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AN ABSTRACT OF THE THESIS OF John M. Barss for the Master of Science in Biology presented May 15, 1985.

Title: The Analysis and Use of Methodologies for the Study of the Diets of Long-eared Owls From Three Environments in North-central Oregon.

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

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Larry W. Price

Part I of this study presents a procedure for standardization of pellet analysis methodologies which improves estimation of prey biomass and determines the

number of pellets needed to estimate prey diversity indices. The procedure was developed to provide a simple, easily replicated methodology for the study of pellets which also retains maximal data recorded from pellet analysis. A sample size of ten Long-eared Owl pellets was found adequate to calculate diversity indices with no significant loss of accuracy when compared to total pellets recovered from beneath a roosting site. Analysis of the total sample of pellets from a specific roost provided information on intraspecies size selection by Long-eared Owls and also increased the probability of finding remains of rare prey in pellets from the areas studied.

Part II of this study investigates the influences of seasonality and habitat differences on prey selection by Long-eared Owls in north-central Oregon. Differences in habitat where Long-eared Owls foraged were found to significantly influence prey species selection of Thomomys talpoides , Lagurus curtatus , Peromyscus maniculatus , Microtus montanus , and Perognathus parvus. Significant seasonal differences were also observed in the consumption of T. talpoides and M. montanus. Analysis of intraspecific size selection of northern pocket gophers by Long-eared Owls supports the observation that size of prey influences the foraging strategies of Long-eared Owls to a greater degree than does species composition.

THE ANALYSIS AND USE OF METHODOLOGIES FOR THE STUDY OF THE
DIETS OF LONG-EARED OWLS FROM THREE ENVIRONMENTS
IN NORTH CENTRAL OREGON

by

JOHN M. BARSS

A thesis submitted in partial fulfillment of the
requirements of the degree of

MASTER OF SCIENCE

in

BIOLOGY

Portland State University

1985

TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

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PREFACE

The study of food habits and feeding behavior of owls contributes valuable insights into the relationships of predators to prey. In addition to better understanding of the foraging techniques utilized by owls for prey capture, the analysis of pellet remains may provide opportunities to measure changes in rodent populations found within the territories of the owls studied. In this study, I chose to focus upon the analysis of Long-eared Owl (Asio otus) pellets following a raptor survey conducted in north central Oregon. Preliminary analysis of raptor food remains taken from collected pellets suggested that Long-eared Owls tended to prey upon small mammal populations in greater frequency than do other raptor species. Literature reviews and the survey determined that: 1) little information concerning Long-eared Owls was available for this region of Oregon ; 2) an adequate population of Long-eared Owls existed so that thorough studies of this species could be conducted; and 3) the populations were found in several different floral communities which could demonstrate possible environmental influences on prey selection by the owls.

The present study was conducted in two phases. Review of the methodologies used in pellet analysis suggested that improvements in the technique could be developed and tested for accuracy and ease of implementation. Part I of this study addresses this question and determines the number of pellets needed to provide reliable data on the composition of small mammal populations preyed upon by Long-eared Owls in north central Oregon. In addition, an attempt has been made to introduce procedures which standardize the laboratory analysis of pellets. Part II of this study applies the findings of Part I to 1) analyze seasonal trends in prey selection by Long-eared Owls, 2) determine if habitat differences influenced prey selection by Long-eared Owls, and 3) study the variability of prey size selection within a prey species population.

PART I

INTRODUCTION

Many investigators have used pellets to analyze feeding habits of owls (Bond 1939, Fairley 1967, Hornfeldt 1978, Marti 1974, Reynolds 1970, Smith and Murphy 1973, and Uttendorfer 1952). Pellets, the undigested remains of prey which have been regurgitated by owls or other predatory birds, are convenient indicators of the species preyed upon by owls. The pellets generally accumulate under roosts, rather than being dispersed throughout a territory, so provide a large and easily collected sample of prey remains.

The analysis of pellets can provide information on many aspects of predator/prey interactions. Such analyses can include information about the number of prey species captured by a predator, species diversity of prey populations, age classes of prey species captured, average daily prey mass consumed, and/or seasonal and annual trends in prey captured by owls. The lack of consistent methods for the study of pellet remains continues to be a major problem in studies of raptor ecology because comparisons of

data collected from different habitats by different researchers are difficult to interpret. Little effort at standardization has been made since Errington (1930) published many of the early studies of owl foods. Development of a standardized procedure is needed in order to provide improved communication between workers within the field.

Several researchers have attempted to present accurate information on biomass of prey captured by owls (Kallander 1977, Nilsson 1981). Southern (1970) established a procedure for determining nutritional equivalencies for prey species of different sizes. Getz (1961) used separate weights for males and females of a given prey species and calculated prey biomass for use in determining caloric intake of several owl species. In each case, the biomass calculated from prey remains found in pellets was based upon adult weights recorded from museum specimens of the same species, or on prey trapped within the study area. The potential source of error in studies which use per cent biomass in discussing prey importance will be greatest when adult prey weights are many times greater than the juveniles within that population and when the juveniles are still available for consumption (Craighead and Craighead 1956, Earhart and Johnson 1970, Marti 1974). Since the caloric equivalent of an individual prey item is mass-dependent, the development of appropriate osteologic measurements which can be applied to pellet remains is needed so that prey biomass

can be estimated more accurately. Hamilton (1980), and Goszczynski (1977) used allometric equations to estimate individual biomass of small rodents from measurements of the length of lower mandibles found in pellets. Goszczynski (1977) found that in common voles (Microtus arvalis), the estimation of body weight based on lengths of mandibular incisors found in pellets was accurate for all size classes except those where individuals were heavier than 25 g. Allometric equations for determining prey mass provide two advantages: 1) they more precisely estimate the energy intake of the owls studied; and 2) information concerning size and age class selection is incorporated into the study.

This study examines different procedures of pellet analysis in order to determine what sampling bias exists in comparison of subgroupings of pellets from a sample of Long-eared Owl pellets. In addition, I have outlined a procedure whereby pellet analysis results in more accurate prey biomass estimates. Lastly, I have applied my procedure to a sample of Long-eared Owl pellets so that comparisons can be made between the biomass calculated from the use of mandible lengths of northern pocket gophers (Thomomys talpoides) with data calculated from average adult weights of this species.

METHODS

Laboratory Analysis

Identification of prey items in pellets entails identification of hard material including skulls and mandibles of small mammals, fish scales, insect exoskeletons or jaws, or portions of long bones of animals too large to be eaten whole in a single feeding period by owls. I estimated the number of birds represented in each pellet from remains of skulls, legs, feet, sterna, and feathers. Heads, jaws, and pincers were used to identify arthropods and estimate the numbers of each species. Remains of mandibles and/or skulls were used to determine the identity and to estimate the numbers of small mammals found in each pellet.

Prior to their dissection all whole pellets from each sample were placed randomly on a numbered grid. A random number chart was then used to determine the order in which whole pellets were dissected and to ensure no bias in pellet selection owing to size, shape, and/or color. For these randomly chosen pellets, care was taken to record data so that I could retrieve information on remains from individual pellets (Figure 1). Pellet fragments were also analyzed,

<u>AREA</u>	<u>SPECIES</u>	<u>PAIR #</u>	<u>DATE</u>	<u>WINTER</u>	<u>NEST</u>	<u>SUMMER</u>
<u>work sheet- individual pellets</u>						
<u>1-10</u>	<u>11-20</u>	<u>21-30</u>	<u>31-40</u>	<u>41-50</u>		
1	11	21	31	41		
2	12	22	32	42		
3	13	23	33	43		
4	14	24	34	44		
5	15	25	35	45		
6	16	26	36	46		
7	17	27	37	47		
8	18	28	38	48		
9	19	29	39	49		
10	20	30	40	50		
<u>THOMOMYS</u> <u>mandible</u>	<u>MICROTUS</u> <u>mandible</u>	<u>LAGURUS</u> <u>mandible</u>	<u>SYVILAGUS</u> <u>diastema</u>			
14	7	6	4			
15	8	7	5			
16	9	8	6			
17	10	9	7			
18	11	10	8			
19	12	11	9			
20	13	12	10			
21	14	13	11			
22	15	14	12			
23	16	15	13			
24	17	16	14			
25	18	17	15			
26	19	18	16			

Figure 1. Food data table.

but remains from these were recorded separately. In addition to identifying species of mammals and estimating their numbers represented in each pellet, I recorded lengths of mandibles, or of diastemas with incisors removed, for the various species (Figure 1). These measurements enabled me to estimate the body mass of each individual, and collectively therewith the average biomass of each species represented. This was accomplished by using allometric equations based on data recorded from museum specimens (Hamilton 1980, Janes and Barss In press). Values for biomass were also estimated by averaging weights from specimens in collections of mammals at Portland State University and Oregon State University. This information was then used to estimate the biomass consumed by each owl per day.

