

ECOLOGICAL FACTORS LIMITING SAGE GROUSE
RECOVERY AND EXPANSION
IN STRAWBERRY VALLEY, UTAH

Manuscripts Presented to the
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By

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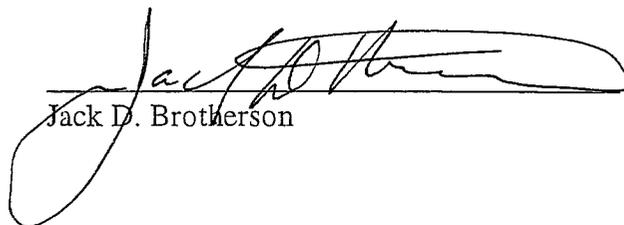
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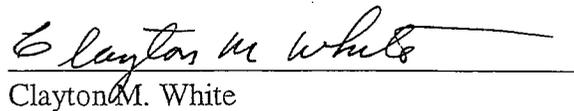
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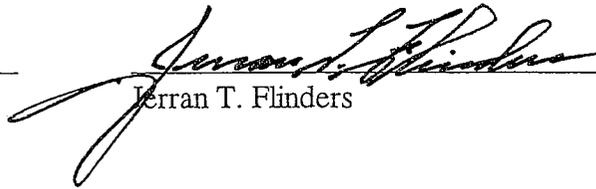
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RH: Sage Grouse Habitat Evaluations • Bunnell et al.

**A COMPREHENSIVE EVALUATION OF OCCUPIED AND UNOCCUPIED SAGE
GROUSE HABITAT IN STRAWBERRY VALLEY, UTAH**

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Abstract: This study evaluated multiple aspects of spring/summer sage grouse (*Centrocercus urophasianus*) habitat in Strawberry Valley, Utah by measuring nest, brood and adult habitat sites. In addition, three types of random habitat were measured including random habitat within core use areas, random sagebrush/grass habitat outside core use areas, and random sagebrush/grass habitat sites that had been converted to an understory of smooth brome by past range management practices. Logistic regression was used to identify those habitat variables that discriminated between site types. Variables that significantly discriminated occupied adult habitat from random habitat outside of core use areas included: 1) percent grass

cover ($p=0.009$) and 2) area of sagebrush canopy ($p=0.032$). Variables that significantly discriminated occupied habitat from random habitat with a smooth brome understory included: 1) percent forb cover ($p=0.002$), 2) shrub canopy cover ($p=0.017$) and 3) area of sagebrush canopy ($p=0.077$). Variables that discriminated adult habitat from brood rearing habitat included: 1) sagebrush height ($p=0.001$) and 2) forb diversity ($p=0.126$).

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Key Words: *Centrocercus urophasianus*, habitat, logistic regression, sage grouse, Utah

Sage grouse habitat requirements have been studied by many different researchers and revised management guidelines are currently being published (Connelly et al. in review). From this collection of research, much has been learned about the vegetative habitat requirements for sage grouse at various life stages. Great attention has been given to sage grouse nesting habitat (Klebenow 1969, Peterson 1980, Wakkinen 1990, Gregg 1991, Connelly et al. 1991, Wakkinen et al. 1992, Fischer et al. 1993, Webb 1993, Gregg et al. 1994, Nelle 1998, Sveum et al. 1998) and brood rearing habitat (Gray et al. 1967, Wallestad 1971, Klott and Lindzey 1990, Drut et al. 1994, Fischer et al. 1996, Nelle 1998, Sveum et al. 1998). Less attention has been given to adult spring/summer habitat requirements (Martin 1970, Wallestad and Schladweiller 1974, Braun et al. 1977, Schoenberg 1982, Hulet 1983, Martin 1990, Apa 1998). Few if any articles in professional journals have simultaneously evaluated vegetative spring/summer habitat requirements for an entire population. In addition, some important sagebrush characteristics have been neglected in relation to sage grouse habitat. For example,

sagebrush stands have not been aged and only one study (Connelly et al. 1991) has measured the area within the canopy of sagebrush. Also, only one study (Dunn and Braun, 1986) has used multivariate statistical techniques to simultaneously analyze data. Although it's true that univariate statistics will detect differences that exist between site types (use sites and random sites for example) multivariate methods are needed to identify the variables that discriminate between site types and the importance of attributes at sites. Not all variables that are significantly different between site types will necessarily contribute to the ability to distinguish one site from another. Multivariate statistical methods, such as logistic regression, analyze all variables simultaneously and account for correlation between variables, and also identify variables that can discriminate between sites having positive or negative relationships with sage grouse.

In our study of sage grouse and their habitat in Strawberry Valley, Utah, we simultaneously (or continuously) measured nesting, brood rearing and adult spring/summer habitats. We also measured the following three types of random sagebrush habitat: 1) random habitat sites within core use areas of sage grouse, 2) random habitat sites outside of core use areas, and 3) random habitat sites outside of core use areas that had been converted to an understory of smooth brome by past range management practices. Smooth brome areas were separated from non-use random sites because the understory composition in these areas was obviously different. Univariate statistical methods were first used to identify differences that existed between the three types of use sites and between use sites and random sites.

Multivariate statistical techniques were then used to identify those variables that most significantly contributed to distinguishing between site types by accounting for correlations between variables.

This study was needed to understand the 90%-95% population decline that has taken place over the past 60 years in the Strawberry Valley (based on a current population estimate of 150 sage grouse compared to a 1939 estimate of 3,000 - 4,000 (Griner 1939)). our objectives in this study were: 1) evaluate sage grouse habitat compared to the recommended guidelines and better understand how habitat was being partitioned among sage grouse at various life stages, 2) identify those variables that most contributed to this partitioning, 3) evaluate the quality of the habitat immediately surrounding the occupied habitat sites to identify limiting factors, and 4) evaluate the unoccupied habitat and identify limiting factors that might be precluding sage grouse from using these areas. We were particularly interested in evaluating the vegetative composition on sites where past range management practices replaced native forbs and bunch grasses with an aggressive sod-forming grass such as smooth brome (*Bromus inermis*) even though mountain big sagebrush (*Artemisia tridentata vaseyna*) had regrown on these sites. This particular research question may be relevant to many places other than Strawberry Valley, Utah. We believe this comprehensive approach is especially useful in identifying critical habitat characteristics as well as those vegetative factors that may limit a sage grouse population.

STUDY AREA

This study was centered in the Strawberry Valley of north-central Utah during 1998-1999. The area is a high mountain valley (2,250 - 2,450 m) and receives approximately 58 cm of annual precipitation. Strawberry Reservoir is the dominant feature of the valley covering up to 6,950 surface hectares. Within the valley there are approx. 8,950 hectares of sagebrush/grass habitat which primarily border the reservoir (URMCC and USFS, 1997). Mountain big sagebrush dominates the area with silver sage (*Artemisia cana*) occurring within wet meadows and riparian corridors.

METHODS

Sage grouse trapping was conducted during March, April, and May 1998 and 1999 using the spotlighting method (Giesen et al. 1982). Necklace style radio telemetry transmitters (Marcstrom et al. 1989) were attached to trapped sage grouse (males and females).

Seasonal habitat use was identified by locating birds with transmitters attached. Once locations were identified they were classified as nest, brood, or adult habitat sites. The following habitat measurements were taken at each site: slope, aspect, G.P.S. location, percent shrub canopy cover, percent herbaceous cover, sagebrush and total shrub density, horizontal obscurity cover, and vertical cover. Percent canopy cover of shrub species was measured using the line intercept method (Bonham 1989). Shrub density was measured using the T^2 analysis for the two shrubs nearest to the habitat point (Ludwig and Reynolds 1988). Each of the four shrubs in the two T^2 analyses was measured for height and area within the canopy (calculated as the area of an ellipse). Percent decadence (defoliated or dying branches) was

estimated for each shrub. Percent composition of shrubs was calculated from the species occurring in the T^2 analyses. Herbaceous understory was quantified by estimating the percent cover of each species that occurred within a 1 m^2 plot at the nest, brood or adult site (micro-habitat) and 25 m from the site in four directions (macro-habitat). Forb and grass diversity was calculated as the mean number of species occurring within each understory plot. Horizontal obscurity cover was measured using a 1 m^2 cover board stratified into thirds (0-33.3 cm, 33.3 cm - 66.6 cm and 66.6 cm - 100 cm) along the vertical axis with each stratification separated into 12 equal squares. Horizontal obscurity cover measurements were taken at of 10 - 14 inches above the ground at distances of 2.5, 5 and 10 meters from the cover board in four directions. Vertical obscurity cover was measured using an 18 cm x 18 cm cover board, separated into 36 equal squares. This board was placed directly over the nest, brood, or adult site and the number of obscured squares was recorded.

Three types of random habitat were also measured in the same manner. Random locations within core use areas (random) were located by taking a random compass bearing from a use site and going 100 m in that direction. Another random bearing and a random distance were then used to arrive at the random habitat location. Random sites within areas that had been converted to a smooth brome understory (brome) and general random points outside the core use areas (non-use random) were also located by taking random compass bearings and a random distance (as described above) from a random point on a road in a particular area.

During 1999 sagebrush ages were estimated at adult, random, brome, and non-use random sites by cutting the sagebrush plant nearest to the data point (sagebrush was also aged for nest and brood sites, but sample sizes were inadequate). Sagebrush cuttings were then sanded and the growth rings counted from the center to the cork cambium with the aid of a microscope. A minimum of two counts were made of each cutting by separate individuals. This process was repeated until agreement of the counts was reached.

