Dietary Trends of Barn Owls in an Agricultural Ecosystem in Northern Utah

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Published By: The Wilson Ornithological Society
DOI: 10.1676/09-025.1
URL: http://www.bioone.org/doi/full/10.1676/09-025.1
DIETARY TRENDS OF BARN OWLS IN AN AGRICULTURAL ECOSYSTEM IN NORTHERN UTAH

CARL D. MARTI

ABSTRACT.—Barn Owl (*Tyto alba*) diets were studied for 15 years in Utah. Ninety-eight percent of 111,016 prey items were mammals, heavily dominated by voles (*Microtus* spp.). Food-niche breadth (FNB) was 3.33 for the entire sample and varied gradually but significantly among the 15 years and among seasons. Frequency of prey in the diet did not vary significantly from year to year or among seasons. Mean daily temperatures did not vary significantly among years but annual precipitation totals and days when deep snow covered the ground varied significantly among years. Irrigation for agriculture may have partially mitigated annual precipitation fluctuations. Hay, one of the most important crops on the study area, increased over the study period and other crops decreased slightly in the amount planted. Hectares of hay planted, hectares of corn planted, and hectares of barley planted were the variables that combined to best predict annual FNB. Received 9 February 2009. Accepted 31 July 2009.

Long-term studies can reveal how variation in prey populations, climatic factors, and changes in the landscape might influence the diet of Barn Owls (*Tyto alba*). Love et al. (2000), for example, found significant changes in diets of Barn Owls in the United Kingdom that they attributed primarily to changing agricultural practices. Taylor (1994) examined Barn Owl diets over 12 continuous years in a Scottish agricultural area and reported fluctuations in prey consumed related to cyclic changes in small mammal populations.

Barn Owls prey mainly on a wide variety of mammalian species over their cosmopolitan range (Taylor 1994, Bruce 1999, Marti et al. 2005); they eat mostly small, nocturnal mammals (Herrera and Jaksic 1980, Jaksic et al. 1982), only occasionally capturing birds at high frequencies (Brosset 1956, Görner 1978). Barn Owl diets have been studied most intensively in the United States and Europe (Campbell et al. 1987, Taylor 1994, Marti et al. 2005), but also in South America (Jaksic et al. 1982, Bellocq 2000), Africa (Vernon 1972, Goodman 1986), Asia (Lenton 1984, Mahmood-Ul-Hassan et al. 2007), and Australia (Morton and Martin 1979, Palmer 2001). The broad geographic distribution and the large quantity of published dietary information make the Barn Owl a good candidate for understanding factors that affect diet variation.

Collectively, the large number of published studies provide an overview of the diet of Barn Owls, including types of prey taken (Taylor 1994, Bruce 1999, Marti et al. 2005), size of prey (Dickman et al. 1991, Ille 1991, Marti et al. 1993), habitats used (Begall 2005, Bond et al. 2004, Askew et al. 2007), effect of season on diet (Baudvin 1983, Campbell et al. 1987), and the influence of climate on diet (Avery 1999, Jaksic and Lazo 1999). However, most studies of Barn Owl diets have been short-term and at risk of being biased because data were often collected during a single season or year and, at times, during atypical conditions, e.g., abnormal weather or in areas with unusual prey populations (Heywood and Pavey 2002, Sahores and Trejo 2004, Altwegg et al. 2006). Short-term studies, thus, cannot provide insight into the dynamics of predation.

I studied Barn Owls in a north-temperate agricultural area with the objectives to: (1) describe the diet over a 15-year period, (2) quantify the effects of weather variation on the diet, and (3) quantify the impact of vegetation changes on the diet.

