Conceptual Framework for Studying the Effects of Fuels Treatments on Avian Communities in Ponderosa Pine Forests of Northern Arizona

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Abstract: Many ponderosa pine (*Pinus ponderosa*) forests in the western US are dense and contain excessive accumulations of ground and ladder fuels, resulting in forests at high risk of catastrophic fire. Prescribed fire and thinning are two potential tools used in the reduction of forest fuels, although the ecological and economic consequences of applying these tools are not well understood. The national Fire and Fire Surrogates (FFS) Program seeks to quantify the effects of prescribed fire and thinning on a set of response variables, including wildlife. We measured the pre-treatment characteristics of Southwestern bird communities on treatment blocks prescribed by the FFS Program in ponderosa pine forests of northern Arizona; specifically, we measured avian community structure and avian foraging patterns. The three avian communities differed from each other across study areas but not across treatment units. To supplement the standard FFS protocols, we examined fine-scale patterns in habitat quality and habitat use by these bird communities. We observed an overall preference by bark-foraging birds for ponderosa pine in the larger diameter classes, a resource use pattern that may be in conflict with management objectives. This preliminary analysis of avian community structure establishes a robust baseline of pre-treatment data for the purpose of assessing the responses of birds to future manipulation of the treatment units. These results will strengthen efforts to integrate data from various components of the FFS Project, facilitating high-resolution correlational analysis of wildlife responses with other study variables including forest structure, arthropod community structure, and microclimate.

Keywords: Arizona, birds, GIS, microclimate, *Pinus ponderosa*, ponderosa pine, prescribed fire, restoration, scale, thinning, wildlife communities.

INTRODUCTION

Many ponderosa pine (*Pinus ponderosa*) forests in the western US are dense and have accumulated large amounts of ground and ladder fuels, resulting in forests at high risk of catastrophic fire (Cooper 1960, Harrington and Sackett 1990, Swetnam 1990, Covington and Moore 1994, Whelan 1995, Allen et al. *in press*). Indeed, recent wildfires that occurred throughout the intermountain west during the spring and summer of 2000 attest to the volatility of the situation and many forest ecologists and fire officials agree that steps must be taken to reduce fuel levels and abate risk of large-scale, stand-replacing wildfire (Allen et al. *in press*, Arno and Allison-Bunnell 2002). Two potential tools that can be used to abate fire risk are prescribed fire and thinning, used singly or in combination. However, the effects of applying these tools on various ecosystem attributes are not well understood (Tiedemann et al. 2000, Wagner et al. 2000). To address this knowledge gap, the national Fire and Fire Surrogates (FFS) Program seeks to quantify the effects of prescribed fire and thinning on a set of response variables, including wildlife.

In the Southwest, the general objective of this Program is to evaluate the effects of these fuels treatments on wildlife in ponderosa pine forests of northern Arizona and northern New Mexico. Specifically, as part of this Program, our objectives are to examine treatment effects on (1) avian community structure, (2) avian foraging patterns, and (3) small mammal demography and community structure. This paper focuses on pre-treatment data collected on avian community structure (namely, bird species richness and abundance) and avian foraging patterns in northern Arizona as our "first-tier" of the initial Program efforts. Ultimately, the data collected from this study will be combined with similar data collected at other research sites from this national program to examine general patterns common to long-needle pine ecosystems.

Experimental design for the national project calls for three experimental treatments (thinning of small trees, prescribed fire, and thinning followed by prescribed fire) and a control, each implemented in 10 ha measurement blocks (with suitable treated buffer around the measurement blocks = treatment unit), replicated three times on a study area (C. P. Weatherspoon, unpublished report). Whereas this design allows a standardized and cost-effective approach to be implemented nationwide, the relatively small block sizes, combined with the vagility of the study taxa introduces questions concerning the movements and behavior of individual organisms within and between the treatment units. This is of particular concern in arid Southwestern ponderosa pine forests which are relatively unproductive and where animal densities tend to be low. The small size of our treatment units restricts the number of individuals detected (i.e., samples) of most species, thereby limiting sample sizes, statistical power, and the ability to draw conclusions. Therefore, problems inherent to the basic FFS design require innovative approaches to maximize the amount of useful information that can be derived from the study.

