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Effects of logging on habitat quality and feeding patterns of Abert squirrels

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EFFECTS OF LOGGING ON HABITAT QUALITY AND FEEDING PATTERNS OF ABERT SQUIRRELS

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Abstract.—In 1973 a timber harvest of ponderosa pine (*Pinus ponderosa*) was conducted in an area southeast of Monticello, Utah, that is inhabited by Abert squirrels (*Sciurus aberti*). Abert squirrel dietary habits, foraging patterns, and population densities were compared in the timber harvest area and in an adjacent nonharvested area. Squirrel feeding patterns and preferences were visually determined by physical evidence of past feeding. Live-trapping and field-marking of animals were used to determine population density and trends in the two areas. Squirrels fed in only 26.3% of sampled plots on the timber harvest areas, while 42.7% of the uncut area plots showed use ($P < 0.001$). Trap days per catch were higher on the harvested area ($P < 0.01$). Similar differences in hypogeous fungi feeding sites between the two study sites were also recorded ($P < 0.01$). Thus, clearcut timber harvest of ponderosa pine did negatively affect Abert squirrels. To minimize long-term effects on squirrels, timber should be harvested in small, selective blocks (< 20 acres) rather than in large-scale areas (> 50 acres) by clear-cut methods commonly employed by management agencies.

Mammalian food habits studies have been conducted in several ways: *ad libitum* feeding of captive animals, fecal analysis, sacrificing free-ranging animals and inventorying the stomach contents, stomach pumping, and field observations of animals' feeding behaviors. All methods have distinct advantages and disadvantages.

Captive feeding allows control of the animals' environment and quantitative/qualitative regulation of intake, but the results may not validly apply to wild populations. Shooting or kill-trapping of individuals, together with subsequent stomach content examination, assumes that a large enough sample has been taken to represent the food habits of that population. The removal of individuals from a small population may also be disadvantageous. The use of observational data is based on the assumption that the observations are representative of the natural habits and that all food items can be properly identified by the observer. In this study, food habits and preferences of free-ranging Abert squirrels (*Sciurus aberti*) were determined by examining physical evidence resulting from squirrel feeding. Such evidence is easily recognized and consists of ground litter disturbance (resulting from digging for fungi), ponderosa pine (*Pinus ponderosa*) cone removal and descaled cone litter, large numbers of terminal needle bunch clippings found under selected ponderosa pine trees, and debarked twigs from ponderosa pine branches (Pederson et al. 1976).

Abert squirrels (*Sciurus aberti* subspp. and *Sciurus aberti kaibabensis*) are dependent on currently available food items since they do not cache foods for later feeding (Keith 1956, 1965, Stephenson 1975). Their diet includes acorns (*Quercus gambelii*), ectomycorrhizal (hypogeous) fungi, and seeds of dwarf mistletoe (*Arceuthobium vaginatum*). Ponderosa pine products include cambium ("inner bark") buds, cones, and seeds (Trowbridge and Lawson 1942, Keith 1956, 1965, Reynolds 1966, Larson and Schubert 1970, Heidmann 1972, Patton 1974, 1975, Stephenson 1975, Rasmussen et al. 1975). The abundance and growth of many of the foods consumed by Abert squirrels are affected by weather conditions.

The current study was undertaken to determine whether timber harvest of ponderosa pine affects the availability of Abert squirrel foods (e.g., inner bark, cone seeds, fungi, etc.). Effects of timber harvest on squirrel densities, foraging patterns, movements, and/or time-energy budgets were also examined.

Objectives of the study were to:

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1. Quantify dietary changes on a seasonal basis.
2. Correlate dietary changes with food item availability.
3. Determine how seasonal changes in diet and food item availability affect foraging patterns.
4. Analyze relative energy content of various food items, i.e., calorie content of ponderosa pine seeds vs. inner bark vs. buds, etc.

