Acoustics Surveys of San Bernardino Flying Squirrels (*Glaucomys sabrinus californicus*) in the San Bernardino and San Jacinto Mountains

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Introduction

The San Bernardino flying squirrel is an arboreal, nocturnal Sciurid associated with high-elevation conifer and mixed conifer forests in southern California. (SBFS; *Glaucomys sabrinus californicus*). This subspecies occurs in the San Bernardino Mountains and San Jacinto Mountains (Grinnell 1908, Grinnell and Swarth 1913), although no recent records from the latter have occurred in over 30 years. Geographically isolated from the northern contiguous populations in the Sierra Nevada Mountains by over 260 km and with occupancy of SBFS's range restricted to high-elevation conifer forests, this subspecies represents a unique peripheral population. Peripheral populations are important to the conservation of a species because these populations are isolated from populations at the core of the geographic range and occur in ecologically marginal or stressful environments, making them disproportionally important for preserving the genetic diversity of their species (Lesica and Allendorf 1995). Additionally, flying squirrels play an important role in the ecological health of forested ecosystems as a disperser of ectomycorrhizal fungi (i.e., truffles; Amaranthus 1998, Fogel and Trappe 1978, Loeb et al. 2000). However, limited work has been conducted on the natural history and distribution of SBFS within its range, information which could increase the efficiency and effectiveness of forest management strategies within the San Bernardino and San Jacinto Mountains.

Within southern California, SBFS are difficult to detect and study due to their rarity on the landscape, nocturnal and arboreal nature, and low detection rates using traditional methods. Other isolated subspecies of flying squirrels also exhibit extremely low capture rates using traditional methods (i.e., live trapping, nest box checks; Stihler et al. 1987, Reynolds et al. 1999, Diggins et al. 2016), making studying these subspecies difficult. However, advances in technology have allowed for rapid assessment of flying squirrel presence at a site (Diggins et al. 2016). Flying squirrels produce ultrasonic calls for communicating with conspecifics (Gilley 2013, Gilley et al. *In Reveiw*) and can be detected using ultrasonic acoustic detectors throughout the year (Diggins et al. *In Prep.*). Acoustic monitoring for federally and state-listed endangered northern flying squirrels has been successfully used in the southern and central Appalachian Mountains (Diggins et al. 2016, Diggins and Ford 2017, Diggins et al. *In Prep.*). Latency to detection (LTD, i.e., the number of survey nights before the initial detection of a species at a site) with acoustics ranges from 1-14 survey nights, depending on habitat quality at the site, with lower LTD occurring in higher quality habitat (1-4 survey nights; Diggins et al. 2016, Diggins and Ford 2017, Diggins et al. *In Prep.*). This method can be used to determine SBFS occupancy spatially and temporally across seasons and years relative to habitat type in the San Bernardino Mountains. Additionally, this technique was employed in North Carolina to determine 3 new populations of the federally endangered Carolina northern flying squirrel at disjunct sites where years of attempting to determine presence with traditional techniques were inefficient and ineffective (C. Kelly, NC Wildlife Resources Commission, unpub. data). Therefore, this technique could be used to determine if SBFS still occur in the San Jacinto Mountains.

Project Objectives

1. Survey 20 sites across the San Bernardino Mountains to determine habitat occupancy using ultrasonic acoustics.
2. Conduct passive surveys at 10 sites in the San Jacinto Mountains to determine if SBNF are extant within that mountain range.

Methods

Objective 1 – Within the San Bernardino Mountains, I conducted passive acoustic surveys using Pettersson D500x detectors (Pettersson Eleckrontik AB, Uppsala, Sweden). I surveyed 25 sites for 6 days each during August 2018. I selected sites located in 5 habitat types known or suspected to be used by SBNF (USFWS 2016): Jeffery Pine, Montane Hardwood, Montane Hardwood Conifer, Sierran Mixed Conifer, and Subalpine Conifer. Of these 5 habitat types, the only habitat type SBNF have not been detected in is Subapline Conifer. Sites ranged from 4,199 – 9,314 feet in elevation. The D500x detectors are a full-spectrum detector with a directional microphone that records in real-time and stores call files onto compact flash cards allowing for multi-day passive sampling. I attached detectors ~1.5 m up on the bole of a tree using bungee cords and point the detector in the direction with the least clutter (i.e., vegetation), increasing call recording quality (Weller and Zabel 2002). I did not bait detectors. I scrubbed noise files using Sonobat Scrubber and confirmed flying squirrel calls using a double observer method and my captive call library of *Glaucomys spp*. calls, including calls obtained from a captive colony of SBNF at the Big Bear Zoo, Big Bear, CA (Diggins et al. 2016). I determined habitat occupancy in relation to habitat type and location in riparian areas (i.e., riparian vs. non-riparian). I determined probability of detection (POD) and latency of detection (LTD; i.e., the number of survey nights until the initial detection of a species at that site; Gommper et al. 2006) between the different habitat types, as well as riparian vs. non-riparian sites. Additionally, I calculated habitat occupancy for each habitat type.

