory cover varied very little within adjacent vegetation stands. In contrast, sage grouse nest understories were uniquely classified from independent macro-habitat sites which suggests third-order selection. Seventy-one percent of sage grouse nests were correctly classified, but independent macro-habitat sites were consistently misclassified as nests. This suggests that grass and forb canopies were unique at sage grouse nest sites. More specifically, much of the covariance of the 8 variables evaluated (HORD, LEGU1, LINA, INUL, CRUC6, CHEN1, SANT, and LEGU) was inherent in 2 variables, HORD (Tribe Hordeae of Family Gramineae) and LEGU1 (Group 1 of Family Leguminosae). HORD included the bunchgrasses, and LEGU1 included the lupines (Lupinus spp.), alfalfa, and yellow sweetclover.

My results in previous analyses suggested that there was no significant difference between nest sites and independent macro-habitat sites for grass (15.1 versus 17.9%) and forb (9.5 versus 8.6%) cover. Therefore, such a result would be misleading and only a detailed evaluation of grass and forb cover would adequately describe sage grouse nest sites and provide a meaningful insight to nest site quality. My data suggest that the general measurement of grass cover is inadequate in the description of sage grouse nest sites. My results suggest that the bunchgrasses in the Tribe Hordeae as well as the forb species in Group 1 of Leguminosae are critical in the classification of sage grouse nest sites from independent macro-habitat sites. Therefore, only the evaluation of grass cover could be misleading and future research should report grass cover in greater detail to better describe sage grouse nesting habitat.

With respect to understory grass and forb cover, Columbian sharp-tailed grouse nest sites were uniquely classified at third-order selection (macro-habitat) levels but not at fourth-order (micro-habitat). There was a great deal of similarity between nest and dependent micro-habitat sites as was illustrated with sage grouse. Eighty-six percent of Columbian sharp-tailed grouse nests were correctly classified when compared to independent macro-habitat sites. Independent macro-habitat sites were equally

misclassified as nests when compared to independent macro-habitat sites. This suggests that Columbian sharp-tailed grouse nest understories were unique from independent macro-habitat sites. More specifically, much of the covariance of the 8 vegetation variables evaluated was inherent in bunchgrasses of HORD and legumes of LEGU1. As previously mentioned with sage grouse, Columbian sharp-tailed grouse total grass and forb cover was 27.8% at nest sites and did not differ from macro-habitat sites (21.7%).

Meints (1991) found in a logistic regression that 96% of the nest sites were correctly classified. He concluded that Columbian sharp-tailed grouse occupied a more heterogeneous shrub-steppe community and demonstrated a more active selection of nest habitat characteristics. My logistic regression was not as successful as Meints (1991) with only 58% of the nests being correctly classified. Tall grass cover and low sagebrush height estimated the occurrence of a Columbian sharp-tailed grouse nest. In the determination of grass cover $> 19\%$ (transformed value = 0.45) resulted in a > 0.5 Columbian sharp-tailed grouse nest site probability. Columbian sharp-tailed grouse also did not require tall sagebrush and sagebrush < 50 cm tall was more predictive of Columbian sharp-tailed grouse nest.

Sage and Columbian sharp-tailed grouse nest sites provided higher security cover when compared to non-use sites. Cover board readings in the Curlew Valley were consistently higher at grouse nests than at dependent micro-habitat sites (30% higher) and independent macro-habitat sites (10% higher). Wakkinen (1990) suggested that cover board readings were not sensitive enough to detect differences in sampling sites and other researchers (Storaas and Wegge 1987) also found no differences in cover board readings. In contrast, and consistent with my results, Fischer (1994) found that cover board readings were consistently higher at sage grouse nest sites than at dependent micro-habitat sites.

Shrub steppe cover board readings can vary and are influenced by the herbaceous horizontal and vertical structure. In my study area the primary influences on herbaceous understory were herbivory and precipitation. Precipitation influenced grass and forb

height. Precipitation was higher during the latter portion of my study than initially portion. The higher precipitation was tracked by a concomitant increase in cover board readings. Another impact on vegetation horizontal and vertical cover would be herbivory (Rickard et al. 1975). I did not specifically evaluate the impact of herbivory on nesting sage or Columbian sharp-tailed grouse, but further research is needed. Livestock grazing is a dominant land use practice in the Curlew Valley and, in combination with dry years, could potentially influence grass and forb cover which have been directly related to sage grouse nest predation (Gregg et al. 1994).

Habitat Sympatry

Sage and Columbian sharp-tailed grouse habitat use was partitioned; I rejected the hypothesis that niche breadth and overlap did not differ. Grouse segregated habitat geographically. Columbian sharp-tailed grouse nested in areas with less slope than sage grouse. In the Curlew Valley an increase in slope typically corresponded with an increase in elevation. Higher elevation sites were typical of sage grouse nests. Sage grouse nests were also higher in elevation than the mean lek elevation and located on steeper slopes than Columbian sharp-tailed grouse. Higher elevation sites were typical of mixed shrub or mountain big sagebrush communities and also exhibited an increase in shrub cover. These habitats also had overall larger sagebrush plants and were more often occupied by sage grouse than Columbian sharp-tailed grouse. Sage grouse nested under larger sagebrush plants and nested in areas with nearly twice as much sagebrush canopy cover, and increased litter cover than did Columbian sharp-tailed grouse.

In the determination of sage or Columbian sharp-tailed grouse nest site predictability, slope and sagebrush canopy cover were important variables. Sage grouse nest sites at $> 4\%$ slope had a > 0.5 estimated probability, while Columbian sharp-tailed grouse nest site typically had reduced slope. In addition, sites with $> 12\%$ sagebrush

canopy cover had a higher probability of being a sage grouse nest site while less sagebrush canopy cover was characteristic of Columbian sharp-tailed grouse nests sites.

Columbian sharp-tailed grouse were not as dependent on an overstory sagebrush cover for nest sites when compared to sage grouse. Grass and forb composition better characterized and correctly classified Columbian sharp-tailed grouse nests when compared to sage grouse nests, although my previous results of grass and forb canopy coverages were found to be similar between sage and Columbian sharp-tailed grouse (24.6 versus 27.8%). As discussed earlier, grouse understory nesting habitat was dominated by bunchgrasses of HORD and the forbs of LEGU1. A preponderance of the covariance at Columbian sharp-tailed grouse nest sites was described by the bunchgrasses of HORD, but to a lesser extent the forbs LEGU1. In contrast, sage grouse nest covariance was more equally divided between bunchgrasses and forbs. This resulted in bunchgrasses and forbs being equally important at sage grouse nests while bunchgrasses were more important in the classification of Columbian sharp-tailed grouse nests. Ninety-five percent of sage grouse nests were misclassified as Columbian sharp-tailed grouse nests, as a result of grasses dominating the Columbian sharp-tailed grouse understory, and sage grouse nest sites were not uniquely classified. Generally, bunchgrass cover is very important in the classification of sage and Columbian sharp-tailed grouse nests, although bunchgrass cover is more descriptive of Columbian sharp-tailed grouse nests. In contrast, while forb cover is also important for both grouse species, a combination of bunchgrasses and forb cover was more descriptive of sage grouse nests. The increased bunchgrass cover represented Columbian sharp-tailed grouse nests which were more characteristic of CRP land and intensively managed sagebrush communities, while understories with a mix of bunchgrasses and forbs were more characteristic of sage grouse nests and more typical of native sagebrush communities and less intensively managed sagebrush communities.

Sage grouse use of less intensively managed habitats is also supported by a concomitant increase in plant species richness at sage grouse sites and lower richness at

Columbian sharp-tailed grouse sites. Approximately 75% of the Curlew National Grasslands was seeded to ≤ 5 species of non-native grasses and ≤ 3 species of non-native forbs (U.S. Dept. of Agriculture, unpublished report). In addition, several thousand hectares of lower elevation BLM land has either been converted to non-native rangeland with similar seed mixes to CRP through rangeland "improvements" or wildfire "rehabilitation." In addition, there also are large blocks of privately owned land that have been enrolled in CRP and plantings consisted of non-native grass (crested wheatgrass) and forb (alfalfa) mixtures that consisted of ≤ 5 species. Many of the aforementioned lower elevation, highly-modified sites were characterized as non-native and extensively used by Columbian sharp-tailed grouse as nest sites, and had 60% less plant species richness than sage grouse nest sites.

Sage and Columbian sharp-tailed grouse have different life history strategies. Bergerud (1988:589) reported that sage and sharp-tailed grouse have 2 distinct clutch sizes and annual mortality rates. Sharp-tailed grouse have a high clutch size (10 - 14 eggs) and a high annual mortality (51 - 75%). In contrast, sage grouse have a low clutch size (5 - 8 eggs) and a low annual mortality rate (21 - 41%). These differences in productivity and mortality also lend credence to other hypotheses concerning life-history strategies in terms of fecundity and mortality (Williams 1966). Williams (1966) suggested that species with high rates of mortality and high fecundity would sacrifice the future expectation of reproduction by trying to raise a large number of young each breeding season. With the inherent risk of mortality, it would be prudent to mature faster (no age class dimorphism). Therefore, the lack of age class dimorphism for Columbian sharp-tailed grouse, their high reproduction, and high annual mortality rates would support Williams (1966) hypothesis. In contrast, sage grouse exhibit low fecundity, low annual mortality, and age class dimorphism. I would suggest that a prudent strategy for a yearling female sage grouse would be to minimize the risk of mortality incurred by reproduction and delay reproduction to future years. Because most females attempt to breed their first year (Bergerud 1988) the

risk of mortality must be reduced in other ways. Therefore, yearling females may minimize their risk of mortality through lower clutch size, higher nest abandonment, and lower renesting rates (Bergerud and Gratson 1988).

MacArthur and Wilson (1967), and Pianka (1970), described r- and k-selection as the 2 principle kinds of selection resulting from the effects of resources on the density of species. In its broadest sense, classic wildlife management has categorized "game birds" in the r-selection category, but most broad generalizations can be incorrect or misleading. More specifically, when the life history strategies of sage and Columbian sharp-tailed grouse are compared, the classic r-selective strategy designation for game birds is in doubt. Natural selection favors r-selected species that have the characteristics of rapid development, a high r_{max} , early reproduction, small body size, and short life-span (high annual mortality) which leads to high productivity. Columbian sharp-tailed grouse (when compared to sage grouse) exhibit these traits. Sage grouse can be depicted as k-selected because of their slower physical development, lower resource threshold (least resistant to changes), delayed reproduction, larger body size, and longer life-span (lower annual mortality). MacArthur and Wilson (1967) further suggested that r-selective forces tend to lead to species generalization and broader niche breadth (Hutchinson 1958, Krebs 1989) while k-selected species are more specialized and have narrower niche breadths.

Although niche breadth estimates between sage and Columbian sharp-tailed grouse did not differ statistically, sage grouse (when compared to Columbian sharp-tailed grouse) appeared to have narrower nesting habitat niche breadths in 6 of 9 resource states. Sage grouse niche breadth was noticeably broader in only 1 resource state and only slightly larger in the remaining 2 resource states. Therefore, I suggest that sage grouse were more specialized in nesting habitat characteristics than Columbian sharp-tailed grouse, who illustrate more generalized classic r-selective strategies.

An evaluation of only niche height and breadth can be misleading and uninformative, especially when species are sympatric (Krebs 1989). The resource

procurement of a variety of resources are important in habitat partitioning, but niches are typically not symmetrical and Krebs (1989) suggested it is more useful to review niche breadth and overlap directly. Total shrub canopy cover (Fig. 1.23) use by sage and Columbian sharp-tailed grouse illustrated a moderate degree of niche overlap, but more specifically sage grouse segregated nest habitat and alleviated competition by nesting in the medium and high canopy cover portion of the shrub canopy gradient while Columbian sharp-tailed grouse use was greater throughout the shrub resource gradient. The resulting niche breadth for Columbian sharp-tailed grouse was broader than for sage grouse. Slope (Fig. 1.24) was partitioned in a slightly different manner than total canopy cover, but there was only a moderate amount of niche overlap. Columbian sharp-tailed grouse use was higher in the lower slope portion of the gradient and use declined dramatically towards the higher sloped portion of the slope gradient. There were 2 lower peaks of sage grouse use at the lower and higher ends of the slope resource gradient, thus alleviating potential competition. In contrast, grass cover (Fig. 1.25) illustrated a large degree of niche overlap and both grouse species use grass cover in the low to medium range, but as grass cover increased, sage grouse use declined more drastically than Columbian sharp-tailed grouse.

Sage and Columbian sharp-tailed grouse partitioned nesting habitats in the Curlew Valley region of southeastern Idaho while still coexisting sympatrically in the niche hypervolume. Habitat sympatry allowed for coexistence of both grouse species with a minimal degree of, or no, competition because sage and Columbian sharp-tailed grouse use many habitat characteristics differently. In addition, sage grouse tended to use available resources in a more specialized manner while Columbian sharp-tailed grouse used available resources in a generalized manner. No single habitat variable can completely describe sage and/or Columbian sharp-tailed grouse habitat, but varying degrees of each habitat variable along a resource continuum is used at differing levels and must be considered in the management of both species of grouse.

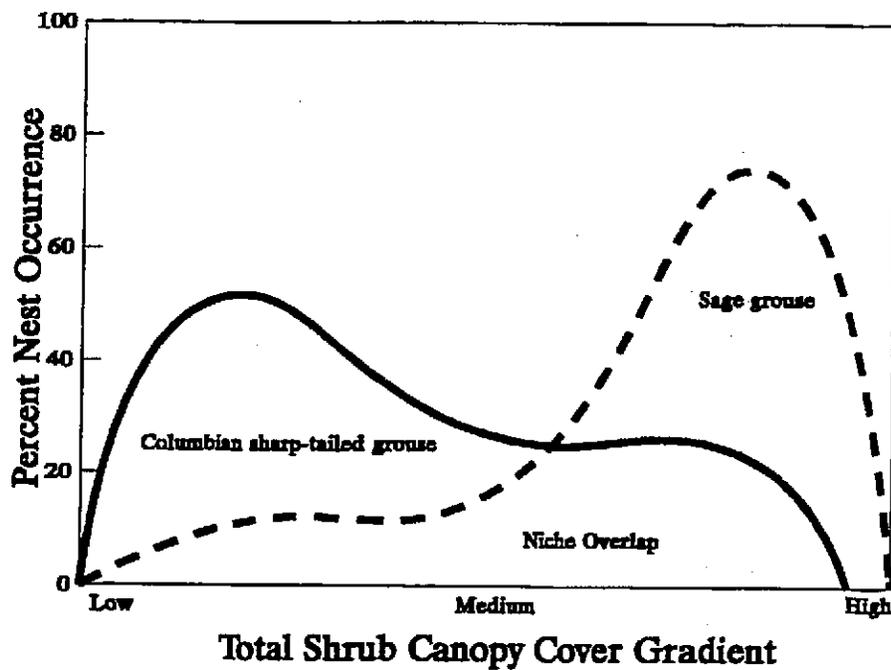


Figure 1.23. Graphical representation of sage and Columbian sharp-tailed grouse nest niche breadth and overlap along the total shrub canopy cover gradient in the Curlew Valley region of southeastern Idaho, 1988-91.

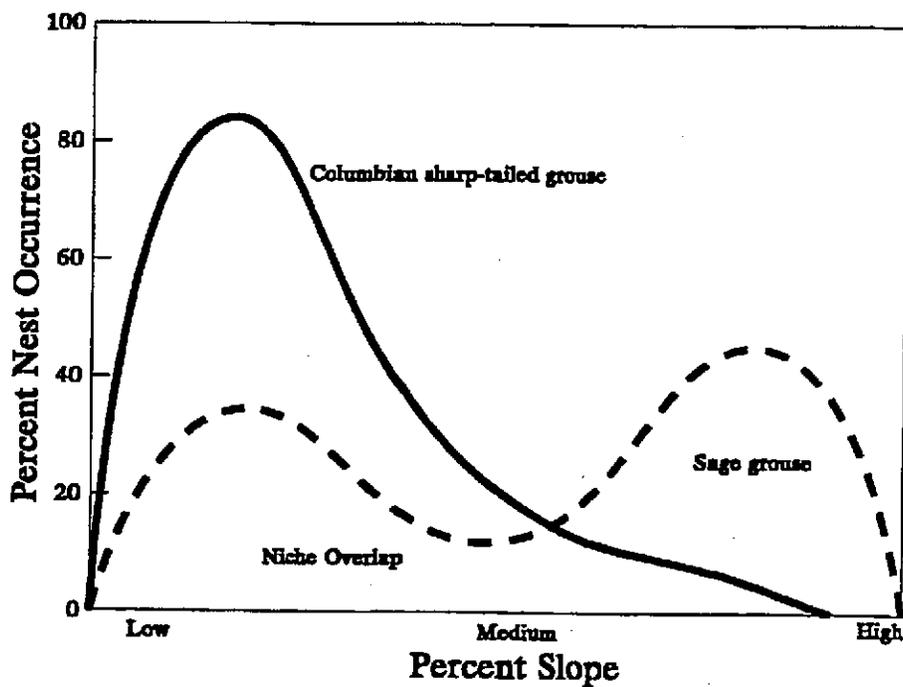


Figure 1.24. Graphical representation of sage and Columbian sharp-tailed grouse nest niche breadth and overlap along the slope gradient in the Curlew Valley region of southeastern Idaho, 1988-91.

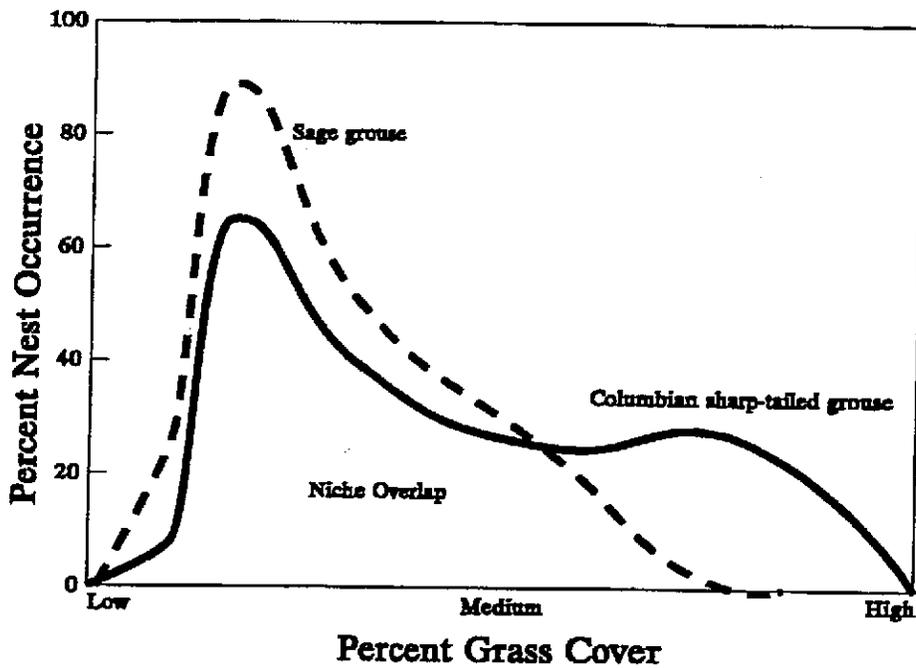


Figure 1.25. Graphical representation of sage and Columbian sharp-tailed grouse nest niche breadth and overlap along the grass cover gradient in the Curlew Valley region of southeastern Idaho, 1988-91.

MANAGEMENT IMPLICATIONS

Single species or "like-species" management is convenient for wildlife and habitat managers, but may be detrimental to sage and/or Columbian sharp-tailed grouse. Habitat management is typically the responsibility of federal agencies and private landowners, and fire is the most commonly prescribed management tool for sagebrush control in the shrub steppe (Blaisdell 1953, Wright et al. 1979). As a result, sagebrush habitats have declined since western settlement (Beetle 1960, Schneegas 1967, Sturges 1973, Braun et al. 1976). My findings have added to the extensive literature that has described the ultimate dependence of sage grouse on sagebrush during the nesting season, but the mere presence of high canopy coverages of sagebrush with a generic understory of grass is not sufficient. There is a level of quality associated with sagebrush-grass cover. Sagebrush plants that are approximately 80-100 cm tall, have plant crowns that are 10,000 - 14,000 cm². bunchgrasses that, at the end of the growing season, have heights of 30 - 40 cm. with 10 - 20 plant species in the community will provide optimal sage grouse nesting habitat. The upper elevation sites in the Curlew Valley managed by the BLM provided the aforementioned habitat characteristics and were critical to sage grouse as nesting habitat. These sagebrush communities are important nesting habitat because of their inherent high quality. My results agree with Gregg et al. (1994) that management activities should allow for the maintenance of grass and forb cover in sagebrush understories and any such activities that drastically and irrevocably damage the over- or understory should be modified or eliminated. My recommendation should also be considered minimal due to the inherently low nest success that occurred in the Curlew Valley. Valuable future research in the Curlew Valley should evaluate sage grouse habitat preference and quality as it relates to habitat fragmentation and nesting habitat patch size.

The sagebrush-grass community in the lower elevations of the Curlew Valley, managed by the USFS, was intensively managed for low sagebrush cover and increased grass production for livestock grazing. The area was also dominated by non-native grass

and forb species. The sites generally have reduced plant species richness, lower sagebrush canopy cover quality and quantity which is inherently unsuitable sage grouse nesting habitat, but apparently suitable for Columbian sharp-tailed grouse.

My data clearly illustrate that Columbian sharp-tailed grouse are nest habitat generalists and can adapt to many different habitats. As a result, Columbian sharp-tailed grouse are the easiest and least controversial species for which to manage nesting habitat. In contrast, sage grouse habitat treatment is more controversial because sage grouse are more specialized in their nesting habitat requirements and require a sagebrush overstory and high quality grass and forb understory for nesting habitat. Therefore, if a land management agency that has sympatrically occurring sage and Columbian sharp-tailed grouse attempts single species management, they should manage rangelands to meet the habitat requirements of the more specialized grouse species, sage grouse. Columbian sharp-tailed grouse are more adaptable and occupy a much broader nesting habitat niche which allows the species to adapt to many different types of management. In addition, all future sagebrush control projects in the Curlew Valley should be approached cautiously and critically reviewed, especially considering recent wildfires which removed sagebrush cover and recent sage grouse declines and low sage and Columbian sharp-tailed grouse nest success rates. If the resulting management of sagebrush is warranted, then site rehabilitation efforts should include a more diverse native plant species mix (≥ 10 shrub, grass and forb species) that would be more beneficial for sage and Columbian sharp-tailed grouse nesting habitat.

CHAPTER II.

SYMPATRIC SAGE AND COLUMBIAN SHARP-TAILED GROUSE BROOD HABITAT USE AND MOVEMENTS IN SOUTHEASTERN IDAHO

INTRODUCTION

Cody (1985) suggested that ecologically similar species, especially congeners, typically segregate through selection of habitat. Because species almost never occur alone in the environment, Wiens (1969) and Cody (1974, 1978) suggested that an ideal pattern of habitat selection is modified by competitive interactions with other community residents that would change and mold patterns of habitat partitioning allowing the coexistence of ecologically similar species. The eastern sage (Centrocercus urophasianus urophasianus) and the Columbian sharp-tailed (Tympanuchus phasianellus columbianus) grouse are sympatric in southeastern Idaho. Aldrich (1963) first reported that sage and sharp-tailed grouse distributions overlapped extensively in the western United States, but only 1 study (Klott and Lindzey 1989, 1990) has attempted to evaluate the sympatric brood habitat relationship of the 2 species.

Numerous observational studies have documented habitat use by each individual grouse species. Sage grouse brood-rearing habitat has been evaluated in Wyoming (Patterson 1952), Oregon (Drut et al. 1994), Montana (Patterson 1952, Peterson 1970, Wallestad 1971), Colorado (Dunn and Braun 1986), Nevada (Oakleaf 1971), and Idaho (Dalke et al. 1963, Klebenow and Gray 1968, Klebenow 1969, Autenrieth 1981, Connelly 1982, Fischer 1994). The Columbian sharp-tailed grouse has not been as extensively studied, although brood-rearing habitat has been described in Wyoming (Oedekoven 1985), Colorado (Giesen 1987), Washington (Stralser 1991) and Idaho (Parker 1970, Meints 1991).

Use of sagebrush (*Artemisia* spp.) habitats by sage grouse varies spatially and temporally. Sage grouse hens with broods are more dependent on sagebrush habitats during the early and late summer (Wallestad 1971). Sage grouse broods also move in response to vegetation (forbs) desiccation (Peterson 1970, Wallestad 1971, Autenrieth 1981, Fisher et al. 1996a, 1996b, 1997) through the summer. Although brood use of sagebrush habitats is less frequent from July through September (Peterson 1970, Connelly and Markham 1983), Dunn and Braun (1986) suggested that shrub horizontal cover and habitat interspersions were important factors of summer habitat.

Columbian sharp-tailed grouse spring and summer habitat in Wyoming was described as mixed shrub communities with high forb densities and higher snowberry (*Symphoricarpos* spp.) frequency than other habitats (Oedekoven 1985, Klott and Lindzey 1990). In Idaho, Meints (1991) found that Columbian sharp-tailed grouse broods were located closer to habitat edges, leks, and riparian areas than random locations, and that the sagebrush and grass were taller at brood locations than at independent locations.

Habitat studies are frequently focused on habitat loss with a single species. With sage and Columbian sharp-tailed grouse, habitat loss due to agricultural development is conspicuous although extensive losses typically occur on private lands. The influence of livestock grazing on public land is more prevalent and noticeable in the remaining sage and Columbian sharp-tailed grouse range (Marshall and Jensen 1937, Rogers 1969, Zeigler 1979). Unfortunately many brood-rearing habitat studies only focus on a single species (either sage or Columbian sharp-tailed grouse) and do not evaluate situations where both species coexist.

Therefore, the goal of my study was to provide scientific knowledge about sympatrically occurring sage and/or Columbian sharp-tailed grouse brood habitat while providing information to aid wildlife and habitat managers in making decisions regarding these 2 shrub-steppe tetraonids. The objectives of my study were, for sympatrically occurring sage and Columbian sharp-tailed grouse in a portion of their remaining imbricate

range, to determine brood-rearing habitat use at micro- and macro-habitat levels, determine brood movements, compare brood-rearing habitat with nesting habitat, and determine brood-rearing habitat niche breadth and overlap.

I hypothesized that: 1) sage and Columbian sharp-tailed grouse do not differ in sites selected for brood-rearing at micro- and macro-habitat levels, 2) sage and Columbian sharp-tailed grouse mean daily movements do not differ between species and between brood-rearing and nonbrood-rearing hens, 3) sage and Columbian sharp-tailed grouse brood-rearing habitat niche breadths do not differ, and 4) nesting habitat and brood-rearing micro- and macro-habitat variables between sage and Columbian sharp-tailed grouse do not differ, and 5) nesting habitat and brood-rearing habitat niche breadths do not differ between sage and Columbian sharp-tailed grouse.

METHODS

Bird capture, marking, and radio-tracking techniques were similar and described in Chapter I. After a general location was defined, I determined a more precise (± 20 m) brood location by circling the hen with her brood at a 30-50 m radius. Markers (surveyors flagging) were placed equidistant in the approximate cardinal directions around the brood location. The precise brood location was determined as the intersection of the 4 markers. Extreme care was taken not to flush or influence movement of the hen and brood. I plotted the brood locations on 7.5' topographic quadrangle maps and the Universal Transverse Mercator (UTM) Coordinates were recorded. I collected detailed micro-habitat measurements in the same manner as described in Chapter I.

Statistical Analyses

Data from all 4 years of the study were pooled into 2 years for statistical analyses. The years 1988 and 1989 were pooled because there were no brood site samples collected for sage grouse in 1988 and for Columbian sharp-tailed grouse in 1989. The years of 1990

and 1991 were also pooled because there were no brood site samples collected for sage and Columbian sharp-tailed grouse in 1990. The 2 years of my study were pooled ($P \geq 0.05$) throughout the statistical analyses unless otherwise stated.

Daily Movements.—I used a Kruskal-Wallis ANOVA to evaluate the daily movements (m/day) for sage and Columbian sharp-tailed grouse. Daily movements were determined by calculating the linear distance between consecutive locations, and the resulting distance was divided by the number of days between locations. Due to observed data distributions and sample size restrictions, consecutive locations > 10 days were excluded from the analyses. Samuel and Fuller (1994) suggested that locations greater than 5 days apart be excluded from daily movement analyses to reduce daily movement bias, although the authors included the caveat that each study data set is unique.

Physiographic Variables.—Slope and elevation were partitioned into the same categories as described in Chapter I. Possible differences in site selection for slope, aspect, and elevation were evaluated between years and between sage and Columbian sharp-tailed grouse brood sites and between sage and Columbian sharp-tailed grouse brood sites and independent macro-habitat locations. I tested for year homogeneity using Chi-square tests (Zar 1984). A final Chi-square test of independence was conducted between sage and Columbian sharp-tailed grouse brood sites and between grouse brood sites and independent macro-habitat sites.

Plant Species Richness.—The analyses of plant species richness data were similar to the analyses described in Chapter I. Species richness for the total number of plant (TOTALRICH), shrub (SHRUBRICH), grass (GRASSRICH), forb (FORBRICH), and grass and forb (UNDERRICH) species were evaluated for normality. Variables were also evaluated for collinearity. The variables of TOTALRICH and UNDERRICH were correlated ($R = 0.9749$, $n = 155$, $P = 0.0001$) as were FORBRICH and UNDERRICH ($R = 0.9656$, $n = 155$, $P = 0.0001$).

Niche Breadth And Overlap.--Niche breadth and overlap was evaluated in the same manner as described in Chapter I for the resource states, except Group 1 was considered shrub or non-shrub sites and Group 4 was used as shrub height \geq or \leq 40 cm (Table 1.1).

Comparisons Of Independent Macro-habitat Locations.--I simplified a potentially complex model to simultaneously evaluate possible differences between sage and Columbian sharp-tailed grouse brood sites with several dependent vegetal variables. The model reduction is similar as earlier described in Chapter I with the exception that there were only 2 years (1989 and 1990) in the brood habitat analyses.

Understory Comparisons Of Nests Versus Independent Macro-habitat Locations.--Throughout the aforementioned analyses, the herbaceous understory was evaluated by pooling all the grass and forb species. The analyses is similar to that described in Chapter I.

Stepwise Logistic Regression And Brood Site Type.--Stepwise logistic regression (maximum likelihood method) was used to evaluate brood and non-brood sites and sage and Columbian sharp-tailed grouse brood sites and is similar to the analyses in Chapter I.

Brood Versus Nest Sites.--A similar process to the aforementioned brood and nest site statistical analyses was used to compare brood and nest sites for sage and Columbian sharp-tailed grouse. Parametric tests were used when possible, but if assumptions of normality were not met by data transformations, I used the appropriate nonparametric statistical tests or multivariate techniques.

RESULTS

Median Daily Movements

Over 4 years, I recorded 431 sage and Columbian sharp-tailed grouse brood and non-brood locations. Of the total locations, 54% ($n = 234$) of the locations were 1-10 days apart, 28% ($n = 120$) were 11-23 days apart, 14% ($n = 59$) were 24-42 days apart, and 4% ($n = 18$) were 46-66 days apart. All consecutive locations > 10 days apart were

excluded from the analyses. The remaining locations represented 54% ($n = 234$) of the total data set and were collected from 34 individual female grouse (Table 2.1).

Median daily movements for sage grouse hens were greater ($H = 8.56$, 1, 29 df, $P = 0.0066$) than that of Columbian sharp-tailed grouse (Table 2.2). In addition, grouse (sage and Columbian sharp-tailed grouse) hens movements without broods had longer ($H = 8.04$, 1, 29 df, $P = 0.0083$) median daily movements than hens with broods (Table 2.2). Sage grouse with (median = 144, range 67 - 192) and without broods (median = 284, range 220 - 491) and Columbian sharp-tailed grouse with and without broods had similar ($H = 2.58$, 1, 29 df, $P = 0.1188$) daily movements (Table 2.2).

Physiographic Habitat Variables

Slope.--No relationship was found with regards to slope for sage ($X^2 = 5.69$, 3 df, $P = 0.128$) or Columbian sharp-tailed ($X^2 = 0.94$, 2 df, $P = 0.624$) grouse and independent macro-habitat sites. Independence of brood site location with regard to slope was exhibited between sage and Columbian sharp-tailed grouse ($X^2 = 0.35$, 1 df, $P = 0.555$).

Elevation.--No relationship was exhibited with respect to elevation for sage ($X^2 = 5.87$; 4 df; $P = 0.209$) or Columbian sharp-tailed ($X^2 = 1.85$; 3 df; $P = 0.604$) grouse and independent macro-habitat sites. Years were heterogeneous for sage and Columbian sharp-tailed grouse with regards to elevation ($X^2 = 9.02$, 3 df, $P = 0.03$) and years were not pooled. In 1989, more ($X^2 = 9.94$, 4 df, $P = 0.041$) Columbian sharp-tailed grouse broods were found at VALLEY (9 vs 4), LOW (0 vs 2), MIDDLE (5 vs 4) elevations than sage grouse, but more sage grouse were found at MED-HIGH (0 vs 2) and HIGH (0 vs 4) elevations than Columbian sharp-tailed grouse. In 1990, sage and Columbian sharp-tailed grouse used brood sites at elevations in proportion with each other ($X^2 = 4.07$, 3 df, $P = 0.254$) and no broods were found in the HIGH elevation category.