I chose not to consider seasonal differences in weights within a prey species as outlined by Nilsson (1981), since decreases in adult weights due to winter stress were assumed to be similar. Weight of prey species for the winter months in Nilsson's study dropped to as much as 80% of the summer values. Such weight reductions would not be observed osteologically and therefore make prey biomass values substantially lower than reported in many studies (Marti 1974, Seidensticker 1968, Voight and Glenn-Lewin 1978). Despite the possible over-estimation of biomass consumption by owls during the winter months, the relative

percentage of prey biomass calculated for each species should remain proportionally similar.

Data Analysis

Data recorded from each collection of pellets were analyzed to estimate average number of prey consumed daily by Long-eared Owls (Figure 1). A random sample of the pellets collected from a single roost was also chosen in order to estimate the minimum number of pellets required to determine which species of prey captured by Long-eared Owls represent more than 2 per cent of the total biomass. This same sample was also used to determine the number of pellets needed to estimate prey species diversity. The Shannon-Weiner index was used to determine prey species diversity for these samples.

The data listed in Figure 1 were used to calculate prey species biomass (Figure 2). Figure 2 includes information on prey species, number of prey consumed, mean mass of larger prey items determined by use of allometric equations, mean biomass of other prey species, and percent total biomass for each prey species. A pellet collection taken from one roost on the Lawrence Grassland Preserve was selected to determine the difference between biomass calculations based on adult weights of T. talpoides consumed and those based on the use of allometric equations. A comparison of the potential error arising from use of only

AREA	SPECIES	PAIR #	DATE	WINTER	NEST	SUMMER
SPECIES LIST - PREY ITEMS						
SPECIES	NUMBER	% #	BIOMASS	% BIOMASS	NOTES	
L. cal					T.t. x=	g.
S. nut					M.m. x=	g.
S. bel					S.n. x=	g.
S. tow					L.c. x=	g.
T. tal						
N. cin					T.t. mandible	
D. ord					14	21
M. mon					15	22
L. cur					16	23
P. man					17	24
P. par					18	25
R. meg					19	26
S. vag					20	
S. mer						
TOTAL					M.m. mandible	
MAMMALS					8	15
					9	16
Sm bird					10	17
Med bird					11	18
Lg bird					12	19
					13	
TOTAL					14	
BIRDS						
TOTAL					L.c. mandible	
REPTILES					4	13
TOTAL					5	14
FISH					6	15
TOTAL					7	16
INVERTS					8	17
					9	18
					10	
TOTAL					11	
ITEMS					12	
MEAN MASS - Total Species x= grams						

1. Abbreviations: - L. cal (Lepus californicus), S. nut/ S.n. (Sylvilagus nuttallii), S. bel (Spermophilus beldingi), S. tow (Spermophilus townsendii), T. tal/ T.t. (Thomomys talpoides), N. cin (Neotoma cinerea), D. ord (Dipodomys ordii), M. mon/ M.m. (Microtus montanus), L. cur/ L.c. (Lagurus curtatus), P. man/ P.m. (Peromyscus maniculatus), P. par/ P.p. (Perognathus parvus), R. meg (Reithrodontomys megalotis), S. vag (Sorex vagrans), S. mer (Sorex merriami).

Figure 2. Food data - final table.

adult mean biomass of prey consumed to those biomass values derived from allometric equations was then calculated for this one sample.

RESULTS

Biomass Consumption

All pellets from a large sample recovered from the Lawrence Memorial Grassland Preserve were divided into subsets of either 10 or 20 pellets to determine if accurate estimates of daily biomass consumption might be made from only a portion of the total pellet sample. Results from this sample are shown on Table I. The average daily biomass consumption based upon 10 pellets is 46.8 (R= 42.9-51.7) g. Using 20 pellets per group results in the estimation of 46.6 (R= 45.2-48.0)g of prey per owl per day. Standard deviations of the samples tested range from 15.4 g to 20.3 g. (Table I). Analysis of these data by Student's t-test found that $t = 0.053$. The results show no statistical difference between the accuracy of the two samples tested. The high variability in the daily consumption of biomass is expected because of the several different species of prey which might be captured each day. These results suggest that adequate accuracy in the estimation of daily biomass can be attained with samples of 10 pellets.

TABLE I

SAMPLE BIAS FOR DETERMINATION OF AVERAGE BIOMASS
CONSUMPTION BY LONG-EARED OWLS.

10 PELLET AVERAGES

<u>SAMPLE NUMBER</u>	<u>BIOMASS g.</u>	<u>S.D.</u>	<u>MEANS g.</u>
1	429	15.6	42.9
2	474.5	15.8	47.5
3	516.5	17.4	51.7
4	450	20.3	45.0

X1 AVERAGE = 46.8

S.D. TOTAL = + 3.78 g.

20 PELLET AVERAGES

<u>SAMPLE NUMBER</u>	<u>BIOMASS g.</u>	<u>S.D.</u>	<u>MEANS g.</u>
1	903.5	15.4	45.2
2	959	18.3	48.0

X2 AVERAGE = 46.6

S.D. TOTAL = + 2.55 g.

Student's t-test of X1 and X2 = 0.053 (D.F. = 4)

TABLE II

ANALYSIS OF SAMPLING BIAS TO DETERMINE NUMBER OF LONG-EARED
 OWL PELLETS NEEDED TO FIND ALL SPECIES WHICH
 REPRESENT MORE THAN 2 PER CENT OF
 PREY BIOMASS IN PELLETS.

SAMPLE NUMBER	# SPECIES $\frac{1}{2}$ 2%	PELLETS NEEDED FOR	
		n-1 species :	n species

1	5	24	31
2	7	14	26
3	4	14	24
4	5	2	4
5	5	4	6
6	7	7	8
7	6	4	13
8	6	20	50
9	5	5	24
10	5	7	29
11	5	7	8

X1= 5.5

X2= 9.8

X3= 20.3

S.D.= + 0.9

S.D.= + 7.2

S.D.= + 14.0

Determination Of Species Diversity

Estimates of the sample size needed to determine all of the prey species representing more than 2% of the total biomass of a given pellet collection were based on 11 different pellet collections. An average of 5.5 pellets was needed to determine this category based on my samples (Table II). An average of 20.3 pellets was needed to include all species of prey that were found in the total sample of pellets studied from each roost. An average of 9.8 pellets was found to include all but one species of prey that were consumed by Long-eared Owls as compared to the total sample. These results suggest that all major prey species of Long-eared Owls can be determined quickly by only portions of a pellet sample.

Statistical Analysis Of Species Diversity

Species diversity of prey captured by Long-eared Owls was estimated from one pellet sample by use of the Shannon index (Table III). The resulting non-dimensional number H' increases in value as either the number of prey species captured by predators or the uniformity of their occurrence increase or both. These pellets were divided to determine what sample size is needed to estimate this index. Use of 20 pellets per group resulted in an average H' value of 0.89. This value is slightly lower than the H' value of

1.06 which was calculated from the total sample. This difference is considered minimal based upon comparisons of this index to those in different studies of Long-eared Owls.

Comparison Of Methodologies

Comparison of biomass values based upon weights of adult gophers to values estimated from the use of allometric equations shows that use of allometric equations markedly changed the per cent biomass calculated in this pellet sample (Table IV). The biomass of T. talpoides was reduced from 62.8% based upon adult weights to only 35.5% of the total biomass of the sample. In addition, without the use of the allometric equation the average prey weight of the sample is 47.6 g which is approximately 7 g more than the average daily biomass consumed by Long-eared Owls as determined earlier in this study. The importance of larger prey items in the diets of Long-eared Owls may be highly inflated unless care is taken to determine average biomass of larger food items.

TABLE III

ANALYSIS OF SAMPLE BIAS OF SPECIES DIVERSITY OF PREY
CAPTURED BY LONG-EARED OWLS 10-23-80.

