Technical Report HCSU-012

POPULATION TRENDS OF NATIVE HAWAIIAN FOREST BIRDS, 1976-2008: the data and statistical analyses

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SUMMARY

The Hawaii Forest Bird Interagency Database Project has produced a centralized database of forest bird survey data collected in Hawai`i since the mid-1970s. The database contains over 1.1 million bird observation records of 90 species from almost 600 surveys on the main Hawaiian Islands—a dataset including nearly all surveys from that period. The primary objective has been to determine the status and trends of native Hawaiian forest birds derived from this comprehensive dataset.

We generated species-specific density estimates from each survey and tested for changes in population densities over the longest possible temporal period. Although this cumulative data set seems enormous and represents the best available information on status of Hawaiian forest birds, detecting meaningful population distribution, density, and trends for forest birds in Hawai`i has been difficult. These population parameters are best derived from long-term, large-scale, standardized monitoring programs. The basis for long-term population monitoring in Hawai`i was established by the Hawaii Forest Bird Survey of 1976-1983 (Scott *et al*. 1986). Since then, however, only key areas have been resurveyed, primarily to monitor rare species. The majority of surveys since the early 1980s have been conducted by numerous, independent programs, resulting in some inconsistencies in methodology and sampling that in some cases has been intermittent and usually at limited scale (temporally or spatially). Thus, despite the consolidation of data into a centralized database, our understanding of population patterns is rather limited, especially at the regional and landscape scales. To rectify their deficiency, we present a framework to improve the understanding of forest bird trends in Hawai`i through an overarching monitoring design that allocates sampling at appropriate regional and temporal scales.

Despite the limitations of the current monitoring effort, important generalities stand out vividly from the multiplicity of species-specific trends. Overall, in marginal habitats the Hawaiian passerine fauna continues to decline, with populations of most species shrinking in size and distribution. Since the early 1980s, 10 species that were rare at the time may now be extinct, although one, the `Alalā (*Corvus hawaiiensis*), survives in captivity. Dedicated search effort for the remaining nine species has been inadequate. Of the 22 species remaining, eight have declined, five appear to be stable, two are increasing, and the trend for seven species is unclear.

On the bright side, native passerines, including endangered species, appear to be stable or increasing in areas with large tracts of native forest above 1,500 m elevation, even while decreasing in more fragmented or disturbed habitats, particularly at lower elevation. For example, all eight native species resident at Hakalau Forest National Wildlife Refuge have shown stable trends or significant increases in density over the long-term. Thus, native birds are ever more restricted to high-elevation forest and woodland refugia. It is these upland habitats that require sustained and all-out restoration to prevent further extinctions of Hawaiian forest birds.

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INTRODUCTION

Scott and Kepler (1985) presented the first comprehensive status evaluation of indigenous Hawaiian forest birds based on the landmark Hawai`i Forest Bird Survey (HFBS)—a series of extensive surveys throughout the main islands conducted from 1976 to 1983 (Scott *et al*. 1986). At that time, they documented declining populations and decreasing ranges for most species, including some recent extinctions. This pattern has continued to the present. For example, nine bird species likely have disappeared since 1980 (Table 1), and an additional species, the `Alala (scientific names are provided in the species accounts and Table 1), is extinct in the wild but survives in captivity. Thus, the Hawaiian avifauna has experienced the highest modern extinction rate in the United States (Loope 1998). On a world-wide basis, extinctions in Hawai`i and the Mariana Islands are why the United States has experienced more bird extinctions than any other country (Wilcove 2005).

It is believed that many of the remaining species continue to decline, although a comprehensive status evaluation of native Hawaiian forest birds has not been updated since the mid-1980s. Since the HFBS, many forest bird surveys have been conducted throughout the main islands for the purpose of monitoring population sizes and changes. Further, select species, such as the Palila, have been studied intensively to monitor population sizes, understand population ecology, and identify and mitigate threats.