Statistical analyses to compare variables between site types were performed with a one-way ANOVA on each variable. Non-parametric statistical procedures were used to analyze differences between individual species in the understory between site types because the data did not meet the assumptions for ANOVA (data were not normally distributed and standard deviations were not equal) . A Kruskal-Wallis analysis was used in place of the ANOVA test and a Mann-Whitney test was used to make pairwise comparisons. Logistic regression (Ramsey and Shafer 1997) was used to identify variables that significantly discriminated between site types. Percent composition of shrubs was statistically analyzed for differences between site types with a chi-square test. Statistics were considered significant at $\alpha = 0.05$.

RESULTS

Mean sagebrush age at adult sites and random sites was significantly greater than at non-use random sites ($p = 0.04$ and 0.008) respectively. Sagebrush age for brome sites was not significantly different from any other sites (Table 1).

Mean sagebrush canopy area was significantly greater at nest and adult sites than at all other sites (experiment error rate = 0.05 , comparison error rate = 0.00454). Also, the canopy area of all shrubs species was significantly higher for adult and nest sites when compared to all other sites (experiment error rate = 0.05 , comparison error rate = 0.00448) (Table 1).

Sagebrush plants were significantly taller at adult, nest and brome sites than at all other sites (experiment error rate = 0.05 , comparison error rate = 0.00454). Also, all non-sagebrush shrubs were significantly taller at adult, nest and brome sites than at all other sites (experiment error rate = 0.05 , comparison error rate = 0.00448) (Table 1).

Mean percent decadence of sagebrush was significantly higher at adult, brome and non-use random sites than at brood and random sites (experiment error rate = 0.05 , comparison error rate = 0.00454). Also, percent decadence for all shrub species was significantly higher at adult sites than at random sites (experiment error rate = 0.05 , comparison error rate = 0.00448) (Table 1).

Percent composition of shrubs appearing in the T^2 analysis at adult sites was significantly different than at nest sites ($p = 0.01$), brood sites ($p = 0.021$) and non-use random sites ($p = 0.030$). Percent composition of shrubs at nest sites was significantly different from brood sites ($p = 0.001$), random sites ($p < 0.001$), brome sites ($p = 0.005$) and non-use random sites ($p < 0.001$). Percent shrub composition at brood sites was significantly different from random sites ($p = 0.001$). In addition, the percent shrub composition at random sites was significantly different than at brome sites ($p = 0.015$) (Fig. 1). No significant differences were

found in sagebrush or total shrub densities.

Mean sagebrush canopy area of the closest shrub ($\bar{x} = 1.45 \text{ m}^2$) at adult sites was significantly greater than the second shrub ($\bar{x} = 1.34 \text{ m}^2$) in the T^2 analyses ($p = 0.031$). No other differences were found in the four shrubs measured at each adult site. No differences were found among the four shrubs measured at other use sites.

No statistical differences were found for sagebrush canopy cover between any site types. Total shrub canopy cover at brome sites was significantly less (Tukey's $p = .004$) from the total shrub canopy at all other sites except nest sites which had a high standard deviation (19.21%) possibly resulting from a small sample size ($n = 10$) (Table 2).

Total percent cover for grass in understory plots was significantly higher at brome sites than at all other site types (Tukey's $p = .004$). Brome sites were the only areas with timothy grass (*Phleum spp.*) in the understory. Percent cover of smooth brome was significantly higher at brome sites than at brood sites ($p < 0.0001$), adult sites ($p < 0.0001$) and random sites ($p < 0.0001$). Smooth brome was not found in the understory at nest sites or non-use random sites (Table 3).

Total percent cover of the 14 most common forb species in understory plots was significantly lower at brome sites than at all other sites except nest sites (Tukey's $p = 0.004$) and was significantly lower at non-use random sites than at brood sites and use random sites (Tukey's $p = 0.004$) (Table 4). Total forb cover was not significantly different between any other sites. Many significant differences were found between site types in the percent cover of

the 14 most common forb species (Table 4). Forb species diversity was significantly lower at brome sites ($\bar{x} = 1.9$) than at brood sites ($\bar{x} = 3.0$) ($p < 0.0001$) and adult sites ($\bar{x} = 2.7$) ($p < 0.0001$). Species diversity was also significantly lower at non-use random sites ($\bar{x} = 2.0$) than at brood ($p < 0.0001$) and adult sites ($p = 0.0001$). Forb diversity at nest sites ($\bar{x} = 2.2$) and random sites ($\bar{x} = 2.4$) was significantly higher than at brood sites ($p = 0.0022$, and $p = 0.0006$) respectively, but did not differ significantly from adult sites (Fig. 2).

Mean horizontal obscurity cover tended to be highest at brome sites and lowest at brood sites. These tendencies became more obvious at the 5 m and 10 m distances (Table 5).

Mean vertical cover was significantly higher at nest sites ($\bar{x} = 97.7\%$) than at brood sites ($\bar{x} = 62.2\%$) ($p = 0.0003$) and adult sites ($\bar{x} = 63.4\%$) ($p < 0.0001$). There were no differences in slope between any site types, although within adult sites, males tended to select steeper slopes ($\bar{x} = 11.31\%$) than females ($\bar{x} = 4.37\%$).

Percent cover of forbs was significantly higher ($p = 0.017$) at brood micro-habitat sites than at brood macro-habitat sites (Fig 3). Forb species diversity was also higher ($p = 0.076$) at brood micro-habitat than brood macro-habitat (Fig. 4). No difference was found in percent cover of forbs or forb diversity in micro and macro habitat at adult sites (Figs. 3 & 4) There was no significant differences in percent cover of grasses in micro-habitat or macro-habitat for either brood sites (micro $\bar{x} = 22.3\%$), (macro $\bar{x} = 19.58\%$) or adult sites (micro $\bar{x} = 26.4\%$), (macro $\bar{x} = 24.1\%$). Micro-habitat and macro-habitat was not analyzed for nest sites because of an insufficient sample size ($n=10$).

Total forb percent cover was the only variable with significant predictive value ($p = 0.021$) in distinguishing micro habitat from macro habitat at brood sites when a binary logistic regression was used with the 14 most common forb species and total forb cover as independent variables (concordance = 61.9%).

Binary logistic regression was used to identify those variables that significantly contributed to distinguishing adult sites from all random site types (use-random, brome, and non-use random). No variables were significant in distinguishing adult sites from random sites within the core use areas. Adult sites were used in the analysis because they were the most general of the use habitat sites. Percent grass cover ($p = 0.009$) and sagebrush canopy area ($p = 0.032$) were significant variables in distinguishing adult sites from random sites outside core use areas (concordance = 70.3%). Percent forb cover ($p = 0.002$), shrub canopy cover ($p = 0.017$), and area of sagebrush canopy ($p = 0.077$), were the most significant variables in distinguishing adult sites from brome sites (concordance = 79.9%). Binary logistic regression was also used to identify the variables that discriminate brood habitat from adult habitat and random habitat within core use areas. Sagebrush height ($p = .001$) and forb diversity ($p = 0.126$) were the only significant variables in discriminating brood and adult habitats (concordance = 76.1%). Forb diversity ($p = 0.008$) and forb cover ($p = 0.007$) were the only variables that contributed to discriminating brood sites from random sites (concordance = 68.4%).

DISCUSSION

One of the unique contributions of this study to the knowledge of sage grouse habitat is that many habitat types were measured simultaneously for a single population. Only one other study (Dunn and Braun, 1986) reported similar data, but with fewer site types. Our use of logistic regression to identify the vegetative habitat variables that discriminate between site types, to our knowledge, is also a unique approach although, Dunn and Braun (1986) used discriminate analysis in a similar manner.

The lack of a significant discriminator between adult sites and random sites indicates that the occupied habitat is in good condition and sage grouse are not having to search for suitable habitat within these areas. Our use of logistic regression in comparing adult habitat to non-use random sites and brome sites identified variables that discriminate the site types. In the case of non-use random sites, sagebrush height and forb diversity were the only discriminating variables identified. Sagebrush in these areas is younger (16.6 yrs.) than the sagebrush found at the adult sites (20.5 yrs.) (Table 1): This helps explain the difference in sagebrush height. This being the case, we expect the understory composition to change as sagebrush stands mature, which may explain the difference in forb diversity. Our recommendation in this particular case is to simply continue to monitor vegetative stands and not apply any treatments. In the case of brome sites, logistic regression identified shrub canopy cover, sagebrush canopy area and percent forb cover as discriminating variables. We believe each of these variables is a result of the competitiveness and abundance of smooth brome in the understory. Reductions in shrub canopy cover, forb cover, and forb diversity are explained by

the presence of an aggressive sod forming grass such as smooth brome. The reduced canopy area of sagebrush is possibly the result of the sagebrush being forced to grow tall rather than spreading the canopy in order to compete for light with the tall, fast growing smooth brome. In this case of brome sites, the treatment prescription is to: 1) greatly reduce smooth brome in the understory, 2) maintain the sagebrush cover (possibly with a monocot-specific herbicide) and 3) reseed with a mix of forbs, native bunch grasses, and shrubs.