Table 2.1. Number of individual female sage and Columbian sharp-tailed grouse by year used for daily movement data in the Curlew Valley region of southeastern Idaho, 1988-91.

<u>Year</u>	<u>Sage Grouse</u>		<u>Columbian Sharp-tailed Grouse</u>	
	<u>Brooding</u>	<u>Nonbrooding^a</u>	<u>Brooding</u>	<u>Nonbrooding^a</u>
1988	0	4	2	6
1989	2	0	0	0
Pooled Total	2	4	2	6
1990	1	0	3	0
1991	6	0	8	1
Pooled Total	7	0	11	1
Total	9	4	14	7

^aFemale is either an unsuccessful nester and/or no nesting attempt was recorded.

Table 2.2 Median daily movements and ranges of female sage and Columbian sharp-tailed grouse with and without broods in the Curlew Valley region of southeastern Idaho, 1988-91.

	<u>Sage Grouse</u>			<u>Columbian Sharp-tailed Grouse</u>		
	<u>n</u>	<u>m/day^a</u>	<u>Range</u>	<u>n</u>	<u>m/day^a</u>	<u>Range</u>
Hens with Brood	9	144	67 - 192	13	86	37 - 154
Hens without Brood	4	284	220 - 421	7	98	52 - 340
Total	13	152	67 - 421	20	88	37 - 340
	<u>Sage and Columbian sharp-tailed Grouse</u>					
Hens with Brood	22	94	37 - 192			
Hens without Brood	11	172	52 - 421			

^aANOVA on ranks, medians and ranges reported.

Aspect.—No relationship was found with regards to aspect for sage ($\chi^2 = 4.92$, 4 df, $P = 0.296$) or Columbian sharp-tailed grouse ($\chi^2 = 4.96$, 4 df, $P = 0.291$) and independent macro-habitat sites. Sage and Columbian sharp-tailed grouse did not use brood-rearing sites in equal proportion at all aspects ($\chi^2 = 12.74$; 4 df; $P = 0.013$). Sage grouse used sites that were more WESTERLY in aspect (11 vs 8) when compared to Columbian sharp-tailed grouse (5 vs 7), whereas Columbian sharp-tailed grouse used sites that had NO ASPECT (12 vs 6) more than sage grouse and sage grouse used NO ASPECT sites less frequently than expected (2 vs 7).

Plant Species Richness

Years could not be pooled ($H = 12.01$, 1, 143 df, $P = 0.0007$) for the species richness analyses (Fig. 2.1). There was differing species richness between species of grouse and years ($H = 6.20$, 1, 143 df, $P = 0.0139$) at the 3 aforementioned sampling locations. There was higher plant species richness at sage grouse sites in 1989 than in 1990 ($P = 0.0001$) (Fig 2.2). There was also higher plant species richness at sage grouse sites in 1989 than at Columbian sharp-tailed sites in 1989 ($P = 0.0001$) and 1990 ($P = 0.0001$) (Fig. 2.2). Although species richness was not significantly different among sampling locations ($H = 2.67$, 2, 143 df, $P = 0.0730$) and was different between years, there was a possible trend with increased plant species richness at brood sites and decreasing at dependent micro-habitat and independent macro-habitat sites (Fig. 2.3).

I evaluated species richness relative to whether or not a brood site was native or non-native habitat. Years were not pooled ($H = 14.04$, 1, 149 df, $P = 0.0003$), although the interaction between type of site and years could not be evaluated in detail ($H = 0.30$, 1, 149 df, $P = 0.5857$). Species richness was higher ($H = 18.42$, 1, 149 df, $P = 0.0001$) at native sites than non-native sites (Fig. 2.4). In contrast, there was no relationship between

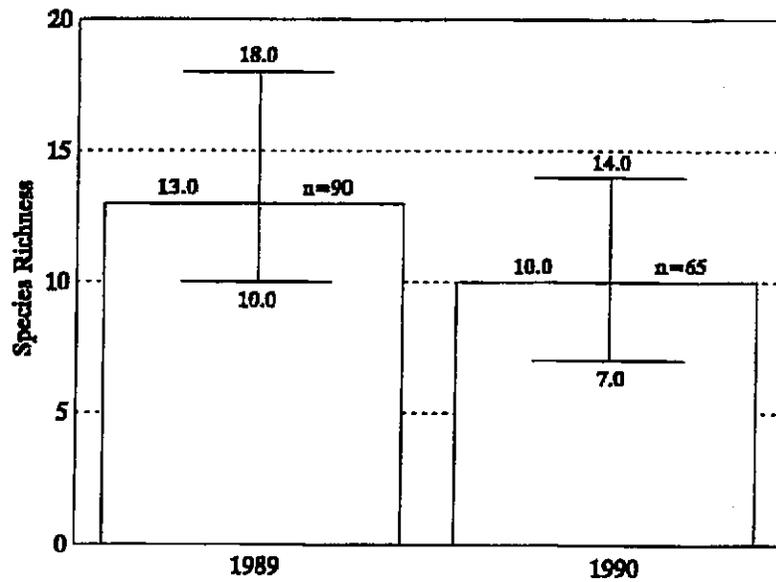


Figure 2.1. Plant species richness median and upper and lower quartiles at combined sage and Columbian sharp-tailed grouse brood, dependent micro-habitat, and independent macro-habitat sites in 1989 (1988 and 1989) compared 1990 (1990 and 1991) in the Curlew Valley region of southeastern Idaho, 1988-91.

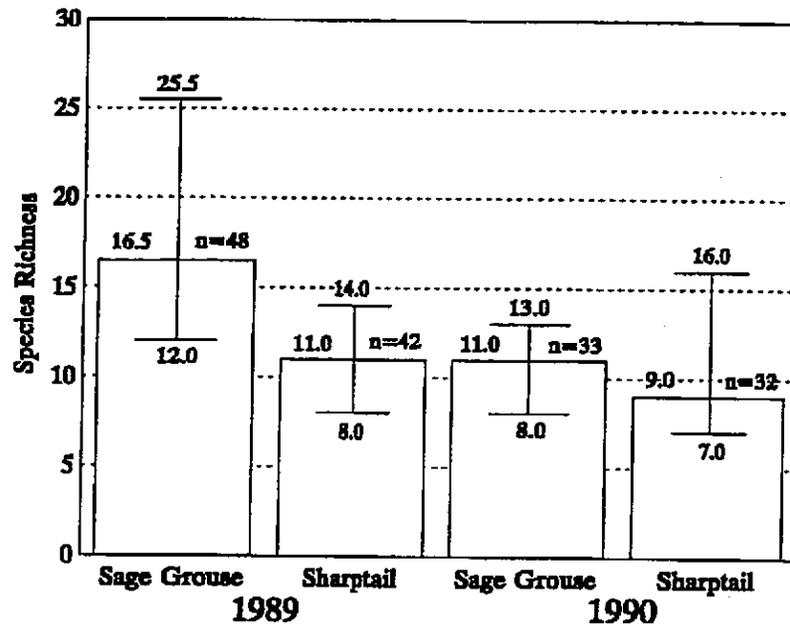


Figure 2.2. Plant species richness median and upper and lower quartiles at combined sage grouse brood, dependent micro-habitat, and independent macro-habitat sites compared to the same Columbian sharp-tailed grouse (Sharptail) brood sites in 1989 (1988 and 1990) and 1990 (1990 and 1991) in the Curlew Valley region of southeastern Idaho, 1988-91.

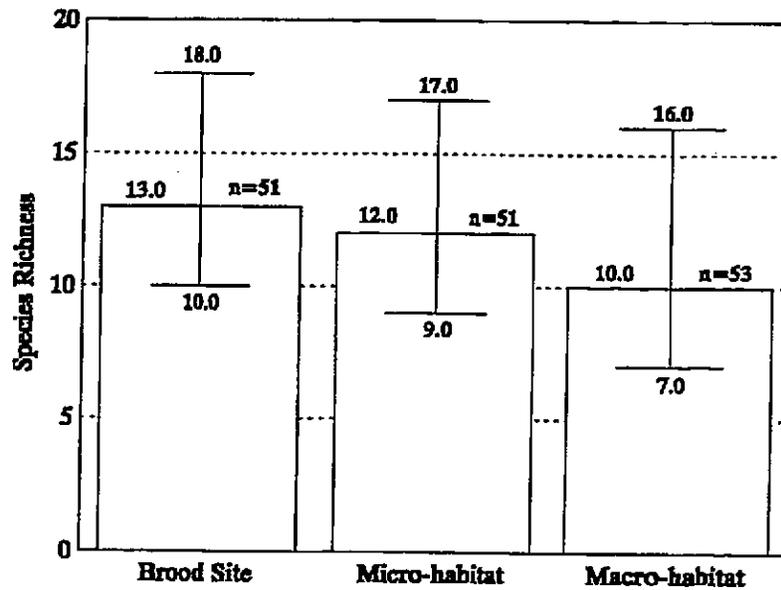


Figure 2.3. Plant species richness median and upper and lower quartiles at all sampling locations in the Curlew Valley region of southeastern Idaho, 1988-91.

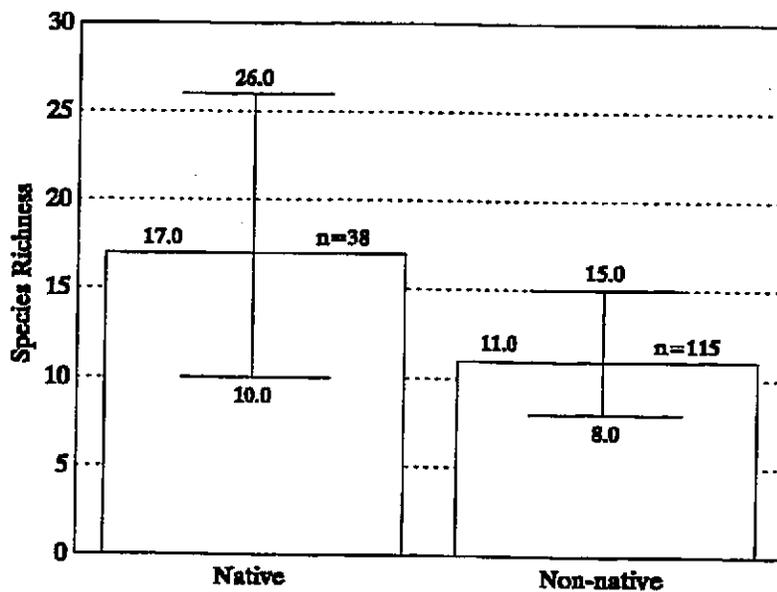


Figure 2.4. Plant species richness median and upper and lower quartiles at native and non-native brood sites in the Curlew Valley region of southeastern Idaho, 1988-91.

sage or Columbian sharp-tailed grouse brood use sites that were located in native or non-native sites ($H = 1.58$, 1 df, $P = 0.2084$).

Niche Breadth and Overlap

Levins' measure of niche breadth estimates for sage grouse brood sites ranged from 0.397 - 0.977 (median = 0.779, $n = 9$), while the Shannon-Wiener measure ranged from 0.685 - 0.999 (median = 0.951, $n = 9$) and Smith's measure ranged from 0.885 - 1.000 (median = 0.991, $n = 9$) (Table 2.3). Columbian sharp-tailed grouse niche breadth measures for Levins', Shannon-Wiener and Smith's ranged from 0.087 - 0.972 (median = 0.766, $n = 9$), 0.250 - 0.990 (median = 0.800, $n = 9$), and 0.837 - 0.998 (median = 0.984, $n = 9$), respectively (Table 2.3). Niche breadth was not different between sage and Columbian sharp-tailed grouse for Levins' measure ($S = 78.0$, 9 df, $P = 0.5078$), Shannon-Wiener ($S = 72.50$, 9 df, $P = 0.2508$), or Smith's ($S = 71.5$, 9 df, $P = 0.2327$) (Table 2.3) (Fig. 2.5).

Five measures of niche overlap were evaluated for each of the 9 categories of resource states. Niche overlap did not differ among ($\chi^2 = 7.49$, 4 df, $P = 0.1121$) any of the 9 resource state categories (Table 2.4).

Dependent Micro- and Independent Macro-Habitat Comparisons

Brood versus Dependent Micro-Habitat Site.—Dependent micro-habitat sites did not differ from brood sites between sage and Columbian sharp-tailed grouse (MANOVA: Wilks' $\lambda = 0.82$, $F = 0.923$; 9, 39 df; $P = 0.5162$), years (MANOVA: Wilks' $\lambda = 0.69$, $F = 1.95$; 9, 39 df; $P = 0.0732$), and within the species by year interaction (MANOVA: Wilks' $\lambda = 0.81$, $F = 1.03$; 9, 39 df; $P = 0.4313$) for the 9 variables evaluated (litter, forb, and grass cover, grass, forb, and sagebrush height, sagebrush and non-sagebrush canopy cover and visual obstruction at 45°) (Table 2.5).

Table 2.3. Niche breadth estimates for brood sites for Levins', Shannon-Wiener, and Smith's measures for 9 resource states for sage (SG) and Columbian sharp-tailed grouse (CSTG) in the Curlew Valley region of southeastern Idaho, 1988-91.

<u>Resource State</u>	<u>Niche Breadth Estimate</u>					
	<u>Levins' Measure</u>		<u>Shannon-Wiener Measure</u>		<u>Smith's Measure</u>	
	<u>SG</u>	<u>CSTG</u>	<u>SG</u>	<u>CSTG</u>	<u>SG</u>	<u>CSTG</u>
Shrub Site	0.715	0.870	0.877	0.250	0.978	0.837
Shrub Canopy Cover	0.797	0.821	0.919	0.940	0.976	0.984
Slope	0.437	0.202	0.685	0.495	0.897	0.849
Sagebrush Height	0.874	0.087	0.951	0.250	0.991	0.837
Litter Cover	0.779	0.766	0.931	0.901	0.974	0.970
Forb Height	0.976	0.972	0.991	0.990	0.998	0.998
Grass Height	0.977	0.946	0.999	0.980	1.000	0.996
Grass Cover	0.397	0.348	0.699	0.693	0.885	0.891
Forb Cover	0.479	0.532	0.801	0.800	0.933	0.924

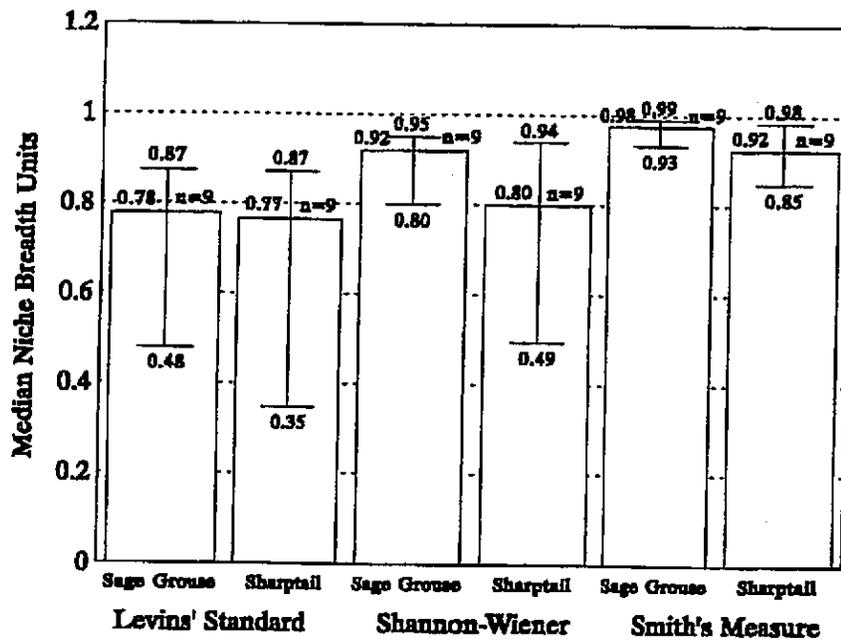


Figure 2.5. Niche breadth median and upper and lower quartiles for Levins', Shannon-Wiener, and Smith's measures for sage and Columbian sharp-tailed (Sharptail) grouse brood sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Table 2.4. Niche overlap estimates for Pianka's Measure (PM), Percentage Overlap Measure (POM), Morisita's Measure (MM), Simplified Morisita's Measure (SMM), and Horn's Index Measure (HIM) for 9 resource states for sage and Columbian sharp-tailed grouse in the Curlew Valley region of southeastern Idaho, 1988-91.

<u>Resource State</u>	<u>Niche Overlap Estimate</u>				
	<u>PM</u>	<u>POM</u>	<u>MM</u>	<u>SMM</u>	<u>HIM</u>
Shrub Site	0.922	70.4	0.898	0.889	0.833
Shrub Canopy Cover	0.756	64.8	0.809	0.756	0.892
Slope	0.964	82.9	0.978	0.954	0.967
Sagebrush Height	0.883	90.2	0.991	0.989	0.949
Litter Cover	0.943	67.1	0.864	0.851	0.867
Forb Height	0.992	93.6	1.000	0.992	0.997
Grass Height	0.974	88.4	1.000	0.974	0.990
Grass Cover	0.589	49.5	0.616	0.589	0.780
Forb Cover	0.982	88.0	1.000	0.982	0.980

Table 2.5. Mean and standard error (SE) percent cover of litter (LITTER), grass (GRASSHT) and forb heights (FORBHT), percent cover of forbs (FORBCC), sagebrush height (SAGEHT), and canopy cover (SAGECC), non-sagebrush shrubs (SHRUBCC), grass cover (GRASSCC), and visual obstruction at 45° (JO45) analyzed in a MANOVA for sage and Columbian sharp-tailed grouse brood sites (BROOD), dependent micro-habitat sites (DEPT) and the mean difference (DIFF) between BROOD and DEPT brood sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Variable	Sage Grouse						Columbian Sharp-tailed Grouse						P ^b
	BROOD	SE	DEPT	SE	DIFF	SE	BROOD	SE	DEPT	SE	DIFF	SE	
LITTER	44.0	3.2	44.5	2.9	-0.5	1.9	44.5	3.3	42.8	3.7	1.7	2.4	0.5074
GRASSHT	31.0	2.2	31.8	2.2	-0.8	1.8	32.4	2.2	30.8	2.3	1.6	1.1	0.1611
FORBHT ^a	23.5	3.2	22.9	3.3	0.6	3.7	25.3	2.5	25.3	3.1	0.0	2.1	0.9668
FORBCC ^a	8.0	1.6	7.3	1.6	0.7	1.2	8.2	2.0	7.6	2.3	0.5	1.2	0.7886
SAGEHT	53.1	5.4	54.8	5.7	-1.7	4.7	90.1	5.7	81.7	6.7	8.5	5.2	0.1397
SAGECC ^a	14.1	1.7	14.3	1.6	-0.2	1.6	12.6	1.9	11.0	1.7	1.6	1.4	0.1994
SHRUBCC ^a	12.2	2.0	10.1	2.2	2.1	2.4	6.3	1.5	7.8	1.2	-1.5	1.5	0.1561
GRASSCC ^a	10.0	1.4	9.0	1.2	1.0	0.9	16.5	1.4	15.0	1.6	1.5	1.3	0.6063
JO45 ^a	39.0	7.5	28.4	6.8	10.6	5.5	75.4	3.0	60.0	5.1	15.4	6.3	0.7282

^aArcSin transformation used in MANOVA, untransformed mean and SE reported.

^bProbability for species main effect in the dependent variable ANOVA.

Brood Site Versus Independent Macro-habitat.--Independent macro-habitat sites differed from brood sites between sage and Columbian sharp-tailed grouse for the 9 aforementioned variables (MANOVA; Wilks' $\lambda = 0.65$; $F = 2.30$; 9, 39 df; $P = 0.0353$) (Table 2.6), but not between years (MANOVA; Wilks' $\lambda = 0.75$; $F = 1.44$; 9, 39 df; $P = 0.2057$) or in the grouse species by year interaction (MANOVA; Wilks' $\lambda = 0.76$; $F = 1.40$; 9, 39 df; $P = 0.2226$).

Sagebrush height at sage grouse brood and dependent micro-habitat brood sites was shorter ($F = 17.82$, 1, 47 df, $P = 0.0001$) than at the independent macro-habitat sites (Table 2.6). The opposite was true for Columbian sharp-tailed grouse sites (Table 2.6). A similar relationship was discovered with visual obstruction. At sage grouse brood and dependent micro-habitat sites, visual obstruction was lower ($F = 5.09$, 1, 47 df, $P = 0.0287$) than at non-use sites (Table 2.6). The opposite was true for Columbian sharp-tailed grouse sites; there was higher visual obstruction at brood and dependent brood micro-habitat sites than was present at independent macro-habitat sites (Table 2.6).

Although there was a significant effect for the species main effect in the MANOVA, there were variables that had difference vectors different from zero. This would suggest a positive or negative trend that was not extreme enough to be detected by the MANOVA. FORBCC was 50% higher at sage grouse brood and dependent micro-habitat sites ($P = 0.0173$) than at independent macro-habitat sites. In addition, SAGECC was 50% lower at sage grouse brood and dependent micro-habitat sites ($P = 0.0353$) than at independent macro-habitat sites. FORBHT was 32% taller ($P = 0.0154$) at Columbian sharp-tailed grouse brood and dependent micro-habitat sites when compared to independent macro-habitat sites.

Understory (Grass and Forb) Brood Versus Dependent Micro-Habitat and Independent Micro-Habitat Sites.--The data reduction technique used for the brood understory analyses was the same as presented in Chapter I. I used stepwise discriminant

Table 2.6. Mean and standard error (SE) percent cover of litter (LITTER), grass (GRASSHT) and forb heights (FORBHT), percent cover of forbs (FORBCC), sagebrush height (SAGEHT), and canopy cover (SAGECC), non-sagebrush shrubs (SHRUBCC), grass cover (GRASSCC), and visual obstruction at 45° (JO45) analyzed in a MANOVA for sage and Columbian sharp-tailed grouse brood sites (BROOD), dependent micro-habitat (DEPT) and independent macro-habitat (INDT) sites and the mean difference (DIFF) between BROOD and DEPENDENT and INDT sites in the Curlew Valley region of southeastern Idaho, 1988-91.

Variable	Sage Grouse								Columbian Sharp-tailed Grouse								P ^c
	BROOD	SE	DEPT	SE	INDT	SE	DIFF ^a	SE	BROOD	SE	DEPT	SE	INDT	SE	DIFF ^a	SE	
LITTER	44.0	3.2	44.5	2.9	44.2	3.3	0.0	3.7	44.5	3.3	42.8	3.7	39.3	3.4	4.3	3.0	0.3468
GRASSHT	31.0	2.2	31.8	2.2	30.1	2.1	1.3	2.9	32.4	2.2	30.8	2.3	28.4	2.6	3.2	1.9	0.5247
FORBHT ^b	23.5	3.2	22.9	3.3	17.1	1.8	6.2	3.5	25.3	2.5	25.3	3.1	17.5	2.6	8.0	3.2	0.6164
FORBCC ^b	8.0	1.6	7.3	1.6	3.5	0.8	4.1	1.8	8.2	2.0	7.6	2.3	3.8	1.4	4.1	2.6	0.8052
SAGEHT	53.1	5.4	54.8	5.7	69.2	5.0	-15.2	6.7	90.1	5.7	81.7	6.7	55.0	7.2	30.9	8.8	0.0001
SAGECC ^b	14.1	1.7	14.3	1.6	21.7	2.5	-7.5	3.0	12.6	1.9	11.0	1.7	12.5	1.6	-0.7	2.4	0.1563
SHRUBCC ^b	12.2	2.0	10.1	2.2	10.2	2.1	0.9	2.1	6.3	1.5	7.8	1.2	7.8	1.1	-0.7	1.6	0.4290
GRASSCC ^b	10.0	1.4	9.0	1.2	8.3	1.5	1.2	1.9	16.5	1.4	15.0	1.6	15.3	2.0	0.4	1.9	0.7268
JO45 ^b	39.0	7.5	28.4	6.8	49.3	8.3	-15.6	6.8	75.4	3.0	60.0	5.1	62.3	4.7	5.4	5.0	0.0287

^aDIFFERENCE = (NEST + DEPENDENT)/2 - INDEPENDENT.

^bArcSin transformation used in MANOVA, mean and SE are reported.

^cProbability for species main effect for each dependent variable ANOVA.

analysis as a data reduction technique to reduce 46 variables to 6 variables (30 species) that successfully discriminated between brood (regardless of grouse species), dependent micro-habitat and independent macro-habitat locations. The variables included the grass tribe of Aveneae (AVEN) from Gramineae, Group IV or subfamily Astereae (ASTE) and Group V or subfamily Cichorieae (CICH) of Compositae, Group II (CHEN2) of Chenopodiaceae, and the families of Liliaceae (LILI) and Convolvulaceae (CONV) (Appendix B).

Sage and Columbian sharp-tailed grouse brood and dependent micro-habitat sites could not be adequately classified based upon the understory groupings in a nonparametric discriminant analysis. The understory vegetation at sage grouse brood sites and dependent micro-habitat locations were consistently misclassified ($\hat{\epsilon}$ (AER) = 0.5185), as were Columbian sharp-tailed grouse brood and micro-habitat sites ($\hat{\epsilon}$ (AER) = 0.5000).

I attempted to discriminate independent macro-habitat locations from sage grouse brood sites. The classification of sage grouse brood sites from independent macro-habitat sites ($\hat{\epsilon}$ (AER) = 0.3333) was technically unsuccessful. However, 63% (17/27) of the brood sites were misclassified as independent macro-habitat sites, but only 4% (1/27) of the independent macro-habitat sites were misclassified as brood sites (Table 2.7). A similar situation occurred with Columbian sharp-tailed grouse brood locations and independent macro-habitat sites ($\hat{\epsilon}$ (AER) = 0.4200) (Table 2.8). Although the classification was technically unsuccessful because 83% of Columbian sharp-tailed grouse brood sites were incorrectly classified, 96% of the independent macro-habitat sites were correctly classified (Table 2.8).

Sage and Columbian sharp-tailed grouse brood sites were discriminated successfully and classified ($\hat{\epsilon}$ (AER) = 0.2745). Only 56% (15 of 27) of sage grouse brood sites were correctly classified while 92% of the Columbian sharp-tailed grouse brood sites were correctly classified (Table 2.9).

Table 2.7. Predicted and actual membership of sage grouse brood sites in the Curlew Valley region of southeastern Idaho (1988-91) using the forb and grass vegetation variables of CICH, ASTE, AVEN, LILI, CHEN2, and CONV.

		Predicted Group Membership		
		<u>Brood</u>	<u>Independent Site</u>	<u>Total</u>
<u>Group</u> <u>Membership</u>	Brood	10	17	27
	Percent	37	63	100
	Independent Site	1	26	27
	Percent	4	96	100
	Totals	11	43	54
	Percent	20	80	100
	Priors	0.50	0.50	

Table 2.8. Predicted and actual membership of Columbian sharp-tailed grouse brood sites in the Curlew Valley region of southeastern Idaho (1988-91) using the forb and grass vegetation variables of CICH, ASTE, AVEN, LILI, CHEN2, and CONV.

		Predicted Group Membership		
		<u>Brood</u>	<u>Independent Site</u>	<u>Total</u>
<u>Group</u> <u>Membership</u>	Brood	4	20	24
	Percent	17	83	100
	Independent Site	1	25	26
	Percent	4	96	100
	Totals	5	45	50
	Percent	10	90	100
	Priors	0.48	0.52	

Table 2.9. Predicted and actual membership of species brood site (sage versus Columbian sharp-tailed grouse) in the Curlew Valley region of southeastern Idaho (1988-91) using the forb and grass vegetation variables of CICH, ASTE, AVEN, LILI, CHEN2, and CONV.

		Predicted Group Membership		
		<u>Sage Grouse</u>	<u>Sharptail</u>	<u>Total</u>
<u>Group</u> <u>Membership</u>	Sage Grouse	15	12	27
	Percent	56	44	100
	Sharptail	2	22	24
	Percent	8	92	100
	Totals	17	34	51
	Percent	33	67	100
	Priors	0.53	0.47	

Stepwise Logistic Regression and Brood Site

I selected 9 variables for the stepwise procedure. The variables included litter cover (LITTER), forb height (FORBHT), grass height (GRASSHT), forb cover (FORBCC), grass cover (GRASSCC), total shrub canopy cover (TOTALCC), slope (SLOPE), sagebrush height (SAGEHT), and sagebrush canopy cover (SAGECC).

Brood Versus Independent Macro-habitat Site.--Two of the 9 variables that entered the Columbian sharp-tailed grouse brood site versus macro-habitat site analysis were identified as significant contributors to the logistic regression model. SAGEHT (Wald $\chi^2 = 10.17$, 7 df, $P = 0.0014$) (Fig. 2.6) and FORBHT (Wald $\chi^2 = 8.75$, 7 df, $P = 0.0031$) (Fig. 2.7) were selected and 81% of the Columbian sharp-tailed grouse brood sites were correctly classified. By substituting the untransformed value for SAGEHT and transformed value of FORBHT the following model results:

$$\text{SHARPTAIL BROOD (P)} = -10.3137 + (10.6970)(\text{FORBHT}) + (0.0709)(\text{SAGEHT}).$$

Then by substituting

$$p = e^{(\text{SHARPTAIL BROOD (P)})}$$

the estimated probability that the site is a Columbian sharp-tailed grouse brood site is determined.

One of the 9 variables that entered into the sage grouse versus macro-habitat site was identified as a significant contributor to the logistic regression model. FORBCC (Wald $\chi^2 = 6.05$, 8 df, $P = 0.0139$) (Fig. 2.8) was selected and 61% of the brood sites were correctly classified. Given the transformed value for FORBCC the following model results:

$$\text{SAGE GROUSE BROOD (P)} = -1.3603 + (6.7430)(\text{FORBCC}).$$

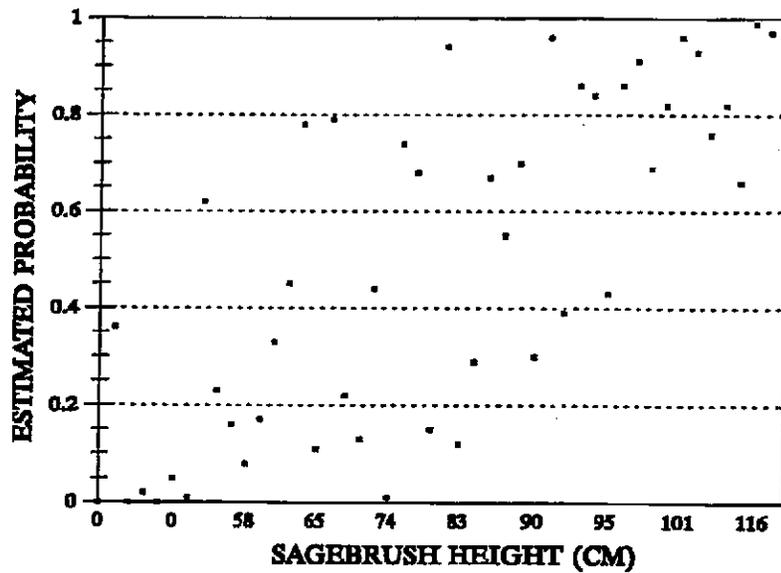


Figure 2.6. The estimated probability of a Columbian sharp-tailed grouse brood site versus an independent macro-habitat site when sagebrush height is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

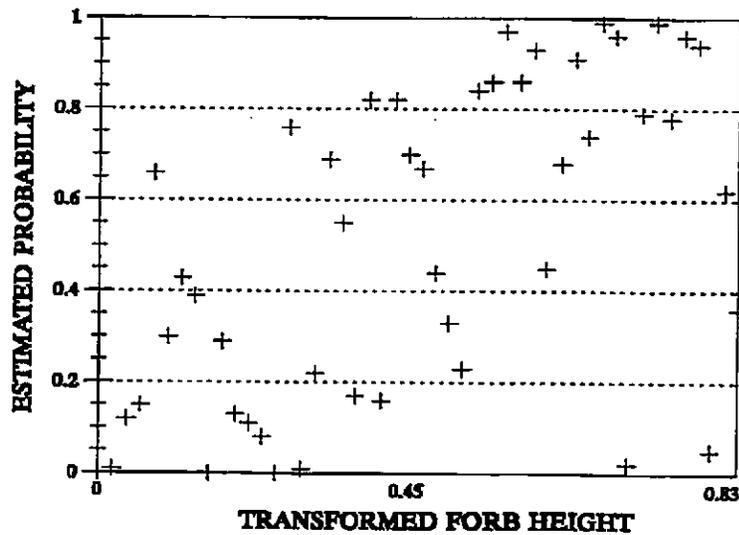


Figure 2.7. The estimated probability of a Columbian sharp-tailed grouse brood site versus an independent macro-habitat site when the transformed value for forb height is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

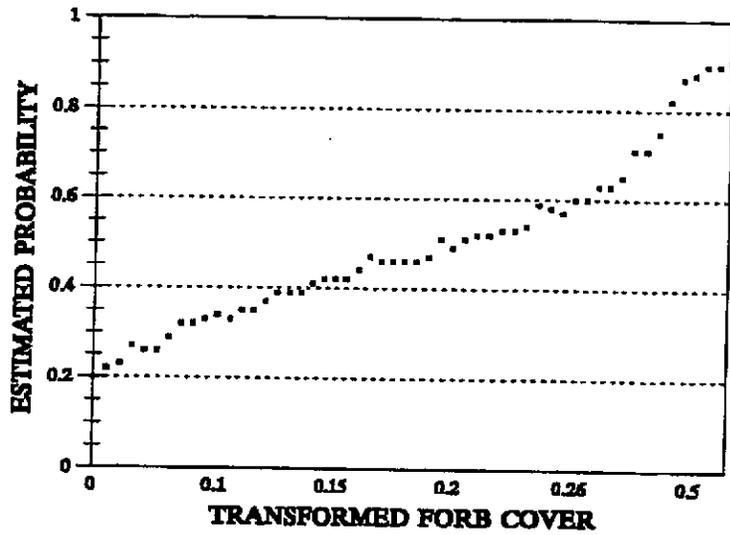


Figure 2.8. The estimated probability of a sage grouse brood site versus an independent macro-habitat site when the transformed value of forb cover is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

Then by substituting

$$p = e^{(\text{SAGE GROUSE BROOD (P)})}$$

the estimated probability that the site is a sage grouse brood site is determined.

