



## FEATURE ARTICLES

The Condor 104:469–481  
© The Cooper Ornithological Society 2002

### TEMPORAL VARIATION IN BIRD COUNTS WITHIN A HAWAIIAN RAINFOREST

JOHN C. SIMON<sup>1</sup>, THANE K. PRATT<sup>1,3</sup>, KIM E. BERLIN<sup>4</sup>, JAMES R. KOWALSKY<sup>5</sup>,  
STEVEN G. FANCY<sup>6</sup> AND JEFF S. HATFIELD<sup>2</sup>

<sup>1</sup>USGS Pacific Island Ecosystems Research Center, P.O. Box 44, Hawai'i National Park, HI 96718-0044

<sup>2</sup>USGS Patuxent Wildlife Research Center, Laurel, MD 20708-4017

*Abstract.* We studied monthly and annual variation in density estimates of nine forest bird species along an elevational gradient in an east Maui rainforest. We conducted monthly variable circular-plot counts for 36 consecutive months along transects running downhill from timberline. Density estimates were compared by month, year, and station for all resident bird species with sizeable populations, including four native nectarivores, two native insectivores, a non-native insectivore, and two non-native generalists. We compared densities among three elevational strata and between breeding and nonbreeding seasons. All species showed significant differences in density estimates among months and years. Three native nectarivores had higher density estimates within their breeding season (December–May) and showed decreases during periods of low nectar production following the breeding season. All insectivore and generalist species except one had higher density estimates within their March–August breeding season. Density estimates also varied with elevation for all species, and for four species a seasonal shift in population was indicated. Our data show that the best time to conduct counts for native forest birds on Maui is January–February, when birds are breeding or preparing to breed, counts are typically high, variability in density estimates is low, and the likelihood for fair weather is best. Temporal variations in density estimates documented in our study site emphasize the need for consistent, well-researched survey regimens and for caution when drawing conclusions from, or basing management decisions on, survey data.

*Key words:* bird counts, density estimation, Hawaiian honeycreepers, phenology, rainforest, variable circular-plot.

#### Variación Temporal en Conteos de Aves en una Selva Lluviosa de Hawái

*Resumen.* Estudiamos la variación mensual y anual en estimaciones de la densidad de nueve especies de aves a lo largo de un gradiente altitudinal en una selva lluviosa del este de Maui. Realizamos conteos mensuales en parcelas circulares por un período de 36 meses consecutivos a lo largo de transectas ubicadas desde la línea del bosque hacia abajo. Las estimaciones de densidad fueron comparadas entre meses, años y estaciones considerando todas las especies de aves residentes con poblaciones considerables, incluyendo cuatro nectarívoros nativos, dos insectívoros nativos, un insectívoro no nativo y dos generalistas no nativos. Comparamos densidades entre tres estratos altitudinales y entre las estaciones reproductivas y no reproductivas. Todas las especies mostraron diferencias significativas en las estimaciones de densidad entre meses y años. Tres nectarívoros nativos presentaron estimaciones de densidad mayores durante sus épocas reproductivas (diciembre–mayo) y

---

Manuscript received 2 July 2001; accepted 18 April 2002.

<sup>3</sup> Corresponding author. E-mail: thane\_pratt@usgs.gov

<sup>4</sup> Present address: 75 Birch Hill Rd., Mt. Sinai, NY 11766.

<sup>5</sup> Present address: P. O. Box 171, Winchester, NH 03470.

<sup>6</sup> Present address: National Park Service, 1201 Oak Ridge Dr., Suite 200, Fort Collins, CO 80525-5589.

mostraron disminuciones durante períodos de baja producción de néctar luego de la estación de cría. Excepto una, todas las especies insectívoras y generalistas presentaron mayores estimaciones de densidad durante sus épocas reproductivas (marzo-agosto). Las estimaciones de densidad de todas las especies también variaron con la altitud, y se encontraron cambios estacionales en las poblaciones de cuatro especies. Nuestros datos muestran que el mejor momento para realizar conteos de aves nativas de selva en Maui es enero-febrero, cuando las aves están criando o preparándose para criar, los conteos son típicamente altos, la variabilidad en las estimaciones de densidad es baja y la probabilidad de buen tiempo es más alta. La variación temporal en las estimaciones de densidad documentadas en nuestro sitio de estudio enfatizan la necesidad de regímenes de muestreo consistentes y bien establecidos, y sugiere cautela a la hora de sacar conclusiones para conservación o tomar decisiones de manejo a partir de datos de muestreos.

## INTRODUCTION

Documenting spatial and temporal changes in bird populations has become an essential component of species and ecosystem management in Hawai'i and elsewhere (Scott, Jacobi, and Ramsey 1981, Verner 1985, Ralph et al. 1995, Bibby et al. 2000). In the 1970s, the methodology for surveying birds using distance-estimation and variable circular-plot (VCP) counts was developed and then applied to the Hawai'i Forest Bird Survey, a one-time comprehensive survey of native forest birds on five main Hawaiian Islands (Reynolds et al. 1980, Scott et al. 1986). This survey mapped the distributions and estimated population sizes for all endangered and nonendangered species and set the stage for long-term monitoring of individual species, such as the endangered Palila (*Loxioides bailleui*; Jacobi et al. 1996), and of local bird communities. Efforts currently are underway to establish a centralized database and reporting system for all VCP surveys in the islands (USGS Pacific Island Ecosystems Research Center [PIERC], unpubl. data). In addition to estimating population geography and size, these count data have been used to draw inferences about habitat suitability and the distribution of other limiting factors, such as disease and interspecific competition (Mountainspring and Scott 1985, Scott et al. 1986, Berlin et al. 2001).

Information on population distribution and numbers, and inferences regarding habitat suitability and distribution of limiting factors, have played an important role in recovery actions for endangered bird species in Hawai'i. Three large reserves, the Hakalau Forest National Wildlife Refuge, the Hanawā Natural Area Reserve, and the Ōla'a-Kīlauea Management Area, encompass key populations of endangered birds first identified by the Hawai'i Forest Bird Survey. Survey data will be the main source of infor-

mation in coming years for delineating critical habitat for all endangered forest birds, as has already been done for the Palila (U.S. Fish and Wildlife Service 1986).

Currently, bird counts in Hawai'i are used for two broad purposes. First, entire populations are counted over large geographic areas on a supra-annual schedule to monitor long-term trends. These counts serve in the place of the roadside counts of the North American Breeding Bird Survey (Robbins et al. 1986), because native Hawaiian forest birds live mainly in habitat without road access, and because of the environmental changes over time introduced by roadways (Keller and Scallan 1999). Native forest birds, including 18 endangered species, inhabit mid- and high-elevation forests having limited accessibility to survey personnel. The second application of bird counts in Hawai'i is to monitor local populations in areas undergoing management. Here the purpose is to document the birds' response to habitat restoration, predator control, and other recovery activity.

Although conservationists rely on density estimates from counts taken at intervals of one or more years for monitoring populations, it requires some understanding of the temporal variations in species density during between-survey periods to determine whether long-term trends are real (Green 1994). Similarly, a comparison of different survey areas must take into account the overall heterogeneity of a species' spatial distribution. A disregard for small-scale variations, combined with the inherent error associated with the survey methodology (Kepler and Scott 1981, Scott and Ramsey 1981, Scott, Ramsey, and Kepler 1981, Desante 1986), could lead to erroneous conclusions regarding the population trend of a given species and the condition of its environment.

