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AVIAN RESPONSE TO MECHANICAL CLEARING OF A NATIVE RAINFOREST IN HAWAII[1]

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Abstract. For the first time, the effect of mechanical clearing of a native ohia/koa (*Metrosideros polymorpha*)/(*Acacia koa*) forest has been determined on some Hawaiian birds. Counts conducted on Keauhou Ranch, Island of Hawaii, at 6-month intervals, from December 1977/January 1978 through June/July 1983, showed that species richness and bird abundance were lower in the mechanically cleared or treated plots than on an adjacent control plot. In the treated plots, the nonnative Japanese White-eye (*Zosterops japonicus*), Northern Cardinal (*Cardinalis cardinalis*), and the Red-billed Leiothrix (*Leiothrix lutea*) were found in higher abundance than native species and they also were the first to recolonize following treatment. The most successful recolonizing species in the treated plots was the Japanese White-eye. Although endangered forest passerines were present in the adjacent control plot, they were not found in the treated plots. Seasonal differences in the number of birds detected in the treated plots were only observed for the native Apapane (*Himatione sanguinea*); it was found in high numbers following initial clearing, but subsequently declined, remaining stable through the study period.

Key words: Hawaii Island; Keauhou Ranch; mechanical clearing; monoculture koa forest; endangered species; species richness; bird abundance.

INTRODUCTION

Logging of a rainforest invariably affects forest birds, but the extent is not well-documented. Pattemore and Kikkawa (1975) compared bird populations in logged and unlogged rainforest of New South Wales, Australia and reported that if logged areas revert back to mature rainforest, bird species composition and abundance eventually come to resemble those of intact areas. Studies of succession among bird populations in coniferous forests indicate that bird species richness is lowest in monoculture forests (James and Wamer 1981), decreases after clearcut (Scott and Gottfried 1983), and increases as the forest matures (Johnston and Odum 1956, Haapanen 1965, James and Wamer 1981). Avian succession in a Hawaiian montane rainforest has never been documented, but I speculate that the general succession pattern should resemble results reported for other rainforest, like in New South Wales, and perhaps even mimic succession described for temperate habitats.

Many Hawaiian native birds have declined and become extinct since the arrival of man to the islands. This decline is attributed not to a single cause, but to numerous causes as clearly discussed by Ralph and van Riper (1985) and Scott et al. (1986:1). Farming practices by early Polynesians, the early commercialization of sandalwood (*Santalum* spp.), modern-day logging for koa (*Acacia koa*), conversion of native forests to pasture and to nonnative conifers, are some of many factors mentioned for causes of extinction. The impact of introduced birds upon the native avifauna is also a candidate for the demise of native species. However, as Ralph and van Riper reported, this factor is difficult to document.

The indigenous Hawaiian flora is unique because it consists of a high proportion, 95%, of endemic species (St. John 1973). The two dominant native tree species is the ohia-lehua, or ohia (*Metrosideros polymorpha*) and the koa. The ohia occurs in a variety of habitats, from sea level to over 2,500 m elevation, where it reaches best development in montane rainforests (Scott et al. 1986:7). The koa range overlaps ohia, but it has a narrower elevational range, reaching best development on upland mesic sites (Scott et al. 1986:7). Invasion by introduced plant and avian species into lowland to mid-elevation habitats