METHODS

Study Area.—I studied Barn Owls in an area of ~1,000 km² in Box Elder, Davis, and Weber counties, Utah. The area was in a long, narrow, and essentially flat valley at an elevation of 1,300 m between the Wasatch Mountains and the Great Salt Lake (41° 01’ N, 112° 11’ W). The area was formerly shrub-steppe desert, but the natural plant community has been supplanted by irrigated agriculture and urban development. Primary crops were hay, corn, wheat, barley, and some livestock pasture. Uncultivated land was limited to narrow strips along roads, water courses, borders of agricultural fields, and adjacent to the Great Salt Lake. Annual precipitation averaged 35 cm, and mean temperatures for January and July were ~3.5° C and 23.9° C,
respectively (http://www.ncdc.noaa.gov/oa/ncdc.html). Barn Owls, resident on the study area, occasionally nested in old buildings and haystacks, but most used nest boxes (Marti 1997).

Source of Data.—Collection sites were nest boxes placed individually in abandoned agricultural silos (Marti et al. 1979); I visited all boxes and collected regurgitated pellets each month from 1977 to 1991. Boxes were placed throughout the study area with locations dictated by availability of silos. I identified and quantified prey items in pellets using standard methods (Marti et al. 2007). The smallest sampling unit for diet analyses consisted of prey from 1 month at one collection site. These samples were combined for analyzing diets by season or year.

Description of Food-niche Breadth.—Food-niche breadth (FNB) is a measure of dietary diversity incorporating measures of the number of kinds of prey eaten and the relative proportions of the kinds of prey in the diet. I prepared dietary data for describing FNB by identifying mammalian prey to species. Birds were also identified to species when possible, but insects were identified only to class. I estimated food-niche breadth (FNB) using the formula:

\[ FNB = \frac{1}{\sum p_i^2}, \]

where \( p_i \) is the proportion of prey category \( i \) (each kind of prey identified) in the Barn Owl diet (Levins 1968). Larger values of this index indicate a higher dietary diversity.

Environmental Variables.—I obtained climatic data—air temperature, precipitation, and number of days with snow on the ground—from National Climatic Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html) weather stations in the study area and calculated daily means for data recorded at three stations for use as variables that might explain changes in FNB. Variation in ambient temperature can influence prey use because changes in temperature may alter prey activity and affect the quantity of food needed by Barn Owls. Precipitation may directly influence Barn Owl hunting activity and indirectly affect prey population size and availability through its influence on vegetation. Snow cover may also affect prey use because some prey species, particularly voles (Microtus spp.), burrow under the snow, making them less vulnerable to owl predation.

Vegetation composition may also affect Barn Owl diets. My study area was agricultural land with interspersed housing developments and most vegetation was not native. I obtained annual crop data—number of hectares of each major crop planted—from the U.S. Department of Agriculture (http://www.nass.usda.gov) for use as explanatory variables of FNB. I calculated an annual crop-diversity index using the same formula used for calculating FNB and then compared it among seasons and years using PROC GLM (SAS Institute 2000).

Dietary Variation.—I used contingency table analysis (PROC REGR) (SAS Institute 2000) to evaluate changes in prey frequencies. Variation in diet was further evaluated by comparing FNB among years and seasons (spring [Mar–May], summer [Jun–Aug], fall [Sep–Nov] and winter [Dec–Feb]) and years using PROC GLM (SAS Institute 2000).

Variation in Food-niche Breadth.—I used multiple linear regression (PROC GLM) (SAS Institute 2000) to examine the relationship of FNB with candidate explanatory variables. The available variables were: mean annual precipitation; mean annual daily temperature; number of days with deep snow cover; hectares planted to hay, wheat, corn, and barley; and the annual diversity of crops planted. I did not include mean daily temperature or crop diversity in model selection because those variables did not vary significantly among years. The fit between candidate models and the data was evaluated using Akaike's information criterion (Burnham and Anderson 2002). I reported the adjusted \( R^2 \) to assist in evaluating the overall fit of the candidate models.