To supplement and further inform results obtained from the standard FFS protocols, we will examine fine-scale patterns in habitat quality and habitat use. Our objectives for this "second-tier" of wildlife investigations will be to obtain a finer-grained understanding of how animals use the treatment areas, including their responses to habitat edges, and how their spatial distribution and behavior drive the coarser patterns in distribution and abundance obtained from the standard FFS protocols.

METHODS

Study Areas

The Arizona component of the FFS research program, which we report upon here, is occurring within three areas of ponderosa pine forest in northern Arizona. Two areas (hereafter "Rudd Tank" and "Powerline") are near A-1 Mountain on the Coconino

National Forest just west of Flagstaff, and the third area (hereafter "KA Hill") is on the Kaibab National Forest, southeast of Williams. All areas are dominated by ponderosa pine, with some alligatorbark juniper (*Juniperus deppeana*) and/or Gambel oak (*Quercus gambelii*) sparsely distributed in each area. Primary land uses of all areas include livestock grazing and recreation. All areas exhibit evidence of past commercial timber harvest, although no area has been harvested recently. Limited thinning of small diameter trees has occurred within the past decade, primarily on the Powerline area (J. D. Bailey, unpublished report).

Each of the three areas represents a replicate and each replicate was divided into four treatment units, varying in size and shape depending on the terrain and designated stand boundary. Treatment unit sizes averaged 16 ha, 30 ha, and 25 ha on the Rudd Tank, Powerline, and KA Hill study areas, respectively. One of four treatments—fire, thinning, thinning plus fire, and no activity (control)—was assigned to each of the four units such that all potential treatments were represented in each replicate. Because of existing stand structure and logistical considerations (proximity to roads and existing fire breaks), treatments were not always assigned randomly to units. Within each treatment unit, a 36-point array was established as a 10 ha block (Fig. 1). Ideally, points were to be arrayed in 6 x 6 grids, with 50 m spacings between points. However, given irregular shapes of units, arrays often deviated from this ideal situation to conform to unit shapes. In all cases, however, a ≥30 m buffer was maintained between the array and treatment unit boundary.

Where possible, we attempted to follow the standardized wildlife protocols for the FFS national study (S. Zack and W. F. Laudenslayer, unpublished report). However, as detailed below, we needed to modify national protocols as appropriate for the local avifauna. Also, study areas and sampling arrays were not established until June 2000, which corresponded to the waning part of the bird breeding season. Consequently, methods were modified somewhat during this first year to sample all units within a short period of time and before too many nestlings had fledged. All modified methods were maintained through the second year of pre-treatment data collection.

Bird Diversity and Abundance

We assessed the diversity and abundance of bird species present on the study sites through the use of a hybrid point count/mapping design that permits standard density estimation by either fixed-radius (see Verner and Ritter 1985) or distance methods (Buckland et al. 1993), as well as spatial analysis of bird locations. Briefly, our method entailed conducting a 50 m fixed-radius point count and mapping the spatial location of all species detected by sight or sound (see Ralph et al. 1995). On a particular morning, an observer sampled 9 points from an array in such a way as to avoid overlap of the areas censused. Once an observer reached a point, he/she waited for two to four minutes before collecting data to allow birds to resume normal activities after being disturbed by the observer. The observer recorded the species, age, sex, mode of detection, distance to the bird, and flock membership (if appropriate) of all birds seen or heard during a 10-minute period. The observer mapped the location of all birds detected on a point count location mapping form. Birds detected as simply flying over the point were recorded, but not mapped. We exported georeferenced point count data and associated attribute information into a vector-based geographic information system (GIS) (ArcView 3.2a; Environmental Systems Research Institute, Redlands, CA).