Our technical report was conceived to provide the data and analytical framework for a review of the status and trends of Hawaiian forest birds to be published as a chapter in the book Pratt *et al*. (2009). The primary objective of our study is to present an update of status and trends of 29 native forest passerines in the main Hawaiian Islands, and we present here the data and statistical analyses of bird survey data from the HFBS and nearly all subsequent surveys. Included are all native forest species extant at the time of these surveys. Not included are more than 30 species of forest birds that became extinct prior to the 1970s (Banko and Banko 2009), and passerines in the Northwest Island chain—Nihoa Millerbird (*Acrocephalus familiaris kingi*), Laysan Finch (*Telespiza cantans*), and Nihoa Finch (*T. ultima*), which were not covered by these surveys (see Gorresen *et al*. [2009] for those species' accounts). The species' accounts presented here were written to include details of status and trend patterns which were to be summarized in Gorresen *et al*. (2009). We also include here initial drafts of the trend and monitoring discussion sections to be published in Gorresen *et al*. (2009) and Camp, Reynolds, et al. (2009), respectively.

This technical report brings together materials from the literature, unpublished reports, the original HFBS data, and additional data from recent and ongoing bird surveys. In particular, we have made use of the data from the almost 600 surveys conducted between 1976 and 2008. The extensive surveys conducted by Scott *et al*. (1986) were considered as the baseline data for our comparisons, and our data have varying cutoff dates depending upon when analyses were conducted. Thus, we have drawn on previously published regional status and trends for Kaua`i Island (Foster *et al*. 2004) and Hawai`i Island, including the central windward region (Reynolds *et al*. 2003, Gorresen *et al*. 2005), Ka`ū (Gorresen *et al*. 2007, Tweed *et al*. 2007), Mauna Kea (Johnson *et al*. 2006, Leonard *et al*. 2008), and Hakalau Forest National Wildlife Refuge (Camp, Pratt *et al*. 2009). Analyses for the Kona districts of Hawai`i Island and for all other islands are reported here for the first time.

The challenges inherent in assessing population trends are many, including limited spatial and temporal coverage, high levels of variability, small sample sizes, low statistical power to detect trends, and so on (see Camp, Reynolds *et al*. 2009). Assessing how abundance changes over time is also complicated by differences in the seasons during which surveys were conducted. Note that most of the HFBS surveys were conducted in the summer months (May–July), somewhat past the peak breeding period for most forest birds, whereas subsequent surveys have usually been conducted in spring (January–May). Because forest birds are generally more vocal and therefore more detectable in spring, and because some species disperse from nesting areas following breeding, comparisons of HFBS data with data collected later may show apparent changes in population size that must be interpreted with caution. Further, in order to make comparisons across years, we had to use identical methods for analyzing all surveys, and in some cases this use of the same methods made it necessary to reexamine older data sets (e.g., those from the HFBS). As a result, some of the population estimates reported here are slightly different from those reported in the original sources which used different analytical methods (Johnson *et al*. 2006). Despite such challenges and limitations, these data are a major resource that have not previously been fully analyzed or synthesized.

Table 1. Status summary of extant and recently extinct Hawaiian passerine birds. Species distributions include all major Hawaiian islands (All), Hawai`i (H), Maui (Ma), Moloka`i (Mo), Lāna`i (L), O`ahu (O), Kaua`i (K) Islands. A species is presumed extinct where island is indicated in parentheses. Species with no records within the past 35 years are identified herein as extinct. Listing designations by the U.S. Fish and Wildlife (USFWS; 2006) and the International Union for Conservation of Nature (IUCN; BirdLife International 2004) include extinct (EX), extinct in wild (EW), critically endangered (CR), critically endangered-potentially extinct (CR-PE), endangered (E), vulnerable (VU), near threatened (NT), candidate for federal listing (C), of least concern (LC), or not listed as endangered or threatened by the U.S. Fish and Wildlife Service (—). Acronyms in parentheses indicate a listing designation at the species level. Population size is the most recent population estimate or long-term survey average, and number of populations refers to the number of geographically distinct groups, regardless of genetic connectivity. Table modified from Jacobi and Atkinson (1995).

