twice as many cones as did our captives for maintenance during inactivity (1159 cones/day vs 583 cones/11-h day in this study). Clearly, the numbers of red cedar cones required by free-living birds would be much greater, but it is not known whether they could actually digest red cedar cones rapidly enough to cover their energy requirements.

The Cedar Waxwing subsists on a large variety of woody plant fruits for most of its nutrition during the fall and winter months. Since the Cedar Waxwing has a low utilization efficiency, it probably consumes large quantities of various fruits. This also implies that large quantities of seeds may pass through the digestive tract, perhaps in a viable condition as was found for red cedar seeds (Holthuijzen and Sharik, Virginia J. Sci. 34:123, 1983). Thus, the Cedar Waxwing may be a major disperser of fruit-bearing plants in eastern North America.

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Short-term changes in bird communities after clearcutting in western North Carolina.—Logging practices have been under increasing scrutiny because of their effects on biotic communities. Songbird populations as integral components of such communities are subject to disturbance by logging. Two goals involving management of songbird populations have surfaced in the literature: to maximize bird species diversity and to protect habitat of endangered and threatened species (Lennartz and Bjugstad, pp. 328–333 *in* USDA For. Serv. Gen. Tech. Rept. WO–1, 1975). The primary objective of this study was to examine effects of clearcutting on the breeding-bird community during the early years of vegetation regrowth, when changes in the avifauna are likely to be greatest.

The relationship of avian communities to timber harvesting in eastern forests has been the subject of several studies. Clearcutting of hardwood forests usually has resulted in an increase in bird species diversity (Ambrose, Ph.D. diss., Univ. Tennessee, Knoxville, Tennessee, 1975; Conner and Adkisson, J. For. 73:781–785, 1975; Nyland et al., Tappi 60:58–61, 1977), whereas, heavy cutting of a pine-oak woodland led to decreased diversity (Conner et al., Wilson Bull. 91:301–316, 1979). Changes in guild structure or other community attributes were not analyzed. Thus, a second objective of the present research was to examine changes in the bird community other than species diversity.

Study areas and methods.—The study was conducted in the Highlands Ranger District, Nantahala National Forest, North Carolina. The Highlands Plateau lies adjacent to the Blue Ridge Escarpment and contains an unusually diverse biota in comparison with the remainder of the southern Appalachians (Oosting and Billings, Am. Midl. Nat. 22:333–350, 1939). The Highlands Biological Station has provided a base from which the distribution and ecology of the avifauna have been studied for many years (see Johnston, J. Elisha Mitchell Sci. Soc. 80:29–38, 1964; and Holt, Wilson Bull. 86:397–406, 1974, for summaries). With an average elevation of 1200 m, the plateau's forests attract typically northern species such as Golden-crowned Kinglets (*Regulus satrapa*), Rose-breasted Grosbeaks, and Dark-eyed

TABLE 1
TERRITORIAL MALES PER KM²

Guild[a]	Bird species	Ellicott Rock		Rich Mt.		Brush Creek		Horse Cove	
		1975[b1]	1976[2]	1975[2]	1976[3]	1975[3]	1976[4]	1975[4]	1976[5]
2OH	Ruby-throated Hummingbird (*Archilochus colubris*)	—	12	7	7	—	—	—	—
1IH	Carolina Chickadee (*Parus carolinensis*)	—	12	—	7	—	—	—	6
1IH	Tufted Titmouse (*P. bicolor*)	—	—	—	—	—	—	—	3
3IL	Winter Wren (*Troglodytes troglodytes*)	—	—	—	—	—	6	—	—
2IL	Carolina Wren (*Thryothorus ludovicianus*)	25	31	7	7	12	—	16	25
2IL	Gray Catbird (*Dumetella carolinensis*)	—	—	14	14	12	12	12	6
2OL	Brown Thrasher (*Toxostoma rufum*)	—	—	—	—	—	—	6	12
2IL	White-eyed Vireo (*Vireo griseus*)	—	—	—	—	—	—	16	12
3IL	Golden-winged Warbler (*Vermivora chrysoptera*)	—	—	—	7	—	6	—	—
2IH	Black-throated Blue Warbler (*Dendroica caerulescens*)	—	6	—	—	—	—	—	—
2IH	Chestnut-sided Warbler (*D. pensylvanica*)	—	25	28	82	25	69	31	38
2IL	Yellow-breasted Chat (*Icteria virens*)	—	—	—	—	—	—	3	6
2IL	Hooded Warbler (*Wilsonia citrina*)	—	—	—	—	—	—	—	12
3IH	Canada Warbler (*W. canadensis*)	—	—	—	—	6	9	—	—
2OL	Cardinal (*Cardinalis cardinalis*)	—	—	—	—	3	—	6	6
2IL	Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	—	—	7	14	3	—	—	—
2OH	Indigo Bunting (*Passerina cyanea*)	25	50	21	21	6	6	19	12
3OL	Rufous-sided Towhee (*Pipilo erythrophthalmus*)	50	75	28	39	25	38	19	31
3OL	Dark-eyed Junco (*Junco hyemalis*)	—	—	—	7	—	—	—	—
Total individuals		100	211	112	205	92	146	128	169
Total species		3	7	7	10	8	7	9	12