<u>SAMPLE SIZE</u>	<u>H' VALUES</u>
<u>10 pellets</u>	<u>.85</u>
<u>20 pellets</u>	<u>.74</u>
<u>30 pellets</u>	<u>.83</u>
<u>40 pellets</u>	<u>1.04</u>
<u>50 pellets</u>	<u>.99</u>
<u>Total pellets</u>	<u>1.06</u>

10 Pellets per Group

<u>Sample Number</u>	<u>H' Values</u>
<u>1</u>	<u>.85</u>
<u>2</u>	<u>.50</u>
<u>3</u>	<u>.85</u>
<u>4</u>	<u>1.21</u>
<u>5</u>	<u>.74</u>

$$\underline{X = .83}$$

20 Pellets per Group

<u>Sample Number</u>	<u>H' Values</u>
<u>1</u>	<u>.74</u>
<u>2</u>	<u>1.04</u>

$$\underline{X = .89}$$

TABLE IV

OBSERVED DIFFERENCES IN BIOMASS VALUES BASED UPON REPORTED
ADULT NORTHERN POCKET GOPHER WEIGHTS TO BIOMASS VALUES
CALCULATED BY USE OF ALLOMETRIC EQUATIONS FOR THIS
SAME SPECIES.

<u>Area</u>	<u>SPECIES</u>	<u>PAIR #</u>	<u>DATE</u>
Lawrence	L.E.O.	West Ravine	1978 to 1983

<u>PREY¹</u>	<u>#PREY</u>	<u>% Biomass(Adult Wt.)</u>	<u>% Biomass(Allometric)</u>
		<u>T.tal = 120 grams</u>	<u>T.tal. = 39.4 grams</u>
S. nut.	2	0.2	0.3
T. tal.	560	62.8	35.5
M. mon.	192	5.4	9.4
L. cur.	836	19.5	33.9
P. man.	349	6.9	11.9
P. par.	169	3.2	5.5
R. meg.	4	Tr	0.1
S. vag.	10	0.1	0.1
S. mer.	8	Tr	0.1
S. species	7	Tr	0.1
TOTAL			
MAMMALS	2,137	98.1	96.8
TOTAL			
BIRDS	41	1.8	3.2
TOTAL			
INVERTS	70	Tr	0.1
TOTAL PREY 2,248			
AVERAGE WT. PREY		47.6 grams	27.3 grams

¹ abbreviations as in Figure 2 page 10

DISCUSSION

Methodology

The methodology used in this study demonstrates that pellet analysis provides an useful approach to many areas of predator/prey relationships. The figures introduced for data tabulation as well as care in storage, randomization of whole pellets for analysis, and measurement of mandibular lengths all contributed to more accurate analysis of data.

The use of skulls or mandibles for determination of total individuals within each pellet was chosen despite possible inaccuracies. Marti (1974) thought that numbers of skulls provided the most accurate estimate of the number of small mammals represented in each pellet. However, I observed that during the owls' breeding season, some pellets contained only portions of small mammals represented in a pellet by skulls or mandibles. In such cases the owl has not eaten the whole animal. Nevertheless, I assumed that by using a large enough sample of pellets, the estimate of prey biomass based on the sample will provide an accurate average biomass of prey captured by a given pair of owls.

The methodology presented here seeks to maximize the amount of information recovered from pellets while minimizing laboratory time. Measurement of mandibles of prey species found in pellet remains does not greatly increase the time spent in pellet analysis, but it markedly improves estimates of prey biomass. Care in recording data so that each pellet is considered separately allows the possibility that data can be quickly reanalyzed if new analyses are developed.

Sample Size Bias

Many previous studies have examined the food habits of Long-eared Owls and other owl species (Marti 1974, Seidensticker 1968, Village 1981); however, none of these determined what bias exists in using pellet collections of variable size. Based on my examination of this bias, I recommend that the following procedure be adopted as a standard for the analysis of owl pellets. First, care should be taken so that all pellets are collected from an owl roost site. Random selection of pellets from the whole sample is most accurately accomplished within the laboratory. Secondly, a random sample of 20 pellets provides the adequate data needed to determine composition of the prey population most important to the owl during the season studied. In addition, the estimation of average daily prey consumption, taxon selection, and prey species diversity can be determined. The remaining pellets not

dissected can easily be stored in a freezer to ensure that destruction of material by insects will not occur. Lastly, if more accurate biomass values are to be calculated later, the sample can be studied further. The benefits resulting from this procedure include substantial reductions in time spent on pellet analysis.

Researchers can use several alternate pellet analysis methodologies. Those interested in inventorying small mammal populations in a local area should choose to analyse pellets following the above procedure. If more detailed pellet analysis is desired for the purpose of studying trends in size selection within a taxon, the researcher may need to analyse all of the pellets encountered when in the field. The additional benefits of such an approach include increased accuracy of information on average prey biomass, and evidence of rare and/or unusual prey that might only be captured occasionally by a predator.

Species Diversity

The use of pellets to determine species diversity of prey captured by owls has only recently been documented (Herrera and Hiraldo 1976, Kallander 1977, Nilsson 1981). Accurate species diversity indices could be calculated from as few as 20 pellets. I calculated Shannon indices of 0.89 a value similar to those reported for Long-eared Owls in Europe ($H' = 0.5 - 1.47$). It should be mentioned here that these values are much less than those observed in Part

II of this study. It is believed that the collection of pellets from all seasons of the year more accurately represents the actual species utilization by Long-eared Owls. Seasonal sampling is very important in habitats having prey species which show seasonal behavior patterns or which produce young only once during the year.

Measurement Of Mandibular Lengths

The use of allometric equations to estimate prey biomass from mandibular lengths provides an important tool for greater insight into predator/prey interactions. The use of a single mean body mass value for prey which vary widely in size, such as mammals, nidifugous birds, fish, reptiles, etc., can result in highly inaccurate biomass estimates. Body mass values used in studies of northern pocket gophers (Marti 1974, and Craighead and Craighead 1956) were almost three to five times greater (75-200 g) than values based on mandibular measurements (39.4 g , Table IV). Such errors contribute to overestimates of the breadth of size selection for many species of owls. Goszczynski (1977) found that measurement of mandibles collected in scats and pellets produced by predators of the Common Vole (Microtus arvalis) in Poland provided information on size class selection within this taxon. If large pellet collections are analyzed it is possible to observe trends in annual and seasonal size class selection of individuals within a species, as is shown in Part II .

Taxon Selection

One surprising finding of this study was that analysis of as few as 20 pellets may account for all prey species that comprise more than two per cent of the prey biomass of a Long-eared Owl pair's diet. Although not all species which are fed upon by Long-eared Owls may be encountered in such a small sample, all ecologically important species for that owl pair are likely to be represented. It should be noted that unless care is taken to sample a locality seasonally, certain important prey species may not be represented in the analysis. This is especially true in temperate environments where many animals show seasonal changes in their behavior. The short breeding seasons of most of the non-microtine rodents is a case in point (see Part II).

PART II

INTRODUCTION

A variety of prey is captured by Long-eared Owls in the north temperate regions of North America, Europe, and Asia (Craighead and Craighead 1956, Grossman and Hamlet 1964, Herrera, and Hiraldo 1976, Kallander 1977, Korschgen and Stuart 1972, Marti 1974, Nilsson 1981, Uttendorfer 1952, Village 1981, Voight and Glenn-Lewin 1978). More than 100,000 pellets have been analysed to observe trends in prey selection by Long-eared Owls. Most of these studies describe the habitat, nest selection, productivity, and food habits of Long-eared Owls.

Previous research on the feeding ecology of owls has rarely considered the importance of seasonal fluctuations of prey populations or how those fluctuations might affect an owl's foraging strategies. Studies of many of the prey species eaten by Long-eared Owls reveal diverse behavioral patterns which would affect the availability of prey to the owls (Getz 1961, Goszczynski 1977, Hansson 1969, Hansson 1960, Kallander 1977, Turner, Hansen, Reid, Teitjen, and Ward 1973). There are also seasonal differences in

the behavior of a given prey species, including seasonal differences in reproductive behavior, foraging behavior, or time spent aboveground. For example, emergence times for estivating or hibernating animals will affect availability of those animals to predators. Changes in shelter for the prey and food resource availability also vary seasonally. This spectrum of variables should be reflected in modified foraging strategies and significant differences in prey selection by avian predators. The only research that has attempted to address seasonal variability of food habits of Long-eared Owls as well as interpair habitat differences were studies by Marti (1976) and Nilsson (1981). Unfortunately, neither Marti nor Nilsson used allometric equations to determine the approximate body mass of captured prey. Hence, estimates of larger prey biomass were biased.