STUDY AREA

The study area is in southeastern Utah on the Monticello Ranger District of the Manti-LaSal National Forest. Lying in the Bulldog-Verdure drainages of the Abajo Mountains, it is approximately 12 k (8 mi) southeast of Monticello, Utah. In 1973 the Bulldog area was part of a timber harvest program by the U.S. Forest Service. The adjacent Verdure area served as a nonharvested control in a three-year Utah Division of Wildlife Resources study conducted to determine the short-term effects of timber harvest on Abert squirrels (Pederson et al. 1976). The Verdure and Bulldog sites, each 56 ha (140 ac) in size, were studied simultaneously.

METHODS AND PROCEDURES

For both the harvested and unharvested areas, two types of food-related data were collected: (1) data on *actual* squirrel food use, and (2) data that reflected *potential* food available.

1. Data on actual Abert squirrel food use was obtained quarterly (April 1977–December 1979) from 300 circular, random-sampled, 10-m^2 plots on each study area. Descaled ponderosa pine cones, peeled ponderosa pine twigs, hypogeous fungi digs, use of dwarf mistletoe, and other feeding evidence were counted and recorded for each plot.

Information was also collected on the number of plots in which any feeding activity occurred on either area. The food item used was also recorded. Foods eaten by Abert squirrels were collected and tested for nutrient and caloric content. Foods were tested for percent moisture, Kjeldahl determination for protein, ash content, and Soxhlet extraction of lipids as described in the Official Methods of Analysis manual (1975).

2. Potential food available (i.e., current-year production of food items) was obtained by surveying 300 randomly selected plots each September and estimating production of ponderosa pine cones and Gambel oak acorns. These production estimates were tied to the food-use plots in the following manner: The closest ponderosa pine tree and Gambel oak tree to each food-use plot were observed through 7 x 35 binoculars. Cones or acorns on a quarter of the tree were counted and multiplied by four to obtain an estimate of the current year's cone and acorn production. These production estimates were converted into a class code using the following key:

Acorn and Ponderosa Pine Cone Production Key

Class	Prod. est./tree (cones or acorns)
0	none
1	1 – 25
2	26 – 50
3	51 – 100
4	101 – 200
5	201 – 400
6	401 – 600
7	601 – 800
8	801 – 1,000+

Data were also collected on the amount of ground and litter disturbance caused by logging activity that occurred between 1973 and 1975. Litter depth was recorded on every tenth plot for both logged and unlogged areas when the ground was free from snowcover. This was converted into a class code as follows:

Litter Depth Key (pine needles to mineral soil)

Class	Depth (cm)
0	none (bare ground)
1	1 – 5
2	6 – 10
3	11 – 16
4	17 – 20+

Live-trapping and field observation techniques were used to aid in the evaluation of responses of squirrels to timber harvest. Squirrels were trapped using Tomahawk live traps, No. 203, 6 x 6 x 24 inches (Tomahawk Live Trap Company, Tomahawk, Wisconsin). The traps were positioned throughout the study areas in eight locations most often frequented by squirrels. These areas were determined by the presence of recent squirrel sign, nest locations, and actual observations of squirrels. Traps were placed in known or sus-

TABLE 1. Utah Abert squirrel food use data, 1977 through 1979.

YEAR AREA Month	Ponderosa pine clips no.	Use %	Fungi digs no.	Use %	pine peeled cones no.	Use %	Mistletoe	Use %
1977								
BULLDOG								
July	58	59	0	0	39	40	0	0
Sept.	206	64	46	14	70	22	1	T
Dec.	58	59	0	0	39	40	1	T
VERDURE								
July	467	76	91	15	57	8	0	0
Sept.	67	21	125	40	124	39	1	T
Dec.	57	75	5	6	15	19	1	T
1978								
BULLDOG								
Feb.	140	100	0	0	0	0	0	0
April	264	96	5	2	6	2	1	T
July	189	72	62	23	13	5	0	0
Sept.	238	100						
Dec.	396	100						
VERDURE								
Feb.	131	100	0	0	0	0	0	0
April	486	100	0	0	1	T	0	0
July	183	39	280	60	3	0.5	3	0.5
Sept.	197	100						
Dec.	285	100						
1979								
BULLDOG								
Feb.	276	100						
April	301	100						
VERDURE								
Feb.	287	100						
April	351	100						