Sage versus Columbian Sharp-tailed Grouse Brood Site.--Two of the 9 variables entered into the sage versus Columbian sharp-tailed grouse brood sites analysis were identified as significant contributors to the logistic regression model. GRASSCC (Wald $\chi^2 = 3.86$, 8 df, $P = 0.0495$) (Fig. 2.9) and SAGEHT (Wald $\chi^2 = 7.74$, 7 df, $P = 0.0054$) (Fig. 2.10) were selected and 74% of the sage grouse brood sites were correctly classified. Given the transformed value for GRASSCC and the untransformed value for SAGEHT the following model results:

$$\text{SAGE GROUSE BROOD (P)} = 6.5703 + (-6.8240)(\text{GRASSCC}) + (-0.0546)(\text{SAGEHT}).$$

Then by substituting

$$p = e^{(\text{SAGE GROUSE BROOD (P)})}$$

the estimated probability that the site is a sage grouse brood site is determined given the transformed value for GRASSCC and the untransformed value for SAGEHT.

GROUSE BROOD VERSUS NEST SITES

Physiographic Habitat Variables

Slope.--No relationship ($\chi^2 = 0.02$, 1 df, $P = 0.884$) between brood and nest sites was found with regards to slope for Columbian sharp-tailed grouse. In contrast, sage grouse broods were located at sites with less slope (22 versus 15 at < 9% and 5 versus 16 at 10-19%) than nest sites ($\chi^2 = 12.58$, 3 df, $P = 0.006$).

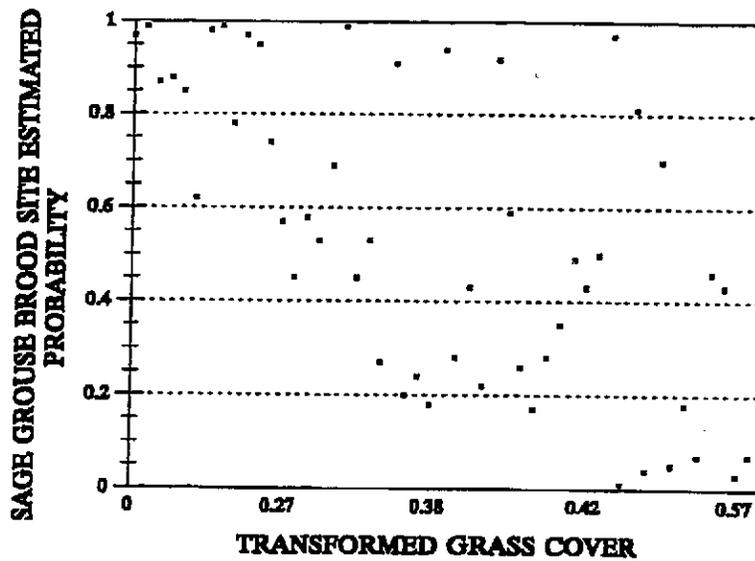


Figure 2.9. The estimated probability of a sage grouse versus a Columbian sharp-tailed grouse brood site when the transformed value of grass cover is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

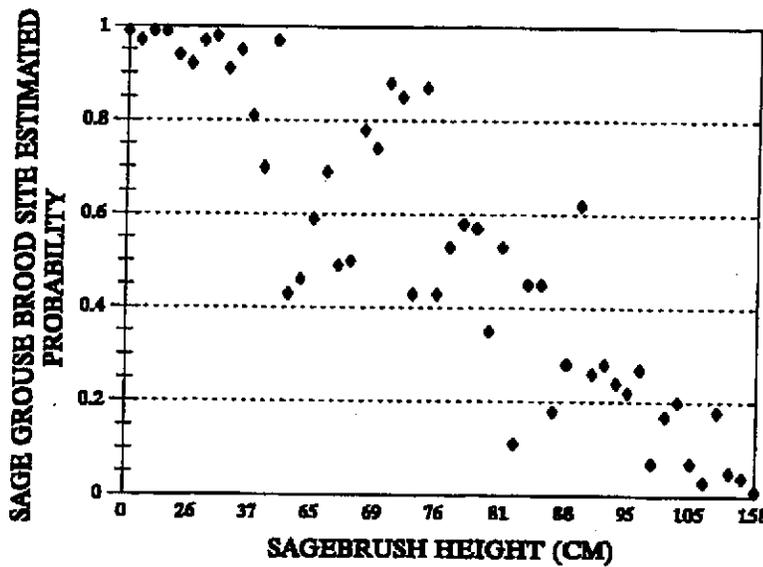


Figure 2.10. The estimated probability of a sage grouse versus a Columbian sharp-tailed grouse brood site when sagebrush height is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

Elevation.—Although a yearly difference ($X^2 = 8.00$, 2 df, $P = 0.021$) was detected with regards to elevation for Columbian sharp-tailed grouse, no relationship was exhibited between brood and nest sites in 1989 ($X^2 = 4.80$, 2 df, $P = 0.091$) or 1990 ($X^2 = 4.27$, 4 df, $P = 0.371$). No relationship ($X^2 = 6.35$, 4 df, $P = 0.174$) was exhibited with respect to elevation for sage grouse.

Aspect.—No relationship was found with regards to aspect and brood and nest sites for sage ($X^2 = 7.32$, 4 df, $P = 0.120$) or Columbian sharp-tailed grouse ($X^2 = 3.21$, 4 df, $P = 0.524$).

Plant Species Richness

Plant species richness varied ($H = 10.41$, 1, 132 df, $P = 0.0016$) between years (Fig. 2.11). Species richness also differed between grouse species and between years ($H = 4.31$, 1, 132 df, $P = 0.0398$) at brood and nest locations. Greater ($P = 0.0002$) species richness occurred at sage grouse brood and nest sites in 1989 than in 1990. Greater species richness occurred at sage grouse brood and nest sites in 1989 and than at Columbian sharp-tailed sites in 1989 ($P = 0.0003$) or 1990 ($P = 0.0001$) (Fig. 2.12). However, species richness was similar ($H = 1.64$, 1, 132 df, $P = 0.2029$) between brood and nest sites for each grouse species.

Niche Breadth and Overlap

Levins' measure produced niche breadth estimates for sage grouse brood sites that ranged from 0.397 - 0.977 (median = 0.779, $n = 9$) and for nest sites ranged from 0.000 - 0.915 (median = 0.699, $n = 9$). The Shannon-Wiener measure produced estimates for niche breadth for brood sites the ranged from 0.685 - 0.999 (median = 0.951, $n = 9$), and for nest sites ranged from 0.000 - 0.968 (median = 0.865, $n = 9$). Smith's measure ranged from 0.885 - 1.000 (median = 0.991, $n = 9$) for brood sites and from 0.707 -

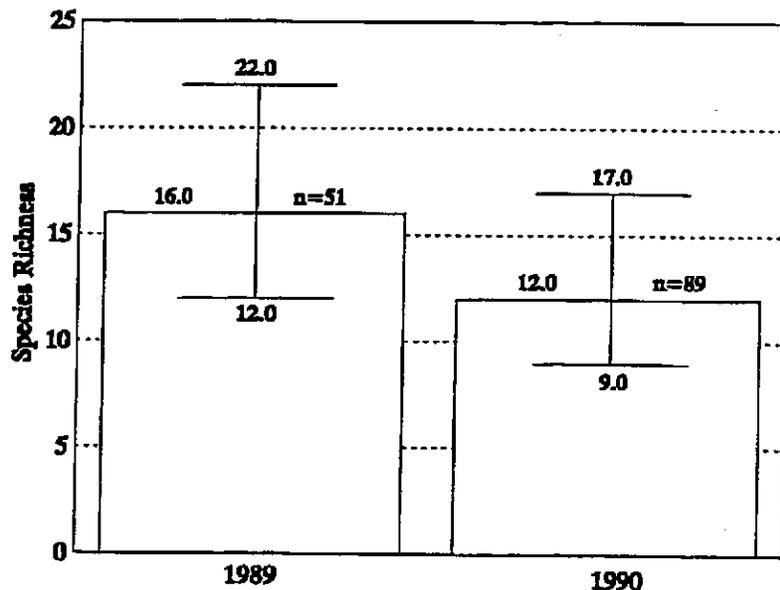


Figure 2.11. Plant species richness median and upper and lower quartiles at combined sage and Columbian sharp-tailed grouse brood and nest sites in 1989 (1988 and 1989) and 1990 (1990 and 1991) in the Curlew Valley region of southeastern Idaho, 1988-91.

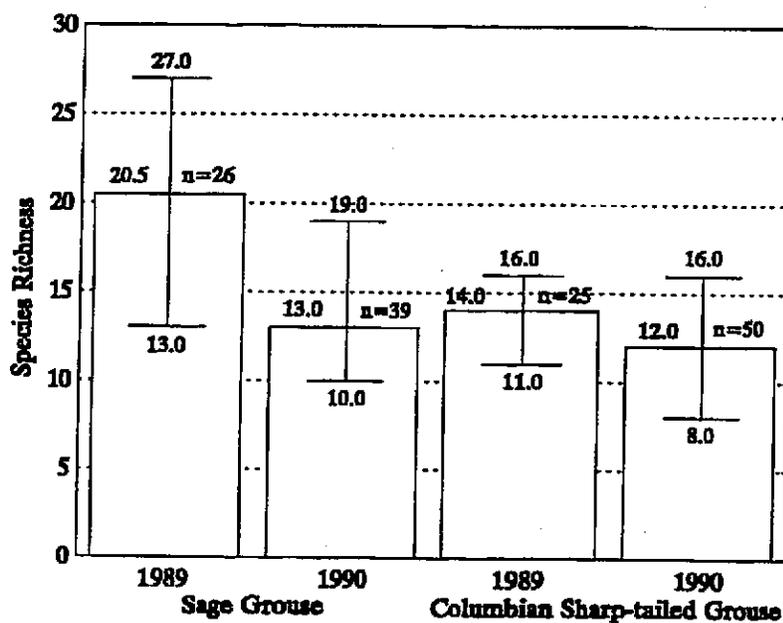


Figure 2.12. Plant species richness median and upper and lower quartiles at combined sage grouse brood and nest sites in 1989 and 1990 compared to Columbian sharp-tailed grouse brood and nest sites in the Curlew Valley of southeastern Idaho, 1988-91.

0.994 (median = 0.958, $n = 9$) for nests (Table 2.10). Columbian sharp-tailed grouse brood site niche breadth estimates for Levins', Shannon-Wiener and Smith's measures ranged from 0.087 - 0.972 (median = 0.766, $n = 9$), 0.250 - 0.990 (median = 0.800, $n = 9$), and 0.837 - 0.998 (median = 0.984, $n = 9$), respectively (Table 2.10). The nest niche breadth for Levins', Shannon-Wiener and Smith's measures ranged from 0.144 - 0.999 (median = 0.710, $n = 9$), 0.400 - 1.000 (median = 0.891, $n = 9$), and 0.814 - 1.000 (median = 0.968, $n = 9$), respectively (Table 2.10). Sage grouse niche breadth was similar between nest and brood sites for Levins' ($S = 96.0$, 1 df, $P = 0.3772$), Shannon-Wiener ($S = 95.0$, 1 df, $P = 0.4268$), and Smith's measure ($S = 96.5$, 1 df, $P = 0.3536$) (Table 2.10). The same was true for Columbian sharp-tailed grouse niche measurements between nest and brood sites for Levins' ($S = 83.0$, 1 df, $P = 0.8598$), Shannon-Wiener ($S = 77.0$, 1 df, $P = 0.4797$), and Smith's measure ($S = 77.0$, 1 df, $P = 0.4797$) (Table 2.10).

Five measures of niche overlap between nest and brood sites were evaluated for 9 resource states. There was no difference in the amount of niche overlap between for nest and brood sites for sage and Columbian sharp-tailed grouse for Pianka's Measure ($S = 77.0$, 1 df, $P = 0.4797$), Percentage Overlap Measure ($S = 74.0$; 1 df; $P = 0.3314$), Morisita's Measure ($S = 78.0$; 1 df; $P = 0.5287$), Simplified Morisita's Measure ($S = 75.0$; 1 df; $P = 0.3772$), or Horn's Index Measure ($S = 74.0$; 1 df; $P = 0.3309$) (Table 2.11).

Nest and Brood Site Micro-Habitat Comparisons

Nest Versus Brood Micro-Habitat Site.—Brood sites differed from nest sites for the aforementioned dependent variables between grouse species (MANOVA; Wilks' $\lambda = 0.68$, $F = 6.47$; 9, 124 df; $P = 0.0001$), between years (MANOVA; Wilks' $\lambda = 0.65$, $F = 11.41$; 9, 124 df; $P = 0.0001$), between species by year (MANOVA; Wilks' $\lambda = 0.85$, $F = 2.43$; 9, 124 df; $P = 0.0140$), between brood and nest sites (MANOVA; Wilks' $\lambda =$

Table 2.10. Niche breadth estimates for Levins', Shannon-Wiener, and Smith's measures for 9 resource states at brood and nest sites for sage and Columbian sharp-tailed (Sharptail) grouse in the Curlew Valley region of southeastern Idaho, 1988-91.

<u>Resource State Groupings</u>	<u>Levins' Measure</u>				<u>Shannon-Wiener Measure</u>				<u>Smith's Measure</u>			
	<u>Sage Grouse</u>		<u>Sharptail</u>		<u>Sage Grouse</u>		<u>Sharptail</u>		<u>Sage Grouse</u>		<u>Sharptail</u>	
	<u>Brood</u>	<u>Nest</u>	<u>Brood</u>	<u>Nest</u>	<u>Brood</u>	<u>Nest</u>	<u>Brood</u>	<u>Nest</u>	<u>Brood</u>	<u>Nest</u>	<u>Brood</u>	<u>Nest</u>
Shrub Site/Nest	0.715	0.054	0.870	0.999	0.877	0.176	0.250	1.000	0.978	0.812	0.837	1.000
Shrub Canopy Cover	0.797	0.364	0.821	0.810	0.919	0.686	0.940	0.937	0.976	0.912	0.984	0.983
Slope	0.437	0.883	0.202	0.144	0.685	0.960	0.495	0.400	0.897	0.989	0.849	0.814
Shrub/Nest Height	0.874	0.000	0.087	0.215	0.951	0.000	0.250	0.463	0.991	0.707	0.837	0.893
Litter Cover	0.779	0.699	0.766	0.660	0.931	0.865	0.901	0.876	0.974	0.958	0.970	0.967
Forb Height	0.976	0.915	0.972	0.987	0.991	0.968	0.990	0.995	0.998	0.994	0.998	0.999
Grass Height	0.977	0.870	0.946	0.710	0.999	0.949	0.980	0.874	1.000	0.991	0.996	0.978
Grass Cover	0.397	0.612	0.348	0.777	0.699	0.819	0.693	0.916	0.885	0.922	0.891	0.968
Forb Cover	0.479	0.736	0.532	0.667	0.801	0.916	0.800	0.891	0.933	0.971	0.924	0.963

Table 2.11. Niche overlap estimates using Pianka's Measure (Pianka's), Percentage Overlap Measure (Percentage Overlap), Morisita's Measure (Morisita's), Simplified Morisita's Measure (Simp. Morisita's), and Horn's Measure (Horn's) between brood and nest sites for each resource state for sage (SG) and Columbian sharp-tailed (CSTG) grouse in the Curlew Valley region of southeastern Idaho, 1988-91.

<u>Resource State Groupings</u>	<u>Pianka's</u>		<u>Percentage Overlap</u>		<u>Morisita's</u>		<u>Simp. Morisita's</u>		<u>Horn's</u>	
	<u>SG</u>	<u>CSTG</u>	<u>SG</u>	<u>CSTG</u>	<u>SG</u>	<u>CSTG</u>	<u>SG</u>	<u>CSTG</u>	<u>SG</u>	<u>CSTG</u>
Shrub Site	0.932	0.693	73.0	49.0	0.915	0.658	0.905	0.654	0.889	0.681
Shrub Canopy Cover	0.784	0.870	66.1	77.5	0.797	0.918	0.768	0.870	0.884	0.954
Slope	0.699	0.999	59.0	95.8	0.714	1.000	0.686	0.998	0.809	0.997
Shrub Height	0.862	0.998	63.0	94.4	0.831	1.000	0.821	0.996	0.784	0.991
Litter Cover	0.997	0.909	95.7	78.1	1.000	0.953	0.997	0.908	0.997	0.960
Forb Height	0.950	0.999	83.9	98.0	0.980	1.000	0.950	0.999	0.981	1.000
Grass Height	0.976	0.975	88.7	87.7	1.000	0.999	0.975	0.973	0.991	0.988
Grass Cover	0.773	0.848	63.4	67.9	0.800	0.863	0.766	0.823	0.893	0.894
Forb Cover	0.968	0.928	85.5	80.6	1.000	0.980	0.959	0.925	0.984	0.932

0.48, $F = 14.60$; 9, 124 df; $P = 0.0001$), between species by brood and nest sites (MANOVA; Wilks' $\lambda = 0.53$, $F = 12.29$; 9, 124 df; $P = 0.0001$), between years within nest and brood sites (MANOVA; Wilks' $\lambda = 0.77$, $F = 4.06$; 9, 124 df; $P = 0.0001$), and the overall interaction between species, years, and brood and nest sites (MANOVA; Wilks' $\lambda = 0.83$, $F = 2.89$; 9, 124; $P = 0.0039$).

Because my primary emphasis was to test the hypothesis of similarity between brood and nest habitats, only those significant results will be presented. More ($F = 4.09$, 1, 132 df, $P = 0.0451$) litter was present at sage and Columbian sharp-tailed grouse brood sites ($\bar{x} = 44.2 \pm 1.7$ pc [S.E.], $n = 51$) than was present at nest sites ($\bar{x} = 40.9 \pm 1.3$ pc [S.E.], $n = 89$). Although the species by brood or nest site by year interaction was significant ($F = 8.74$, 1, 132 df, $P = 0.0030$), I could not detect any differences among the pertinent contrasts. This non-significant result indicated that grass height (Fig. 2.13) was equally important at brood and nest sites. Grass cover was also higher ($F = 18.05$, 1, 132 df, $P = 0.0001$) at nest sites when compared to brood sites. Grass cover was 7% higher at nest sites ($\bar{x} = 20.2 \pm 0.8$ pc [S.E.], $n = 89$) than brood sites ($\bar{x} = 13.1 \pm 1.1$ pc [S.E.], $n = 51$).

Concerning the overstory variables, combined grouse brood sites had taller ($P = 0.0011$) sagebrush in 1989 ($\bar{x} = 82.3 \pm 5.1$ cm [S.E.], $n = 30$) than nest sites ($\bar{x} = 49.1 \pm 4.7$ cm [S.E.], $n = 21$). Although yearly differences were apparent, and there was a difference in the 3-way interaction of grouse species, site type and year. I extensively evaluated the 2-way interaction of grouse species by site for sagebrush height. Sagebrush was taller ($P = 0.0251$) at sage grouse nest sites ($\bar{x} = 69.0 \pm 2.6$ cm [S.E.], $n = 38$) than at brood sites ($\bar{x} = 53.1 \pm 5.4$ cm [S.E.], $n = 27$). The reverse was true for Columbian sharp-tailed grouse; sagebrush was taller ($P = 0.0001$) at brood sites ($\bar{x} = 90.1 \pm 5.7$ cm [S.E.], $n = 24$) than at nest sites ($\bar{x} = 44.8 \pm 4.4$ cm [S.E.], $n = 51$). Sagebrush canopy cover was higher ($P = 0.0011$) at combined grouse species nest sites in

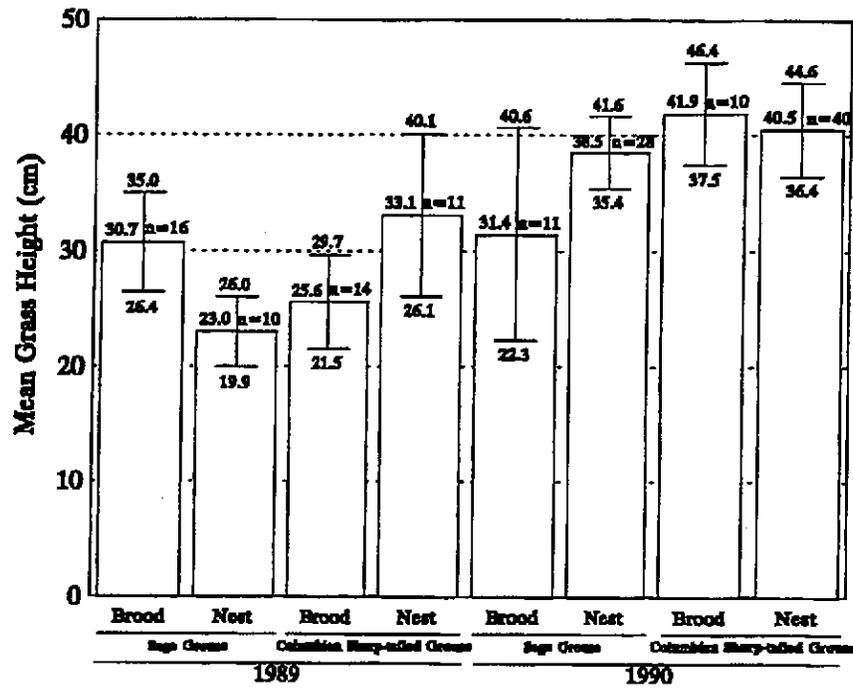


Figure 2.13. Mean grass height and 95% confidence limits for sage and Columbian sharp-tailed grouse nest and brood sites in 1989 and 1990 in the Curlew Valley region of southeastern Idaho, 1988-91.

1989 ($\bar{x} = 10.6 \pm 1.3$ pcc [S.E.], $n = 30$) than at brood sites ($\bar{x} = 17.0 \pm 2.2$ pcc [S.E.], $n = 21$). Sagebrush canopy cover was also higher ($P = 0.0009$) at combined grouse species brood sites in 1990 ($\bar{x} = 17.3 \pm 2.2$ pcc [S.E.], $n = 21$) than in 1989.

Non-sagebrush canopy cover was higher ($F = 6.03$, 1, 132 df, $P = 0.0154$) at combined grouse nest sites ($\bar{x} = 13.8 \pm 0.8$ pcc [S.E.], $n = 89$) than at brood sites ($\bar{x} = 9.5 \pm 1.1$ pcc [S.E.], $n = 51$). The aforementioned non-sagebrush cover values were presented as means of the raw data although statistical analyses were conducted on transformed values.

Differences in visual obstruction occurred between sage and Columbian sharp-tailed grouse brood and nest sites between 1989 and 1990 ($F = 10.58$, 1, 132 df, $P = 0.0015$). There was higher visual obstruction at sage grouse nest sites than brood sites in 1989 ($P = 0.0001$) and 1990 ($P = 0.0001$) (Fig 2.14). Columbian sharp-tailed grouse nest sites also had higher ($P = 0.0439$) visual obstruction than brood sites in 1989, but visual obstruction did not differ ($P = 0.0678$) between nest and brood sites in 1990 (Fig 2.14).

Understory (Grass and Forb) Nest Versus Brood Micro-Habitat Sites.—I used stepwise discriminant analysis, as described in Chapter I, to reduce 46 variables to 9 variables (54 species) that successfully separated and classified the class variables of nest (regardless of grouse species) and brood micro-habitat locations. The variables included the grass tribes of Hordeae (HORD), Aveneae (AVEN), Festuceae (FEST), and Agrostideae (AGRO) from Gramineae, Group I (CARY1) of Caryophyllaceae, Group III (CHEN3) of Chenopodiaceae, subfamily Heliantheae (HELI) of Compositae, and the families of Polemoniaceae (POLE) and Labiatae (LABI) (Appendix B).

Sage grouse nest and brood sites were not successfully classified ($\hat{\epsilon}$ (AER) = 0.3077) technically. Seventy percent (19) (Table 2.12) of sage grouse brood sites were misclassified as nests and 97% (37) of the nests were correctly classified. Columbian sharp-tailed grouse brood and nest sites were also not successfully classified ($\hat{\epsilon}$ (AER) = 0.3200) technically. The higher error rate was a result of all 24 brood sites being

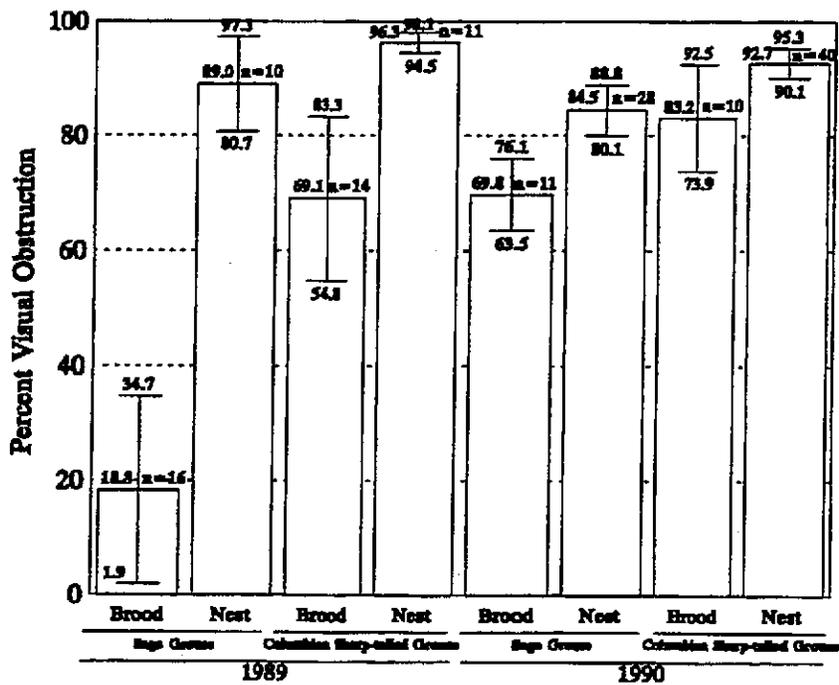


Figure 2.14. Mean visual obstruction and 95% confidence limits for sage and Columbian sharp-tailed grouse nests and brood sites in 1989 and 1990 in the Curlew Valley region of southeastern Idaho, 1988-91. Mean values are reported and statistical analyses were conducted on transformed values.

Table 2.12. Predicted and actual membership of sage grouse brood versus nest sites in the Curlew Valley region of southeastern Idaho (1988-91) using the forb and grass vegetation variables of HORD, AVEN, FEST, AGRO, HELI CARYI, CHEN3, POLE, and LABI.

		Predicted Group Membership		
		<u>Brood Site</u>	<u>Nest Site</u>	<u>Total</u>
<u>Group</u> <u>Membership</u>	Brood Site	8	19	27
	Percent	30	70	100
	Nest Site	1	37	38
	Percent	3	97	100
	Totals	9	56	51
	Percent	14	86	100
	Priors	0.41	0.59	

misclassified as nests, but 100% of the Columbian sharp-tailed grouse nests were correctly classified (Table 2.13).

Stepwise Logistic Regression for Nest and Brood Sites

I selected 9 variables for the stepwise procedure. The variables included litter cover (LITTER), forb height (FORBHT), grass height (GRASSHT), forb cover (FORBCC), grass cover (GRASSCC), total shrub canopy cover (TOTALCC), slope (SLOPE), sagebrush height (SAGEHT), and sagebrush canopy cover (SAGECC).

Three of the 9 variables entered into the sage grouse nest versus brood site model were identified as significant contributors to the logistic regression model. GRASSCC (Wald $\chi^2 = 9.40$, 6 df, $P = 0.0022$) (Fig. 2.15), SLOPE (Wald $\chi^2 = 4.03$, 6 df, $P = 0.0448$) (Fig. 2.16), and SAGECC (Wald $\chi^2 = 7.06$, 6 df, $P = 0.0079$) (Fig. 2.17) were selected and 72% of the sites were correctly classified. Given the transformed values for GRASSCC, SLOPE, and SAGECC the following model results:

$$\text{SAGE GROUSE BROOD SITE (P)} = 7.6588 + (-10.3547)(\text{GRASSCC}) + (-5.1901)(\text{SLOPE}) + (-7.7470)(\text{SAGECC}).$$

Then by substituting

$$p = e^{(\text{SAGE GROUSE BROOD SITE (P)})}$$

the estimated probability that the site is a sage grouse brood site is determined.

Two of the 9 variables entered into the Columbian sharp-tailed grouse nest versus brood site analysis were identified as significant contributors to the logistic regression model. SAGEHT (Wald $\chi^2 = 14.96$, 7 df, $P = 0.0001$) (Fig. 2.18) and GRASSCC (Wald $\chi^2 = 5.03$, 7 df, $P = 0.0249$) (Fig. 2.19) were selected and 81% of the sites were

Table 2.13. Predicted and actual membership of Columbian sharp-tailed grouse brood versus nest sites in the Curlew Valley region of southeastern Idaho (1988-91) using the forb and grass vegetation variables of HORD, AVEN, FEST, AGRO, HELI CARYI, CHEN3, POLE, and LABI.

