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## **Cover Page Footnote**

The authors wish to thank the staff at RSABG for their support in conducting this work as well as Drs. Andres Aguilar and Paul Narguizian for their review of an earlier draft. Also, thank you to the three anonymous reviewers whose comments helped improve this research note.

## Food Selection of Coexisting Western Gray Squirrels and Eastern Fox Squirrels in a Native California Botanic Garden in Claremont, California

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Southern California is home to one native and one introduced species of tree squirrel. The native Western Gray Squirrel (*Sciurus griseus*; here on gray squirrel), is a highly arboreal tree squirrel that can be found inhabiting mixed oak and pine forest habitats and tree dominated parks and gardens in suburban areas within California (King 2004; Muchlinski et al. 2009). Gray squirrels feed primarily on fungi, pine nuts, acorns, and bay fruit. They have also been documented to feed on *Eucalyptus* seeds, samaras, and berries (*Morus* and *Phoradendron* spp.) along with bird eggs and nestlings (Carraway and Verts 1994). Fungi are one of the gray squirrel's most highly utilized food items. By consuming fungi, gray squirrels assist in providing a healthy soil environment for the development and growth of oak-woodland communities (Maser et al. 1981).

The introduced Eastern Fox squirrel (*Sciurus niger*; here on fox squirrel) is an invasive generalist species (Tatina 2007) typically found in upland areas, open forests, or areas neighboring open spaces such as agricultural lands and pastures (Sexton 1990). The presence of the fox squirrel in California has been a concern of the general public, land managers, and researchers. The Los Angeles County Agricultural Commission considers the fox squirrel a pest species and potentially aggressive. In their native range, the fox squirrel has been important ecologically in the succession of grasslands to forests by caching their food within open grasslands (Stapanian and Smith 1986). Seeds cached and fed on by the fox squirrel come from persimmon, blue gum *Eucalyptus*, cottonwood, pines, and many others (Koprowski 1994). Fox squirrels incorporate animal foods in their diet such as insects, butterflies, ants, birds, and bird eggs (Koprowski 1994). It is reported that the fox squirrel takes advantage of fruits found within backyards such as avocados, oranges, and strawberries, an activity often disliked by human occupants (Becker and Kimball 1947; Salmon et al. 2005).

Very little is known regarding food preferences of the two species within Southern California and detailed information is limited. This study sought to gain information on what foods each species selects, and which food items overlap and differ between gray and fox squirrels. Knowledge of food preferences among species promotes making management decisions that sustain their populations. For example, improving habitat by adding particular plants or trees preferred by the gray squirrel can aid in the recovery of its population (Linders and Stinson 2006). Information on food selection may also reveal a high degree of overlap such that competition is possible in years of food shortage. Competition could lead to extirpation of the gray squirrel where food selection is limited. Muchlinski et al. (2009) established that fox squirrels replace gray squirrels at locations

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within Southern California. Food availability could be a factor in the replacement of gray squirrels from habitats invaded by the fox squirrel.

Observations on food selection were conducted at Rancho Santa Ana Botanic Garden (RSABG) in Claremont, California. RSABG is a native California garden of approximately 35 hectares containing a heterogeneous mixture of trees, shrubs, and grasses. Food available within the garden is all natural with very little human influence (e.g. trash, birdfeeders). Tree species present include but are not limited to *Quercus*, *Juglans*, *Pinus*, *Umbellularia*, and *Sequoia*. The study was conducted March 2013 to February 2014. Three transect lines and surrounding trails within the garden were visited in the same order for each observation period. Observations occurred as follows for a total of 124 hrs: (1) every other week from 14:00 to 17:00 hrs (72 hrs, 6 hrs/month, 24 observational days), (2) during a monthly census of the squirrels (36 hrs, 3 hrs/month, 12 observational days), and (3) during general behavioral observations conducted as a separate study (16 hrs total, 2 observational days per species). Data were collected using binoculars (8x30mm) and recorded creating a list of food items consumed by each species per observation day. The number of individuals consuming the food item was not recorded; however, the total number of days a food item was selected by each species was documented (Table 1). Food items were recorded only if the squirrel was eating at the time of the encounter.