pected centers of squirrel activity to establish home ranges (Hayne 1949). These activity centers were determined during a previous study (Pederson et al. 1976). Each trap was baited with both roasted peanuts and peanut butter. Each squirrel trapped was placed in a Plexiglas cone and then anesthetized with methoxyflurane (Metofane, Pitman-Moore, Inc., Fort Washington, Pennsylvania) using Barry's (1972) method on gray squirrels. The anesthetized squirrel was removed from the cone for measuring and tagging. Sex, age, weight, rectal temperature, tail length, total length, length of hind foot, ear and ear tassel length (if present), coloration, presence of parasites,. and any abnormalities were recorded. Parasites were collected for later identification. A careful record was kept on the time required to relax, time under, and recovery time from anesthesia.

While the animal was still anesthetized, it was numbered with aluminum rabbit tags (National Band and Tag Co.) placed through each ear and secured with 3/8-inch (.94-cm) celluloid colored washers for later field and in-trap identification. A backup identification system insured future identification in case of tag loss; it consisted of a colored collar, made from TY-RAP CABLE ties (#TY-525 M. manufactured by Thomas Betts Co., Elizabeth, New Jersey), which was fastened around the squirrel's neck. Each collar was factory numbered as an additional aid in identifying recaptured squirrels.

RESULTS AND DISCUSSION

Food-Use Data

A comparison of overall feeding activity between the two study areas during the two years shows that squirrel feeding occurred in 26.3% of the harvested Bulldog plots. Feeding was recorded in 42.7% of the nonharvested Verdure plots. The difference is signif-

TABLE 2. Utah Abert squirrel trapping record, 1977–1978.

Month	Bulldog					Verdure				
	New squirrels caught	Total catches	Trap days	Trap days per new catch	Trap days per catch	New squirrels caught	Total catches	Trap days	Trap days per new catch	Trap days per catch
1977										
April	7	9	58	8.28	6.44	14	15	58	4.14	3.86
July	1	2	42	42.00	21.00	4	10	52	13.00	5.20
September	1	1	24	24.00	24.00	2	4	24	12.00	6.00
December	3	6	72	24.00	12.00	2	18	72	36.00	4.00
TOTAL	12	18	196	16.33	10.88	22	47	206	9.36	4.38
1978										
February	0	4	36	0	9.00	0	1	36	0	36.00
April	4	6	21	5.25	3.50	1	9	21	9.00	2.33
September	1	10	32	10.00	3.20	6	17	32	5.33	1.88
December	0	21	22	0	22.00	0	2	22	0	11.00
TOTAL	5	41	111	22.20	2.36	7	29	111	15.85	3.82
Two-year summary	17	59	307	18.05	5.20	29	76	317	10.93	4.17

icant at the $P < 0.01$ level (Table 1). This difference is also significant when the data are compared separately by year. The lower incidence of feeding activity in the area where ponderosa pine was harvested shows that some degradation of Abert squirrel habitat has occurred. The difference in feeding activity suggests lower population numbers and apparently lower recruitment of young in the Bulldog area. Squirrel movement from Bulldog to Verdure for feeding was documented. Evidence of lowered population numbers in the Bulldog area is shown in both the higher number of trap days required for catching new squirrels and in lower total squirrel catches (Table 2).

Feeding activity in both areas was of four specific types: ponderosa pine bark (needle bunch clips), ponderosa pine seeds (cones), dwarf mistletoe, and hypogeous fungi (digs). Data collected during the study show the majority of the feeding was on ponderosa pine inner bark or cambium tissue (Table 1). This contrasts with other reports that twig feeding occurs mainly during winter months (Keith 1965, Stephenson 1975, Rasmussen et al. 1975). Frequent use of ponderosa pine seed was recorded only in 1977 and coincided with a very large cone crop (Table 1). Dwarf mistletoe was used only in trace amounts. Stephenson (1975) also reported that squirrels in Arizona used very little mistletoe. The use of ectomycorrhizal fungi was highest during July and September and was a direct reflection of summer precipitation (Table 1).