Few studies on the feeding ecology of Long-eared Owls have been conducted in Washington and Oregon (Knight 1977, Maser and Brodie 1966, Maser 1970, Reynolds 1970). Of these studies, none was conducted for more than three years, nor did any deal with seasonal variability of food habits. Most studies of food habits of Long-eared Owls were conducted during the winter when the owls gathered in flocks. Seasonal shifts in prey importance are not revealed in such studies.

This study assesses the food preferences of pairs of Long-eared Owls found in three different floral communities and determines the effects of seasonality on prey selection.

My objectives in this study were : 1) to develop a procedure which would incorporate data concerning individual prey size in order to reveal seasonal trends in size of prey selected by owls; 2) to look for interpair, seasonal, and habitat differences in prey taken; and 3) to determine whether such patterns in prey selection, if they exist, are stable or vary from one year to the next. These data are germane to the larger ecological question of whether Long-eared Owls can be characterized as generalists or specialists. These data may also demonstrate selection for prey relative to optimal size. The results of this study should be important for making intelligent decisions concerning the management of Long-eared Owls.

STUDY AREA

The three areas selected for this study are located in northcentral Oregon. They are the Lawrence Memorial Grassland Preserve, range and agricultural lands within the Antelope Valley, and highly disturbed grazing lands in the Clarno Basin. The total study area covers 311 km² and includes the communities of Antelope and Clarno.

The weather station nearest the study area is in the town of Antelope (Rajneesh). Rainfall there over the past forty years has averaged 32.2 cm. Average monthly temperatures for this same time period range from 19.5 °C in July to - 0.9 °C in January. Winter temperatures below - 18 °C and summer temperatures above 38 °C are not uncommon. The rainfall averages recorded in Antelope are most applicable to the Antelope Valley and are the best available for the Lawrence Grassland and the Clarno Basin. There is a trend toward higher temperatures and decreased rainfall as one goes from west to east through the study area. Temperature records taken at Camp Hancock Field Station in the Clarno Basin are 3° to 8 °C higher in the spring and summer than those in the Antelope Valley. Winter

Figure 3. The locations of the study areas in Wasco and Wheeler Counties, Oregon.

temperatures are similar in both areas. Trends in rainfall are partially reflected in the rate of desiccation of annual plants in each of the study sites.

The Lawrence Grassland is located in Wasco County, approximately 10 km southwest of the town of Shaniko. The preserve is approximately 1040 m above sea level. The grassland is primarily composed of a mosaic of mound and intermound areas classified as biscuit scabland (Franklin and Dyrness 1973). Noticeable differences exist in vegetation of the mounds and intermounds. The typical plant species occupying the mounds consist of bluebunch wheatgrass (Agropyron spicatum ¹) and Idaho fescue (Festuca idahoensis). The principal species in the intermound areas are scablands sage (Artemisia rigida), various biscuit-roots (Lomatium sp.), and Sandberg's bluegrass (Poa sandbergii) (Youti 1975). In addition to this vegetational mosaic, several draw systems are found in the study area. They contain various plant species including bluebunch wheatgrass, Sandberg's bluegrass, giant wildrye (Elymus cinereus), syringa (Phiadelphus lewisii), big leaf sage (Artemisia tridentata), common chokecherry (Prunus virginiana), western juniper (Juniperus occidentalis), and black hawthorn (Crataegus douglasii). Shrubs and trees within the draws provide most of the roosts and nesting sites frequented by

¹ Plant identification and species names taken from Hitchcock 1973

the Long-eared Owls on the preserve.

The Antelope Valley is characterized by low rolling hills used predominantly for agriculture and for cattle ranching. Soils 1.3 to 1.6 m deep are not uncommon and are considerably deeper than in either the Lawrence Grassland or Clarno Basin. Although little of the native plant community remains within the valley as a whole, the study site is vegetated primarily by bluebunch wheatgrass, big leaf sage, matchweed (Gutierrezia sp.), rabbitbrush (Chrysothamnus sp.), and western juniper. Elevations range from 670 m to 1070 m . The study site is situated at an elevation of approximately 700 m .

The Clarno Basin covers parts of both Wasco and Wheeler Counties. Elevations of the region vary from 410 m along the John Day River to 1220 m at the top of Iron Mountain. The basin generally has a hilly, much eroded landscape consisting primarily of thin, rocky soils and relatively sparse vegetation. The riparian communities along the John Day River are an exception, but they constitute less than 5% of the habitat found within the basin. Junipers are scattered throughout the area with densities of more than 500 trees per sixteenth-section in higher draws. Most Long-eared Owl territories are situated in the upper ravines about 600 m to 700 m above sea level. No active territories were found in the riparian communities, although several inactive nest sites were found in ravines within 0.4 km of the John Day River. The plant

communities found within the territories of Long-eared Owls studied were typified by dense associations of western juniper and big leaf sage surrounded by open fields of matchweed, rabbitbrush, and cheatgrass (Bromus tectorum). The patches of juniper provide excellent habitat for roosting owls. The great number of these patches within the Clarno Basin provides more numerous nesting and perching sites for the owls than can be found in either the Antelope Valley or the Lawrence Grassland.

METHODS

Preliminary Survey

A general survey of owl populations in the Clarno Basin was conducted from 1972 to 1974 to determine the number of species, species density, roost sites, and productivity of each species encountered. Pellets were collected beneath nest sites and roost sites where the species of owl were identified, and were later analyzed for their contents. Specific pairs of owls were then selected for more intensive study from 1975 to 1983, and their pellets were collected throughout the year. Selections were based upon those owl pairs which could be located with moderate ease. Although observations of Great Horned Owls and Barn Owls were continued throughout the study, most of my attention was directed towards finding additional pairs of Long-eared Owls in different habitats having close proximity to the Clarno Basin. After 1977, four pairs of owls became the focus of my field work. One pair was located in each of the three different areas selected for study. A second pair of owls from the Lawrence Grassland was included in the study to determine if the foraging

behavior of this pair was similar to that of the other pair studied from the same area.

Field Work

I collected pellets from beneath nests, roosts, and loafing sites of the four pairs of Long-eared Owls. Pellets were kept in "zip-lock" plastic bags until they were analyzed. The bags were stored carefully to minimize breakage of pellets. Data recorded for each pellet collection included site, date, general information concerning the roost, and any owl activity observed during the visit. All pellets were removed from beneath roosts to ensure that only recent pellet material would be collected subsequently.

When flocks of wintering owls were found within the study area, attempts were made bimonthly to collect pellets from beneath their roosts. These collections provided information on food habits and indicated arrival and departure times for each owl flock. Nest sites were visited only once during the breeding season to minimize disturbance of incubating females.

I observed activity of owls on moonlit nights during the summers of 1982 and 1983. The intensity and duration of activity and its proximity to the nest were recorded. Most observations lasted several hours at different times during the late afternoon, evening, or early morning. In

the 1982 nesting season, an attempt to use telemetry to follow the owls during the evenings was unsuccessful.

Sherman live traps and Museum Special traps were used to sample small mammal populations on the Lawrence Preserve during each season of 1982. The data collected were inadequate for statistical analysis although they supplied information on weights of small mammals and trends in species composition within the preserve.

Data Analysis Of Pellets

Pellets were dissected following the procedure outlined in Part I of this study. Data was recorded so that trends in seasonality of prey capture could be analyzed. Kriskal/Wallis H tests were used to determine whether interhabitat differences exist between Long-eared Owl pairs, and if there was any variability in prey taken by a single pair of Long-eared Owls. The Shannon- Weiner index was used to calculate food niche-breadth of each owl pair. Additionally, calculations were made for each year of the study. Variability in the size and age classes of T. talpoides captured by Long-eared Owls was analyzed by use of mandible lengths found in pellets (Hamilton 1980, Goszczynski 1977).

RESULTS

Pairs of Long-eared Owls were present in all three areas throughout the study. The owls occupied territories for three to five months during the breeding season and from one to five months during the fall and winter. More than 3,000 pellets were analyzed, yielding 9,981 identified food items, mostly remains of small mammals (Tables V through VIII). The average biomass consumed by each owl each day was estimated to be 48.3g (S.D. = 20.2g).

In all three sites, the two prey species most frequently captured comprised about two-thirds of the total biomass taken. Northern pocket gophers (T. talpoides), and sagebrush voles (L. curtatus) shared equal rank in biomass consumed by both owl pairs on the Lawrence Grassland. These prey species comprised 69 % of the biomass captured by the owls. Great Basin pocket mice (P. parvus) comprised 40% of the biomass consumed by the owls in the Clarno Basin. The addition of the next most significant species, deer mice (P. maniculatus), accounted for 65% of the total biomass captured. P. maniculatus was the primary food source of the Antelope Valley pair, comprising 35% of

the biomass they captured. Montane voles (M. montanus), the second most commonly captured species, were 31% of the consumed biomass..