Species	Island Distribution	USFWS	IUCN	Population Size	Number of Wild Populations	Comments
Kaua`i `Ō`ō *Moho braccatus*	(K)	E	EX	—	?	last sighting in 1985, last audio detection in 1987
Bishop's `Ō`ō *Moho bishopi*	(Mo, Ma?)	E	EX	—	0	last detected on Moloka`i in 1904, unconfirmed reports in the 1980s from Maui
`Alalā *Corvus hawaiiensis*	H	E	EW	60	0	entire population in captivity; extinct in wild
Kaua`i `Elepaio *Chasiempis sandwichensis sclateri*	K	—	(E)	152,000	1	common above 600 m in native and exotic forest; stable to increasing
O`ahu `Elepaio *Chasiempis sandwichensis ibidis*	O	E	(E)	<2,000	2	range 55 km^2; 6+ subpopulations on 2 mountain ranges; numbers rapidly decreasing
Hawai`i `Elepaio *Chasiempis sandwichensis sandwichensis, C. s. ridgwayi, C. s. bryani*	H	—	(E)	<200,000	~5	densities decreasing in Hualālai, Kona and east windward Hawai`i Island; stable or increasing in upper elevation Ka`ū and Hakalau Forest NWR
Kāma`o *Myadestes myadestinus*	(K)	E	EX	—	?	last detections (unconfirmed) in 1991
Moloka`i Oloma`o *Myadestes lanaiensis rutha*	(Mo)	E	(CR-PE)	—	?	last detection during 1980 HFBS; unconfirmed report in 1988
`Ōma`o *Myadestes obscurus*	H	—	VU	170,000	1	extirpated from Kona and Kohala; possibly declining in central and east windward Hawai`i Island; stable in Hakalau Forest NWR and Ka`ū

Table 1. Status summary of extant and recently extinct Hawaiian passerine birds cont.

Species	Island Distribution	USFWS	IUCN	Population Size	Number of Wild Populations	Comments
Puaiohi *Myadestes palmeri*	K	E	CR	300-500	1	small range (<20 km^2); narrow habitat requirements; captive propagation on-going
\`Ō\`ū *Psittirostra psittacea*	(All)	E	CR-PE	—	?	rapid decline on Kaua\`i and Hawai\`i; last confirmed sighting on Hawai\`i in 1987 and on Kaua\`i in 1989
Palila *Loxioides bailleui*	H	E	E	3,900	1	population within 30 km^2 range contracting and density decreasing from 2003 to 2007; west Mauna Kea habitat vulnerable to fire; captive propagation on going
Maui Parrotbill *Pseudonestor xanthophrys*	Ma	E	CR	500	1	single, small range (<50 km^2); density appears stable; captive propagation on going
Hawai\`i \`Amakihi *Hemignathus virens virens*	H	—	(LC)	800,000	1	density variable in central and south Kona, declining in mid-elevation windward Hawai\`i Island but stable or increasing elsewhere; expanding range locally at low elevations
Hawai\`i \`Amakihi *Hemignathus virens wilsoni*	Ma, Mo, (L)	—	(LC)	50,000	3	small disjunct population on west Maui; increasing densities on east Maui; stable on Moloka\`i; extirpated from Lāna\`i in 1970s; expanding range locally at low elevations
O\`ahu \`Amakihi *Hemignathus flavus*	O	—	VU	52,000	2	density possibly increasing; expanding range locally into lower elevation and non-native habitats
Kaua\`i \`Amakihi *Hemignathus kauaiensis*	K	—	VU	51,000	1	densities increasing
\`Anianiau *Viridonia parva*	K	—	VU	37,500	1	densities increasing
Kaua\`i \`Akialoa *Hemignathus ellisianus stejnegeri*	(K)	E	EX	—	?	last reported in 1969
Kaua\`i Nukupu\`u *Hemignathus lucidus hanapepe*	(K)	E	(CR-PE)	—	?	unconfirmed reports up to mid-1990s
Maui Nukupu\`u *Hemignathus lucidus affinis*	(Ma)	E	(CR-PE)	—	?	unconfirmed reports up to 1996
\`Akiapōlā\`au Hemignathus munroi	H	E	E	1,900	4	density increasing in Hakalau Forest NWR and stable in upper Ka\`ū; likely decreasing in central windward Hawai\`i Island; extirpated from subalpine Mauna Kea and probably Kona districts; range contracting

Table 1. Status summary of extant and recently extinct Hawaiian passerine birds cont.

