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## EFFECTS OF HABITAT DISTURBANCE ON DIETS OF GREAT HORNED OWL (*BUBO VIRGINIANUS*) IN A COLD DESERT

Shelly R. Kremer<sup>1</sup> and Mark C. Belk<sup>1,2</sup>

**ABSTRACT.**—To determine the potential effect of habitat disturbance, Great Horned Owl (*Bubo virginianus*) diets were quantified in disturbed and undisturbed habitats over a 2-year period at Dugway Proving Ground in the Great Basin Desert of Tooele County, Utah. Invertebrates were the most abundant prey by count, whereas mammals constituted the majority of diet by biomass. Species richness in the diet did not differ between habitats or among seasons after correcting for the number of pellets in each sample. However, the number of vertebrate species was greater than the number of invertebrate species in the diet, and this ratio differed between disturbed and undisturbed habitats. Invertebrate species made up a greater proportion of total species richness in the diet in the undisturbed than the disturbed habitat. Nineteen species occurred in the diet in only 1 of the 2 habitat types (7 unique species in disturbed habitat, 12 unique species in undisturbed), but all such species were rare and contributed little both by count and biomass to the overall diet. Of the 20 most important species found in owl diets in both habitats (based on percent biomass), none were more common in 1 habitat than the other after correcting for multiple tests. Although there were minor differences in the diet between disturbed and undisturbed habitats, habitat alteration and degradation of native vegetation on Dugway Proving Ground did not affect the major components of the diet of Great Horned Owls.

*Key words:* Great Horned Owl, diet, desert habitat, invertebrates, habitat disturbance, *Bubo virginianus*, Great Basin.

Throughout western North America human-induced disturbances, such as overgrazing and physical disturbance, have contributed to the replacement of native perennial grasses with exotic species. For example, on Dugway Proving Ground (DPG), a military training facility located in west central Utah, USA, native shrub and perennial grasslands have been replaced largely by a monoculture of exotic annuals in areas disturbed by military activity.

Military activity leads to degradation of native vegetation through increased fire periodicity and effects of tracking by military equipment. Presettlement fire periodicity in the Great Basin was 75–100 years (Houston 1973). Military activity at DPG has increased the burn frequency to 2–10 years. Once native vegetation is destroyed by fire, a 5-year cycle of secondary succession of exotic annuals begins, starting with Russian thistle (*Salsola kali*), then mustard (*Sisymbrium* and *Descurainia* sp.), and finally cheat grass (*Bromus tectorum*; Piemeisel 1951). Exotic annuals feed subsequent fires by providing fine fuels, which further destroy native shrub-perennial grassland communities, thus increasing the spread of exotic annuals (U.S. Department of the Interior 1996).

Training with military vehicles, especially tanks, disturbs soil, degrades native vegetation, and creates open areas where exotic annuals can invade (U.S. Department of the Interior 1996).

Loss of native habitat by fire and invasion of exotic annuals can adversely affect small mammal populations by reducing density and diversity (Larrison and Johnson 1973, Hedlund and Rickard 1981). For example, accompanying the shift in vegetative structure at DPG is a documented decline in 6 species of small mammals in disturbed areas (*Peromyscus maniculatus*, *Ammospermophilus leucurus*, *Tamias minimus*, *Dipodomys ordii*, *Dipodomys microps*, and *Neotoma lepida* [AGEISS 1996]). As small mammal populations decline due to habitat fragmentation and degradation, predators that depend on small mammals for food may also be affected.

The Great Horned Owl (*Bubo virginianus*) is an important predator of small animals throughout North America. Although the Great Horned Owl is a diet generalist, its main prey is small mammals and lagomorphs, which typically comprise over 90% of the owl diet by biomass (Fitch 1947, Maser and Brodie 1966, Seidensticker 1968, Marti 1974, Pine 1978, Knight

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and Jackman 1984, Donazar et al. 1989, Von Kuster and Schneberger 1992, Aigner et al. 1994, Marti and Kochert 1996). In arid areas of western North America, destruction of native perennial grasslands may affect Great Horned Owl populations by reducing availability of their prey.

This study provides a test of the hypothesis that destruction of native vegetation communities affects diet composition of Great Horned Owls. We compared species counts and relative biomass in Great Horned Owl diets in disturbed and undisturbed habitats on DPG. In addition, we provide a quantification of Great Horned Owl diets in a cold desert, an area where they have seldom been studied.

