ECOLOGICAL INVESTIGATIONS OF CHUKARS (ALECTORIS CHUKAR) IN WESTERN UTAH

By

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GRADUATE COMMITTEE APPROVAL

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ABSTRACT

ECOLOGICAL INVESTIGATIONS OF CHUKARS (ALECTORIS CHUKAR) IN WESTERN UTAH

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This thesis presents three separate manuscripts in chapter format dealing with the ecology of Chukars (*Alectoris chukar*) in western North America. All three manuscripts have been formatted for publication in professional journals. Chapter one confirms discovery of ingested lead pellets in Chukars across a broad region of western Utah including all four western counties sampled. Prevalence rates were 1.9% (n=105) for crops and 10.7% (n=75) of gizzards showing no evidence of penetration wounds. Ingestion is likely related to grit size preferences that are consistent with common shot sizes. The second chapter describes watering patterns and water-site selection of Chukars. Chukars watered during daylight hours with a modal hour from 1100 hours to 1200hours. Annual patterns suggest no use of water sources from November to May with first visits occurring in June of each year and last visits in October. Shrub canopy cover was the only variable to discriminate between use and non-use watering sources ($P < 0.01$). Cross validation showed a predictive success rate of 84%. Significant differences were found between use and non-use sites in terms of protective cover ($P <$

0.01), but not total cover ($P > 0.05$). Chukars were found to have a shrub canopy threshold near 11%; water sources meeting this threshold received use, whereas those not meeting this threshold did not. Chapter three challenges several claims postulating negative conservation implications relative to exotic Chukars in North America. These claims were proven to be unfounded with no evidence of cheatgrass (*Bromus tectorum*) dispersal despite widespread utilization. Furthermore, guzzlers designed to benefit Chukar populations were heavily utilized by native species and only slightly (two species at three sites) by other exotics. These three manuscripts illuminate several areas of Chukar ecology and represent a significant advancement in our understanding of this bird and its management.

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CHAPTER 1. GRIT SIZE PREFERENCES AND CONFIRMATION OF INGESTED LEAD PELLETS IN CHUKARS (ALECTORIS CHUKAR)

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Introduction

Lead shot ingestion has been well documented in waterfowl (Tsuji et al. 1998), raptors (Mateo et al. 2003), and Mourning Doves (*Zenaida macroura*) (Lewis & Legler Jr. 1968). Ingestion of lead shot by upland game birds other than doves is less well-documented, but a growing body of literature suggests it does occur and can be a source of mortality (Keymer & Stebbings 1987, Lewis & Schweitzer 2000).

Walter & Reese (2003) found ingested lead pellets in 7.1% of 140 crops and 5.7% of 123 gizzards from Chukars (*Alectoris* chukar) in Oregon, the first known discovery of ingested lead pellets in Chukars, but cautioned that their results were site specific and that the possibility of lead pellet ingestion by other populations of Chukars should be investigated. Our objectives were: 1) to determine if and to what extent lead shot ingestion by Chukars occurs in Utah and 2) to compare the size of grit collected from gizzards with common shot sizes to increase understanding of potential risks to Chukars.

Methods

Hunters were solicited both prior to the season and when encountered in the field to save gizzards and crops from Chukars legally harvested in Utah during the fall of 2003 and 2004. Additional Chukars were collected with shotguns during both summers as part of an ongoing dietary study. Birds were collected June – January during the study years. Crops and gizzards were placed in plastic bags, labeled (location & date), and frozen until analysis. Both crops and gizzards were carefully examined for entry wounds to distinguish between ingested lead pellets and those imbedded (Walter & Reese 2003). Organs showing evidence of penetration wounds were not included in analysis. Crop contents were sorted into component parts; gizzard contents were washed (to facilitate removal of animal and vegetable matter), dried, and sifted over graduated soil sieves (3.96, 2.00, 1.68, 1.00, and 0.50 mm diameter openings). Gizzard contents arrested at each sieve graduation were weighed to the nearest 0.1 g and the results combined for all gizzards.

Ingested pellets discovered during analysis were weighed on an electronic scale to the nearest 0.0001 g and average diameter measurements (two directions) were calculated after measurement with calipers to the nearest 0.1 mm. These measurements were then compared to data adapted from the 2005 Federal Ballistics Catalog (www.federalcartridge.com) in an effort to estimate the original size of each ingested pellet.

Results

We considered 106 crops and 75 gizzards acceptable for analysis and found a single ingested lead pellet in two crops (1.9%) and eight gizzards (10.7%). Chukars collected from four different counties were found to have ingested lead pellets (Table 1). Birds with ingested pellets were harvested as early as August and as late as January with discovery of lead occurring from birds harvested in both years. Nine of ten pellets were estimated to be size 6 or 7.5 based on weight and diameter; one pellet was estimated to be a size 5. Nearly one third of sieved grit arrested at the 2.00 mm sieve—as would all of the major shot sizes, with the exception of some Turkey and buck shot loads (Table 2). Almost 100 % of all grit ingested meets or exceeds the 1.00 mm diameter threshold positively correlated with ingestion of lead pellets in waterfowl (Mateo et al. 2000).

Discussion

Ingestion of lead pellets by Chukars was not reported in early (pre 1980) research of Chukars in North America despite several studies (Knight et al. 1979, Zembal 1977, and others) evaluating dietary preferences from crop contents. Our results coupled with results from eastern

Oregon mark the discovery of ingested lead pellets in two of the three most recent studies (Walter & Reese 2003, Churchwell & Ratti 2004) conducted after a nearly twenty year absence of diet research raising concerns about general accumulation of lead pellets during the last twenty years.

Walter and Reese (2003) attributed ingestion of lead pellets to the rocky nature of Chukar habitat and heavy hunting pressure in their study area. Chukars are known to utilize rocky areas (Lindbloom 1998, Walter 2000) and pellet settlement rates are reduced on firmer soils (Schranck & Dollahon 1975). Our results are symptomatic of a regional problem more consistent with habitat and general accumulation of lead shot rather than localized hunting pressure as ingested lead pellets were found from birds harvested in four different counties on several different mountain ranges. Furthermore, ingested pellets were found in Chukars harvested in August before hunting seasons commence suggesting availability of pellets from previous years, although no determination of specific ingestion dates were made.

Unfarmed arid rangelands, such as much of the western United States, may be at a greater risk of lead pellets remaining near the surface than more mesic areas due to lack of tillage, relatively slow soil formation, and reduced precipitation. Tillage, for example, has been found to dramatically reduce the number of lead pellets per hectare available for ingestion (Thomas et al. 2001).

Additionally, birds such as Chukars that frequent both artificial and man-made water sources may be exposed to areas with higher concentrations of lead pellets—stock tanks in New Mexico are reported to have higher lead densities in the surrounding soil than other heavily hunted areas across the United States (Best et al. 1992, Kendall et al. 1996). Water sources throughout the west are frequently shot over during the Mourning Dove hunt. We did find lead pellets in

Chukars collected during the end of the summer and early fall when use of water sources by Chukars is high. Nonetheless, birds with ingested lead pellets were also collected during December and January. Pellet retention times within the digestive tract vary from hours to several weeks (McConnell 1968, Pattee et al. 1981) depending on diet, physiology, chance events, condition of the shot, and other factors (Kendall et al. 1996). Erosion rates are also highly variable as a function of similar factors, but decreased pellet size has been noted after 4 days with complete dissolution of lead pellets as early as 22 days in Japanese Quail (Coturnix coturnix)(Yamamoto et al. 1993).

No known research exists concerning the toxicity of lead pellets to Chukars, but results with ducks (Chasko et al. 1984), Brown-headed Cowbirds (*Molothrus ater*) (Vyas et al. 2001), and Mourning Doves (Buerger et al. 1986) indicate that one retained pellet can be lethal. Multiple retained pellets are lethal to partridge (*Perdix perdix*) (Keymer & Stebbings 1987), Willow Ptarmigan (*Lagopus lagopus*) (Fimreite 1984, Gjerstad and Hanssen 1984), and Bobwhites (Damron and Wilson 1975). Sublethal effects from ingestion of one or multiple pellets are an additional concern well documented in other species (Kendall et al 1996, Scheuhammer and Norris 1996).

Conclusions

These results provide compelling evidence of lead shot ingestion by Chukars across a wide region suggesting that earlier results with Chukars (Walter & Reese 2003) are not site specific. Nearly one third of grit ingested by Chukars corresponds to a size equivalent of all major shot sizes—highlighting the risk for this species. Much more research is needed to evaluate the more widespread prevalence of ingested lead pellets in Chukars, toxicity of lead to Chukars, incidence of occurrence and toxicity in sympatric avian taxa, and the influence of habitat on lead pellet availability. Unfortunately, problems associated with lead pellet ingestion seem to worsen with weathering of pellets as shot erosion within the gizzard is accelerated for weathered pellets compared to new shot (Vyas et al. 2001). Ultimately, problems with lead pellet ingestion will only be avoided by encouraging or requiring the use of non-toxic alternatives.