RESULTS

Food-niche Description.—I identified 111,016 prey items from 1,426 monthly samples collected at 31 sites. Owls consumed at least 26 species of prey, but 93.6% of the prey items were voles (75.9%; Microtus pennsylvanicus and M. montanus) and mice (17.7%; Peromyscus maniculatus, Reithrodontomys megalotis, and Mus musculus; Table 1). The number of prey items collected each year (1977 = 10,043; 1978 = 7,784; 1979 = 13,607; 1980 = 9,069; 1981 = 9,460; 1982 = 7,437; 1983 = 9,306; 1984 = 6,181; 1985 = 4,247; 1986 = 9,370; 1987 = 8,609; 1988 = 4,055; 1990 = 6,688; 1991 = 4,547) varied among years in relation to the number of nesting Barn Owls (rs = 0.59, P < 0.02).

FNB was 3.33 when calculated with all prey items combined (n = 111,016), whereas the mean

\[ FNB = 1/\sum p_i^2, \]

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FNB was 3.33 when calculated with all prey items combined (n = 111,016), whereas the mean
FNB of the 1,426 monthly samples was 2.78 (SD = 0.85, range = 1.07–8.7). FNB varied among years ($F_{14,399} = 4.1, P = 0.0001$), gradually decreasing during the study (Fig. 1). FNB differed significantly between consecutive years only for 1979 and 1980 ($F_{1,57} = 6.96, P = 0.01$) and 1987 and 1988 ($F_{1,58} = 12.0, P = 0.001$). The decrease in FNB was correlated with an increase in the frequency of voles in the diet ($r_s = -0.99, P < 0.0001$). Overall, FNB varied among seasons (Fig. 2) and, although FNB was not statistically different among seasons ($F_{3,56} = 2.4, P = 0.07$), the pattern observed may be biologically significant.

Environmental Variability.—Total precipitation varied among years ($F_{14,28} = 11.8, P = 0.0001$), but mean daily temperature did not ($F_{14,165} = 0.2, P = 0.99$). The number of days with snow sufficiently deep (≥15 cm) to interfere with prey detection and capture by Barn Owls also varied among years ($F_{14,75} = 3.4, P = 0.0003$). The frequency of voles in the diet of Barn Owls during winters having the greatest number of days with deep snow was less than in milder winters, but the relationship was not significant ($F_{1,14} = 0.16, r^2 = 0.01, P = 0.69$). Winters when the ground was covered longest with deep snow were followed by