Seasonal variation in density estimates is rarely documented for tropical birds generally, in-

cluding for Hawaiian forest birds (Ralph and Fancy 1995). At the time of the Hawai'i Forest Bird Survey, the annual cycles of most native and non-native species were essentially unknown. However, the past two decades have seen an explosion in studies of Hawaiian bird biology (Scott et al. 2001). To examine whether seasonal variation introduces uncertainty into year-to-year comparisons, we integrated an intensive bird survey regimen into ecological studies of two endangered Maui Island species, the 'Ākohekohe (*Palmeria dolei*), or Crested Honeycreeper, and the Maui Parrotbill (*Pseudonestor xanthophrys*). We conducted monthly bird counts for three years to investigate the differences in density estimates by month, season, year, and elevational stratum. We compared elevational strata to investigate whether birds moved seasonally between strata. Because nectar availability of the dominant tree, 'ōhi'a lehua (hereafter simply 'ōhi'a, *Metrosideros polymorpha*), affects distribution of nectarivores (Ralph and Fancy 1995, Berlin et al. 2001), and because flower scoring has traditionally been incorporated into bird counts, we compared response of bird density to both flower scoring and to the more accurate method of flower counting (Berlin et al. 2000).

## METHODS

### STUDY AREA AND SAMPLING DESIGN

From January 1995 through December 1997, we conducted monthly VCP surveys at 40 permanent stations established between treeline (ca. 2125 m) and 1550 m elevation within the State of Hawaii's Hanawā Natural Area Reserve, Maui (20°45'N, 156°08'W, Fig. 1). The first nine stations on each of four roughly parallel transects were located within the Pu'u-'alaea management unit, one of four fenced units designed to exclude feral ungulates; the tenth station on each transect was 40–100 m below the lower (northern) boundary fence. In this paper, we refer to the approximately 80-ha area sampled by these 40 stations as our study area.

Within our study area, the forest canopy was dominated by 'ōhi'a with few other trees and a relatively dense subcanopy and understory (Jacobi 1989, Berlin et al. 2000). The study area was located on a steep, windward, north-facing slope (approx. 25°) of ridges and small ravines up to 15 m deep. Because a random placement

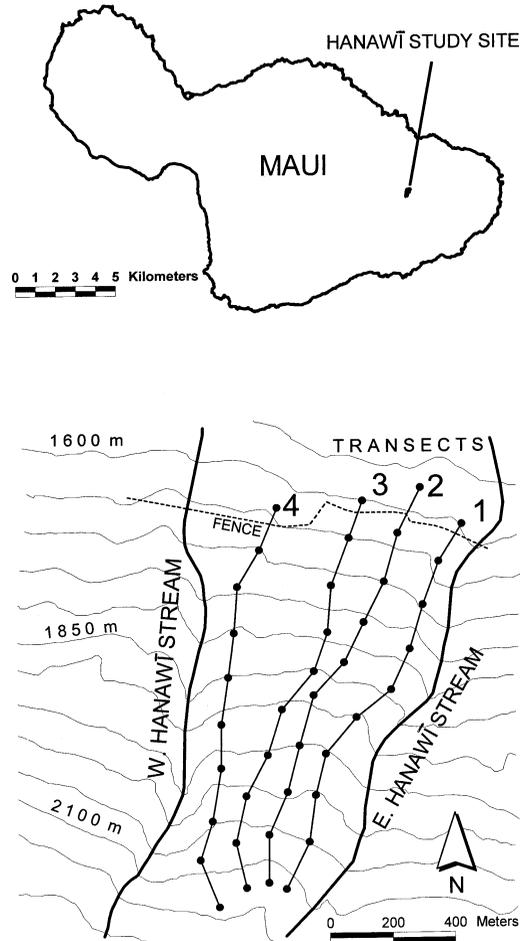


FIGURE 1. Map of the east Maui study site at Hanawā Natural Area Reserve showing four parallel transects with count stations marked as dots. Contour elevations are at 50-m intervals.

of count stations was impractical, we ran transects along the more or less parallel ridges, approximately 100 m apart wherever possible. A concern when setting up the study was that by siting stations on ridges, bird counts for some species would be biased (Scott et al. 1986, Reynolds and Snetsinger 2001). However, we decided the bias would be small because the distance between ridge crests and streams on the study site was usually shorter than the effective detection distance for any species (Scott et al. 1986). In other words, we could adequately hear and see birds in these ravines.

The first station on each transect was established approximately 50 m below treeline. Sta-

tions 1–10 were spaced at ca. 150-m intervals (horizontal, straight line) down the transect, although our initial physical measurements were crude due to thick undergrowth. We subsequently used GPS (global positioning system) and ground truthing to establish coordinates for all stations, and found that the mean distance between successive stations was 148.6 m (SD = 10.2 m, range 127–170 m). Counts on adjacent transects were performed on different days to minimize overlap of detection area. The minimum distance between contemporaneously sampled stations on nonadjacent transects was 129 m; however, distances between all remaining station pairs exceeded 150 m (min = 178 m, max = 470 m; overall mean for 20 pairs = 293.8 m, SD = 96.5).

Five different individuals conducted the counts; however, data for one counter, who surveyed only a single transect, were pooled with those of the reference observer. We retrained ourselves on distance estimation before each monthly count. To provide visual references for distance estimates during counts, we placed two sets of vinyl flagging markers at 10 and 20 m from each station (Scott et al. 1986). To minimize double-counting, we recorded each bird's approximate position, relative to the station center, on a data sheet having concentric circles representing 10-m intervals (Ralph et al. 1995).

We recorded birds at each station using the VCP method (Reynolds et al. 1980), with a count duration of 8 min. We estimated distances to the nearest meter. We began counts on each transect at the uppermost station 30 min after local sunrise and followed with counts at each successive station down the transect. Each day's counts were typically completed within 4 hr unless interrupted by poor weather.

We recorded weather conditions and 'ōhi'a flower abundance immediately prior to each count. We estimated overhead cloud cover to the nearest 10%, classified rainfall (0 = no rain, 1 = fog, 2 = mist or light rain), and estimated wind strength using the Beaufort scale. We postponed counts if more than light rain fell or if average wind strength was higher than Beaufort scale 3.

At each station, we scored 'ōhi'a flowers for five randomly selected trees by estimating the percent of foliated branch tips with flowers, using the following scores: 0 = no flowers; trace = <1%; 1 = 1–10%; 2 = 11–20%; 3 = 21–

30%; etc. We counted 'ōhi'a flower clusters (hereafter called "flowers") for 2–3 marked trees at each station, so that the same trees were sampled monthly, as reported in Berlin et al. (2000). For both flower scoring and flower counting, we selected trees that met three criteria: (1) one complete side of the canopy was visible, (2) the tree was large enough to bear flowers, and (3) the closest trees to the station that were off the trail (to avoid trampling).

#### STATISTICAL ANALYSES

We calculated bird densities by analyzing pooled data from monthly surveys using the programs DISTANCE (Laake et al. 1994), VCPSC, and VCPADJ as described in Fancy (1997). The latter two programs made corrections for covariates that affect detection distances (e.g., observer, weather conditions, time of day) by adjusting the effective area surveyed for each species during each sample period to standard reference conditions.