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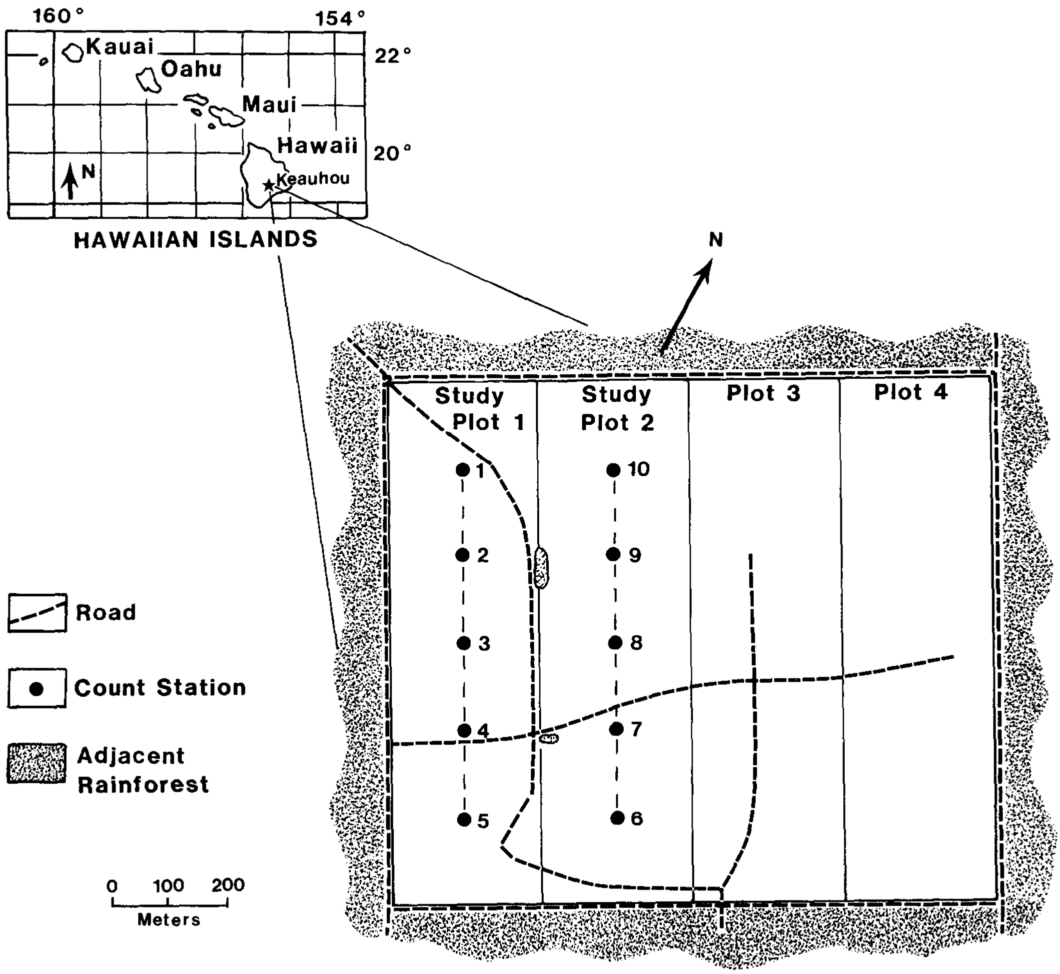

FIGURE 1. Location of treated plots and bird count stations on Keauhou Ranch, Island of Hawaii.

has resulted in major modification to the native avifauna (Berger 1981:5, Scott et al. 1986:8). However, less disturbance to montane rainforest and upper alpine habitats have been noted (Scott et al. 1986:8). This study was undertaken to determine the effects of large-scale mechanical clearing of a high elevation, montane rainforest ecosystem on bird species richness and bird abundance.

STUDY AREA

The study area was on Keauhou Ranch, elevation 1,720 m, approximately 16 km north of Kilauea Volcano, on the Island of Hawaii. Annual precipitation measured from a rain gauge placed at the study site averaged 40.5 cm from January 1978 through June 1982. About 7% of this total rainfall occurred in June and July and 21% in December and January. The mean daily temperature at the study site was 18.0°C in June and July and 14.2°C in December and January.

The upper canopy of the native rainforest was composed of 80% ohia with scattered koa (Skolmen and Fujii 1980). The lower canopy consisted of olapa (*Cheirodendron trigynum*), pilo (*Coprosma rhynchocarpa*), kawau (*Ilex anomala*), akala (*Rubus hawaiiensis*), tree fern (*Cibotium* spp.), naio (*Myoporum sandwicensis*), ohelo (*Vaccinium calycinum*), and other native plants (Cooray 1974).

Bulldozers were used to clear the native forest and scarify the ground. This stimulated regeneration of a pure stand of koa. One 20-ha plot was cleared of vegetation each spring for 4 years from 1977 to 1980, but only the first two 20-ha plots were included in this study (Fig. 1). Two small remnants of native forest (<0.01 ha each) were left intact between the two treated plots. These two mechanically cleared plots (hereafter called the treated plots), consisting of only young koa trees, served as the core area to document the changes in avian population following mechanical clearing. Vegetation cover and structure varied over time as succession proceeded.