<table>
<thead>
<tr>
<th>Category</th>
<th>Number in diet (%)</th>
<th>% Occurrence at 31 collection sites</th>
<th>% Occurrence in 1,426 pellet collections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammals</td>
<td>109,035 (98.2)</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Sorex vagrans</td>
<td>4,223 (3.8)</td>
<td>100.0</td>
<td>70.1</td>
</tr>
<tr>
<td>Myotis spp.</td>
<td>8 (tr.)</td>
<td>16.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Eptesicus fuscus</td>
<td>7 (tr.)</td>
<td>6.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Sylvilagus nuttalii (neonate)</td>
<td>3 (tr.)</td>
<td>9.7</td>
<td>0.2</td>
</tr>
<tr>
<td>Thomomys talpoides</td>
<td>649 (0.6)</td>
<td>54.8</td>
<td>8.6</td>
</tr>
<tr>
<td>Perognathus parvus</td>
<td>2 (tr.)</td>
<td>6.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Reithrodontomys megalotis</td>
<td>6,157 (5.9)</td>
<td>100.0</td>
<td>74.7</td>
</tr>
<tr>
<td>Peromyscus maniculatus</td>
<td>6,853 (6.2)</td>
<td>100.0</td>
<td>82.6</td>
</tr>
<tr>
<td>Ondatra zibethicus (juvenile)</td>
<td>40 (tr.)</td>
<td>35.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Microtus pennsylvanicus</td>
<td>42,718 (38.5)</td>
<td>100.0</td>
<td>99.2</td>
</tr>
<tr>
<td>M. montanus</td>
<td>41,527 (37.4)</td>
<td>100.0</td>
<td>99.3</td>
</tr>
<tr>
<td>Rattus norvegicus (juvenile)</td>
<td>308 (0.3)</td>
<td>90.3</td>
<td>13.2</td>
</tr>
<tr>
<td>Mus musculus</td>
<td>6,193 (5.6)</td>
<td>100.0</td>
<td>78.2</td>
</tr>
<tr>
<td>Mastella frenata</td>
<td>1 (tr.)</td>
<td>3.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Birds</td>
<td>2.5 (1.8)</td>
<td>96.4</td>
<td>30.6</td>
</tr>
<tr>
<td>Rallus limicola</td>
<td>4 (tr.)</td>
<td>12.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Porzana carolina</td>
<td>76 (tr.)</td>
<td>51.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Charadrius vociferus</td>
<td>1 (tr.)</td>
<td>3.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Recurvirostra</td>
<td>1 (tr.)</td>
<td>3.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Gallinago gallinago</td>
<td>16 (tr.)</td>
<td>16.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Colomba livia</td>
<td>23 (tr.)</td>
<td>35.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Tyto alba (nestling)</td>
<td>1 (tr.)</td>
<td>3.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Cistothorus palustris</td>
<td>36 (tr.)</td>
<td>29.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Sturnus vulgaris</td>
<td>382 (0.3)</td>
<td>90.3</td>
<td>15.3</td>
</tr>
<tr>
<td>Sturnella neglecta</td>
<td>11 (tr.)</td>
<td>19.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Passer domesticus</td>
<td>146 (0.1)</td>
<td>74.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Unidentified blackbird$^b$</td>
<td>198 (0.2)</td>
<td>90.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Unidentified small bird (≈20 g)</td>
<td>603 (0.5)</td>
<td>93.5</td>
<td>22.3</td>
</tr>
<tr>
<td>Unidentified small bird (≈40 g)</td>
<td>455 (0.4)</td>
<td>100.0</td>
<td>17.7</td>
</tr>
<tr>
<td>Insects, unidentified</td>
<td>14 (tr.)</td>
<td>29.0</td>
<td>0.8</td>
</tr>
</tbody>
</table>

$^a$ *p* < 0.1.

$^b$ Red-winged (Agelaius phoeniceus) or Yellow-headed (Xanthocephalus xanthocephalus) blackbirds.

FIG. 1. Barn Owl food-niche breadth in northern Utah by year.

a significant increase in the frequency of voles in spring Barn Owl diets ($F_{1,14} = 7.79$, $r^2 = 0.32$, $P = 0.01$; Fig. 3). Summer diets following winters with deep snow cover also contained a higher frequency of voles ($F_{1,14} = 4.6$, $r^2 = 0.26$, $P = 0.05$). The same relationship continued into autumn but the trend was not significant ($F_{1,14} = 1.5$, $r^2 = 0.1$, $P = 0.25$).

The number of hectares planted in different crops varied among years with the number of hectares of hay increasing during the study and the area devoted to other crops decreasing (Fig. 4). Crop diversity did not vary among years ($F_{11,35} = 1.0$, $r^2 = 0.32$, $P = 0.45$).

**Dietary Variation.**—Frequencies of different prey items consumed did not vary among years ($\chi^2 = 64.3$, df = 70, $P = 0.67$; Fig. 5), among seasons for all years combined ($\chi^2 = 6.4$, df = 15, $P = 0.97$), or among seasons within years. The percentage of voles (both species combined) in the diet of Barn Owls varied by an average of only 2.9% from year to year ($\chi^2 = 4.6$, df = 14, $P = 0.99$).

**Variation in Food-niche Breadth.**—The model that best explained variation in FNB among years included the variables: hectares of hay planted, hectares of corn planted, and hectares of barley planted (Table 2).

