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Distribution and Population Status of the Endangered 'Akiapōlā'au[1]

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ABSTRACT: The 'Akiapōlā'au (*Hemignathus munroi* Rothschild) is an endangered Hawaiian honeycreeper that is found only in high-elevation native forests on the island of Hawai'i. The Hawai'i Forest Bird Surveys (HFBS) during 1976–1979 on Hawai'i found four disjunct populations of 'Akiapōlā'au totaling 1500 ± 400 (95% CI) birds. This total included 533 ± 320 in the Ka'ū Forest Reserve and 46 ± 51 birds in dry māmane (*Sophora chrysophylla* [Salisb.] Seem.) forest on Mauna Kea. Because 'Akiapōlā'au are so rare, it was necessary to use data for other species to determine the effective area surveyed for 'Akiapōlā'au and to use data interpolation and smoothing techniques to derive the HFBS estimate of 1500 'Akiapōlā'au. We used a newly developed analysis approach to estimate the population size for 'Akiapōlā'au based on surveys conducted during 1990–1995. We plotted all recent detections of 'Akiapōlā'au and stratified the current distribution of the species based on distribution of koa (*Acacia koa* A. Gray) forests and elevation contours. A population estimate was derived by multiplying the density of 'Akiapōlā'au within each stratum, as determined from variable circular plot counts, by the area within each stratum. We estimate that there are 1163 ± 54 (90% CI) 'Akiapōlā'au in the world. The distribution of 'Akiapōlā'au has been greatly reduced in the Ka'ū District, where the estimated population has declined from 533 to 44 birds, and relic populations in māmane forest and South Kona are likely to become extinct within the next 5 yr. Protection and management of the remaining isolated stands of koa forest at higher elevations where mosquitoes are absent or occur only seasonally are critical to the survival of this species.

THE 'AKIAPŌLĀ'AU (*Hemignathus munroi* Rothschild), with its stout, woodpecker-like lower mandible and elongated and decurved maxilla, is one of the most bizarre and specialized species of Hawaiian honeycreeper (Scott et al. 1986, Freed et al. 1987, Pratt et al. 1994, Ralph and Fancy 1996). 'Akiapōlā'au were once fairly abundant and found as low as 500 m elevation in koa (*Acacia koa* A. Gray) forests near Hilo (Perkins 1903). In the 1940s, they were still present in koa-'ōhi'a (*Metrosideros polymorpha* Gaud.) forests above 1700 m in Hawai'i Volcanoes National Park (Baldwin 1953), but by 1970 they had disappeared from the park and were less common elsewhere (Conant 1975, Banko and Banko 1980).

In the late 1970s, the Hawai'i Forest Bird Surveys (HFBS) found 'Akiapōlā'au in four disjunct populations totaling 1500 ± 400 (95% CI) individuals, with 900 ± 200 birds along the Hāmākua coast and 500 ± 300 birds in the Ka'ū District (Scott et al. 1986). The distribution of 'Akiapōlā'au was mostly confined to native forests above 1100 m dominated by koa, although some individuals in the Hāmākua study area were observed in forests dominated by 'ōhi'a. Scott et al. (1986) also estimated that 50 ± 50 'Akiapōlā'au occurred in the māmane- (*Sophora chrysophylla* [Salisb.] Seem.) and naio- (*Myoporum sandwicense* A. Gray) dominated dry forests above 1900 m on Mauna Kea, and they documented a small population of about

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two dozen individuals in central and South Kona that were on the verge of extinction.

Because of the rarity of ʻAkiapōlāʻau, Scott et al. (1986) found it necessary to calculate the effective area surveyed for this species from detection distances for other bird species with similarly loud vocalizations. Data interpolation and smoothing methods were used to derive the estimates of ʻAkiapōlāʻau density (Scott et al. 1986:49–50). The HFBS were designed to systematically sample forests throughout the state of Hawaiʻi for all species. Some areas now known to contain the highest densities of ʻAkiapōlāʻau fell between transects used by Scott et al. (1986; J. Scott, pers. comm.). The development of new approaches for calculating densities of rare forest birds, and the availability of current survey data for areas throughout the distribution of ʻAkiapōlāʻau, have made it possible for us to derive a more accurate, updated estimate of the ʻAkiapōlāʻau population.