A 16-ha area of adjacent forest (hereafter called the control plot) was located 150 m south of the study area. This plot had been established in the winter of 1977 as part of a long-term study on the habitat requirements of forest birds. The census data were supplied to me by C. J. Ralph (pers. comm.) from that study. The detailed data provided on census results will also serve as a reference point for future work in the area.

METHODS

BIRD ABUNDANCE

Bird populations in the first treated plot and the control plot were sampled at 6-month intervals from December 1977/January 1978 through June/July 1983. Similar counts in the second treated plot were initiated in December 1978/ January 1979 and continued through June/July 1983. No data were collected in the treated plots in the winters of 1979, 1982, and 1983. Twenty-five census stations were located in the control plot with 150 m between stations. Five census stations were located at 150-m intervals along a transect in each treated plot.

The point count method (Blondel et al. 1981) was used to sample bird populations at each station in the treated and control plots. Sampling began 30 min before sunrise and continued for approximately 4 hr. All birds heard or seen during an 8-min count were recorded at each station. In the treated plot, after a 10-min rest period following each of five stations, this procedure was repeated on the same stations two more times. Only those birds inside the plot being surveyed were included in the count. The treated plot was surveyed 45 times per season and the control 50 times per season. The direction of travel on transect lines was reversed on alternate sampling dates to adjust the time of day that counts were made at each station.

The number of birds detected per station and the percent occurrence of birds detected by season were used as an index of bird abundance. Number of birds detected per station was computed by dividing the number of censused stations (n = 45 or 50) into the total birds detected for each species. Percent occurrence of birds was determined by dividing the total census stations into the total number of stations in which birds were detected.

Within-season comparisons of species differences (between the control plot and the first treated plot) and between-season comparisons of species differences for each separate plot (control and treated) were analyzed using the paired t-test at the 5% level. Comparisons between the control and treated plots were limited to only the first plot because of insufficient data for the second treated plot.

VEGETATION

Six months after clearing and 6 years following treatment, the point intercept method was used to assess changes in the regenerating vegetation in the first treated plot. I sampled vegetation at each census station along 25-m transects located in each of the four cardinal compass directions. All plant species touching or crossing the tape at each meter interval were recorded. Vertical diversity in vegetation was measured by tallying the number of "hits" by species at 1-m height intervals on a telescopic rod held vertically.

RESULTS

SPECIES RICHNESS

The number of species detected was higher on the control plot (Table 1) than on the treated plots (Tables 2 and 3). Three to four native species listed as endangered by the U.S. Fish and Wildlife Service (1975) were counted in the control plot throughout the course of the study (Table 1). A greater proportion of the species on the treated plots was nonnative (Tables 2 and 3). With the exception of the endangered Hawaiian Hawk (*Buteo solitarius*) which was seen in the more open treated plots during the winter, no endangered species occurred in the treated plots at any time during the study.

BIRD ABUNDANCE

The number of birds and the percent occurrence of birds detected per station in the treated plots were generally far fewer than those on the control plot (Tables 1, 2, and 3). The general trend for the treated plots showed that, on the average, the

TABLE 1. Number of birds detected per census station and the percent occurrence of birds detected by season on the untreated control forest on Keauhou Ranch, Island of Hawaii. n = number of counts per season. Code designation for Tables 1–4: * = native species, ** = endangered native species, and † = nonnative species.