The discovery that sagebrush age differed significantly between use areas and non-use areas is important in understanding sage grouse habitat. Knowing that sagebrush plants are significantly older in areas occupied by sage grouse than in unoccupied areas (Table 1), we can begin to understand the disturbance regime that will most benefit sage grouse in the mountain big sagebrush habitat type. Natural disturbance cycles have been disrupted or eliminated in many sagebrush habitats by increased fire intervals, due to the introduction of cheatgrass (*Bromus tectorum*), or by decreased fire intervals, due to overgrazing or fire suppression. Knowledge of the age dynamics of sites that are occupied and unoccupied by sage grouse can help managers in their efforts to restore or mimic natural disturbance regimes to benefit sage grouse. Also, the discovery that the age of sagebrush at brome sites does not differ significantly from the age of sagebrush at use sites, and yet brome sites remain unoccupied, indicates that past range management practices, intended to decrease sagebrush and increase livestock forage in the Strawberry Valley, had negative effects on sage grouse habitat. More importantly, it indicates that the negative effects continue even though the sagebrush has had

adequate time to re-establish adequate density within the past treatments. We believe this may also be true in many areas throughout the Western U.S. where similar practices occurred.

Sagebrush canopy cover is an essential part of sage grouse habitat. This cover in all occupied and unoccupied sites measured in the Strawberry Valley meet the guidelines suggested for productive breeding and brood rearing sage grouse habitat (Connelly et al. In review). Although sagebrush canopy cover in brome sites is within the guidelines, our data suggests that smooth brome may be competitively excluding the establishment of other shrub species and reducing the overall shrub cover to a level that may be insufficient for sage grouse. Sveum et al (1998) identified total shrub cover in addition to sagebrush canopy cover as an important characteristic of nesting habitat in central Washington. We suggest it may be important in all types of sage grouse habitat.

It appears that the most limiting impact of smooth brome treatments to sage grouse habitat is the reduced cover and diversity of the forb component. Many studies have documented the importance of forbs in sage grouse habitat (Dunn and Braun 1986, Klott and Lindzey, 1990, Drut et al. 1994, Apa 1998). Our data show that the competitive ability of smooth brome seriously degrades the value of treated areas for sage grouse by reducing forb cover and diversity. We believe that because the grass component was significantly higher and the forb component was significantly lower and less diverse at brome sites than at use sites these areas are not providing adequate sage grouse habitat in the Strawberry Valley. In addition we believe that even though tall sod forming grasses such as smooth brome increase

horizontal obscuring cover, they may be so thick and tall as to impede ground travel by sage grouse, especially young chicks. This overrides their value as cover and further limits the potential of treated areas as sage grouse habitat. The importance of forbs in sage grouse habitat is further demonstrated by the data we collected in non-use habitat sites. Data collected at these sites show a higher and more diverse forb component than found at broom sites. However, the forb component is still significantly lower and less diverse than at brood sites and random sites in use areas.

Much as other studies have found (Oakleaf 1971 and Peterson 1970, Autenrieth 1981, Dunn and Braun 1986, Klott and Lindzey 1990, Drut et al. 1994, Apa 1998, Sveum et al. 1998) sage grouse broods in Strawberry Valley seem to prefer areas with high forb cover and diversity. We refined the forb information by documenting a higher and more diverse forb component not only when brood sites were compared to other use and random sites, but also when brood micro-habitat (exact location) was compared to brood macro-habitat (25 m from location). These findings are significant because the macro-habitat was well within the recommended guideline for percent cover of forbs in brood habitat (Connelly et al. in review) and yet sage grouse still selected areas with significantly greater forb cover (Fig. 2) and greater diversity (Fig. 3). This suggests that the guidelines may be accepting lower forb cover than is optimum for sage grouse brood rearing habitat in Strawberry Valley. In addition, the fact that logistic regression did not identify any forb species as being a significant predictor of brood micro-habitat when compared to brood macro-habitat and yet total forb cover was significant

suggests that broods do not key on particular forb species when a robust suite of species are available. Rather, they selected habitat based on the overall abundance of forbs. We did not find any differences in forb cover (Fig. 2) or diversity (Fig. 3) between adult micro and macro habitat. This suggests that forb cover may not be as important as other variables in adult habitats.

Measurements of sagebrush and shrub canopy area showed that sage grouse selected shrubs having a greater canopy area for nest and adult habitat than was found at all other site types. Our measurements of sagebrush size at nest sites were similar to those of Connelly et al. 1991 (1.53 m² compared to 1.19 m²). It is not surprising that canopy area at brood sites was lower than at nest and adult flush sites. It has been well documented that sage grouse seek areas with lower sagebrush canopy cover and greater access to succulent forbs for brood habitat (Klebenow 1969, Klott and Lindzey 1990, Drut et al 1994).

The difference in sagebrush canopy area for non-use random sites vs adult flush sites is likely explained by the fact that these areas contained sagebrush that were significantly younger than those found at adult flush sites. The significance in these findings is that the canopy area for sagebrush and other shrubs in brome sites was significantly lower than at nest and adult flush sites. These findings may partially explain why the treated areas have remained unoccupied by sage grouse (differences in understory composition may also contribute). It is possible that sagebrush and other shrubs growing in areas with tall aggressive grasses such as smooth brome are forced to grow tall rather than spreading in order to compete for available

sunlight. This competition changes the natural growth form of these shrubs and further degrades the areas potential as sage grouse habitat. This interpretation is supported by the fact that the age of the sagebrush and the height of sagebrush and other shrubs growing in brome sites did not differ from the age and height of the sagebrush at nest or adult sites.

Sagebrush and shrub height was significantly taller at adult, nest and brome sites than at other sites. These findings support other research that found sage grouse nest beneath taller sagebrush than are randomly available (Klebenow 1969 and Sveum et al. 1998). The fact that neither height nor canopy area differ between nest sites and adult flush sites suggests that hens are not choosing bigger/taller shrubs specifically for nesting activities, but are merely selecting shrubs that they would find suitable as adult birds under any circumstances. A larger sample of nest sites is needed to confirm these findings.

The fact that sagebrush was significantly more decadent at adult sites than at nest sites, even though the ages of the shrubs did not differ, might be explained by the time of year that decadence estimates were made. Sagebrush decadence at nest sites sagebrush was estimated during the spring, when the plants were presumably unstressed. Sagebrush decadence at adult flush sites was estimated throughout the spring and summer which increased the chances that the plants were stressed. The finding that sagebrush was more decadent at non-use random sites than at other sites may show that these sites are simply less productive due to edaphic factors. Further data are needed to explain this.

In our comparison of brood habitat with adult habitat, logistic regression allowed us to

better understand how the available habitat was partitioned between adults and broods.

Conventional wisdom would say these habitats are partitioned by sagebrush canopy cover and forb cover (Connelly et al. in review). In our analysis neither sagebrush canopy cover or forb cover were identified as discriminating variables, rather it was sagebrush height and forb diversity that most significantly discriminated between brood and adult habitat. Although we found significant differences between several variables using univariate statistical methods, when all of the variables were analyzed simultaneously, only sagebrush height and forb diversity were identified as significantly contributing to the ability to discriminate between the two site types. Logistic regression was also best for our comparisons between adult sites with non-use and brome random sites. Logistic regression identified only a few variables as being significant while the univariate techniques identified several variables as being significantly different. The ability of multivariate statistics (such as logistic regression) to identify fewer discriminating variables than are significant using univariate statistics, stems from simultaneously evaluating the variables for correlation and eliminating all but the most discriminating variables. This reduction in the number of variables identified, as a result of accounting for correlation, allows managers to focus their efforts on a few identified limiting factors. If these factors are addressed correctly the correlated factors will also be corrected. Another advantage of logistic regression over univariate statistical methods is that the resulting function allows managers to calculate the probability that an area of habitat is suitable by measuring only the identified discriminating variables. For example, the function describing differences between adult and brome habitat types in Strawberry Valley is: $\text{logit}(Y) = -2.510 + 10.650(\text{forb cover}) + 4.754(\text{shrub canopy cover}) + 0.559(\text{sagebrush canopy area})$, where logit

(Y) = the probability of being classified as occupied (or suitable) habitat. Using this function a manager can calculate the probability that any sagebrush habitat in Strawberry Valley that has an understory of smooth brome will provide suitable adult sage grouse habitat by measuring the three variables in the function. A manager could also evaluate the effectiveness of a prescribed treatment designed to address limiting factors in brome habitat by measuring the same variables pre and post treatment.

MANAGEMENT IMPLICATIONS

Sage grouse are important components of big sagebrush communities. The more we understand about this dynamic biotic relationship the better are our chances to preserve and enhance sage grouse populations. Further work is needed on the age dynamics of big sagebrush stands in known sage grouse habitat. We also need to know the age dynamics of occupied and unoccupied sage grouse habitat in association with other species and subspecies of sagebrush (e.g. basin big sagebrush, Wyoming big sagebrush, three tip sagebrush and black sagebrush). Data are needed showing age differences in sagebrush stands used for different purposes (ie. nesting, brood rearing, etc.) in all sagebrush types. In addition more information is needed regarding adult sage grouse habitat, and we need to expand our knowledge of nest and brood habitat needs

Our data show the benefits of a comprehensive approach that simultaneously measures the habitat use of an entire population rather than focusing on a specific type of habitat (ie nest habitat or brood habitat). This kind of approach will lead to a better understanding of habitat partitioning within populations and thus a better understanding of habitat requirements. We recommend that multivariate statistical methods be used to simultaneously evaluate differences

between habitat types, so the variables that most significantly contribute to the discrimination between habitat types and elements can be identified. In addition, we suggest that in areas where sage grouse populations occupy only a portion of the available sagebrush habitat, occupied and unoccupied habitat be measured and analyzed simultaneously. This will allow treatment alternatives to be identified that will address the variables that separate occupied and unoccupied habitat and increase the habitat suitable to the local population.