MATERIALS AND METHODS

We estimated ʻAkiapōlāʻau density by combining data from 29 surveys of forest birds conducted during 1990–1995 using the variable circular-plot method (Reynolds et al. 1980) and 8-min counts (Scott et al. 1986). The combined data set included 13 surveys conducted by the National Biological Service in the Hakalau Forest National Wildlife Refuge (NWR); spring surveys of the Hakalau Forest NWR during 1990–1993 and one fall survey from 1991; three surveys of forests near Kūlani Prison in 1991 and 1992; five surveys of Keauhou Ranch and the Kīlauea Forest during 1993–1995; two surveys of the Kapāpala Forest Reserve during 1993–1994; and one survey of the Kaʻū Forest Reserve during 1993. We also included all incidental observations of ʻAkiapōlāʻau from other surveys, including intensive searches for ʻAlalā (*Corvus hawaiiensis*) in the Kaʻū Forest Reserve during 1995 (J. Klavitter and P. Banko, unpubl. data).

We plotted all known observations of ʻAkiapōlāʻau since 1987 on vegetation maps (Jacobi 1990) and found that all observations occurred in open- and closed-canopy koa-ʻōhiʻa forests above 1340 m or in high-elevation māmane forest. Open-canopy forests were those with 15–60% crown cover, whereas closed-canopy forests had >60% canopy cover and trees with interlocking crowns. The current distribution of ʻAkiapōlāʻau was delineated by following boundaries of koa-dominated forest stands and the 1340-m contour interval (Figure 1). Stations within this known distribution were grouped into five strata: closed-canopy koa-ʻōhiʻa forests in Hāmākua; open-canopy koa-ʻōhiʻa forests in Hāmākua; a high-density stratum that included surveys from Kūlani, Puʻu Kīpū, Kīlauea Forest, and the upper elevations of Keauhou Ranch; a low-density stratum that included lower elevations of Keauhou Ranch; and a stratum that included surveys in the Kaʻū and Kapāpala forest reserves. We estimated the number of ʻAkiapōlāʻau in māmane forest on Mauna Kea and in koa forest in South Kona directly because these individuals occurred at extremely low density in intensively studied areas where essentially all individuals could be accounted for.

The density of ʻAkiapōlāʻau at each counting station was calculated by dividing the number of ʻAkiapōlāʻau detected by the effective area surveyed at that station. In addition to observer effects, factors such as weather, visibility conditions, and time of day are known to influence detectability of birds and thus affect the estimates of effective area surveyed. In the case of rare species such as the ʻAkiapōlāʻau, it is rarely possible to account for factors affecting detectability and still obtain adequate sample sizes for fitting a detection function to the data. For a particular observer or set of survey conditions, Buckland et al. (1993) recommended 60–80 detections as a practical minimum for developing a detection function. An alternative approach introduced by Ramsey et al. (1987) is to include the influencing factors as covariates and to adjust detection distances as if all distances were recorded by the same observer under a specific set of conditions. For the combined survey data, we applied