	Winter (n = 50)							
	1977		1978		1979		1980	
Bird species	#	%	#	%	#	%	#	%
*Apapane (*Himatione sanguinea*)	9.8	100.0	6.4	100.0	9.2	100.0	7.1	100.0
†Japanese White-eye (*Zosterops japonicus*)	1.8	88.0	1.7	76.0	2.0	80.0	1.7	88.0
†Northern Cardinal (*Cardinalis cardinalis*)	0.6	48.0	0.9	60.0	0.6	44.0	0.8	48.0
†Red-billed Leiothrix (*Leiothrix lutea*)	2.0	56.0	2.0	60.0	2.3	80.0	1.4	44.0
*Common Amakihi (*Hemignathus virens*)	1.4	76.0	2.1	92.0	1.2	68.0	0.8	52.0
*Omao (*Myadestes obscurus*)	4.4	100.0	4.6	100.0	4.9	100.0	3.1	100.0
†House Finch (*Carpodacus mexicanus*)	0.5	20.0	0.1	12.0	0.0	0.0	0.2	8.0
†Melodious Laughing-thrush (*Garrulax canorus*)	0.04	4.0	0.0	0.0	0.0	0.0	0.2	4.0
*Iiwi (*Vestiaria coccinea*)	1.6	100.0	1.8	76.0	1.6	84.0	1.4	72.0
*Elepaio (*Chasiempis sandwichensis*)	1.4	88.0	1.8	84.0	1.5	72.0	1.3	68.0
**Akiapolaau (*Hemignathus munroi*)	0.2	24.0	0.6	40.0	0.3	20.0	0.1	8.0
**Akepa (*Loxops coccineus*)	0.2	16.0	0.2	8.0	0.3	0.8	0.2	12.0
**Hawaiian Hawk (*Buteo solitarius*)	0.0	0.0	0.01	0.4	0.0	0.0	0.04	0.2
**Hawaii Creeper (*Oreomystis mana*)	0.1	12.0	0.4	24.0	0.2	20.0	0.2	12.0
†California Quail (*Callipepla californica*)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
†Ring-necked Pheasant (*Phasianus colchicus*)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

species increased in abundance as succession progressed (Tables 2 and 3). Certain species like the native Apapane (*Himatione sanguinea*) and the Omao (*Myadestes obscurus*) fluctuated more, but the nonnative California Quail (*Callipepla californica*), Eurasian Skylark (*Alauda arvensis*), and Nutmeg Mannikin (*Lonchura punctulata*) decreased in numbers. Comparison in abundance between the control and first treated plot by seasons showed that some nonnative and native species differed, suggesting some treatment effect (paired t-test, $P < 0.05$) (Table 4). Native species occurred in fewer numbers or were not detected at all in the treated plots (Tables 2 and 3) as compared to the control plot (Table 1).

Of all species studied, only the Apapane showed any significant seasonal difference in the number of birds detected on the first treated plot, with the greater abundance in winter (paired t–test, $P < 0.05$) (Table 4). On the control plot, seasonal differences were detected for the nonnative Japanese White-eye (*Zosterops japonicus*), Red-billed Leiothrix (*Leiothrix lutea*), and the native Elepaio (*Chasiempis sandwichensis*) (paired t-test, $P < 0.05$) (Table 4). These three species were more abundant in the summer seasons (Table 1).

Bird recolonization of treated areas usually began with establishment of the nonnative Japanese White-eye, after which it was seen regularly in high numbers (Tables 2 and 3). The nonnative Northern Cardinal (*Cardinalis cardinalis*) and Red-billed Leiothrix were the next two species to become established in the treated plots (Tables 2 and 3). About 3 years after clearing of the treated plots, other nonnative species, such as the Eurasian Skylark, California Quail, and Nutmeg

TABLE 1. Extended.

Winter (*n* = 50)		Summer (*n* = 50)									
1981		1978		1979		1980		1981		1982	
#	%	#	%	#	%	#	%	#	%	#	%
7.2	100.0	6.2	100.0	5.3	100.0	3.7	100.0	7.1	100.0	10.2	100.0
1.0	80.0	2.7	100.0	3.2	100.0	2.8	100.0	1.4	96.0	1.8	96.0
0.8	56.0	1.7	88.0	2.8	100.0	2.7	96.0	1.2	92.0	1.3	80.0
0.3	16.0	3.8	100.0	6.8	100.0	6.9	100.0	4.2	100.0	0.8	36.0
0.7	56.0	1.8	96.0	1.1	64.0	1.2	72.0	0.6	44.0	1.1	64.0
2.8	100.0	3.4	100.0	4.5	100.0	3.5	96.0	2.3	92.0	3.2	100.0
0.2	12.0	1.3	56.0	1.9	64.0	0.8	32.0	0.4	28.0	0.2	20.0
0.0	0.0	0.5	32.0	0.2	12.0	0.2	20.0	0.0	0.0	0.0	0.0
1.6	88.0	2.5	100.0	3.3	88.0	2.4	92.0	0.7	72.0	1.5	92.0
1.4	88.0	2.6	100.0	3.6	96.0	3.4	100.0	1.9	100.0	1.5	96.0
0.04	4.0	0.6	44.0	0.3	24.0	0.2	16.0	0.1	8.0	0.1	12.0
0.1	4.0	0.5	24.0	0.2	16.0	0.1	12.0	0.2	16.0	0.2	12.0
0.0	0.0	0.04	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2	16.0	0.1	12.0	0.1	8.0	0.2	8.0	0.04	4.0	0.1	8.0
0.0	0.0	0.2	12.0	0.2	4.0	0.04	4.0	0.0	0.0	0.0	0.0
0.0	0.0	0.6	44.0	0.1	12.0	0.04	4.0	0.0	0.0	0.0	0.0