Data shown on Tables V through VIII includes all pellet remains from each pair of Long-eared Owls studied. In contrast, Figures 4 through 7 present data on prey items for each year pellet remains were found in the territories of the pairs of Long-eared Owls studied. Figures 8 through 13 present the same data listed by species rather than by territory. These figures permit easy comparison of use of prey by owls from different environments. Kruskal/Wallis H tests of these data (Tables IX and X) revealed that prey selection for T. talpoides , L. curtatus , P. maniculatus , M. montanus , and P. parvus was significantly different in the three study sites. The two pairs of Long-eared Owls on the Lawrence Grassland did not vary significantly from each other in prey selection.

The greatest variation in prey selection was in the Antelope Valley and Clarno Basin. In the Clarno Basin the capture of P. parvus during 1978 and 1979 was only about half of that recorded for this species during the other years of the study, whereas the capture of T. talpoides increased so that this species was the primary prey item in terms of biomass in 1978 and secondary in 1979. In the Antelope Valley, during 1981 and 1982, M. montanus changed from 26% to 52% of the total prey biomass taken. During

TABLE V

LONG-EARED OWL FOOD DATA FROM 1978 TO 1983 ON THE
LAWRENCE GRASSLAND PRESERVE (WEST RAVINE).

PREY SPECIES CONSUMED				
SPECIES ¹	NUMBER	% #	BIOMASS G.	% BIOMASS
L. cal				
S. nut	2	0.1	190	0.3
S. bel				
S. tow				
S. lat				
T. tal	560	24.9	21,867	35.5
D. ord				
M. mon	192	8.5	5,760	9.4
L. cur	836	37.2	20,900	33.9
P. man	349	15.5	7,329	11.9
P. par	169	7.5	3,380	5.5
R. meg	4	0.2	48	0.1
S. vag	10	0.4	60	0.1
S. sp.	7	0.3	42	0.1
S. mer	8	0.4	48	0.1
TOTAL MAMMALS	2,137	95.1	59,624	96.8
Sm bird	35	1.6	1,050	1.7
Med bird	4	0.2	400	0.7
Lg bird	2	0.1	500	0.8
TOTAL BIRDS	41	1.9	1,950	3.2
TOTAL REPTILES				
TOTAL FISH				
TOTAL INVERTS	70	3.1	35	0.1
TOTAL ITEMS	2,248	100.0	61,609	100.1
AVERAGE WEIGHT - Total Species x= 27.3 grams				

¹ abbreviations as in Figure 2 page 10

TABLE VI

LONG-EARED OWL FOOD DATA FROM 1981 TO 1983 ON THE
LAWRENCE GRASSLAND PRESERVE (EAST RAVINE).

SPECIES ¹	PREY SPECIES CONSUMED			
	NUMBER	% #	BIOMASS G.	% BIOMASS
L. cal				
S. nut				
S. bel				
S. tow				
S. lat				
T. tal	194	29.0	6,936	37.7
D. ord				
M. mon	80	12.0	2,400	13.0
L. cur	231	34.6	5,775	31.4
P. man	90	13.5	1,890	10.3
P. par	58	8.7	1,160	6.3
R. meg				
S. vag	1	0.1	6	tr
S. sp.				
S. mer	3	0.4	18	0.1
TOTAL				
MAMMALS	657	98.4	18,185	98.8
Sm bird				
7 1.0 210 1.1				
Med bird				
Lg bird				
TOTAL				
BIRDS	7	1.0	210	1.1
TOTAL				
REPTILES				
TOTAL				
FISH				
TOTAL				
INVERTS	4	0.6	2	tr
TOTAL				
ITEMS	668	99.9	18,397	99.9
AVERAGE WEIGHT - Total Species x= 27.5 grams				

¹ abbreviations as in Figure 2 page 10

TABLE VII

LONG-EARED OWL FOOD DATA FROM 1974 TO 1980
IN THE CLARNO BASIN .

PREY SPECIES CONSUMED				
SPECIES ¹	NUMBER	% #	BIOMASS G.	% BIOMASS
L. cal				
S. nut	25	0.5	3,010	2.6
A. pal	8	0.2	216	0.2
M. sp.	1	tr	5	tr
S. lat				
T. tal	224	4.5	9,936	8.7
D. ord	46	0.9	3,128	2.7
M. mon	465	9.4	13,950	12.2
L. cur	42	0.8	1,050	0.9
P. man	1,325	26.6	27,825	24.3
P. par	2,283	45.9	45,660	39.9
R. meg	334	6.7	4,008	3.5
S. vag	10	0.2	60	0.1
S. sp.				
S. mer				
TOTAL				
MAMMALS	4,763	95.8	108,848	95.2
TOTAL				
Sm bird	40	0.8	1,200	1.0
Med bird	33	0.7	3,300	2.9
Lg bird	3	0.1	900	0.8
TOTAL				
BIRDS	76	1.6	5,400	4.7
TOTAL				
REPTILES				
TOTAL				
FISH				
TOTAL				
INVERTS	133	2.7	66	0.1
TOTAL				
ITEMS	4,972	100.0	114,314	99.9
AVERAGE WEIGHT - Total Species $\bar{x}$ = 23.0 grams				

¹ abbreviations as in Figure 2 page 10

TABLE VIII

LONG-EARED OWL FOOD DATA FROM 1975, 1978, 1979,
1981, AND 1982 IN THE ANTELOPE VALLEY.

SPECIES [†]	NUMBER	PREY SPECIES CONSUMED		
		% #	BIOMASS G.	% BIOMASS
L. cal				
S. nut	10	0.5	1,535	2.8
A. pal	1	tr	27	tr
S. tow				
S. lat				
T. tal	172	8.2	8,692	15.6
D. ord	2	0.1	136	0.2
M. mon	584	27.9	17,520	31.5
L. cur	87	4.2	2,175	3.9
P. man	919	43.9	19,299	34.7
P. par	245	11.7	4,900	8.8
R. meg	52	2.5	624	1.1
S. vag	2	0.1	12	tr
S. sp.				
S. mer				
TOTAL				
MAMMALS	2,074	99.0	54,920	98.8
Sm bird	13	0.6	390	0.7
Med bird	3	0.1	300	0.5
Lg bird				
TOTAL				
BIRDS	16	0.7	690	1.2
TOTAL				
REPTILES				
TOTAL				
FISH				
TOTAL				
INVERTS	5	0.2	2	tr
TOTAL				
ITEMS	2,095	100.0	55,612	99.8
AVERAGE WEIGHT - Total Species x= 26.5 grams				

[†] abbreviations as in Figure 2 page 10

Figure 4. The diets of the west ravine Long-eared Owl pair of the Lawrence Grassland for the years 1978, 1979, 1980, 1981, and 1982.

Figure 5. The diets of the east ravine Long-eared Owl pair of the Lawrence Grassland for the years 1981 and 1982.

Figure 6. The diets of the Clarno Basin Long-eared Owl pair for the years 1974, 1975, 1976, 1977, 1978, 1979, and 1980.

Figure 7. The diets of the Antelope Valley Long-eared Owl pair for the years 1975, 1977, 1979, 1981, and 1982.

Figure 8. Comparison of the predation of T. talpoides by the four pairs of Long-eared Owls.

Figure 9. Comparison of the predation of L. curtatus by the four pairs of Long-eared Owls.

Figure 10. Comparison of the predation of M. montanus by the four pairs of Long-eared Owls.

Figure 11. Comparison of the predation of *P. maniculatus* by the four pairs of Long-eared Owls.

Figure 12. Comparison of the predation of P. parvus by the four pairs of Long-eared Owls.

Figure 13. Comparison of the predation of all other species captured by the four pairs of Long-eared Owls.

TABLE IX

VARIATION IN THE BIOMASS OF FIVE PREY SPECIES CONSUMED BY
LONG-EARED OWLS FROM THREE STUDY SITES.

SPECIES	H VALUE	df	P
<u>T. talpoides</u>	10.08	2	<.01 *
<u>L. curtatus</u>	10.97	2	<.01 *
<u>P. maniculatus</u>	10.19	2	<.01 *
<u>M. montanus</u>	12.45	2	<.01 *
<u>P. parvus</u>	12.23	2	<.01 *
<u>S. nuttallii</u>	0.51	2	<.80

TABLE X

VARIATION IN THE PREY CONSUMED BY TWO PAIRS OF LONG-EARED
OWLS FROM THE LAWRENCE GRASSLAND.