A significantly higher number of feeding activity occurrences of hypogeous fungi were recorded for the uncut Verdure area. Fungi digs in the Bulldog area were 176, with 549 at Verdure. This difference is significant at the $P < 0.001$ level. Hypogeous fungi grow beneath a layer of ponderosa pine needles having a depth greater than 5 cm. Bulldog litter depth greater than 5 cm was present in only 23.3% of the plots, while this depth at Verdure occurred in 40.2%. This is also the percent hypogeous fungi digs found between the two sites (Table 1). Bulldog plots show 15.9% bare ground and Verdure 8.2%. Disturbance to ground cover by logging activity was found in 38.4% of the plots examined ($N = 1{,}250$). The opening of the upper canopy cover by timber harvest and accompanied logging activity has removed and reduced the litter cover and depth, thus reducing the microclimate necessary for production of hypogeous fungi, a sought-after and preferred food of the Abert squirrel. Stephenson (1975) reports that fungi were the "most important item on an annual basis, by volume and frequency of occurrence." He found fungi in the diet every season of the year, comprising as much as 91.9% of the summer diet. In addition, hypogeous fungi grow only on the roots of live ponderosa pine. Logging that kills the root system will also obviously cause the loss of this food source to Abert squirrels (Ure and Maser 1982).

TABLE 3. Chemical and caloric content on Abert squirrel foods in Utah, 1977–79.

Date collected	Food item	Moisture %	Protein %	Fats & oils %	Ash %	Calories per g
1977						
22 April	Pipo* staminant cone	71.92	4.46	4.84	4.07	
22 April	Pipo seed	36.89	4.05	5.47	7.95	
4 July	Pipo cambium	44.12	4.62	7.65	4.34	
4 July	Pipo seed	8.77	9.48	11.59	4.63	
4 July	Mistletoe	56.74	6.60	2.14	10.52	
22 Sept.	Mistletoe	59.14	6.23	2.40	4.63	
22 Sept.	*Boletus*	87.99	25.06	5.03	9.68	
22 Sept.	Fairy ring	72.76	17.75	6.74	34.32	
22 Sept.	Cantlarelaceae	72.35	13.79	1.72	25.23	
22 Sept.	*Russula*	87.61	16.61	5.50	16.14	
22 Sept.	Pipo seed	62.44	5.06	11.89	31.22	
3 Nov.	Pipo seed	19.76	6.43	11.08	14.14	5,479.0
2 Dec.	Mistletoe	54.69	6.73	1.16	4.48	2,586.1
2 Dec.	Pipo cambium	47.74	2.07	3.40	10.16	2,454.4
1978						
20 Feb.	Pipo cambium					
	Bulldog	48.08	1.65	3.84	8.20	4,155.9
	Verdure	52.21	1.56	5.39	5.04	4,212.9
16 April	Pipo cambium					
	Bulldog	44.68	1.80	4.59	9.34	4,039. 5
	Verdure	51.28	2.40	3.93	6.89	3,889.0
16 April	Pipo mistletoe	60.13	7.24	2.22	5.76	4,669.5
29 May	Pipo cambium (Bulldog)					
	Feed tree	47.85	2.10	4.51	5.05	4,146.0
	Nonfeed tree	48.33	2.09	4.22	7.80	4,195. 3
	Pipo buds	76.70	7.29	3.36	3.01	4,384.9
	Pipo mistletoe	62.30	6.60	1.91	5.16	4,999.2
	Juos mistletoe	60.61	8.51	2.16	13.06	4,195.3
4 July	Pipo cambium (Bulldog)					
	Feed tree	48.97	2.20	6.91	8.68	3,932.0
	Nonfeed tree	46.92	1.78	5.41	9.21	3,724.9
	Pipo mistletoe	64.92	5.45	1.36	5.30	4,793.0
22 Sept.	Pipo cambium (Bulldog)					
	Feed tree	51.90	2.70	2.80	9.30	—
	Mistletoe	59.74	5.20	1.15	4.83	—
	Acorns	46.63	5.53	.04	1.28	4,220.0
30 Dec.	Pipo cambium (Bulldog)					
	Feed tree	43.34	2.34	.85	2.84	3,765.0
	Nonfeed tree	49.66	2.41	1.87	2.41	3,955.0
1979						
11 Feb.	Pipo cambium (Bulldog)					
	Feed tree	51.23	2.83	1.13	6.38	4,150.0
	Nonfeed tree	51.23	2.68	.81	9.44	3,860.0
1 April	Pipo cambium (Bulldog)					
	Feed tree	53.86	2.56	1.78	5.58	4,498.0
	Nonfeed tree	55.29	2.38	1.72	5.48	4,254.0