#### STUDY AREA

The U.S. Army Dugway Proving Ground is located in Tooele County, Utah. A study area of 68 km<sup>2</sup> was established on DPG. The foothills of the Cedar Mountains, Little Granite Peak, Little Davis Mountain, and the eastern edge of the sand dunes define the area. Elevation ranges from 1400 m on the valley floor to approximately 2000 m on mountain peaks. Major habitat types within the study area include Utah juniper (*Juniperus osteosperma*) stands, stabilized and dynamic sand dunes, mixed-shrub and perennial grassland communities, and communities dominated by exotic annuals. Juniper stands are distributed in patches along the valley floor. Dynamic sand dunes surrounded by stabilized sand dunes vegetated with various perennial grasses are found in the northwestern part of the area. Mixed-shrub communities (*Artemisia* sp., *Purshia* sp., *Xanthocephalum* sp., and *Sarcobatus* sp.) are sparsely distributed and often intermixed with perennial and exotic annual grasses. The main exotic annual plant species are cheat grass, Russian thistle, and mustard.

The north portion of the area consists of the foothills to the Cedar Mountains and portions of the eastern sand dunes. The northern area remains free of military training activity throughout the year.

The southern portion of the study area consists of Little Granite Peak, Little Davis Mountain, and portions of stabilized sand dunes. This area receives the greatest disturbance. Much of the impact is seasonal and the direct result of military training. National Guard units

train in 3- to 4-week sessions during the summer months. Training includes live fire of large projectiles and concentrated traffic of both tracked and wheeled vehicles. Detailed information and maps of the study area can be found in Kremer-Goodell (1999).

#### METHODS

To determine owl usage areas, we conducted surveys during January through March 1996 following protocol detailed by Fuller and Mosher (1987). We established 15 transects with lengths from 0.62 to 1.86 km on roads that crossed the study area. We selected transects that would allow maximum possible coverage of the study area. We detected owls by their calls and then located day roosts and possible nest sites during daytime follow-up visits. Owl usage areas were defined as areas in which owls were known to roost or possibly nest. We assumed that owls hunted in the general area surrounding their roost sites.

Fire burned portions of both the disturbed and undisturbed habitat in 1996. The fire did not affect any known pairs in the undisturbed habitat, but did burn an owl usage area occupied by a nonbreeding pair of owls in the disturbed habitat. After the burn the owls left and did not return to the area.

To quantify owl diets, we used prey remains in pellets collected from identified owl usage areas. We collected pellets once a month from March 1996 to August 1997 from a total of 6 usage areas in undisturbed habitat and 5 in disturbed habitat.

Most pellets were whole when collected, but we found some loose pellet material. To determine the volume of loose material represented by a single pellet, we measured the volume of 20 whole pellets that had been pulled apart and used this volume to quantify the number of pellets represented by the loose material.

When possible, we identified pellet contents to species, using standard methods as described by Marti (1987) to identify and quantify prey remains. To identify mammal species, we used reference collections from the Monte L. Bean Life Science Museum at Brigham Young University. For insect remains, we made a reference collection from the study area during the summer months of 1997 using pitfall traps and black-light techniques (Upton 1991).

We characterized diets by species richness, number of individual prey found in pellets, and estimated biomass of prey. Estimates of species richness are dependent on the number of pellets sampled. To correct this problem and provide unbiased estimates of species richness, we transformed both species richness and pellet number (natural log-transform). This resulted in a linear relationship between these 2 variables so that we could then use number of pellets collected as a covariate in the analysis of differences in richness. Natural log-transformed values of species richness were approximately normally distributed (PROC UNIVARIATE; SAS 1990). To determine biomass represented by prey items, we used published values of wet mass for mammal, bird, reptile, and amphibian species identified as prey (Durrant 1952, Steenhof 1983, Hoffmeister 1986, Dunning 1993). We measured wet mass for invertebrates directly from reference specimens. Biomass was calculated as total number of individuals per species multiplied by mean biomass estimates for an individual of the species. We calculated percent biomass of the diet represented by individual species as estimated biomass of a given species divided by the total estimated biomass of all prey.