To assess and compare pre-treatment avian community structure across treatment units and study areas, we ordinated our point count data using nonmetric multidimensional scaling (NMDS; Gauch 1982) and performed an analysis of similarity (ANOSIM; P. R. Minchin, Louisiana State University, LA) (test statistic = R; P-values = 0.05 are considered significant).

Rather than sampling only four grid points within each unit as suggested in the national FFS protocol, we modified the design to sample all 36 grid points in each array. To ensure that areas sampled during a morning did not overlap, only nine points could be sampled on a unit each day. This required us to conduct at least four visits to each unit to make sure that we sampled each point. We spaced visits to a given unit such that no two visits were =10 days apart. Additionally, we spaced visits to a given unit over the breeding season to account for temporal heterogeneity in bird detectabilities.

We modified the national protocol the first year to accommodate a sampling window restricted by delayed establishment of the sampling arrays and to maintain compatibility with other local research projects. The national protocol proposed counting birds at grid points spaced 200 m apart, counting four to six different points per unit six times during the season. Our revised methodology allowed us to sample more points, using a smaller count radius, so that we could cover the treatment areas more completely and provide a more accurate sample of the birds present. If desirable, data collected under the revised protocol can be degraded, through sub-sampling, to approximate the results that would be obtained via the standard protocol.

Bird Foraging Behavior and Microhabitat Use

We assessed resource-use patterns by birds on the study sites by collecting data on foraging behavior and microhabitat use. Observations were collected on foraging birds during a two-hour period following point counts. An observer systematically searched for birds along transects connecting grid points, varying the route daily to completely cover the unit. Once a bird was located, the observer watched the bird for 10 seconds, but recorded no data. This period of time allowed the bird to resume "normal" activity patterns after possibly being disturbed by the observer. It also restricted observers from recording only conspicuous behaviors of the bird, behaviors that may have been those that allowed the observer to find the bird in the first place. Immediately following this waiting period, observers recorded data for 10 seconds related to foraging behavior, foraging location, foraging substrate, and the structural attributes of the tree species on which a behavior was observed (e.g., diameter at breast height). To strive for independence among observations, we limited observations of a given species to those separated by at least 200 m on the day when data were collected. Further, we collected no more than three samples per species per unit per day to spread observations over the course of the breeding season and not bias estimates towards periods when birds were more easily observed. We exported georeferenced data and attribute information on avian foraging behavior and microhabitat use into the GIS.

The national protocol suggests evaluating the functional response of woodpeckers and other "bark-gleaning" (e.g., chickadees, titmice, nuthatches, and creepers) birds only. Although we emphasized bark-foraging birds, we collected data on all species present. We sampled all species because we doubted that adequate samples (cf. Morrison 1984) could be collected for any species on any unit given the small size of the plots and relatively low density of breeding birds in ponderosa pine forests of northern Arizona. Collecting data on all species provided us with flexibility to group species a posteriori into functional groups (sensu Salt 1953, 1957) to examine general patterns of microhabitat use.

We developed a frequency distribution of the diameters of ponderosa pine trees used by bark-foraging birds during all foraging behaviors. We then compared this distribution with the existing size-class distribution (in trees per hectare) and with the management "target" diameter class distribution developed by J. D. Bailey, Northern Arizona University (J. D. Bailey, unpublished report).

PRE-TREATMENT RESULTS

During avian point counts conducted on all three study areas between June and July of 2000 and May and June of 2001, we recorded 1,778 detections of 47 species. The Rudd Tank study area had the greatest number of detections (652) and the most species (34). On the Powerline study area, we recorded 598 detections across 28 species. KA Hill had the fewest number of detections (528) but the second highest species richness (32). The three avian communities differed from each other, according to NMDS (ANOSIM: $R = 0.507$, $P < 0.005$), but structure among treatment units within each study area was not significantly different (ANOSIM: $R = 0.156$, $P = 0.188$) (Fig. 2).