SPECIES	H VALUES	df	P
<u>T. talpoides</u>	0.00	1	<.99
<u>L. curtatus</u>	1.35	1	<.30
<u>P. maniculatus</u>	0.00	1	<.99
<u>M. montanus</u>	1.35	1	<.30
<u>P. parvus</u>	0.15	1	<.70

* = significant at .05

these same years, the occurrence of P. maniculatus dropped from 58% of prey biomass in 1979 to 13% in 1982.

Significant seasonal changes in prey selection by Long-eared Owls on the Lawrence Grassland occurred for two of the five important prey species (Table XI). This change was most evident in predation on T. talpoides (Figure 14). Between the time pocket gophers disperse from maternal burrows until they attain reproductive maturity, they may grow from 12 g to over 200 g. Figures 15 and 16 show diastema lengths of gophers taken by Long-eared Owls on a seasonal and annual basis, respectively. Juvenile gophers seem to be taken more than adults. There is no evidence that Long-eared Owls prey on large gophers, although data collected from barn owl (Tyto alba) pellets showed that larger gophers were available in the study area. Figure 15 demonstrates the very high rate of capture of immature gophers during the spring and summer. Adult gophers appear to be captured at similar rates at any season. Predation on L. curtatus was extremely varied but not correlated with season (Figure 17).

Shannon-Weiner index equations were diversity indices used to evaluate the diversity of mammalian species represented in pellets in this study range from 1.11 to 1.88 (Table XII). The latter value is comparatively high; values above 1.50 have not been recorded in other Long-eared Owl studies (Kallander 1977).

TABLE XI

SEASONAL VARIATION IN THE DIET OF A PAIR OF
LONG-EARED OWLS - LAWRENCE GRASSLAND
(WEST RAVINE).

SPECIES	H VALUES	df	P
<u>T. talpoides</u>	9.42	3	<.05 *
<u>L. curtatus</u>	4.32	3	<.40
<u>P. maniculatus</u>	6.30	3	<.10
<u>M. montanus</u>	10.06	3	<.02 *
<u>P. parvus</u>	6.32	3	<.10

*= significant at .05

Figure 14. Seasonal variation in the predation of T. talpoides by Long-eared Owls on the Lawrence Grassland from 3/16/80 to 12/27/82.

Figure 16. Annual variation in the predation of T. talpoides by Long-eared Owls from the Lawrence Grassland for the years 1979, 1980, 1981, and 1982.

Figure 17. Seasonal variation in the predation of L. curtatus by Long-eared Owls on the Lawrence Grassland from 3/16/80 to 12/27/82.

TABLE XII

SHANNON-WEINER INDICES OF ANNUAL SPECIES DIVERSITY OF
PREY OF LONG-EARED OWLS (1975-1983).

Owl Pair-	year	# ind.	H' by ind.	H' by bio.
Borthwicks- Antelope Valley				
	1975	873	1.48	1.62
	1978	316	1.48	1.63
	1979	153	1.11	1.15
	1981	443	1.28	1.28
	1982	280	1.44	1.40
MEANS =			1.36	1.42
Juniper Basin - Clarno Basin				
	1974	438	1.44	1.72
	1975	1650	1.61	1.81
	1976	256	1.49	1.62
	1977	439	1.62	1.79
	1978	182	1.87	1.88
	1979	132	1.52	1.53
	1980	1873	1.41	1.52
MEANS =			1.57	1.70
West Ravine- Lawrence Grassland				
	1978	123	1.75	1.69
	1979	627	1.67	1.57
	1980	375	1.67	1.62
	1981	441	1.59	1.40
	1982	686	1.61	1.47
MEANS =			1.66	1.55

DISCUSSION

Diet

Analysis of small mammal remains in pellets from the Long-eared Owls I studied supports the following ideas: 1) juvenile pocket gophers, when they are available, are taken more often than any other mammalian prey; 2) microtines are captured more often than deer mice; 3) pocket mice are also captured more often than deer mice; 4) deer mice can be captured in high enough numbers to be a primary food resource; and 5) the Long-eared Owls tend to be opportunistic feeders.

Small mammals, especially Microtus spp. , are usually the most important food resource of Long-eared Owls (e.g., Marti 1976, Nilsson 1981, Village 1981). In contrast, the primary prey of the Long-eared Owls I studied were pocket gophers, pocket mice, or deer mice depending upon the habitat studied. Furthermore, the owls consumed two-thirds of their dietary requirements from only two different prey species. This suggests specialist tendencies in the behavior of Long-eared Owls in prey selection. The variability of prey selected demonstrates that specific

species available are less important to Long-eared Owls than the availability of prey of appropriate size for capture.

Neither of two microtines (sagebrush and montane voles) represented in the pellets I studied could ever be ranked as being clearly the most important food in terms of biomass. This contrasts sharply with other studies of Long-eared Owl food habits which found that this subfamily of rodents was commonly ranked as the major food resource of these owls. Perhaps this is a reflection of my sampling of different habitats, which are comparatively dry relative to most areas studied by other researchers. Marti (1976) found only two studies where pocket mice were the primary food of Long-eared Owls, as was the case in the Clarno Basin. Both studies were conducted in the Great Basin where drier climatic conditions are often recorded. Future studies of Long-eared Owls in the Great Basin or further south into the Mojave Desert should reveal high predation on pocket mice by these owls.

The use of T. talpoides as a primary prey item has never been reported. Lundberg (1976) found that in Ural Owl (Strix uralensis) populations in central Sweden, 37% of the prey individuals were young water voles (Arvicola terrestris), which can weigh as much as 115 g and have growth patterns similar to those of small pocket gophers.

I found that Long-eared Owls are able to utilize a wide array of different prey species. Primary species were different in each habitat, which suggests that the owls feed

on those populations which are most common in the habitat encountered. Nilsson (1981), found that in Sweden Microtus spp. were captured in greater frequency than Sorex sp., based on numbers of prey available for capture. Goszczynski (1977) observed that woodland species were much less represented in the diet of Long-eared Owls than meadow species. Such studies show that Long-eared Owls tend to hunt in open areas rather than in timber or in areas with dense undergrowth. The habitats selected for this study were such that neither of these two considerations is relevant. The areas have few dense stands of timber and almost no dense undergrowth. Where such conditions do arise they are localized to draws and canyons.

Seasonal Variability

Marti (1974), Nilsson (1981), and Voight and Glenn-Lewin (1978) found large seasonal fluctuations in prey of Long-eared Owls. I also found similar fluctuations in prey captured by Long-eared Owls, particularly in the consumption of T. talpoides and M. montanus. Unfortunately, my data had to be pooled by season when analyzed by the Kruskal/Wallis H test. Weather, impassable roads, and other scholastic pursuits made it impossible to sample pellets on a schedule which included consistent periods of time between collections. Grouping data by season made the analysis insensitive to changes in diet composition that occur at more frequent intervals. Furthermore, seasonal weather

conditions varied in duration and intensity which may affect the meaning of data grouped according to calendar periods. Figures 14 and 15 show definite changes in the selection of prey represented in pellets collected over a period of several weeks. Such major shifts in prey selection show how quickly Long-eared Owls can modify their foraging behavior to take advantage of available prey.

The major seasonal shifts in prey captured by Long-eared Owls were best illustrated in the use of T. talpoides (Figure 15). Juvenile gopher remains are first observed in pellets in late April or early May. They comprise more than three-fourths of the individual gophers captured by the Long-eared Owls during this time period. Predation by Long-eared Owls on adult gophers remains similar throughout the year. The low rate of predation of adult gophers is especially notable when compared with juvenile predation. Availability of adults for capture should change markedly from season to season with this species although no changes are noted in this study. The only variable I believe can affect predation on adult gophers as indicated by the data appears to be the large body mass of adults that effectively removes them from the class of resources capturable by Long-eared Owls. Large size of some adult gophers may cause owls to avoid such individuals or to be unable to capture them. Because some large adult gophers are captured, it seems that difficulty in successful capture is the probable explanation.