		Predicted Group Membership		
		<u>Brood Site</u>	<u>Nest Site</u>	<u>Total</u>
<u>Group</u> <u>Membership</u>	Brood Site	0	24	24
	Percent	0	100	100
	Nest Site	0	51	51
	Percent	0	100	100
	Totals	0	75	75
	Percent	0	100	100
	Priors	0.32	0.68	

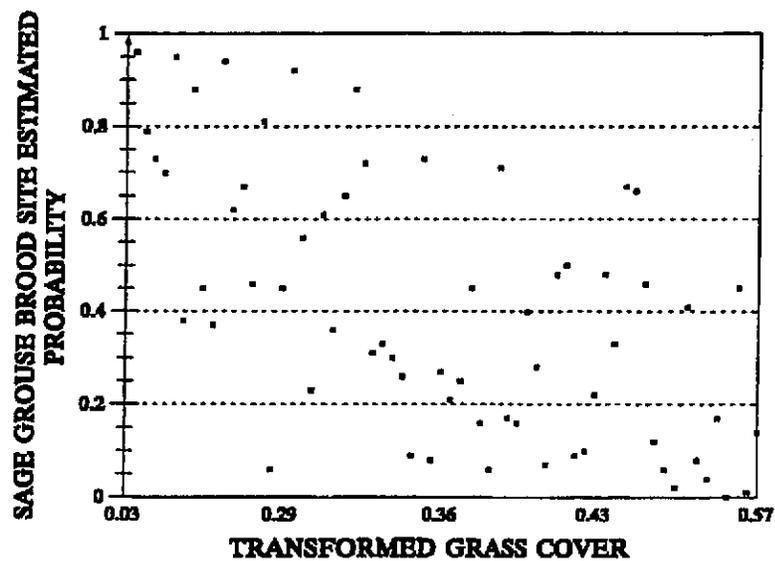


Figure 2.15. The estimated probability of a sage grouse brood site versus a nest site when the transformed value for grass cover is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

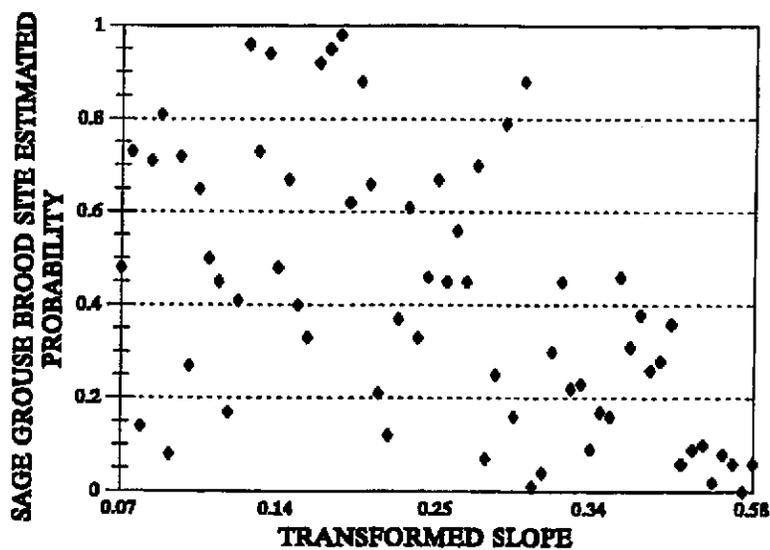


Figure 2.16. The estimated probability of a sage grouse brood site versus a nest site when the transformed value for slope is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

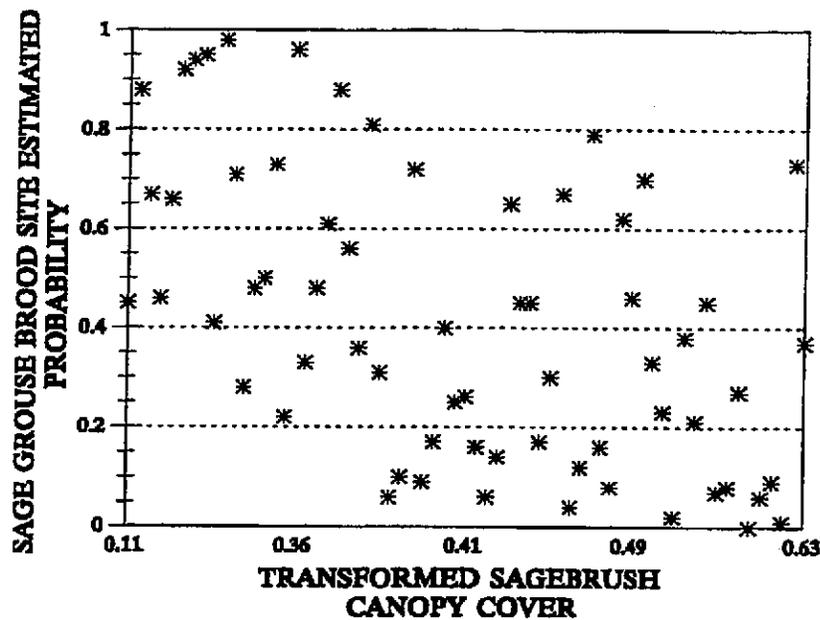


Figure 2.17. The estimated probability of a sage grouse brood site versus a nest site when the transformed value for sagebrush canopy cover is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

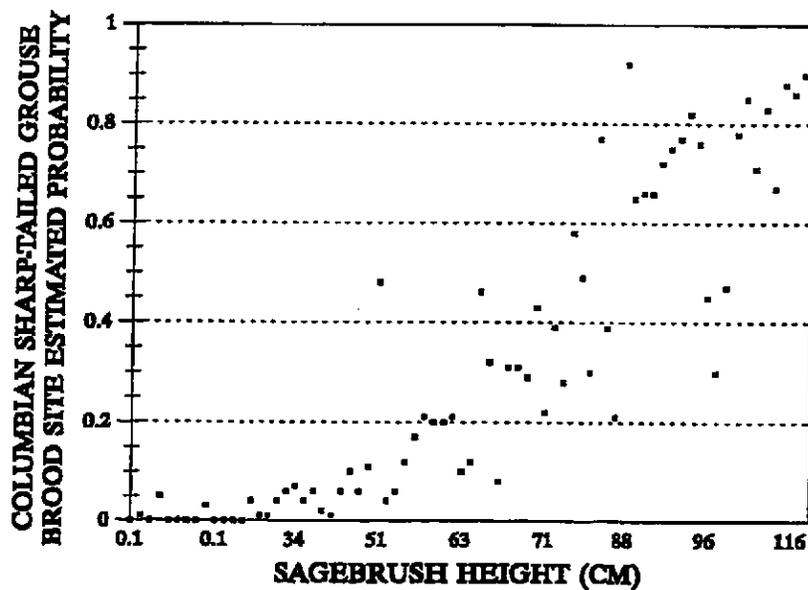


Figure 2.18. The estimated probability of a Columbian sharp-tailed grouse brood site versus a nest site when sagebrush height is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

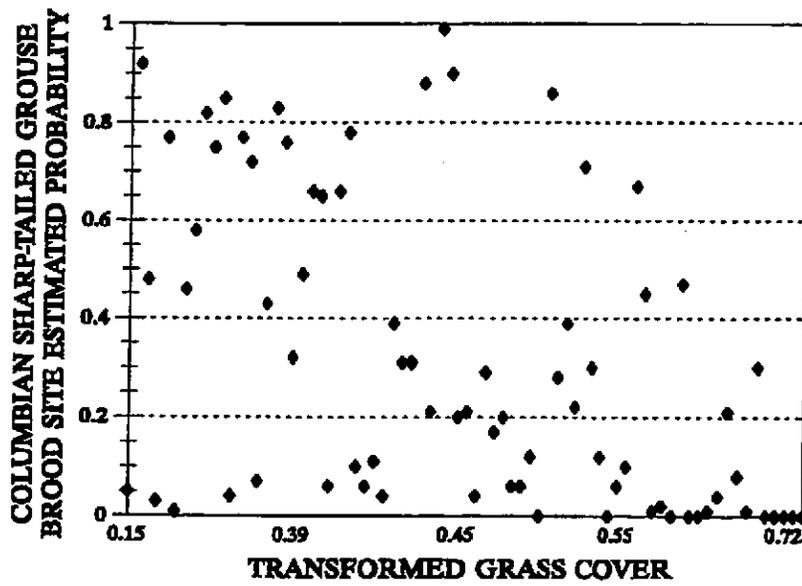


Figure 2.19. The estimated probability of a Columbian sharp-tailed grouse brood site versus a nest site when the transformed value for grass cover is considered in the logistic regression in the Curlew Valley region of southeastern Idaho, 1988-91.

correctly classified. Given the transformed value for GRASSCC and the untransformed value of SAGEHT the following model results:

$$\text{SHARPTAIL BROOD SITE (P)} = -1.7335 + (-7.9128)(\text{GRASSCC}) + (0.0628)(\text{SAGEHT}).$$

Then by substituting

$$p = e^{(\text{SHARPTAIL BROOD SITE (P)})}$$

the estimated probability that the site is a Columbian sharp-tailed grouse brood site is determined given the transformed value for GRASSCC and SAGEHT.

DISCUSSION

Sage grouse brood movements in the Curlew Valley region did not appear to follow plant desiccation elevational changes as reported by Fischer et al. (1996b) (Appendix D). Fischer et al. (1996b) found in Idaho that the timing of sage grouse migration and vegetal moisture occurred earlier in the summer during dry years and later in July in wet years. My study occurred during the same seasonal time frame, but I did not find more sage grouse broods at higher elevations which would indicate movement to higher elevation, mesic locations (Fischer et al. 1996b). Wallestad (1971) suggested that brood range can be relatively small and occur in a single vegetation community or be relatively large and encompass several vegetation communities. Median daily movements of sage grouse broods in the Curlew Valley (144 m/day) were much less than reported by Autenrieth (1981) (500 m/day, $n = 3$) and Wallestad (1971) (400 - 800 m/day). Although movement comparisons between sage grouse hens with (median = 144 m/day, $n = 9$) and without broods (median = 284 m/day, $n = 4$) were not statistically different, the median daily movements of hens without brood appeared to be twice as far as hens with broods.

Columbian sharp-tailed grouse in the Curlew Valley did not appear to follow elevational or plant desiccation changes as has been reported with sage grouse (Fischer et al. 1996b). Columbian sharp-tailed grouse with broods in the Curlew Valley moved slightly smaller median daily movements (86 m/day) than reported by Meints (1991) (100 m/day), and Gratson (1988) (132 m/day) during the early-brood rearing period.

To my knowledge, no other study has investigated comparative brood movements between sympatric sage and Columbian sharp-tailed grouse. I rejected the hypothesis that sage and Columbian sharp-tailed grouse movements do not differ, but failed to reject the hypothesis of differing daily movements between brooding and nonbrooding hens for each grouse species. Sage grouse median daily movements (regardless of the presence of a brood) were 73% longer than for Columbian sharp-tailed grouse. Reasons for the differing movements are unclear, but may be due to differing selective pressures (e.g. increased predation risk). Bergerud and Gratson (1988:540) suggested that increased movements by grouse broods may be indicative of adaptations to reduce predation risk and avoid encounters with predators. Fischer (1994) also suggested that migrating sage grouse may encounter selective pressures that are different from non-migrating populations. In contrast, the predation risk involved with increased movement must be weighed with foraging strategies, and may be indicative of a lack of adequate brood habitat near nesting habitat. Risk of movement and increased predation may be more important to Columbian sharp-tailed grouse than sage grouse. Compared to sage grouse, Columbian sharp-tailed grouse are smaller in size (more possible predators) and have lower annual survival (Bergerud 1988:589). In a response to increased predatory pressure, they may reduce their daily movements and remained more sedentary in brood habitat that has more security cover. In contrast, sage grouse appeared to incur a greater risk of predation with higher daily movements, but are larger in size (fewer potential predators) and have higher annual survival rates than Columbian sharp-tailed grouse (Bergerud 1988:589). In addition, sage grouse broods occupied less secure habitat when compared to nesting habitat. Therefore,

the benefits of increased movement (e.g. improved foraging habitat or the need for more food due to the larger size of sage grouse) must outweigh the increased predation risks.

Plant species richness at sage grouse brood sites was higher than at Columbian sharp-tailed grouse brood sites. The higher plant species richness can be explained by sage grouse use of higher elevation, mixed shrub and mountain big sagebrush communities, whereas Columbian sharp-tailed grouse broods occupied lower elevation (and lower precipitation), highly modified, sagebrush/grass cover types and Conservation Reserve Program (CRP) fields that had lower species richness.

The presence of higher plant species richness at sage grouse brood sites may also be a result of hens with broods searching for higher quality brood-rearing habitat. Forbs have higher protein levels than other vegetation (Klebenow and Gray 1968, Peterson 1970) and also provide higher (and probably more species rich) insect abundances that occur from increased forb and plant diversity (Potts 1986). Sage grouse chicks in Oregon consumed a very diverse diet that included 122 different foods which were dominated by plant species (Drut et al. 1994). In Washington, Jones (1966) found less than half that number of food items (51) in Columbian sharp-tailed grouse diets, but the diets were also dominated by plant species. Sage grouse broods may require a higher diversity of plant species to meet dietary requirements. Those requirements may be minimally met in non-native rangelands. Although there was no significant difference in plant species richness between native and non-native sites, there appeared to be 35% fewer plant species in non-native rangelands.

The habitats occupied by sage and Columbian sharp-tailed grouse with broods were essentially homogenous with no fourth-order selection (Johnson 1980), therefore I failed to reject the hypothesis of no difference between brood and dependent micro-habitat sites. In contrast, I rejected the hypothesis of similar brood and independent macro-habitat characteristics. There was a degree of third-order selection (availability was not measured) related to macro-habitat horizontal and vertical overstory and understory vegetation variables. Sage grouse hens with broods used sites that provided less vertical sagebrush

cover, had lower visual obstruction, higher forb cover, and lower sagebrush canopy cover than independent macro-habitat sites. In contrast, Columbian sharp-tailed grouse broods used sites with more vertical sagebrush cover, higher visual obstruction cover, and taller forbs than independent macro-habitat sites. Klott (1987) reported similar results for sage grouse but did not detect a movement of Columbian sharp-tailed grouse broods to increased cover. He found that both grouse species selected sites where the shrub height was less than the average for the habitat. Curlew Valley sage grouse did not move from shorter to taller sagebrush as reported in other studies (Peterson 1970, Wallestad and Pyrah 1971). I may not have detected a similar habitat transition because I completed data collection in late-July and early-August. The use of taller sagebrush by Columbian sharp-tailed grouse, when compared to macro-habitat sites, in the Curlew Valley was also documented in another Idaho study. Meints (1991) also found that 11 cover variables were greater at Columbian sharp-tailed grouse brood sites than at corresponding independent and dependent random sites. In the Curlew Valley I did not detect differences between brood and dependent micro-habitat sites.

Sage and Columbian sharp-tailed grouse brood sites had twice as much forb cover (8%) than was present at independent macro-habitat sites (4%). Although forb cover data measurements in the Curlew Valley were slightly lower than reported by Drut et al. (1994) (10-14%), Wallestad (1971) (17-27%) and Klott and Lindzey (1990) (17% at sage grouse sites and 29% at Columbian sharp-tailed grouse sites), my results were similar to Klebenow (1969), Dunn and Braun (1986), and Schoenberg (1982). In Idaho, Meints (1991) found more alfalfa (20%) at brood sites than was present at independent random sites (1%). Drut et al. (1994) suggested that the forb cover readings in Oregon may be a minimum value needed to support sage grouse broods. Forb cover in the Curlew Valley may not meet the minimum standard proposed by Drut et al. (1994), but the lower forb cover percentages I reported may be an artifact of data collection; reported forb cover

percentages are medians for a 6-25% cover class. Therefore, forb cover values recorded in the Curlew Valley may be well within the minimum value suggested by Drut et al. (1994).

Additional, and more detailed, analyses of understory grass and forb cover provided additional credence to my hypothesis of similar brood and dependent micro-habitat sites. In contrast, additional analyses of the grass and forb understory supported the earlier rejection of my brood site versus macro-habitat hypothesis. Sage and Columbian sharp-tailed grouse brood sites had higher forb coverage than independent macro-habitat sites, but the brood use sites were dominated by a few taxonomic families than existed in the large number of forb and grass species present throughout my study area. Brood sites, which were quite specific, were frequently misclassified as independent macro-habitat sites (63% and 83% for sage and Columbian sharp-tailed grouse, respectively). Conversely, independent macro-habitat sites encompassed a much broader spectrum of plant species families and misclassification of independent macro-habitat sites as brood sites was rare (4% for both sage and Columbian sharp-tailed grouse).

The plant species categories used to classify differing sites were dominated by asters (Astereae) and milky-juiced composites (Cichorieae). Daisies (Erigeron spp.), poverty weed (Iva axillaris), mixed asters (Machaeranthera spp.), solidago (Solidago spp.), mountain dandelion (Agroseris spp.), hawksbeard (Crepis spp.), prickly lettuce (Lactuca serriola), skeleton plant (Lygodesmia juncea), common dandelion (Taraxacum officianale) and yellow salsify (Tragopogon dubius) were the dominant species in the categories. The aforementioned composite tribe plant species consisted of 85% and 99% of the forb cover for 5 tribes and/or families used to classify sage and Columbian sharp-tailed grouse sites from independent macro-habitat sites, respectively. With the exception of poverty weed, the mixed asters, solidago, and skeleton plant, all of the aforementioned plant species have been identified in previous food habit studies as either potential (identified as dominant items found at brood sites) or documented sage and/or Columbian sharp-tailed grouse food items (Peterson 1970, Wallestad 1971, Klott and Lindzey 1990, Drut et al. 1994,

Schneider 1994). I did not find the same association with oniongrass, sulfur buckwheat, and snowberry cover as Klott and Lindzey (1990) found in Wyoming. Group II of Chenopodiaceae and the families of Liliaceae and Convolvulaceae were also represented categories, and were dominated by species that commonly occurred throughout my study area; Hooker onion (Allium acuminatum) and paniced death-camus (Zigadenus paniculatus) frequently occurred as well as species commonly referred to as "weeds" that inhabited disturbed sites, goosefoot (Chenopodium spp.) and bindweed (Convolvulus arvensis).

When sage and Columbian sharp-tailed grouse brood sites were compared, using the aforementioned categories, sage grouse sites were frequently misclassified (44%) as Columbian sharp-tailed grouse brood sites. In contrast, Columbian sharp-tailed grouse brood sites were rarely (8%) classified as sage grouse sites. The narrower and more specific understory requirements of sage grouse (CICH more dominant) fit into a broader habitat requirement for Columbian sharp-tailed grouse which resulted in a high number of misclassifications. The broader, more-generalized use of the understory by Columbian sharp-tailed grouse allowed for more correct classifications.

A site with $> 7\%$ forb cover (0.26 transformed value) had a high probability (> 0.6) of being a sage grouse brood site, while > 90 cm tall sagebrush and > 20 cm tall forbs (0.45 transformed value) provided a high probability (> 0.6) of being a Columbian sharp-tailed grouse brood site when compared to independent macro-habitat sites. Interspecific comparisons suggested that sage grouse required less vertical and horizontal cover than Columbian sharp-tailed grouse. Sites that had less (14%) grass cover, and shorter sagebrush (< 70 cm) had a greater probability (> 0.6) of being a sage grouse brood site than Columbian sharp-tailed grouse brood site.

Although the niche breadth analyses failed to reject the equal niche hypothesis, Columbian sharp-tailed grouse (when compared to sage grouse) appeared to have narrower brood site niche breadths for individual resources. Columbian sharp-tailed grouse niche

breadth appeared to be narrower in 6 of 9 resource states when compared to sage grouse. Columbian sharp-tailed grouse niche breadth appeared noticeably broader in the 3 remaining resource states. Therefore, it appears that Columbian sharp-tailed grouse are more specialized in their use of brood-rearing habitat than sage grouse. It is more specialized because brood-rearing habitat for Columbian sharp-tailed grouse had increased cover.

Simply viewing each grouse species from the perspective of niche height and breadth can be misleading and uninformative when 2 species are sympatric, therefore the resource procurement and variety of resources used are important in habitat partitioning. Niches are typically not symmetrical and Krebs (1989) suggested it is more useful to review niche breadth and overlap directly. The use of varying degrees of grass cover (Fig 2.20) illustrated a moderate degree of niche overlap between grouse species. Sage grouse brood use was higher in the lower grass cover portion of the gradient. In contrast, Columbian sharp-tailed grouse brood use was concentrated along the medium to high portion of the grass cover gradient. Forb cover (Fig. 2.21) use was not symmetrical for either grouse species, but illustrated a situation where both species of grouse had nearly 100% niche overlap. Both species used essentially equivalent levels of the forb cover gradient and there was little to no niche separation. If forb cover was potentially limiting, interspecific competition could become a factor and possibly limit the less competitive grouse species.

Brood Versus Nest Sites

Overall (both grouse species) brood habitat had higher litter cover, less grass cover, taller sagebrush, lower sagebrush and non-sagebrush canopy cover, and less visual obstruction than nest sites. These trends were not maintained and differed when each grouse species was considered.

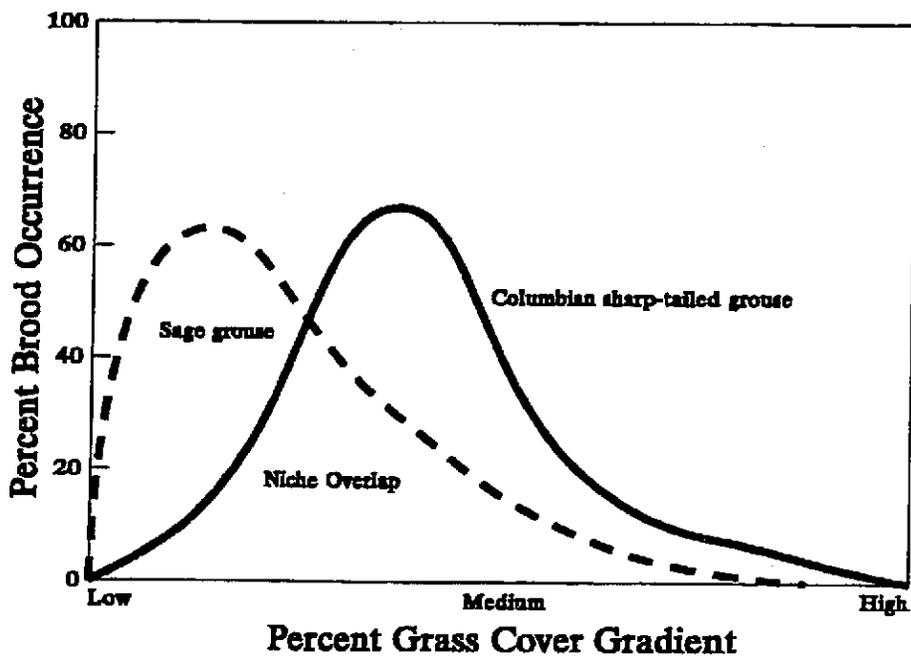


Figure 2.20. Niche breadth and overlap along the grass cover gradient for sage and Columbian sharp-tailed grouse brood habitat in the Curlew Valley region of southeastern Idaho, 1988-91.

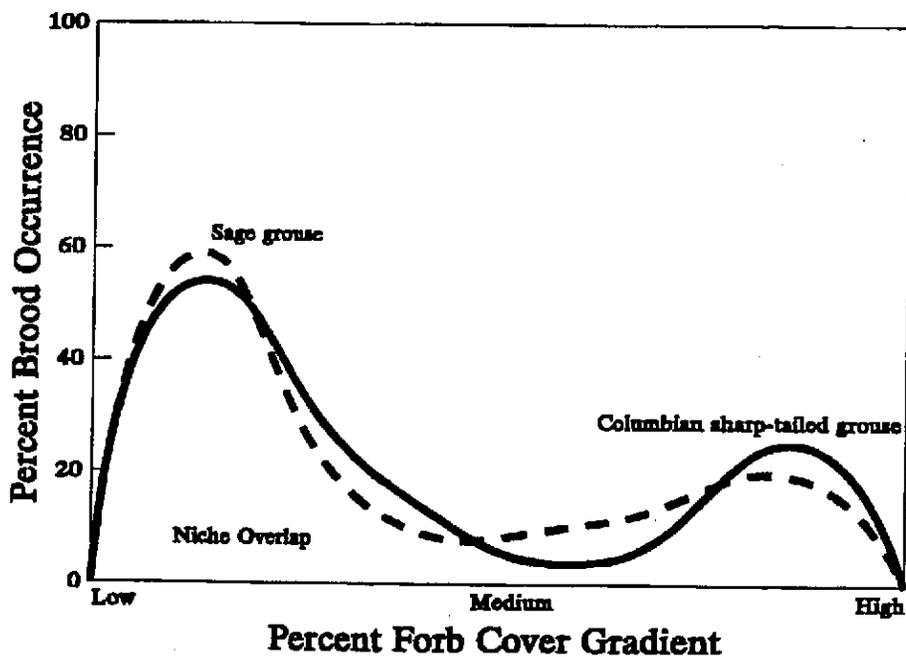


Figure 2.21. Niche breadth and overlap along the forb cover gradient for sage and Columbian sharp-tailed grouse brood habitat in the Curlew Valley region of southeastern Idaho, 1988-91.

Following nesting, sage grouse hens with broods moved from nests to brood habitats that had less slope, shorter sagebrush and less grass cover and sagebrush canopy cover. In general, sage grouse sought out less cover when they moved from nest to brood sites. However, Columbian sharp-tailed grouse broods moved from nest sites to brood sites with taller sagebrush, but had lower grass cover in an effort to seek out increased security cover from predators.

Although nest sites differed in various structural characteristics from brood sites, the understory also had unique characteristics for sage and Columbian sharp-tailed grouse. Sage grouse brood sites were frequently (70%) misclassified as nest sites, but only 3% of nest sites were misclassified as brood sites. Although the grass component was very important for the classification of each site, forb species from the subfamily Heliantheae (HELI) and Family Compositae constituted a large portion of the covariance. Therefore, HELI was a unique component at nest sites. Specifically, it included the balsamorhizas (Balsamorhiza spp.), hoary false-yarrow (Chaenactis douglasii), Rocky Mountain helianthella (Helianthella uniflora), and common sunflower (Helianthus annuus). The Gramineae tribes of Hordeae (HORD) and Festuceae (FEST) contributed equally and dominated nest sites, whereas only HORD dominated brood sites. HORD species members included the bunchgrasses (Agropyron spp.) and FEST members included hairy brome (Bromus commutatus), and cheatgrass brome (B. tectorum). Other grass species included oniongrass (Melica bulbosa), Sandberg's bluegrass (Poa sandbergii), and bulbous bluegrass (P. bulbosa). The dominance of HORD at brood sites is even more important due to the structural nature of bunchgrasses and the security cover it provided. Both HORD and FEST contributed equally to nest sites which provided more cover at differing vertical structure levels in the understory.

Columbian sharp-tailed grouse brood and nest sites were also unique in their understory characteristics. While 100% of the nest sites were classified correctly, 100% of the brood sites were misclassified as nests. This is partially explained by brood use of

greater cover during the brood-rearing period than was present at nest sites. Brood sites were classified as nest sites, although brood sites provided more cover, they were similar enough to nesting habitat cover requirements. In addition, Columbian sharp-tailed grouse nest site understory was dominated by FEST. Many of the grasses that represented this Tribe were early, cool-season (Stoddart et al. 1975) grasses that provided cover during the nesting season, but were dormant during the brood-rearing season. Brood sites were dominated by the bunchgrasses in HORD and provided an increased level of security cover that was sought out during the brood-rearing period. An additional component that provided a level of uniqueness to nest sites was the presence of grass species in the Tribe Agrostideae (AGRO). Species included Indian ricegrass (Oryzopsis hymenoides) and the needlegrasses (Stipa spp.). AGRO was present at brood and nest sites but covariance levels were much less at brood than at nest sites.

There was also a level of predictability associated with understory and overstory characteristics for brood and nest sites with sage and Columbian sharp-tailed grouse. A sage grouse brood site (when compared to a nest site) had < 13% grass cover, < 6% slope, and < 16% sagebrush canopy cover. In contrast, sites with > 13% grass cover, > 6% slope, and > 16% sagebrush cover were more characteristic of a sage grouse nest sites and were less characteristic of brood sites.

Only 2 variables provided a level of predictability with Columbian sharp-tailed grouse brood and nest sites. Sites with > 80 cm tall sagebrush and < 16% grass cover were more typical of brood sites. Sites that had < 70 cm tall sagebrush and > 16% grass cover were more predictably nest sites rather than brood sites.

Nesting habitat niche breadth for sage grouse was narrower than brood habitat. Even though no statistical differences were apparent, nest site niche breadth for each resource state appeared narrower for 6 of 9 resource states. This suggests that sage grouse were more specialized in their use of nesting habitat than brood habitat. The variable of total shrub canopy cover illustrated a large niche breadth for brood habitat, with use in

both extremes of the shrub cover gradient (Fig. 2.22). In contrast, a narrower niche breadth for nesting habitat (Fig. 2.22) resulted from a low amount of use in the low total shrub canopy cover end of the gradient and much higher use in the high cover end of the gradient. More sage grouse brood sites occurred at lower slopes (Fig. 2.23) and use decreased with high slopes which resulted in a narrower niche breadth, whereas there was a much larger and more extensive use of low, medium, and high slopes with nesting habitat. This resulted in a much larger niche breadth.

For Columbian sharp-tailed grouse, only 5 of 9 niche breadths were narrower for nesting habitat when compared to brood habitat. There appeared to be a lesser degree of niche separation between nest and brood habitats. Brood habitat niche breadth for total shrub canopy cover (Fig. 2.24) was quite extensive as was nest niche breadth. Because of extensive brood use in the high and low total shrub canopy cover gradient, the breadth is high. Niche overlap between the 2 use types was also extensive. Slope (Fig. 2.25) illustrated 100% niche overlap and was identical in use for nesting and brood-rearing habitats. Essentially, all of the nest and brood-rearing habitat was located in the low to medium slope sites. If the availability of low sloped areas becomes limiting, both brood and nest site availability will be impacted.

Sage and Columbian sharp-tailed grouse partitioned brood habitat resources differently. Sage grouse broods used habitat that provided less cover than nest sites and Columbian sharp-tailed grouse brood habitat, whereas Columbian sharp-tailed grouse broods sought out increased security cover. Brood habitat resources were partitioned between sympatric sage and Columbian sharp-tailed grouse. In habitats where sage and Columbian sharp-tailed grouse occur sympatrically, there must be an emphasis for the management of a diversity among and within habitats due to the complex nature of differing interspecific habitat needs and differing seasonal (nest versus brood) needs for each species.

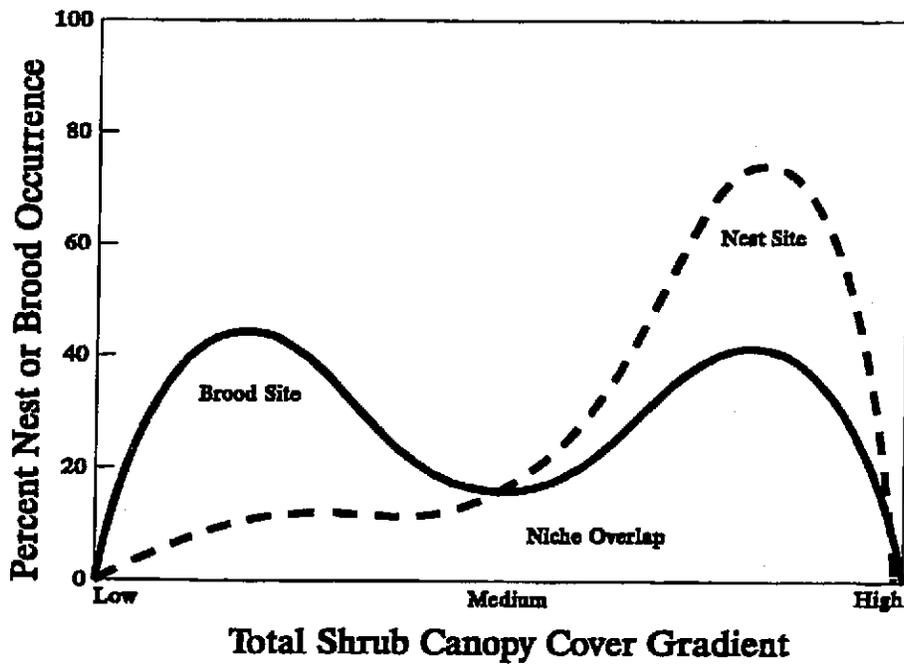


Figure 2.22. Niche breadth and overlap along the total shrub canopy cover gradient for sage grouse nest and brood sites in the Curlew Valley region of southeastern Idaho, 1988-91.

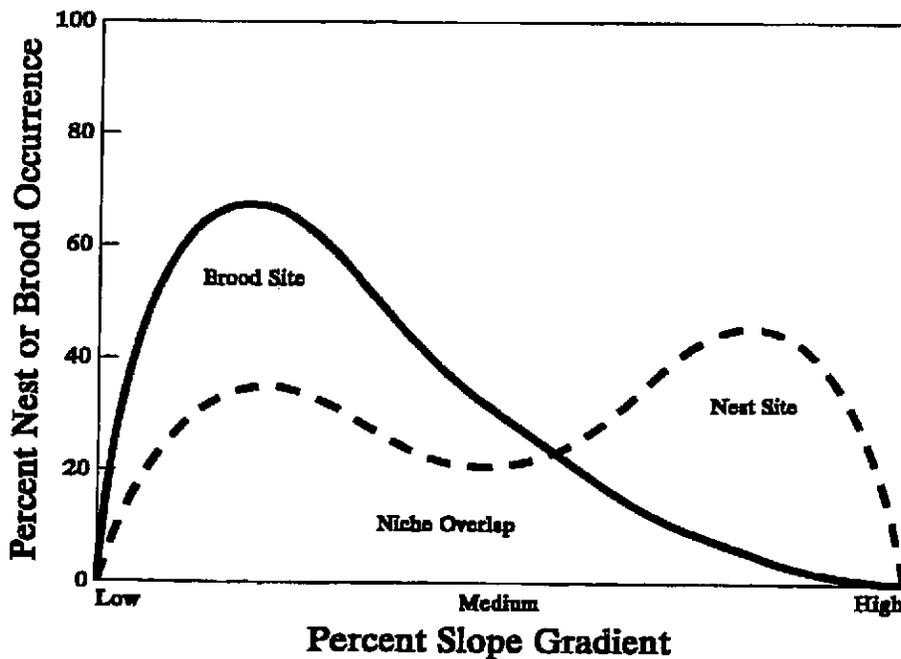


Figure 2.23. Niche breadth and overlap along the slope gradient at sage grouse nest and brood sites in the Curlew Valley region of southeastern Idaho, 1988-91.