We conducted analyses on density estimates calculated for each station. We had a total of 480 counts per year on the study area (40 stations, 12 months). We did not correct counts for vegetation type because nearly all the stations lay with a single vegetation type, a closed-canopy forest with a closed understory 2–10 m high (Scott et al. 1986). The study area was divided into low (1567–1733 m), medium (1750–2030 m), and high (2044–2128 m) elevational strata to test for elevation differences. These strata were initially based on elevational breeding distribution of 'Ākohekohe and roughly correspond to gradual changes in vegetation, as described in Berlin et al. (2001).

We calculated flower abundance at the count station by substituting a value of 0.1 for the <1% score and then taking a mean value of the scores for all five trees for each month and year. Flower scores for 11 of the 1440 counts conducted on the study site were not recorded, leaving a sample size of 1429 when comparing flower abundance to nectarivore density. We also used a second estimate of flower abundance based on direct counts of flowers, calculating the mean number of flowers at each station and including this variable as a continuous covariate in the ANCOVA (Berlin et al. 2001).

To compare densities of each species in the study area, we used a three-way repeated measures ANOVA using the mixed-models proce-

ture in SAS (SAS Institute 1997; PROC MIXED). The 40 stations were considered the random subject factor, nested within elevational categories (Littell et al. 1996, Berlin et al. 2000). The main effects were month, year, and elevational category, along with two-way and three-way interactions of these variables. We assumed a compound symmetry, homogeneous variance model for the variance-covariance structure of the repeated measures (Littell et al. 1996). The Tukey multiple comparison procedure was used to sort out differences ( $\alpha < 0.05$ ) among months, years, and elevational categories.

We performed contrasts, averaging over groups of months, to compare breeding season densities of each species with nonbreeding season densities. For the native nectarivorous species, 'Ākohekohe, 'Apapane (*Himatione sanguinea*), Hawai'i 'Amakihi (*Hemignathus virens*), and 'I'iwi (*Vestiaria coccinea*), the breeding season was defined as December–May (Ralph and Fancy 1994, Berlin et al. 2001), while for the remaining species, the breeding season was defined as March–August (Brazil 1991, Ralph et al. 1998, Baker and Baker 2000, Simon et al. 2000). Pairwise comparisons (1) between seasons for each elevational stratum and (2) among the three elevational strata within each season were obtained from contrasts specified from the ANOVAs. Bonferroni adjustments were used to keep the overall alpha level at 0.05 for the nine contrasts performed for each species.

We performed repeated measures ANCOVA to compare the mean 'ōhi'a flower scores calculated in this study with the mean flower counts reported in Berlin et al. (2000). The dependent variable in this analysis was mean 'ōhi'a flower score from this study, the covariate was the flower count from Berlin et al. (2000), and the categorical independent variables were month and year, and their interaction. As with the ANOVA, stations were the random subject factor. We also performed repeated measures ANCOVAs to compare bird densities for each species with 'ōhi'a flower abundance using both mean flower scores and flower counts (in separate ANCOVAs) along with month, year, and elevational category and their interactions.

To determine whether certain months were better than others for conducting surveys for the 6 native species, we calculated the coefficient of variation (CV) for each species in each month over the plots in each elevational stratum. We

then analyzed the CVs for differences among months and species using a repeated measures ANOVA in which the elevational strata were considered to be the sampling unit. Tukey pairwise comparisons were performed for month and species  $\times$  month to determine the best months (with lowest CVs) for surveying these six species. We also used Tukey's studentized range tests to compare monthly means of density estimates and to determine highest and lowest, assuming that the months with highest means were best for counting. We then identified consecutive months that produced the highest counts, for use in planning large-scale surveys requiring more than one month to complete.

## RESULTS

### SPECIES DETECTED

We detected nine species in sufficient numbers to produce density estimates for various comparisons. Six species were Maui natives: 'Ākohekohe ( $n = 3065$  detections), 'Apapane ( $n = 9002$ ), Hawai'i 'Amakihi ( $n = 3964$ ), 'I'iwi ( $n = 2668$ ), Maui 'Alauahio (*Paroreomyza montana*,  $n = 1784$ ), and Maui Parrotbill ( $n = 429$ ). Three species were non-native: Japanese Bush-Warbler (*Cettia diphone*,  $n = 710$ ), Japanese White-eye (*Zosterops japonicus*,  $n = 1189$ ), and Red-billed Leiothrix (*Leiothrix lutea*,  $n = 2343$ ). Eighty-eight percent of all detections were exclusively auditory; the rest were visually confirmed. Three endangered native species, Maui 'Ākepa (*Loxops coccineus ochraceus*), Maui Nukupu'u (*Hemignathus lucidus affinis*), and Po'o-uli (*Melamprosops phaeosoma*), were not detected at any station nor elsewhere in the study area. Three non-native species, House Finch (*Carpodacus mexicanus*,  $n = 20$ ), Northern Cardinal (*Cardinalis cardinalis*,  $n = 19$ ), and Nutmeg Mannikin (*Lonchura punctulata*,  $n = 4$ ), were present throughout the year, but in such low numbers that no density estimates were calculated for them.

### TEMPORAL VARIATION

Although we found significant differences among years for all species except Maui Parrotbill, a trend emerged for only one: Maui 'Alauahio showed a modest but significant decline between 1995 and 1997 (Table 1, 2). The native nectarivores ('Ākohekohe, 'Apapane, Hawai'i 'Amakihi, and 'I'iwi) and the introduced generalists (Japanese White-eye and Red-billed

TABLE 1. ANOVA table for repeated measures analyses, comparing bird densities among months, years, and elevational categories. All nine species showed significant differences for month, year, and elevation (except that there were no differences among years for Maui Parrotbill).

Native nectarivores, breeding December–May									
Source	df	‘Ākohekohe		‘Apapane		Hawai‘i ‘Amakihi		‘I‘iwi	
		F	P	F	P	F	P	F	P
Month	11, 1295	4.4	<0.001	26.6	<0.001	30.9	<0.001	21.8	<0.001
Year	2, 1295	16.7	<0.001	44.9	<0.001	29.5	<0.001	24.7	<0.001
Month × year	22, 1295	4.7	<0.001	11.3	<0.001	12.2	<0.001	7.8	<0.001
Elevation	2, 37	65.0	<0.001	10.2	<0.001	25.8	<0.001	6.6	0.004
Month × elevation	22, 1295	1.9	0.01	2.1	0.002	1.3	0.16	1.3	0.14
Year × elevation	4, 1295	0.9	0.48	1.1	0.35	1.1	0.37	1.2	0.29
Month × year × elevation	44, 1295	1.5	0.02	1.4	0.04	1.7	0.002	1.2	0.14
Breeding vs. nonbreeding	1, 1295	2.8	0.09	124.5	<0.001	197.7	<0.001	61.4	<0.001

Insectivores and generalists, breeding March–August <sup>a</sup>										
Source	Maui ‘Alauahio		Maui Parrotbill		Japanese Bush-Warbler		Japanese White-eye		Red-billed Leiothrix	
	F	P	F	P	F	P	F	P	F	P
Month	3.6	<0.001	3.7	<0.001	48.1	<0.001	5.6	<0.001	17.2	<0.001
Year	3.3	0.04	1.1	0.34	60.6	<0.001	10.3	<0.001	5.8	0.003
Month × year	3.7	<0.001	1.8	0.01	6.9	<0.001	5.3	<0.001	6.7	<0.001
Elevation	18.4	<0.001	5.0	0.01	38.5	<0.001	20.9	<0.001	33.5	<0.001
Month × elevation	1.2	0.27	1.0	0.49	16.3	<0.001	0.8	0.71	2.0	0.004
Year × elevation	0.9	0.46	0.8	0.51	21.7	<0.001	0.7	0.60	0.4	0.82
Month × year × elevation	0.1	0.69	1.1	0.29	2.7	<0.001	1.2	0.22	1.4	0.04
Breeding vs. nonbreeding	11.7	0.001	6.5	0.01	231.3	<0.001	1.2	0.28	102.8	<0.001

<sup>a</sup> Except for aseasonal Maui parrotbill.