[a] Guild designations: nest located (1) in cavities, (2) in thickets, or (3) on ground; feeding (O) omnivorous or (I) insectivorous; foraging height (L) low or (H) high.
[b] Superscript indicates number of breeding seasons since logging.

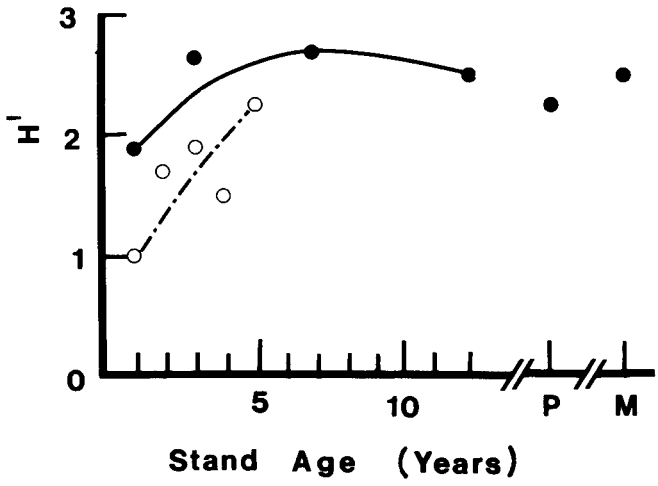

FIG. 1. Values of the Shannon diversity index, H', plotted against stand age. Open circles and dashed line indicate Highlands sites; closed circles and solid line are data from southwestern Virginia (Conner and Adkisson 1975). P = pole stand, M = mature forest.

Juncos, but lack many species found at lower elevations, including Eastern Bluebirds (*Sialia sialis*), and Red-bellied Woodpeckers (*Melanerpes carolinus*). (Scientific names not given in text are in Table 1.)

Within this escarpment four sites were selected and censused throughout two consecutive breeding seasons. The sites ranged in age from one to four seasons after logging in 1975 and two to four seasons in 1976. Size, elevation, and site index (average height of major hardwoods after 50 years of growth) were: Ellicott Rock, 8 ha, 880 m elev., 71; Rich Mountain, 14 ha, 1200 m elev., 73; Brush Creek, 16 ha, 1200 m elev., 91; Horse Cove, 16 ha, 950 m elev. 91. All exposures were east or southeast. Each area had been clearcut during the winter without site preparation and all marketable timber removed. Importance values (relative frequency plus relative density) before logging for white oak (*Quercus alba*), chestnut oak (*Q. prinus*), northern red oak (*Q. rubra*), and white pine (*Pinus strobus*) were: Ellicott Rock, 31, 22, 10, 31; Rich Mt., 35, 24, 26, 33; Brush Creek, 11, 23, 45, 0; Horse Cove, 28, 44, 12, 45. After logging oak and hickory (*Carya* spp.) sprouts were prominent but subordinate to sprouts of red maple (*Acer rubrum*) at all sites. Seedlings of tuliptree (*Liriodendron tulipifera*) increased with time since logging; by the fifth season they surpassed red maple in importance value. There was little regeneration of white pine. Vegetation on the first-year site was very sparse in spring but nearly covered the ground by autumn. Plant height averaged 1 m at the first-year site and 3–4 m at the fifth-year site. Numbers of stems per ha after logging for all tree species were: Ellicott Rock 5200; Rich Mt. 12,700; Brush Creek 10,500; Horse Cove 7400. A more complete description of the sites and their vegetation is available in Horn (Castanea 45:88–96, 1980).