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Table 1. Mean Mountain Big Sagebrush and other shrub characteristics measured in association with sage grouse habitat in Strawberry Valley.

Site Type	Sagebrush Age (yrs.)	Sagebrush Canopy Area (m ²)	Shrub Canopy Area (m ²)	Sagebrush Height (cm)	All Shrub Height (cm)	Sagebrush Decadence (%)	All Shrub Decadence (%)
Adult	20.50 ^a	1.35 ^a	1.20 ^a	54.07 ^a	51.06 ^a	30.05 ^a	25.05 ^a
Nest	---	1.53 ^a	1.36 ^a	54.32 ^a	50.67 ^a	21.53 ^{a,b}	20.87 ^{a,b}
Brood	---	.83 ^b	.82 ^b	37.60 ^b	37.14 ^b	16.11 ^b	19.04 ^{a,b}
Random	22.80 ^a	.88 ^b	.69 ^b	42.71 ^b	37.87 ^b	16.83 ^b	16.62 ^b
Brome	20.23 ^{a,b}	.82 ^b	.73 ^b	49.87 ^a	48.68 ^a	26.81 ^a	23.31 ^{a,b}
Non-use	16.57 ^b	.88 ^b	.74 ^b	40.28 ^b	38.96 ^b	26.22 ^a	23.14 ^{a,b}
Random							

Within each column means with different letters are significantly different using Tukey's pairwise comparison (experiment error rate = 0.05)

Table 2. Mean percent canopy cover of mountain big sagebrush and all shrubs measured in association with sage grouse habitat in Strawberry Valley.

Site Type	Nest n=10	Brood n=28	Adult n=59	Random n=55	Brome n=30	Non-use Random n=30
Sagebrush Canopy	24.8	22.9	24.7	23.2	18.5	20.2
Cover						
Total Shrub	36.3	33.4	33.9	35.1	23.3*	28.5
Canopy Cover						

* Statistically different from all other site types except nests sites ($\alpha = 0.05$)

Table 3 : Mean percent cover of grass species measured at sage grouse habitat sites in Strawberry Valley.

Site Type	Nest n=55	Brood n=150	Adult n=320	Random n=290	Brome n=150	Non-use Random n=150
Smooth Brome	0.0	0.1 Br < .0001	0.2 Br < .0001	0.2 Br < .0001	21.8	0.0
Phleum spp.	0.0	0.0	0.0	0.0	1.7	0.0
Carex spp.	0.9 BR = 0.0073 NR = 0.0015	2.1 A < .0001 R = 0.0099 BR < 0.0001 NR < 0.0001	0.3 R = 0.0067	0.7 BR = 0.0028 NR = 0.0008	0.2	0.01
Stipa spp.	0.3 B = 0.0364 A = 0.046 R = 0.019 NR = 0.0001	1.3 NR = 0.0004	1.1 NR < 0.0001	1.6 NR = 0.0002	0.0	3.7
Poa spp.	16.7	14.6 A = 0.0046	19.2	17.9 TUKEY'S p = 0.0045 FOR ALL SITES	7.7	15.9
Agropyron spp.	3.2 BR < 0.0001	1.7 BR = 0.0001	3.7 R = 0.0457 BR < 0.0001 NR = 0.0298	2.4 BR < 0.0001	0.3 NR < 0.0001	1.8
Total Grass	21.1	19.9	24.6	22.8	31.9 TUKEY'S p = 0.0045 FOR ALL SITES	21.5

Within each column p-values are reported for each site type that was significantly different for the row species. N = Nest,

B = Brood, A = Adult, R = Random, BR = Brome, NR = Non-use Random

Table 4. Mean percent cover of forb species measured at sage grouse habitat sites in Strawberry Valley.

Site Type	Nest n = 55	Brood n = 150	Flush n = 320	Random n = 290	Brome n = 150	Non-Use Random n = 150
Pacific aster (<i>Aster chilensis</i>)	0.012 B = 0.004 BR = 0.031	1.27 F = 0.006 R = 0.013 NR = 0.013	.81	1.01	0.89	0.74
Western yarrow (<i>Achillea millefolium</i>)	0.19 B = .0026	1.08 R = 0.03 BR = 0.008 NR = 0.031	1.23 BR = 0.008	0.91 BR = 0.064	0.19	0.39
Pussytoes (<i>Antennaria spp.</i>)	0.07 B = 0.065	01.4 F = 0.049 R = 0.049 BR = 0.001 NR = 0.062	0.42 BR = 0.026	0.96 BR = 0.030	0.05 NR = 0.058	0.24
Looseflower milkvetch (<i>Astragalus tenellus</i>)	0	0.24 BR = 0.006	0.19 R = 0.043 BR < 0.001 NR = 0.01	1.0 BR = 0.006	0.82 NR = 0.08	0.29
Spearleaf fleabane (<i>Erigeron lonchophylus</i>)	0	0.71 F = 0.001 R = 0.050	0.09	0.44	0	0
Sulfur eriogonum (<i>Eriogonum umbellatum</i>)	3.33 BR = 0.032 NR = 0.052	4.47 BR = 0.067 NR = 0.084	3.54	3.89 BR = 0.029 NR = 0.045	1.45	2.70
Geranium (<i>Geranium spp.</i>)	0	0.55	0.37	1.21	0.43	0
Silky lupine (<i>Lupinus sericeus</i>)	4.49	2.86 BR = 0.007	2.86 BR = 0.072	5.96 BR = 0.034	3.36 NR = 0.004	2.52
Yellow owlclover (<i>Orthocarpus luteus</i>)	0	0.88 F = 0.011 BR < 0.001 NR < 0.001	0.72 R = 0.002 BR = 0.008 NR = 0.09	1.82 BR < 0.001 NR < 0.001	0.01	0.08

Penstemon (<i>Penstemon spp.</i>)	1.0	0.59	0.29	0.49	0.09	0.62
	F = 0.001	F = 0.032	NR = 0.063			
	R = 0.011	BR = 0.072				
	BR = 0.003					
Hoods phlox (<i>Phlox hoodii</i>)	1.28	0.09	0.04	0.19	0.01	0
	B = 0.005					
	F < 0.001					
	R = 0.001					
	BR = 0.002					
Douglas knotweed (<i>Polygonum douglasii</i>)	0	0.39	0.66	0.74	0.65	0.74
		F = 0.017	R = 0.004	BR < 0.001		
		BR = 0.001	BR = 0.094	NR < 0.001		
		NR < 0.001	NR = 0.016			
European strawberry (<i>Fragaria vesca</i>)	0	0.66	0.37	0.59	0	0
		F = 0.005				
		R = 0.084				
Common dandelion (<i>Taraxacum officinale</i>)	0.07	0.85	1.15	1.42	0.07	0.23
	B = 0.007	BR < 0.001	BR < 0.001	BR < 0.001	NR = 0.024	
	F = 0.014	NR = 0.010	NR = 0.021			
	R = 0.048					
Total Forb Cover	11.04	16.01	13.05	14.75	8.42	9.39
					Tukey's (p =	Tukey's (p =
					.0045) for B	.0045) for B
					, F and R	and R

Within each column p-values are reported for each site type that was significantly different for the row species. N = Nest,

B = Brood, A = Adult, R = Random, BR = Brome, NR = Non-use Random

Table 5. Horizontal Obscurity Cover (%) at Sage Grouse Nest and Adult Habitat Sites

Site	2.5m	2.5m	2.5m	5m (0-	5m (33.3-	5m (66.6-	10m (0-	10m	10m (66.6-
Type	(0-	(33.3-	(66.6-	33.3cm)	66.6cm)	100cm)	33.3cm)	(33.3-	100cm)
	33.3cm)	66.6cm)	100cm)					66.6cm)	
Nest	99.3 b	87.5 ab	47.2 a	100 a	94.8 abc	74.6 abc	100 a	98.3 ab	87.5 ab
Sites									
Adult	97.1 a	86.1 ab	65.3 ab	99.6 a	95.9 a	84.3 a	100 a	98.9 ab	93.2 a
Sites									
Brood	96.2 a	78.1 a	52.2 a	99.0 a	90.6 b	71.0 b	99.9 a	95.5 a	84.5 b
Sites									
Random	95.7 a	79.9 a	58.0 a	98.1 a	91.4 ab	74.3 ab	99.8 a	96.6 ab	91.6 a
Sites									
Brome	99.6 b	89.1 b	72.4 b	99.9 a	97.2 c	88.1 c	100 a	99.2 b	96.2 a
Sites									
Non-use	98.6 a	85.7 ab	62.4 ab	100 a	95.6 abc	76.1 abc	100 a	99.0 ab	91.5 ab
Random									
Sites									

Within each column means with different letters are significantly different (alpha = 0.05).