The fluctuations in predation on L. curtatus on the Lawrence Grassland appear less cyclic than do those of T. talpoides (Figure 17). Still, the changes in predation on this species from month to month can be remarkable. Figure 14 shows an increase of 34 per cent in capture rate from 7/16/82 to 8/11/82 . This probably corresponds to the period during which the activity of gophers aboveground decreased sharply. Although L. curtatus were active throughout the spring and summer, they were not preyed upon extensively as long as gopher activity remained high. This shift from predation on gophers to predation on microtines varied as to time of onset from year to year. Winter prey of Long-eared Owls consisted primarily of L. curtatus and P. maniculatus . In years when microtine numbers were low, predation on deer mice increased. The increased frequency of capture of microtines during the late winter was probably due to the early onset of breeding by microtines as compared with deer mice or pocket gophers.

Foraging

Much of the recent research involving pellet analysis has attempted to determine the food niche-breadth of various raptor species (Herrera and Hiraldo 1976, Kallander 1977, Nilsson 1981). These values are based upon the Shannon-Weiner index ($H' = -\sum p \log p$), a procedure initiated by MacArthur (1961). This index assumes that sampling of the populations studied is random. Values generated by the

equation are greatest when the abundance of different species in a habitat sampled is equal. Most of the research on the food niche-breadth of Long-eared Owls has been in Europe. H' values from these studies ranged from 0.47 to 1.47 (Hagen 1965, Herrera and Hiraldo 1976, Kallander 1977, Sulkava 1965). The food niche-breadth values I calculated for Long-eared Owls varied from 1.15 in 1979 in the Antelope Valley to a high of 1.88 in 1978 in the Clarno Basin (Table VIII). Many of the H' values seen in this study are greater than those previously reported. The large values appear to be due to the wider array of prey available to the Long-eared Owls I studied. A difference in values of 0.50 is a sizable difference when using this calculation (Herrera and Hiraldo 1976). Unfortunately, analysis of index values cannot be analyzed statistically because they are not normally distributed.

Researchers have generally concluded that Long-eared Owls are prey species specialists (Marti 1974). In contrast, my data suggest that Long-eared Owls are restricted more to the selection of certain weight classes of prey rather than to certain species. T. talpoides is a food resource for several owl species in the study area. Comparison of Long-eared Owl with Barn Owl predation on this species shows that gophers above 120 g were never taken by Long-eared Owls even though larger gophers were available. Presumably, such large gophers were simply too big to be captured successfully. Even the smaller adult gophers were

taken less often by Long-eared Owls than by Barn Owls and Great Horned Owls. The measurement of niche-breadth based on the food remains from pellets of Long-eared Owls reflected the number of species within the size classes used by the owls rather than the number of species found in the territories.

Long-eared Owls migrated within the study areas, although many left the region entirely after young were fledged. In addition, several wintering groups of owls migrated to local areas of high rodent density rather than feeding on alternate prey in close proximity to breeding season roost sites. Wintering Long-eared Owls often moved around the region from month to month. Furthermore, the roosting sites selected varied from year to year and use of a site within a season varied as to length of use, number of owls occupying the site, and of arrival of owls at the site. Energetically, movement is moderately inexpensive for Long-eared Owls as a result of their low wing-loading values. It appears that Long-eared Owls are adapted to find locally high densities of rodents and exploit them until the populations are reduced to low numbers after which the owls move on.

Long-eared Owls which arrived in the study area during the late winter or early spring for nesting were selective in their choice of territory. Despite the constancy in total numbers of owls, nest sites were usually changed from year to year. Such behavior is significant in view of the

scarcity of suitable nests. Nests selected included older nests that were not used in the previous nesting season. An exception to this trend occurred when one pair of Long-eared Owls used the same nest for three consecutive years. In areas where rodent density is high, nests may be used every year. This suggests that the owls' breeding territories are chosen in areas of high rodent densities that are in close proximity to suitable nesting sites. Breeding pairs also varied the amount of time spent near the nest from a few days after the fledging of young to months after the nest was abandoned.

Management Of Long-eared Owls

This study has established that the feeding behavior of Long-eared Owls makes this species especially valuable for analysis of small mammal populations. In a broader sense, these owls' specialization on small mammals as a food resource makes them very compatible with human use of these same habitats. Selection by owls of habitats where high densities of rodents are encountered aids in moderating the increase in size of rodent populations. Such activity benefits both ranchers and farmers by reducing competition of certain rodent species with cattle, and by reducing consumption by rodents of farm crops.

Several important findings were made during this study which are not directly related to the analyses presented. These findings are a result of general observations of

Long-eared Owl behavior which were recorded while collecting pellet samples. Because of the importance of these observations to the management of Long-eared Owls, I briefly introduce the following ideas. To ensure that owls continue to inhabit this section of Oregon in desirable numbers, two steps should be taken: Islands of dense junipers or willows should be set aside on farms and ranches for use by Long-eared Owls as refugia. These refugia could be located along seasonal streams or creeks or in draws. Secondly, nests of black-billed magpies are essential for Long-eared Owls. Many ranchers and farmers find magpies offensive yet they provide almost all of the nests used by Long-eared Owls. Protection of Magpies should be encouraged. Implementation of these steps should provide Long-eared Owls with adequate nesting and roosting sites and assure that this species will continue to be found in sizable numbers.

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APPENDIX

Regurgitated pellet data for each pair of Long-eared Owls studied presented in a table format. The information is a compilation of all pellet samples analysed for each year from each Long-eared Owl territory.

Table 1

Regurgitated pellet data of the Long-eared Owl - 1978
(Lawrence Memorial Grassland Preserve)
(West Ravine Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	39	31.7	975.0	35.8
<u>Thomomys talpoides</u> Northern Pocket Gopher	36.6	27	22.0	988.0	30.0
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	16	13.0	336.0	10.2
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	16	13.0	320.0	9.7
<u>Microtus montanus</u> Mountain Vole	30.0	14	11.4	420.0	7.6
Other Species	---	7	5.7	254.0	7.7
<u>Totals</u>	-----	123	99.8	3293.0	100.0

Table 2

Regurgitated pellet data of the Long-eared Owl - 1979
(Lawrence Memorial Grassland Preserve)
(West Ravine Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	243	38.8	6,073.0	39.0
<u>Thomomys talpoides</u> Northern Pocket Gopher	31.4	150	23.9	4,712.0	30.3
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	86	13.7	1,806.0	11.6
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	47	7.5	940.0	6.0
<u>Microtus montanus</u> Mountain Vole	30.0	43	6.9	1290.0	8.3
Other Species	---	58	9.3	747.5	4.8
<u>Totals</u>	-----	627	100.1	15,570.5	100.0

Table 3

Regurgitated pellet data of the Long-eared Owl - 1980
(Lawrence Memorial Grassland Preserve)
(West Ravine Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	135	36.0	3,375.0	32.1
<u>Thomomys talpoides</u> Northern Pocket Gopher	38.1	94	25.1	3,578.0	34.1
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	68	18.1	1,428.0	13.6
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	22	5.9	440.0	4.2
<u>Microtus montanus</u> Mountain Vole	30.0	34	9.1	1,020.0	9.7
Other Species	---	22	5.9	660.0	6.3
<u>Totals</u>	-----	375	99.9	10,501.0	100.0

Table 4

Regurgitated pellet data of the Long-eared Owl - 1981
(Lawrence Memorial Grassland Preserve)
(West Ravine Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	141	32.0	3,525.0	26.1.
<u>Thomomys talpoides</u> Northern Pocket Gopher	43.7	150	34.0	6,557.0	48.6
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	70	15.9	1,470.0	10.9
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	25	5.7	500.0	3.7
<u>Microtus montanus</u> Mountain Vole	30.0	311	7.0	930.0	7.1
Other Species	---	24	5.4	509.5	3.8
<u>Totals</u>	-----	441	100.0	13,491.5	100.2

Table 5

Regurgitated pellet data of the Long-eared Owl - 1982
(Lawrence Memorial Grassland Preserve)
(West Ravine Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	278	40.5	6,950.0	37.1
<u>Thomomys talpoides</u> Northern Pocket Gopher	43.4	139	20.3	6,032.0	32.2
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	109	15.9	2,289.0	12.2
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	59	8.6	1,180.0	6.3
<u>Microtus montanus</u> Mountain Vole	30.0	70	10.2	2,100.0	11.2
Other Species	---	31	4.5	201.0	1.1
<u>Totals</u>	-----	686	100.0	18,752.0	100.0

