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Northern Flying Squirrel Seasonal Food Habits in the Interior Conifer Forests of Central Idaho, USA

Abstract

Microhistological analysis of 200 scats collected from two artificial nest boxes used by northern flying squirrels (*Glaucomys sabrinus*) in central Idaho show distinct seasonal variation. The flying squirrels consumed hypogeous, mycorrhizal fungi in the summer and arboreal lichens and hypogeous, mycorrhizal fungi in the winter. Dominant summer foods included boletoid genera and *Leucogaster*, while dominant winter foods include lichens in the genus *Bryoria*, boletoid genera and the genus *Gautieria*. Central Idaho conifer forests developed under a continental climate characterized by summer drought and long, snow-covered winter and spring conditions. These climatic and vegetation conditions are considerably different from those found west of the Cascades where most studies of northern flying squirrels have been conducted.

Introduction

Studies of northern flying squirrel (*Glaucomys sabrinus*) diets in western North America (McKeever 1960, Fogel and Trappe 1978, Maser et al. 1978, Maser et al. 1985, Carey 1991, Hall 1991, Carey 1995) suggest a complex functional relationship in which mycorrhizal fungi critical to the growth of trees are dispersed by arboreal rodents. West of the Cascade Mountains, the diet of the northern flying squirrel consists largely of fungi. East of the Cascade Mountains and in Alaska, where winters are long and snow-covered, northern flying squirrels consume fungi and arboreal lichens (Maser et al. 1986, McKeever 1960, Mowrey et al. 1984). Lichen species reported in flying squirrel diets include: *Bryoria fremontii* (Tuck.) Brodo and Hawksworth (Maser et al. 1986), *Alectoria fremontii* (*Alectoria* syn.= *Bryoria*) and *Usnea ceratina* Ach. (McKeever 1960), *Usnea barbata* (L.) Weber ex Wigg. (Cowan 1936), and *Letharia, Physcia,* and unidentified lichens (Hall 1991). Other authors have merely classified the observed food by the category "lichens" (Conner 1960, Maser et al. 1978).

Unfortunately voucher specimens of lichens were either not made or have not been located for studies by Maser et al. (1986), McKeever (1960), or Mowrey and Zasada (1984), leaving the taxonomy unverified. The complexity of lichen taxonomy, which in some cases requires chemical tests for species determinations, raises doubts regarding the identity of some lichen genera and species reported. An understanding of the taxa consumed by flying squirrels is further confused because the genus *Usnea* has frequently been misapplied to *Alectoria,* which it superficially resembles both morphologically and ecologically. *Alectoria* has been subdivided (Brodo and Hawksworth 1977) into several genera, including *Alectoria* and *Bryoria.* We suspect that many reports of *Usnea* are either *Alectoria sarmentosa* or *Bryoria* species.

Therefore, based on chemistry and taxonomic confusion, we suggest that flying squirrels do not regularly consume any of the previously reported lichen taxa except *Bryoria fremontii,* which lacks secondary chemical compounds (Brodo and Hawksworth 1977, Rosentreter and Eslick 1993).

Previous studies have identified lichen fragments from stomach contents or scats of the northern flying squirrel. In studies of northern flying squirrel recovery in West Virginia, Mitchell (1994) recorded lichen presence in scats by quantifying the presence of algal cells.

In this study, we sought to identify the range of foods consumed by northern flying squirrels in an interior forest of the Northern Rocky Mountains. We were particularly interested in the diversity of mycorrhizal fungi eaten by the squirrels and the relative consumption of fungi and lichen. We also wished to determine the seasonal variation in foods consumed in light of the long period of deep snow-cover experienced by squirrels in this region.

Study Area

We examined flying squirrel scats collected on the Payette National Forest in central Idaho near McCall, Idaho, USA. Scats were collected in two drainages, the North Fork Payette River and Goose Creek. The Payette National Forest is mountainous; elevations range from 1,520 to 2,140 m. Its climate has a strong Pacific coastal influence during winter but follows continental patterns in summer (Finklin 1988). Annual precipitation averages over 100 cm a year and falls largely as snow, which accumulates to depths of 1.5 to 2 m. In most years 50% of the ground at higher elevations is covered by snow until after June 1st. The landscape is dominated by conifer forests, most stands supporting a sparse shrub layer but an extensive ground layer of low shrubs (*Vaccinium*), grasses, and forbs. Forest types included spruce-fir (*Picea engelmannii* Parry- *Abies lasiocarpa* (Hook.) Nutt.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and lodgepole pine (*Pinus contorta* Dougl.) (Steele et al. 1981).