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Table 1. Number of Utah Chukars with ingested lead pellets in gizzards and crops by County

County	No. gizzards examined	No. with lead pellets	No. crops examined	No. with lead pellets
Box Elder	46	5	27	0
Juab	17	3	31	0
Tooele	9	0	22	1
Utah	1	0	17	1
Unknown	2	0	9	0
Total	75	8	106	2
Percentage		10.7%		1.9%

Table 2. Fractionation of sieved grit from Chukar gizzards & equivalent shot sizes

> Diam. (mm)	Grams	Percentage	Shot Equivalent[a]
3.96	.1	.00	Buck, T, BBB, BB
2.00	87.1	.32	2,3,4,5,6,7,7.5,8,8.5,9
1.68	90.1	.33	--
1.00	98.8	.36	--
0.50	.4	.00	--

[a] Estimated From 2005 Federal Ballistics Catalog (www.federalcartridge.com)

CHAPTER 2. WATERING PATTERNS AND WATER SITE-SELECTION BY CHUKARS IN WESTERN UTAH

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Abstract

We evaluated annual and daily Chukar (*Alectoris chukar*) watering patterns as well as habitat variables influencing water site selection in western Utah. Motion-sensing cameras and Chukar dropping counts conducted every two weeks during the summer months were primary techniques to evaluate watering patterns. Vegetative and other habitat measurements were taken at each water source ($n = 43$) and those variables were used to discriminate use and non-use sites using logistic regression. Cross validation was conducted wherein five models were developed and then validated against randomly withheld samples. In addition, comparisons were made between site types for obscurity measures that differentiated between total cover and security cover. Chukars watered during daylight hours with a modal hour from 1200 hours to 1300 hours daylight savings time. Annual patterns suggest limited use of most water sources from November to May with first observed visits occurring in June of each year and last observed visits in October. Shrub canopy cover was the only variable to discriminate between site types ($P < 0.01$) for each model generated. Cross validation showed a predictive success rate of 84%. Significant differences were found between use and non-use sites in terms of security cover ($P < 0.01$), but not total cover ($P > 0.05$). Chukars were found to have a shrub canopy threshold near 11%; water sources meeting this threshold received use, whereas those not meeting this threshold did not. Increasing shrub canopy cover above 11% did not translate into increased water source use. Managers may want to consider annual patterns when setting hunt season timing and structure as well as judging sites for new water developments based on shrub canopy cover prior to installation. Additional research is needed to further understand habitat use, behavior, and other factors likely to influence use of water developments during summer months.

Introduction

Chukars (*Alectoris chukar*), native to mountainous regions in parts of Asia, Western Europe, and the Middle East (Dement'ev & Gladkov 1952; Cramp & Simmons 1980; Ali & Ripley 2001), have purposely been established in many parts of the world including Hawaii (Walker 1967), New Zealand (Williams 1950), North America (Long 1981), South Africa (Winterbottom 1966), and St. Helena Island, Atlantic Ocean (Watson 1966). Chukars were first introduced into North America in 1893 (Lever 1987) and by 1954 California, Idaho, Nevada, and Washington considered Chukars as successfully established (Christensen 1954). By 1968, six additional western states (Arizona, Colorado, Montana, Oregon, Utah, and Wyoming) harbored sufficient populations to consider establishment successful and therefore allow hunting seasons (Christensen 1970). Currently, persistent, self-sustaining wild populations in North America are found in the following states and Canadian province: Arizona, California, Colorado, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming, and British Columbia, Canada (Christensen 1996).

Habitat management for Chukars in the United States has generally been limited to water development with particular emphasis placed on the installation of rainwater catchments (guzzlers) to expand populations into new areas (Benolkin & Benolkin 1994; Christensen 1970, 1996). Nevada, for example, has installed over 1500 guzzlers; many of which are designed to primarily benefit Chukars (Nevada Division of Wildlife 1999). Despite sizeable monetary investments in water developments, no quantitative data are available regarding watering patterns, watering site use, or important habitat variables that may influence water site selection by Chukars.

Our specific objectives were: 1) to describe Chukar watering patterns, 2) to identify habitat variables important in predicting use of water developments by Chukars in an effort to develop a model that can guide future placement of water developments, and 3) to test Benolkin's hypotheses (1988) suggesting that fire will preclude establishment of Chukars on water developments and that units should be placed in narrow canyon bottoms within 9 m of a steep hill or cliffs. In addition, we tested the hypothesis—formulated by observation—that used watering sites have significantly higher security cover (shrubs and trees) than unused sites, but not differences in total cover (all vegetation combined to include forbs and grasses). Results of this research should contribute to more effective water projects since at least ten western states have ongoing water development programs with annual expenditures ranging from $11,000 to $755,000 (Rosenstock et al. 1999).

Methods

We evaluated forty-three water sources (six springs and thirty-seven guzzlers) for use by Chukars in three different areas of western Utah located in Box Elder, Juab, and Tooele counties. These water sources included a majority of upland game guzzlers from both the north end of the Pilot Mountains, and the south end of the Grouse Creek/Bovine Mountains, Box Elder County (centered approximately at lat 41° 24' 14" long 113° 54' 34"); all known guzzlers and springs on the Keg Mountains, Juab County (centered at lat 39° 47' 8" long 112° 52' 22"); and all known water sources north of Hastings Pass Road on the Cedar Mountains, Tooele County (centered at lat 40° 44' 22" long 112° 54' 20"). The water sources evaluated in Box Elder County were selected for inclusion based on access and proximity to each other with an attempt to evaluate all known water sources on several small foothill ranges and mountains of both the Pilot and Grouse

Creek/Bovine Mountains. These 43 watering sources are considered representative of sites in Utah, Nevada, and other areas of western North America.

All three study areas are encompassed within the Great Basin physiographic region—characterized by roughly parallel mountain ranges separated by desert basins (Fenneman 1931), hot summers and moderately cold winters (Dice 1943), and a deficiency of precipitation at all seasons (Thornthwaite 1931). Water sources ranged in elevation from 1473 m to 1922 and were all located in Chukar habitat. All guzzlers evaluated were designed and intended to benefit Chukars as a primary species, whereas all springs included in analysis were in Chukar habitat with the potential for use.

Abundant native trees in each study area included juniper (*Juniperus* sp.) and pinyon pine (*Pinus edulis* Engelm). Native shrubs found included sagebrush (*Artemisia* sp.), Mormon tea (*Ephedra* sp.), Mexican cliff rose (*Cowania mexicana* D. Don), curl leaf mountain mahogany (*Cercocarpos ledifolius* Nutt in T. & G.), saltbush (*Atriplex sp.)*, and others. Grasses and forbs include several native species as well as many exotics. A partial list includes the following: cheatgrass (*Bromus tectorum* L.), bluebunch wheatgrass (*Elymus spicatum* Pursh), indian rice grass (*Stipa hymenoides* Roem. & Schult), needle and thread grass (*Stipa comata* Trin. & Rupr.), sandberg bluegrass (*Poa secunda* Presl), halogeton (*Halogeton glomeratus* Bieb), Russian thistle (*Salsola iberica* Sennen & Pau), and redstem filaree (*Erodium cicutarium* L. L'Her). Generalized vegetative communities found in the study areas include the following: Great Basin Xeric Mixed and Inter-Mountain Basins Sagebrush Shrubland, Great Basin Pinyon Juniper Woodland, Inter-Mountain Basins Mixed Salt Desert Scrub, Invasive Annual and Perennial Grassland, and Inter-Mountain Basins Semi-Desert Grassland (Lowry et al. 2005).

Beginning in May of 2003 and 2004 water sources were visited and an area approximately 12 square m, centered at the guzzler or spring, was cleared of all Chukar droppings. Each water source was visited approximately every two weeks and droppings counted and cleared throughout the summers terminating by October. Dropping counts were conducted on 33 of the 43 (77%) sites in 2003 and all sites in 2004. Watering sites where dropping counts were not made in 2003 were monitored with cameras and/or periodic visits to establish use or non use for 2003. Digital motion-sensing cameras (Camtrakker Inc®) were placed at guzzlers and springs such that approaching animals triggered the cameras. Photographs were used to verify use of water sources by Chukars and other wildlife as well as to evaluate watering patterns. Cameras were moved sequentially, beginning in May and ending in December, approximately every two weeks to different guzzlers and springs; each water source generally received four weeks of photographic sampling each year.

The following measurements were taken at each water source during late summer or early fall: G.P.S. location, distance to rock cover (defined as a collection of two or more boulders of sufficient size to offer cover for a Chukar), distance to the nearest shrub, distance to the nearest road, average shrub density, percent shrub canopy cover, average shrub height, horizontal obscurity cover (both total and shrub/tree only), and vertical obscurity cover (both total and shrub/tree only).

Both vertical and horizontal obscurity were measured with cover boards (Bunnell et al. 2004) placed at pre-determined locations along belt transects originating from the center of watering sites and stretched in each of the cardinal directions for 30 m. Horizontal cover boards measuring 1 m x 1 m were divided into 36 equal squares and read from distances of 2.5, 5, and 10 m along each cardinal axis centered at the watering site. Vertical obscurity cover boards (measuring 18cm x 18cm and divided into 36 equal squares) were read at 2.5, 5, 10, 15, 20, and 30 m along each axis. Cover boards were read either from directly overhead (vertical obscurity) or from a height of 12-25 cm (horizontal obscurity) and all measurements averaged for each site.

Average shrub density, percent shrub canopy cover, and average shrub height were measured along 30 m belt transects (Mueller-Dombois & Ellenberg 1974) extending in each of the four cardinal directions. All shrubs and trees rooted within one meter of the transect line on either side were measured for height, and area within the canopy (calculated as the area of an ellipse).

An additional factor variable was created to represent the general description of the watering site as 0 (in a canyon or ravine bottom) and 1 (not in a canyon or ravine bottom) to test Benolkin's (1988) hypothesis about the need to place guzzlers in canyon bottoms.

Two measures of slope were obtained from a 30 m resolution digital elevation model (DEM) available from the United States Geological Survey (USGS) to include immediate slope, the calculated slope of the 30 m square area on which the water source is located, and average slope inside of a circle centered at the water source with a radius of 280 m—the approximate average daily movement of Chukars (Lindbloom 1998; Walter 2002). Calculations of both immediate slope and average slope were performed using options available with ArcMap® version 9.1.