TABLE 2. Summary of density estimates (individuals ha<sup>-1</sup> ± SD) for nine bird species in each of three years in Hanawī, Maui. Yearly means followed by the same letter are not significantly different. Note that all species except Maui Parrotbill showed year-to-year differences, with the nectarivorous species most abundant in 1996. Also shown are months with mean density significantly highest or lowest. (Yearly and monthly means compared with Tukey’s studentized range test, α < 0.05).

Native nectarivores				
	‘Ākohekohe	‘Apapane	Hawai‘i ‘Amakihi	‘I‘iwi
All years	2.9 ± 2.6	14.4 ± 11.1	11.8 ± 8.8	3.6 ± 3.2
1995	2.7 ± 2.4a	11.0 ± 7.4a	9.6 ± 7.5a	2.9 ± 2.9a
1996	3.3 ± 2.8b	15.9 ± 11.1b	13.1 ± 8.6b	4.2 ± 3.4b
1997	2.6 ± 2.5a	16.4 ± 13.2b	12.7 ± 9.7b	3.7 ± 3.3c
Highest months	none	Jan–Feb, Apr	Jan–Apr	none
Lowest months	May–Jul, Nov	Jun–Oct	Jun–Sep	Jun–Jul

Insectivores and generalists					
	Maui ‘Alauahio	Maui Parrotbill	Japanese Bush-Warbler	Japanese White-eye	Red-billed Leiothrix
All years	10.6 ± 13.0	0.4 ± 0.8	0.4 ± 0.9	5.2 ± 8.9	2.0 ± 2.8
1995	11.7 ± 13.7a	0.5 ± 0.9a	0.2 ± 0.5a	4.4 ± 7.6a	2.3 ± 2.5a,b
1996	10.9 ± 13.4a,b	0.3 ± 0.8a	0.5 ± 1.1b	6.6 ± 10.4b	2.6 ± 3.5a
1997	9.3 ± 11.6b	0.4 ± 0.8a	0.6 ± 1.1b	4.5 ± 8.4a	2.1 ± 2.3b
Highest months	none	Aug–Oct, Dec	Apr–Jun	none	Apr–Jun, Aug
Lowest months	none	none	Aug–Dec	none	Sep, Nov–Mar

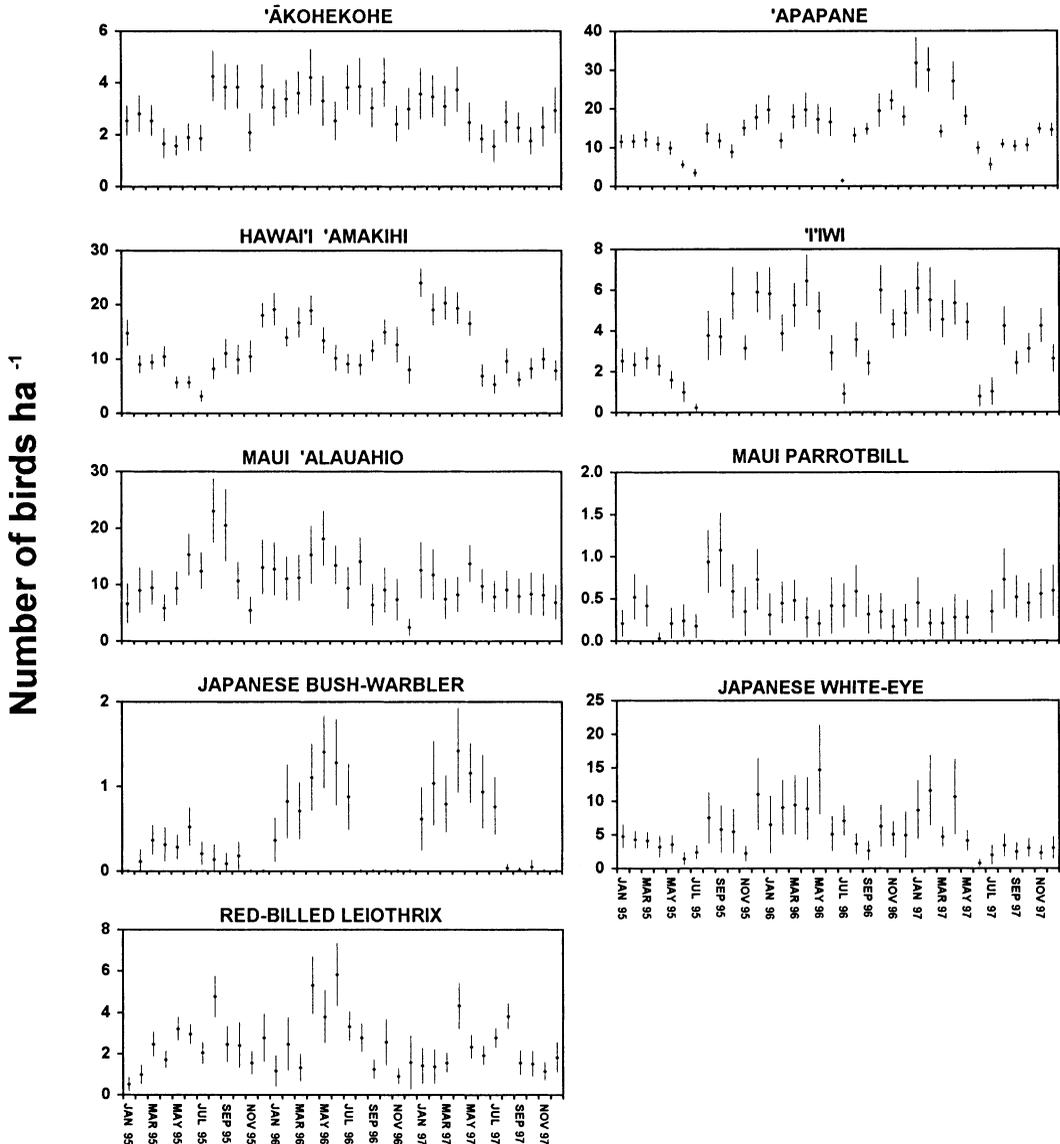


FIGURE 2. Mean  $\pm$  2 SE monthly density estimates from variable circular-plot counts for nine forest bird species at Hanawā, Maui. The top four species are mainly nectarivorous, whereas the rest are either insectivorous or are generalists. Note that while seasonal patterns are apparent for most species, variance is high within counts and among months and years.