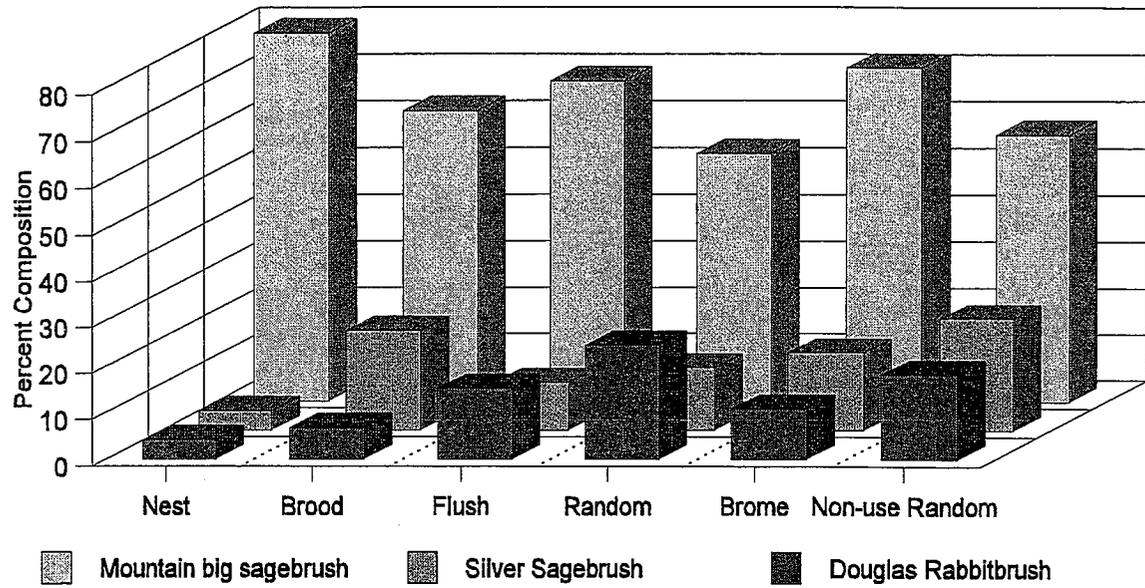


Fig. 1. Percent composition of shrub species measured in association with sage grouse habitat in Strawberry Valley.

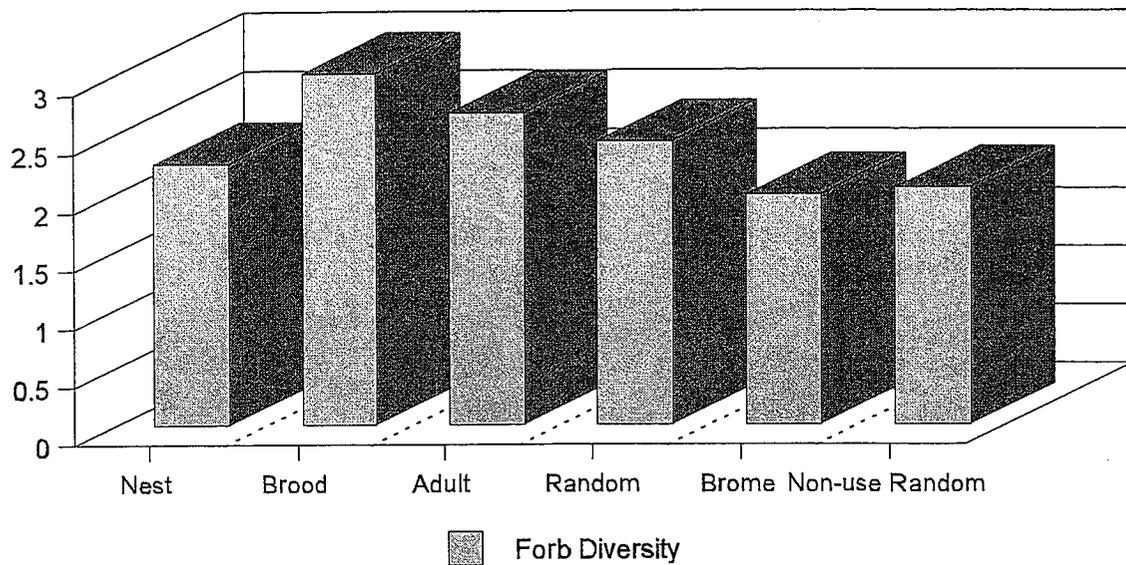


Fig. 2. Forb diversity measured in association with sage grouse habitat in Strawberry Valley.

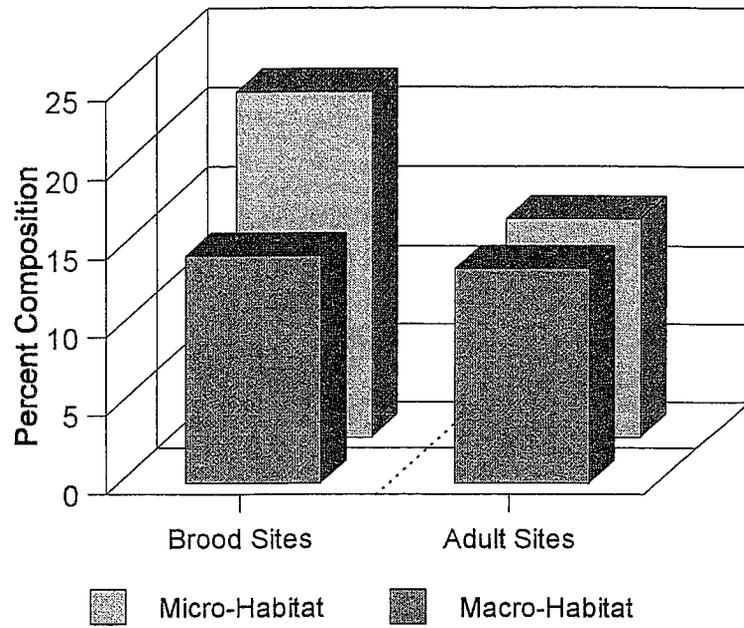


Fig. 3. Percent forb cover in micro and macro sage grouse habitat measured at brood and adult habitat sites in Strawberry Valley

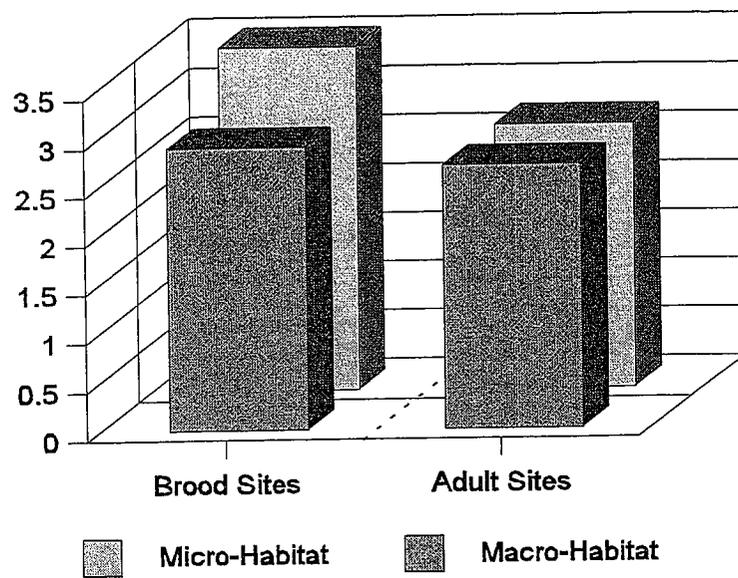


Fig. 4. Forb diversity in micro and macro sage grouse habitat measured at brood and adult habitat sites in Strawberry Valley

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RH: Red Fox Predation on Sage Grouse

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**RED FOX PREDATION ON SAGE GROUSE IN STRAWBERRY VALLEY,
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Abstract: Red fox are a non-native predator that arrived in the Strawberry Valley of northeastern Utah sometime following 1979. A two year study identified red fox as a major limiting factor in the recovery and expansion of the resident sage grouse population. Adult sage grouse survival rates in Strawberry Valley are the lowest ever reported, 30% for females and 29.7% for males. Red fox are also suspected to be the

chief cause of the almost complete reproductive failure of sage grouse between 1998-1999. Other food sources associated with Strawberry Reservoir, the dominant feature of the area, likely contributes to the high density of red fox.

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Key Words: *Centrocercus urophasianus*, red fox, sage grouse, *Vulpes vulpes*, Utah

In March of 1998 we began to study a population of sage grouse (*Centrocercus urophasianus*) in the Strawberry Valley of northeastern Utah. This population decreased from an estimated 3,000- 4,000 birds in 1939 (Griner 1939) to a current population estimate of 150 - 200 birds, a 95% reduction over 60 years. The goal of the current research effort was to identify factors limiting the population and recommend measures to mitigate or eliminate those factors. Initial work with radio instrumented sage grouse shows predation by red fox (*Vulpes vulpes*), a non-native predator, as one major limiting factor contributing to the decreased population.

The devastating effect that introduced foxes can have on bird populations is well documented. In 1976, Moe (1977) reported an estimated 13 red foxes on Big Koniujji Island in the Shumagin Island group killed 800 crested auklets (*Aethia cristatella*) and 100 horned puffins (*Fratercula corniculata*) in less than three months. Likewise, Skepkovych (1986) reported an estimated 12 red foxes on Baccaleiu, a 600 ha island near Newfoundland, killed approximately 31,000 Leach's storm-petrels (*Oceanodroma leucorhoa*) in a single breeding season. Southern et al. (1985) reported that over a nine year period intense red fox predation reduced the nesting population of ring-billed gulls (*Larus delawarensis*) by 84% on an island in Lake Michigan from the original 5,500

pairs. In 1975, red fox killed an average of 87 chicks per night and many more died of exposure after adults abandoned nests approached by foxes. Petersen (1982) reported that two red fox that reached Shaiak Island, in the Bearing Sea, were responsible for the complete nesting failure of roughly 100 pairs of common eiders (*Somateria mollissima*) and approximately 2,500 glaucous-winged gulls (*Larus glaucescens*). In addition, most of the 25,000 pairs of common murrelets (*Uria aalge*) on the island lost their eggs to the same pair of red fox. Petersen also found eggs cached all over the island and hundreds of dead adult tufted puffins (*Fratercula cirrhata*) and gulls. In all, of the 156,000 seabirds nesting on the island, the two red fox severely reduced the nesting success of seven species. An analysis of red fox scat at a seabird colony in the Baltic Sea found the proportion of birds in their diets rose from 14% during the winter months to 80% in June (Pruter and Vauk 1990). Bailey (1993) reported that rock ptarmigans (*Lagopus mutus*) were extirpated from six Alaskan islands after the introduction of red and arctic fox (see Bailey 1993 for a more comprehensive review of the effects of introduced red and arctic fox on bird populations).