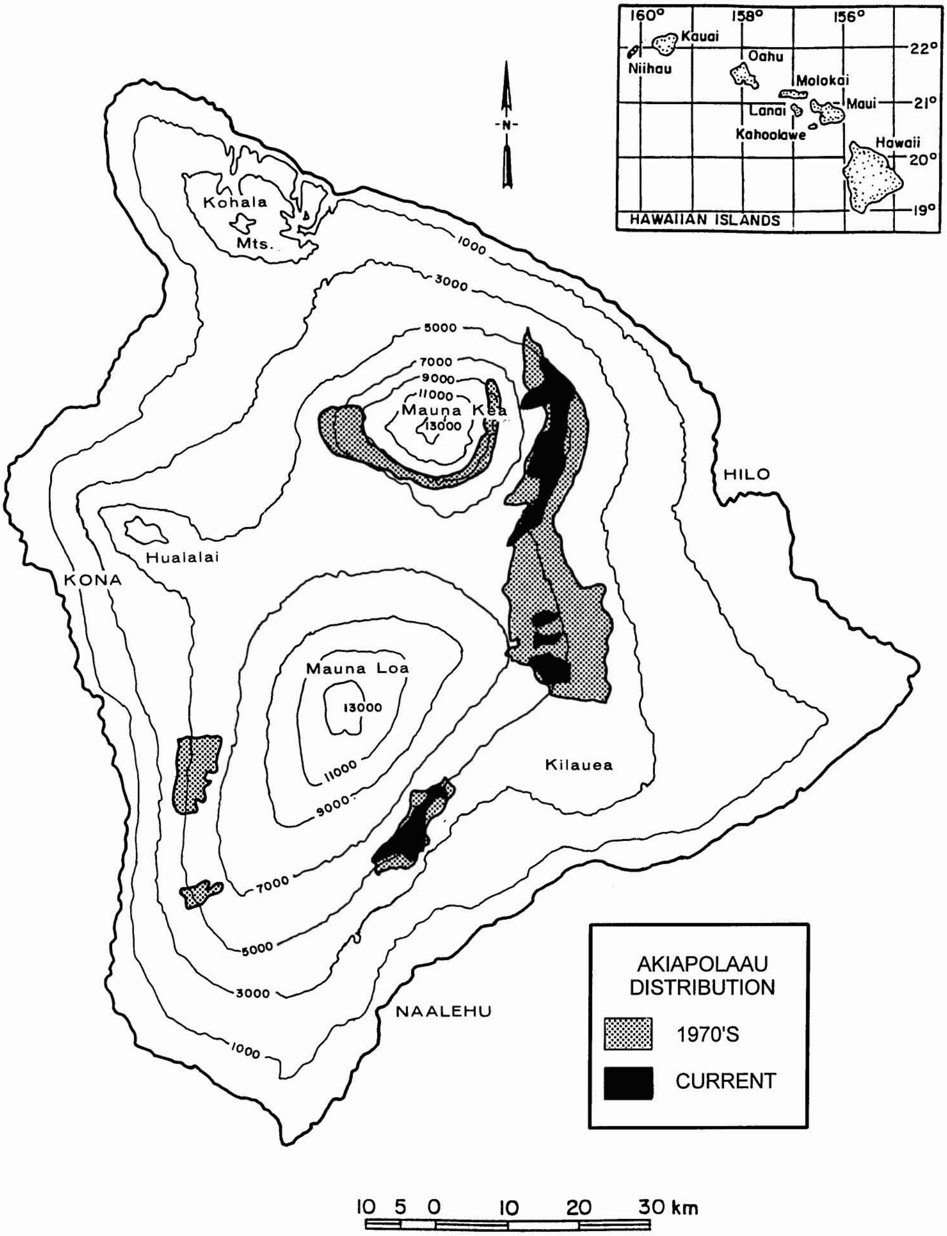

FIGURE 1. Distribution of 'Akiapōlā'au during the 1970s and during surveys in 1990–1995.

this approach by transforming distances to areas and using multiple linear regression to fit the model:

$$ln(Area) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n$$

where $X_1 \ldots X_n$ are covariates such as observer and time of day and $\beta_0 \ldots \beta_n$ are regression coefficients that explain the effect of each covariate on detection distances (Ramsey et al. 1987). In addition to surveys conducted since 1990, we included five additional surveys of the Hakalau Forest NWR during 1987–1989 in the regression analysis to determine the effects of observer and other factors on detection distances.