\`Akikiki *Oreomystis bairdi*	K	C	CR	3,600	1	small population and range (<40 km^2); range contraction
Hawai\`i Creeper *Oreomystis mana*	H	E	E	14,000	3	density stable in Hakalau Forest NWR and possibly upper Ka\`ū; likely decreasing in central windward Hawai\`i Island; nearly extirpated from Hualālai and central Kona
O\`ahu \`Alauahio *Paroreomyza maculata*	(O)	E	CR-PE	—	?	last confirmed sighting in 1985
Kākāwahie *Paroreomyza flammea*	(Mo)	E	EX	—	?	last confirmed sighting in 1963
Maui \`Alauahio *Paroreomyza montana newtoni*	Ma	—	(E)	35,000	2	north population density possibly increasing, but range may be contracting; southwest population small and trends unknown
\`Akeke\`e *Loxops caeruleirostris*	K	—	E	7,900	2	densities fluctuate widely and range contracting; Makaleha Mt. population status unknown
Maui \`Ākepa *Loxops coccineus ochraceus*	(Ma)	E	(E)	—	?	unconfirmed sighting in 1988
Hawai\`i \`Ākepa *Loxops coccineus coccineus*	H	E	(E)	12,000	4	density stable in Hakalau Forest NWR and possibly stable in upper Ka\`ū; likely decreasing in central windward Hawai\`i Island; nearly extirpated from Hualālai and central Kona
\`I\`iwi *Vestiaria coccinea*	All, (L)	—	NT	360,000	8	density decreasing throughout Hawai\`i but stable in Hakalau Forest NWR and increasing on east Maui; range contracting at lower elevations
\`Ākohekohe *Palmeria dolei*	Ma	E	CR	3,800	1	small population and range (~60 km^2); density possibly increasing
\`Apapane *Himatione sanguinea*	All	—	LC	1,300,000	6	densities increasing or stable in much of range but decreasing in mid-elevation east windward Hawai\`i Island; expanding range locally at low elevations
Po\`o-uli *Melamprosops phaeosoma*	Ma	E	CR	—	?	rapid population decline and range contraction; last seen in the wild in 2004

METHODS

Surveys

Hawaiian birds occupy diverse forest types, ranging from sea level to more than 3,000 m elevation. The variety of climate and vegetative types occupied by native forest birds is described in Scott *et al*. (1986). Jacobi (1989) provides detailed descriptions of plant communities and maps. Furthermore, no Hawaiian forest bird species are restricted to one or another of the six largest Hawaiian islands.

The major goals of most Hawaiian forest bird surveys have been to determine species distributions, densities, and changes in populations. To these ends, almost 600 surveys using point transect distance sampling, also called variable circular plot (VCP), have been conducted across the main Hawaiian Islands between 1976 and 2008 (Appendix 1).

The HFBS established the basis for long-term population monitoring and in most cases provided the only range-wide survey of the main Hawaiian Islands. Surveys were conducted on Hawai`i, Maui, Lāna`i, Moloka`i, and Kaua`i islands between 1976 and 1983 (Figures 1, 2, and 3; Appendix 1). Most sampling stations were established approximately every 134 m (a distance equal to "about twice the effective detection distance of `Ōma`o", a species with the largest detection distance of those sampled; Scott *et al*. 1986:34) along transects spaced three–five km apart that spanned forests above 600 m elevation, except on Kaua`i. The Kaua`i forest bird survey was restricted to a small area in the Alaka`i Wilderness Preserve that encompassed the core ranges of endangered species on that island, as determined by USFWS (1983). The HFBS did not conduct surveys on O`ahu due to logistical constraints and the belief that native bird populations on O`ahu were too small to be effectively sampled by point transect methods (Scott *et al*. 1986:5).