The time stamps from all photographs depicting Chukars at watering sites were pooled together and descriptive statistics used to evaluate daily watering patterns. Dropping counts at each interval were converted to relative percents to more accurately compare 2003 with 2004 given the larger sample size in 2004. Dates of first and last visits for each year are reported based on time and date stamps associated with photographs.

Logistic regression (Hosmer & Lemeshow 2000) was used in a backwards stepwise elimination procedure based on significance to identify variables (both slope measures, distance to rock cover, distance to the nearest shrub or tree, distance to the nearest road, percent shrub canopy cover, average shrub height, and the factor variable describing location) important in discriminating between use and non-use sites. Use sites were defined as watering sources where droppings were observed and/or Chukars were photographed in either year.

Independent variables were evaluated for correlation to avoid problems with multicollinearity. Average shrub density was excluded from logistic regression analysis because of concern for pairwise correlation with canopy cover. Both measures were calculated along the same belt transect and originate from the same shrub-area interaction. Canopy cover was retained due to a long tradition of use and interpretation in wildlife sciences across a broad range of species and habitats (Turchi et al. 1995; Main 1996) compared to a more limited and obscure reliance on shrub density. Elimination of this variable alleviates concern for multicollinearity—ensuring proper usage of logistic regression.

Prior to analysis, we divided the sample (n=43) into five randomly assigned groups to allow for cross validation. Elimination based on significance was performed with samples from four of the five groups pooled together and the resulting model then tested on the withheld group. We conducted all five iterations of this procedure and report these results along with results from the full model accordingly. Percent concordance—the percentage of pairwise comparisons in which the event (use site) had a higher predicted probability according to the model (Bunnell et al. 2004)—is reported as a measure of the model's ability to discriminate between site types. In addition, we report figures from Hosmer and Lemeshow's (2000) goodness-of-fit test with significance an indication of gross lack of fit and model inadequacy (Vittinghoff et al. 2005).

All four obscurity measures were withheld from logistic regression analysis to test our hypothesis of differences in security cover between use and non-use sites, but not differences in total cover between sites. We evaluated this hypothesis with *t*-tests adjusted for multiplicity with a Bonferroni correction (Ramsey & Schaffer 2002) to avoid type I error rate inflation. Due to violation of the normality assumption caused by bounds of zero and one for percentage measures—thereby violating the asymptotic properties of the normal distribution—a logit transformation was performed on all four obscurity measures. Assumptions of transformed data were then evaluated graphically and with a Levene's test for homogeneity of variance (Levene 1960). In addition, results were cross checked using a Mann-Whitney test (Ramsey & Schaffer 2002) to ensure confidence of interpretation.

Habitat variables that successfully discriminated use from non-use groups were evaluated using ordinary least squares (OLS) regression analysis (dependent variable natural logarithm of each year's dropping counts) to try and further understand underlying mechanisms. Logistic regression analysis was performed using Minitab® release 13.31, whereas *t*-tests and descriptive statistics were done with S-Plus® 6.2.

Results

Twenty-five of the 43 (58%) watering sites (21 guzzlers and 4 springs) received use by Chukars over the two-year study period, whereas 18 (42%) water sources (16 guzzlers and 2 springs) had no indication of use. Use was consistent year to year with only one guzzler (2%) receiving use by Chukars in one year, but not the other. Results from dropping counts and motion photography were consistent with no discrepancies classifying use or non use sites based on either method.

Chukars appeared at watering sites in June of each year with the first photograph on 6 June 2003 and 18 June 2004. The last photographs of Chukars at watering sites were taken on 29 October 29 2003 and 15 October 2004. Dropping counts followed similar patterns in both years—increasing slowly through June and the first half of July, jumping sharply during the last half of July, remaining high through August, and steadily decreasing in September to low levels by the beginning of October (Fig. 1).

Chukars visited watering sites during daylight hours (results presented as in daylight savings time) with the earliest time stamp at 0548 hours, 28 June 2004 and the latest daily visit occurring at 2146 hours, 22 June 2004. Median visit (n = 3558) occurred at 1154 hours with the third quartile complete by 1417 hours. Chukars generally watered from mid-morning to early afternoon with a modal hour from 1200 hours to 1300 hours and the four highest hourly photograph counts occurring between 1000 hours and 1400 hours (Fig. 2).

Both slope measures, distance to rock cover, distance to the nearest shrub, distance to the nearest road, average shrub height, and the factor describing location were not significant ($P > 0.05$) in any of the iterations of cross validation, nor the model developed with the full data set. Shrub canopy cover was the only variable to successfully discriminate between use and non-use sites ($P < 0.01$ and concordance ≥ 0.93) for each model; correct prediction of withheld samples based on the model generated from all iterations was 84% (Table 1). Cross validation is used as the best indication of the model's predictive power when applied to data points not used to generate respective models.

We were unable to disprove our hypothesis about differences in security cover (shrubs and trees) between use and non-use sites, but not differences in total cover (shrubs, trees, grasses, and forbs) using percentages measured from cover boards and then normalized with a logit transformation. Untransformed mean values are reported for ease of interpretation with associated p values calculated from transformed numbers. Total horizontal obscurity values for use ($\bar{x} = 0.82$) and non-use ($\bar{x} = 0.77$) sites did not differ ($P > 0.44$), nor did total mean vertical obscurity differ for use ($\bar{x} = 0.42$) versus non-use ($\bar{x} = 0.40$) sites ($P > 0.52$). Significant differences were found, however, with comparisons of obscurity measures between site types looking only at security cover. Mean values for the shrub and tree component of vertical obscurity cover (0.28 and 0.07) differed significantly ($P < 0.001$), as did mean values for the shrub and tree component of horizontal obscurity (0.69 and 0.20, $P < 0.001$) between use and non-use sites respectively (Fig. 3) Mann-Whitney tests confirm these differences.

To further understand underlying mechanisms, shrub canopy cover was evaluated with OLS regression on the natural logarithm of each year's dropping counts for use sites. Shrub canopy cover was not significant in OLS regression models for either year ($P > 0.05$).

Discussion

Intensity of guzzler use by Chukars has been correlated inversely with moisture in vegetation (Nicolls 1961). Our data are confirmatory in that dropping counts do not jump markedly until after mid-July despite average high temperatures in late June near 30°C and average high temperatures during the first half of July near or above 35°C (Fig. 4; weather data from Wendover, Utah obtained from www.wunderground.com). Intensity of guzzler use is not immediately a function of air temperature and thus shows a lag perhaps attributable to relictual moisture in vegetative food items.

Empirical evidence suggests that Chukars do not require free-standing water if succulent vegetation is available (Degen et al. 1982; Degen et al. 1984). Other sources of water (pre-formed, metabolic, or precipitation) coupled with cooler temperatures suggest that Chukars need not rely on water sources from November thru May. Managers wanting to minimize vulnerability of Chukars due to reliance on water sources should avoid hunting seasons scheduled in September and the first part of October.

Chukars watered during daylight hours with only a handful of photographs showing an activated flash. This pattern suggests that Chukars are relatively inactive during nighttime darkness. Peak daily watering times between 1000 hours and 1400 hours (Fig. 2) suggest that other activities (such as foraging) generally occur before visits to water.

We reject part of Benolkin's hypothesis (1988) concerning the need to place guzzlers in canyon bottoms. Water sources used by Chukars throughout this study were found in canyon bottoms, mid slope, on benches, and along ridgelines. Furthermore, the factor variable assigned to represent placement was not significant in predicting use or non-use. The part of Benolkin's hypothesis (1988) about the negative impacts of fire is not discounted, and our data affirm the potential of fire to preclude use of watering sources by Chukars due to elimination of security shrub cover.

Cross validation was performed to ensure models were tested on independent data—the lack thereof is a nearly universal problem in wildlife sciences elucidated by Guthery et al. (2005). Cross validation also provides a more conservative, and we argue a more robust, way to estimate predictive power than concordance or other validations against the same data used to develop a given model. Thus, we are much more confident with 84% predictive power as compared to an average concordance of 95 % (Table 1). In addition, cross validation removes concern—through evaluation—for cited problems of model selection using stepwise logistic regression; problems that can include selection of too few variables for a good prediction (Shtatland et al. 2001).

Chukar selection of watering sources with sufficient security cover implies concern for avian predators. Review of relevant literature suggests that avian predators are the predominant source of mortality for Chukars, and that they account for nearly half of all mortalities—more than twice that of the next closest category (Table 2). In addition, Chukars are a commonly reported prey item of raptors throughout the Great Basin. Chukars have been found in eyries of Peregrine Falcons (*Falco perigrinus*) in western Utah (Porter & White 1973), ranked fourth in dietary prevalence based on weight for nesting Golden Eagles (*Aquila chrysaetos*) on the California-Nevada border (Bloom & Hawks 1982), and were found in 15.8 % of Prairie Falcon (*Falco mexicanus*) nests in California's Mojave Desert (Boyce 1985). These values may underestimate the annual importance of Chukars to raptors as most dietary studies are conducted during the nesting season when Chukar populations are generally at the lowest point of the year (Alkon 1974). Raptor annual dietary studies are logistically difficult to conduct and therefore lacking in the literature. Nonetheless, some evidence suggests that birds in general may be more prevelant in raptor diets outside of the breeding season (Manosa 1994); in this study Red-legged Partridge (*Alectoris rufa*) ranked 1st in annual dietary frequency (18%) and relative weight (57%) for Goshawks (*Accipiter gentilis*) in Spain.

In addition to security cover, shrubs and trees provide thermal cover for Chukars that have a preferred air temperature of 25.1—31.9°C (Laudenslager & Hammel 1977) and are often found loafing beneath shrubs and trees near water during summer months (Oelklaus III 1976). Preference for shrub cover around watering sites also correlates well with preferences of broods for shrub habitats (Walter 2002; Lindbloom et al. 2003)—in both our study years the majority of Chukars in most photographs were young of the year.