Methods

Field Methods

Northern flying squirrel scats were collected in 1989 from a system of artificial wooden nest boxes established on the Payette National Forest (Hayward and Rosentreter 1994). Scats deposited during the winter months and collected in early June when snow still covered the ground were classified as winter scats. Scats deposited from June through August were classified as summer scats. These seasonally produced scats differed in color and hardness; winter scats were harder and darker.

Some boxes were used as communal latrines rather than roosts or natal nests and provided a large number of scats, numbering from 20 to 400 per box. Two such latrine boxes from comparable habitats were sampled and analyzed. One latrine box contained summer scats and the other contained only winter scats. Both latrine box sites were in older aged stands (greater than 180 years old) with north-facing aspects classified as potential *Abies lasiocarpa* habitat series (Steele et al. 1981) at ca. 1920 m elevation. The winter scat box site was dominated by *Abies lasiocarpa* while the summer scat box was dominated by *Pinus contorta*. The two communal latrine boxes probably represent scats from between 2-12 individual squirrels. Maser et al. (1981) reported aggregations of northern flying squirrels, and we have observed up to six adult squirrels in a nest box at one time. Scats were stored dry until analysis began in December 1993.

Laboratory analysis

Dried flying squirrel scats were placed in formalin (4% formaldehyde) to prevent any exposure to Hantavirus. One hundred scats were randomly selected from each of the two large communal latrines. Each scat was soaked in a glass vial in approximately 2 ml formalin and then set on a slide warmer at 45°C for 24 hours (summer scats) or 48 hours (winter scats) to soften. Winter scats were harder and required more time to soften. After the warm soaking, scats were crushed in the glass vials with a glass rod. An eyedropper was inserted into the vial and squeezed quickly eight times to thoroughly mix the sample. One drop of the mixture was placed on a clean glass slide. Two drops of Melzer's solution were added. The slide was allowed to partially air dry. Two drops of Poly-vinyl alcohol (PVA) were then added, and a plastic cover slip was placed over the material. Ten random area views were examined under a light microscope at 400x, or when viewing larger structures, 100x. This method was a modification of Colgan et al. (in press), Maser et al. (1986) and McIntire and Carey (1989). Algal cells were compared to fresh specimens of the common *Bryoria* species from the study area (Hayward and Rosentreter 1994). All *Bryoria* species contained the algal genus *Trebouxia*. *Trebouxia* are green, single-celled algae with round to ovate cells and a distinctive starch pyrenoid. Nomenclature for the lichens follows Egan (1987). Fungal spores were identified by use of Castellano et al. (1989). Nomenclature for fungi follows that used by Castellano et al. (1989).

Permanent voucher slides were made of each type of fungal spore by adding five or more drops of PVA and drying slides on a warmer at 30°C for approximately 30 minutes. Voucher specimens of spores were verified by Teresa Label, Wesley Colgan III, and Michael Castellano.

Voucher slides are stored with the mycological collections at the Snake River Plains Herbarium (SRP) at Boise State University.

The presence of each type of fungal spore, vascular plant tissue, or algal cell was recorded and frequency of occurrence calculated for each type of material (Holechek and Gross 1982). Abundance, relative density, or percentage by volume (Maser et al. 1978) were not rated due to different spore sizes, making these ratings difficult and inaccurate (Williams 1987).

Results

Seasonal Variation

Results from microhistological investigations demonstrated distinct differences between summer and winter scats (Fig. 1). Dominant summer foods included boletoid genera and *Leucogaster*, while dominant winter foods were *Bryoria* lichens, boletoid genera and the genus *Gautieria* (Fig. 1). The greater dependence on lichens in the winter is indicated by the higher frequency of algal cells in the scats.

Lichens

Winter scats contained a higher frequency of *Trebouxia* (86%), the phycobiont alga for the arboreal lichen *Bryoria*, than the summer scats (25%) (Table 1). The winter scats also had a higher incidence of intact lichens, suggesting that as fungi became scarce in winter, lichens were more frequently eaten.