A)

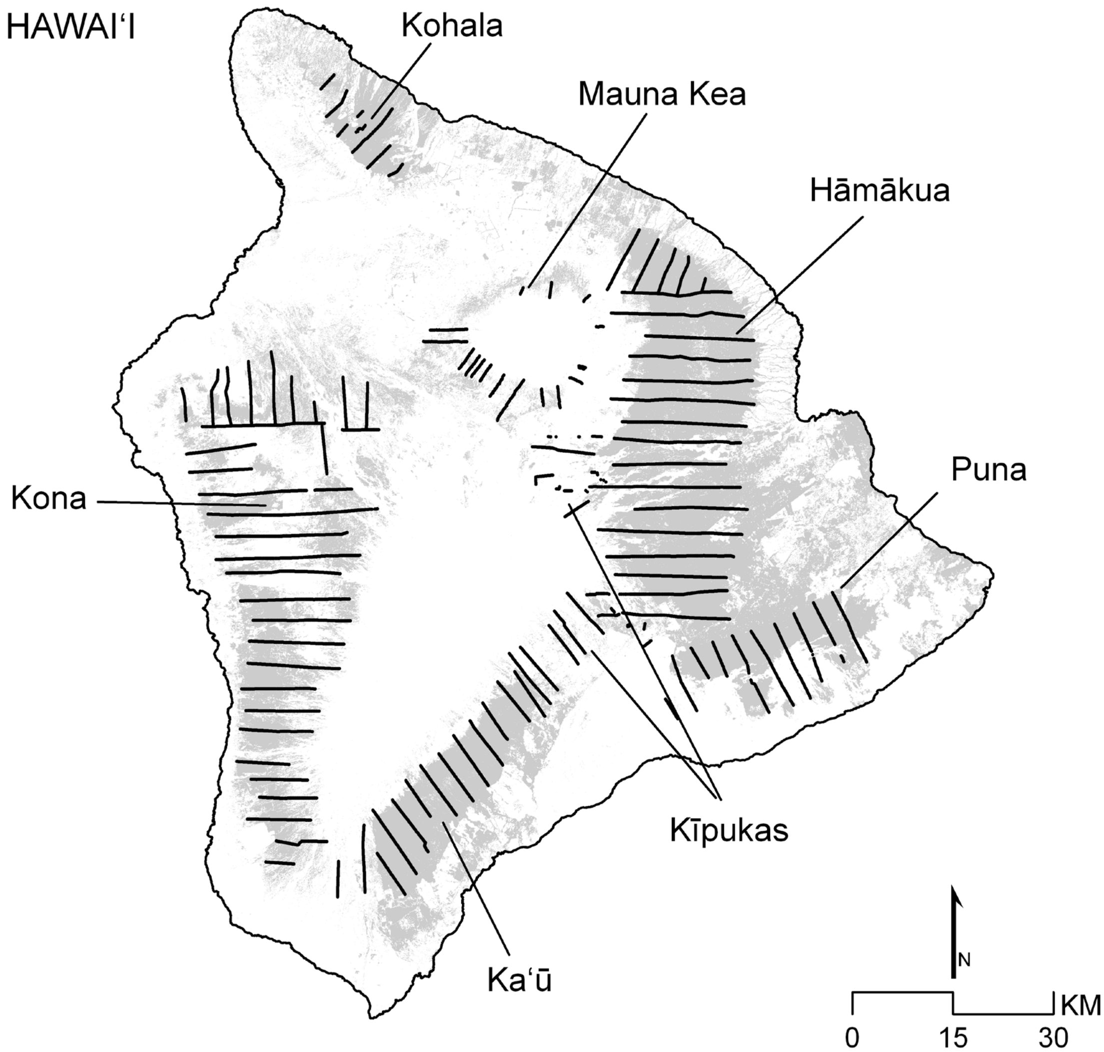


Figure 1. Location of forest bird survey transects (heavy lines), region names, and native and exotic forests and woodlands (shaded area) on the island of Hawai`i for (A) Hawaii Forest Bird Surveys (HFBS; Scott *et al*. 1986) and (B) subsequent surveys. The HFBS was conducted between 1976 and 1983 with transect coverage closely matching forest extent. Spatial extent and coverage of subsequent surveys was generally more restricted and of limited use for broad scale, range-wide monitoring. The numbers by location name in Figure 1.B reference the study areas in trend summary Figures 20–23.