The significance of shrub canopy cover in logistic regression, but not in OLS regression with the natural logarithm of each year's dropping counts is congruent with a threshold for security cover—evaluation of the data suggests a value near 11% (Fig. 5). Use of watering sources occurs above this value, but increasing levels of shrub canopy cover do not translate into increased dropping counts.

The distinction between total and security cover measured via cover boards has not, to our knowledge, been made prior to this study. Nonetheless, it was proven a valuable measure (Fig. 3) that helped clarify underlying mechanisms and we believe that drawing this distinction with other species and/or in other habitats may be of value. Cover boards can be easily read from the same location twice with one reading accounting only for security cover (shrubs and trees), and the other evaluating total cover (forbs, grasses, shrubs, trees, etc.).

If applied properly, logistic regression can be a valuable tool in habitat-selection studies (Keating & Cherry 2004). In general, multivariate statistics are able to identify fewer discriminating variables than multiple comparisons with univariate techniques enabling researchers to give managers a more concise list of variables—in our case only one—to look at when designing habitat improvement projects or evaluating the effects of perturbations. Logistic regression also allows one to quickly calculate the probability that a given habitat (e.g. water source) is suitable based on relatively few discriminating variables. As an example, using the model developed with the full data set (n=43), the function describing differences between use and non-use watering sites is: logit (Y) = -3.956 + 2.91(shrub canopy cover), where logit (Y) = the probability of being classified into the use group. With this function, one can quickly calculate the probability that any water source in Chukar habitat will be used or that a given area is acceptable for water development.

Conclusions

Research into the watering patterns of Chukars has, to our knowledge, never been done before. Patterns show somewhat predictable usage on an annual basis with limited use in June and the first part of July, increased and high use during the second half of July through August tapering off through September and terminating in October suggestive of limited or no use of water sources from November through May (Fig. 1). Daily patterns show high use during the late morning and early afternoon hours (Fig. 2) suggesting limited activity during nighttime darkness and that other activities generally occur before water visits. Managers may want to incorporate annual water source usage patterns into decisions affecting hunting season timing and structure to minimize vulnerability of Chukars around water sources.

Conventional thought has been that Chukars will seek out and use watering sources, including water developments, regardless of specific placement (Benolkin 1988) or habitat components surrounding each site—this assumption has proven incorrect and has now been quantified to show that Chukars have a threshold value of shrub canopy cover around watering sources of somewhere near 11% (Fig. 5), and that other variables measured do not discriminate between use and non-use groups. This threshold value is likely a function of concern for avian predators which are reported as the predominant source of mortality for Chukars (Table 2). Water developments placed in areas that do not meet this requirement will receive no use by Chukars and should not be built under the presupposition of benefiting Chukar populations. In addition, fire that destroys security cover around watering sites will preclude establishment and use by Chukars. Future research and efforts should look at the effectiveness of rehabilitating the shrub habitat component around watering sources that have been impacted by fire and perhaps installation of some form of cover to facilitate continued use by Chukars until regeneration of shrubs is adequate to meet threshold values for canopy cover.

Cross validation and the distinction between security and total cover are two techniques that should be incorporated into future research efforts, including studies with other species and/or habitats—both are easily performed and provide more accuracy and resolution than traditional techniques. In addition, cross validation ensures properly conservative values for predictive estimates that are much more appropriate than standard measures such as concordance (Table 1) given that validation is conducted on independent data.

Despite these advancements, much more research is needed to better understand specific life history characteristics of Chukars that play an important role in management decisions concerning water developments. For example, only limited information from a couple of studies is available on nest site selection, brood-rearing habitat, and brood mobility (Alkon 1983; Walter 2002; Lindbloom et al. 2003)—questions that impact the spacing and placement of water developments given that Chukars are persistent nesters and will often hatch chicks as late into the year as August (Christensen 1970). Furthermore, with the exception of two recent theses and resulting publications (Lindbloom 1998; Walter 2000, 2002; Lindbloom and Reese 2003), no one to our knowledge has treated habitat use and ecology in North America during the several month summer period that Chukars use water.

In addition, these results raise questions about specific habitat requirements around watering sources for other species using water developments in the western United States. Mountain Quail (*Oreortyz pictus*), for example were observed to prefer guzzlers within and near pinyon woodlands (Delehanty et al. 2004). Preferences of other species have not to our knowledge been reported.

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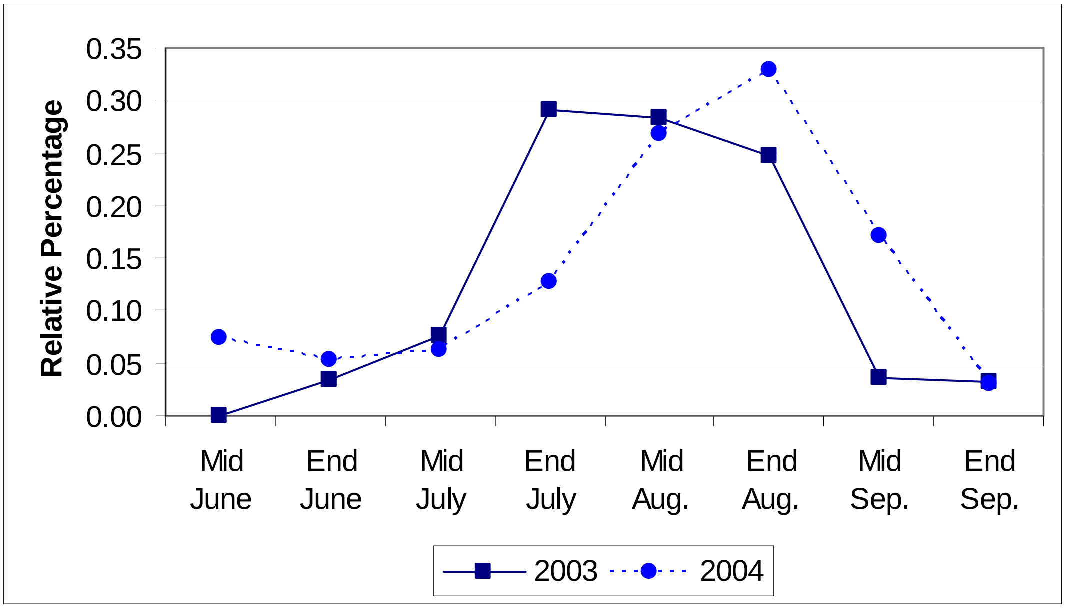

Figure 1. Shown here are the relative percentages of each year’s total summer droppings at each count interval.

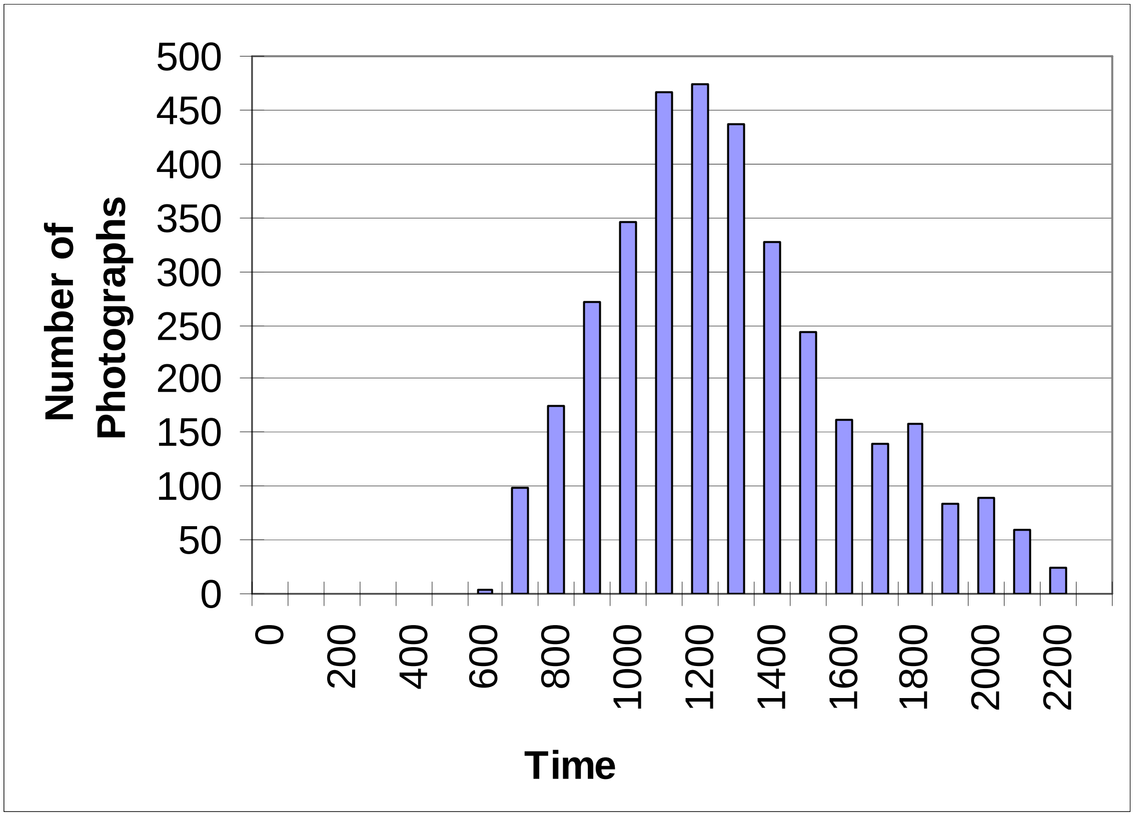

Figure 2. This histogram of daily watering patterns is based on time stamps (n=3558) of photographs depicting Chukars at guzzlers or springs from all three study areas with data combined from both years.