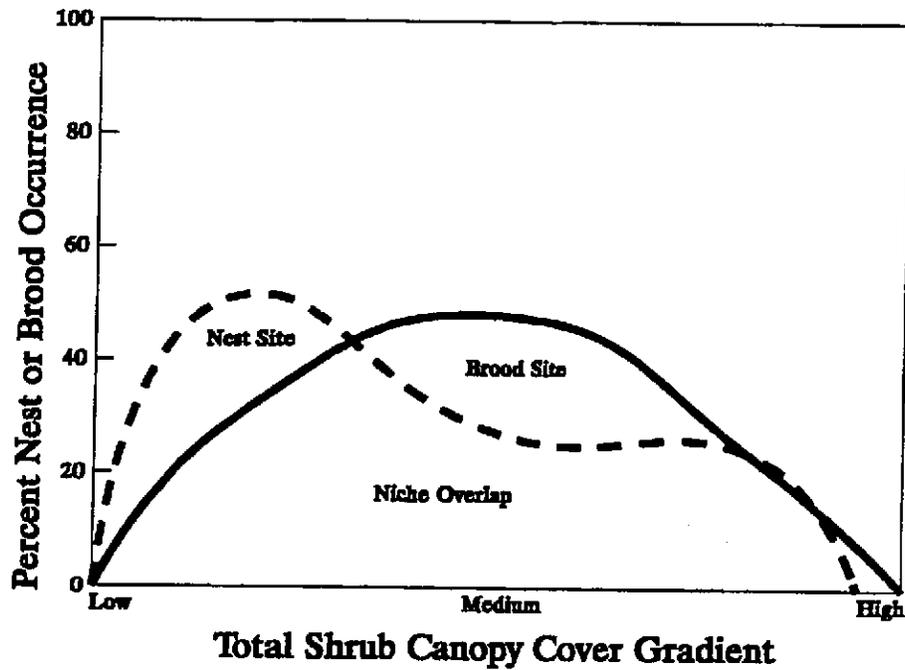


Figure 2.24. Niche breadth and overlap along the total shrub canopy cover gradient for Columbian sharp-tailed grouse nest and brood sites in the Curlew Valley region of southeastern Idaho, 1988-91.

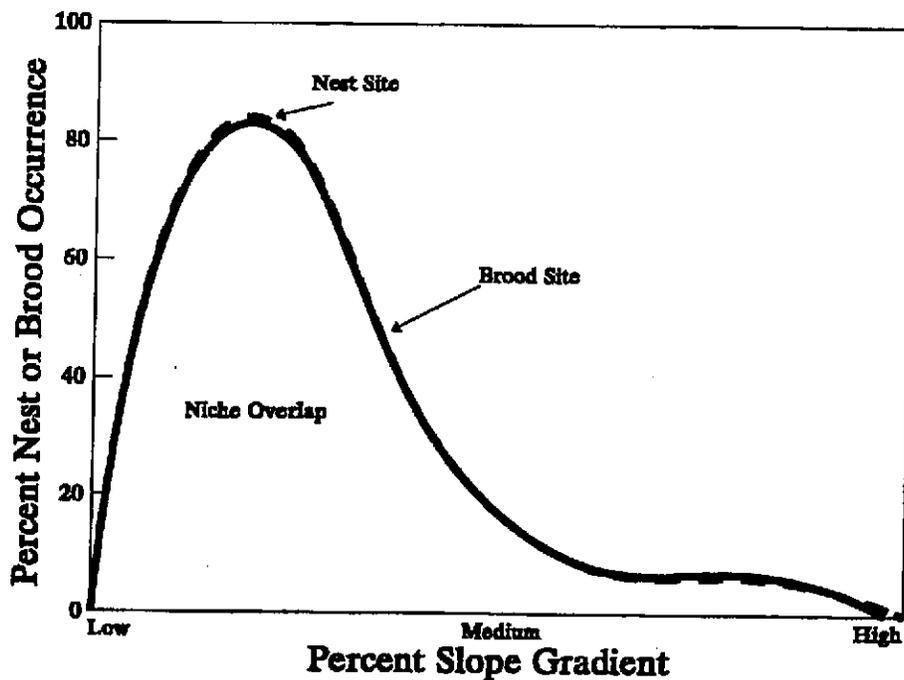


Figure 2.25. Niche breadth and overlap along the slope gradient for Columbian sharp-tailed grouse nest and brood sites in the Curlew Valley region of southeastern Idaho, 1988-91.

MANAGEMENT IMPLICATIONS

Sagebrush/grass and mountain shrub communities are much reduced from historic levels (Beetle 1960, Schneegas 1967, Sturges 1973, Braun et al. 1976). In addition, these habitats are quite vulnerable to disturbance through wildfire and prescribed fire. Sage and Columbian sharp-tailed grouse use these habitats in different ways both interspecifically and intraspecifically during the nesting and brood-rearing periods. My results suggest that sage grouse broods require lower sagebrush cover than during nesting. Therefore, a diversity of sagebrush age structures and canopy coverages are needed for nesting and brood-rearing habitat. Land managers could suggest the need to reduce sagebrush cover to enhance brood habitat, but Fischer et al. (1996a) concluded that the most popular form of sagebrush control (prescribed fire) did not enhance brood-rearing habitat and may be detrimental. They also cautioned against the use of fire in xeric sagebrush habitats as a management tool for sage grouse brood habitat. Therefore, a land management prescription to control sagebrush that benefits only 1 land use or wildlife species is short-sighted. Sagebrush treatments could also be used to improve Columbian sharp-tailed grouse nesting or brood-rearing habitat and may appear to benefit Columbian sharp-tailed grouse. Benefits would be provided in the short-term, by increasing understory cover, but in situations where sage and Columbian sharp-tailed grouse occur sympatrically it would be very detrimental to sage grouse habitat (Fischer et al. 1996a) and also detrimental to Columbian sharp-tailed grouse brood habitat. Therefore, any sagebrush management in brood habitat of both grouse species is best directed towards small (< 100 ha) areas. Treatments should not eliminate sagebrush cover, but reduce its density because elimination of sagebrush would irreparably damage sage grouse nesting habitat.

If management of sagebrush communities is needed for shrub steppe community health, then efforts should be directed towards the creation of true mosaics of habitat qualities. Differing levels of sagebrush abundance must occur across the landscape within the sagebrush/grass community. In addition, sagebrush/grass community restoration

projects should be emphasized in situations where non-native understories (i.e. crested wheatgrass, bulbous bluegrass, or cheatgrass brome) exist. Following control of exotic understories, land managers should restore the sagebrush/grass community by seeding a high plant species diversity (≥ 10 shrub, grass and forb species) that will maintain $> 10\%$ forb and 10 - 20% grass cover in the understory and maintain sagebrush cover. These techniques are recommended to maintain and/or improve degraded sagebrush communities in remaining and historic sage and Columbian sharp-tailed grouse habitat.

CHAPTER III.

AN EVALUATION OF NEST PLACEMENT THEORY USING ARTIFICIAL AND COLUMBIAN SHARP-TAILED GROUSE NESTS

INTRODUCTION

Predation is the major factor affecting nest success in many bird species (Skutch 1966, Ricklefs 1969, Nilsson 1984), especially ground nesting birds (Campbell et al. 1973). In certain situations predation could act as a dominant selective force influencing population fluctuations, local abundances (Potts 1980, Angelstam 1983, Myrberget 1984), and assemblages (Martin 1987b). Predators do not randomly remove individuals or nests (Horkel et al. 1978, Ricklefs 1979) from populations. Therefore, if predatory pressure and search image (Tinbergen 1960) differ among species, habitats (Whitcomb et al. 1981, Askins et al. 1990, Andr en 1992), and areas, predation could influence life history traits, habitat use, and population and community patterns (Duebbert and Kantrud 1974, Slagsvold 1982, Martin 1987a).

Mammals are the primary predators of ground nests (Klimstra and Roseberry 1975, Baker 1980, Nol and Brooks 1982), although avian predators, specifically corvids (Corvus spp.), readily prey upon ground nests (Picozzi 1975, Yahner and Voytko 1989, Andr en 1992). Avian predators exhibit the greatest pressure during the egg-laying period when the nest is unattended (Dwernychuk and Boag 1972). Engel and Young (1989) found that bird remains were most prevalent in common raven (C. corax) pellets during the spring when nestling birds and eggs were abundant.

If predation influences nest placement by hens of lek-attending species, it may also have an indirect influence on lek evolution and development. Various theories attempt to explain lek formation which may directly or indirectly relate to nest placement by ground-nesting Tetraoninae. Bradbury (1981) suggested in the "female-preference" (F-P) model that males provide very little except a situation (clustered males) where females can quickly

evaluate phenotypic differences between possible mates. The F-P model provides no direct testable prediction when considering nest site selection. Bradbury and Gibson (1983) and later Bradbury et al. (1986) proposed the "hotspot" (H-SP) model. They suggested that males establish leks in areas with increased female density. As with the F-P model, a direct testable prediction of the H-SP model would be difficult. Beehler and Foster (1988) proposed the "hotshot" (H-SH) model which relates to female mate selection. They suggested that mating patterns relate to differences in male attractiveness which facilitates exclusive mating by a select group of males (hotshots). Hotshots proliferate as a result of female mate fidelity and associated mimicking females, thus resulting in a non-testable prediction when considering nest placement.

Two additional models allow more testable predictions concerning nest placement. Wrangham (1980) hypothesized the "male-avoidance" (M-A) model which suggests females should select males away from nesting areas to avoid negative impacts accompanying advertising males. This is supplemented by the predation influences proposed by Brown (1964) and Crook (1965). The M-A model allows a testable prediction that nesting success would increase with distance from displaying males. In a more aggressive prediction of the M-A model, Gratson (1988) hypothesized that sharp-tailed grouse (Tympanuchus phasianellus) hens should nest as far as possible from displaying males while still remaining in their home range. Although this nesting strategy could be associated with food and/or habitat availability, Gratson (1988) contended that nesting farther from active leks could reduce predation on the hen or her clutch by nesting far from conspicuously advertising males that attract predators (Berger et al. 1963, Hamerstrom et al. 1965, Sparling and Svedarsky 1978). Phillips (1990) disagreed with earlier theories and proposed the "sentinel/decoy" (S-D) model, and suggested that lek-displaying male birds reduce nest-related predation by decoying predators away from incubating females and alerting them to approaching predators. The S-D model further predicts that an area of reduced predator density exists in a maximum range because predators are attracted to

displaying males. The S-D model hypothesizes that nests located in a region of reduced predator density should be susceptible to reduced predation rates relative to nests located both closer and farther from displaying males.

Credible empirical tests of theoretical models of avian nesting strategy in natural systems are sparse because sample sizes of natural nests are typically small. Artificial nests provide large sample sizes and are an acceptable tool to evaluate predation rates (Andrén 1992). Although predation rates on artificial nests cannot be directly related to natural nests (Wilcove 1985, Martin 1987a, Willebrand and Marcström 1988, Andrén 1992), because artificial nest predation rates are typically higher, the results from artificial nests can be used as an index to natural situations (Andrén 1992).

I experimentally tested predictions of the M-A model (Gratson 1988) and the S-D model (Phillips 1990) by using artificial nests placed at increasing distances from active Columbian sharp-tailed grouse (*T. p. columbianus*) leks. I also compared artificial nest predation rates and habitat with Columbian sharp-tailed grouse nests in the same area.

METHODS

Artificial Nests

I selected 7 different active Columbian sharp-tailed grouse dancing grounds (leks) over 2 years (1990-91) around which I placed artificial nests. Only 1 lek was used both years. Leks used in the study were required to have ≥ 12 dancing males, were > 4 km apart, and were representative (spatially and vegetally) of the study area.

I placed artificial nests at 6 sequentially increasing distances (0.25, 0.50, 0.75, 1.00, 1.50, 2.00 km) from the center of a lek while driving along secondary roads and trails. I positioned a nest 40 m on each side of the road at each predetermined distance. Nest site locations were marked inconspicuously along the road with wooden stakes ≤ 15 cm tall. I located and relocated artificial nest sites using a compass bearing and a 40 m

tape. Nests were constructed and checked at night (2100-0400) to avoid observer-induced predation.

Artificial nests consisted of a small (10-cm diameter) scrape in the soil under a sagebrush plant ≥ 40 cm in height. If there was not a sagebrush plant within 1 m of the selected location I placed the nest under the nearest available vegetation. I placed 3 paraffin-coated, brown, chicken eggs in each depression. Eggs had been earlier coated with paraffin to reduce the scent of spoilage and I wore rubber gloves to reduce human scent. Pilot studies (1988-89; Apa, unpubl. data) indicated that nest depredations were largely caused by avian rather than mammalian predators in my study area.

I checked nests at 1, 3, 6, and 9 nights following nest placement. Two egg placement periods (Trial I and II) were evaluated. Trial I occurred from 29 April to 14 May corresponding with the initial egg-laying period for Columbian sharp-tailed grouse (Meints 1991, Apa, unpubl. data) (Appendix C). Trial II occurred from 5 June through 23 June simulating the egg-laying period for renesting Columbian sharp-tailed grouse (Meints 1991, Apa, unpubl. data) (Appendix C).

Artificial nests were classified as survived or destroyed. Surviving nests had at least 1 unmolested egg following a visit. Predator type, avian or mammalian, was determined (Rearden 1951) at all destroyed nests. At most (99%) destroyed nests no egg shell remains were present and the predator type was presumed to be avian.

Columbian Sharp-tailed Grouse Nests

I captured Columbian sharp-tailed grouse with funnel traps on leks during the spring (Marks and Marks 1987). I radio-tagged 12, 3, 19, and 22 female Columbian sharp-tailed grouse in 1988, 1989, 1990, and 1991, respectively. Females were fitted with poncho-mounted, solar, radio transmitters (Amstrup 1980) weighing 14 g with a 15-cm antenna. Sex of the grouse was determined from crown and tail feathers (Henderson et al. 1967) and birds were classified by age using primary feather wear (Ammann 1944). I

weighed all grouse using a pesola scale, and individually marked each bird with an aluminum leg band.

I located 48 Columbian sharp-tailed grouse on nests. I classified each nest as successful (at least 1 egg hatched) or unsuccessful. Predator type at unsuccessful nests was determined in the same manner as artificial nests.

Vegetation Measurements

I measured numerous micro-habitat variables, both horizontal and vertical vegetation structure, at each sharp-tailed grouse nest and at 83 artificial nests randomly selected of 551. Four transects (20 m each) were situated in the cardinal directions using the nest bowl as the intersecting point. Intercept distance of shrub species was measured to calculate percent cover (TOTALCC) (Canfield 1941). At 5-m intervals the height of the nearest living or dead sagebrush plant (SAGEHT) within 2-m of the transect was measured. Cover board measurements (Jones 1968) were taken at 0° (JO2) and 45° (JO45). Distance of the nest from the capture lek was determined using Universal Transverse Mercator (UTM) grid ticks on 7.5' quadrangle topographic maps.

Statistical Analyses

Because of the categorical (survived or destroyed) nature of the data, I used logistic regression with nest fate as the dependent variable and the independent variables were 4 leks each year (LEK), 2 years (YEAR), 2 egg placement trials (TRIAL), and 6 distances (DIST). A separate logistic regression analysis was conducted for each day the nests were exposed and checked (DAY). A repeated measures logistic regression analysis was more appropriate, considering the sampling procedure, but a valid repeated measures analysis requires that all possible combinations of the survival (1 = survive, 0 = destroyed) by DAY matrix, $X' = (1\ 1\ 1\ 1, 1\ 1\ 1\ 0, \dots, 0\ 0\ 0\ 0)$, should occur in each statistical population (SAS 1988). All possible combinations did not occur in my data. Logistic regression

aided in the determination of which independent variables had a significant ($\alpha = 0.05$) influence on the dependent variable. My analysis was similar to Samuel et al. (1987) who used a logistic model to predict sightability of elk (*Cervus elaphus*).

I used a Chi-square test (a Wald test) (SAS 1988) for each effect based on the information matrix from the maximum likelihood calculations. For each significant source of variation there was also an analysis of contrasts. The Chi-square value was used to determine the significance probability of specific contrasts.

I also used logistic regression to analyze the relationship of distance from lek to nest and nest fate of Columbian sharp-tailed grouse nests. The dependent variable was nest fate and the independent variables included 3 years (YEAR) and 4 distance intervals (DIST) from the capture lek. Only 1 sharp-tailed grouse nest was located in 1989, so this nest was combined with the 1988 data. I used 4 distance intervals: 200 - 519, 664 - 1740, 1940 - 3159, and 4161 - 12,749 m. The distance intervals were selected from observable patterns in the distance frequencies and were not equivalent to the 6 distance categories used in the artificial nest analysis.

To determine if vegetation structure differed across distances, at grouse and artificial nests, between years and between grouse and artificial nests, I used linear discriminate function analysis or multivariate analysis of variance (MANOVA). MANOVA was the preferred approach although sometimes the assumptions of variance-covariance homogeneity and multivariate normality (Johnson and Wichern 1992) were unattainable. Johnson and Wichern (1992) suggested that the condition of multivariate normal populations can be relaxed by appealing to the central limit theorem, although the same is not true for variance-covariance heterogeneity. When the assumption of variance-covariance homogeneity and/or multivariate normality was violated ($\alpha = 0.10$) (Morrison 1976) nonparametric discriminate analysis (the kernel method) (Rosenblatt 1956, Parzen 1962) was used to evaluate the presence of 1 or more quantitative variable classifications. If the percent of misclassifications, the expected actual error rate, (\hat{e} (AER)) ≥ 0.30 then

each observation was considered from 1 population. An \hat{e} (AER) < 0.30 would indicate observations were from multiple populations. The \hat{e} (AER) is preferred over the apparent error rate (APER) because the APER is optimistically biased (Johnson and Wichern 1992). The APER is also biased because it is calculated from the training set, whereas the \hat{e} (AER) is calculated using a crossvalidation (SAS 1988) or a holdout (Johnson and Wichern 1992) procedure which produces a more precise estimate of the error rate.

Finite daily survival was calculated using a modification of the Mayfield (1975) method (Bart and Robson 1982). I used MAYFIELD (Krebs 1989) to calculate finite daily survival and 95% confidence limits.

I used a Student's t-test to test for differences between mean distances of successful and unsuccessful Columbian sharp-tailed grouse nest and survived and destroyed artificial nests. A variance ratio test was used to examine differences between distance variances for the aforementioned categories for Columbian sharp-tailed grouse and artificial nests.

I determined artificial nest density (number of nests/100 ha) by dividing the number of nests by the area estimate ($A = \pi r^2$) of each concentric distance band (e.g. 1000 m band area was in the radius 751-1000 m). All previous centrally located area bands were excluded from the total band area parameter. I used the same method to determine grouse nest density. The number of nests located varied by year and lek for each distance. Mean density was first calculated by lek and year for each distance and then a mean density for each distance over all 4 years was calculated for each distance. All data for the 2 years of my study were pooled ($P \geq 0.05$).

RESULTS

I constructed and checked 551 artificial nests over 2 years. In 1990 and 1991, 262 (47.5%) and 289 (52.5%) nests were constructed, respectively. The number of nests was equally divided between egg placement Trials within years. During 1990, Trials I and II had 130 (49.6%) and 132 (50.4%) nests, respectively. During 1991, Trials I and II had

148 (51.2%) and 141 (48.8%) nests, respectively. Artificial nest sample sizes do not always sum consistently/equally across years, days, and/or placement trials due to logistic problems associated with relocation techniques (at night) and extreme weather (rain).

Nest survival for the entire 9 day exposure period was low. During Trial I, 23 (8.3%) nests survived. Twenty-six (9.5%) nests survived during Trial II.

The LEK variable was significant in each DAY model. LEK was significant in the DAY1 ($P = 0.000$), DAY3 ($P = 0.001$), DAY6 ($P = 0.006$), but not in the DAY9 ($P = 0.195$) model. Even though LEK contributed significantly to the logistic regression model, I propose that a biological interpretation of the data would be difficult and possibly meaningless. Therefore data from the 7 leks were pooled and LEK was dropped from the model to develop a less complex model and to aide in an explainable interpretation.

DIST (6 distances) and TRIAL (2 trials) were evaluated with each DAY model. Following the first day of exposure DIST ($P = 0.002$) and TRIAL ($P = 0.036$) were significant contributions to the logistic regression model, indicating a distance and temporal influence on nest survival. Following 1 day of exposure, artificial nest survival was higher at 2,000 m than at 250, 500, 750, and 1,000, but not at 1,500 m (Table 3.1). Artificial nest survival was also higher at 1,500 than at 500 m ($P = 0.011$) (Table 3.1).

Following 3 days of exposure a distance ($P = 0.001$) and temporal influence ($P = 0.047$) were retained in the logistic regression model. Artificial nest success was higher at 2,000 m than at 250, 500, 750, and 1,000 (Table 3.1). Additional survival differences were also identified. The number of nests surviving at 250 m differed from 1,500 m and the number of nests surviving at 500 m differed from 1,000 and 1,500 m (Table 3.1).

Following 6 days of exposure only the distance ($P = 0.018$) influence was retained in the logistic regression model. Because of the low number of surviving nests only extreme distance contrasts were significant. The number of nests that survived at 250 m differed from 1,500 and 2,000 m. The number of surviving nests at the next closest distance, 500 m, differed from 1,000, 1,500, and 2,000 m (Table 3.1).

Table 3.1. Paired contrasts of artificial nest distances from active Columbian sharp-tailed grouse leks following 1, 3, 6, and 9 days of exposure in the Curlew Valley region of southeastern Idaho, 1990-91.

Contrasts	DAY1 ^a			DAY3 ^a			DAY6 ^a			DAY9 ^{a,b}		
	n	Chi-Square	P	n	Chi-Square	P	n	Chi-Square	P	n	Chi-Square	P
250 vs 500	135	0.01	0.924	120	0.91	0.339	131	0.54	0.463	--	--	--
250 vs 750	126	0.59	0.441	107	2.72	0.099	119	2.28	0.131	219	1.87	0.171
250 vs 1000	176	1.15	0.284	158	3.67	0.055	169	3.59	0.058	270	7.70	0.005
250 vs 1500	173	3.45	0.063	166	5.38	0.020	174	4.66	0.031	271	8.24	0.004
250 vs 2000	109	9.55	0.002	97	7.13	0.008	110	4.69	0.030	208	10.88	0.001
500 vs 750	177	1.18	0.277	159	1.95	0.162	170	1.92	0.166	--	--	--
500 vs 1000	227	2.35	0.125	210	4.34	0.037	220	4.95	0.026	--	--	--
500 vs 1500	224	6.52	0.011	218	9.43	0.002	225	7.78	0.005	--	--	--
500 vs 2000	160	14.55	0.000	149	13.58	0.000	161	7.18	0.007	--	--	--
750 vs 1000	218	0.10	0.751	197	0.34	0.557	208	0.68	0.411	219	2.49	0.115
750 vs 1500	215	1.76	0.184	205	2.78	0.095	213	2.19	0.139	220	2.89	0.089
750 vs 2000	151	7.89	0.005	136	6.06	0.014	149	2.07	0.151	157	5.17	0.023
1000 vs 1500	265	1.32	0.250	256	1.75	0.186	263	0.64	0.422	271	0.03	0.864
1000 vs 2000	201	7.73	0.005	187	5.18	0.023	199	0.66	0.417	208	1.17	0.279
1500 vs 2000	198	3.56	0.059	195	1.44	0.230	204	0.02	0.892	209	0.88	0.349

^aThe Chi-Square and significant probabilities generated from Wald Statistics based on the estimated standard errors.

^bDistances 250 and 500 were combined in analysis to achieve non-redundant parameters in logistic regression.

Following 9 days of exposure the number of nests surviving close to the lek was so few that I combined some distances. Because many statistical populations were identical, distances 250 and 500 m were pooled into a single distance (250 m) to eliminate redundant parameters (Table 3.1). Following 9 days of exposure the distance influence remained ($P = 0.007$) in the logistic regression model. Fewer artificial nests survived at 250 m than at 1,000, 1,500 m, and 2,000 m. The next minimum distance (750 m) had fewer nests that survived than at 2,000 m (Table 3.1).

Finite Daily Survival And Nest Density

During Trial I, the finite daily survival rate of artificial nests increased with distance from 0.425 at 250 m to 0.777 at 2,000 m (Table 3.2). During Trial II the same trend of increasing finite daily survival rate with distance was evident. Survival was 0.403 at 250 m and increased to 0.781 at 2,000 m.

Artificial nest density exhibited an inverse relationship during Trial I (Fig. 3.1) and Trial II (Fig. 3.2) to daily survival; artificial nest density decreased with increasing distance from the lek. Densities were very similar during Trial I and II. During Trial I artificial nest densities were 10.7, 7.8, 4.2, 4.8, 1.7, and 0.6 nests/100 ha at 250, 500, 750, 1,000, 1,500, and 2,000 m, respectively. A regression analysis revealed a negative relationship ($\beta = -0.032$, $P = 0.005$) between daily survival (dependent variable) and nest density (independent variable). A significant amount ($R^2 = 0.889$) of variation explained in daily survival is accounted for by nest density. During Trial II artificial nest densities were 10.7, 8.0, 4.4, 5.0, 1.7, and 0.7 nests/100 ha at the 6 distances. A regression analysis revealed a negative relationship ($\beta = -0.039$, $P = 0.002$) between daily survival and nest density. A significant amount ($R^2 = 0.930$) of the variation explained in survival is accounted for by nest density.

Table 3.2. Maximum likelihood estimates of finite daily survival of artificial nests exposed for 9 days at 6 distances from active Columbian sharp-tailed grouse leks during 2 nest placement trials in the Curlew Valley region of southeastern Idaho, 1990-91.

Distance from Lek (m)	TRIAL I			TRIAL II		
	n	Daily Survival	95% CI	n	Daily Survival	95% CI
250	21	0.425	0.179-0.569	21	0.403	0.198-0.555
500	46	0.588	0.474-0.679	47	0.429	0.304-0.534
750	41	0.611	0.482-0.705	43	0.591	0.473-0.686
1000	66	0.707	0.629-0.770	69	0.658	0.577-0.727
1500	68	0.740	0.676-0.794	68	0.718	0.645-0.789
2000	35	0.777	0.687-0.844	38	0.781	0.694-0.848

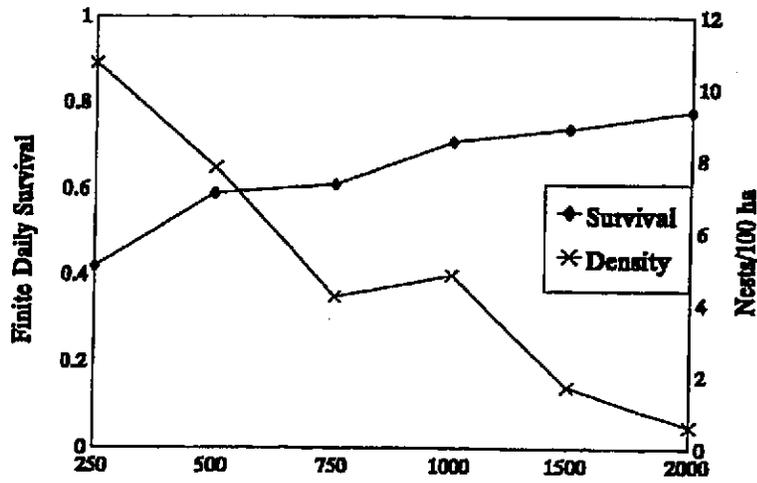


Figure. 3.1. Artificial nest survival and density in relation to distance from active Columbian sharp-tailed grouse leks during Trial I in the Curlew Valley region of southeastern Idaho, 1990-91.

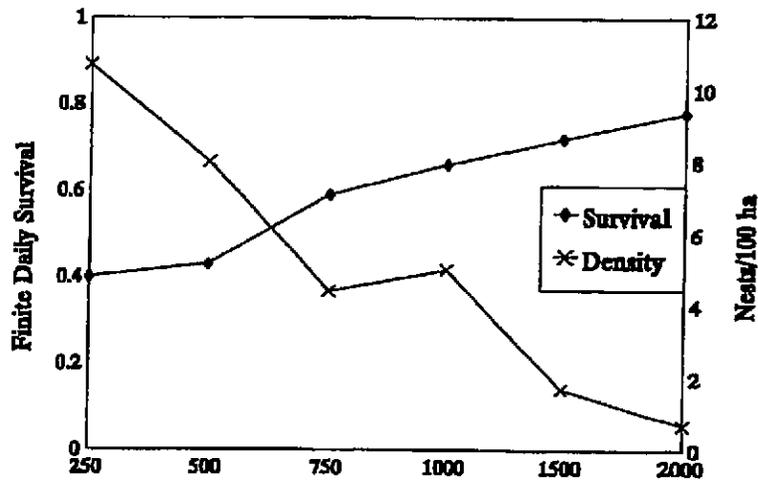


Figure. 3.2. Artificial nest survival and density in relation to distance from active Columbian sharp-tailed grouse leks during Trial II in the Curlew Valley region of southeastern Idaho, 1990-91.

Artificial Nest Vegetation Measurements

I evaluated vegetation variables TOTALCC, SAGEHT, JO2, and JO45 across each distance from the lek using MANOVA because of homogeneous covariance structures ($P > X^2 = 0.256$, 50 df). The aforementioned vegetation variables were homogeneous (MANOVA; Wilks' $\lambda = 0.75$, $F = 1.11$; 20, 246 df; $P = 0.3430$) among distances (Table 3.3).

Columbian Sharp-tailed Grouse Nests

Distances from the lek of capture to Columbian sharp-tailed grouse nests ($n = 48$) were divided into 4 intervals. Forty-one of the nests were initial nesting attempts, 6 were first renests and 1 was a second renest. Interval 1 included 12 (25%) nests occurring from 200 - 519 m from leks. Interval 2 included 20 (41%) nests occurring from 665 - 1,739 m from leks. Interval 3 included 8 (17%) nests occurring from 1,940 - 3,159 m and Interval 4 included the remaining 8 (17%) nests occurring from 4,162 - 12,749 m from the leks. Thirty-four (71%) of the nests were located within 2,000 m of leks. One nest was not used in the vegetation analysis due to missing data.

The daily survival rates for Columbian sharp-tailed grouse nests at 4 distance intervals were 0.988, 0.953, 0.983, and 0.963, respectively (Table 3.4). Nest density at the 4 distance intervals was 1.9 ± 0.21, 0.07, and 0.004 nest/100ha, respectively (Fig. 3.3). Daily survival rate was not dependent on nest density ($\beta = 0.011$, $P = 0.384$) (Fig. 3.3). Little variation ($R^2 = 0.380$) could be accounted for by nest density.

Distance from lek of capture was not significant ($P = 0.237$) in the logistic regression model although YEAR was significant ($P = 0.047$). Although yearly differences occurred in Columbian sharp-tailed grouse nest survival, I pooled the 4 years to make a meaningful interpretation.

Table 3.3. Vegetation structure variables of percent total shrub canopy cover (TOTALCC), sagebrush height (SAGEHT), visual obstruction at 0° (JO2) and 45° (JO45) at artificial nests at sequentially increasing distances from active Columbian sharp-tailed grouse leks in the Curlew Valley region of southeastern Idaho, 1990-91.

Distance from lek (m)	n	Vegetation Structure Characteristics							
		TOTALCC	SE	SAGEHT (cm)	SE	JO2 ^a	SE	JO45 ^a	SE
250	7	15.3	5.3	31.7	13.8	97.3	4.3	86.9	8.2
500	18	20.4	3.3	64.7	8.6	99.1	2.7	86.9	5.1
750	12	20.5	4.0	66.7	10.6	99.6	3.3	87.2	6.2
1000	15	23.0	3.6	68.2	9.5	95.7	2.9	75.6	5.6
1500	21	22.6	3.0	75.8	8.0	94.7	2.5	81.6	4.7
2000	10	19.4	4.4	75.3	11.6	95.7	3.6	84.5	6.8

^aMeans and S.E. reported but analyses were conducted on the Arcsin (squareroot) transformation of visual obstruction.

Table 3.4. Maximum likelihood estimates of finite daily survival of Columbian sharp-tailed grouse nests at 4 distance intervals in the Curlew Valley region of southeastern Idaho, 1988-91.

Distance from Lek (m)	n	Daily Survival	95% CI
200-520	12	0.988	0.968 - 0.997
665-1740	20	0.953	0.909 - 0.976
1940-3160	8	0.983	0.951 - 0.996
> 4160	8	0.963	0.891 - 0.987

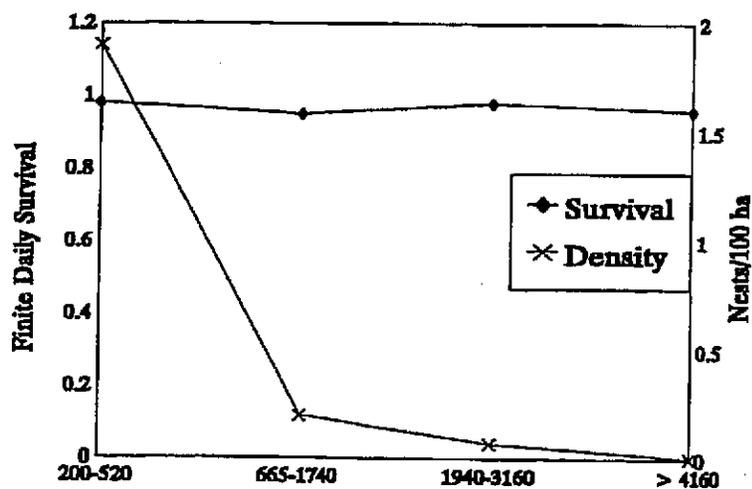


Figure 3.3. Columbian sharp-tailed grouse nest survival and mean density in relation to distance from active Columbian sharp-tailed grouse leks in the Curlew Valley region of southeastern Idaho, 1988-91.

The same vegetation variables collected at artificial nests were collected at Columbian sharp-tailed grouse nests. The 5 aforementioned vegetation structure variables were evaluated across the 4 distance intervals. Within covariance heterogeneity ($P > X^2 = 0.0001$; 30 df) required the use of nonparametric linear discriminate analysis. The 4 vegetation structure variables were included in 1 distance population rather than 4 (\hat{e} (AER) = 0.575).