The combined data set included 382 detections of ‘Akiapōlā‘au. Weather variables and time of day did not affect detection distances significantly ($P > 0.05$) and were dropped from the regression model. We determined from initial runs with different numbers of detections that regression coefficients stabilized at sample sizes greater than 10 detections for most observers. Regression coefficients for nine observers who recorded distances for more than 10 ‘Akiapōlā‘au were used to adjust detection distances as if all distances were recorded by the reference observer (J. Jeffrey). Data for observers with fewer than 10 detections of ‘Akiapōlā‘au were pooled with those for the reference observer because adjustment factors for those observers would be unreliable. Adjusted distances were analyzed by the program DISTANCE (Laake et al. 1994) to calculate effective area surveyed under the reference conditions. Distances were grouped into 10 intervals of 16 m to improve accuracy and reduce the effects of rounding errors. The effective area surveyed at each station during the 29 surveys was calculated from the effective area for the reference observer and the regression coefficient (i.e., adjustment factor) for the observer who actually surveyed that station. Mean density within each stratum was calculated from the densities at each station, and 90% confidence intervals were calculated from 5000 bootstrap samples of the data set within each stratum (Buckland et al. 1993 : 95). Sampling error for the effective area surveyed at each station was included by using the coefficient of variation in effective area to sample from a random normal distribution centered on the effective area. Total population size and confidence intervals were computed using formulas presented in Manly (1992 : 29). The area within each stratum was determined with an electronic planimeter on 1 : 24,000 scale topographic maps.

RESULTS

The effective areas surveyed for ‘Akiapōlā‘au by nine observers were 30–154% (mean = 77%) as large as the area surveyed by the reference observer. The best estimate of effective area was obtained by fitting a Fourier function to detection distances ($x^2 = 5.08$, df = 6, $P = 0.53$), giving an effective detection radius of 54.5 m with a coefficient of variation of 2.58%.

We estimate that 65% of the world's ‘Akiapōlā‘au occur in the 66.1-km^2 closed-canopy koa-‘ōhi‘a stratum on the Hāmākua coast. Mean density of ‘Akiapōlā‘au in that stratum was 11.51 ± 1.13 SEM birds per square kilometer (Table 1), based on 143 ‘Akiapōlā‘au detections during 1141 count periods. Density in the open-canopy koa-‘ōhi‘a stratum in Hāmākua was 1.15 birds/km^2 $\pm$ 0.67 based on three detections during

TABLE 1

Density (Birds/km^2) of ‘Akiapōlā‘au in Five Strata on Hawai‘i

				Birds/Station		Density		
Stratum	Area (km^2)	Stations sampled	Birds detected	Mean	SEM	Mean	SEM	No. of individuals (90% Conf. Int.)
Ka‘ū/Kapāpala	30.40	188	3	0.016	0.009	1.44	0.84	44 (10–90)
Lower Keauhou Ranch	11.51	148	3	0.020	0.012	1.87	1.07	22 (6–44)
Upper Keauhou/Kūlani	20.09	760	119	0.156	0.019	14.41	1.79	290 (232–351)
Hāmākua—Open canopy	27.82	225	3	0.013	0.008	1.15	0.67	32 (8–65)
Hāmākua—Closed canopy	66.10	1,141	143	0.102	0.009	11.51	1.13	761 (641–883)
Total	155.92	2,462	271					1,148 (1,094–1,202)

225 count periods. The highest density was found in the 20.09-km^2 Upper Keauhou/ Kūlani stratum, which had 14.41 ± 1.79 'Akiapōlā'au per square kilometer, for an estimated population of 290 ± 40 birds. The Lower Keauhou Ranch stratum had a density of 1.87 ± 1.07 birds/km^2, for a total estimate of 22 'Akiapōlā'au. Finally, we estimated that the 30.4 km^2 of koa-dominated forest in the Ka'ū and Kapāpala forest reserves contained 44 'Akiapōlā'au, based on three detections at 188 stations (Table 1). The combined population estimate for these five strata is 1148 'Akiapōlā'au, with a 90% confidence interval of 1094 to 1202 individuals.