Table 1. Summary table of logistic regression models along with the cross validation procedure

GROUP	N	DISCRIMINATING VARIABLE	P	CONCORDANCE	HOSMER-LEMESHOW	NO. WITHHELD	NO. CORRECTLY PREDICTED	%
1	35	SH. CAN. COVER	.003	.963	.422	8	7	0.88
2	34	SH. CAN. COVER	.006	.957	.287	9	8	0.89
3	34	SH. CAN. COVER	.003	.930	.298	9	8	0.89
4	35	SH. CAN. COVER	.002	.960	.578	8	6	0.75
5	34	SH. CAN. COVER	.002	.944	.915	9	7	0.78
FULL MODEL	43	SH. CAN. COVER	.001	.951	.426	43*	36*	0.84*

* Sum and average values respectively

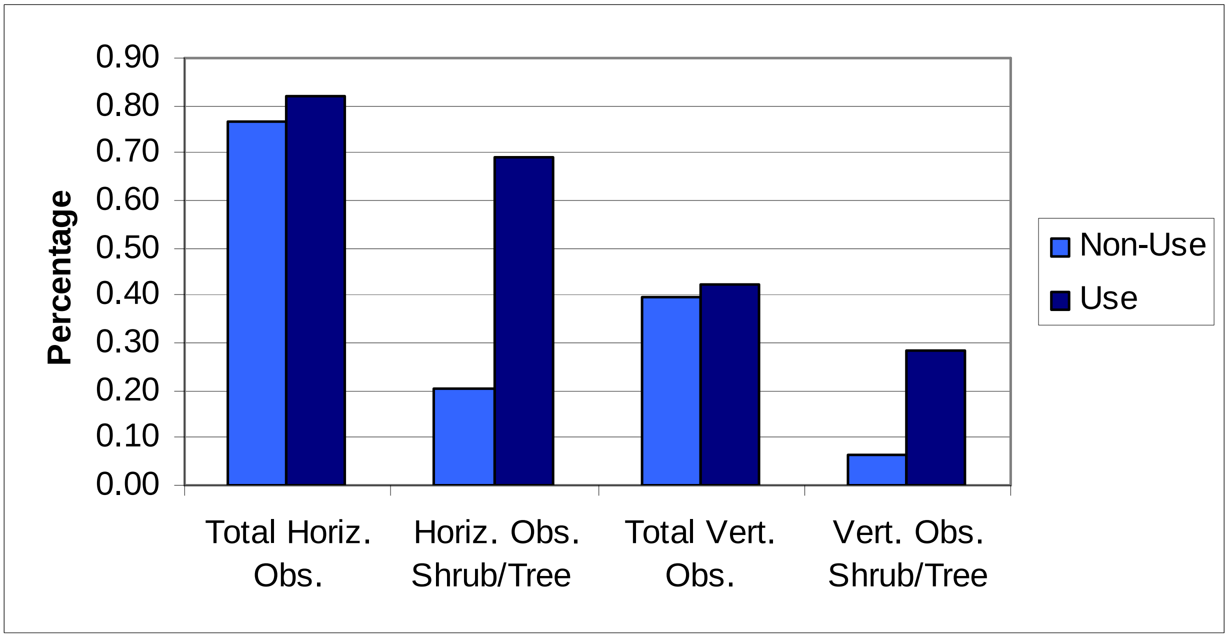

Figure 3. In comparisons of obscurity values at use and non-use sites—both shrub and tree only measures were significantly different (P <0.001), whereas total measures were not for horizontal (horiz.) and vertical (vert.) obscurity (obs.).

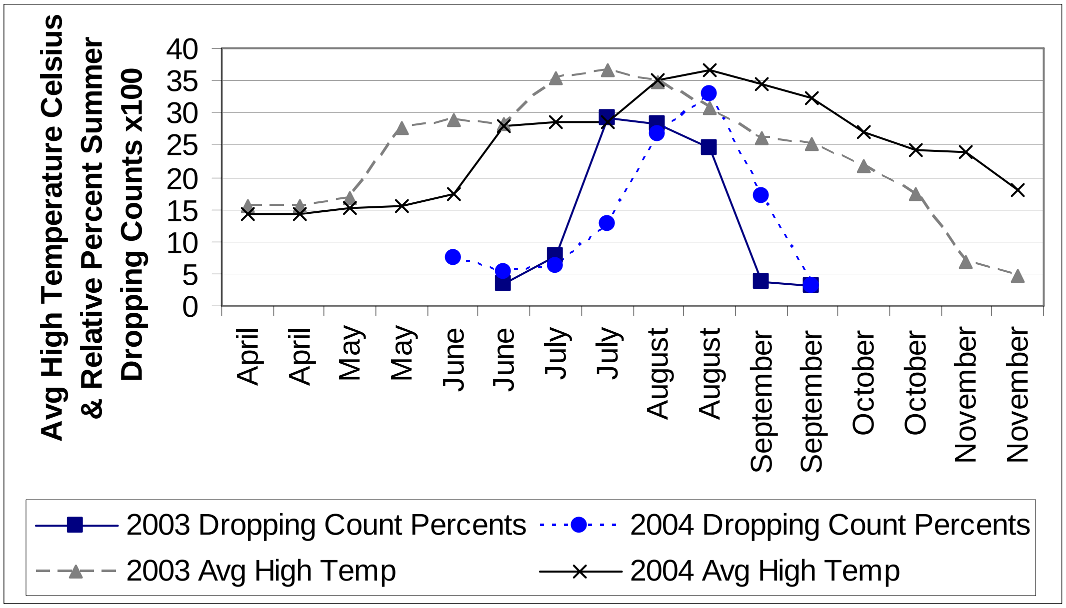

Figure 4. This graph depicts percent of summer fecal droppings by count interval in relation to bi-monthly average (avg) high temperatures (data from Wendover, Nevada—www.wunderground.com), clearly showing a lag between high temperatures and subsequent increased dropping counts.

Table 2. Identified sources of mortality for Chukars in western North America

SOURCE	YEAR	N	MAMMAL	AVIAN	HUNTIN	OTHE	UNKNOW	%AVIA
GALBREATH & MORELAND	1953	21	3	13	--	--	5	62
JONKEL	1954	53	9	17	6	6	15	32
BOHL	1957	20	4	15	--	--	1	75
MESSERLI	1970	4	2	1	--	--	1	25
SHAW	1971	1	--	1	--	--	--	100
LINDBLOOM	1998	17	7	10	--	--	--	59
WALTER	2000	27	7	10	6	--	4	37
TOTAL		143	32	67	12	6	26	47*

*Average value

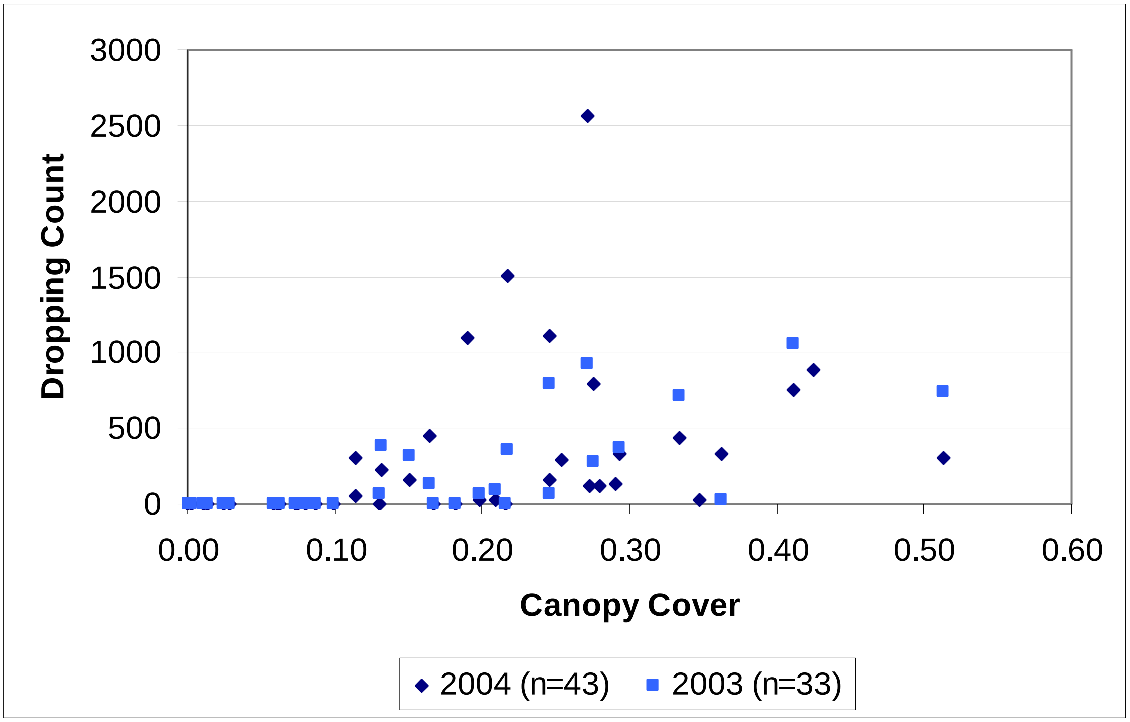

Figure 5. Compiled here are annual fecal dropping counts from both years in relation to percent shrub canopy cover.