Breeding bird censuses were made between 11 May and 5 July by the spot-map method (Van Velzen, Am. Birds 26:1007–1010, 1972). Each area was mapped, with flagged stakes placed every 50 m to facilitate plotting of bird observations on the map. Following the

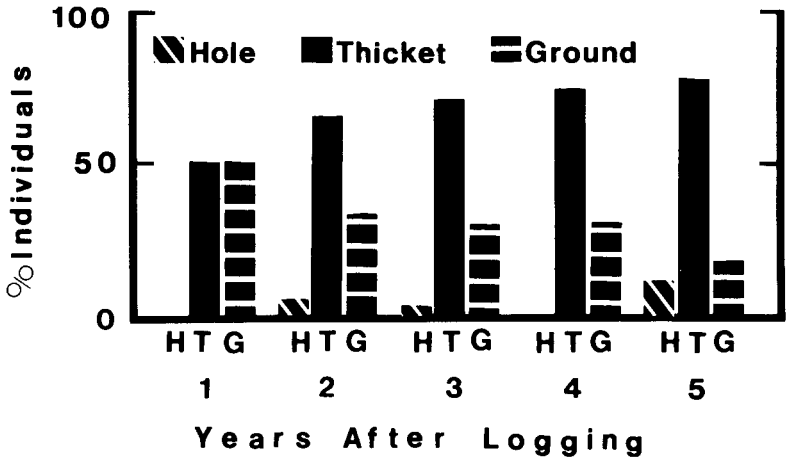

FIG. 2. Percentage of individuals in various nest guilds at the Highlands clearcuts. H = cavity or hole guild; T = thicket guild; G = ground guild.

recommendations of Best (Auk 92:452–460, 1972), I included all bird encounters and registered males singing simultaneously. Because of concurrent vegetation sampling only four formal censuses per site were made in 1975, although much non-census time was spent at each area. Ten trips per site were made in 1976. All visits took place between dawn and 09:00. In analyzing data, at least three song encounters (or two song encounters with simultaneous registration and supportive sightings) were used to determine a territory. Census results were relativized to 100 ha (1 km^2).

The limited number of formal census trips in 1975 probably resulted in underestimated numbers on all but the first-year site. The denuded vegetation of that site neither attenuated songs nor hindered complete, rapid coverage, allowing an accurate census from a few trips. Because of this difference in censusing between years, the 1975 data from all but the first-year site were excluded from the analysis.

For comparison with other work it was necessary to compute the Shannon diversity index, H′ (Pielou, An Introduction to Mathematical Ecology, John Wiley and Sons, New York, New York, 1969). In addition, changes in nest and food guilds were examined. Guilds for each species were determined from data in Bent (U.S. Natl. Mus. Bull. 176, 1940; 191, 1946; 195, 1948; 197, 1950; 203, 1953; 237, 1968) and Willson (Ecology 55:1017–1029, 1974). Nest locations were separated into: (1) cavities, (2) ground, and (3) thickets below 3 m in height. Feeding categories were: insectivores (I) vs omnivores (O) and low foragers (L) vs high foragers (H). The number of individuals in each guild was determined for every area, and the resultant table analyzed for independence of rows (guilds) and columns (years since logging) using Chi-square analysis (Steel and Torrie, Principles and Procedures of Statistics, McGraw-Hill, New York, New York, 1960:366).

Results and discussion.—Four species were found at nearly all sites both years, and can be considered characteristic of young clearcuts in this area: Carolina Wren, Rufous-sided Towhee, Indigo Bunting, and the dominant Chestnut-sided Warbler (Table 1). At the two youngest sites, forest species foraged only along the periphery. In older clearcuts they spent