The remnant population of 'Akiapōlā'au in dry māmane forest on Mauna Kea contains no more than 10 birds, and probably numbers fewer than five individuals. At least 10,000 person-days of fieldwork since 1989 in the course of intensive research on the Palila (*Loxioides bailleui*) has yielded captures and sightings of six adult male 'Akiapōlā'au on the southwestern slope of Mauna Kea, with only two males remaining by 1993. The isolated population at Kanakaleonui, on the eastern slope of Mauna Kea, dwindled from eight adult males and three females in 1990 (all of which were banded) to five individuals in 1993 (T. Pratt, unpubl. data). No 'Akiapōlā'au could be located at Kanakaleonui during three surveys there in 1994 and 1995. No more than six other 'Akiapōlā'au have been located during surveys throughout the remaining areas of māmane forest on Mauna Kea since 1990. Only three 'Akiapōlā'au have been detected in leeward Hawai'i during the past 3 yr, despite more than 1000 person-days of fieldwork by federal and state biologists. Portions of the koa-dominated forests of leeward Hawai'i have not been systematically surveyed during the past 5 yr, and it is possible that a small population of 'Akiapōlā'au has not been detected there, but we think it is unlikely that more than 10 'Akiapōlā'au occur in leeward Hawai'i. Our best estimate of the number of 'Akiapōlā'au occurring outside of our five strata is 15 individuals; we thus estimate that there are 1163 ± 54 (90% CI) 'Akiapōlā'au in the world.

DISCUSSION

The greatest change in the number of 'Akiapōlā'au since the late 1970s occurred in the Ka'ū District, where the estimated population decreased from 500 (Scott et al. 1986) to 44 'Akiapōlā'au. Most of the stations in Ka'ū sampled by Scott et al. (1986) were in 'ōhi'a-dominated forests where 'Akiapōlā'au are now extremely rare or absent (Scott et al. 1986, Ralph and Fancy 1996; this study), and yet Scott et al. (1986) detected 30 'Akiapōlā'au at 19 of 199 stations. During 1990–1995 surveys, only three 'Akiapōlā'au were detected at 188 stations. Mean number of 'Akiapōlā'au per station declined from 0.39 (1300–1500 m elevation band) and 0.28 (1500–1700 m band) in 1976 (Scott et al. 1986) to the current estimate of 0.02 ± 0.01 'Akiapōlā'au per station. Ralph and Fancy (1996) did not find any 'Akiapōlā'au in surveys of a Ka'ū Forest Reserve site in 1976–1981, but their study area lacked koa and was to the west of the current 'Akiapōlā'au distribution.

The Hāmākua study area of the HFBS incorporated the areas within all of our strata except the Ka'ū/Kapāpala stratum. Scott et al. (1986) detected 126 'Akiapōlā'au at 10.5% of 669 stations in Hāmākua. Mean number of 'Akiapōlā'au per station was 0.068 (1300–1500 m elevation), 0.103 (1500–1700 m), and 0.041 (1700–1900 m), with densities of two to five 'Akiapōlā'au per square kilometer for the three elevation bands (Scott et al. 1986). We detected 'Akiapōlā'au during 8.8% of the 2275 count periods sampled in the four strata that occurred within their Hāmākua study area, but our study area did not include 'ōhi'a-dominated forests and lower elevations as theirs did, indicating that the prevalence of 'Akiapōlā'au has declined since their surveys. In our Upper Keauhou/ Kūlani and Hāmākua closed-canopy strata where we found highest densities of 'Akiapōlā'au (Table 1), the number of 'Akiapōlā'au per station in 1990–1995 was comparable with the highest value reported by Scott et al. (1986) (0.103 birds per station, 1500–1700 m). The density and number of 'Akiapōlā'au per station in our other strata were lower than those reported by Scott et al. (1986), again suggesting a decline in 'Akiapōlā'au numbers. The transects sampled by the HFBS did not pass through several areas on the Hāmākua coast that are now known to contain the highest densities of 'Akiapōlā'au, further suggesting that the estimate of 1500 'Akiapōlā'au in the late 1970s may have been low and that the 'Akiapōlā'au population has declined more than the estimates of 1500 (Scott et al. 1986) and 1163 (current estimate) indicate.