Columbian Sharp-tailed Grouse And Artificial Nests

The vegetation variables (TOTALCC, SAGEHT, JO2, and JO45) were compared between Columbian sharp-tailed grouse and artificial nests, regardless of distance because there was no difference across distances. Nonparametric discriminate analysis was used because of assumption violations ($P > X^2 = 0.0002$; 10 df). Based on the vegetation variables, the discriminate analysis revealed that artificial nest sites simulated natural grouse nests (\hat{e} (AER) = 0.3308) (Table 3.5). Most (89%) of the 47 grouse nests were misclassified as artificial nests.

The mean distance from the lek of artificial nests that survived was greater than that of destroyed artificial nests during each day the nests were checked for both trials (Table 3.6). There was no difference in the variances for artificial nests during the same time periods (Table 3.6).

A different situation existed with Columbian sharp-tailed grouse nests. The mean distance from capture lek between successful and unsuccessful Columbian sharp-tailed grouse nests was similar during initial ($P = 0.998$) and subsequent ($P = 0.742$) nesting attempts (Table 3.6). In addition, the variances between survived and destroyed Columbian sharp-tailed grouse nests did not differ during initial ($P = 0.128$) and subsequent ($P = 0.856$) nesting attempts.

Table 3.5. Predicted and actual membership of artificial and Columbian sharp-tailed grouse (Sharptail) nests using the vegetation variables of TOTALCC, SAGEHT, JO2, and JO45 in the Curlew Valley region of southeastern Idaho, 1988-91.

		Predicted Group Membership		
		<u>Artificial</u>	<u>Sharptail</u>	<u>Total</u>
Actual Group Membership	Artificial	82	1	83
	Percent	99	1	100
	Sharptail	42	5	47
	Percent	89	11	100
	Totals	124	6	130
	Percent	95	5	100
	Priors	60	40	

Table 3.6. Nest distance from active Columbian sharp-tailed grouse leks of artificial (1990-91) and natural (1988-91) nests following 1, 3, 6, and 9 days of exposure and 2 egg placement trials in the Curlew Valley region of southeastern Idaho.

Days Exposed	\bar{x}	Survived	SD	Destroyed	SD	p^b	p^c
TRIAL I							
DAY1	278	1131.2	531.8	993.5	509.1	0.663	0.031
DAY3	227	1322.1	483.4	1025.7	500.0	0.800	0.000
DAY6	257	1280.5	468.4	1038.2	528.8	0.362	0.007
DAY9	277	1402.7	456.9	1042.3	522.6	0.464	0.002
TRIAL II							
DAY1	273	1173.5	539.1	926.3	468.6	0.104	0.000
DAY3	285	1316.7	492.6	1028.1	521.0	0.672	0.001
DAY6	286	1294.1	490.3	1047.6	527.3	0.663	0.010
DAY9	286	1336.5	468.7	1051.0	527.7	0.490	0.008
NATURAL NESTS							
INITIAL ^a	40	1972.0	2081.7	1973.4	1461.6	0.128	0.998
SUBSEQUENT	7	837.1	995.4	1083.4	818.7	0.856	0.742

^aOutliers (± 3 SD) excluded.

^bVariance test.

^cMeans test.

DISCUSSION

Artificial nests that adequately simulate the vegetation structure and placement of natural nests provide a unique opportunity to evaluate predation rates or patterns with the luxury of large sample sizes plus the control of nuisance variables. The artificial nests I constructed simulated Columbian sharp-tailed grouse nests vegetally and by temporal exposure.

The primary avian predators of artificial nests during my study were the common raven and black-billed magpie (Pica pica). In most depredated nests there were no signs of disturbance, except for egg removal, but occasionally egg shell fragments were present. Personal observations supporting corvids as the primary predators included rapidly depredated nests (4 nests with 3 eggs/nest were depredated in 20 minutes in a 1989 pilot study), egg shell fragments observed at the base of fence posts and along roads, and the depredation of a mallard (Anas platyrhynchos) nest (6 eggs removed by 3 ravens in 10 minutes). The depredated mallard nest had no sign of disturbance except the lack of eggs.

Braun et al. (1978) suggested that nest predation by ravens is a persistent and sometimes serious problem for waterfowl management. The common raven is well adapted to widely scattered and limited food supplies (Jollie 1976, Knight and Call 1980) and, although ravens eat a diverse diet, they are opportunistic and can quickly develop a search image on abundant foods (Engle and Young 1992).

Artificial nests were depredated more quickly early in the exposure period during Trial II than Trial I, although after the 9 days of exposure there was no difference (92 vs 91% destroyed). I believe the higher predation rate early in Trial II is partially explained from learned behavior by ravens from Trial I. In addition, a compounding factor involves the life history of common ravens. Kochert et al. (1975, 1976, 1977) reported average fledging dates of common ravens in Idaho to be 1-3 June. This is precisely when Trial II egg placement was initiated. Increased depredation by fledged ravens plus the learned behavior from Trial I likely caused increased predation rates early during Trial II.

My artificial nest data strongly support the M-A model and suggest that female Columbian sharp-tailed grouse may reduce nest predation by nesting relatively far from leks. My data also support Gratson's (1988) hypothesis that females move relatively far from leks to avoid nest predation. Common ravens are opportunistic scavengers but do not prey on dancing, male Columbian sharp-tailed grouse. However, corvids may develop a search-image (Tinbergen 1960, Tinbergen et al. 1967) for dancing male grouse because they associate dancing males with successful hunting of an often encountered prey (nests). My study did not evaluate the other possible explanations of the M-A model; that male avoidance may be associated with conspicuousness to predators, competition for food, or wasted time and energy from unwanted courtship behavior.

Females nesting relatively close to a lek could encounter higher nest densities and higher predation rates than hens nesting farther from the lek where lower nest densities and lower predation rates occur. Thus, natural selection should select against hens nesting close to the lek and favor hens nesting farther from the lek. However, all nests located at greater distances from leks do not survive. On the contrary, nests far from a lek are also depredated. Therefore, I suggest that as densities increase in local areas predation rates increase which may influence population dynamics, nesting patterns, and habitat use.

Columbian sharp-tailed grouse nest density appeared to decrease with increasing distance from the lek. The highest Columbian sharp-tailed grouse nest density (1.9 nests/100 ha) was only similar to artificial nest densities at 1500 m (2.1 nests/100 ha). This low nest density is most likely reflected in my inability to locate all grouse nests within the area and the density estimate was based upon radio-tagged hens with nests. There appears to be an apparent pattern of density of grouse nests decreasing with distance from the lek, but there is no apparent pattern with nest survival. The nesting strategy exhibited by Columbian sharp-tailed grouse may be to limit maximum movements to nest sites (probably biologically controlled), and nest in densities low enough to avoid the

development of a search image by local predators. If predators detect higher densities they search for and depredate a series of nests.

My data do not support the S-D model as a possible mechanism in lek evolution. The S-D model suggests that the mean distance of successful and unsuccessful nests should be similar, and standard deviations should be higher with unsuccessful nests than successful nests. Neither my artificial nor natural nest data support the model's predictions. Not only were surviving artificial nests significantly farther from the lek, there was no difference in variance. Initial and subsequent nesting attempts with natural nests were not different, as the S-D model predicts and there were no differences in variance.

Distance and density of nests from active leks are interrelated aspects of nest survival. I suggest that the primary nesting strategy should be to move as far from a lek as possible (also dependent on adjacent leks) while remaining at low densities. A hen nesting close to a lek increases the probability of nest depredation from higher nest densities, which results in a uniform, low nest density around leks that is influenced by predation.

MANAGEMENT IMPLICATIONS

My study suggests, through the use of artificial nests, that habitat components that provide critical security cover must occur within 2-km radius of a Columbian sharp-tailed grouse dancing ground. In addition, habitat components become even more important relatively close to the lek. Predation rates on artificial nests were higher close to the lek. Any land management practice that would reduce nesting/security cover near leks would make nesting hens and their clutch more vulnerable.

DeLong et al. (1995) and Gregg et al. (1994) suggested that increased amounts of canopy cover (tall grass and medium-height shrub cover) may reduce overhead visibility of nests, thereby reducing the predation success of avian predators in Oregon. In addition, other authors have suggested that predation rates on artificial nests are reduced when overhead cover is increased (Dwernychuck and Boag 1972, Sugden and Beyersbergen

1987). Dense cover and increased visibility of eggs can also be an important factor in American crow predation.

Although my study did not evaluate grass cover directly, visual obstruction measurements were conducted. Livestock grazing reduces herbaceous horizontal and vertical cover (Galbraith and Anderson 1971, Rickard et al. 1975) in the Great Basin where grass cover is limiting (Winward 1991). Therefore, land managers should attempt to decrease or eliminate livestock or wild ungulate grazing within 2 km of Columbian sharp-tailed grouse dancing grounds to afford a higher level of nest protection through the management of ground cover.

LITERATURE CITED

- Aldrich, J.W. 1963. Geographic orientation of American Tetraonidae. *J. Wildl. Manage.* 27:529-545.
- Ammann, G.A. 1944. Determining the age of pinnated and sharp-tailed grouse. *J. Wildl. Manage.* 8:170-171.
- _____. 1957. The prairie grouse of Michigan. Michigan Dep. Conserv. Tech. Bull. 200pp.
- Amstrup, S.C. 1980. A radio-collar for game birds. *J. Wildl. Manage.* 44:214-217.
- Andrén, H. 1992. Corvid density and nest predation in relation to forest fragmentation: a landscape perspective. *Ecology* 73:794-804.
- Angelstam, P. 1983. Population dynamics of tetraonids, especially the black grouse (*Tetrao tetrix* L.) in boreal forests. Ph.D. Thesis, Uppsala Univ., Sweden.
- Artmann, J.W. 1970. Spring and summer ecology of sharp-tailed grouse. Ph.D. Diss. Univ. Minnesota, St. Paul. 129pp.
- Askins, R.A., J.F. Lynch, and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. *Current Ornith.* 7:1-57.
- Autenrieth, R.E. 1981. Sage grouse management in Idaho. Idaho Dept. Fish and Game, Boise. Wildl. Bull. No. 9. 239pp.
- _____, W.R. Brigham, W. Molimi, P. Shields, J. Slosson, and M. Wickersham. 1977. Livestock and upland wildlife. *in* J.W. Menke, ed. Proc. -- workshop on livestock and wildlife -- fisheries relationships in the Great Basin. Spec. Publ. 3301. 77-86.
- Baker, B.W. 1980. Hair-catchers aid in identifying mammalian predators of ground-nesting birds. *Wildl. Soc. Bull.* 8:257-259.
- Bart, J., and D.S. Robson. 1982. Estimating survivorship when the subjects are visited periodically. *Ecology* 63:1078-1090.

- Bean, R.W. 1941. Life history studies of the sage grouse (Centrocercus urophasianus) in Clark County Idaho. M.S. Thesis, Utah State Univ., Logan. 44pp.
- Beck, T.D.I. 1977. Sage grouse flock characteristics and habitat selection in winter. *J. Wildl. Manage.* 41:18-26.
- _____, and C.E. Braun. 1978. Weights of Colorado sage grouse. *Condor* 80:241-243.
- Beehler, B.M., and M.S. Foster. 1988. Hotshots, hotspots, and female preference in the organization of lek mating systems. *Am. Nat.* 131:203-219.
- Beetle, A.A. 1960. A study of sagebrush, the section Tridentatae or Artemisia. Univ. Wyoming, Agric. Exp. Stn, Stan. Bull. 368. 83pp.
- Berger, D.D., F. Hamerstrom, and F.N. Hamerstrom, Jr. 1963. The effect of raptors on prairie chickens on booming grounds. *J. Wildl. Manage.* 27:778-791.
- Bergerud, A.T. 1988. Increasing the numbers of grouse. Pages 686-731 in Adaptive strategies and population ecology of northern grouse, A.T. Bergerud and M.W. Gratson, eds. Univ. Minnesota Press, Minneapolis. 809pp.
- _____, and M.W. Gratson. 1988. Population ecology of North American grouse. Pages 578-685 in Adaptive strategies and population ecology of northern grouse, A.T. Bergerud and M.W. Gratson, eds. Univ. Minnesota Press, Minneapolis. 809pp.
- Berry, J.D., and R.L. Eng. 1985. Interseasonal movements and fidelity to seasonal use areas by female sage grouse. *J. Wildl. Manage.* 49:237-240.
- Blaisdell, J.P. 1953. Ecological effects of planned burning of sagebrush-grass range on the Upper Snake River Plains. U.S. Dept. Agr., Tech. Bull. 1075. 39pp.
- Bradbury, J. 1981. The evolution of leks. In: Natural selection and social behavior: recent research and theory. Pages 138-169 in R.D. Alexander and D. Tinkle, eds. Chiron Press, New York.
- _____, and R. Gibson. 1983. Leks and mate choice. in Mate choice. (P. Batson, ed.), pp. 109-138. Cambridge Univ. Press., Cambridge.

- _____, _____, and I.M. Tsai. 1986. Hotspots and the dispersion of leks. *Anim. Behav.* 34:1694-1709.
- Braun, C.E. 1985. Map of sage grouse distribution as provided by the Western State Sage Grouse Committee. *Trans. 13th Sage Grouse Workshop, Alturas, CA. July 22-23.*
- _____, K.W. Harmon, J.J. Jackson, and C.D. Littlefield. 1978. Management of national wildlife refuges in the United States: its impact on birds. *Wilson Bull.* 90:309-321.
- _____, M.F. Baker, R.L. Eng, J.W. Gashwiler, and M.H. Schroeder. 1976. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. *Wilson Bull.* 88:165-171.
- Brown, J.L. 1964. The evolution of diversity and avian territorial systems. *Wilson Bull.* 76:160-168.
- _____, R.L. 1966. Response of sharp-tail breeding populations to annual changes in residual grassland cover. *Proc. Ann. Conf. West. Assn. State Game and Fish. Comm.* 46:219-222.
- Buss, I.O., and E.S. Dziedzic. 1955. Relation of cultivation to the disappearance of the Columbian sharp-tailed grouse from southeastern Washington. *Condor* 57:185-187.
- Campbell, H., D.K. Martin, P.E. Ferkovich, and B.K. Harris. 1973. Effects of hunting and some other environmental factors on scaled quail in New Mexico. *Wildl. Monogr.* 34. 49 pp.
- Canfield, R.H. 1941. Application of the line interception method in sampling range vegetation. *J. For.* 39:388-394.
- Carr, H.D. 1967. Effects of sagebrush spraying on abundance, distribution, and movements of sage grouse. M.S. Thesis, Colorado State Univ., Fort. Collins. 106pp.
- Christensen, C.D. 1970. Nesting and brooding characteristics of sharp-tailed grouse (*Pedioecetes phasianellus jamesi* Lincoln) in southwestern North Dakota. M.S. Thesis, Univ. North Dakota, Bismarck. 53pp.

- Cody, M.L. 1974. Competition and the structure of bird communities. Pages 1-318 in *Monographs in Population Biology*. Princeton Univ. Press, Princeton, New Jersey.
- _____. 1978. Habitat selection and interspecific territoriality among the sylviid warblers of England and Sweden. *Ecol. Monogr.* 48:351-396.
- _____. 1985. An introduction to habitat selection in birds. Pages 3-56 in M.L. Cody, ed. *Habitat Selection in Birds*. Academic Press, Inc. New York, New York. 558pp.
- Colwell, R.K., and D.J. Futuyma. 1971. On the measurement of niche breadth and overlap. *Ecology* 52:567-576.
- Connelly, J.W., Jr. 1982. An ecological study of sage grouse in southeastern Idaho. Ph.D. Diss., Wash. State Univ., Pullman. 84pp.
- _____, and O.D. Markham. 1983. Movements and radionuclide concentrations of sage grouse in southeastern Idaho. *J. Wildl. Manage.* 47:169-177.
- _____, H.W. Browsers, and R.J. Gates. 1988. Seasonal movements of sage grouse in southeastern Idaho. *J. Wildl. Manage.* 52:116-122.
- _____, W.L. Wakkinen, A.D. Apa, and K.P. Reese. 1991. Sage grouse use of nest sites in southeastern Idaho. *J. Wildl. Manage.* 55:521-524.
- Crook, J.H. 1965. The adaptive significance of avian social organization. *Symp. Zool. Soc. Lond.* 14:181-218.
- Dalke, P.D., D.B. Pyrah, D.C. Stanton, J.E. Crawford, and E.F. Schlatterer. 1963. Ecology, productivity, and management of sage grouse in Idaho. *J. Wildl. Manage.* 27:811-841.
- Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. *Northw. Sci.* 33:43-64.
- Davidson, D.F. 1977. Soils inventory of the Curlew National Grasslands. Caribou National Forest, U.S. Forest Service. Malad City, Idaho. 5pp.

- DeLong, A.K., J.A. Crawford, and D.C. DeLong, Jr. 1995. Relationships between vegetational structure and predation of artificial sage grouse nests. *J. Wildl. Manage.* 59:88-92.
- Drut, M.S., J.A. Crawford, and M.A. Gregg. 1994a. Brood habitat use by sage grouse in Oregon. *Great Basin Nat.* 54:170-176.
- _____, W.H. Pyle, and J.A. Crawford. 1994b. Technical Note: Diets and food selection of sage grouse chicks in Oregon. *J. Range Manage.* 47:90-93.
- Duebbert, H.F., and H.A. Kantrud. 1974. Upland duck nesting related to land use and predator reduction. *J. Wildl. Manage.* 38:257-265.
- Dunn, P.O. and C.E. Braun. 1986. Summer habitat use by female and juvenile sage grouse. *J. Wildl. Manage.* 50:228-235.
- Dwernychuk, L.W., and D.A. Boag. 1972. How vegetative cover protects duck nests from egg-eating birds. *J. Wildl. Manage.* 36:955-958.
- Emmons, S.R., and C.E. Braun. 1984. Lek attendance of male sage grouse. *J. Wildl. Manage.* 48:1023-1028.
- Emmel, T.C. 1976. Population biology. Harper & Row, Pub. New York. N.Y. 371pp.
- Eng, R.L., and P. Schladweiler. 1972. Sage grouse winter movements and habitat use in central Montana. *J. Wildl. Manage.* 36:141-146.
- Engel, K.A., and L.S. Young. 1989. Spatial and temporal patterns in the diet of common ravens in southwestern Idaho. *Condor* 372-378.
- _____. 1992. Movements and habitat use by common ravens from roost sites in southwestern Idaho. *J. Wildl. Manage.* 56:596-602.
- Evans, K.E. 1968. Characteristics and habitat requirements of the greater prairie chicken and sharp-tailed grouse - a review of the literature. U.S. For. Serv. Conserv. Res. Rep. 12. 31pp.
- Fischer, R.A. 1994. The effects of prescribed fire on the ecology of migratory sage grouse in southeastern Idaho. Ph.D. Diss., Univ. Idaho. 150pp.

- _____. A.D. Apa, W.L. Wakkinen, K.P. Reese, and J.W. Connelly. 1993. Nest-area fidelity of sage grouse in southeastern Idaho. *Condor* 95:1038-1041.
- _____, K.P. Reese, and J.W. Connelly. 1996a. An investigation on fire effects within xeric sage grouse brood habitat. *J. Range Manage.* 49:194-198.
- _____, _____, and _____. 1996b. Influence of vegetal moisture content and nest fate on timing of female sage grouse migration. *Condor* 98:868-872.
- _____, W. L. Wakkinen, K.P. Reese, and J. W. Connelly. 1997. Effects of prescribed fire on movements of female sage grouse from breeding to summer ranges. *Wilson Bull.* 109:82-91.
- Galbraith, W.A., and E.W. Anderson. 1971. Grazing history of the Northwest. *J. Range Manage.* 24:6-12.
- Gill, R.B. 1965. Distribution and abundance of a population of sage grouse in North Park, Colorado. M.S. Thesis. Colo. State Univ., Ft. Collins. 147pp.
- Giesen, K.M. 1987. Population characteristics and habitat use by Columbian sharp-tailed grouse in northwest Colorado. Project No. W-37-R. Pages 251-280 in Colorado Div. of Wildl., Wildl. Research Report, April 1987.
- _____, and J.W. Connelly. 1993. Guidelines for management of Columbian sharp-tailed grouse habitats. *Wildl. Soc. Bull.* 21:325-333.
- _____, T.J. Schoenberg, and C.E. Braun. 1982. Methods for trapping sage grouse in Colorado. *Wildl. Soc. Bull.* 10:224-231.
- Girard, G.L. 1937. Life history, habits, and food of sage grouse. (Centrocercus urophasianus Bonaparte). Univ. Wyoming Publ. 3. 56pp.
- Gratson, M.W. 1988. Spatial patterns, movements, and cover selection by sharp-tailed grouse. In: Adaptive strategies and population ecology of northern grouse Pages 158-192 in A.T. Bergerud and M.W. Gratson, eds. Univ. Minnesota Press, Minneapolis. 809pp.

- Gray, G.M. 1967. An ecological study of sage grouse broods with reference to nesting movements, food habits, and sagebrush strip spraying in the Medicine Lodge drainage, Clark County Idaho. M.S. Thesis, Univ. Idaho, Moscow. 200pp.
- Gregg, M.A. 1991. Use and selection of nesting habitat by sage grouse in Oregon. M.S. Thesis. Oregon State Univ., Corvallis. 46pp.
- _____, J.A. Crawford, M.S. Drut, and A.K. DeLong. 1994. Vegetational cover and predation of sage grouse nests in Oregon. *J. Wildl. Manage.* 58:162-166.
- Griner, L.A. 1939. A study of the sage grouse (*Centrocercus urophasianus*), with special reference to life history, habitat requirements, and numbers and distribution. M.S. Thesis, Utah State Agricultural College, Logan. 111pp.
- Hamerstrom, F., D.D. Berger, and F.N. Hamerstrom, Jr. 1965. The effect of mammals on prairie chickens on booming grounds. *J. Wildl. Manage.* 29:536-542.
- Hamerstrom, F.N. and F. Hamerstrom. 1961. Status and problems of North American grouse. *Wilson Bull.* 73:284-294.
- Hart, C.M., O.S. Lee, and J.B. Low. 1950. The sharp-tailed grouse in Utah. Utah. Dep. Fish and Game Publ. 3. 79pp.
- Henderson, F.R., F.W. Brooks, R.E. Wood, and R.B. Dahlgren. 1967. Sexing of prairie grouse by crown feather patterns. *J. Wildl. Manage.* 31:764-769.
- Hickey, J.J. 1955. Some American population research on gallinaceous birds. Pages 326-396 in Recent studies in avian biology, A. Wolfson, ed. Univ. Illinois Press. Urbana.
- Higby, L.W. 1976. A summary of the Longs Creek sagebrush control project. Proc. Bien. West. States Sage Grouse Workshop. 6:164-168.
- Hironaka, M., M.A. Fosberg, and A.H. Winward. 1983. Sagebrush-grass habitat types of southern Idaho. For., Wildl., and Range Exp. Stn. Bull. 35. Univ. Idaho, Moscow. 44pp.

- Hitchcock, A.S. 1971. Manual of the grasses of the United States. Dover Pub., Inc. New York. 1051pp.
- _____, C.L., and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Washington Press. Seattle. 730pp.
- Hofmann, L.A., and F.C. Dobler. 1988. Observation of wintering densities and habitat use by Columbian sharp-tailed grouse in three counties of eastern Washington. Washington Dep. of Wildl., Olympia. 11pp.
- Horkel, J.D., R.S. Lutz, and N.J. Silvy. 1978. The influence of environmental parameters on nesting success of upland game birds. Proc. Ann. Conf. S.E. Assoc. Fish and Wildl. Agencies. 32:234-241.
- Horn, H.S. 1966. Measurement of "overlap" in comparative ecological studies. Am. Natur. 100:419-424.
- Hulet, B.V., J.T. Flinders, J.S. Green, and R.B. Murray. 1986. Seasonal movements and habitat selection of sage grouse in Southern Idaho. Pages 168-175 in E.D. McArthur, and B.L. Welch, compilers. Proc. of a symposium on the biology of Artemisia and Chrysothamnus U.S. For. Serv. Gen. Tech. Rep. INT-200.
- Hupp, J.W. 1987. Sage grouse resource exploitation and endogenous reserves in Colorado. Ph.D. Diss. Colorado State Univ., Fort. Collins. 73pp.
- Hurlbert, S.H. 1978. The measurement of niche overlap and some relatives. Ecology 59:67-77.
- Hutchinson, G.E. 1958. Concluding remarks. Cold Spring Harbor Symp. Quant. Biol. 22:415-427.
- Jarvis, J.M. 1974. Sage grouse population studies on the Parker Mountains in south-central Utah. P-R Fed. Aid Job Comp. Report. W-65-R. Job C-1.
- Jewett, S.G., W.P. Taylor, W.T. Shaw, and J.W. Aldrich. 1953. Birds of Washington State. Univ. Washington Press. Seattle. 767pp.
- Johnsgard, P.A. 1983. The grouse of the world. Univ. Nebraska Press, Lincoln. 413pp.

- Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65-71.
- _____, R.A., and D.W. Wichern. 1992. Applied multivariate statistical analysis. Third ed. Prentice-Hall, Englewood Cliffs, N.J. 642pp.
- Jollie, M. 1976. Species interrelationships of three corvids. *Biol.* 58:89-111.
- Jones, R.E. 1966. Spring, summer, and fall foods of the Columbian sharp-tailed grouse in eastern Washington. *Condor* 68:536-540.
- _____. 1968. A board to measure cover used by prairie grouse. *J. Wildl. Manage.* 32:28-31.
- Kessler, W.B., and R.P. Bosch. 1982. Sharp-tailed grouse and range management practices in western rangelands. Pages 133-143 in J.M. Peek and P.D. Dalke, eds., *Wildlife-Livestock Relationship Symposium: Proceedings* 10.
- Klebenow, D.A. 1969. Sage grouse nesting and brood habitat in Idaho. *J. Wildl. Manage.* 33:649-662.
- _____, and G.M. Gray. 1968. Food habits of juvenile sage grouse. *J. Range. Manage.* 21:80-83.
- Klimstra, W.D., and J.L. Roseberry. 1975. Nesting ecology of bobwhite quail in southern Illinois. *Wildl. Monogr.* 41. 37pp.
- Klott, J.H. 1987. Use of habitat by sympatrically occurring sage grouse and sharp-tailed grouse with broods. M.S. Thesis, Univ. Wyoming, Laramie. 82pp.
- _____, and F.G. Lindzey. 1989. Comparison of sage and sharp-tailed grouse leks in south central Wyoming. *Great Basin Nat.* 49:275-278.
- _____, and _____. 1990. Brood habitats of sympatric sage grouse and Columbian sharp-tailed grouse in Wyoming. *J. Wildl. Manage.* 54:84-88.
- Knight, R.L., and M.W. Call. 1980. The common raven. U.S. Dep. Inter., Bur. Land Manage. Tech. Note 34. 61pp.

- Kochert, M.N., A.R. Bammann, R.P. Howard, J.H. Doremus, M. DeLate, and D. Donahue. 1975. Reproductive performance, food habits, and population dynamics of raptors in the Snake River Birds of Prey Natural Area. Pages 1-50 in Snake River Birds of Prey research project, annual report. U.S. Dep. Inter., Bur. Land Manage. Boise, ID.
- _____, _____, J.H. Doremus, M. Delate, and J. Wyatt. 1976. Reproductive performance, food habits, and population dynamics of raptors in the Snake River Birds of Prey Natural Area. Pages 1-57 in Snake River Birds of Prey research project, annual report. U.S. Dep. Inter., Bur. Land Manage. Boise, ID.
- _____, _____, K. Steenhof, J.H. Doremus, M. DeLate, J. Oakley, and T. Hamer. 1977. Reproductive performance, food habits, and population dynamics of raptors in the Snake River Birds of Prey Natural Area. Pages 1-39 in Snake River Birds of Prey research project, annual report. U.S. Dep. Inter., Bur. Land Manage. Boise, ID.
- Kohn, S.D. 1976. Sharp-tailed grouse nesting and breeding habitats in south-western North Dakota. M.S. Thesis, South Dakota State Univ., Brookings. 96pp.
- Krebs, C.J. 1989. Ecological methodology. Harper and Row. New York. 654pp.
- Laycock, W.A. 1967. How heavy grazing and protection affect sagebrush-grass ranges. *J. Range Manage.* 20:206-213.
- Levins, R. 1968. Evolution in changing environments: Some theoretical explorations. Princeton Univ. Press, Princeton, N.J.
- MacArthur, R.H., and E.O. Wilson. 1967. The theory of island biogeography. Princeton Univ. Press. Princeton.
- Marks, J.S., and V.S. Marks. 1987. Habitat selection by Columbian sharp-tailed grouse in west-central Idaho. Department of the Interior, BLM, Boise District, Idaho. 115pp.
- Marshall, W.H., and M.S. Jensen. 1937. Winter and spring studies of sharp-tailed grouse in Utah. *J. Wildl. Manage.* 1:87-99.

- Martin, N.S. 1970. Sagebrush control related to habitat and sage grouse occurrence. *J. Wildl. Manage.* 34:313-320.
- _____, T.E. 1987a. Artificial nest experiments: effects of nest appearance and type of predator. *Condor.* 89:925-928.
- _____. 1987b. Food as a limit on breeding birds: a life-history perspective. *Ann. Rev. Ecol. Syst.* 18:453-487.
- Mayfield, H.F. 1975. Suggestions for calculating nest success. *Wilson Bull.* 87:456-466.
- McArdle, B.A. 1977. The effect of sagebrush reduction practices on sharp-tailed grouse use in southeastern Idaho. M.S. Thesis. Utah State Univ., Logan. 72pp.
- McIntosh, R.P. 1967. An index of diversity and the relation of certain concepts to diversity. *Ecology* 48:392-404.
- Mech, L.D. 1983. Handbook of animal radio tracking. Univ. of Minnesota Press. Minneapolis. 107pp.
- Meints, D.R. 1991. Seasonal movements, habitat use, and productivity of Columbian sharp-tailed grouse in southeastern Idaho. M.S. Thesis. Univ. Idaho, Moscow 74pp.
- _____, J.W. Connelly, K.P. Reese, A.R. Sands, and T.P. Hemker. 1992. Habitat suitability index procedures for Columbian sharp-tailed grouse. *Idaho For., Wildl. and Range Exp. Stn., Bull.* 55, Moscow. 27pp.
- Miller, G.C., and W.G. Graul. 1980. Status of sharp-tailed grouse in North America. Pages 18-28 in P.A. Vohs Jr., and F.L. Knopf, eds. *Proc. prairie grouse symp.* Oklahoma State Univ., Stillwater.
- Morrison, D.F. 1976. Multivariate statistical methods. McGraw-Hill. New York.
- Morisita, M. 1959. Measuring of interspecific association and similarity between communities. *Mem. Fac. Sci. Kyushu Univ. Ser. E (Biol.)* 3:65-80.

- Mosley, J.C., S.C. Bunting, and M. Hironaka. 1986. Determining range condition from frequency data in mountain meadows of central Idaho. *J. Range Manage.* 39:561-565.
- Myrberget, S. 1984. Population dynamics of willow grouse (Lagopus lagopus) on an island in north Norway. *Fauna Norv. Ser. C. Cinclus* 7:95-105.
- Nelson, O.C. 1955. A field study of sage grouse in southeastern Oregon with special reference to reproduction and survival. M.S. Thesis, Oregon State Univ., Corvallis. 113pp.
- Nice, M.M. 1942. Analysis of losses in the nesting of birds (review). *Bird Banding* 13:90.
- Nilsson, S.G. 1984. The evolution of nest-site selection among hole-nesting birds: the importance of nest predation and competition. *Ornis Scand.* 15:167-175.
- Nol, E., and R.J. Brooks. 1982. Effects of predator exclosures on nesting outcome of killdeer. *J. Field Ornithol.* 53:263-268.
- Oakleaf, R.J. 1971. The relationship of sage grouse to upland meadows in Nevada. Nevada Fish and Game Comm., Job Prog. Rept. W-48-2. 64pp.
- Oedekoven, O. 1985. Columbian sharp-tailed grouse population distribution and habitat use in south-central Wyoming. M.S. Thesis. Univ. Wyoming, Laramie. 58pp.
- Parker, T.L. 1970. On the ecology of sharp-tailed grouse in southeastern Idaho. M.S. Thesis. Idaho State Univ., Pocatello. 140pp.
- Parzen, E. 1962. On estimation of a probability density function and mode. *Ann. of Math. Stat.* 33:1065-1076.
- Patterson, R.L. 1952. The sage grouse of Wyoming. Sage Books, Inc. Denver. 341pp.
- Pepper, G.W. 1972. The ecology of sharp-tailed grouse during spring and summer in the aspen parklands of Saskatchewan. *Sask. Dep. Nat. Resour. Wildl. Rep. 1.* 56 pp.
- Peterson, J.G. 1970. The food habits and summer distribution of juvenile sage grouse in central Montana. *J. Wildl. Manage.* 34:147-155.