Between June and August of 2000 and 2001, we recorded 634 unique observations of behavior and microhabitat use by foraging birds on all three study areas. We noted foraging behaviors of 26 species on three tree species. Birds foraged upon ponderosa pine in all but seven instances (Gambel oak = 5; alligatorbark juniper = 2). Woodpeckers and other bark-gleaning species accounted for 64% (*n* = 402) of all foraging observations. Woodpeckers and other bark-gleaning species foraged upon larger (mean diameter = 37 cm, SD = 15) ponderosa pine and among the larger diameter classes available on the study areas (Fig. 3). On average, foraging birds were most active at the central portion (mean height = 9 m, SD = 6) of more vigorous trees and closer to the centroid (e.g., bole) than more distal part (e.g., branch tip) of the tree (Fig. 4).

DISCUSSION

Preliminary analyses of avian community diversity and structure have established a rigorous baseline of pre-treatment data available for assessing the response of birds to future manipulation of the treatment units. Within each replicate, the structural homogeneity of avian communities among the treatment units is encouraging. Although significant, the structural differences that exist across replicates were less than expected. Within an experimental framework, this inherent variability will enhance our ability to detect fine-scaled avian response to the treatments.

Relative to the overall availability of different diameter classes of ponderosa pine (the only tree species with enough data to permit analysis), we observed an overall preference by bark-foraging birds for ponderosa pine in the larger diameter classes. Although the metrics used to describe the size-class distribution of trees that birds used and the target size-class distribution differed, our objective was to visually compare the shapes of two size-class distributions. That this distribution of resource-use differs from both the existing diameter class distribution and the management target distribution has implications for this and other restoration treatment designs. For example, variability that may be detected in the post-treatment response of avian communities could result from the excessive removal of functionally important forest structure, possibly confounding research objectives and inferences. Additionally, avian use of trees is likely some combination of learned and innate responses (e.g., foraging birds are exhibiting a functional response to a greater abundance of food available on larger trees), and for many species these responses have evolved over time. As a result, the distribution of tree species size-classes currently used by avian species might provide evidence for the type of management distribution to be strived for.

We believe that avian and other wildlife responses to the fuel treatments may occur at scales that are not captured effectively by a simple assessment of animal density within the 10 ha measurement blocks prescribed by the national protocol. For many species, all life requisites are not provided within single small blocks and treatment units (e.g., woodpeckers). Territories and home ranges may include portions of different treatment units, and edge effects near the boundary of each 10 ha measurement block may influence animal abundance and behavior (Fagan et al. 1999, Sisk and Battin *in press*). For example, birds preferring dense forest for nesting may forage in adjacent openings created by experimental treatments, resulting in increased abundance and/or reproductive success, compared to birds utilizing either forest type exclusively (the "resource supplementation hypothesis" of Fagan et al. 1999). We expect to observe movement of individuals among treatment units on a regular basis, and we hypothesize that habitat use and movement patterns near edges, for birds and other wildlife, will differ from that observed near the centers of the units, due to the close proximity of different forest structural types (see Finch et al. 1997 and Kotliar et al. *in press*).

To help identify the factors underlying such fine-grained responses, we are monitoring microclimate variables that may serve as possible explanatory variables for animal distributions and behavior. We expect to see marked changes in forest microclimate, as well as forest structure, following implementation of fuel management treatments. Insolation, temperature, and vapor pressure deficit are expected to increase in treatments that open up the forest canopy, and the edges of the treatment units are expected to exhibit unique microhabitat conditions. Because both birds and other wildlife are sensitive to changes in forest structure and microclimate, and because they are capable of moving across entire treatment units in short periods, we hypothesize that the spatial patterning of these variables will influence the distribution, movement patterns, and habitat use by the study taxa.