We feel Island case studies are appropriate comparisons for sage grouse. During the breeding season, when the majority of predation takes place, sage grouse are not evenly distributed throughout their habitat, rather they are concentrated on and around leks, much like birds on an island. This comparison is particularly appropriate for the Strawberry Valley since the only remaining lek in the valley is on an island in Strawberry Reservoir. Red fox were present on this island during the 1998, 1999 and 2000 breeding seasons.

No one knows exactly when red foxes reached Strawberry Valley, but before the mid 1980's they were very uncommon. Kendall Nelson (personal communication) a retired wildlife biologist for the Utah Division of Wildlife Resources (UDWR) who spent extensive time in Strawberry Valley between 1966 and 1978 and Alden Thomas (personal communication) a retired conservation officer for the UDWR who worked in the Strawberry Valley from the late 1960's until 1980 both reported never to have seen red fox in the area. Personal interviews with Blaine Dabb a UDWR conservation officer who worked in Strawberry Valley from the early 1980's until he retired in 1999 and S. Dick Worthen a retired UDWR biologist who worked extensively in the area from 1971-1987 began commonly seeing red fox in the Strawberry Valley by the mid 1980's.

The purpose of this paper is to report the results of a study in the Strawberry Valley that identified predation, especially by invading red fox, as a major factor limiting the recovery of the resident sage grouse population.

We thank the Utah Reclamation Mitigation and Conservation Commission, the Utah Division of Wildlife Resources, the Uintah National Forest and Brigham Young University for the financial support of this study. We also thank Dave Stricklan, Lara Peterson, Leslie Tullis Jackee Webber-Alston and Phalan Whitehair for their help in collecting data

STUDY AREA

This study was centered in the Strawberry Valley, of northeastern Utah, during 1998-1999. The area is a high mountain valley (2,250 - 2,450 m) and receives approx. 58 cm of annual precipitation. Strawberry Reservoir is the dominant feature of the valley

covering up to 6,950 surface hectares. Within the valley there are approx. 8,950 hectares of sagebrush/grass habitat which primarily border the reservoir (URMCC and USFS, 1997). Mountain big sagebrush (*Artemisia tridentata vaseyana*) dominates the area with silver sage (*Artemisia cana*) occurring within wet meadows and riparian corridors.

METHODS

Sage grouse trapping was conducted during March, April and May of 1998 and 1999 using the spotlighting method (Giesen et al. 1982). A necklace style radio telemetry transmitter (Marcstrom et al. 1989) was attached to trapped sage grouse (cocks and hens).

Nesting hens were monitored by radio telemetry until they left the nest site. Nests were then located and the fate of the nest determined. Hens that successfully hatched a brood were then monitored by radio telemetry to determine the fate of the brood. Efforts were made not to flush the hen until her chicks were capable of flight (approximately 21 days old). After the chicks could fly the brood was flushed and counted once a week. Because sage grouse chicks are sometimes reluctant to fly, a trained German short-haired pointer was used to help locate broods of hens with and without transmitters. All birds with transmitters were also located and flushed weekly to monitor survival and habitat use.

Horizontal obscenity cover, the habitat characteristic that has the greatest influence on predation (Gregg 1991, Gregg et al. 1994 and Delong et al. 1995), was measured at nest sites and adult flush sites using a 1 m² cover board stratified into thirds (0-33.3 cm, 33.3 cm - 66.6 cm and 66.6 cm - 100 cm) along the vertical axis with each stratification separated into 12 equal squares. Horizontal obscenity cover measurements

were taken from a height of 10 - 14 inches at 2.5, 5 and 10 meters from the cover board in four directions.

Fox dens were located from a fixed-wing aircraft in March and April of 1999 and 2000. Fox dens are readily identified from an aircraft by the presence of soil on top of the snow. Fox dens located by the aircraft were subsequently treated by personnel from Wildlife Services of the U.S. Department of Agriculture by request of the UDWR. Each den was treated with a large gas cartridge (EPA registration no. 56228-21) in an effort to kill resident red fox and reduce their predation on the sage grouse during the spring when the birds are concentrated on breeding grounds and hens are nesting and raising broods.

RESULTS

In March, April and May 1998, 24 sage grouse (11 female and 13 male) were trapped and fitted with radio telemetry transmitters. Three birds trapped in 1998 (1 female and 2 males) were never located again after being trapped and were dropped from the sample making a total sample of 10 females and 11 males for 1998. In spring of 1999, 6 female and 16 male sage grouse were trapped and fitted with transmitters. One male trapped in 1999 lost his transmitter shortly after being trapped and one transmitter placed on a male broke, so both males were dropped from the sample. Three females and 2 males with transmitters remained from 1998 and were included in the 1999 sample for a total of 9 female and 16 male sage grouse monitored during 1999.

In 1998, 7 of 10 female and 8 of 11 male sage grouse were killed by predators for a total of 71% of birds with transmitters lost to predation. In 1999, 5 of 9 female and 11 of 16 male sage grouse were lost to predation for a total of 64% of birds with transmitters

killed by predators. Of the 31 sage grouse depredated during 1998 and 1999 only 4 were attributed to avian predators, all others were attributed to mammalian predators with strong evidence involving red fox.

In 1998, 6 of 10 hens initiated nests and 4 successfully hatched broods (one from a second nest). One of the unsuccessful hens was killed by a mammalian predator while feeding, the other unsuccessful hen deserted her nest probably as a result of research disturbance. The 4 successful hens produced 21 chicks. One of the four broods was killed by a late snow storm that arrived in the second week of June within 2 or 3 days of the brood hatching leaving a total of 3 broods and 16 chicks to monitor in 1998. Of the three broods only 2 young, both from the same brood, survived long enough to fly and were successfully recruited into the fall population.

In 1999, 6 of 9 hens initiated nests, 4 of which successfully produced 21 chicks. Both of the unsuccessful hens were killed on or near their nests, one by a mammalian predator and the other by an avian predator. Of the four broods, a single chick survived long enough to fly and was successfully recruited into the fall population. During brood counts in August 1999 a total of 12 chicks were counted with 44 hens giving a ratio of 0.27 chicks/hen or 3.67 hens/chick. Throughout its range long-term chick/hen ratios have ranged from 1.4 - 2.96 and the ratio since 1985 has varied from 1.21 - 2.19 (Connelly and Braun 1997).

Horizontal obscurity cover for nest and adult flush sites at 2.5m from ground level to 33.3cm were measured at 99.3% and 97.1% respectively. Horizontal cover was measured at 100% for both nest and adult flush sites at 5m and 10m from ground level to

33.3cm (Table 1).

During March and April 1999, 24 active fox dens were located within the core areas used by sage grouse in the Strawberry Valley for a density of approximately 0.77 dens/km² (Fig. 1). Each den represents a pair of adult foxes for a total of at least 48 adult foxes in an area of approximately 31km². During March and April 2000, the number of active fox dens located in the same area increased to 32 for a density of 1den/km² (Fig. 2). The fact that fox densities increased in 2000 despite the 1999 control effort brings the effectiveness of the control effort into question. Red fox are distributed throughout the Strawberry Valley, so it may be that a control effort that focuses only on the core sage grouse use areas may never be effective. The density of red fox outside of core use areas needs to be determined to see if they are equal to the densities within the sage grouse use areas.

DISCUSSION

In our opinion, the red fox was not a causative factor in the early decline of the sage grouse population in Strawberry Valley. It is likely that habitat loss was the major cause of the original population reduction. In Strawberry Valley 10,000 - 15,000 acres of sage grouse habitat were treated to reduce sagebrush cover and increase forage for livestock (URMCC and USFS 1997). In addition, Strawberry Reservoir was expanded in 1985 from 3,510 ha to its current size of 6,950 ha and thus flooded 3,440 ha of sage grouse habitat. In spite of this loss, some available and apparently suitable habitat is currently unoccupied by sage grouse (Bunnell and Flinders unpublished data). Although red fox were not responsible for the initial reduction in the sage grouse population, our

data argue that red fox predation is a major factor limiting the recovery of the population and even threatens its extirpation.

Sage grouse mortality rates in Strawberry Valley are well above the levels reported in other studies (Connelly et al. 1994, Zablan 1993) (Fig. 3) and recruitment is only a fraction of the recommended guideline for stable or increasing populations (Connelly et al, in review) (Fig. 4). These data show that predation is a major factor limiting this population of sage grouse. We know that many adult birds are being killed and red fox are the implicated predator based on examination of bird carcasses and the density of red fox in the area. Although we do not have hard evidence that predation is limiting recruitment (radio transmitters have not been placed on chicks) we feel strongly that given the information available, predation on chicks is the major factor limiting recruitment. The fact that entire broods, rather than portions of broods, are being lost is consistent with our hypothesis that predation and not habitat is limiting recruitment.

