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INTRODUCTION

Bird densities in a particular habitat are believed to be regulated by a vast constellation of factors interacting with one another. This becomes apparent when one examines the breeding bird community of a particular habitat and discovers that it is a dynamic system. Any alteration of that habitat may result in changing the suitability of the habitat for a given species' niche requirements. Subsequently, certain species may be drastically affected by such alterations while others will remain relatively stable. How this system is affected by changes in habitat physiognomy resulting from timber management is the focal point of this study.

The relationship between breeding bird populations and vegetation has interested avian ecologists for quite some time (for example, Johnston and Odum 1956, Bond 1957, Anderson 1970). Much work has been done on correlating the foliage height diversity of the habitat with bird species diversity (MacArthur 1965, Pianka 1966, Orians 1969, Karr 1971, Karr and Roth 1971, Recher 1971). As the structural complexity of a community increases, the number of bird species increases (MacArthur and MacArthur 1961, MacArthur et al. 1966, Karr 1968, Recher 1969, and others). MacArthur (1964) working in succulent desert scrub and montane communities in southeastern Arizona, speculated that birds here were using more than foliage layers for habitat selection in these structurally more complex habitats. A significant relationship was found between physiognomic cover diversity and breeding species diversity (Tomoff 1974). Most of these works, however, had at least four dominant species of plants present, thus offering the birds a wide variety of microhabitats. In contrast, the ponderosa pine (*Pinus ponderosa*) forest, the habitat studied here, is a monoculture with only one other tree species, gambel oak (*Quercus gambelii*) appearing with regularity.

To date, no information has been gathered as to how foliage volume and its pattern of distribution is related to breeding bird densities in a pure coniferous forest. Studies by Balda (1967, 1969) and Pearson (1971) recorded the vertical distributions of the various bird species within mixed forest type communities. Breeding bird densities may be related to the distribution and total volume of tree foliage because of the foraging and nesting habits of the different bird species (Balda 1969, 1970). Moreover, no information has been gathered on how differences in foliage volume affect bird behavior. The population density of Blackburnian Warblers (*Dendroica fusca*) and Myrtle Warblers (*Dendroica coronata*) appears to be closely correlated with foliage volume (MacArthur 1958). Foliage volume may also be an important factor in limiting the densities of Parula Warblers (*Parula americana*) and nuthatches (Morse 1967, Balda 1969). Data by Balda (1969) strongly suggest that the removal of tall ponderosa pines (12 to 21 m) may have a negative effect on the density of Grace's Warblers (*Dendroica graciae*), while removal of the understory may reduce the populations of the Gray-headed Junco (*Junco caniceps*) and the Chipping Sparrow (*Spizella passerina*).

Since the foliage configuration is probably related to the resource base, that is the food supply, it may be assumed that the bird community may be affected by changes in foliage distribution. Bock and Lynch (1970) and Kilgore (1971) showed that habitat alteration increased bird densities and diversities. The total effect on the bird community will be influenced by the magnitude of the logging operation and the method of tree removal. Therefore, it is necessary to know not only the distribution of the available foliage but how the birds use the trees.

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

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