Mannikin, were present in low numbers during both winter and summer seasons (Tables 2 and 3). A few sightings of Lesser Golden-Plovers (*Pluvialis dominica*) were recorded but only during the winter counts (Tables 2 and 3).

The percent occurrence and the number of birds detected per station in the treated areas showed a similar trend within each season. The nonnative Japanese White-eye, Red-billed Leiothrix, and Northern Cardinal were the most common species seen during the summer seasons (Tables 2 and 3). Japanese White-eye and Northern Cardinal as well as the native Apapane were most common in the winter seasons (Tables 2 and 3). The percent occurrence figures for both seasons showed that the nonnative House Finch (*Carpodacus mexicanus*), Nutmeg Mannikin, Eurasian Skylark, California Quail, the native Lesser Golden-Plover, and the endangered Hawaiian Hawk, were more common in the earlier successional stages and were generally absent (or at much lower levels, e.g., House Finch) 2 to 3 years following treatment. House Finches were also more common in the summer than winter seasons (Tables 2 and 3). The Melodious Laughing-thrush (*Garrulax canorus*) seemed to prefer the later successional stages, as they were not encountered until 4 years posttreatment, when koa trees formed a young dense forest averaging 3.5 m tall (Skolmen and Fujii 1980).

For the duration of the study, 5 years for the second treated plot and 6 years for the first treated plot, Apapane were the only native species to be consistently detected (Tables 2 and 3) in the koa-dominated canopy-layered forest that developed on the treated sites (Table 5). The Apa-

TABLE 2. Number of birds detected per census station and the percent occurrence of birds detected by season on the first treated plot on Keauhou Ranch, Island of Hawaii. Winter counts for 1979 and 1982 were not made. n = number of counts per season.

	Winter (n = 45)							
	1977		1978		1980		1981	
Bird species	#	%	#	%	#	%	#	%
*Apapane	8.40	100.0	2.60	91.1	1.51	68.9	2.64	88.9
†Japanese White-eye	0.56	31.1	1.24	80.0	1.51	77.8	2.42	97.8
†Northern Cardinal	0.0	0.0	0.11	22.2	0.31	35.6	0.42	42.2
†Red-billed Leiothrix	0.0	0.0	0.11	6.7	0.13	11.1	0.11	8.9
*Common Amakihi	0.60	35.6	0.01	2.2	0.02	4.4	0.09	6.7
*Omao	0.36	31.1	0.18	20.0	0.09	13.3	0.07	4.4
†House Finch	0.09	4.4	0.11	6.7	0.2	17.8	0.04	2.2
†Melodious Laughing-thrush	0.0	0.0	0.0	0.0	0.04	4.4	0.04	4.4
*Iiwi	0.13	13.3	0.0	0.0	0.0	0.0	0.01	2.2
†Nutmeg Mannikin	0.0	0.0	0.04	2.2	0.0	0.0	0.0	0.0
†Eurasian Skylark	0.38	24.4	0.33	44.4	0.04	24.4	0.0	0.0
*Elepaio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
**Hawaiian Hawk	0.07	6.7	0.01	2.2	0.0	0.0	0.0	0.0
†California Quail	0.06	2.2	0.01	2.2	0.0	0.0	0.0	0.0
*Lesser Golden-Plover	0.01	2.2	0.01	2.2	0.0	0.0	0.0	0.0

pane were not as consistent in occurrence and abundance on the control plot (Table 1). The native thrush, the Omao (*Myadestes obscurus*) and Common Amakihi (*Hemignathus virens*), although present in all seasons, were not found in high numbers throughout the study period on either the control or treated plots. The native Elepaio was not observed in any of the winter season counts but occurred in the summers 4 years after clearing of the first treated plot and 5 years after clearing of the second treated plot (Tables 2 and 3).