Twenty-nine food items were consumed during the year by gray and/or fox squirrels (Fig. 1). In instances when observations are separated by at most three months it is assumed the species utilized that food item during the time between observations. Eleven food items including *Pinus* spp. (female cone), *Sequoia* spp. (female cone), *Quercus* spp. (acorn, flower bud, leaf/insect, and catkin), *Juglans* spp. (walnut and catkin), *Fragaria* spp. (fruit), *Aesculus* spp. (fruit/husk) and bark/insects from various species were consumed by both gray and fox squirrels (Table 1). Abundantly available acorns were utilized by both species the entire year while less abundant pine cones were utilized the first half of the year (January-July). Walnuts off the branch or from cached stores were utilized by both species most of year. Remaining food items were consumed seasonally, prior to spoilage or drying out (personal observation), when alternative food items were unavailable.

Gray squirrels consumed 7 food items that fox squirrels did not (Table 1), including *Fremontodendron* spp. (flower bud, flower/nectar, and fruit), *Umbellularia californica* (flower bud, fruit), *Arctostaphylos* spp. (fruit) and fungi. Gray squirrels utilized fruits from the California Bay Laurel (*Umbellularia californica*) from July to February. Fungi were documented as a food item for the gray squirrel October through January.

Fox squirrels consumed 11 food items not consumed by the gray squirrel (Table 1). Food items eaten by fox squirrels included *Washingtonia* spp. (leaf), *Liquidambar* spp. (fruit), *Heteromeles* spp. (fruit), *Arctostaphylos* spp. (flower), *Rosa* spp. (flower bud), *Mahonia* spp. (fruit), *Comarostaphylis* spp. (fruit), *Cornus* spp. (fruit), *Berberis nevadensis* (fruit), *Pinus* spp. (male cone), and *Allium* spp. (bulb). Such foods fill the fox squirrel's diet when acorns or pine seeds were unavailable. Many food items were utilized for only one to two months. Fruits of the American Dogwood (*Cornus*) served as a food source for a majority of the year.

Both species preferred a variety of food items at RSABG, yet observations at several urban/suburban parks indicated gray squirrels were limited in food choices (Ortiz 2014). Gray squirrels at these parks ate acorns, female and male cones (*Pinus* spp.), black berries from an unknown ornamental tree, and fruit from the California Bay Laurel

Table 1. Number of days food items were selected by *Sciurus griseus* and *Sciurus niger* out of 38 total observational days at Rancho Santa Ana Botanic Garden in Claremont, California from March 2013 to February 2014.

Food item	<i>S. griseus</i> *	<i>S. niger</i> *
<i>Fragaria</i> spp. (Fruit)	4	4
<i>Washingtonia</i> spp. (Leaf)	0	2
Fungi	3	0
<i>Umbellularia californica</i> (Fruit)	10	0
<i>Umbellularia californica</i> (Flower Bud)	1	0
<i>Mahonia</i> spp. (Fruit)	0	1
<i>Liquidamba</i> spp. (Fruit)	0	1
<i>Heteromeles</i> spp. (Fruit)	0	1
<i>Cornus</i> spp. (Fruit)	0	4
<i>Comarostaphylis</i> spp. (Fruit)	0	1
<i>Berberis nevini</i> (Fruit)	0	1
<i>Arctostaphylos</i> spp. (Fruit)	5	0
<i>Arctostaphylos</i> spp. (Flower)	0	1
<i>Aesculus</i> spp. (Fruit/Husk)	2	1
<i>Pinus</i> spp. (Male Cone)	0	1
<i>Pinus</i> spp. (Female Cone)	3	2
<i>Fremontodendron</i> spp. (Fruit)	1	0
<i>Fremontodendron</i> spp. (Flower Bud)	1	0
<i>Fremontodendron</i> spp. (Flower/Nectar)	4	0
<i>Rosa</i> spp. (Flower Bud)	0	1
<i>Sequoia</i> spp. (Female Cone)	3	1
<i>Juglans</i> spp. (Walnut)	13	11
<i>Juglans</i> spp. (Catkin)	1	3
Various spp. (Bark/Insect)	3	5
<i>Allium</i> spp. (Bulb)	0	1
<i>Quercus</i> spp. (Flower Bud)	1	1
<i>Quercus</i> spp. (Leaf/Insect)	2	4
<i>Quercus</i> spp. (Catkin)	4	6
<i>Quercus</i> spp. (Acorn)	28	21