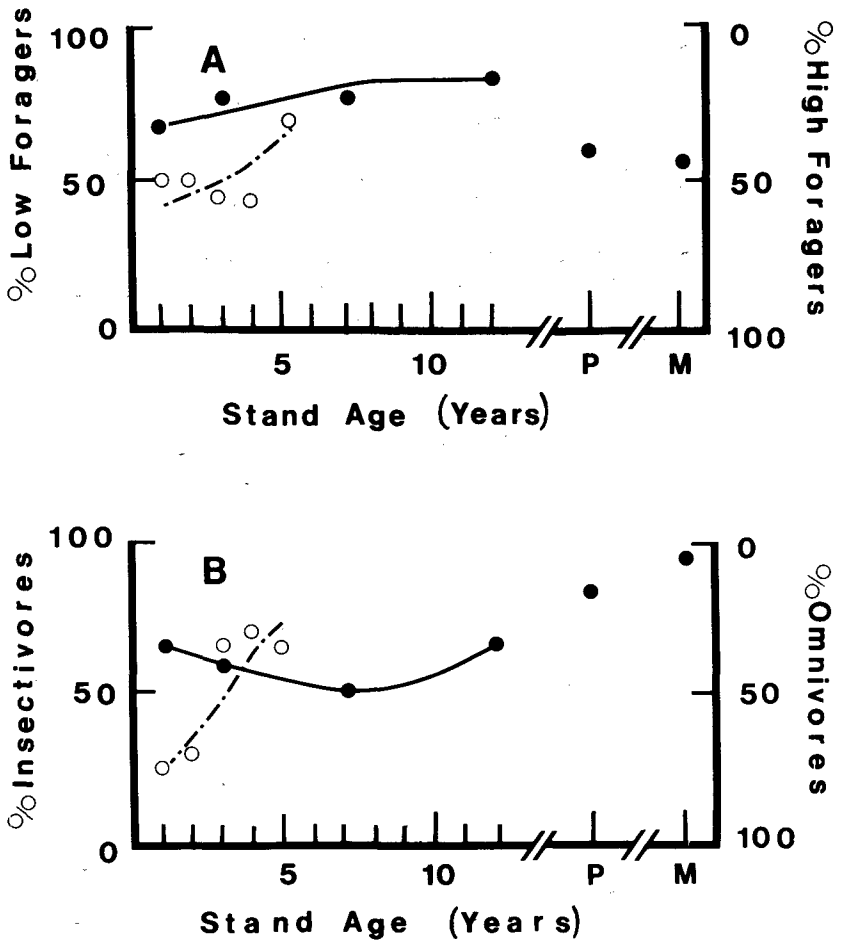

FIG. 3. Percentage of individuals in food guilds at various clearcuts. A: Low vs high foragers. B: Insectivores vs omnivores. Open circles and dashed lines indicate Highlands sites; closed circles and solid lines are data from southwestern Virginia (Conner and Adkisson 1975). P = pole stand, M = mature stand.

more time within the rapidly developing vegetation. Some (such as Tufted Titmouse and Hooded Warbler at 5-year-old Horse Cove) actually established territories in these older areas.

A paucity of birds at the first-year site was quite evident; only three species bred there, presumably because of the lack of vegetation during the period of establishment of territories. As regrowth occurred later in the season, some species occasionally foraged there.

Changes in the diversity index were positively correlated with time since logging (Fig. 1). These results parallel those of Conner and Adkisson (1975) who found generally higher

values for H′ for all years of their study, perhaps due to a larger logged area and greater species pool. Several of their more numerous bird species were not found within the Highlands area. Their work, extending over a greater range of site ages, suggested a diversity peak after about 12 years of regrowth.

With increasing site age there was a statistically significant increase in the numbers of thicket-nesting individuals and a concurrent decrease in ground nesters ($\chi^2 = 49.57$, df = 8, $P < 0.001$; Fig. 2). This may have resulted from increasing diversity of above-ground nesting habitats as plant regeneration proceeded. Only slash piles and small sprouts provided cover at the first-year site; few species of birds nested there. Regrowth was rapid and dense, suitable for more thicket nesters during succeeding years. Cavity nesters were irregular and dependent on the presence of snags (Conner and Crawford, J. For. 72:564–566, 1974; Conner et al., J. Wildl. Manage. 39:144–150, 1975), few of which were in any of the areas studied. Woodpeckers occasionally visited the clearcuts, but only the Common Flicker (*Colaptes auratus*) regularly foraged there.

Food guild changes were more complex. The number of birds which typically forage in low vegetation showed a significant increase with site age ($\chi^2 = 43.83$, df = 4, $P < 0.001$), achieving numbers nearly as high as those derived from data of Conner and Adkisson (1975) (Fig. 3A). Insectivores were clearly more abundant in older than younger cuts at Highlands ($\chi^2 = 94.12$, df = 4, $P < 0.0001$; Fig. 3B). The early stages of regrowth contained many annuals and biennials not found in mature stands (Horn 1980). This greater seed source evidently made young clearcuts more attractive to omnivores.

One problem with this study was the lack of replicate sites. Observed changes in diversity and guild structure may have been the result of intersite differences, rather than time since logging. Without replication of study areas the time/site interaction is difficult to distinguish statistically, particularly over such a short regeneration sequence. The spot-map method is a time-consuming process, making replication difficult in dense second-growth forests. For such studies it may be more advantageous to use strip transects (Emlen, Auk 94:455–468, 1977; Conner and Dickson, Wildl. Soc. Bull. 8:4–9, 1980).

In summary, clearcutting can yield significant short-term changes in both diversity and guild structure of bird communities. As indicated earlier, one forest management goal has been to maximize diversity. Clearcutting apparently creates greater habitat diversity than selective cutting (Franzreb and Ohmart, Condor 80:431–441, 1978). Habitat diversity can also be increased by clearcutting adjacent areas at different times, resulting in a range of age and area classes (Boyce, USDA For. Serv. Resear. Pap. SE-168, 1977; Boyce and Cost, USDA For. Serv. Resear. Pap. SE-194, 1978). As I have shown here, there are also significant changes in community guild structure. Further research, thus, should be designed to examine both numerical and behavioral changes.

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