Differences in species richness of owl diets were assessed using analysis of covariance (ANCOVA; Sokal and Rohlf 1981). In the ANCOVA model the response variable was the natural log-transformed species richness value. Independent variables were habitat (disturbed or undisturbed), season (winter—November to February; spring—March to June; summer—July to October), and vertebrate or invertebrate species. Natural log-transformed number of pellets was used as the covariate. Differences in percent biomass of the diet represented by individual species between habitat types were assessed using analysis of variance (ANOVA; Sokal and Rohlf 1981).

## RESULTS

### Combined Habitat Diet Analysis

We collected 3926 Great Horned Owl pellets (1478 from disturbed and 2448 from undisturbed habitats) from which 24,738 prey items were identified. Numerically, for both habitats combined, invertebrates composed about 58% of prey consumed, mammals about 38%, and miscellaneous other vertebrates (i.e., birds,

reptiles, and amphibians) about 4% of the diet. Five species contributed about 64% numerically to the diet for both habitats combined (Jerusalem cricket, *Stenopelmatus fuscus*, 32%; scorpion, *Anuroctonus* sp., 8%; 2 species of kangaroo rat, *Dipodomys ordii* and *D. microps*, 17%; and deer mouse, *Peromyscus maniculatus*, 7%; for complete species list see Table 1).

Conversely, using biomass estimates for prey species from both habitats combined, mammals composed about 93% of prey, miscellaneous other vertebrates (i.e., birds, reptiles, and amphibians) composed about 5%, and invertebrates about 2% of the diet. Five species of mammals contributed about 86% by biomass to the overall diet for both habitats combined. Those species included 2 species of lagomorphs (*L. californicus* and *S. audubonii*, 54% combined), 2 species of kangaroo rats as noted above (20%), and valley pocket gophers (*Thomomys bottae*, 12%; Table 1).

### Species Richness of the Diet by Season and Habitat

Total species richness in diets did not differ significantly between habitats (disturbed or undisturbed;  $F_{1,13} = 0.33$ ;  $P = 0.5739$ ) or among seasons (winter, spring, and summer;  $F_{2,13} = 3.45$ ;  $P = 0.0627$ ). Vertebrate species richness in the diet was greater than invertebrate species richness (mean vertebrate richness = 19.3; mean invertebrate richness = 13.8;  $F_{1,13} = 37.26$ ;  $P < 0.0001$ ). Owl diets from undisturbed areas had a greater proportion of invertebrate species and a lower proportion of vertebrate species compared to owl diets in the disturbed habitat (Fig. 1;  $F_{1,13} = 6.08$ ;  $P = 0.0283$ ). There were no other significant interactions. The covariate, number of pellets, explained a significant amount of variation ( $F_{1,13} = 124.29$ ;  $P < 0.0001$ ).

### Individual Prey Species Differences in the Diet by Habitat

Nineteen prey species were found in diets of Great Horned Owl from only 1 habitat type (7 species in disturbed habitats and 12 species in undisturbed; see Table 1). All such species were uncommon in the diet. After correcting for multiple statistical tests (according to methods in Rice [1989], corrected  $\alpha = 0.0025$ ), none of the 20 most important prey species (representing over 99% of total biomass) were found to represent a greater percent biomass

TABLE 1. Percent frequency and percent biomass of prey species in the diets of Great Horned Owls at Dugway Proving Ground, Tooele County, Utah.