- Phillips, J.B. 1990. Lek behaviour in birds: do displaying males reduce nest predation? *Anim. Behav.* 39:555-565.
- Pianka, E.R. 1970. On r- and K-selection. *Am. Nat.* 104:592-597.
- _____. 1973. The structure of lizard communities. *Annu. Rev. Ecol. Syst.* 4:53-74.
- Picozzi, N. 1975. Crow predation on marked nests. *J. Wildl. Manage.* 39:151-155.
- Potts, G.R. 1980. The effects of modern agriculture, nest predation and game management on the population ecology of partridges (*Perdix perdix* and *Alectoris rufa*). *Adv. Ecol. Res.* 11:1-79.
- _____. 1986. The partridge. Pesticides, predation and conservation. Collins, London. 274pp.
- Ramharter, B.G. 1976. Habitat selection and movements of sharp-tailed grouse hens during the nesting and brood rearing periods in a fire maintained brush prairie. Ph.D. Diss, Univ. Minnesota, St. Paul. 78pp.
- Rasmussen, D.I., and L.A. Griner. 1938. Life history and management studies of the sage grouse in Utah, with special reference to nesting and feeding habitats. *Trans. North Am. Wildl. Conf.* 3:852-864.
- Rearden, J.D. 1951. Identification of waterfowl nest predators. *J. Wildl. Manage.* 15:386-395.
- Remington, T.E., and C.E. Braun. 1985. Sage grouse food selection in winter, North Park, Colorado. *J. Wildl. Manage.* 49:1055-1061.
- Renkonen, O. 1938. Statisch-okologische Untersuchungen uber die terrestische kaferwelt der finnischen bruchmoore. *Ann Zool. Soc. Bot. Fenn. Vanamo* 6:1-231.
- Rickard, W.H., D.W. Uresk, and J.F. Cline. 1975. Impact of cattle grazing on three perennial grass in south-central Washington. *J. Range. Manage.* 28:108-112.
- Ricklefs, R.E. 1969. An analysis of nesting mortality in birds. *Smithson. Contrib. Zool.* 9:1-48.
- _____. 1979. *Ecology*, Second ed. Chiron Press. New York. 966pp.

- Riley, T.Z., C.A. Davis, M. Ortiz, and M.J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of lesser prairie-chickens. *J. Wildl. Manage.* 56:383-387.
- Roberson, J.A. 1986. Sage grouse-sagebrush relationships: A review Pages 157-167, in E.D. McArthur and B.L. Welch, compilers. *Proc.--Sym. on the biology of Artemisia and Crysothamnus*. U.S. For. Serv., Gen. Tech. Rep. INT-200. Ogden, UT.
- Rogers, G.E. 1964. Sage grouse investigation in Colorado. Colorado Game, Fish, and Parks Dep. Tech. Publ. No. 16. Division Game Res. 132pp.
- _____. 1969. The sharp-tailed grouse in Colorado. Colorado Game, Fish and Parks. 94pp.
- Rosenblatt, M. 1956. Remarks on some nonparametric estimates of a density function. *Ann. Math. Stat.* 27:832-837.
- Saab, V.A., and J.S. Marks. 1992. Summer habitat use by Columbian sharp-tailed grouse in western Idaho. *Great Basin Nat.* 52:166-173.
- Samuel, M.D., E.O. Garton, M.W. Schlegel, and R.G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. *J. Wildl. Manage.* 51:622-630.
- _____, and M.R. Fuller. 1994. Wildlife radiotelemetry. Pages 370-418 in T.A. Bookout, ed. *Research and management techniques for wildlife and habitats*, 5th ed. The Wildlife Society, Bethesda, MD.
- SAS Institute Inc. 1988. *SAS/STAT User's Guide*, Release 6.03 Ed. Cary, NC. 1028 pp.
- _____. 1990. SAS Technical Report P-200. *SAS/STAT Software: CALIS and LOGISTIC Procedures*. Release 6.04. Cary, NC. 230pp.
- Savage, D.E. 1969. The relationship of sage grouse to upland meadows in Nevada. Nevada Coop. Wildl. Res. Unit, Reno. 101pp.

- Schiller, R.J. 1973. Reproduction ecology of female sharp-tailed grouse (Pedioecetes phasianellus) and its relationship to early plant succession in northwestern Minnesota. Ph.D. Diss, Univ. Minnesota, St. Paul.
- Schlatterer, E.F., and D.B. Pyrah. 1970. Ecological effects of chemical and mechanical sagebrush control. Montana Fish and Game Dep. 121pp.
- Schneegas, E.R. 1967. Sage grouse and sagebrush control. Trans. North Am. Wildl. Conf. 32:270-274.
- Schneider, J.W. 1994. Winter feeding and nutritional ecology of Columbian sharp-tailed grouse in southeastern Idaho. M.S. Thesis. Univ. Idaho, Moscow. 118pp.
- Schoenberg, T.J. 1982. Sage grouse movements and habitat selection in North Park Colorado. M.S. Thesis, Colorado State Univ., Fort Collins. 86pp.
- Schoener, T.W. 1974. Resource partitioning in ecological communities. Science 185:27-39.
- Sirotnak, J.M., K.P. Reese, J. W. Connelly, and K. Radford. 1991. Effects of the Conservation reserve program (CRP) on wildlife in southeastern Idaho. Idaho Dep. Fish and Game, Job Completion Rep., Proj. W-160-R-18. 45pp.
- Skutch, A.F. 1966. A breeding bird census and nesting success in Central America. Ibis 108:1-16.
- Slagsvold, T. 1982. Clutch size variation in passerine birds: the nest predation hypothesis. Oecologia 54:159-169.
- Smith, E.P. 1982. Niche breadth, resource availability, and inference. Ecology 63:1675-1681.
- Sokal, R.R., and F.J. Rohlf. 1981. Biometry. W.H. Freeman and Co. New York. 859pp.
- Sparling, D.W., Jr. and W.D. Svedarsky. 1978. Responses of prairie grouse to avian and mammalian visitors on display grounds in northwestern Minnesota. Prairie Nat. 10:17-22.

- Stoddart, L.A., A.D. Smith, and T. W. Box. 1975. Range Management-Third Ed. McGraw-Hill Book Co. 532pp.
- Storaas, T., and P. Wegge. 1987. Nesting habits and nest predation in capercaillie and black grouse. *J. Wildl. Manage.* 51:167-172.
- Stralser, T. 1991. A description of habitats surrounding Columbian sharp-tailed grouse leks in Lincoln county, Washington. M.S. Thesis. Eastern Wash. Univ.. 71pp.
- Sturges, D.L. 1973. Soil moisture response to spraying big sagebrush the year of treatment. *J. Range Manage.* 26:444-447.
- Sugden, L.G., and G.W. Beyersbergen. 1987. Effect of nesting cover density on American crow predation of simulated duck nests. *J. Wildl. Manage.* 51:481-485.
- Tinbergen, L. 1960. The natural control of insects in pinewoods, I: Factors influencing the intensity of predation by songbirds. *Arch. Néerl. Zool.* 13:266-336.
- _____, M. Impekoven, and D. Franck. 1967. An experiment on spacing out as a defense against predation. *Behaviour* 28:307-321.
- Trueblood, R.W. 1954. The effects of grass reseeding in sagebrush lands on sage grouse populations. M.S. Thesis. Utah State Univ.. Logan. 77pp.
- Wakkinen, W.L. 1990. Nest site characteristics and spring-summer movements of migratory sage grouse in southeastern Idaho. M.S. Thesis. Univ. Idaho. Moscow. 57pp.
- _____, K. P. Reese, and J.W. Connelly. 1992. Sage grouse nest locations in relation to leks. 56:381-383.
- _____, _____, _____, and R.A. Fischer. 1992. An improved spotlighting technique for capturing sage grouse. *Wildl. Soc. Bull.* 20:425-426.
- Wallestad, R.O. 1971. Summer movements and habitat use by sage grouse broods in central Montana. *J. Wildl. Manage.* 35:129-136.
- _____. 1975. Male sage grouse responses to sagebrush treatment. *J. Wildl. Manage.* 39:482-484.

- _____. and D.B. Pyrah. 1974. Movement and nesting of sage grouse hens in central Montana. *J. Wildl. Manage.* 38:630-633.
- _____. and P. Schladweiler. 1974. Breeding season movements and habitat selection of male sage grouse. *J. Wildl. Manage.* 38:634-637.
- _____. J.G. Peterson, and R.L. Eng. 1974. Foods of adult sage grouse in central Montana. *J. Wildl. Manage.* 39:628-630.
- Whitcomb, R.R., C.S. Robbins, J.F. Lynch, B.L. Whitcomb, M.K. Klimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pages 125-205 *in* R.L. Burgess and D.M. Sharpe, eds. *Forest island dynamics in man-dominated landscapes*. Springer-Verlag, New York.
- Wiens, J.A. 1969. An approach to the study of ecological relationships among grassland birds. *Ornithol. Monogr.* 8:1-93.
- _____. 1985. Habitat selection in shrub-steppe birds. Pages 227-251 *in* M.L. Cody, ed. *Habitat Selection in Birds*. Academic Press, Inc. New York, New York. 558pp.
- Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. *Ecology* 66:1211-1214.
- Willebrand, T., and V. Marcström. 1988. On the danger of using dummy nests to study predation. *Auk* 105:378-379.
- Williams, G.C. 1966. *Adaptation and natural selection: a critique of some current evolutionary thought*. Princeton Univ. Press, Princeton, N.J. 307pp.
- Winward, A.H. 1991. A renewed commitment to management of sagebrush grasslands. Pages 2-7 *in* R.F. Miller, ed. *Management in the sagebrush steppe*. Agric. Exp. Stn. Spec. Rep. 880. Oregon State Univ., Corvallis.
- Wrangham, R.W. 1980. Female choice of least costly males: a possible factor in the evolution of leks. *Z. Tierpsychol.* 54:357-367.

- Wright, H.A., L.F. Neuenschwander, and C.M. Britton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities: a state-of-the-art review. Gen. Teck. Rep. INT-58. Ogden, UT: USDA For. Ser., Intermountain For. and Range Expt. Stn. 48pp.
- Yahner, R.H., and R.A. Voytko. 1989. Effects of nest-site selection on depredation of artificial nests. *J. Wildl. Manage.* 53:21-25.
- Yocum, C.F. 1952. Columbian sharp-tailed grouse in the state of Washington. *Amer. Midl. Nat.* 48:185-192.
- Zar, J.H. 1984. *Biostatistical analysis*, 2nd ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 718pp.
- Zeigler, D.L. 1979. Distribution and status of the Columbian sharp-tailed grouse in eastern Washington. Upland Game Invest. Compl. Rep. Project W-70-R-18. Washington Dept. Game. 26pp.

APPENDICES

Appendix A. Data on sage and Columbian sharp-tailed grouse captured in the Curlew Valley region of southeastern Idaho, 1988-91.

Date Captured	Age/Sex	Trap Site ^d	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
Sage Grouse								
1988								
4/5	MA	N.C. Seeding			320			
4/5	MA	N.C. Seeding			321			Harvested 9/17/88
4/5	MY	N.C. Seeding			322			
4/5	MA	Rushton			323			
4/5	MA	Rushton			324			
4/5	MY	Rushton			325			
4/5	MA	Rushton			326			
4/5	FY	Rushton	1,360	151.313	77	7	U 5/19/88	
4/6	FY	Rushton	1,312	151.011	78	1+	U 5/4/88	Last located 7/28/88
4/8	FY	Cedar Hill	1,582	150.891	79			Last located 5/12/88
4/8	FY	N.C. Seeding	1,407	151.162	80			Last located 4/12/88
4/8	FY	N.C. Seeding	1,492	151.100	81			Dead 6/13/88
4/9	MA	Cedar Hill			327	9	U 5/9/89	Last located 5/28/90
4/12	MY	Meadows Divide			328			
4/13	MA	Cedar Hill		151.034	329			Lost 6/29/88
4/13	MA	Cedar Hill			330			
4/13	MA	Cedar Hill			331			Recapt. 4/14/88
4/13	MA	Cedar Hill			332			
4/14	MA	Meadows Divide		150.892	333			Harvested 9/2/92
4/14	FY	N.C. Seeding		150.807	82			Last located 6/28/89
1989								
3/20	MA	Meadows Divide			334			
3/20	MA	Meadows Divide			368			
3/20	MA	Meadows Divide			369			
3/21	MA	F.S. Exchange			370			Recapt. 3/22/89
3/21	MA	F.S. Exchange			371			4/3/88
3/21	MA	F.S. Exchange			372			Recapt. 3/31/89
3/21	MA	F.S. Exchange			373			
3/22	FY	F.S. Exchange	1,400	151.939	83			Recapt. 3/26/89
3/22	MA	F.S. Exchange			374			Never located
3/22	MA	F.S. Exchange			375			Recapt. 3/30/89
3/22	MA	F.S. Exchange			376			Recapt. 4/1/89
3/22	MA	F.S. Exchange			377			Harvested 9/23/89
3/22	MY	F.S. Exchange			378			Recapt. 3/26/89
3/24	MA	South 13			379			Recapt. 3/30/89
3/24	MA	South 13			380			
3/24	MA	South 13			381			Recapt. 3/14/90,

Appendix A. continued

Date Captured	Age/Sex	Trap Site ^a	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
3/24	MA	South 13			382			4/13/90
3/24	MY	South 13			383			
3/24	MA	Little Rock Spring			384			
3/24	MA	Baker		151.501	385			Recapt. 3/18/90 I.S.U. Study
3/24	MA	Baker			386			
3/24	MA	Meadows Divide			387			
3/24	MA	Meadows Divide			388			Harvested 9/16/89
3/24	MA	Meadows Divide			389			
3/26	MY	F.S. Exchange			390			
3/26	MA	F.S. Exchange			391			
3/27	MA	South 13			392			
3/27	FA	South 13	1,600	151.960	84	7	U 5/27/89	Last located 11/15/90
3/27	MA	Ketchum			393			Harvested
3/29	FY	South 13	1,500	151.620	85			Last located 7/27/89
3/29	MA	Ketchum			394			
3/29	FY	Meadows Divide	1,475	151.749	86			Never located
3/29	FY	Meadows Divide	1,300	151.541	87	?	S ?	Last located 7/7/89
3/29	FA	Meadows Divide	1,425	151.150	88			Never located Harvested 9/22/89
3/30	MA	F.S. Exchange			395			
3/30	FY	F.S. Exchange	1,450	151.809	89	?	S ?	Last located 7/27/89
3/30	FY	Meadows Divide	1,425	151.029	90			Never located
3/30	MA	Meadows Divide			396			
3/30	FA	Meadows Divide	1,725	151.521	91			Dead 5/9/89
3/30	MA	Ketchum			397			
3/30	MA	Ketchum			398			
3/30	MA	Ketchum			400			
3/30	FA	South 13	1,500	151.898	92	10	S 5/18/89	Dead 3/10/90
3/31	FA	F.S. Exchange	1,600	150.760	93			Never located
3/31	MA	F.S. Exchange			367			Recapt. 4/2/89, 3/15/91
3/31	MA	Cedar Hill			335			
3/31	MA	Cedar Hill			336			
3/31	FY	Cedar Hill	1,350	151.830	94	5 6+ 5	S 6/7/89 S 6/14/90 U 6/3/91	Harvested 9/21/91
3/31	MY	Cedar Hill			337			
3/31	FY	Cedar Hill	1,400	150.720	95	4+	U 5/22/89	Harvested 9/16/89
4/1	MA	Cedar Hill			338			
4/1	MA	Cedar Hill			339			
4/1	MA	South 13			340			
4/2	MA	Meadows Divide			341			
4/2	FA	F.S. Exchange	1,400	151.590	96	?	S ?	Last located 1/9/90

Appendix A, continued

Date Captured	Age/Sex	Tran Site ^a	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
4/3	PA	F.S. Exchange	1,500	150.671	98	7	S 5/20/89	
4/3	MY	Cedar Hill			343	?	S ?	Last located 2/19/90
4/3	MA	Ketchum			344			
4/4	MA	Cedar Hill			345			
4/4	MA	Cedar Hill			348			Harvested 9/16/89
4/4	MA	Cedar Hill			349			
4/4	MA	Little Rock Spring			350			
4/4	FA	Baker	1,650	150.530	100			Recpt. 4/8/89
4/4	MA	Baker			351			Last located 7/27/89
4/4	FA	F.S. Exchange	1,350	150.690	51	7	U 6/1/89	
4/5	MY	White			352			Last located 6/1/89
4/5	MA	Ketchum			353			
4/5	MA	Little Rock Spring			354			
4/6	MA	Ketchum			355			
4/7	MA	South 13			356			
4/7	MA	South 13			357			
4/7	MA	Baker			358			Recapt. 3/30/90
4/7	MA	Baker			359			Dead 5/1/89
4/7	MA	Baker			360			Recapt. 4/8/89
4/7	FA	Little Rock Spring	1,400	151.160	310	4+	U 5/22/89	
4/8	MY	Little Rock Spring			361			Last located 7/28/89
4/8	MA	Baker			301			
<u>1990</u>								
3/6	MA	South 13			402			
3/9	MA	F.S. Exchange			403			Recapt. 3/17/90
3/9	MA	F.S. Exchange			404			
3/9	FY	Meadows Divide	1,150	150.511	311	4+	S 6/15/90	
3/9	MA	Meadows Divide			405			Last located 6/20/90
3/10	MA	South 13			406			
3/10	MY	South 13			407			
3/15	MA	F.S. Exchange			408			
3/15	FA	Meadows Divide	1,400	150.829	313			Last located 5/13/90
3/15	MA	Meadows Divide			409			
3/15	MA	Baker		150.051	410			
3/16	MA	Meadows Divide			411			Recapt. 3/14/91, (no collar), I.S.U. Study
3/16	FY	Meadows Divide		151.660	412			Recapt. 3/20/90
3/16	MA	South 13			412			Never located
3/16	MA	South 13			413			Recapt. on 3/19/91

Appendix A. continued

Date Captured	Age/Sex	Trap Site ^a	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
3/17	FA	South 13	1,450	151,919	314			
3/17	MY	South 13			414	7	S 6/7/91	Last located 8/2/91
3/17	MY	South 13			415			
3/17	MA	South 13			416			
3/17	MY	Baker		151,889	417			I.S.U. Study
3/17	MA	Ketchum		151,666	418			I.S.U. Study
3/17	MA	Ketchum		151,144	419			I.S.U. Study
3/17	MA	Ketchum			420			
3/17	MA	Meadows Divide			421			
3/18	MA	Baker		150,780	422			I.S.U. Study
3/18	MA	South 13			423			Recapt. 3/24/90
3/18	MA	South 13			424			
3/19	MA	South 13			425			
3/19	MA	South 13			426			
3/19	MA	South 13			427			Recapt. 3/21/90
3/19	MA	Baker		151,521	428			
3/19	MA	Baker		150,410	429			I.S.U. Study
3/20	MA	Baker			430			I.S.U. Study
3/20	FY	South 13	1,200	151,870	315			Recapt. 3/24/90
3/21	FA	South 13	1,400	151,640	316			Dead 4/20/91
3/21	MY	South 13			431			Dead 4/21/90
3/21	MY	South 13			432			Recapt. 3/22/90
3/21	MY	South 13			433			Recapt. 4/13/90
3/21	MA	Ketchum		151,480	434			Harvested 9/29/90, (no collar), I.S.U. Study
3/21	MA	Ketchum		151,561	435			I.S.U. Study
3/21	MA	Ketchum		151,134	436			I.S.U. Study
3/23	MA	Nalder			437			I.S.U. Study
3/23	FY	Baker	1,350	150,009	317			Never located
3/23	FY	Baker	1,300	151,980	318			Last located 7/23/90
3/23	MA	South 13			438			
3/23	MY	South 13			439			
3/24	MY	South 13			440			
3/24	MY	South 13			441			Recapt. 3/16/91, harvested 9/21/91
3/24	FY	South 13	1,350	150,630	319			Harvested 9/19/92
3/24	FA	Nalder	1,450	151,790	320	6+	S 5/29/90	Last located 7/23/90
3/24	MA	Nalder			442			
3/25	MA	Nalder			443			Harvested 9/27/92
3/25	MA	Meadows Divide			444			
3/25	FY	Baker	1,400	151,215	321	?	U 5/18/90	Last located 5/18/90

Appendix A. continued

Date Captured	Age/Sex	Trap Site ^a	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
3/25	FA	Baker	1,450	150.991	322			
3/25	MY	Baker		151.680	445			Never located
3/25	MY	Baker	1,550	151.325	323	6	U 5/15/90	I.S.U. Study
						6	U 6/17/90	
						9	S 6/27/91	
3/25	FA	South 13	1,400	151.309	324	3+	S 5/15/90	Last located 8/2/91
3/26	FA	F.S. Exchange	1,500	151.327	325	-		Harvest 9/9/90
3/26	MY	F.S. Exchange			446			Harvested 9/27/91
3/26	FA	F.S. Exchange	1,650	150.904	326	5+	U 6/20/90	
3/26	FA	Nalder	1,550	151.417	327	8	S 5/14/90	Last located 6/20/90
3/29	MY	Meadows Divide			447			Harvested, 9/90
3/30	MA	Meadows Divide			448			
3/30	MA	Ketchum			449			
3/31	MA	N. Canyon Seeding			450			
3/31	FY	South 13	1,400	151.206	328			Recapt. 3/30/91
4/1	FY	Ketchum	1,350	151.178	329			Last located 6/2/91
4/1	MY	Meadows Divide			451	?	U 6/10/91	Last located 7/30/91
4/1	FY	Nalder	1,450	151.265	330			
4/13	MA	South 13			452	4+	U 6/10/91	
4/13	MA	Baker			455			Recapt. 3/19/91
4/16	MA	Ketchum		151.665	453			Recapt. 3/13/91 I.S.U. Study
<u>1991</u>								
3/13	MA	South 13			233			
3/13	FY	South 13	1,430	151.461	331			
3/13	MA	F.S. Exchange			235			Last located 7/30/91
3/13	FY	F.S. Exchange	1,280	151.960	332	6	S 6/10/91	Last located 8/1/91
3/13	FY	F.S. Exchange	1,330	151.740	333	6	U 5/16/95	Last located 8/1/91
3/14	MA	South 13			230			
3/14	MY	South 13			231			
3/14	FY	South 13	1,430	151.368	334	?	U 5/22/91	Recapt. 3/18/91
3/14	FY	Meadows Divide	1,430	151.065	335	5	U 6/14/91	Last located 5/22/91
3/14	MA	Meadows Divide			232			Last located 6/14/91
3/14	FA	Meadows Divide	1,480	151.590	336	6	U 6/14/91	
						5	U 7/3/91	
3/15	MA	F.S. Exchange			473			Last located 8/2/91
3/15	MA	F.S. Exchange			463			Harvested 9/30/92
3/15	MA	F.S. Exchange			462			Recapt. 3/17/91
3/15	MA	F.S. Exchange			461			
3/15	MY	Baker			460			Recapt. 3/18/91 Recapt. 3/19/91, harvested 9/22/91

Appendix A. continued

Date Captured	Age/Sex	Trap Site ^a	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
3/15	FA	Baker	1,480	150.780	337	7	S 6/23/91	
3/16	FY	Meadows Divide	1,430	151.429	338			Last located 8/1/91
3/16	MA	F.S. Exchange			201			Last located 6/10/91
3/16	MY	F.S. Exchange			493			
3/17	MA	F.S. Exchange			497			
3/17	MY	F.S. Exchange			490			
3/17	MY	F.S. Exchange			489			
3/17	MY	Cedar Hill			491			
3/17	MA	Baker			478			Recapt. 3/21/91, 3/27/91
3/17	MA	South 13			459			Recapt. on 3/30/91
3/18	MA	South 13			494			
3/18	MA	South 13			492			
3/18	MA	Ketchum			464			
3/18	MA	F.S. Exchange			470			
3/19	FA	South 13	1,530	151.073	339	6	S 5/28/91	Last located 7/30/91
3/19	FA	South 13	1,580	151.415	340	1+	U 6/3/91	Last located 8/1/91
3/19	MY	Baker			481			
3/19	MA	F.S. Exchange			457			
3/19	MA	F.S. Exchange			476			
3/19	FY	F.S. Exchange	1,530	150.466	341			Recapt. 3/20/91
3/21	MA	Cedar Hill			475			Last located 7/30/91
3/22	FA	Nalder	1,480	151.745	342			Never located
3/22	MA	Nalder			499			
3/22	FY	Cedar Hill	1,380	150.284	343			Never located
3/22	MA	Cedar Hill			474			
3/22	FY	Baker	1,430	150.993	344			Dead 7/30/91
3/22	FA	Baker	1,630	150.951	345			Dead 5/20/91
3/23	MY	F.S. Exchange			465			
3/23	FA	F.S. Exchange	1,680	150.585	346	5	S 6/3/91	Last located 8/1/91
3/23	MA	Cedar Hill			483			
3/25	FY	F.S. Exchange	1,430	151.432	347			Never located
3/25	MY	Baker			336			
3/27	MA	Baker			477			
3/27	MY	Baker			482			
3/27	MY	Baker			496			
3/27	FA	Meadows Divide	1,630	151.898	348	4+	U 6/5/91	
3/28	FA	Nalder	1,630	150.044	349			Last located 5/22/91
3/28	FY	Nalder	1,480	150.502	350			Last located 5/28/91
3/30	FY	South 13	1,480	151.307	351	1+	U 6/26/91	Last located 7/22/91
3/30	MA	Meadows Divide			300			
4/1	MY	Baker			498			Harvested 9/2/91

Appendix A. continued

Date Captured	Age/Sex	Tran Site ^a	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
4/1	FY	Baker	1,455	151,748	352			
4/2	FY	F.S. Exchange	1,555	150,384	353			Never located
4/2	MA	F.S. Exchange			479			Last located 6/26/91
4/2	FY	F.S. Exchange	1,480	150,145	354	?	U 6/5/91	Harvested 9/11/93
4/2	FY	Baker	1,430	150,523	355			Last located 7/31/91
Columbian Sharp-tailed Grouse								
1988								
3/30	MA	Hill	760	-	802			
3/30	MA	Hill	765	-	803			
4/3	MA	Hill	760	-	804			Recapt. 4/3/88, 4/5/90
4/3	MA	Hill	775	-	805			
4/4	FA	Hill	695	150,714	806	13	U 5/16/88	Recapt. 4/10/88, 4/10/91
4/5	MA	Hill	795	-	807			Dead 7/19/88
4/5	MA	Hill	765	-	808			
4/8	FY	Vanderhoff	725	151,293	809			Recapt. 4/8/88
4/8	MY	Vanderhoff	780	-	810			Dead 6/27/88
4/8	MA	Vanderhoff	795	-	811			Recapt. 4/9/88
4/8	MA	Vanderhoff	745	-	812			Transplanted
4/8	MA	Hill	710	-	813			Recapt. 4/2/91
4/8	FA	Hill	705	151,025	814	8	U 6/21/88	Recapt. 4/4/91
4/8	FA	Hill	685	150,195	815	8	U 6/14/88	Lost 6/14/88
4/8	MY	Vanderhoff	755	-	816			Last located 8/1/88
4/8	M?	Vanderhoff	790	-	817			Recapt. 4/9/88
4/9	MA	Vanderhoff	735	-	818			Recapt. 4/14/88
4/9	MY	Vanderhoff	740	-	819			
4/9	M?	Vanderhoff	805	-	820			Transplanted
4/9	MA	Vanderhoff	800	-	821			Transplanted
4/10	FA	Vanderhoff	680	150,983	822			Transplanted
4/10	FA	Vanderhoff	695	150,905	824			Lost 4/28/88
4/10	F?	Vanderhoff	740	151,072	823			Transplanted
4/10	FA	Vanderhoff	645	151,050	825			Transplanted
4/10	FY	Hill	655	151,145	826	10/7	S 6/21/88	Transplanted
4/10	FY	Hill	685	151,134	827			Last located 8/1/88
4/10	FY	Hill	720	150,962	828			Dead 6/2/88
4/11	MY	Vanderhoff	790	-	829			Transplanted
4/11	MY	Vanderhoff	740	-	830			Transplanted
4/11	FA	Vanderhoff	720	151,026	831			Transplanted
4/11	MA	Vanderhoff	810	-	832			Transplanted
4/11	FY	Vanderhoff	665	150,875	833			Transplanted
4/11	M?	Vanderhoff	740	-	834			Transplanted
4/11	FA	Vanderhoff	680	150,936	835			Transplanted
4/11	FA	Vanderhoff	745	150,953	836			Transplanted

Appendix A. continued

Date Captured	Age/Sex	Trap Site ¹	Weight (g)	Radio Freq.	Band #	Clutch Size ⁰	Nest Fate ⁶	Comments ⁴
4/11	FA	Vanderhoff	715		837			
4/13	FA	Cedar Hill	660	150.684	838	13/2	S 6/1/88	Last located 7/23/88
4/13	FA	Cedar Hill	740	151.175	839	12	U 5/19/88	Radio died 6/7/88, new radio 6/22/88
				151.162		10	U 6/22/88	
4/13	FA	Cedar Hill	735	-	840			Transplanted
4/13	FA	Cedar Hill	695	-	841			Transplanted, arrived dead in Lewiston
4/13	MA	Cedar Hill	795	-	842			Transplanted
4/13	MA	Cedar Hill	750	-	843			Transplanted
4/13	MY	Cedar Hill	780	-	844			Transplanted
4/13	MY	Hess Haws	800	-	845			Recapt. 4/14/88 harvested 9/28/88
4/13	MA	Hess Haws	735	-	846			Transplanted
4/13	MA	Hess Haws	765	-	847			Transplanted
4/13	FA	Hess Haws	630	150.953	902			Lost 5/19/88
4/13	MA	Hess Haws	615	-	903			Transplanted
4/14	MA	Vanderhoff	715	-	848			Transplanted
4/15	FA	Hess Haws	575	-	844			Transplanted
4/17	MY	Cedar Hill	-	-	850			Transplanted
4/17	MY	Kurtz	-	-	851			
1989								
4/8	FA	North Canyon	650	150.379	852	3+	U 6/14/89	Last located 7/28/89
4/12	FA	North Canyon	740	150.780	853			Dead 5/24/89
4/12	FA	North Canyon	745	150.740	854			Dead 5/16/89
4/20	MA	Vanderhoff	780	-	855			Harvested 9/15/90
4/21	MA	Cow Hollow	785	-	856			
4/21	MY	Cow Hollow	730	-	857			
4/21	M?	Vanderhoff	-	-	-			
1990								
4/2	MA	Vanderhoff	740	-	858			Recapt. 4/3/90
4/2	FA	Vanderhoff	720	151.386	859	9+	S 5/25/90	Last located 4/21/90, dead 3/9/90
4/2	MA	Vanderhoff	750	-	860			Harvested 9/16/90
4/3	MA	Hill	780	-	861			Dead 7/9/90
4/3	MY	Vanderhoff	730	-	862			Harvested 9/28/90
4/3	MA	Vanderhoff	760	-	863			
4/4	FA	Vanderhoff	640	151.086	864			
4/4	F?	Vanderhoff	690	151.251	865	3+	S 6/17/90	Last located 5/10/90
4/4	MY	Vanderhoff	740	-	866			Dead 6/20/90
4/4	MA	North Pasture	730	-	502			

Appendix A. continued

Date Captured	Age/Sex	Trap Site ^a	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
4/4	FA	Vanderhoff	635	151.192	870	? 12	U ? S 7/18/90	6 hatched/6 pipped Last located 7/25/90, Dead 3/7/91
4/5	FA	Hill	690	151.161	867	10+ 9+	S 6/14/90 U 6/5/91	Last located 7/31/91
4/5	MY	Vanderhoff	710	-	868			
4/5	FA	Vanderhoff	710	150.951	869	11 ?	U 5/17/90 U 6/17/90	
4/6	FA	Hill	710	151.025	871	6 9+	S 7/25/90 S 6/25/90	Last located 7/25/90 Last located 7/25/90
4/6	FY	Hill	650	151.341	872	9+	S 5/24/90	Last located 5/30/90
4/6	FA	Vanderhoff	630	-	907			
4/6	FA	Vanderhoff	680	-	908			
4/6	FY	Vanderhoff	670	151.041	909	3+ 8+ 3+	U 5/28/90 U 6/5/91 U 7/3/91	Recap. 4/8/91
4/6	FY	Vanderhoff	670	-	910			Last located 7/31/91
4/6	FA	Vanderhoff	710	-	911			Harvested 9/15/90
4/6	FY	North Pasture	635	151.116	912	? ?	U 6/25/90	Recap. 4/8/91 Last located 6/30/90, Dead 3/7/91
4/7	MY	Lower Badger	680	-	913			Recap. 4/12/90
4/8	MY	Lower Badger	750	-	914			
4/10	MY	Kurtz	670	-	916			
4/10	FA	Kurtz	690	150.921	915			Recap. 4/10/90 Never located
4/10	M?	Lower Badger						Escaped from trap
4/10	FY	Lower Badger	685	151.176	917	? ?	U 6/1/90	Dead 6/19/90
4/11	MA	North Pasture	720	-	503			
4/11	FY	Kurtz	650	150.005	918	12	S 5/30/90	Lost 7/2/90
4/11	FY	Kurtz	730	150.982	919	9+ 9+	S 6/1/90	Last located 7/11/90, Dead 3/7/91
4/11	FA	Lower Badger	720	150.875	920	11+ 11+	S 6/19/90	Last located 6/19/90, Dead 5/12/91
4/12	FY	Lower Badger	650	151.056	504	9+ 9+	S 6/12/90	Last located 6/19/90, Dead 7/7/90
4/12	MY	Lower Badger	680	-	505			Recap. 4/18/90, Harvested 9/15/90
4/13	MA	Kurtz	720	-	921			
4/13	MY	Kurtz	N/A	-	922			
4/13	MA	Cow Hollow	720	-	923			Recap. 4/15/90
4/13	FY	Lower Badger	705	151.281	506	13/1	S 5/30/90	Last located 7/21/90
4/15	MA	Kurtz	680	-	924			
4/15	FY	Kurtz	720	150.936	925	? ?	U 6/29/91	No nest located Last located 8/1/91