CHAPTER 3. CONSERVATION IMPLICATIONS OF CHUKARS (ALECTORIS CHUKAR) IN WESTERN NORTH AMERICA

Author Page

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Abstract

It has been suggested that Chukars (*Alectoris chukar*) aid in the dispersal of cheatgrass (*Bromus tectorum* L.) throughout western North America via passage of seed through the gut and that water developments (guzzlers), often installed to primarily benefit Chukars, are frequently utilized by other exotic and/or feral species at the presumed detriment of native species. Our specific objectives were: 1) to document species using water developments designed to benefit Chukar populations to determine if and at what prevalence exotic species appear to use and presumably benefit from guzzlers, 2) to describe Chukar diet with specific reference to cheatgrass and other exotic plant seeds, and 3) to determine if Chukars are a likely vector for dispersal of cheatgrass or other plant seeds via passage through the gut. A total of 27 different wildlife species were photographed across all 36 sampled guzzlers. Three exotic species were photographed to include Chukars, Rock Dove (*Columbia liva*), and red fox (*Vulpes vulpes*) with the latter two species photographed at only two and one site respectively. Mean number of species photographed (5.69 ± 1.09) ranged from 1-13, but was estimated near ten after accounting for sampling time. Cheatgrass seed was found in 76.3% of crops and constituted 45.2% of dry weight. Thirteen plants germinated from 503 Chukar fecal droppings; cheatgrass did not germinate from any of the flats. We found no evidence of widespread use of guzzlers designed for Chukars by other exotic species or dispersal of cheatgrass seed via passage through the gut. Chukars appear (at least initially) benign and they are not significant drivers behind the expansion of cheatgrass currently plaguing much of western North America. Furthermore, Chukars may be beneficial in that they consume vast quantities of primarily exotic plant seed and do not show a propensity for dispersal of seeds.

Introduction

Chukars (*Alectoris chukar*), medium-sized gallinaceous birds native to mountainous regions in parts of Asia; Western Europe; and the Middle East (Dement'ev & Gladkov 1952; Cramp & Simmons 1980; Ali & Ripley 2001), have purposely been established in many parts of the world including Hawaii (Walker 1967), New Zealand (Williams 1950), North America (Long 1981), South Africa (Winterbottom 1966), and St. Helena Island, Atlantic Ocean (Watson 1966). Chukars were first introduced into North America in 1893 when several pairs were brought to Illinois (Lever 1987). The sheer scale of subsequent releases is astonishing; between 1931 and 1970 over 800,000 birds were released in 41 states (Hawaii included) and six Canadian provinces (Christensen 1970). Original releases were made by private individuals and organizations; however, after 1930 large-scale, federally funded efforts to establish Chukars throughout the United States were conducted by state wildlife organizations (Christensen 1996) as part of what Aldo Leopold termed in a critical essay on foreign game introductions “Chukaremia” (Leopold 1938).

By 1954 California, Idaho, Nevada, and Washington considered Chukars as successfully established (Christensen 1954). Between 1954 and 1968 six additional western states (Arizona, Colorado, Montana, Oregon, Utah, and Wyoming) established sufficient populations to consider establishment successful and conduct hunting seasons (Christensen 1970). Currently, persistent self-sustaining wild populations in North America are found in the following states and province: Arizona, California, Colorado, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming, and British Columbia, Canada (Christensen 1996). Chukars now occupy roughly 252,800 square kilometers of habitat in North America and an additional 578 square kilometers in Hawaii on the islands of Hawaii, Kauai, Lanai, Maui, Molokai, and Oahu (Christensen 1996). Large-scale releases into unoccupied habitat have largely stopped; nonetheless, Chukars remain a prized game bird and are often propagated and released on game farms by private individuals and organizations.

Concomitant habitat management for Chukars in the United States has generally been limited to water development with particular emphasis placed on the installation of rainwater catchment devices (guzzlers) to expand populations into new areas (Benolkin 1988; Christensen 1970, 1996). Nevada, for example, has installed over 1500 guzzlers; many of which are designed to primarily benefit Chukars (Nevada Division of Wildlife 1999). Guzzlers come in many shapes and sizes, but most recent developments specifically targeting Chukar populations are a small model designed in Nevada to collect annual precipitation in a approximately 1.4 m^3 tank located directly beneath the precipitation collection area (apron). The tank is designed with a descending slope; as water recedes, smaller animals can walk into the tank and down the slope to drink. Use, benefits, and implications of guzzlers and other water developments remain poorly evaluated (Devos Jr. et al. 1997; Rosenstock et al. 1999) and controversial (Broyles 1995; Broyles & Cutler 1999; Rosenstock et al. 2001).

Despite over 60 years in western North America, much remains to be learned about the broad conservation implications of Chukars in the New World. Chukar distribution and success in North America is purportedly linked to cheatgrass (*Bromus tectorum* L.) (Cox 1999; Walter & Reese 2003)—a frequently consumed annual plant considered by some to be the most significant plant invasion in North America (D'Antonio & Vitousek 1992)—and it has been suggested that Chukars aid in its dispersal (Peterson 2001). In addition, concern has been raised that water developments may favor exotic and/or feral species allowing them to invade otherwise dry areas and out compete native species adapted to live without free-standing water (Brown 1997; Broyles 1995, 1997) Consequently, we investigated questions relative to these proposed direct and indirect ecosystem-level impacts of Chukars in western North America from the framework outlined by Patten et al. (2001) wherein impacts are evaluated against null hypotheses of negative effects. Our specific objectives were: 1) to document species using water developments designed to benefit Chukar populations to determine if and at what prevalence exotic species appear to use and presumably benefit from guzzlers, 2) to describe Chukar diet with specific reference to cheatgrass and other exotic plant seeds, and 3) to determine if Chukars are a likely vector for dispersal of cheatgrass and/or other plant seeds via passage through the gut.

Methods

We evaluated 36 small (~1325 l) guzzlers designed to benefit Chukars in five different areas of western Utah located in Box Elder, Juab, and Tooele counties. These water sources were found on the Cedar Mountains, Tooele County (centered at Latitude 40° 44’ 22” Longitude 112° 54’ 20”); Fish Springs Range, Juab County (centered at Latitude 39° 51’ 36” Longitude 113° 26’ 19”); the Grouse Creek/Bovine Mountains and Pilot Mountains, Box Elder County (centered approximately at Latitude 41° 24’ 14” Longitude 113° 54’ 34”); and the Thomas/Dugway Mountains, Juab County (centered at Latitude 39° 51’ 58” Longitude 113° 07’ 15”). These 36 guzzlers were considered representative of other guzzler sites in the Great Basin.

All study areas are encompassed within the Great Basin—characterized by roughly parallel mountain ranges separated by desert basins (Fenneman 1931), hot summers and moderately cold winters (Dice 1943), and a deficiency of precipitation at all seasons (Thornthwaite 1931). Guzzlers ranged in elevation from 1320 meters to 1922 meters and were all located in Chukar habitat.

Abundant native trees in each area were juniper (*Juniperus* sp.) and pinyon pine (*Pinus edulis* Engelm). Native shrubs found include sagebrush (*Artemisia* sp.*),* Mormon tea (*Ephedra* sp.*),* Mexican cliff rose (*Cowania mexicana* D. Don), curl leaf mountain mahogany (*Cercocarpos ledifolius* Nutt in T. & G.), shadscale (*Atriplex sp.)*, and others. Grasses and forbs include several native species as well as many exotics. A partial list includes the following: bluebunch wheatgrass (*Elymus spicatum* Pursh), cheatgrass, halogeton (*Halogeton glomeratus* Bieb), indian rice grass (*Stipa hymenoides* Roem. & Schult), needle and thread grass (*Stipa comata* Trin. & Rupr.), redstem filaree (*Erodium cicutarium* L. L'Her), Russian thistle (*Salsola iberica* Sennen & Pau), and sandberg bluegrass (*Poa secunda* Presl). Generalized vegetative communities found in the study areas according to the 2004 Southwestern Regional Gap Analysis (Lowry et al. 2005) include: Great Basin Xeric Mixed and Inter-Mountain Basins Sagebrush Shrubland, Great Basin Pinyon Juniper Woodland, Inter-Mountain Basins Mixed Salt Desert Scrub, Invasive Annual and Perennial Grassland, and Inter-Mountain Basins Semi-Desert Grassland.

Additional descriptions of the vegetative component of the study areas were made using a one eighth meter square quadrat placed at random locations originating from evaluated guzzlers. These analyses showed all sites where Chukars and fecal droppings were collected suffering from cheatgrass invasion as it occupied from 6-22% of understory cover and tied or ranked first in comparison to other plants.

Digital motion-sensing cameras (Camtrakker Inc.®) placed at each guzzler so that approaching animals triggered the camera to take a photograph were used to document with photographic evidence use of water sources by wildlife species. Cameras were moved sequentially approximately every two weeks to different guzzlers between May and October of each year. In 2005, we assigned five cameras to remain on individual separate guzzlers throughout the summer. We moved the remaining cameras (n=5) in sequence. Photographed species were catalogued and results reported (mean number of species per site—alpha richness, total number of species—gamma richness, number of exotic species, etc.) using descriptive statistics. In addition beta richness is reported across sampling sites because of its value as a descriptive measure (Schulter & Ricklefs 1993). Due to disproportionate sampling time (result of the nature of data from remote cameras and our study design) and as a correction for such, the number of species per site was plotted against Julian sampling days and fit to a log-linear regression (integer counts in space-time). This relationship was hypothesized to be asymptotic with values near the asymptote representing a better estimate of mean number of species utilizing each guzzler than raw averages due to unequal sampling time.

Hunters were asked to participate prior to the season and solicited to save crops from Chukars legally harvested during the fall and winter of 2003 through 2005 from the Cedar, Grouse Creek/Bovine, and Keg Mountains. Additional Chukars were collected with shotguns outside of the season during the summer months under approval of the Utah Division of Wildlife Resources. Crops were placed in plastic bags, labeled (location & date), and frozen until analysis. Crop contents were sorted into component parts, weighed, dried in a plant dehydrator, and then reweighed again. Both frequency and aggregate dry weight data are reported with all information pooled into one sample representing general diet. No collection of birds was made during the spring period. We made a single estimate of individual seed weights by collecting and pooling several common seeds pulled from Chukar crops, weighing the accumulated seeds (after drying), and then counting them to determine average weight for one seed and estimate the number of seeds found in crops containing given food items. Food items found in < 3.0% of crops and constituting < 3.0% of dry weight are not reported (Walter & Reese 2003).