Fungi

Flying squirrel scats contained spores representing many taxa of fungi (Table 1). The Ascomyotina fungi that are lichenized are considered lichen and are not included here as Ascomyotina. The percentage of Ascomycotina to Basidiomycotina consumed was 36/64% in the winter and 27/73% in the summer (Table 1). All these fungi are predominantly hypogeous, with most forming ectomycorrhizal associations with tree roots. The

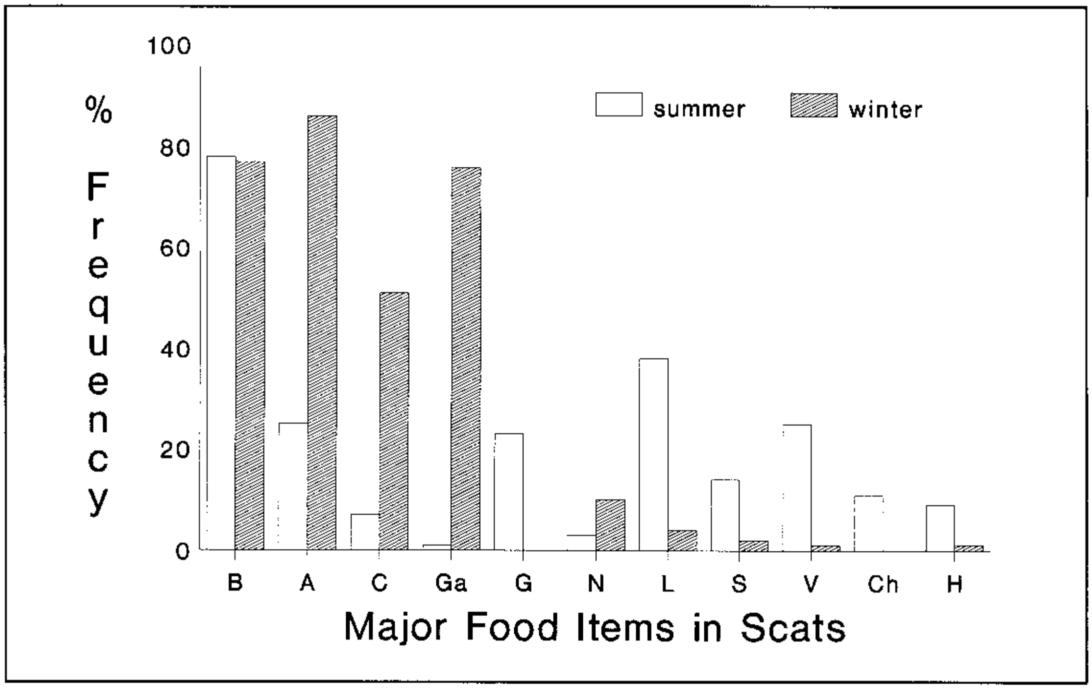

Figure 1. Major winter and summer food items in scats of northern flying squirrels. Scats collected from two nest boxes (2,000 views of 200 scats; 100 scats each from summer and winter periods). Symbols used for the major food items in order that they appear: B=Boletoid genera, A=Algae indicating lichens, C=Cortinarioid genera, Ga=Gautieria, G=Genea, N=Nivatogastrium, L=Leucogaster, S=Sclerogaster, V=Vascular plant tissue, Ch=Choiromyces, H=Hydnotrya.

TABLE 1. Percent frequency of occurrence in winter and summer foods of northern flying squirrels from 2,000 views of 200 scats (100 scats each from summer and winter periods). Trace amounts (t) were less than 1%.

Genus or Type of Material	Percent Frequency of Occurrence	
	Winter	Summer
Lichen, algae	86	25
Fungi		
Ascomycotina		
Pezizales		
Choiromyces	11	
Fisherula	t	1
Genea	t	23
Geopora	8	t
Hydnotrya	1	9
Pachyphloeus	t	t
Peziza	4	8
Picoa	t	-
Sarcosphaera	t	-
Tuber	t	2
Elaphomycetales		
Elaphomyces	2	t
Gautieriales		
Gautieria	76	1
Basidiomycotina		
Agaricales		
Cortinarioid genera	63	7
Russuloid genera	3	3
Boletales		
Boletoid genera	77	78
Hymenogastrales		
Octarianina	t	4
Sclerogaster	2	14
Lycoperdales		
Radiigera	1	1
Melanogastrales		
Leucogaster	4	38
Melanogaster	1	2
Phallales		
Hysterangium	t	t
Podaxales		
Endoptychum	t	-
Nivatogastrium	10	3
Zygomycotina		
Endogonales		
Glomus	t	-
Modicella	t	-
Sclerocystis	t	-
Vascular plant tissue	1	25