\* Total number of food items consumed by each species.

(*Umbellularia californica*). Gray squirrels expanded their diet in the city of Redlands to include oranges from neighboring orchards. Fox squirrels had a broader diet in the parks including fruits and buds of *Eucalyptus* spp., fruit of the *Plantanus* spp., bark and leaves from various tree species, samaras (*Ulmus* spp.), peaches, cones from *Casuarina*, legumes, seed pods (*Jacaranda* spp.) and *Arecaceae* fruits. Fox squirrels also supplemented their diet with peanuts and dry dog food supplied by park visitors and food in trash cans (personal observation). In contrast, King (2004) found gray squirrels did not supplement their diet with food from trash cans during her study in a park with a high level of human activity.

Food choices of gray and fox squirrels within their native and non-native ranges have been documented through observation and stomach analyses (Ingles 1947; Cross 1969; Steinecker and Browning 1970; Byrne 1979). Many of these food studies show an overlap in diet between the species. Each species also consumed unique food items. Food preferences found at RSABG are in line with many published works (Cross 1969; Wolf and Roest 1971; Steinecker 1977; Byrne 1979; Carraway and Verts 1994; Crabtree 2008); however, this study was the first to document several native plants of California.

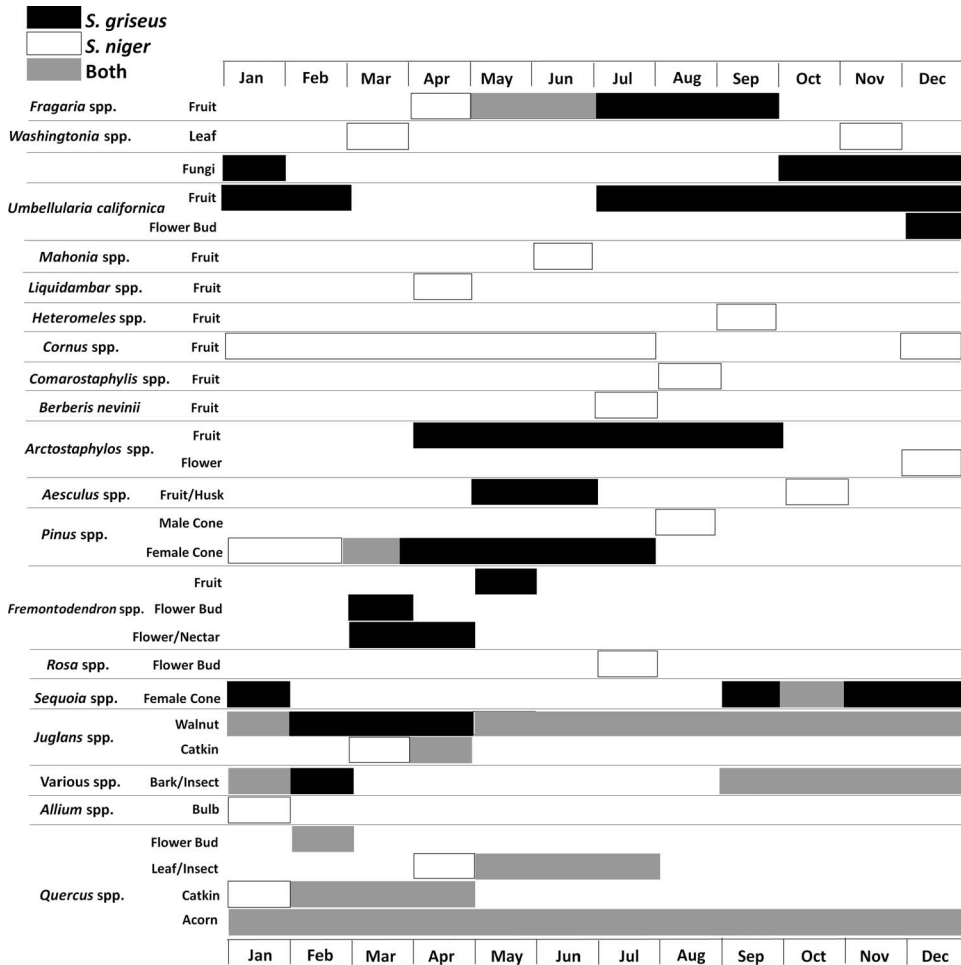


Fig. 1. Food items consumed by *Sciurus griseus* and *Sciurus niger* from March 2013 to February 2014 at Rancho Santa Ana Botanic Garden in Claremont, California. Black bars indicate food items consumed by *S. griseus*, white bars indicate food items consumed by *S. niger*, and gray bars indicate food items consumed by both species.

Fox squirrels consumed a wider variety of foods including fruits/seeds of RSABG natives and exotic species at local parks. A broader diet allows the fox squirrel a more stable, year-round food supply. Even with California’s on-going drought affecting the production of fruits, fox squirrels are able to supplement their diet with birdseed and hand-feeding from humans (King 2004). Food items previously documented include fruits of *Eucalyptus globulus* (Boulware 1941; King 2004), *Ulmus parvifolia* flowers (King 2004), samaras of *Acer macrophyllum* (King 2004; personal observation), plus other food items unique to the fox squirrel.