The most successful species on the treated plots was the nonnative Japanese White-eye (Tables 2 and 3). Although nest searches were conducted only while walking between sampling points, and not done systematically over the entire study area, the first nest found was that of a Japanese White-eye. The nest was found in the summer of 1981, 3.5 years after clearing of the first treated plot.

TABLE 3. Number of birds detected per census station and the percent occurrence of birds detected by season on the second treated plot on Keauhou Ranch, Island of Hawaii. Winter counts for 1979 and 1982 were not made. n = number of counts per season.

	Winter (n = 45)						Summer (n = 45)			
	1978		1980		1981		1979		1980	
	#	%	#	%	#	%	#	%	#	%
*Apapane	4.67	88.9	0.38	46.7	1.10	68.9	0.60	4.4	0.53	37.8
†Japanese White-eye	2.22	37.8	1.31	95.6	2.33	86.7	2.04	97.8	2.91	100.0
†Northern Cardinal	0.04	6.7	0.16	24.4	0.27	24.4	0.24	55.6	0.13	20.0
†Red-billed Leiothrix	0.0	0.0	0.0	0.0	0.06	2.2	0.17	35.6	0.51	31.1
*Common Amakihi	0.09	8.9	0.02	2.2	0.90	6.7	0.20	15.6	0.07	6.7
*Omao	0.13	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
†House Finch	0.29	13.3	0.13	15.6	0.16	4.4	1.91	88.9	0.91	42.2
†Melodious Laughing-thrush	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
*Iiwi	0.07	6.7	0.13	13.3	0.16	2.2	0.0	0.0	0.0	0.0
†Nutmeg Mannikin	0.29	8.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
†Eurasian Skylark	0.64	55.6	0.13	13.3	0.13	4.4	0.16	22.2	0.02	2.2
*Elepaio	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
**Hawaiian Hawk	0.02	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
†California Quail	0.0	0.0	0.0	0.0	0.0	0.0	0.09	8.9	0.0	0.0
*Lesser Golden-Plover	0.07	2.2	0.0	0.0	0.0	0.0	0.04	2.2	0.0	0.0
†Kalij Pheasant	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 2. Extended.

Summer (*n* = 45)											
1978		1979		1980		1981		1982		1983	
#	%	#	%	#	%	#	%	#	%	#	%
0.47	44.4	0.13	22.2	0.04	4.4	1.69	80.0	2.18	84.4	0.89	62.2
1.36	68.9	2.69	82.2	2.22	100.0	2.89	100.0	1.51	88.9	4.18	97.8
0.18	22.2	0.20	26.7	0.13	28.9	1.00	77.8	0.67	62.2	1.40	95.6
0.42	40.0	0.18	20.0	0.36	31.1	1.56	77.8	0.87	53.3	4.56	97.8
0.11	13.3	0.04	6.7	0.27	17.8	0.0	0.0	0.11	11.1	0.84	32.2
0.36	31.1	0.04	8.9	0.04	8.9	0.18	22.2	0.22	24.4	0.18	11.1
1.16	68.9	4.33	75.6	0.62	44.4	0.29	15.6	0.16	11.1	0.27	15.6
0.0	0.0	0.0	0.0	0.0	0.0	0.06	2.2	0.07	6.7	0.29	24.4
0.11	8.9	0.0	0.0	0.0	0.0	0.03	2.2	0.04	2.2	0.16	15.6
0.07	4.4	0.07	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.40	24.4	0.16	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.09	4.4	0.27	26.7	0.80	66.7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.20	24.4	0.04	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Other nests discovered in the first treated plot in the summer of 1982 were Red-billed Leiothrix, Elepaio, and Apapane.