sporocarps of hypogeous fungi vary from 0.3- 5+ cm in size. Many fruit near the soil surface or beneath the litter layer while others are produced within the soil, where they are protected by the litter layer, and can persist for several weeks (Maser et al. 1978). The genera of hypogeous fungi consumed represent diverse species and ecological niches. *Alpova, Gastroboletus, Rhizopogon, Truncocolumella*, and *Trappea* were grouped as "boletoid genera" due to similar spore morphology and size. *Cortinarius* and *Hymenogaster* were grouped as "cortinarioid genera" due to similar spore morphology. Epigeous fungi such as *Peziza* was consumed in small amounts and only in the summer (Table 1). The genera of fungi consumed in winter differed greatly from those consumed in summer (Fig. 1). Northern Flying squirrel summer diets contained a wider range of genera, while the winter diet relied heavily on four to five genera.

Discussion

Flying squirrel diets were more varied in summer than winter, largely as a consequence of a greater array of fungi being consumed. This increased variety in the summer diet is similar to the trend observed by Carey (1995) west of the Cascade Mountains. Boletoid genera were frequent in both summer and winter diets in Idaho. The boletoid genera are a large group of common, small-spored mycorrhizal, hypogeous fungi that can be stored for winter food or harvested around the tree wells upon snow melt.

The most significant seasonal change in the fungal diet of the northern flying squirrel in Idaho was the increase from 1% to 76% frequency of *Gautieria* from summer to winter (Fig. 1, Table 1). *Gautieria* is very odoriferous and dries more readily than the other fungi (Trappe, personal communication). Observations in the Cascades indicate *Gautieria* is often found cached in trees during the summer months (Trappe, personal communication). The high incidence of *Gautieria* in the winter diet in Idaho suggests that squirrels may frequently cache these sporocarps for winter consumption or find dried sporocarps in patchy, snow-free areas. The most common *Gautieria* species in the study area is *G. monticola*.

In our study, the winter diet contained a higher frequency of "cortinarioid genera" than in other studies. In general, winter scats were harder, more dense, and contained fewer vascular plant tissue fragments and more whole lichen fragments than the summer scats. These dietary results are more detailed but similar to those found in eastern Oregon by Maser et al. (1986).

Forest Management Implications

Mycorrhizal fungal diversity and forest health are directly linked (Maser et al. 1985). Thus, forest managers concerned about forest health should strive to maintain healthy mycorrhizal fungi populations, particularly critical in the dry interior forests. The role of flying squirrels in forest ecosystem functions, specifically as fungus and lichen dispersers, may be more critical in these interior forests than in the more diverse coastal forests (Trappe, personal communication). Maintaining flying squirrels may facilitate fungal diversity. Forest managers must recognize the importance of lichens, fungi, and tree cavities for the maintenance of northern flying squirrel populations and ultimately forest productivity.

Conclusions

Seasonal weather patterns in the conifer forests of the northern Rockies demand shifts in the food habitats of many animals, including the northern flying squirrel. In central Idaho, the dominant summer foods included boletoid genera and *Leucogaster*, while dominant winter foods were *Bryoria* lichens, boletoid genera and the genus *Gautieria*. Based on the abundance of *Gautieria* spores in winter scats and the deep snow of winter, we suggest that *Gautieria* is cached during the summer and consumed in the winter.

Flying squirrels may play an important role in ecosystem function through the dispersal of mycorrhizal fungi. Trees require these mycorrhizal fungi for growth and without dispersal and the resulting species mixing, the fungal diversity in the forest may decrease. Therefore, the interdependence and functional relationships among mycorrhizal fungi, conifers, flying squirrels, and arboreal lichens suggests a coevolution requiring each component for the optimal functioning of the interior coniferous forest.

We believe that lichens may also be seasonally utilized by northern flying squirrels in other regions, but researchers are either unaccustomed to analyzing scats for lichens, or the squirrels remain unstudied due to snow cover in the winter months. The long period of snow cover and deep snow depths found in the northern Rockies, however, may lead squirrels to depend on lichen to a greater extent in this climate. Because winter constitutes the major stress period for these and other arboreal rodents, research should begin to include or focus on this critical season.

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