Leiothrix) had higher densities in 1996 than in 1995, but none showed a similar rise in 1997, when some species actually declined.

Monthly density estimates differed significantly for all species, and the interactions between months and years were also significant (Table 1, Fig. 2). Among the native nectarivores, which breed from December through May, means for breeding and nonbreeding seasons

differed significantly, except for 'Ākohekohe (Table 1). Highest consecutive monthly means for 'Apapane and Hawai'i 'Amakihi occurred in winter and spring, whereas 'Ākohekohe and 'I'iwi showed no trends, and lowest consecutive monthly means for all species fell in summer (Table 2).

Insectivorous and generalist species, which breed from March through August, showed sig-

nificant differences between means for breeding and nonbreeding seasons, except for the Japanese White-eye (Table 1). The common native insectivore, Maui 'Alauahio, showed no consistent pattern of monthly highs or lows, whereas highest consecutive monthly means for the endangered native insectivore, Maui Parrotbill, occurred from August to December (Table 2). For a non-native insectivore, Japanese Bush-Warbler, and generalist, Red-billed Leiothrix, highest consecutive means occurred from April–June and August, respectively, and lowest consecutive means occurred in fall and winter. The Japanese White-eye, a non-native generalist, showed no month-to-month trends.

Coefficients of variation (CV) were generally large, indicating that counts were not very predictable (range of means  $\pm$  SD for the six native species [ $n = 108$ ]:  $55.5 \pm 22.8$  to  $178.4 \pm 111.7$ ). CVs differed significantly among species ( $F_{5,430} = 63.9$ ,  $P < 0.001$ ), months ( $F_{11,430} = 2.3$ ,  $P < 0.01$ ) and two interaction terms, species  $\times$  month ( $F_{55,430} = 1.8$ ,  $P < 0.001$ ), and species  $\times$  year ( $F_{10,430} = 3.5$ ,  $P < 0.001$ ). Pairwise comparisons of months for all six native species combined showed that the CV for July was significantly higher than any other month, but that, for the most part, remaining months did not differ amongst each other.

#### EFFECTS OF ELEVATION AND BLOOM

Elevation accounted for significant variation in density for all species, and significant interaction terms for 'Ākohekohe, 'Apapane, Japanese Bush-Warbler, and Red-billed Leiothrix indicated elevational shifts in population distribution with season (Table 1). Among the native nectarivores, 'Ākohekohe densities were highest year round in the medium elevational stratum, but densities dropped slightly in this stratum in the nonbreeding season while remaining the same in the high and low strata (Table 3). 'Apapane densities in the breeding season were highest in the medium and low elevational strata, but during the nonbreeding season, densities declined dramatically in these two strata, becoming the same across all strata. Hawai'i 'Amakihi densities were highest in the high and medium strata, declining substantially and proportionately in all strata during the nonbreeding season. 'Iwi densities showed little effect with elevational stratum but were lower in the nonbreeding season.

Among insectivorous and generalist species, Maui 'Alauahio densities were highest in the medium elevational stratum, where densities declined slightly in the nonbreeding season (Table 3). Maui Parrotbill densities varied little with elevational stratum or season; however, differences may not have been detectable owing to low densities. Among the introduced species, Japanese Bush-Warbler densities were much higher in the low elevational category, and Japanese White-eye and Red-billed Leiothrix were higher in the high elevational category. We found significant interactions between elevation and month for Japanese Bush-Warbler and Red-billed Leiothrix, but in opposite directions. Whereas density estimates of both species declined during the nonbreeding season, proportionately more Japanese Bush-Warblers remained in the low elevational stratum while more Red-billed Leiothrix remained in the high elevational stratum.

We found a close relationship between the two 'ōhi'a flower abundance variables, flower scores and flower counts (Fig. 3). The ANCOVA comparing the two resulted in  $r^2 = 0.53$  with a significant relationship between the two variables ( $F_{1,1351} = 80.1$ ,  $P < 0.001$ ). Month, year, and their interaction were also significant in this ANCOVA ( $P < 0.001$ ). Despite the close relationship between mean flower scores and mean flower counts, neither method of phenological measurement was associated with any of the bird densities in the ANCOVAs which tested for these effects at the scale of stations used in this study ( $P > 0.05$ ).

#### DISCUSSION

##### LONG-TERM TRENDS

Population densities of bird species on our study site have not changed measurably, with some notable exceptions, over the 15–17 years since they were first counted by the Hawai'i Forest Bird Survey (HFBS). We could not make statistical comparisons with the HFBS data because only two HFBS transects occurred within 1 km of our study site. However, species distribution and abundance maps in Scott et al. (1986) present isometric bands of population density across comparable habitat over east Maui as a whole, and from these we identified for each species the highest densities at our study site (Table 3). Note that densities were calculated by

TABLE 3. Summary of density estimates (individuals ha<sup>-1</sup> ± SD) for nine bird species in Hanawī, Maui, in the breeding and nonbreeding seasons, by elevational stratum (high = 2040–2130 m, medium = 1750–2039 m, low = 1567–1749 m). Pairwise comparisons were obtained from contrasts specified in the ANOVAs (Bonferroni-adjusted α = 0.05). Different lowercase letters indicate significantly different means between seasons for each elevational stratum, while different uppercase letters indicate significantly different means among the three elevational strata within each season. A nonstatistical comparison with the last row, which gives highest densities estimated by the Hawai‘i Forest Bird Survey (Scott et al. 1986) in the elevational band representing our site, shows the populations have not undergone large changes, except for invading Japanese Bush-Warbler.

Native nectarivores					
	‘Ākohekohe	‘Apapane	Hawai‘i	‘Amakihi	‘I‘iwi
Breeding season (Dec–May)					
High	2.6 ± 2.2a,A	12.5 ± 8.4a,A	17.0 ± 10.3a,A		3.4 ± 3.5a,A
Medium	4.3 ± 2.4a,B	17.3 ± 11.7a,B	15.4 ± 8.9a,A		4.7 ± 3.6a,B
Low	1.1 ± 1.5a,C	20.7 ± 14.9a,C	11.9 ± 7.9a,B		4.1 ± 2.8a,A,B
Nonbreeding season					
High	2.7 ± 2.3a,A	10.6 ± 6.8a,A	12.7 ± 8.4b,A		2.2 ± 2.9b,A
Medium	3.8 ± 2.6b,B	11.5 ± 8.5b,A	9.0 ± 7.2b,B		3.0 ± 2.9b,A
Low	1.0 ± 1.6a,C	12.1 ± 9.3b,A	6.4 ± 5.9b,C		3.3 ± 3.1b,A
Hawai‘i Forest Bird Survey estimates (May–August 1980)					
	2–4	16–32	4–8		2–4
Insectivores and generalists					
	Maui ‘Alauahio	Maui Parrotbill	Japanese Bush-Warbler	Japanese White-eye	Red-billed Leiothrix
Breeding season (Mar–Aug)					
High	7.7 ± 8.9a,A	0.1 ± 0.4a,A	0.4 ± 0.7a,A	7.4 ± 10.4a,A	4.1 ± 3.3a,A
Medium	14.8 ± 13.6a,B	0.4 ± 0.9a,B	0.3 ± 0.7a,A	4.5 ± 8.2a,B	2.7 ± 2.6a,B
Low	9.5 ± 11.8a,A	0.4 ± 0.8a,A,B	1.5 ± 1.4a,B	4.7 ± 8.9a,A,B	3.1 ± 2.8a,B
Nonbreeding season					
High	5.0 ± 7.9a,A	0.3 ± 0.7a,A	0.1 ± 0.3b,A	9.9 ± 12.6a,A	3.1 ± 3.7b,A
Medium	11.9 ± 14.9b,B	0.5 ± 0.9a,A	0.04 ± 0.2b,A	4.0 ± 6.7a,B	1.1 ± 2.0b,B
Low	8.3 ± 12.2a,A,B	0.5 ± 1.0a,A	0.5 ± 1.1b,B	4.2 ± 8.2a,B	1.4 ± 2.3b,B
Hawai‘i Forest Bird Survey estimates (May–Aug 1980)					
	8–16	0.5–1.0	0	4–8	1–2