DISCUSSION

For both treated plots, more species were detected in the summers than in the winters. The higher summer occurrences could be attributed to the elevational migration of birds to food sources (Baldwin 1953) and/or the greater availability of fruiting plants during this period (Sakai et al. 1986).

The number of bird species and abundance apparently decreased following clearing of the native rainforest (Tables 1, 2, and 3), as has been reported at other sites. During the 6 years of the study, the only endangered species seen in the developing monocultural koa forest was the Hawaiian Hawk and this only during the winter season. The other endangered species, the Akepa (*Loxops coccineus*), Akiapolaau (*Hemignathus munroi*), and Hawaii Creeper (*Oreomystis mana*) did not use the young treated forest during this study, implying the need for older forests. The question of when will these endangered species return to use the treated koa forests is an important one. Previous studies have shown that the three species use older trees for most of their foraging (Ralph, in press) and nesting requirements (Sakai 1980, Sincock and Scott 1980, Sakai and Johanos 1983, Collins 1984). Therefore, as the understory plants become established and the dominant koa trees mature, bird abundance and species richness, including endangered species, should eventually start to resemble those found in uncut areas. Pattemore and Kikkawa (1975) found a similar pattern of bird abundance in New South Wales. Since the Hawaii Creeper and the Akiapolaau foraged by probing and pecking, mainly on well-developed rugose bark surfaces, development of this specific surface will most likely influence when they use the trees in

TABLE 3. Extended.

Summer (*n* = 45)					
1981		1982		1983	
#	%	#	%	#	%
0.91	66.7	1.30	80.0	0.42	31.1
2.40	95.6	1.89	88.9	4.18	100.0
0.51	44.4	0.69	57.8	1.31	93.3
0.69	53.3	0.89	51.1	4.24	100.0
0.0	0.0	0.0	0.0	0.11	11.1
0.04	4.4	0.29	11.1	0.01	2.2
0.53	31.1	0.29	20.0	0.51	37.8
0.0	0.0	0.0	0.0	0.09	8.9
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.07	8.9	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.07	6.7
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.07	4.4

TABLE 4. Within- and between-season comparisons of the mean species differences between the control and the treated plots. ^ = significant at 0.05 level.

	Control vs. first treated plot		Control	First treated plot	Second treated plot
	Winter	Summer	Winter vs. summer	Winter vs. summer	Winter vs. summer
	t-value (df = 3)	*t*-value (df = 4)	*t*-value (df = 3)	*t*-value (df = 2)	*t*-value (df = 1)
*Apapane	4.30^	7.97^	1.87	4.44^	0.12
†Japanese White-eye	0.21	0.52	−5.15^	−2.53	−1.09
†Northern Cardinal	6.46^	3.07^	−3.07	−0.70	−0.78
†Red-billed Leiothrix	3.22^	3.02^	−5.02^	−1.68	−9.50
*Common Amakihi	3.13	5.94^	0.17	−0.93	0.89
*Omao	8.78^	8.44^	1.30	−1.17	−1.00
†House Finch	1.43	−0.77	−2.63	−2.36	−2.80
†Melodious Laughing-thrush	0.92	1.47	−1.48	0.38	—
*Iiwi	17.22^	4.54^	−1.14	−0.11	9.67
†Nutmeg Mannikin	−1.00	−1.63	—	−1.00	—
†Eurasian Skylark	−1.92	−1.43	—	−0.31	3.40
*Elepaio	13.30^	5.57^	−3.25^	−1.00	—
**Akiapolaau	1.86	2.80^	−1.63	—	—
**Akepa	7.00^	3.54^	−0.52	—	—
**Hawaiian Hawk	−0.33	1.00	0.17	1.00	—
**Hawaii Creeper	3.57^	4.19^	2.23	—	—
†California Quail	−1.00	1.29	−2.09	−1.00	—
†Ring-necked Pheasant	—	1.29	−1.32	—	—
*Lesser Golden-Plover	−1.73	—	—	1.00	—
†Kalij Pheasant	—	—	—	—	—

the monocultural koa site. Akepa, however, foraged mainly by gleaning on leaves of ohia, but they also gleaned on koa foliage (Ralph, in press), and this difference in use of forage substrates between the three species may also influence when they use the habitat in the treated plots.

