Biomass and energy relations of avian communities have proven useful in understanding the evolution of community structure (Karr 1968, Wiens 1969, Karr and Roth 1971, Wiens and Innis 1974, Wiens and Nussbaum 1975). Lasiewski and Dawson (1967) and Zar (1968) calculated the standard metabolic rate of birds from mean body weight. Of greater ecological interest, however, is the energy requirement of normal activities under free-living conditions. Existence energy requirements for birds can be calculated from mean body weight and ambient temperature (Kendeigh 1970, Wiener and Glowacinski 1975). Thus, the total energy flux through a bird community can be examined and related to changes in foliage volume and bird densities.

The present study was undertaken to measure and evaluate 1) the effects on the diversity, density, and behavior patterns of the breeding birds of the ponderosa pine forest of such results of habitat manipulation as differing foliage volumes, foliage patterns, and densities of trees, and 2) the standing crop biomass, consuming biomass, and existence energy requirements of the breeding birds on each plot.

METHODS AND MATERIALS

Five study plots were chosen in relatively homogeneous stands of ponderosa pine, each with a 100-m minimum buffer around the periphery. An attempt was made to choose study plots that contained about the same proportions of different size classes of trees and density of gambel oak. All study areas were set up as 15-ha plots except for the clear cut area which encompassed 45 ha.

The study plots were set up with the aid of a compass, steel tape, alidade, plane table, and tripod. A grid pattern was set up by implanting stakes at 60-m intervals and marking trees. Weather data were collected and analyzed by the U.S. Forest Service.

VEGETATION

Tree measurements were made on all plots except the clear cut plot. The plotless point-quarter method of Cottam and Curtis (1956) was utilized to sample trees with a DBH of 7.5 cm or more. A total of 104 points (416 trees) was sampled on each plot and the data were analyzed quantitatively using the standard formulas of Cottam and Curtis (1956) in order to obtain the following: absolute density, relative density, relative dominance, relative frequency, importance value, mean area, and mean distance between trees for each tree species. On each study plot 104 circular plots were measured in order to count seedlings, saplings, and shrubs. Further, the following data were recorded for the four trees sampled at each point: total tree height, height from the ground to the lowest live limb, outer crown diameter, and inner crown diameter at the lowest live limb. Trees were classified as being conical, cylindrical, or hemispherical. These data were then analyzed using the standard volume formulas for the three shapes (Selby 1973). Foliage data are expressed in terms of foliage per tree species per hectare and volume of foliage per 2-m height class per hectare.

BIRDS

Breeding bird counts were made using the spot-map method described by Kendeigh (1944). Territory size was measured on the composite map as the minimum area encompassed by the observations on a particular bird pair. Differences in mean territory size were tested by the t- and F-statistics, depending upon the number of means compared. Comparisons of yearly variations in population densities were made using the coefficient of variation (Sokal and Rohlf 1973).

After each early morning census the remainder of the day was spent observing foliage use behavior using a modification of Sturman's (1968) technique. At each sighting of a bird the following information was recorded: date, time, bird species, time spent in a particular activity, height in tree, position from trunk, substrate being utilized, and tree species. The G-statistic was used to test the association between bird behavior and treatment (Sokal and Rohlf 1973).

Species diversity (H') (Shannon and Weaver 1948) was calculated by

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where p_i is the proportion of the ith species in the population composed of s species.

Evenness (E) was calculated by

$$E = H'/\ln s$$

In order to assess the behavioral similarity between pairs of species on any given study plot we may construct an m-dimensional Euclidean space in which the relative position of the species can be measured. The relationship among pairs of species within an ecological space may be measured by their Euclidean distances, D (Power 1971). Distance between the jth and kth species is given by

$$D_{jk} = \left[\sum_{i=1}^{m} (p_{ij} - p_{ik})^2\right]^{1/2}$$

where p_{ij} is the proportion of the jth species and p_{ik} is the proportion of the kth species in m number of behavioral categories. Euclidean distances between pairs of species were calculated for the following behavioral parameters: activity pattern, foraging method, tree species selection, horizontal tree position, perch selection, stance, and foliage use.

Then to examine the overall relationship among pairs of species we can measure the composite Euclidean distance (*CED*). The *CED* between the jth and kth species is given by

$$CED = \left[\sum_{i=1}^{n} (D_{ijk})^2\right]^{1/2}$$

where n is the number of behavioral parameters.

Dendrograms showing hierarchial arrangements of species were obtained by subjecting the matrices of D and *CED* to cluster analysis. The unweighted pair-group method on arithmetic averages was used (Sokal and Sneath 1963, Rohlf 1970, Power 1971, Cody 1974).

The foliage use index (*FUI*) was the calculation of the Euclidean distance between a particular bird species and the composite foliage configuration for a particular study plot. Distance between the jth species and the foliage profile is given by

$$FUI = \left[\sum_{i=1}^{n} (p_{ij} - p_{ik})^2\right]^{1/2} \Big/ n$$

where p_{ij} is the proportion of bird observations and p_{ik} is the proportion of the total foliage volume in n number of foliage strata. The *FUI* has a range of 0 to $\sqrt{2}/n$ where 0 indicates a bird species is using the foliage profile in exact relation to its availability. In contrast a *FUI* of $\sqrt{2}/n$ indicates the selection of a single stratum in which the proportion of the foliage volume is close to zero. Thus as the *FUI* becomes smaller the fit with the foliage profile becomes better. That is, an individual bird species or the entire bird community uses the foliage profile in closer relation to its availability.

The correlation coefficient (r) was calculated between foliage volume and bird density or a given behavioral parameter (Sokal and Rohlf 1973).

Consuming biomass (*CB*) was calculated using fresh dead weights whenever possible (Karr 1968). *CB* is given by

$$CB = W^{0.633}$$

where W is the mean weight of a given species.

Existence energy (*EMR*) was calculated as suggested by Kendeigh (1970) and later modified by Weiner and Glowacinski (1975). Thus, the relationship between ambient temperature and body weight in a passerine bird is given by

$$EMR = 1.572W^{0.621} + 0.06514W^{0.3625}(30 - t)$$

where t is ambient temperature in degrees celsius. The above expression was also used for the non-passerines on the study plots as they are undoubtedly closer to the passerines than to the Galliformes, Anseriformes, and Falconiformes on which the non-passerine equation is based.

DESCRIPTION OF STUDY AREAS

The five study areas are in the Coconino National Forest, Coconino County, Arizona (Fig. 1). All the areas are located within a 21-km radius on the Beaver Creek Watershed. The areas included a clear cut, a uniformly thinned, a strip cut, a silviculturally cut, and a control plot. All study sites were cut before the