**DISCUSSION**

Barn Owls exhibited little variation in diet over a 15-year period in northern Utah where habitat changes were minimal and variation in precipitation was buffered by crop irrigation, minimizing the effects of year-to-year variation of precipitation on vegetation. In contrast to my findings, Taylor (1994) found pronounced fluctuation in Barn Owl diets corresponding to vole population cycles during a long-term study in Scotland. The proportion of voles in the diet of Barn Owls in my study, unlike several studies in Europe (Bohnsack 1966, de Bruijn 1979, Taylor 1994), did not show cyclic fluctuations, possibly because irrigated agriculture produced a consistent, high-quality
habitat that damped vole population fluctuations (Negus et al. 1986). Changes in Barn Owl diets sampled in two periods separated by a 19-year interval (1956–1974 and 1993–1997) in the United Kingdom were mostly attributable to a change from mixed-crop farms to more homogenous farms (Love et al. 2000). The mode of farming did not change during my study, but changes in proportion of crops planted did and those changes were related to the small changes in

the diet—the more hay planted, the more voles in the diet. Voles are known to be abundant in forage crops like hay (Getz 1985), and Barn Owls in Utah may have concentrated their foraging in the vegetation that served as best vole habitat as they did in the United Kingdom (Askew et al. 2007).

Voles were the most common prey in the diet of Barn Owls in my study, and have been the most numerous prey of these owls in many other studies conducted in the north-temperate zone (Campbell et al. 1987, Taylor 1994, Bruce 1999). In studies where an index of small mammal population size was available, Barn Owls captured voles in greater proportion than expected based on relative abundance (Marti 1974, Colvin 1984, Askew et al. 2007). The high proportion of voles in the diet of Barn Owls in my study also suggests that voles were taken selectively. I found strong evidence of selective predation by Barn Owls on voles inhabiting an island in the Great Salt Lake 10 km from the present study area, probably due to the owls hunting preferentially in vole habitat (Marti 1986); Barn Owl diets on that island contained 81% voles by number despite vole habitat being extremely limited. Voles were not known to occur on Antelope Island prior to my finding them in the Barn Owl diet (Bowers 1982,

FIG. 5. Frequency of major prey in Barn Owl diets in northern Utah by year.

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent in Barn Owl diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>10%</td>
</tr>
<tr>
<td>1979</td>
<td>20%</td>
</tr>
<tr>
<td>1981</td>
<td>30%</td>
</tr>
<tr>
<td>1983</td>
<td>40%</td>
</tr>
<tr>
<td>1985</td>
<td>50%</td>
</tr>
<tr>
<td>1987</td>
<td>60%</td>
</tr>
<tr>
<td>1989</td>
<td>70%</td>
</tr>
<tr>
<td>1991</td>
<td>80%</td>
</tr>
</tbody>
</table>

TABLE 2. Models of variation in food-niche breadth among years using seven explanatory variables: annual precipitation (AP), number of days with deep snow on ground (DDS), hectares of corn planted (HC), hectares of hay planted (HH), hectares of barley planted (HB), and hectares of wheat planted (HW).

<table>
<thead>
<tr>
<th>Model</th>
<th>$\Delta_i^a$</th>
<th>$w_i^b$</th>
<th>Adj. $R^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH + HC + HB</td>
<td>0</td>
<td>0.962</td>
<td>0.99</td>
</tr>
<tr>
<td>HC + DDS + AP</td>
<td>6.65</td>
<td>0.035</td>
<td>0.99</td>
</tr>
<tr>
<td>HH + HC + HW</td>
<td>12.78</td>
<td>0.002</td>
<td>0.96</td>
</tr>
<tr>
<td>HH + HB + AP</td>
<td>14.11</td>
<td>0.001</td>
<td>0.95</td>
</tr>
<tr>
<td>HH + HC + AP</td>
<td>14.91</td>
<td>0.001</td>
<td>0.94</td>
</tr>
</tbody>
</table>

$^a$ Akaike’s information criterion (AIC) for the best model was −42.83.

$^b$ $\Delta_i$ = difference between the AIC value of a given model and that of the best-fitting model.

$^c$ $w_i$ = AIC model weight.
Marti 1986). A similar pattern was seen in southwestern Idaho where frequency of voles was higher in Barn Owl diets at nests surrounded by irrigated agricultural land (Marti 1988). Barn Owls appeared to concentrate their foraging in habitats where voles were most numerous both on Antelop Island and in southwestern Idaho.