These pre-treatment data and modified protocols establish a baseline for comparing conditions among treatments and replicates and will permit more robust analysis of fine-scaled patterns in animal distribution, abundance, and behavior. Our localized methods will complement post-treatment data collection, monitoring efforts, and inferences and should identify causal mechanisms that underlie patterns in wildlife community structure associated with thinning and prescribed fire in northern Arizona.

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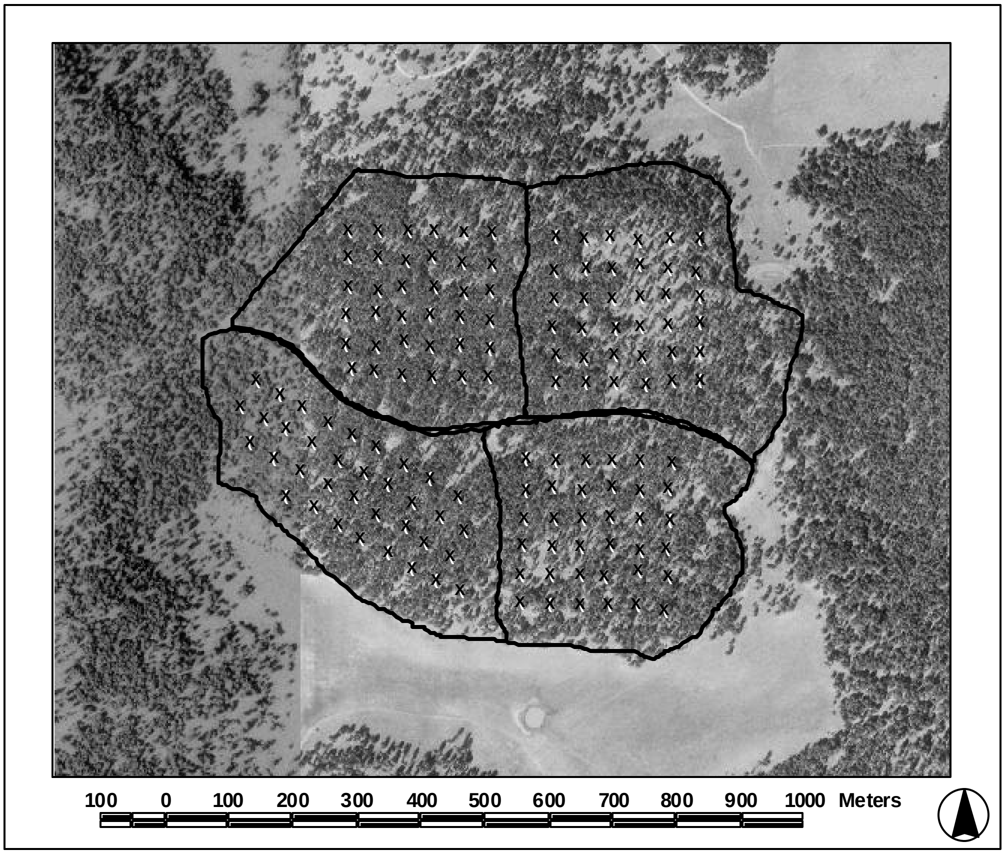

Fig. 1. Aerial view detailing 36-point grid arrays on each of the four treatment units at the Rudd Tank study area near A-1 Mountain on the Coconino National Forest, AZ.