Taxa	Disturbed		Undisturbed	
	% individuals	% biomass	% individuals	% biomass
<b>MAMMALIA</b>	<b>37.69</b>	<b>89.76</b>	<b>37.67</b>	<b>95.74</b>
Sorex spp.	0.02	tr <sup>a</sup>	0.01	tr
Lagomorph spp.	2.27	55.24	1.79	53.01
Ammospermophilus leucurus	0.12	0.17	0.10	0.18
Spermophilus townsendii			0.05	0.16
Eutamias dorsalis	0.01	0.01	0.01	0.01
Thomomys bottae	4.06	10.06	4.32	13.02
Perognathus parvus	0.05	0.02	0.06	0.03
Perognathus longimembris	0.01	tr	0.12	0.02
Perognathus formosus	0.55	0.19	0.36	0.16
Perognathus spp.	0.17	0.05	0.19	0.06
Dipodomys spp.	17.17	17.81	17.49	22.06
Reithrodontomys megalotis	2.82	0.64	3.60	1.00
Peromyscus maniculatus	7.20	2.25	7.27	2.76
Peromyscus trueii	0.29	0.11	0.36	0.16
Peromyscus spp.	0.12	0.03	0.10	0.03
Neotoma cinerea	0.02	0.10	0.04	0.19
Neotoma lepida	0.66	1.21	0.69	1.54
Neotoma spp.	0.01	0.04	0.01	0.05
Onychomys leucogaster	0.01	0.01	0.07	0.05
Microtus spp.	1.70	1.23	0.71	0.62
Unidentified Rodentia	0.33	0.31	0.24	0.28
Unidentified Sciuridae	0.01	0.04	0.05	0.24
Mustela frenata	0.07	0.23	0.03	0.12
<b>AVES</b>	<b>2.36</b>	<b>7.07</b>	<b>0.85</b>	<b>0.85</b>
Podiceps spp.	0.60	2.68	0.01	0.03
Anas crecca			0.01	0.02
Unidentified Anatini	0.18	2.49	0.01	0.10
Unidentified Accipitridae			0.02	tr
Alectoris chukar			0.01	0.07
Unidentified Rallidae	0.01	0.01		
Fulica americana	0.08	0.83		
Zenaid macroura	0.05	0.10	0.03	0.07
Athene cucularia	0.02	0.06	0.02	0.07
Caprimulgid spp.	0.01	0.01		
Aphelocoma coerulescens			0.01	0.01
Pipilo chlorurus	0.01	0.01		
Zonotrichia leucophrys	0.01	0.01		
Sturnella neglecta	0.02	0.02	0.02	0.01
Unidentified passerine	0.35	0.09	0.31	0.10
Unidentified Aves	1.00	0.76	0.40	0.37

of the diet in 1 habitat compared to the other (all  $P$ -values > 0.0048).

#### DISCUSSION

The documented reduction in small mammal species richness in areas with high exotic annual invasion on DPG (AGEISS 1996) might be expected to result in a similar reduction in small mammal species richness in the diet of Great Horned Owls. On the contrary, in this study owl diets from the undisturbed habitat showed greater invertebrate species

richness, and there was no evidence for switching from vertebrate to invertebrate prey in the disturbed habitat.

Minor differences between counts of individual prey species in the diet for both habitats can be explained partially by location of a sewage lagoon in the disturbed portion of the study area. Many avian species in the disturbed habitat were likely associated with this lagoon (e.g., grebes, *Podiceps* sp.; ducks, *Anas* sp.; and coots, *Fulica americana*) and thus more likely to be found in diets of owls from the disturbed habitat.

TABLE I. Continued.

Taxa	Disturbed		Undisturbed	
	% individuals	% biomass	% individuals	% biomass
<b>REPTILES AND AMPHIBIANS</b>	<b>3.44</b>	<b>1.20</b>	<b>1.65</b>	<b>0.96</b>
Serpentes	0.54	0.65	0.45	0.66
Squamata	0.13	0.04	0.24	0.09
Scaphiopus intermontanus	2.76	0.50	0.95	0.21
<b>INVERTEBRATES</b>	<b>56.52</b>	<b>1.98</b>	<b>59.83</b>	<b>2.46</b>
<b>Scorpionida</b>				
Anuroctonus spp.	11.53	0.21	5.35	0.12
Vaejovis spp.	1.13	0.01	5.29	0.04
<b>Solpugida</b>	0.14	tr	0.02	tr
<b>Acarina</b>	0.29	tr	0.01	tr
<b>Araneida<sup>b</sup></b>	0.48	tr	0.54	tr
<b>Orthoptera</b>				
Acrididae	4.00	0.13	1.92	0.08
Rhaphidophorinae	4.76	0.02	3.72	0.02
Stenopelmatinae	30.95	1.58	34.05	2.12
<b>Hemiptera</b>				
Pentatomidae			0.02	tr
<b>Coleoptera</b>	0.57	tr	0.43	tr
Silphidae	0.01	tr	0.01	tr
Elateridae	0.04	tr	0.02	tr
Coccinellidae	0.02	tr	0.04	tr
Carabidae	0.06	tr	0.07	tr
Cerambycidae			0.11	tr
Prionus spp.			0.19	tr
Melolonthidae	1.64	0.01	2.76	0.03
Scarabaeidae	0.02	tr	0.02	tr
Bothynus spp.	0.28	tr	3.27	0.03
Phyllophaga spp.	0.02	tr		
Diploptaxis spp.	0.16	tr	0.10	tr
Serica spp.			0.01	tr
Rutela spp.			0.01	tr
Tenebrionidae	0.02	0.01	0.06	0.02
Edrotes spp.	0.08	tr	0.44	tr
Eleodes spp.	0.02	tr	0.16	tr
Eusattus spp.	0.01	tr	0.23	tr
Trogloderus spp.			0.03	tr
<b>Diptera</b>	0.01	tr		
<b>Hymenoptera</b>			0.05	tr
Formicidae	0.25	tr	0.89	tr
Chrysididae	tr	tr	0.01	tr

<sup>a</sup>Trace (<0.01%).<sup>b</sup>Approximate mass used.