We opportunistically collected Chukar fecal droppings from the Cedar Mountains, Grouse Creek/Bovine Mountains, and the Keg Mountains throughout the year in an effort to represent each of the four seasons. Fecal droppings collected in the summer and fall were collected at watering sites where previous removal had occurred allowing for accurate estimates of deposition season. We limited our collection of fecal droppings during winter and spring time periods to those obviously of recent origin. Fecal droppings were stored in paper bags in a paper box placed outside over the winter to allow for vernalization until March of each year at which point they were planted in flats with sterilized soil, placed in a greenhouse, and watered intermittently (Cole et al. 1995). Due to concerns about the effectiveness of vernalization for fecal droppings stored outside, half (n = 121) of the total fecal droppings collected in 2004 (n = 242) were randomly assigned to receive both a cold and wet treatment in greenhouse refrigerators for five weeks. Following this treatment and prior to experimentation we laid all fecal droppings on the surface of the soil to simulate natural deposition. We checked the flats periodically and removed any seedlings upon identification. As a cross check of this technique, 93 fecal droppings representing summer, fall, and winter time periods were reserved prior to germination experiments and screened over soil sieves to look for evidence of viable seeds. Seeds appearing intact and potentially viable were catalogued and recorded.

Results

A total of 27 different wildlife species (appendix I) were photographed across all 36 guzzlers with 11 (31%) occurring at more than ten percent of guzzlers. Fourteen of the species (54%) were birds, eleven (42%) mammals, and one reptile (4%). Mourning Dove (*Zenaida macroura*), desert cottontail (*Sylvilagus audobonii*), bobcat (*Lynx rufus*), wood rat (*Neotoma* sp.), Chukar, and Rock

Wren (*Salpinctes obsoletus*) were the most commonly photographed species and all occurred at more than 50% of guzzlers sampled. Three exotic species were photographed to include Chukars, Rock Dove (*Columbia liva*), and red fox (*Vulpes vulpes*) with the latter two species photographed at only two and one site respectively. Mean number of species photographed at guzzlers was 5.69 ± 1.09 with a range from 1-13. Estimated average number of species utilizing a given small guzzler after accounting for sampling time of up to 100 Julian days was near ten (Fig. 1.) with the log-linear relationship meaningful and significant (R^2 0.46; $p < 0.001$). Lower and upper confidence limits were near 7 and 12 respectively. Gamma richness (27) was described by alpha (5.69) and beta (.13) richness with sampling units of 36 and the equation $\gamma = \alpha \times \beta \times 36$ where β is equal to the inverse of the average number (7.48) of guzzlers from which detections of each species were made (Schulter & Ricklefs 1993).

Fourteen food items met or exceeded 3.0% of total dry weight or were found in > 3.0% of examined crops. Cheatgrass seed was found in 76.3% of crops and constituted 45.2% of dry weight (Table 1). Red-stem filaree (*Erodium cicutarium*) seed, an exotic forb, was found in 6.5% of crops and equaled 1.3% of dry weight. Other common food items originating from native species included ricegrass (*Stipa hymenoides*) seed, hawksbeard (*Crepis acuminate* Nutt) seed, and arthropods (mostly Orthoptera). Seeds accounted for 81% of dry mass confirming the granivorous nature of Chukars. Grass leaves (48.4% frequency and 3.0% dry weight) were largely suspected to be those of cheatgrass.

Estimated numbers of seeds per crop for birds consuming given food items ranged from 79 sunflower seeds (*Helianthus annuus* L.) to 900 spurge seeds (*Euphorbia* sp.); the estimated average number of cheatgrass seeds per crop was 522 (Table 1). Thus, our sample of 93 crops was estimated to contain 37,041 cheatgrass seeds, 15,680 hawksbeard seeds, 5,967 ricegrass seeds, 5,441 spurge seeds, 1,167 red-stem filaree seeds, and 632 sunflower seeds.

Thirteen plants germinated from 503 Chukar fecal droppings to include red-stem filaree, halogeton, littlepod false flax (*Camelina microcarpa*), and a kochia (*Kochia* sp.) (Table 2). Cheatgrass did not germinate from any of the flats. Screening of fecal droppings (n = 93) to look for evidence of viable seeds revealed similar results with detection of only three viable red-stem filaree seeds. Results were similar for fecal droppings given a cold—wet treatment in a refrigerator and those only vernalized outside over the winter and early spring.

Discussion

Criticism of guzzlers and water developments in general has intensified in recent years both with respect to their efficacy (Campbell 1960; Burkett & Thompson 1994; Broyles 1995; Rosenstock et al. 1999) and the potential for deleterious effects (Broyles 1997; Rosenstock et al. 1999; Andrew et al. 2001). Of specific concern here are suggestions that guzzlers may facilitate expansion of non-target exotic and/or feral species (Brown 1997; Broyles 1995, 1997). Our results do not validate this concern with respect to guzzlers developed for Chukars in western Utah as only two exotic and/or feral species (other than targeted Chukars) were photographed using guzzlers. Red fox were photographed at one guzzler on one of the five study areas whereas Rock Dove were photographed at two different guzzlers in one of the five study areas.

Twenty-three of the 26 (88%) identifiable species detected were natives (Appendix I) with a raw average of 5.69 species utilizing each guzzler. Our hypothesis of an asymptotic relationship between species counts and sampling time was not dismissed ($R^2 = .46$; p-value < 0.001) and the resulting plot (Fig. 1) is suggestive of a mean number of species per guzzler somewhere near ten (95% confidence limits near 8 and 12). Species turnover (beta richness) was relatively low (.13) across sampling units indicative of a small and somewhat steady suite of species utilizing guzzlers designed for Chukars in western Utah. This concept is further strengthened in that only 11 species (Appendix I) were photographed at > 10% of guzzlers. Interestingly, raptors are missing from the list despite use of other water developments (Rosenstock et al. 2004). Explanations could include a failure to recognize small-model guzzlers as a source of water, difficulty in use of small-model guzzlers, preferential use of other sources (springs, other water developments), or other reasons.

Our results are confirmatory of the granivorous nature of Chukars throughout their range (Weaver & Haskell 1967; Oakleaf & Robertson 1971; Cole et al. 1995;) with cheatgrass seed the predominant food item in North America (Christensen 1996). Cheatgrass seed was found in 87.5% of fall crops collected in Eastern Oregon (Walter & Reese 2003), 56.1% of late summer and early fall crops in Nevada (Alcorn & Richardson 1951), between 39% and 64% of Washington crops dependent on season (Galbreath & Moreland 1953), and 69% of an annual sample in California (Zembal 1977). Similar results with respect to the prevalence of seeds from ricegrass, red-stem filaree, sunflower, etc have also been reported (Weaver & Haskell 1967; Christensen 1952, 1970). Most dietary studies involving Chukars in North America report heavy utilization of cheatgrass in seed and/or leaf form. Hence, some authors (Cox 1999; Walter & Reese 2003) have suggested an apparent functional link between the establishment of Chukars and cheatgrass. Interestingly, however, cheatgrass specifically has not shown up in dietary studies from Hawaii (Cole et al. 1995) or Eurasia (Oakleaf & Robertson 1971; Alkon et al. 1985; Dayani 1986; Naifa 1995), although these studies report high reliance on seeds of both native and exotic grasses and forbs. Furthermore, Chukars have not followed cheatgrass expansion across the Midwest, to the east coast, or into the extreme southwest and thus their distribution is contingent on other factors.

We challenge a suggestive link between Chukar distribution in North America and cheatgrass based solely on dietary frequency or aggregate weight of crop contents—particularly in the absence of data documenting important factors other than utilization (e.g. preference, fitness, etc. of Chukars eating cheatgrass) and given that Chukars apparently maintain themselves without it (Oakleaf & Robertson 1971; Alkon et al. 1985; Dayani 1986; Cole et al. 1995; Naifa 1995). Frequent utilization of a given food species is not necessarily the same as a functional link to the establishment of another species.

Seed counts or estimates per crop are lacking in the literature; nonetheless, Alcorn and Richardson (1951) reported over 900 cheatgrass seeds in one crop and over 2000 red-stem filaree seeds in another. Seed weights confirm observations by others (Dayani 1986; Walter & Reese 2003) that Chukars appear to be opportunistic foragers willing to consume a wide variety of food items, but relying on a small subset to comprise the bulk of their diet (Dayani 1986; Walter & Reese 2003) composed largely of grass and forb seeds with particular emphasis on cheatgrass seed in North America (Christensen 1996).

Cole et al. (1995) conducted similar germination experiments from Chukar fecal droppings collected in Hawaii. Results included germination of 115 seeds from eight plant species. Native species outnumbered exotics five to one with a general conclusion that exotic game birds in Hawaii served (at least superficially) as ecological surrogates for extinct and endangered indigenous species such as the Nene (*Branta sandvicensis*) in the distribution of native plant seed.

Differences between our results are likely attributable to digestibility of respective food items—cheatgrass in particular has a relatively large and soft seed easily digested in the gizzard. Fecal droppings screened over soil sieves generally contained plant material beyond any recognition to plant part, or specific taxa indicative of relatively complete digestion. The plants that did germinate

(Table 2) have small and/or tough seeds more likely to pass through the digestive tract. Red-stem filaree, six of thirteen (46%) germinated seeds, in particular has a small seed protected by a sharp and tough sheath.