Gregg 1991, Gregg et al. 1994 and Delong et al. 1995 all suggested horizontal obscuring cover provided by grass is a major factor influencing predation on nesting sage grouse. Delong 1995, suggested that vegetative cover around nest sites provides scent, visual and physical barriers to potential predators. Based on these findings, the newly revised sage grouse guidelines recommend that herbaceous cover be kept at a height >18cm in nesting habitat. Given that horizontal cover at both nest and adult sites approaches 100% at 33.3cm, a lack of horizontal cover does not seem to be a contributing factor to the high level of predation.

Many factors likely contribute to the density of red foxes in Strawberry Valley. The area is a very popular recreation destination for campers and fisherman, who contribute to the problem by filling trash cans and leaving litter along the shoreline and at campsites. The productivity of Strawberry Reservoir as a fishery contributes to the red fox density by providing foxes with fish entrails washed ashore or left on the banks by fisherman. Localized areas in Strawberry Valley have high populations of Uinta ground squirrels (*Spermophilus armatus*) and Strawberry Reservoir hosts a sizeable breeding population of waterfowl, both provide red fox with alternative prey bases. Strawberry Valley is also home to sizeable deer and elk populations and has a busy highway (U.S. 40) that runs the entire length of the valley. This provides foxes with an almost year around supply of road kill. Strawberry Reservoir is also home to a population of introduced kokanee salmon (*Oncorhynchus nerka*). Each fall, this salmon population provides foxes with thousands of fish that spawn and then die in almost all of the 11 tributaries that feed the reservoir. The presence of the spawning salmon may significantly contribute to the high red fox density in the area by providing them with a rich food supply during September and October. This rich food supply can be consumed to bolster fat supplies going into the winter or stored in caches to be consumed later.

The effectiveness of efforts to control the number of red fox in Strawberry Valley remain to be seen, but given the current situation, the future of sage grouse in the area may depend on this effort. It may not be practical to expect to ever remove all red fox from Strawberry Valley; however, if their numbers can be suppressed long enough to

allow the sage grouse population to expand, the grouse population may reach a level where it can withstand a certain level of predation from red fox. Given the body of research on the devastating impact of foxes on bird populations, outlined in the introduction, even this hope may be naively optimistic. Even so, sage grouse deserve our best combined efforts.

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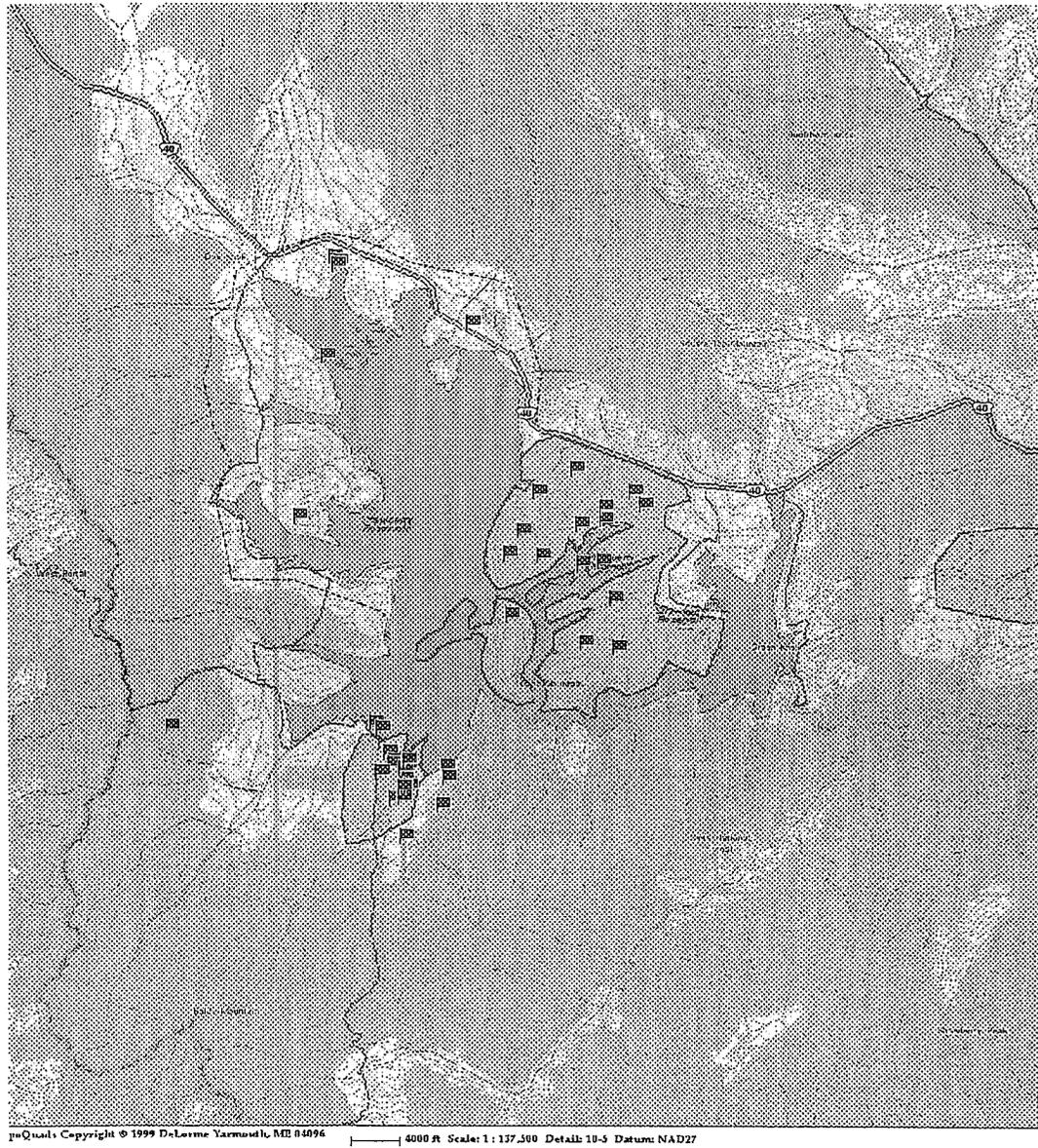
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J-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 4000 ft Scale: 1:137,500 Detail: 10-S Datum: NAD27

Shaded = Sage Grouse Core Use Areas
Flag = Fox Dens

Fig. 1. Spring 1999, red fox den locations in sage grouse habitat in Strawberry Valley, Utah



Shaded = Sage Grouse Core Use Areas
Flag = Fox Dens

Fig. 2. Spring 2000, red fox den locations in sage grouse habitat in Strawberry Valley, Utah

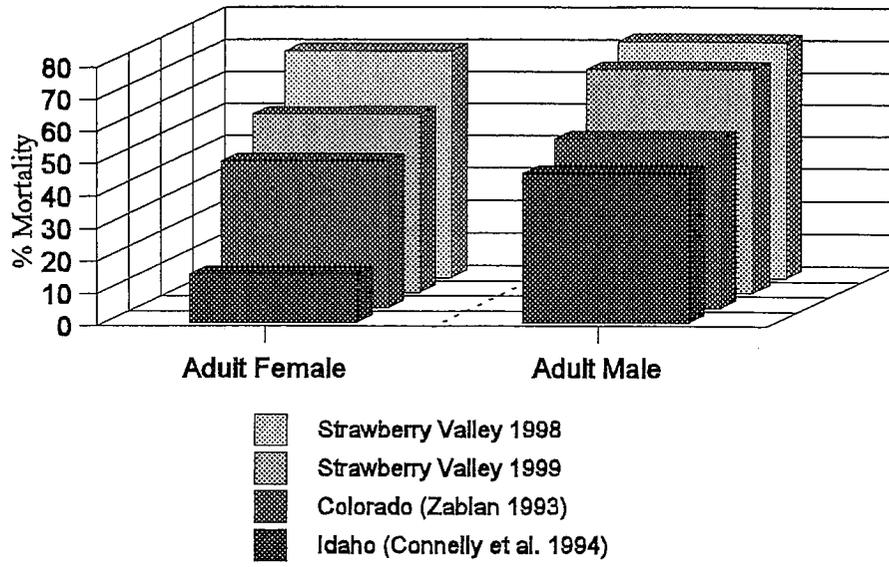


Fig. 3. Sage grouse mortality rates in Strawberry Valley, Utah compared to mortality rates reported for Idaho and Colorado.