Gray squirrels continued to be restricted in food choices based on the habitat in which they were found. Although there were alternative trees with additional food items available, gray squirrels still fed almost exclusively on acorns and pine nuts. Gray squirrels move away from acorns and pine nuts when seasonally unavailable. They have been documented to eat bay fruit, pecans, almonds, cypress, mulberry, maple, and elm in

other locations (Ingles 1947). Yet none of these food items, with the exception of bay fruit, were emphasized in publications as part of gray squirrels' diet in Southern California. Gray squirrels in South Pasadena were found to have consumed seeds of *Eucalyptus* (Little 1934), which has only been observed once in Trabuco Canyon, California where oaks were drastically affected by a drought, producing little to no acorn crop (personal observation). Cross (1969) showed the importance of fungi in their diet, with specialty in subterranean fungi but also epigeous fungi and gill mushrooms (Steinecker 1977; Byrne 1979).

Although gray and fox squirrels overlap in many food choices including fungi (Carraway and Verts 1994; Koprowski 1994), fox squirrels were not observed consuming fungi during our study. The population of fox squirrels at RSABG may not need to utilize fungi since the garden contains a variety of food items such as fruits and catkins to consume instead. Utilization of fungi by the gray squirrel is reported to occur most during spring and summer (Carraway and Verts 1994), whereas fox squirrels utilize fungi during the summer and winter (Koprowski 1994). Timing of fungi consumption by the gray squirrel varies from year-long usage (Cross 1969) to primarily late summer (Byrne 1979). The benefit of fungi to their diet remains unknown.

Conserving the native Western Gray Squirrel will prove to be a complex issue. As of now, the best conservation method in urban/suburban habitats is to preserve isolated populations of gray squirrels that currently exist. Habitat improvements such as planting trees like the California Bay Laurel and conifers and shrubs like *Fremontodrendon* may sustain the isolated populations of gray squirrels for a longer period of time.

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The authors wish to thank the staff at Rancho Santa Ana Botanic Garden for their support in conducting this work as well as Drs. Andres Aguilar and Paul Narguizian for their review of an earlier draft. Also, thank you to the three anonymous reviewers whose comments helped improve this research note.

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