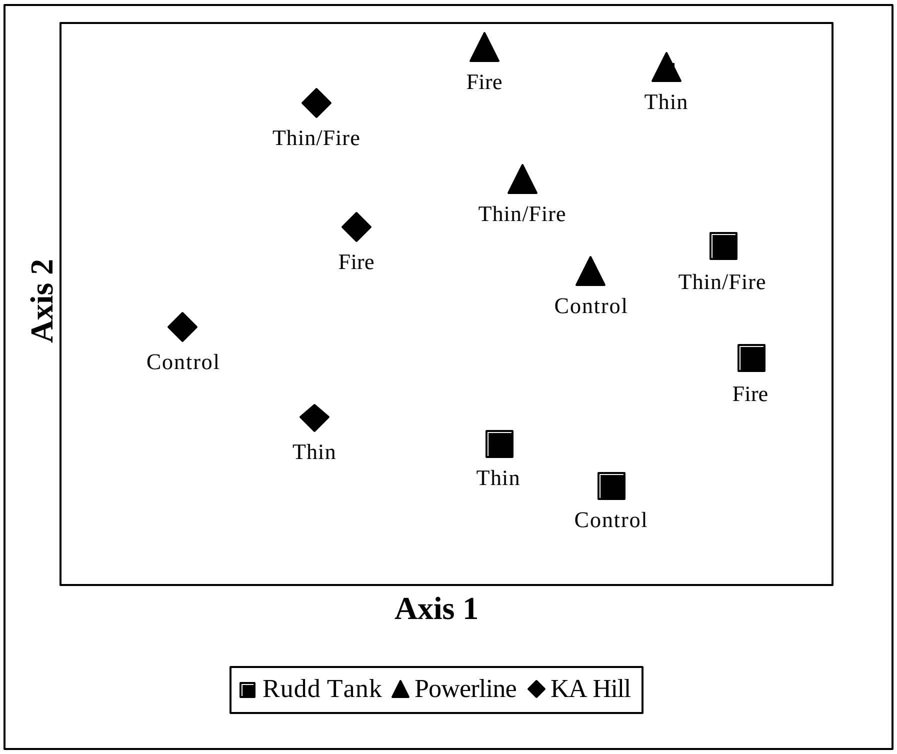

Fig. 2. Based on an ordination of pre-treatment avian community data using nonmetric multidimensional scaling, the three study areas differed from one another (evidenced by clustering of the four treatment units at each area), but differences among treatment units within each study area showed no regular variation, suggesting no selection bias. These results indicate that the experimental design is reasonably robust and that detected post-treatment differences are unlikely to be attributable to bias in site selection.