Nest-site selection of these three endangered species infer the importance of cavities. Although the number of reported nests for these endangered species is not large, Akepa seems to be a cavity specialist (Sincock and Scott 1980, Collins 1984, Freed et al. 1987). The other two species are known to use cavities, as well as other nesting substrates (van Riper 1973, Sakai 1980,

TABLE 5. Vegetation composition of the first treated plot 6 months and 6 years following clearing of a native rainforest on the Island of Hawaii.

Species	6 months following treatment	6 years following treatment		
	Ground cover %	Ground cover %	Shrub cover %	Canopy cover %
Kikuyu grass (*Pennisetum clandestinum*)	12	51	—	—
Koa (*Acacia koa*)	2	0	0	86
Puu lehua grass (*Microlaena stipodes*)	8	44	—	—
Sword fern (*Dryopteris* spp.)	2	0	10	—
Alligator sedge (*Carex alligata*)	1	1	—	—
Akala (*Rubus hawaiiensis*)	1	0	32	0
Sweet vernal grass *Anthoxanthum odoratum*)	1	4	—	—
Bare ground	83	0	—	—
Gosmore (*Hypochoeris radicata*)	0	0	—	—
Ohia (*Metrosideros polymorpha*)	0	0	1	0
Pilo (*Coprosma rhynchocarpa*)	0	0	1	2
Naio (*Myoporum sandiwcensis*)	0	0	2	3
Ohelo (*Vaccinium calycinum*)	0	0	4	0
Total % cover	27	100	50	91

Sakai and Ralph 1980, Scott et al. 1980, Sakai and Johanos 1983). Therefore, these endangered species also probably did not occur in the treated plots because the koa trees do not yet provide these specialized nest sites.

The native Apapane, Common Amakihi, and Elepaio, and the nonnative Japanese White-eye, Red-billed Leiothrix, and Northern Cardinal seem to adapt and use the young, treated koa forests. The nonnative Eurasian Skylark, California Quail, Nutmeg Mannikin, and the native Lesser Golden-Plover favored open space over areas covered with thick vegetation and therefore were only found in the earlier successional stages following treatment. Nutmeg Mannikin were commonly seen perched on grass stalks along the open roadside and forest clearings; however, 2 to 3 years following treatment these open areas were overgrown by koa trees or taken over by the more competitive grasses like kikuyu (*Pennisetum clandestinum*) and puu lehua (*Microlaena stipoides*). The Lesser Golden-Plover, Eurasian Skylark, and Nutmeg Mannikin will probably not be seen again as the overstory matures. The nonnative Japanese White-eye, Red-billed Leiothrix, and Northern Cardinal, as well as the native Apapane are species that seem to establish themselves sooner than other species following disturbance. Apapane were often observed in nonforaging activities like preening, singing, sitting, and calling from fallen snags or stumps in the first 6 months following treatment; this may account for their higher abundance during this period. These fallen snags seemed to serve as a congregational area, and it was not uncommon to observe flocks of 20 to 30 Apapanes perched on them in the early morning hours.

The occurrence of Japanese White-eye immediately following treatment demonstrates their ability to become established in disturbed areas faster than native species. Others have commented on the Japanese White-eye's ability to thrive in disturbed environments (Gill 1971, Berger 1981, Scott et al. 1986). Their omnivorous feeding habits (Guest 1973) and their tendency to occur in large winter flocks (Guest 1973) gives them an advantage in repopulating disturbed areas quickly. The native Elepaio, Common Amakihi, Omao, and Iiwi (*Vestiaria coccinea*) and the nonnative Melodious Laughing-thrush seemed to take longer to reestablish themselves following the clearing. The delay may be due to the scarcity of food plants in the treated areas and/or a preference for taller canopy trees.

Koa logging is of great interest to organizations and agencies in Hawaii. Documentation of the vegetation changes associated with silvicultural treatments designed to produce monocultural koa forests and the effects of these changes on wildlife is needed if we are to fully understand the effects of this forestry practice. Continued monitoring of these treatments is needed to reveal the long-term effects of producing monoculture koa forests.

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