Objective 2 – I conducted acoustic surveys in the San Jacinto Mountains using passive acoustic surveys. I surveyed 10 sites with passive acoustic surveys over 14-15 survey days during August 2018 using the same methods described in Objective 1. I conducted passive surveys near historic capture sites and within high quality habitat similar to SBNF preferred habitat in the San Bernardino Mountains. As a conservative measure, I only confirmed SBFS presence with diagnostic calls (i.e., trills, upsweeps), as whistles are trickier to identify and may be misidentified bat call. This methodology is standard protocol to confirm extant or newly discovered populations of flying squirrels in the eastern U.S. (C. Kelly, pers. comm., NCWRC).

Results

San Bernardino Mountain Surveys

I conducted 144 survey nights at 25 sites, adjusted for recorder failure. Only one site had CF card failure that resulted in no sound files (MH5). The total amount of data recorded was 127.2 GB (44,618 call files). After scrubbing data to remove noise files, I manually analyzed 70.5 GB (24,744 call files). During the analysis, I found 409 call files by SBFS, bats, *Peromyscus* spp., insects, and unknown species. I identified 72 squirrel call files at 13 sites (54.2% of the 24 successfully surveyed sites). The call types included trills, whistles (tonal and arc), and upsweeps. I detected calls of flying squirrels in all 5 forest types: 2 Jeffery Pine sites, 1 Montane Hardwood site, 4 Montane Hardwood Conifer sites, 3 Sierran Mixed Conifer sites, and 3 Subalpine Conifer sites. Average POD was 0.21±0.05 (range 0 – 0.83) for all sites. For individual habitat types, average POD was: 0.1±0.07 for Jeffery Pine, 0.13±0.13 for Montane Hardwood, 0.23±0.08 for Montane Hardwood Conifer, 0.26±0.15 for Sierran Mixed Conifer, and 0.33± for Subapline Conifer. Average POD for riparian vs. non-riparian sites was 0.22±0.07 and 0.21±0.08, respectively. Average LTD was 4.3 days ±0.05 for all sites. Of the 13 sites where SBFS were detected during this study, 69.2% detected SBFS on the first survey night (i.e., 37.5% of 24 sites that were successfully surveyed during this study). Occupancy rates for each

habitat were the following: 0.4 for Jeffery Pine, 0.2 for Montane Hardwood, 0.8 for Montane Hardwood Conifer, 0.6 for Sierran Mixed Conifer, and 0.6 for Subapline Conifer.

San Jacinto Mountain Surveys

I conducted 146 survey nights at 10 sites. The total amount of data recorded was 215.7 GB (75,680 call files). After scrubbing files, I manually analyzed 84.5 GB (29,754 call files). I did not obtain any call files from these surveys that I can classify as flying squirrel vocalization.

Conclusions

My surveys for SBFS in the San Bernardino Mountains have expanded ecological knowledge of this species. The previous known elevation range for this species was 3,390-8,250 ft. I surveyed for SBFS at 4 sites over 8,250 in elevation and detected SBFS at 3 of these sites. The highest elevation I detected SBFS was 9,314 ft. During past efforts work was not conducted in Subapline Conifer. POD was the highest in Subapline Conifer forests and habitat occupancy was 0.6, suggesting this habitat type may be important for long-term conservation of SBFS, especially as high-elevation refugia.

Habitat occupancy was highest in Montane Hardwood Conifer, followed by Subapline Conifer, Sierran Mixed Conifer, Jeffery Pine, and Montane Hardwood. Although occupancy is not necessarily linked to denser populations within those habitat types or preferential selection of those habitat types by flying squirrels, occupancy rates over 50% indicate that Montane Hardwood Conifer, Subapline Conifer, and Sierran Mixed Conifer are important habitats for SBFS. However, Jeffery Pine forests around Big Bear Lake were much drier than around Arrowhead Lake, anecdotally suggesting that this forest type may also be important depending on how mesic the site is and factors, such as stand structural complexity, may also be important. Additionally, our study did not look at habitat occupancy in burned vs. unburned sites, which may influence long-term SBFS occupancy on the landscape depending on burn severity at a site.

There was a recent reclassification of flying squirrels in California and portions of the Pacific Northwest from northern flying squirrels to a new species, Humboldt's flying squirrel (*G. oregonesis*; Arborgast et al. 2017), although the U.S. Fish and Wildlife Service currently recognizes SBFS by their old designation as a subspecies of northern flying squirrel. The trills I recorded for SBFS looked more like southern flying squirrels vs. northern flying squirrels (Figure 1). Southern flying squirrels produce 2-3 trill syallbles per 500 msec, whereas northern flying squirrels produce >4 trill syllables per 500 msec (Gilley et al. *In Review*). Although further analysis needs to be conducted, my acoustic observations preliminarily confirm this new species designation, indicating that these squirrels are not the same species as northern flying squirrels. We do not believe our observed calls are range variation, since calls myself and my collaborating researchers have obtained of northern flying squirrels from Idaho, Alaska, Wyoming, Pennsylvania, West Virginia, and North Carolina all produce trills with >4 syllables per 500 msec. Further call libraries from the Sierra Nevadas and southern Oregon need to be recorded to understand the variation of calls types within the range of Humboldt's flying squirrel.

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Figure 1. Example of trill calls by A) northern flying squirrel (*Glaucomys sabrinus*) in western North Carolina, B) San Bernardino flying squirrel (*G. oregonesis*) in southern California, and C) southern flying squirrel (*G. volans*) in western North Carolina.