One problem with the current analysis is that most of the open- and closed-canopy strata in Hāmākua south of the Hakalau Forest NWR has not been systematically surveyed since 1978. We included these areas within the distribution of 'Akiapōlā'au based on vegetation type and elevation contours, but we recognize that extrapolation of densities calculated from sampling sites that are concentrated in the northern portion of these strata may bias the results. Poor survey coverage of forests in South Kona is also problematic, although the surveys that have been conducted indicate that the population there is very small and declining. Also, we recognize that a few 'Akiapōlā'au have been sighted outside of our strata in small isolated stands of koa or in 'ōhi'a-dominated forest. However, it is more likely that we have overestimated rather than underestimated the 'Akiapōlā'au population because of problems with uneven survey coverage within strata and extrapolation of relatively high densities to unsurveyed areas in the open- and closed-canopy Hāmākua strata.

Several factors may be responsible for the continued decline of the 'Akiapōlā'au. 'Akiapōlā'au currently survive in several isolated stands of koa forest, and habitat loss and modification that started with the arrival of humans in Hawai'i more than 15 centuries ago was a major factor causing the species to become endangered (Ralph and van Riper 1985, Scott et al. 1986). Certainly, the continued logging of koa has adversely affected numbers of 'Akiapōlā'au, because the 'Akiapōlā'au is a specialist that requires large, old-growth koa above the putative disease belt (Ralph and Fancy 1996). However, logging, grazing, and other habitat modifiers cannot explain the large decline in the 'Akiapōlā'au population in the Ka'ū District and the indicated declines within the Hakalau Forest NWR and other areas along the Hāmākua coast during the past 20 yr. Avian disease may be responsible for the declines. Some native forest birds are known to be highly susceptible to avian malaria (*Plasmodium relictum*) and avian pox (Warner 1968, van Riper et al. 1986, Atkinson et al. 1995), which are transmitted by mosquitoes. Disease outbreaks and/or mosquito breeding occur above 1200 m during seasonally warm weather (C. Atkinson, unpubl. data). Densities of 'Ākepa (*Loxops coccineus*) and Hawai'i Creeper (*Oreomystis mana*) in the Ka'ū Forest Reserve, which also would be susceptible to avian disease, have also decreased since 1976 (P. Conry, unpubl. data).

Predation by introduced rats and cats (*Felis catus*), the native Hawaiian Hawk (*Buteo solitarius*), and Pueo (*Asio flammeus*) have probably also contributed to the decline, and may be the primary factor causing the dry-forest population of 'Akiapōlā'au on Mauna Kea to go extinct (Atkinson 1977, Scott et al. 1986, Snetsinger et al. 1994; T. Pratt, unpubl. data). Hawaiian Hawks have been attracted by playbacks of juvenile and adult 'Akiapōlā'au calls that are used to lure 'Akiapōlā'au into nets (M. Moore and S. Langridge, unpubl. data). The Pueo has been observed taking nestlings of other honeycreepers from nests on Mauna Kea (T. Pratt, unpubl. data) and is known to be an important predator of forest birds (Snetsinger et al. 1994). The feral cat, which has been described as "the most dangerous predator ever introduced by man" (Ebenhard 1988), occurs throughout wet and dry forests on Hawai'i, where it preys on native birds (Snetsinger et al. 1994; T. Pratt, unpubl. data; G. Lindsey, unpubl. data). The loud vocalizations of adult 'Akiapōlā'au, persistent calling of juveniles, and the species' habit of foraging on the trunks and larger branches of large trees may make the 'Akiapōlā'au more vulnerable to predators than other species.

The protection and management of the remaining koa forests above 1200 m elevation where 'Akiapōlā'au still occur are critical to the survival of this species. Small population theory suggests that it is better to have several smaller populations than one larger population (Dennis et al. 1991). If this is true, the fragmented distribution of the 'Akiapōlā'au may, in some ways, be an asset, but it is important that the populations and suitable habitat be close enough to allow interchange of individuals. Long-term management actions such as reducing mosquito breeding sites, removing cattle, and planting koa trees in key land parcels located near and between disjunct populations of 'Akiapōlā'au may determine whether this species will survive another 50 yr or join the list of native Hawaiian species that have gone extinct within our lifetime.

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