*Pipo = ponderosa pine = *Pinus ponderosa*

The difference in feeding activity might be accounted for in lower population numbers and lower recruitment of young in the Bulldog area or a movement from Bulldog to Verdure for feeding.

Food Chemical Analysis

The moisture content of Abert squirrel foods ranged from a low of 8.77% in ponderosa pine seed to a high of 87.99% in boletus fungi

(Table 3). Ponderosa pine inner and outer bark showed a 49.30% moisture content for the study period (range = 43.34–55.29%). Mistletoe was the most consistent in percent moisture with a mean of 59.8 and a range of 54.69–64.92.

Protein expressed on a dry-matter basis was highest in the fungi species (*Boletus* spp. averaged 25.06%; *Marasmius oreades*, 17.75%; *Cantorelaceae*, 13.79%; and *Russula* spp., 16.61%). These high protein levels for fungi are consistent with the Abert squirrel food habits study by Stephenson (1975). Southwestern dwarf mistletoe was relatively low in percent protein with a mean of 6.30 and a range of 5.20–7.24 (Table 3).

Ponderosa pine cambium (inner bark) was very low in percent protein. Thirteen samples collected during the study period yielded a mean of 2.28% (range = 1.56–4.62%) (Table 3). These data are similar to those of 1.5–3.2% reported by Pederson and Welch (1985). Inner bark, long thought to be the mainstay of the Abert squirrel diet, had a very low protein level (Table 3). Stephenson (1975) found inner bark in the diet throughout the year, but in significant quantities only in winter months. During very dry summers we found that feeding activity was as high as 76% on ponderosa pine inner bark (Table 1). The high moisture level of inner bark (averaging 49.30%) may account for its use as a water source in the diet.

A study by Stephenson and Brown (1980) shows an annual mortality of 66% in a year with snowcover of 10 cm or more for 85 days. Their finding shows a positive correlation of the number of days of snow depth greater than 10 cm with the annual mortality rate of Abert squirrels in Arizona. During these periods of 10 cm or more of snow, squirrels were forced to eat only bark with its low protein content when higher protein foods such as fungi were unavailable for use. If deep snow lasted long enough, the squirrels could develop a severe nitrogen deficiency that could greatly increase the mortality rate (Pederson and Welch 1985). During snow-free months if hypogeous fungi habitat is reduced, this source of protein is unavailable to squirrels and the population declines.

Squirrel Weights

The weights of squirrels differed between areas. Those captured in the Bulldog timber harvest area weighed an average of 658.8 grams; those from Verdure averaged 670.8. Males weighed 640.2 grams and 653 grams, respectively. These data do not show significant statistical differences but suggest a trend to better body condition on the nonharvested Verdure area.

Ectoparasites

Captured squirrels were combed and external parasites collected. Two species of flea were recovered and identified. On 21 April 1977 a female *Monopsyllus eumolpi* was collected from an adult male Abert squirrel captured in the Verdure area. The same species was also found on another adult male Verdure squirrel on 2 July 1977. On 8 September 1977 a large male *Hystrichopsylla dippiei* was removed from an adult female squirrel trapped in the Bulldog study area. During the same time period an adult female Abert squirrel was captured, and a male and female *Dermacentor andersoni* were removed from her ears. The presence of external parasites did not appear to affect body condition or health of Abert squirrels on either area.

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