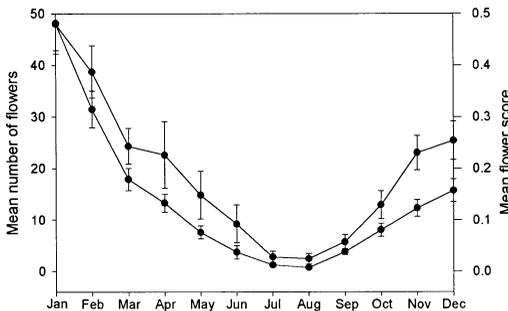


FIGURE 3. The close relationship of two measures of ‘ōhi‘a flower abundance: flower counting versus flower scoring, for the period January 1995 through December 1997 at Hanawī, Maui. The upper curve (left axis) shows mean ± SE number of flowers counted per marked tree (n = 92 trees; Berlin et al. 2001). The lower curve shows mean ± SE flower score computed over 3 years and 40 stations (n = 120)

Scott et al. (1986) without making the same adjustments as we did for certain factors affecting detection distances (also see Fancy 1997). Nevertheless, until all HFBS data for Maui are re-analyzed (as is planned by the new Hawai‘i Forest Bird Database Project, USGS-PIERC), these somewhat unequal comparisons must suffice.

For five species of native and non-native forest birds, our density estimates, averaged over three years for the appropriate season, fell within the range of estimates found by Scott et al. (1986). For three other species, our estimates were either higher or lower than the HFBS range of values, but these apparent differences would not have been statistically significant given the large variance of the means. The eighth species, Japanese Bush-Warbler, invaded east Maui since the HFBS and over this period increased at our

study site from 0 to a highest density of 1.5 birds  $\text{ha}^{-1}$  in the low elevational stratum during the breeding season.

Three endangered species reported by the HFBS were not found by us. Tragically, the Po'ou-uli has declined in the past 20 years and now barely survives as only three individuals to the east of our study site (Baker 2001). The Maui 'Akepa and Maui Nukupu'u were scarcely detected by the HFBS. However, these and other recent records were never confirmed by well-described visual sightings, and intensive surveys now strongly indicate that both species are probably extinct (Pratt and Pyle 2000, Baker 2001). These declines are concurrent with extinctions of other species on Kaua'i and elsewhere in the Hawaiian Islands (Conant et al. 1998), although the specific causes in these Maui cases are unknown, and the surviving species have not been affected to the same extent (Scott et al. 1986, Baker 2001).

#### SEASONAL PATTERNS BY SPECIES

In our study area, 'Ākohekohe densities remain relatively stable throughout the year, but 'Āpāpāne, Hawai'i 'Amakihi, and 'I'iwi densities fluctuate seasonally with 'ōhi'a bloom and decrease 50–80% in July; these birds presumably follow bloom to elevations below our study site (Berlin et al. 2001). In the present analysis, we detected seasonal shifts along the elevational gradient of the study site for 'Ākohekohe and 'Āpāpāne. The slight decrease in 'Ākohekohe densities in the medium elevational stratum in the nonbreeding season could be attributed either to a decrease in vocalizing, and therefore detectability, or to the short-distance movement of some individuals, particularly birds in their first year. Although most 'Ākohekohe remained on small year-round home ranges, some moved either upslope to timberline, which we documented with net captures and resightings of banded birds, or downslope outside the study area (Pratt et al. 2001, Simon et al. 2001). 'Āpāpāne densities varied similarly with season and elevation, but to a more striking degree, with the high densities in the medium and low elevational strata declining markedly so that densities across the elevational gradient became the same. We believe that this decrease was mainly due to birds emigrating in pursuit of blooming 'ōhi'a, which flower at lower elevations during the summer (Berlin et al. 2000). Decreases in den-

sities in the nonbreeding season for Hawai'i 'Amakihi and 'I'iwi may also have resulted from reduced detectability or emigration, but if the latter, then the populations responded proportionally across the elevational gradient.

Earlier we reported that 'ōhi'a flower counts appeared to be associated with changes in density for some nectarivorous species when analyzed at the level of the study site, rather than at the station level (Berlin et al. 2001). For this reason, and because results of flower scoring and flower counts were closely correlated (this paper), we recommend continuing the practice of measuring flower availability during bird counts using the more practical method of flower scoring.

Of the two native insectivores, Maui 'Alauahio densities appeared to increase in their medium elevation stronghold during the breeding season. As this species is territorial year round, and young often remain in the natal territory through the following breeding season (Baker and Baker 2000), seasonal variability in density estimates is best explained by an increase in detectability of singing males, of birds engaged in territorial disputes, and of noisy juveniles added to the population. Densities for Maui Parrotbill, the other sedentary, territorial native insectivore, did not vary significantly between breeding and nonbreeding seasons, which are only weakly defined for this species (Simon et al. 2000, Pratt et al. 2001). Highest consecutive monthly means for Maui Parrotbill were from August to December, perhaps because of conspicuousness of calling juveniles.

Two introduced species, Japanese Bush-Warbler and Red-billed Leiothrix, showed strong seasonal trends with elevation. Japanese Bush-Warblers are inconspicuous except when the polygynous males sing, especially during the breeding season. However, it is unlikely singing phenology can entirely account for seasonal variation in density estimates, because the species is known to be an altitudinal migrant in its original range (Brazil 1991) and possibly in Hawai'i. Density estimates in our study area decreased more in the high and medium elevational strata, suggesting immigration downslope. Red-billed Leiothrix showed the reverse trend, with densities of this noisy, flocking species decreasing disproportionately more in the medium and low elevational strata during the nonbreeding season. Ralph et al. (1998:470) also noted for Red-billed

Leiothrix on their Hawai'i Island study site that "capture/resighting history of individual birds suggested that some individuals left the study area during the nonbreeding season," although it was not determined where they went. Japanese White-eye density estimates, however, showed no seasonal pattern. This situation is a departure from the species' migratory behavior in the temperate climate of its native Japan, where the birds leave montane deciduous forest in winter (Brazil 1991). The demography and natural history of this species is little known in Hawai'i (van Riper 2000), although it is conspicuous for its frequent, year-round vocalizing.