Appendix A, continued

Date Captured	Age/Sex	Trap Site ^a	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
4/15	MY	Lower Badger	660		926			
4/15	MY	Lower Badger	650		508			
4/18	FA	Kurtz	705	151.355	927	?	U 6/2/90	
4/18	FY	Kurtz	645	151.237	928	9/1 11+	S 7/8/90 S 6/17/90	Last located 7/26/90 Last located 7/11/90
<u>1991</u>								
3/31	MY	Vanderhoff	770		302			
3/31	MA	Vanderhoff	830		303			Recap. 4/3/91, 4/4/91, 4/8/91 on Hill lek
4/2	MA	Vanderhoff	740		304			Recap. 4/1/91, 4/2/91, 4/9/91
4/2	MA	Vanderhoff	815		305			
4/3	FY	Hill	660	150.100	306			
4/3	MA	Vanderhoff	790		307			Recap. 4/9/91, Never located
4/4	F?	Vanderhoff						Recap. 4/4/91, 4/10/91
4/6	FA	N-13	690	151.295	604			Escaped from trap
4/6	FY	N-13	650	151.101	605	5+	S 6/8/91	Dead 5/91
4/6	MA	N-13	730		602			Last located 7/30
4/6	MA	N-13	N/A		603			Recap. 4/8, Harvested 9/26/92
4/7	MA	Hill	690		308			
4/7	MA	N-13	730		606			
4/7	MY	Nalder	770		607			
4/8	FA	Vanderhoff	710	150.264	908	11/1	S 5/30/91	
4/8	FY	Vanderhoff	670	151.622	309	?	U 6/5/91	Recap. from 1990, last located 7/16/91
4/8	FY	Vanderhoff	680	150.024	310			Last located 8/2/91
4/8	FA	Vanderhoff	N/A	150.325	N/A			Dead 5/15/91
4/8	FY	Vanderhoff	725	150.860	311	1+	U 6/5/91	Dead 5/91/91
4/9	FY	N-13	625	150.343	312	?	U 6/19/91	Dead 9/18/92
4/9	FA	N-13	695	150.862	313	11	S 6/8/91	Harvested 9/26/91
4/9	MA	Bowen	730		314			Last located 8/2/91
4/9	FA	Nalder	730	150.823	315	10+	S 6/18/91	
4/9	FY	Nalder	690	151.484	316	11	S 6/19/91	Last located 8/2/91
4/9	FY	Nalder	640	150.765	317			Last located 8/2/91, Recap. 3/31/92
4/9	FY	Hill						Dead 5/17/91
4/9	MA	Vanderhoff	730		608			Died in hand
4/10	MY	Bowen	640		318			

Appendix A. continued

Date Captured	Age/Sex	Tran Site ^a	Weight (g)	Radio Freq.	Band #	Clutch Size ^b	Nest Fate ^c	Comments ^d
4/10	MY	Bowen	730		319			
4/10	FY	Bowen	710	150.644	320	9+	S 6/26/91	Last located 8/2/91, Recap. 4/1/92 Died in hand
4/10	MY	Bowen	705		321			
4/10	MY	Bowen	750		322			
4/10	FA	Hill	730	151.056	609	?	U 6/2/91	Last located 7/31/91
4/10	MA	N-13	805		610			
4/11	FA	Bowen	745	150.905	323	?	U 6/26/91	Last located 7/29/91
4/14	FA	Lower Badger	640	151.430	324			Dead 7/??/91
4/14	MA	Lower Badger	750		325			
4/14	FY	Upper Badger	655	150.783	326	?	U 6/29/91	Last located 7/30/91
4/14	MA	Upper Badger	780		327			Harvested 9/19/92
4/14	MY	Upper Badger	720		328			
4/14	MA	Lower Badger	740		329			Recap. 4/15/91, 4/18/91, 4/19/91
4/14	MA	Lower Badger	770		330			
4/15	MY	Lower Badger	690		331			
4/15	MA	East Jacobson	670		332			
4/15	MY	East Jacobson	750		333			Recap. 4/16/91, 4/17/91
4/15	MA	East Jacobson	740		334			
4/16	FY	East Jacobson	730	151.401	335			Dead 5/??/91
4/16	MY	East Jacobson	730		336			
4/16	MY	East Jacobson	730		337			
4/17	FA	Lower Badger	620	151.250	338	9	S 6/29/91	Last located 8/2/91
4/17	MY	Lower Badger	725		339			
4/17	FA	East Jacobson	740	151.386	340	13	S 6/29/91	Last located 8/2/81
4/17	MY	East Jacobson	770		341			
4/18	MA	Lower Badger	730		342			
4/19	FY	Lower Badger	595	151.192	343			Dead 5/??/91
4/19	MY	Lower Badger	690		344			
4/19	FA	Lower Badger	700	151.293	345			Never located
4/19	FY	Lower Badger	660	150.714	346			Never located

^aSage grouse strutting ground or Columbian sharp-tailed grouse dancing ground capture site

^bx/y = clutch size/number hatched

x+ = more egg shell remains were found but precise clutch size could not be determined

? = clutch size could not be determined

^cU x/y/z = unsuccessful followed by date destroyed

S x/y/z = successful followed by hatch date

^dRecapt. x/y/z = Recapture followed by date(s)

Transplanted = Birds transplanted to Lewiston area by IDFG

I.S.U. Study = Male sage grouse movement study by Idaho State University

Appendix B. Plant species and associated Families and Tribes/Subfamilies identified at sage and Columbian sharp-tailed grouse nests and brood sites, dependent micro-habitat and independent macro-habitat sites in the Curlew Valley Region of southeastern Idaho, 1988-91.

Forb Species

Scientific Name	Common Name	Tribe/Subfamily	Family
<i>Achillea millefolium</i>	Common yarrow	Anthemieae	Compositae
<i>Agrostis glauca</i> ^b	Short-beaked agroseis	Cichorieae	Compositae
<i>Allium acuminatum</i> ^b	Hooker onion	Liliaceae	Liliaceae ^a
<i>Alyssum desertorum</i>	Desert alyssum	Group III	Cruciferae
<i>Antennaria dimorpha</i> ^d	Low pussy-toes	Inuleae	Compositae
<i>Antennaria umbrinella</i> ^d	Umber pussy-toes	Inuleae	Compositae
<i>Arabis holboellii</i> ^d	Holboell's rockcress	Group VI	Cruciferae
<i>Arenaria kingii</i>	King's sandwort	Group I	Caryophyllaceae
<i>Arnica fulgens</i>	Orange arnica	Senecioneae	Compositae
<i>Artemisia dracunculus</i>	Dragon sagewort	Anthemieae	Compositae
<i>Asperugo procumbens</i>	Madwort	Boraginaceae	Boraginaceae ^a
<i>Aster chilensis</i> ^b	Long-leaved aster	Astereae	Compositae
<i>Astragalus argophyllus</i> ^d	Slender-leaved milk-vech	Group I	Leguminosae
<i>Astragalus beckwithii</i> ^d	Beckwith's milk-vech	Group I	Leguminosae
<i>Astragalus calycosus</i> ^d	Torrey's milk-vech	Group I	Leguminosae
<i>Astragalus covallarii</i> ^{d,s}	Lesser rushy milk-vech	Group I	Leguminosae
<i>Astragalus lentiginosus</i> ^d	Freckled milk-vech	Group I	Leguminosae
<i>Astragalus purshii</i> ^d	Pursh's milk-vech	Group I	Leguminosae
<i>Balsamorhiza hookeri</i> ^c	Hookers' balsamroot	Heliantheae	Compositae
<i>Balsamorhiza sagittata</i> ^c	Arrowleaf balsamroot	Heliantheae	Compositae
<i>Berberis repens</i>	Low oregonrape	Berberidaceae	Berberidaceae ^a
<i>Calochortus nuttallii</i> ^b	Nuttall's sego lily	Liliaceae	Liliaceae ^a
<i>Camelina microcarpa</i>	Littlepod falseflax	Group III	Cruciferae
<i>Carthamus tinctorius</i>	Safflower	Cynareae	Compositae
<i>Castilleja chromosa</i>	Desert paintbrush	Scrophulariaceae	Scrophulariaceae ^a
<i>Castilleja linariaefolia</i>	Narrow-leaved paintbrush	Scrophulariaceae	Scrophulariaceae ^a
<i>Chaenactis douglasii</i> ^c	Hoary false-yarrow	Heliantheae	Compositae
<i>Chenopodium album</i> ^c	Lamb's quarter	Group II	Chenopodiaceae
<i>Chenopodium fremontii</i> ^c	Fremont's goosefoot	Group II	Chenopodiaceae
<i>Chenopodium leptophyllum</i> ^c	Slimleaf goosefoot	Group II	Chenopodiaceae
<i>Chorispora tenella</i> ^d	Blue mustard	Group I	Cruciferae
<i>Cirsium spp.</i>	Thistle	Cynareae	Compositae
<i>Collinsia parviflora</i>	Small-flowered blue-eyed Mary	Scrophulariaceae	Scrophulariaceae ^a
<i>Collomia gradiflora</i> ^c	Large flowered collomia	Polemoniaceae	Polemoniaceae ^a
<i>Collomia linearis</i> ^c	Narrow leaved collomia	Polemoniaceae	Polemoniaceae ^a
<i>Comandra umbellata</i> ^d	Bastard toad-flax	Santalaceae	Santalaceae ^a
<i>Convolvulus arvensis</i> ^b	Small bindweed	Convolvulaceae	Convolvulaceae ^a
<i>Crepis acuminata</i> ^b	Lone-leaved hawksbeard	Cichorieae	Compositae
<i>Crepis modocensis</i> ^b	Siskiyou hawksbeard	Cichorieae	Compositae
<i>Cryptantha flavoculata</i>	White forget-me-not	Boraginaceae	Boraginaceae ^a
<i>Cryptantha scoparia</i>	Desert cryptantha	Boraginaceae	Boraginaceae ^a
<i>Cymopterus terebinthinus</i>	Turpentine cymopterus	Group IV	Umbelliferae
<i>Cynoglossum officinale</i>	Common hound's-tongue	Boraginaceae	Boraginaceae ^a
<i>Delphinium nuttallianum</i>	Upland larkspur	Ranunculaceae	Ranunculaceae ^a
<i>Descurainia pinnata</i>	Western tansymustard	Group V	Cruciferae
<i>Descurainia richardsonii</i>	Mountain tansymustard	Group V	Cruciferae
<i>Descurainia sophia</i>	Flixweed	Group V	Cruciferae
<i>Epilobium minutum</i>	Small flowered willow-herb	Onagraceae	Epilobium
<i>Epilobium paniculatum</i>	Autumn willow-herb	Onagraceae	Onagraceae ^a
<i>Eriastrum sparsiflorum</i> ^c	Eriastrum	Polemoniaceae	Polemoniaceae ^a

Forb Species

Scientific Name	Common Name	Tribe/Subfamily	Family
<i>Erigeron corymbosus</i> ^b	Foothill daisy	Astereae	Compositae
<i>Erigeron humilis</i> ^b	Arctic-alpine daisy	Astereae	Compositae
<i>Erigeron pumilus</i> ^b	Shaggy fleabane	Astereae	Compositae
<i>Eriogonum cernuum</i>	Nodding buckwheat	Polygonaceae	Polygonaceae ^a
<i>Eriogonum microrhynchum</i>	Slenderbrush buckwheat	Polygonaceae	Polygonaceae ^a
<i>Eriogonum ovalifolium</i>	Cushion buckwheat	Polygonaceae	Polygonaceae ^a
<i>Eriogonum umbellatum</i>	Sulfur buckwheat	Polygonaceae	Polygonaceae ^a
<i>Erodium cicutarium</i>	Crane's-bill	Geraniaceae	Geraniaceae ^a
<i>Erysimum asperum</i>	Rough wallflower	Polygonaceae	Polygonaceae ^a
<i>Fritillaria pudica</i> ^b	Yellow-bell	Liliaceae	Liliaceae ^a
<i>Galium aparine</i>	Goose-grass	Rubiaceae	Rubiaceae ^a
<i>Geranium viscosissimum</i>	Sticky purple geranium	Geraniaceae	Geraniaceae ^a
<i>Geum macrophyllum</i>	Oregon avens	Group II	Rosaceae
<i>Gilia aggregata</i> ^c	Scarlet gilia	Polemoniaceae	Polemoniaceae ^a
<i>Grindelia squarrosa</i> ^b	Curly-cup gumweed	Astereae	Compositae
<i>Gymnosteris parvula</i> ^c	Small flowered gymnosteris	Polemoniaceae	Polemoniaceae ^a
<i>Hackelia patens</i>	Spreading stickseed	Boraginaceae	Boraginaceae ^a
<i>Halogeton glomeratus</i> ^c	Halogeton	Group II	Chenopodiaceae
<i>Haplopappus acutis</i> ^b	Stemless goldenweed	Astereae	Compositae
<i>Helianthella uniflora</i> ^c	Rocky Mountain helianthella	Heliantheae	Compositae
<i>Helianthus annuus</i> ^c	Common sunflower	Heliantheae	Compositae
<i>Hydrophyllum capitatum</i>	Ballhead waterleaf	Hydrophyllaceae	Hydrophyllaceae ^a
<i>Iva axillaris</i> ^b	Poverty-weed	Astereae	Compositae
<i>Kochia scoparia</i> ^{bc}	Kochia	Group I	Chenopodiaceae
<i>Lactuca serriola</i> ^b	Prickly lettuce	Cichorieae	Compositae
<i>Lappula texana</i>	Western stickseed	Boraginaceae	Boraginaceae ^a
<i>Lathyrus nevadensis</i>	Sweet-pea	Leguminosae	Leguminosae ^a
<i>Lepidium perfoliatum</i>	Clasping pepperweed	Group IV	Cruciferae
<i>Lepidium virginicum</i>	Tall pepperweed	Group IV	Cruciferae
<i>Leptodactylon pungens</i> ^c	Leptodactylon	Polemoniaceae	Polemoniaceae ^a
<i>Linum perenne</i> ^d	Wild blue flax	Linaceae	Linaceae ^a
<i>Lithospermum ruderales</i>	Western gronwell	Boraginaceae	Boraginaceae ^a
<i>Lomatium grayi</i>	Gray's lomatium	Group III	Umbelliferae
<i>Lomatium triternatum</i>	Nine-leaved lomatium	Group III	Umbelliferae
<i>Lupinus argenteus</i> ^d	Silvery lupine	Leguminosae	Leguminosae ^a
<i>Lupinus leucophyllus</i> ^d	Velvet lupine	Leguminosae	Leguminosae ^a
<i>Lygodesmia juncea</i> ^b	Rush-like skeletonplant	Cichorieae	Compositae
<i>Machaeranthera commixta</i> ^b	Mixed aster	Astereae	Compositae
<i>Machaeranthera canescens</i> ^b	Hoary aster	Astereae	Compositae
<i>Medicago hispida</i> ^d	Bur-clover	Group I	Leguminosae
<i>Medicago sativa</i> ^d	Alfalfa	Leguminosae	Leguminosae ^a
<i>Melilotus officinalis</i> ^d	Yellow sweet-clover	Leguminosae	Leguminosae ^a
<i>Mentha piperita</i> ^c	Peppermint	Labiatae	Labiatae ^a
<i>Mertensia oblongifolia</i>	Leafy bluebells	Boraginaceae	Boraginaceae ^a
<i>Microsteris gracilis</i> ^c	Pink microsteris	Polemoniaceae	Polemoniaceae ^a
<i>Nemophila breviflora</i>	Great Basin nemophila	Hydrophyllaceae	Hydrophyllaceae ^a
<i>Oenothera pallida</i>	Pale evening primrose	Onagraceae	Onagraceae ^a
<i>Opuntia polyacantha</i>	Starvation cholla	Cactaceae	Cactaceae ^a
<i>Pachistima myrsinites</i>	Oregon boxwood	Celastraceae	Celastraceae ^a
<i>Penstemon cyaneus</i>	Dark-blue penstemon	Scrophulariaceae	Scrophulariaceae ^a
<i>Penstemon procerus</i>	Small flowered penstemon	Scrophulariaceae	Scrophulariaceae ^a
<i>Phacelia hastata</i>	Whiteleaf phacelia	Hydrophyllaceae	Hydrophyllaceae ^a
<i>Phlox hoodii</i> ^c	Hood's phlox	Polemoniaceae	Polemoniaceae ^a
<i>Phlox longifolia</i> ^c	Long-leaf phlox	Polemoniaceae	Polemoniaceae ^a

Appendix B. continued.

Forb Species

Scientific Name	Common Name	Tribe/Subfamily	Family
<i>Plantago patagonica</i>	Indian-wheat	Rubiaceae	Rubiaceae ^a
<i>Polygonum aviculare</i>	Doorweed	Polygonaceae	Polygonaceae ^a
<i>Polygonum sawatchese</i>	Sawatch knotweed	Polygonaceae	Polygonaceae ^a
<i>Ranunculus testiculatus</i>	Hornseed buttercup	Ranunculaceae	Ranunculaceae ^a
<i>Rumex salicifolius</i>	Narrow leaved dock	Polygonaceae	Polygonaceae ^a
<i>Solidago missouriensis</i>	Solidago	Astereae	Compositae
<i>Salsola kali</i> ^d	Russian thistle	Chenopodiaceae	Chenopodiaceae ^a
<i>Sanquisorba minor</i> ^b	Small burnet	Roseaceae	Roseaceae ^a
<i>Sedum lanceolatum</i>	Lanceleaved stonecrop	Crassulaceae	Crassulaceae ^a
<i>Senecio dimorphophyllus</i>	Payson's groundsel	Senecioneae	Compositae
<i>Senecio integerrimus</i>	Western groundsel	Senecioneae	Compositae
<i>Senecio streptanthifolius</i>	Cleft-leaf groundsel	Senecioneae	Compositae
<i>Silene menziesii</i>	Menzies' silene	Caryophyllaceae	Caryophyllaceae ^a
<i>Smilacina racemosa</i> ^b	Western Solomon's seal	Liliaceae	Liliaceae ^a
<i>Sphaeralcea munroana</i>	Munro's globemallow	Hypericaceae	Hypericaceae ^a
<i>Taraxacum officinale</i> ^b	Common dandelion	Cichorieae	Compositae
<i>Thlaspi arvense</i> ^d	Field pennycress	Group IV	Cruciferae
<i>Tragopogon dubius</i> ^b	Yellow salsify	Cichorieae	Compositae
<i>Veronica biloba</i>	Bilobed speedwell	Scrophulariaceae	Scrophulariaceae ^a
<i>Viola nuttallii</i>	Nuttall's violet	Violaceae	Violaceae ^a
<i>Viola purpurea</i>	Goosefoot violet	Violaceae	Violaceae ^a
<i>Wyethia amplexicaulis</i> ^c	Northern mule's-ears	Heliantheae	Compositae
<i>Zizadenus paniculatus</i> ^b	Panicled death-cannus	Liliaceae	Liliaceae ^a

Grasses

<i>Agropyron cristatum</i> ^{cd}	Crested wheatgrass	Hordeae	Gramineae
<i>Agropyron intermedium</i> ^{cd}	Intermediate wheatgrass	Hordeae	Gramineae
<i>Agropyron repens</i> ^{cd}	Quackgrass	Hordeae	Gramineae
<i>Agropyron smithii</i> ^{cd}	Bluestem wheatgrass	Hordeae	Gramineae
<i>Agropyron spicatum</i> ^{cd}	Bluebunch wheatgrass	Hordeae	Gramineae
<i>Avena fatua</i> ^{bc}	Wild oat	Aveneae	Gramineae
<i>Bromus commutatus</i> ^c	Hairy brome	Festuceae	Gramineae
<i>Bromus inermis</i> ^c	Smooth brome	Festuceae	Gramineae
<i>Bromus mollis</i> ^c	Bromus	Festuceae	Gramineae
<i>Bromus tectorum</i> ^c	Cheatgrass brome	Festuceae	Gramineae
<i>Carex douglasii</i>	Douglas' sedge	Cyperaceae	Cyperaceae
<i>Elymus cinereus</i> ^{cd}	Giant wildrye	Hordeae	Gramineae
<i>Elymus junceus</i> ^{cd}	Russian wildrye	Hordeae	Gramineae
<i>Festuca idahoensis</i> ^{bc}	Idaho fescue	Aveneae	Gramineae
<i>Festuca octoflora</i> ^{bc}	Six-weeks fescue	Aveneae	Gramineae
<i>Koeleria cristatum</i> ^{bc}	Junegrass	Aveneae	Gramineae
<i>Melica bulbosa</i> ^c	Oniongrass	Festuceae	Gramineae
<i>Oryzopsis hymenoides</i> ^c	Indian ricegrass	Agrostideae	Gramineae
<i>Poa bulbosa</i> ^c	Bulbous bluegrass	Festuceae	Gramineae
<i>Poa juncifolia</i> ^c	Alkali bluegrass	Festuceae	Gramineae
<i>Poa sandbergii</i> ^c	Sandberg's bluegrass	Festuceae	Gramineae
<i>Poa scabrella</i> ^c	Pine bluegrass	Festuceae	Gramineae
<i>Sitanion hystrix</i> ^{cd}	Squirreltail	Hordeae	Gramineae
<i>Stipa compacta</i> ^c	Needle-and-thread	Agrostideae	Gramineae
<i>Stipa occidentalis</i> ^c	Western needlegrass	Agrostideae	Gramineae
<i>Triticum aestivum</i> ^{cd}	Wheat	Hordeae	Gramineae
<i>Typha spp.</i>	Cat-tail	Typhaceae	Typhaceae

Appendix B. continued.

Shrub Species			
<u>Scientific Name</u>	<u>Common Name</u>	<u>Tribe/Subfamily</u>	<u>Family</u>
<i>Amelanchier utahensis</i>	Serviceberry		Roseaceae
<i>Artemisia ludoviciana</i>	Prairie sagewort		Compositae
<i>Artemisia tridentata tridentata</i>	Basin big sagebrush		Compositae
<i>Artemisia tridentata vaseyana</i>	Mountain big sagebrush		Compositae
<i>Artemisia tripartita</i>	Three-tipped sagebrush		Compositae
<i>Ceanothus velutinus</i>	Tobacco-brush		Rhamnaceae
<i>Chrysothamnus nauseosus</i>	Common rabbit-brush		Compositae
<i>Chrysothamnus viscidiflorus</i>	Green rabbit-brush		Compositae
<i>Gutierrezia sarothrae</i>	Broom snakeweed		Compositae
<i>Juniperus osteosperma</i>	Utah juniper		Cupressaceae
<i>Pachistima myrsinites</i>	Myrtle boxwood		Celastraceae
<i>Purshia tridentata</i>	Antelope-bitterbrush		Roseaceae
<i>Rosa woodsii</i>	Rose		Roseaceae
<i>Sarcobatus vermiculatus</i>	Greasewood		Amaranthaceae
<i>Symphoricarpos oreophilus</i>	Mountain snowberry		Caprifoliaceae
<i>Tetradymia canescens</i>	Horse-brush		Compositae

^aSubfamilies/tribes were not present so the next highest taxonomic pooling, family, was used.

^bSpecies of grasses and forbs selected in the brood only stepwise discriminant analysis and included in the nonparametric discriminant analyses.

^cSpecies of grasses and forbs selected in the brood and nest stepwise discriminant analysis and included in the nonparametric discriminant analyses.

^dSpecies of grasses and forbs selected in the nest only stepwise discriminant analysis and included in the nonparametric discriminant analyses.

Appendix C. Sage and Columbian sharp-tailed grouse breeding and nesting dates in the Curlew Valley region of southeastern Idaho, 1988-91.

	Sage Grouse			Columbian Sharp-tailed Grouse		
	<u>n</u>	<u>Median</u>	<u>Range</u>	<u>n</u>	<u>Median</u>	<u>Range</u>
Male Display/Trap	10	3/13	3/6 - 3/20	12	4/2	3/30 - 4/8
Nest Initiation ^a	14	5/1	4/15 - 5/10	20	5/10	4/16 - 5/11
Hatch Date	14	6/5	5/20 - 6/14	20	6/13	5/31 - 6/19

^aColumbian sharp-tailed grouse nest initiation date was calculated using 34 days for egg-laying and incubation (Meints 1990).

Sage grouse nest initiation date was calculated using 35 days for egg-laying and incubation (Dalke et al. 1963, Johnsgard 1973).

Appendix D. Sage and Columbian sharp-tailed grouse elevational movements in the Curlew Valley region of southeastern Idaho, 1988-91.

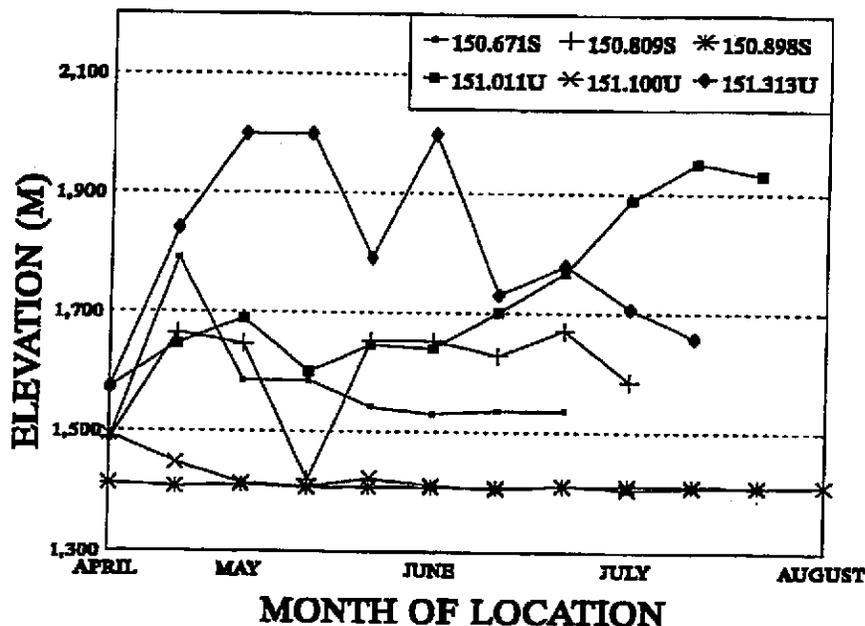


Figure A.1. Successful sage grouse hens with broods (S) and unsuccessful hens without broods (U) elevational movements from 1988 and 1989 in the Curlew Valley region of southeastern Idaho.

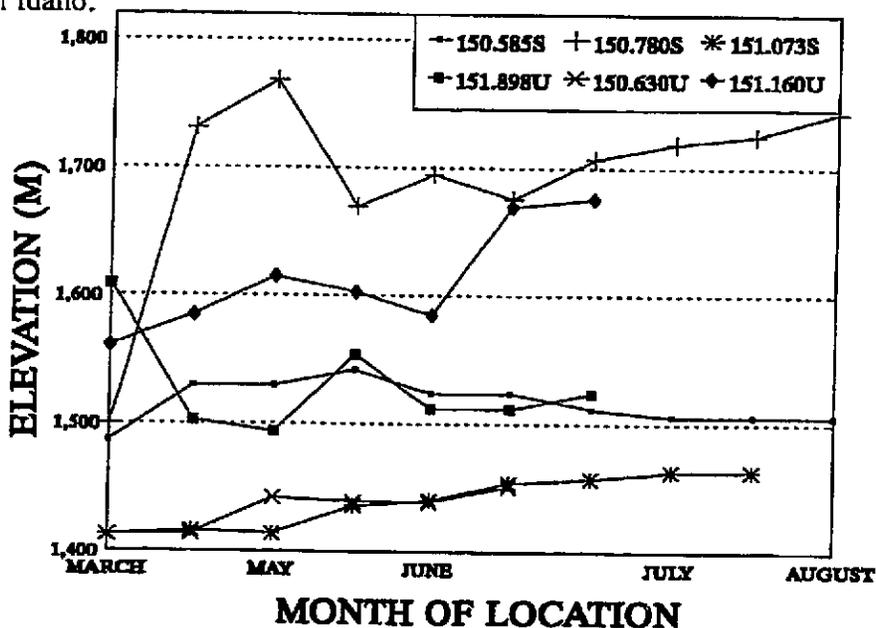


Figure A.2. Successful sage grouse hens with broods (S) and unsuccessful hens without broods (U) elevational movements from 1990 and 1991 in the Curlew Valley region of southeastern Idaho.

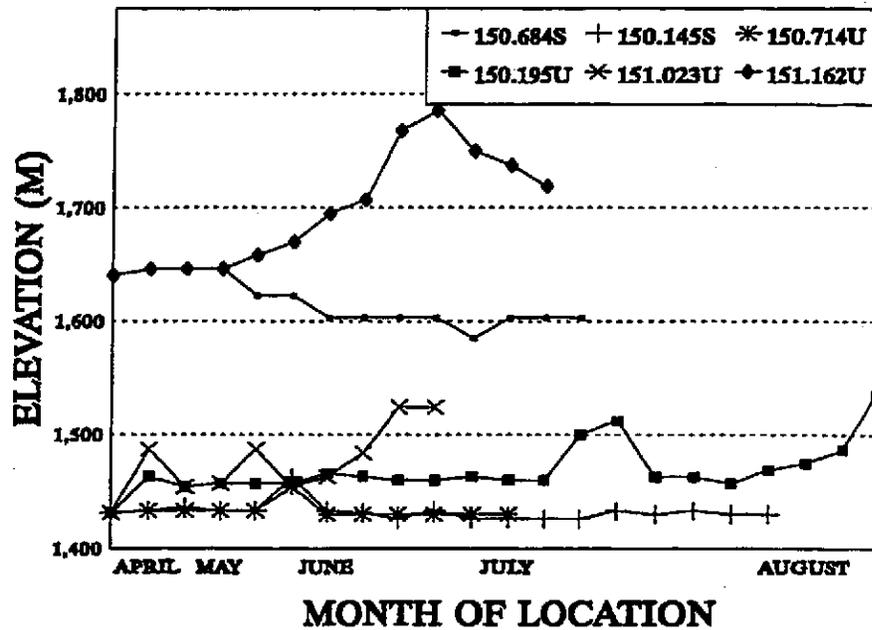


Figure A.3. Successful Columbian sharp-tailed grouse hens with broods (S) and unsuccessful hens without broods (U) elevational movements from 1988 in the Curlew Valley region of southeastern Idaho.

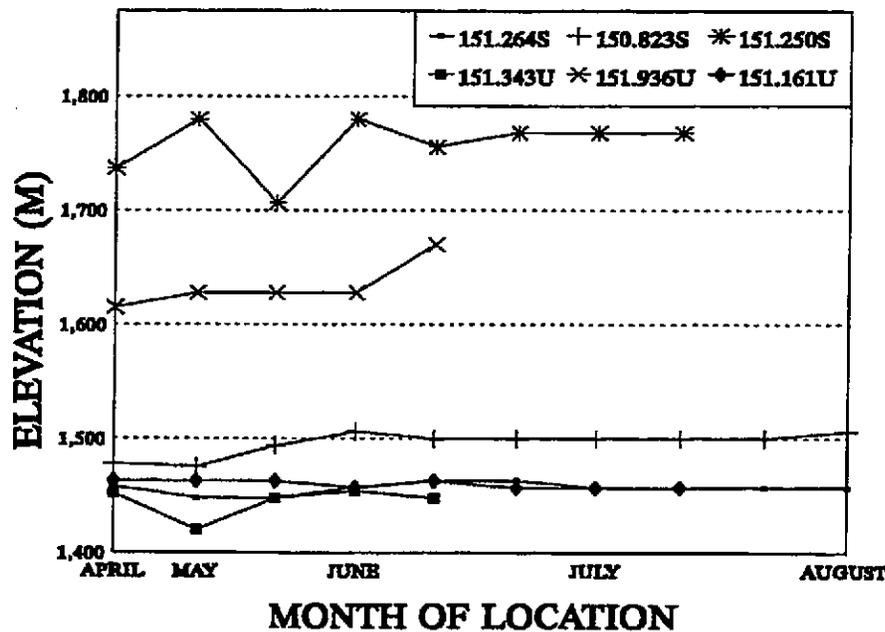


Figure A.4. Successful Columbian sharp-tailed grouse hens with broods (S) and unsuccessful hens without broods (U) elevational movements from 1991 in the Curlew Valley region of southeastern Idaho.