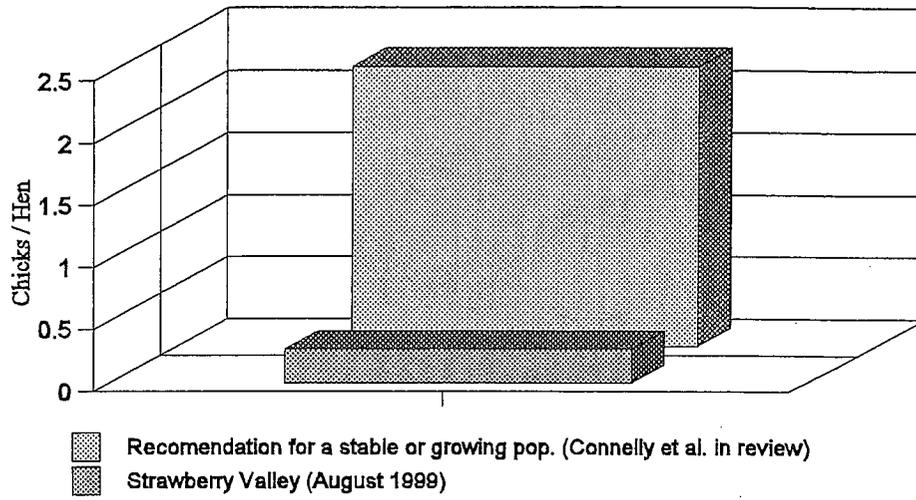


Fig. 4. Sage grouse recruitment in Strawberry Valley compared to the recommended guideline

APPENDIX

Table 1. Percent cover of forb species occurring in occupied and unoccupied sage grouse habitat in Strawberry Valley, Utah

Forb Species	Nest Sites	Brood Sites	Adult Sites	Use-Random Sites	Brome Random Sites	Non-use Random Sites
<i>Achillea millefolium</i>	.1852	1.0811	1.231	.9059	.1933	.3867
<i>Agoseris glauca</i>			.3481			
<i>Allium acuminatum</i>			.0411	.00348		
<i>Androsace septentrionalis</i>	.3148	.3243	.1867	.1916	.1067	
<i>Antennaria spp.</i>	.0741	1.3986	.4241	.6237	.0533	.24
<i>Arabis spp.</i>			.1392	.0174		.0933
<i>Arenaria congesta</i>		.1622	2184	.1463	.1	.4133
<i>Arenaria lateriflora</i>		.0203	.0538			
<i>Artemisia dracuncululus</i>					.06	.06
<i>Aster chilensis</i>	.0185	1.2703	.8228	.6585	.8933	.74
<i>Astragalus convallarius</i>		.0135	.1487	.1359	.04	.0267
<i>Astragalus tenellus</i>		.2365	.1962	.6516	.82	.2933
<i>Astragalus spp.</i>		.1689	.00633	.00697		.1867
<i>Castilleja linariaefolia</i>	.0741	.0541	.038	.0488	.02	.0733
<i>Cerastium arvense</i>	.1667		.0411			
<i>Chaenactis spp.</i>	.0741	.0743	.0475	.0627		.0333
<i>Chenopodium capitatum</i>			.0696			
<i>Chaenactis douglasii</i>	.0185	.0338	.0411	.00348		
<i>Chenopodium spp.</i>			.1709			
<i>Chenopodium fremontii</i>			.1487			
<i>Cirsium spp.</i>		.0338	.1804	.1951	.02	

<i>Corydalis aurea</i>		.0135	.0316			
<i>Comandra pallida</i>	.2037	.0811	.1582	.4808	.12	.1067
<i>Collinsia parviflora</i>	.8889	.1824	.3956	.216	.38	.1533
<i>Cordylanthus ramosus</i>			.1741	.216		
<i>Crepis acuminata</i>		.0608	.0506			.00667
<i>Cryptantha flavoculata</i>	.0741			.0139		
<i>Cymopterus longipes</i>				.0174		
<i>Cymopterus hendersonii</i>			.00949			
<i>Cynoglossum officinale</i>				.00697		
<i>Delphinium bicolor</i>			.0475			
<i>Descurainia pinnata</i>		.1959	.1519	.2404		.00667
<i>Draba nemorosa</i>				.0174		
<i>Draba stenoloba</i>	.0370					
<i>Epilobium spp.</i>		.0338				
<i>Equisetum spp.</i>	.0185	.3446	.0253	.2334		.0667
<i>Erigeron asperugineus</i>			.00316			
<i>Erigeron engelmannii</i>			.0316			
<i>Erigeron lonchophyllus</i>		.7095	.0981	.2857		
<i>Erigeron speciosus macranthus</i>						.26
<i>Erigeron spp.</i>	.0556			.0383		.00667
<i>Eriogonum salsuginosum</i>			.0253			
<i>Eriogonum umbellatum</i>	3.3333	4.4730	3.5443	3.885	1.4533	2.7
<i>Fragaria vesca</i>		.6554	.3449	.3868		

<i>Galium boreale</i>		.0270	.0633			
<i>Galium spp.</i>		.0743	.0601		.0267	.0133
<i>Gentiana affinis</i>			.0601			
<i>Gentiana amarella</i>		.1149		.1394		
<i>Geranium richardsonii</i>		.5473	.1013	.4634		
<i>Geum triflorum</i>		.0743	.0222	.0209		
<i>Geranium viscosissimum</i>		.00676	.2722	.324	.4267	.68
<i>Gilia spp.</i>			.0285	.0314	.02	
<i>Gutierrezia sarothrae</i>			.019			
<i>Hackelia patens</i>						.00667
<i>Helenium hoopesii</i>	.4444	.2297	.0949	.0139		
<i>Helianthella uniflora</i>			.00316			.08
<i>Iva axillaris</i>			.0411			
<i>Lathyrus spp.</i>		.0608	.0854		.8467	.7867
<i>Lesquerella utahensis</i>			.0759	.0105		.0667
<i>Linum lewisii</i>		.0676	.0411	.1672		.0267
<i>Linum spp.</i>			.0127			
<i>Lithophragma parviflora</i>	.5926	.0203	.0411	.0557		
<i>Lomatium juniperum</i>	.0370					
<i>Lomatium triternatum</i>				.0279		
<i>Lupinus sericeus</i>	4.3889	2.8649	2.8924	3.4634	3.36	2.52
<i>Lychnis drummondii</i>						.0267
<i>Machaeranthera canescens</i>		.0270		.0453	.00667	

<i>Machaeranthera grindelioides</i>			.0316		.00348	
<i>Mertensia brevistyla</i>	.1111	.0743	.0981	.1359	.1133	.1
<i>Melilotus officinalis</i>	.0185	.0541	.2943	.3902	.1267	
<i>Medicago sativa</i>		.0473	.0506	.216		
<i>Myosotis spp.</i>				.00697		
<i>Myosurus minimus</i>				.0662		
<i>Navarretia breweri</i>		.0541				
<i>Orthocarpus luteus</i>		.8851	.7278	1.1882	.0133	.08
<i>Pedicularis groenlandica</i>			.0443			
<i>Penstemon spp.</i>	.7037	.0608	.00949	.0627		.22
<i>Penstemon watsonii</i>	.2963	.5270	.712	.2578	.0867	.4
<i>Perideridia gairdneri</i>					.0133	
<i>Phacelia hastata</i>	.1481		.0823	.108	.0867	.0333
<i>Phacelia howelliana</i>	1.2778	.0878	.038	.1254	.0133	
<i>Phlox longifolia</i>		.0135	.0918			.0333
<i>Phacelia sericea</i>			.0348	.0279		
<i>Polanisia dodecandra</i>		.3851	.6677	.4808	.6533	.74
<i>Polygonum douglasii</i>			.038			
<i>Potentilla gracilis</i>		.4324	.2595	.3066	.0533	.00667
<i>Ranunculus inamoenus</i>		.0608	.0981	.0662		
<i>Ranunculus macounii</i>		.0135				
<i>Ranunculus testiculatus</i>			.0411			
<i>Rorippa curvipes</i>			.0127			
<i>Salsola iberica</i>				.0418		

<i>Saxifraga odontoloma</i>			.00949			
<i>Sedum spp.</i>			.0791		.00667	.0333
<i>Selaginella douglasii</i>			.00949	.2578		
<i>Senecio integerrimus</i>	.1667	.0338	.0127	.0139	.1	
<i>Senecio spp.</i>		.00676	.00949			
<i>Senecio streptanthifolius</i>	.1667		.0348	.0488	.00667	.0533
<i>Smilacina stellata</i>			.038	.0105		
<i>Solidago missouriensis</i>		.2432	.1203	.2962		
<i>Sphaeralcea coccinea</i>			.00949	.0314		
<i>Stanleya pinnata</i>					.06	
<i>Stellaria jamesiana</i>						.0267
<i>Taraxacum officinale</i>	.0741	.8514	1.1646	.9233	.0733	.2333
<i>Thelypodium sagittatum</i>	.1111			.00697		
<i>Thistle</i>		.0473	.1582	.0488		.00667
<i>Tragopogon dubius</i>			.1677	.0348		.16
<i>Trifolium gymnocarpon</i>		.1149	.0696	.0174		
<i>Trifolium longipes</i>		.3243				
<i>Urtica dioica</i>						.133
<i>Verbascum spp.</i>			.0443	.0418		.0333
<i>Viguiera multiflora</i>						.1
<i>Viola purpurea</i>		.277	.0316	.0348		.0133
<i>Wyethia amplexicaulis</i>						.7733
<i>Wyethia mollis</i>			.019		.0267	
UNK#4	.0370					

UNK#15	.0926		.0316		
UNK#17			.00949		
UNK#27				.0209	
UNK#36				.0279	
UNK#38			.00949		
UNK#46	.3889	.2635		.0244	
UNK#65		.0878			
UNK#68				.0174	
UNK#72		.1081			
UNK#2-6		.00676			
UNK#2-13			.0127		.00667
UNK#2-14			.00633	.0139	.0267
UNK#2-19			.038		
UNK#2-24		.1351	.0633	.1429	
UNK#2-28					.1067
UNK#2-30			.0285		
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UNK#2-46		.00676			
UNK#2-47		.2568	.019		
UNK#2-48		.0135			
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UNK#2-51		.0203			
UNK#2-52		.0203			
UNK#2-54		.0405	.0475		
UNK#2-56		.0338			
UNK#2-61			.00949		
UNK#2-62					
UNK#2-64			.0506		
UNK#2-65			.0316		

<i>UNK#2-67</i>			.00633			.00667
<i>UNK#2-73</i>			.00633			
<i>UNK FORB</i>				.0209		.0133
TOTAL	14.6	21.4	19.2	20.0	10.4	13.6