Japanese White-eyes are believed to compete to some extent with the native birds (Mountain-spring and Scott 1985, Scott et al. 1986), potentially reducing populations of the latter. The arrival of the Japanese Bush-Warbler to Maui invites inquiry into the impacts of this invasive species on native birds and their habitat, particularly since Japanese Bush-Warblers have reached higher elevations on Maui than elsewhere in the Hawaiian Islands. It is encouraging to note that Japanese Bush-Warbler densities throughout the study area were low, and that they were lowest in the high and medium elevational strata, where most native birds live. This pattern of elevational distribution appears also at Wai-ka-moi and Kī-pahulu, the western and easternmost extent of the montane rainforest on Maui (TKP, pers. obs.). Whether Japanese Bush-Warbler numbers will increase with time and spread farther upslope remains to be seen.

#### UTILITY OF VARIABLE CIRCULAR-PLOT COUNTS

Variable circular-plot methodology has had a long history of development and application in Hawai'i (Ralph and Scott 1981, Scott et al. 1986, Fancy 1997) and is in use elsewhere for surveying and monitoring bird populations (Verner 1985, Bibby et al. 2000). Field studies in Hawai'i have found that, under certain conditions, density estimates from VCP counts are the same as those determined by intensive studies where most of the birds are banded or carry radio-transmitters (Fancy 1997, Nelson and Fancy 1999). VCP counts are also the most practical method available for monitoring forest birds in Hawai'i, where dense vegetation and steep, hazardous terrain makes the use of line-transect sampling impractical (Fancy 1997). For these

same reasons, VCP methodology has been the technique of choice for surveying threatened avifauna at other tropical locales (Marsden 1998, Frith and Poulsen 1999, Hill et al. 2001).

Our study examining monthly variation in density estimates for an entire Hawaiian forest bird community reveals some strengths and weaknesses of monitoring birds with VCP or any other methodology. Fortunately, methodological and observer error (for example, identifying species or estimating distances) and variability introduced by count conditions (such as weather and vegetation) can be reduced for the most part by properly training observers and standardizing counts, and additionally can be adjusted for in the analyses (Fancy 1997). Instead, we wish to draw attention to the sources of variability introduced by life history of the birds and phenological changes in their habitat.

Ideally, counts sampling entire forest bird populations for monitoring purposes should be timed when birds are breeding, so that densities can be associated with breeding habitat and distribution, and also because breeding birds are more detectable, thereby increasing the accuracy of surveys. Additional sampling outside the breeding season can complete the picture of seasonal habitat requirements for each species, important information for determining recovery habitat. A further consideration is that counts may be more variable in some months than in others. Also, it is difficult to determine within a bird community which months are best for counting, because species' breeding schedules do not overlap completely (Ralph and Fancy 1994), a problem particularly acute in the tropics, including Hawai'i. In this study, we found that count results varied by nearly all variables examined: month, year, interaction between month and year for many species, breeding vs. nonbreeding season, and availability of 'ōhi'a bloom for nectarivores. In addition, some species showed seasonal changes with elevation.

For timing surveys of Maui birds, the months of March and April deceptively appear to be the best, disregarding an important consideration, weather. Native nectarivores are still nesting in these spring months, and the remaining species are beginning, or are well into, their breeding seasons. However, March and April are also among the wettest months in the islands. By scheduling counts for January or February, field teams are more likely to encounter dry periods

associated with winter cold fronts (Blumenstock and Price 1967), and they would also find the nectarivores breeding while the other species are preparing to breed. Year-to-year variability in same-month counts is low for both periods, although in that regard the only months to avoid are June–August. Whichever months are chosen, count schedules should keep to the same months from year to year to avoid seasonal variability associated with population phenology.

Understanding seasonal variation in Hawaiian bird counts remains confounded by the effect of detectability, particularly as influenced by song, other vocalizations, and behavior. Seasonal differences in song phenology (Ralph and Fancy 1994) and differences in vocalization types and rates among age classes and sexes are known to have an important effect on detectability (Wilson and Bart 1985), and for some species the “population” that we are monitoring may consist of only one sex or age group. For example, most detections of Maui Parrotbill were of vocalizing birds, and the singing rate of male Maui Parrotbills appeared to vary monthly at Hanawī. Female Maui Parrotbills did not sing, called rarely, and were seldom detected unless seen (TKP, pers. obs.). Thus, our density estimates for Maui Parrotbill apply mainly to the adult male cohort. For social species, group size can be underestimated by VCP counts when birds are heard only, as for example babbler species in Viet Nam (Hill et al. 2001). In our study, the abundance of Red-billed Leiothrix, a social babbler, was probably underestimated. Future studies of vocalization rates will likely identify which subset of the population is monitored because of differences in detecting sex and age cohorts.

In Hawai‘i, where the loss of species has taken place at an alarming rate, bird surveys will remain a useful and important management tool, but their accuracy is inherently limited. Density estimates should not be the sole catalyst for habitat management (Green 1994, Greenwood et al. 1994). Immediate and permanent protection of the remaining middle and high elevation forests is imperative for all Hawaiian forest birds. Waiting for rare species to show measurable population declines may mean waiting until their extinction is all but inevitable.

#### ACKNOWLEDGMENTS

We thank K. Fluetsch for field assistance during early counts and in the preparation of the study area tran-

sects. M. Gorresen redrafted Figure 1. R. Camp, S. Conant, L. Johnson, and J. M. Scott reviewed and improved earlier drafts of this paper. Funding for fieldwork was provided by the U.S. Fish and Wildlife Service, the U.S. Geological Survey, the Hawai‘i Department of Land and Natural Resources, and the Nature Conservancy of Hawai‘i. Access to the Hanawī study site and existing support facilities was granted by Hawai‘i Natural Areas Reserve System. We also thank the staffs of Haleakalā National Park and Windward Aviation, Inc. for logistical support and safe transportation.