Based on count, Great Horned Owl diets in desert communities predominantly consisted of *Lepus* sp., *Dipodomys* sp., and *Peromyscus* sp. (Fitch 1947, Barrows 1989, Aigner et al. 1994). Similarly, diet studies conducted in desert regions reported invertebrate consumption, but only in low frequencies (Fitch 1947, Jaksic and Marti 1984, Knight and Jackman 1984, Barrows 1989, Jaksic et al. 1992, Marti and Kochert 1996). Diet studies conducted in temperate and boreal regions report almost no invertebrate consumption (Maser and Brodie

1966). In this study the diet, based on count, was predominantly composed of scorpions, Jerusalem crickets, *Dipodomys* sp., and *P. maniculatus*. This study contrasts with most other published reports on Great Horned Owls because of the high count of invertebrates included in the diet.

Most literature dismisses invertebrate consumption as prey for juvenile birds that are inexperienced hunters or insects associated with carrion accidentally consumed on a kill (e.g., Errington et al. 1940). The high level of



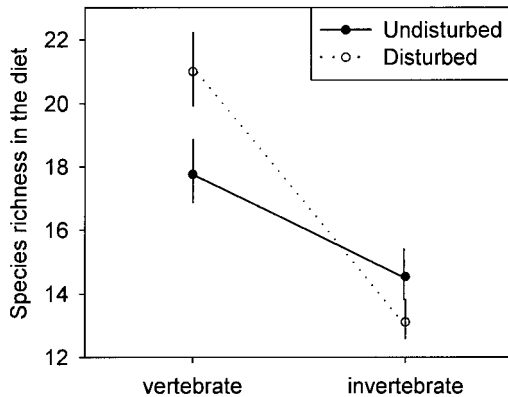


Fig. 1. Least-squares means  $\pm$  1 standard error of the mean (adjusted for the number of pellets collected) of species richness (grouped as vertebrate or invertebrate species) in the diet of Great Horned Owls in disturbed and undisturbed habitats on Dugway Proving Ground, Tooele County, Utah.

invertebrate consumption found in this study is not consistent with the explanation of lack of experience or incidental ingestion.

It may be instructive to consider why adult owls might consume such large numbers of invertebrates even though they appear to contribute only minimal biomass to the diet. Terrestrial invertebrates become superabundant in the summer months, and they are likely easy to capture. Additionally, invertebrates probably have low handling time, and even though biomass is extremely low, a high encounter rate and a possibly high nutrient value may make them a valuable food item (Bulmer 1994).

It has been suggested that high invertebrate consumption may be a functional response to decreased small mammal availability (Donazar et al. 1989). In this study we found that spring and summer had highest densities of both vertebrate and invertebrate prey. Thus, this shift does not seem to be in response to a decrease in mammals but rather a response to the increased availability of invertebrates. Optimal diet models suggest that less preferred prey should be consumed only when more preferred prey decline (Schoener 1971). Our data suggest that either invertebrates are consumed more just because they become more abundant, or they are a more preferred prey item than suggested by biomass alone.

Although there were some differences in the diet between habitats, they seemed to be inconsequential. Overall prey biomass does

not seem to change in any significant way between the 2 habitat types. The difference in the ratio of vertebrate to invertebrate species in the diet between disturbed and undisturbed habitats does not translate into important differences in the diet. There are many species that were found in small numbers that may influence species richness estimates. However, none of the species that were important (by biomass) differed in their representation between habitats. Diet composition did not seem to be affected by habitat alteration, but the effects of overall availability of prey in altered habitat types are not included in this analysis. This study focuses on relative biomass of prey items in the diet and does not address the issues of nutrient availability, digestibility, handling time, and energetic costs of foraging. Such issues should be addressed before a conclusion can be reached about the effect of habitat alteration on foraging behavior and population dynamics of predators.

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