Fast and Ambrose (1976) and Derting and Cranford (1989) found that captive Barn Owls selected *Microtus* over *Peromyscus* when given a simultaneous choice. Prey size may be an important factor in prey selection—*Microtus* are about twice the mass of *Peromyscus* and *Mus*, the next largest among the most commonly taken prey in my study. Captive Barn Owls, given a simultaneous choice between two sizes of the same species, selected larger prey up to the point where prey became hard to subdue (Ile 1991).

It seems likely that Barn Owls may not discriminate between the two vole species because both are found in the same habitats (Getz 1985), and are similar in appearance and mass. A sample of voles trapped near my study area (University of Utah Museum collection; H. J. Egoscue, unpubl. data) revealed no difference in mass between the species (*t* = 1.53, *df* = 63, *P* = 0.13). Despite these similarities, I separated the two voles in my analyses because I did not know whether Barn Owls can or do distinguish between them.

Tores et al. (2005) concluded that Barn Owls prefer the kind of prey that voles exemplify, but readily switch to different prey if the preferred species declines below a certain level. Barn Owls in Utah ate all of the small mammal species known to occur in the area (Newey 1951, Frost 1970). Some prey were available or vulnerable only at certain times of the year; seasonal variation in uncommon prey was most noticeable for northern pocket gophers (*Thomomys talpoïdes*), which were numerous in the diet in May when young animals disperse above ground (Nowak 1991). Birds were a minor component of the diet, and the frequency of some species in the Barn Owl diet could be attributed to migration. *Sora (Porzana carolina)*, for example, occurred in the diet only in spring and early summer. Others, like European Starlings (*Sturnus vulgaris*), were not migratory and Barn Owls preyed on them throughout the year. However, starlings reached their highest numbers in the Barn Owl diet in winter when communal roosting may have made them more vulnerable.

I observed the same pattern of seasonal variation in the diet of Barn Owls in Utah that Taylor (1994) reported in Scotland—frequency of voles in the diet was lowest in spring, increased into summer, and peaked in late fall and early winter. During winters with more days of deep snow cover, Barn Owls in my study preyed on fewer voles. Winter fluctuations were likely explained by voles under deep snow cover having reduced vulnerability to predators (Canova 1989, Halonen et al. 2007).

The number of Barn Owls breeding in the study area varied 12-fold over the study period (Marti 1994, 1997), primarily due to differences in severity of winter weather (Marti and Wagner 1985). However, owl population density did not influence the rate of predation on voles; owl density as indexed by the number of nest attempts per year was not correlated with the frequency of voles in the diet (*r* = −0.25, *P* = 0.37).

Diets of Barn Owls inhabiting this agricultural ecosystem exhibited remarkable uniformity over the long term. The measures I applied—FNB variation and prey frequencies—showed the diet of Barn Owls in my study exhibited little variation. The owls preyed primarily on voles at all collection sites and during all seasons and years, and the small changes that I found from year to year likely were the result of an increase in the amount of hay grown and a concomitant increase in vole numbers. The reverse—changing from grass-oriented agriculture to corn and soybeans—has been associated with declines of Barn Owl populations in Ohio (Colvin 1985). Variation in annual precipitation in my study area was mitigated by crop irrigation providing consistent moisture levels each year, and, in turn, consistent prey habitat. The only weather variable strongly associated with diet variation of Barn Owls in Utah was the number of days the ground was covered with deep snow which interfered with owls ability to prey on voles.

**ACKNOWLEDGMENTS**

I thank Weber State University for financial support through Research and Professional Growth grants, and equipment to conduct much of this research. P. W. Wagner helped with data collection during the first 6 years of this study. I thank B. C. Harvey for advice on using Akaike’s information criterion. I also thank Karen Steenhof, M. N. Kochert, Motti Charter, Marco Restani, and an anonymous reviewer for their comments which helped refine this paper.
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