#### LITERATURE CITED

- BAKER, H., AND P. E. BAKER. 2000. Maui ‘Alauahio (*Paroreomyza montana*). In A. Poole and F. Gill [EDS.], *The Birds of North America*, No. 504. The Birds of North America, Inc., Philadelphia, PA.
- BAKER, P. E. 2001. Status and distribution of the Po‘ouli in the Hanawī natural area reserve between December 1995 and June 1997. *Studies in Avian Biology* 22:144–150.
- BERLIN, K. E., T. K. PRATT, J. C. SIMON, J. R. KOWALSKY, AND J. S. HATFIELD. 2000. Plant phenology in a cloud forest on the island of Maui, Hawaii. *Biotropica* 32:90–99.
- BERLIN, K. E., J. C. SIMON, T. K. PRATT, J. R. KOWALSKY, AND J. S. HATFIELD. 2001. ‘Ākohekohe response to flower availability: seasonal abundance, foraging, breeding, and molt. *Studies in Avian Biology* 22:202–212.
- BIBBY, C. J., N. D. BURGESS, D. A. HILL, AND S. H. MUSTOE. 2000. *Bird census techniques*. 2nd ed. Academic Press, San Diego, CA.
- BLUMENSTOCK, D. I., AND S. PRICE. 1967. *Climates of the states: Hawaii*. U.S. Department of Commerce, Environmental Science Data Service, *Climatology of the United States* no. 60–51. U.S. Government Printing Office, Washington, DC.
- BRAZIL, M. A. 1991. *The birds of Japan*. Smithsonian Institution Press, Washington, DC.
- CONANT, S., H. D. PRATT, AND R. J. SHALLENBERGER. 1998. Reflections on a 1975 expedition to the lost world of the Alaka‘i and other notes on the natural history, systematics, and conservation of Kaua‘i birds. *Wilson Bulletin* 110:1–22.
- DESANTE, D. F. 1986. A field test of the variable circular-plot censusing method in a Sierran subalpine forest habitat. *Condor* 88:129–142.
- FANCY, S. G. 1997. A new approach for analyzing bird densities from variable circular-plot counts. *Pacific Science* 51:107–114.
- FRITH, C. B., AND M. K. POULSEN. 1999. Distribution and status of the Paradise Crow *Lycocorax pyrrhopterus* and Standardwing Bird of Paradise *Semioptera wallacii*, with notes on biology and nidification. *Emu* 99:229–238.
- GREEN, R. E. 1994. Diagnosing causes of bird population declines. *Ibis* 137:S47–S55.
- GREENWOOD, J. J. D., S. R. BAILLIE, R. D. GREGORY, W. J. PEACH, AND R. J. FULLER. 1994. Some new approaches to conservation monitoring of British breeding birds. *Ibis* 137:S16–S28.

- HILL, M., J. C. EAMES, L. T. TRAI, AND N. CU. 2001. Population sizes, status and habitat associations of forest birds in Chu Yan Sin Nature Reserve, Da Lak Province, Vietnam. *Bird Conservation International* 11:49–70.
- JACOBI, J. D. 1989. Vegetation maps of the upland plant communities on the islands of Hawai'i, Maui, Moloka'i, and Lana'i. Technical Report 68. Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu, HI.
- JACOBI, J. D., S. G. FANCY, J. G. GIFFIN, AND J. M. SCOTT. 1996. Long-term population variability in the Palila, an endangered Hawaiian honeycreeper. *Pacific Science* 50:363–370.
- KELLER, C. M. E., AND J. T. SCALLAN. 1999. Potential roadside biases due to habitat changes along breeding bird survey routes. *Condor* 101:50–57.
- KEPLER, C. B., AND J. M. SCOTT. 1981. Reducing bird count variability by training observers. *Studies in Avian Biology* 6:366–371.
- LAAKE, J. L., S. T. BUCKLAND, D. R. ANDERSON, AND K. P. BURNHAM. 1994. DISTANCE user's guide V2.1. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, CO.
- LITTELL, R. C., G. A. MILLIKEN, W. W. STROUP, AND R. D. WOLFINGER. 1996. SAS system for mixed models. SAS Institute Inc., Cary, NC.
- MARSDEN, S. J. 1998. Changes in bird abundance following selective logging on Seram, Indonesia. *Conservation Biology* 12:605–611.
- MOUNTAINSPRING, S., AND J. M. SCOTT. 1985. Interspecific competition among Hawaiian forest birds. *Ecological Monographs* 55:219–239.
- NELSON, J. T., AND S. G. FANCY. 1999. A test of the variable circular-plot method when exact density of a bird population was known. *Pacific Conservation Biology* 5:139–143.
- PRATT, T. K., AND R. L. PYLE. 2000. Nukupu'u in the twentieth century: endangered species or phantom presence? *'Elepaio* 60:35–41.
- PRATT, T. K., J. C. SIMON, B. P. FARM, K. E. BERLIN, AND J. R. KOWALSKY. 2001. Home range and territoriality of two Hawaiian honeycreepers, the 'Akohekohe and Maui Parrotbill. *Condor* 103:746–755.
- RALPH, C. J., AND S. G. FANCY. 1994. Timing of breeding and molting in six species of Hawaiian honeycreeper. *Condor* 96:151–161.
- RALPH, C. J., AND S. G. FANCY. 1995. Demography and movements of Apapane and Iiwi in Hawaii. *Condor* 97:729–742.
- RALPH, C. J., S. G. FANCY, AND T. D. MALE. 1998. Demography of an introduced Red-billed Leiothrix population in Hawaii. *Condor* 100:468–473.
- RALPH, C. J., J. R. SAUER, AND S. DROEGE [EDS.]. 1995. Monitoring bird populations by point counts. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-149.
- RALPH, C. J., AND J. M. SCOTT [EDS.]. 1981. Estimating numbers of terrestrial birds. *Studies in Avian Biology* 6.
- REYNOLDS, M. H., AND T. J. SNETSINGER. 2001. The Hawaii rare bird search 1994–1996. *Studies in Avian Biology* 22:133–143.
- REYNOLDS, R. T., J. M. SCOTT, AND R. A. NUSSBAUM. 1980. A variable circular-plot method for estimating bird numbers. *Condor* 82:309–313.
- ROBBINS, C. S., D. BYSTRAK, AND P. H. GEISSLER. 1986. The Breeding Bird Survey: its first fifteen years, 1965–1979. U.S. Fish and Wildlife Service Resource Publication 157, Washington, DC.
- SAS INSTITUTE. 1997. SAS/STAT software: changes and enhancements through release 6.12. SAS Institute, Inc., Cary, NC.
- SCOTT, J. M., S. CONANT, AND C. VAN RIPER III [EDS.]. 2001. Evolution, ecology, conservation, and management of Hawaiian birds: a vanishing avifauna. *Studies in Avian Biology* 22.
- SCOTT, J. M., J. D. JACOBI, AND F. L. RAMSEY. 1981. Avian surveys of large geographical areas: a systematic approach. *Wildlife Society Bulletin* 9:190–200.
- SCOTT, J. M., S. MOUNTAINSPRING, F. L. RAMSEY, AND C. B. KEPLER. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. *Studies in Avian Biology* 9.
- SCOTT, J. M., AND F. L. RAMSEY. 1981. Length of count period as a possible source of bias in estimating bird numbers. *Studies in Avian Biology* 6:409–413.
- SCOTT, J. M., F. L. RAMSEY, AND C. B. KEPLER. 1981. Distance estimation as a variable in estimating bird numbers. *Studies in Avian Biology* 6:334–340.
- SIMON, J. C., T. K. PRATT, K. E. BERLIN, AND J. R. KOWALSKY. 2000. Reproductive ecology of the Maui Parrotbill. *Wilson Bulletin* 112:482–490.
- SIMON, J. C., T. K. PRATT, K. E. BERLIN, AND J. R. KOWALSKY. 2001. Reproductive ecology and demography of the 'Akohekohe. *Condor* 103:736–745.
- U. S. FISH AND WILDLIFE SERVICE. 1986. Palila recovery plan. U.S. Fish and Wildlife Service, Portland, OR.
- VAN RIPER, S. G. 2000. Japanese White-eye (*Zosterops japonicus*). In A. Poole and F. Gill [EDS.], *The birds of North America*, No. 487. The Birds of North America, Inc., Philadelphia, PA.
- VERNER, J. 1985. Assessment of counting techniques. *Current Ornithology* 2:247–302.
- WILSON, D. M., AND J. BART. 1985. Reliability of singing bird surveys: effects of song phenology during the breeding season. *Condor* 87:69–73.