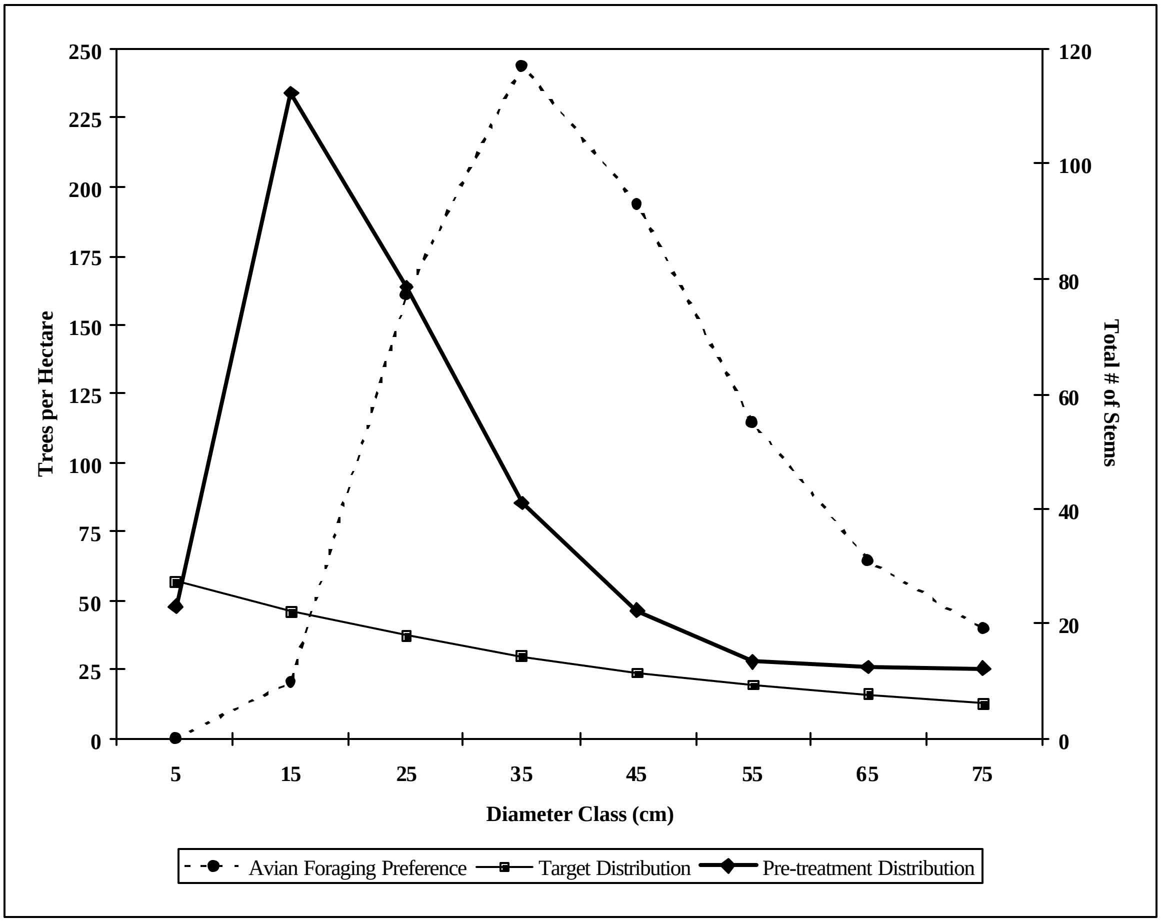

Fig. 3. Frequency distributions of avian preference for different ponderosa pine diameter classes (based on the total number of stems utilized in each class by woodpeckers and other bark-gleaning species), the management "target" diameter class distribution (in trees per hectare), and the mean pre-treatment distribution (in trees per hectare) of diameter classes across the three study areas. Foraging behaviors were most frequently observed on ponderosa pine among the larger diameter classes available on the study areas.

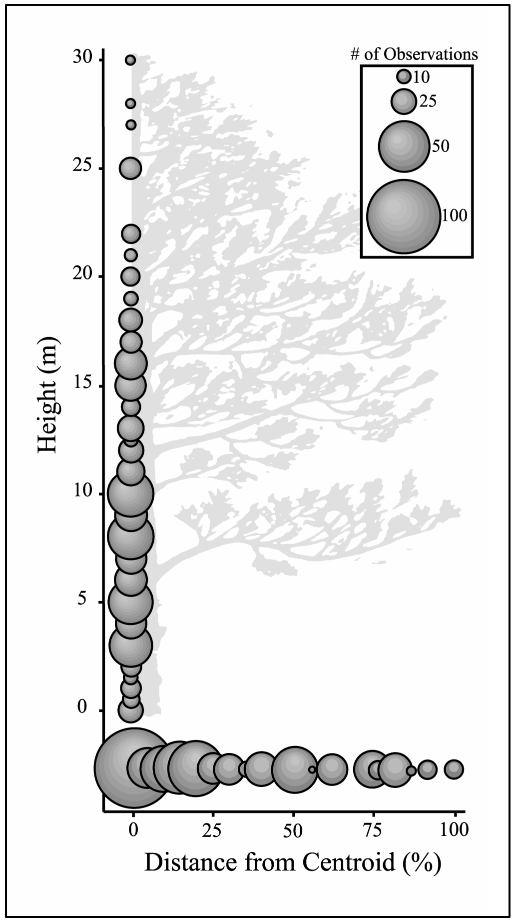

Fig. 4. Distribution of locations (n = 445) of all birds observed foraging on ponderosa pine relative to tree height (Y-axis) and the proportional distance between a tree's central axis and its outermost branch tip (X-axis). Foraging behaviors were most often observed at the central portion of more vigorous trees and closer to the centroid than more distal part of the tree.