Cheatgrass first appeared in North America in the late 1800s originating from multiple introductions (Upadhyaya et al. 1986; Novak & Mack 2001) and quickly spread throughout the Intermountain West (Mack 1981). Considered the quintessential invader (Novak & Mack 2001), cheatgrass is the dominant plant on at least 200,000 km^2 in the Intermountain West (Mack 1989) and a potential dominant on over 250,905 km^2 (Pellent & Hall 1994). Cheatgrass dominated communities are likely a permanent part of the landscape in some areas (Knapp 1992).

Not favored by other rangeland birds (Goebel & Berry 1976) and palatable to grazing animals only during a short window (Cook & Harris 1968; Upadhyaya et al. 1986; Mayland et al. 1994), cheatgrass quickly invades disturbed areas (Evans & Young 1970) out competing native species through a variety of adaptations (Hironaka 1961; Chatterton 1994; Nasri & Doescher 1995). Problems associated with invasion of cheatgrass include increased fire cycles (Stewart & Hull 1949; Savage et al. 1969; Billings 1994), reduced soil moisture (Hulbert 1955), elimination of native perennials (Savage et al. 1969; Whisenant 1990), and other ails (see Billings 1990; Billings 1994; Zouhar 2003 for a more thorough enumeration of problems). Some (D'Antonio & Vitousek 1992) consider cheatgrass and other exotic plant invasions large and serious enough to threaten disruptions of global climate.

Chukars have certainly not slowed the spread of cheatgrass, which has happened in spite of increased distribution and density of Chukars over the last 50 years. Prolific seed production with natural seeding rates as high as 70.8 million seeds per acre (Hull & Pechanec 1947) may allow cheatgrass to overwhelm granivores. Nonetheless, Chukars may foster localized plant diversity through selective consumption of large quantities of cheatgrass seed in heavily utilized areas. Cheatgrass density increases in the absence of utilization by granivores (Pyke & Novak 1994), and we found no evidence of seed dispersal.

Conclusions

Although we concur with (Patten et al. 2001) that exotic species should be evaluated under the null hypothesis of negative effects, we caution against de facto assignment of specific problems in the absence of scientific inquiry. Chukars may pose as yet undefined conservation implications to North American ecosystems, but recognition of negative effects has not been made. We found no evidence of widespread use of guzzlers designed for Chukars by other exotic species or dispersal of cheatgrass seed via passage through the gut (contra Peterson 2001). Chukars appear (at least initially) to fall into Williamson and Fitter's (1996) second tier of the "rule of tens"—i.e. those that become established but not problematic. Furthermore, Chukars may be beneficial in that they consume vast quantities of primarily exotic plant seed and do not show a propensity for dispersal of seeds through fecal droppings. Management of rangelands for Chukars does not foster cheatgrass dispersal or significant exotic animal use of water developments. Other potential implications such as dispersal of seed in their feathers, role as a food resource for avian and mammalian predators, direct or indirect competition with native species, the potential for alteration in native species diversity as a result of water development, etc. are candidates for future investigation. To date however, Chukars appear benign if not beneficial to North American ecosystems.

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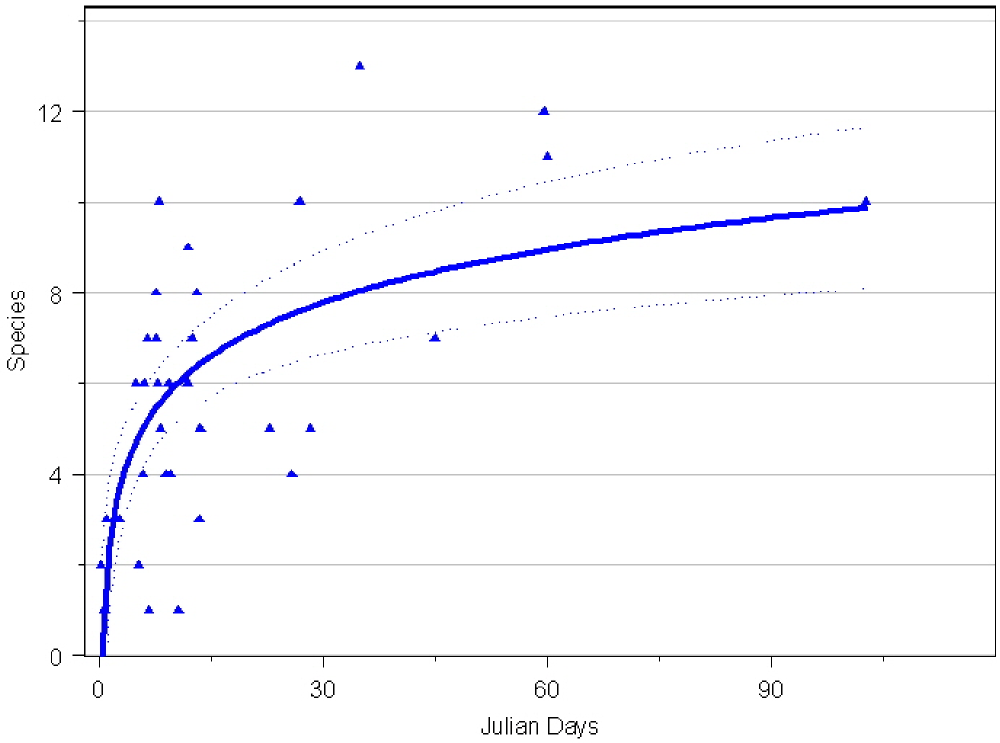

Figure 1. Shown here is the number of species photographed at guzzlers scaled to sampling time and resultant log-linear function $y = 1.70 \times \ln(x) + 2.02$ that fits these data ($R^2 = .46$; $p < 0.001$)

Table 1. Food items found in Chukar crops from western Utah (n = 93) during summer, fall, and winter.

Crop Item[a]	Scientific Name	Frequency (%)	Dry Weight (%)	Average Weight (g)[b]	No. Seeds
Cheatgrass seeds	*Bromus tectorum*	76.3	45.2	1.21	522
Grass leaves	Various	48.4	3.0	0.13	n/a
Grit	n/a	46.2	1.4	0.06	n/a
Ricegrass seeds	*Stipa hymenoides*	36.6	21.0	1.17	175
Arthropods	Arthropoda spp.	34.4	5.5	0.33	n/a
Hawksbeard seeds	*Crepis acuminata*	25.8	10.1	0.80	661
Bulbous bluegrass bulbs	*Poa bulbosa* L.	8.6	0.90	0.21	n/a
Sunflower seeds	*Helianthus annus*	8.6	2.0	0.48	79
Onion bulbs	*Allium* sp.	6.5	2.6	0.82	n/a
Spurge seeds	*Euphorbia* sp.	6.5	1.4	0.45	900
Red-stem filaree seeds	*Erodium cicutarium*	6.5	1.3	0.39	193
Sage brush galls	*Artemisia* sp.	4.3	1.1	0.53	n/a
Unidentified	n/a	21.5	2.0	0.19	n/a
Other roots	n/a	3.2	<0.1	0.12	n/a

[a] Only items occurring in > 3.0% of sample or constituting >3.0% of total dry weight included.

[b] Average of contents for crops containing given food items.

Table 2. Shown here are the results of germination experiments from Chukar fecal droppings.

Year Collected	Area(s)	Season	Fecal Droppings Planted	Plants Germinated	No.
2002	CM	Summer	37	*Erodium cicutarium*	2
2003	CM,KM	Summer	72	*Kochia* sp. *Erodium cicutarium*	2 3
2003	BE,KM	Fall	70	*Halogeton glomeratus*	1
2003/2004	KM	Winter	37	--------------	0
2004	KM	Spring	45	--------------	0
2004	CM,KM	Fall	208	*Camelina microcarpa* *Erodium cicutarium*	2 3
2004	KM	Winter	34	--------------	0
Total	CM,KM,BE	4 Seasons	503	Four different species	13

BE = Box Elder County; CM = Cedar Mountains; KM = Keg Mountains

Appendix I. List of species photographed across 36 small guzzlers in western Utah.

Species	**Scientific Name**	**Number Sites**	**Frequency**
Mourning Dove	*Zenaida macroura*	25	0.69
Desert Cottontail	*Sylvilagus audubonii*	22	0.61
Bobcat	*Lynx rufus*	21	0.58
Chukar	*Alectoris chukar*	19	0.53
Woodrat	*Neotoma* sp.	19	0.53
Rock Wren	*Salpinctes obsoletus*	18	0.50
Chipmunk	*Tamias* sp.	15	0.42
Mouse	*Peromyscus* sp.	13	0.36
Spotted Skunk	*Spilogale Gracilis*	10	0.28
House Finch	*Carpodacus mexicanus*	6	0.17
Coyote	*Canis latrans*	4	0.11
Black-throated Sparrow	*Amphispiza bilineata*	3	0.08
Black-tailed Jackrabbit	*Lepus californicus*	3	0.08
Lark Sparrow	*Chondestes grammacus*	3	0.08
Western Meadow Lark	*Sturnella neglecta*	3	0.08
Badger	*Taxidea taxus*	3	0.08
Black-billed Magpie	*Pica hudsonia*	2	0.06
Unknown Passerine	N/A	2	0.06
Rock Dove	*Columbia liva*	2	0.06
Striped Skunk	*Mephitis mephitis*	2	0.06
Gopher Snake	*Pituophis melanoleucus*	1	0.03
Red Fox	*Vulpes vulpes*	1	0.03
Blue-gray Gnatcatcher	*Polioptila caerulea*	1	0.03
Lazuli Bunting	*Passerina amoena*	1	0.03
Gray Fox	*Urocyon cinereoargenteus*	1	0.03
Sage Thrasher	*Oreoscoptes montanus*	1	0.03
Kit Fox	*Vulpes macrotis*	1	0.03