Table 6

Regurgitated pellet data of the Long-eared Owl -1981
(Lawrence Memorial Grassland Preserve)
(East Ravine Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	122	32.5	3,050.0	31.3
<u>Thomomys talpoides</u> Northern Pocket Gopher	33.7	76	20.3	2,558.0	26.3
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	76	20.3	1,596.0	16.4
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	41	10.9	820.0	8.4
<u>Microtus montanus</u> Mountain Vole	30.0	54	14.4	1,620.0	16.6
Other Species	---	6	1.6	91.5	0.9
<u>Totals</u>	-----	375	100.0	9,735.5	99.9

Table 7

Regurgitated pellet data of the Long-eared Owl -1982
(Lawrence Memorial Grassland Preserve)
(East Ravine Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	109	37.2	2,725.0	31.5
<u>Thomomys talpoides</u> Northern Pocket Gopher	37.1	118	40.3	4,378.0	50.5
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	14	4.8	294.0	3.4
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	17	5.8	340.0	3.9
<u>Microtus montanus</u> Mountain Vole	30.0	26	8.9	780.0	9.0
Other Species	---	9	3.1	144.0	1.7
<u>Totals</u>	-----	293	100.1	8,661.0	100.0

Table 8

Regurgitated pellet data of the Long-eared Owl -1975
(Antelope Valley Antelope Ore.)
(Borthwicks Canyon Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	34	3.9	850.0	3.6
<u>Thomomys talpoides</u> Northern Pocket Gopher	53.9	91	10.4	4,900.0	20.7
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	411	47.1	8,631.0	36.4
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	146	16.7	2,920.0	12.3
<u>Microtus montanus</u> Mountain Vole	30.0	160	18.3	4,800.0	20.2
Other Species	---	31	3.6	1,605.0	6.8
<u>Totals</u>	-----	873	100.0	23,706.0	100.0

Table 9

Regurgitated pellet data of the Long-eared Owl -1978
(Antelope Valley Antelope Ore.)
(Borthwicks Canyon Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	23	7.3	575.0	7.4
<u>Thomomys talpoides</u> Northern Pocket Gopher	42.6	17	5.4	725.0	9.4
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	171	54.1	3,591.0	46.4
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	36	11.4	720.0	9.3
<u>Microtus montanus</u> Mountain Vole	30.0	49	15.5	1,470.0	19.0
Other Species	---	20	6.3	655.0	8.5
<u>Totals</u>	-----	316	100.0	7,736.0	100.0

Table 10

Regurgitated pellet data of the Long-eared Owl -1979
(Antelope Valley Antelope Ore.)
(Borthwicks Canyon Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	1	.7	25.0	0.7
<u>Thomomys talpoides</u> Northern Pocket Gopher	37.0	4	2.6	148.0	4.2
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	97	63.4	2,037.0	57.8
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	9	5.9	180.0	5.1
<u>Microtus montanus</u> Mountain Vole	30.0	33	21.6	990.0	28.1
Other Species	---	9	5.9	144.0	4.1
<u>Totals</u>	-----	153	100.1	3,524.0	100.0

Table 11

Regurgitated pellet data of the Long-eared Owl -1981
(Antelope Valley Antelope Ore.)
(Borthwicks Canyon Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	3	0.7	75.0	0.6
<u>Thomomys talpoides</u> Northern Pocket Gopher	55.1	26	5.9	1,432.0	12.0
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	160	36.1	3,360.0	28.0
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	25	5.6	500.0	4.2
<u>Microtus montanus</u> Mountain Vole	30.0	205	46.3	6,150.0	51.3
Other Species	---	24	5.4	466.0	3.9
<u>Totals</u>	-----	443	100.0	11,983.0	100.0

Table 12

Regurgitated pellet data of the Long-eared Owl -1982
(Antelope Valley Antelope Ore.)
(Borthwicks Canyon Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	26	9.3	650.0	8.1
<u>Thomomys talpoides</u> Northern Pocket Gopher	43.7	34	12.2	1,487.0	18.5
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	50	17.9	1,050.0	13.1
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	29	10.4	580.0	7.2
<u>Microtus montanus</u> Mountain Vole	30.0	137	48.9	4,110.0	51.2
Other Species	---	4	1.4	154.0	1.9
<u>Totals</u>	-----	280	100.1	8,031.0	100.0

Table 13

Regurgitated pellet data of the Long-eared Owl -1974
(Clarno Basin - John Day River)
(Juniper Basin Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	1	0.2	25.0	0.2
<u>Thomomys talpoides</u> Northern Pocket Gopher	55.0	9	2.1	495.0	4.8
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	126	28.8	2,646.0	25.7
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	219	50.0	4,380.0	42.5
<u>Microtus montanus</u> Mountain Vole	30.0	28	6.4	840.0	8.2
Other Species	---	55	12.6	1,908.0	18.5
<u>Totals</u>	-----	438	100.1	10,298.5	100.0

Table 14

Regurgitated pellet data of the Long-eared Owl -1975
(Clarno Basin - John Day River)
(Juniper Basin Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	26	1.6	650.0	1.7
<u>Thomomys talpoides</u> Northern Pocket Gopher	45.4	67	4.1	3,043.0	7.9
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	411	24.9	8,631.0	22.4
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	744	45.1	14,880.0	38.5
<u>Microtus montanus</u> Mountain Vole	30.0	175	10.6	5,250.0	13.6
Other Species	---	227	13.8	6,146.0	15.9
<u>Totals</u>	-----	1650	100.1	38,600.0	100.0

Table 15

Regurgitated pellet data of the Long-eared Owl -1976
(Clarno Basin - John Day River)
(Juniper Basin Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	0	0	0.0	0.0
<u>Thomomys talpoides</u> Northern Pocket Gopher	38.6	10	3.9	386.0	6.6
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	69	27.0	1,449.0	24.7
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	117	45.7	2,340.0	39.9
<u>Microtus montanus</u> Mountain Vole	30.0	28	10.9	840.0	14.3
Other Species	---	32	12.5	842.0	14.4
<u>Totals</u>	-----	256	100.0	5,858.5	100.0

Table 16

Regurgitated pellet data of the Long-eared Owl -1977
(Clarno Basin - John Day River)
(Juniper Basin Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	4	0.9	100.0	1.0
<u>Thomomys talpoides</u> Northern Pocket Gopher	40.2	33	7.5	1,327.0	12.7
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	72	16.4	1,512.0	14.4
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	221	50.3	4,420.0	42.2
<u>Microtus montanus</u> Mountain Vole	30.0	46	10.5	1,380.0	13.2
Other Species	---	63	14.4	1,740.5	16.6
<u>Totals</u>	-----	439	100.0	10,479.5	100.0

Table 17

Regurgitated pellet data of the Long-eared Owl -1978
(Clarno Basin - John Day River)
(Juniper Basin Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	3	1.6	75.0	1.5
<u>Thomomys talpoides</u> Northern Pocket Gopher	39.4	34	18.7	1,340.0	26.1
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	43	23.6	903.0	17.6
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	49	26.9	980.0	19.1
<u>Microtus montanus</u> Mountain Vole	30.0	23	12.6	690.0	13.5
Other Species	---	30	16.5	1,141.5	22.3
<u>Totals</u>	-----	182	100.0	5,129.5	100.0

Table 18

Regurgitated pellet data of the Long-eared Owl -1979
(Clarno Basin - John Day River)
(Juniper Basin Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	6	4.5	150.0	4.8
<u>Thomomys talpoides</u> Northern Pocket Gopher	43.3	14	10.6	607.0	19.5
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	62	47.0	1,302.0	41.8
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	24	18.2	480.0	15.4
<u>Microtus montanus</u> Mountain Vole	30.0	15	11.4	450.0	14.4
Other Species	---	11	8.3	127.0	4.1
<u>Totals</u>	-----	132	100.1	3,116.0	100.0

Table 19

Regurgitated pellet data of the Long-eared Owl -1980
(Clarno Basin - John Day River)
(Juniper Basin Pair)

Species Captured	Average Mass Grams	#ind.	%ind.	Total Mass Grams	%Bio.
<u>Lagurus curtatus</u> Sagebrush Vole	25.0	2	0.1	50.0	0.1
<u>Thomomys talpoides</u> Northern Pocket Gopher	48.0	57	3.0	2,738.0	6.7
<u>Peromyscus maniculatus</u> Deer Mouse	21.0	542	28.9	11,382.0	27.9
<u>Perognathus parvus</u> Great Basin Pocket Mouse	20.0	909	48.5	18,180.0	44.5
<u>Microtus montanus</u> Mountain Vole	30.0	150	8.0	4,500.0	11.0
Other Species	---	213	11.4	3,972.5	9.7
<u>Totals</u>	-----	1873	99.9	40,822.5	100.0