B)

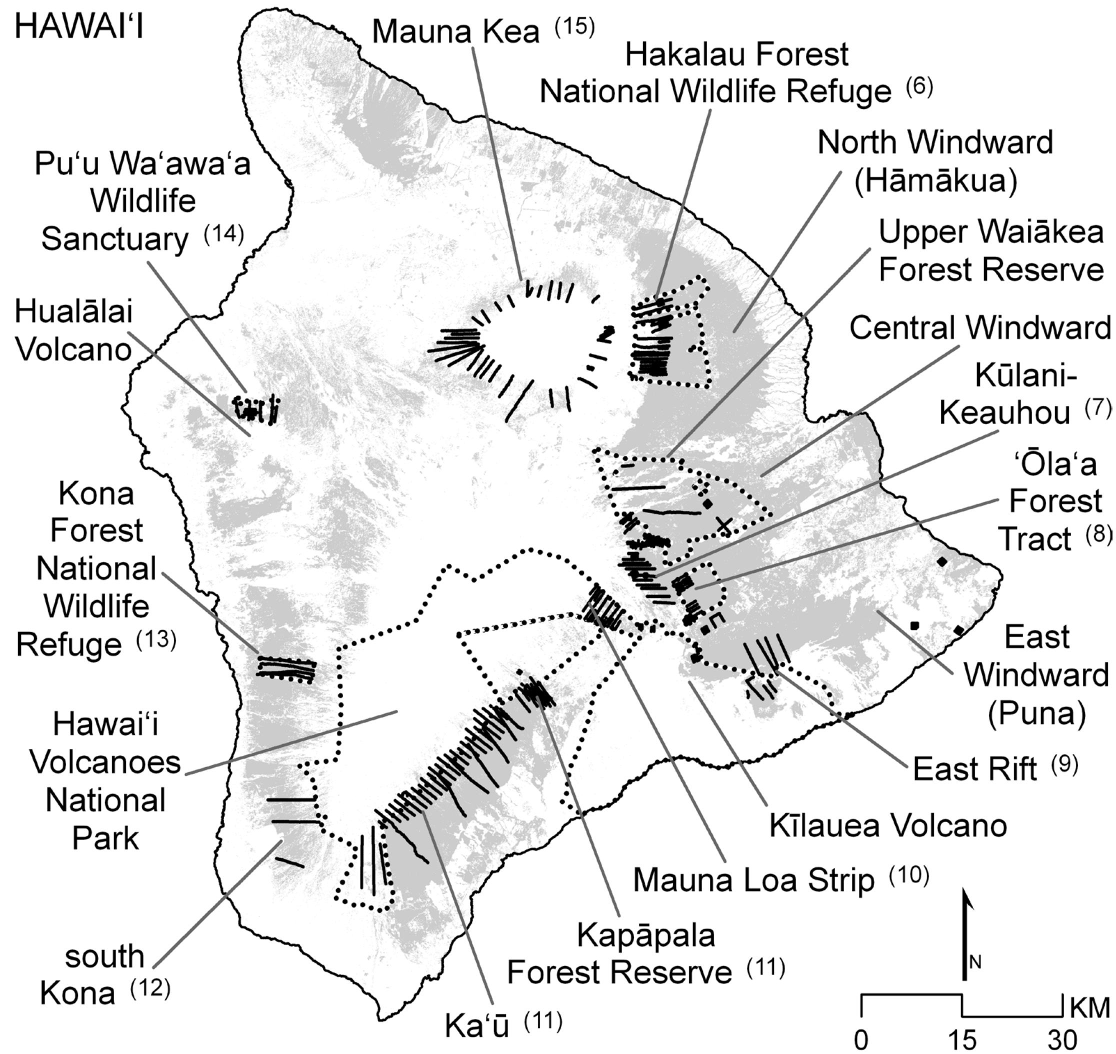
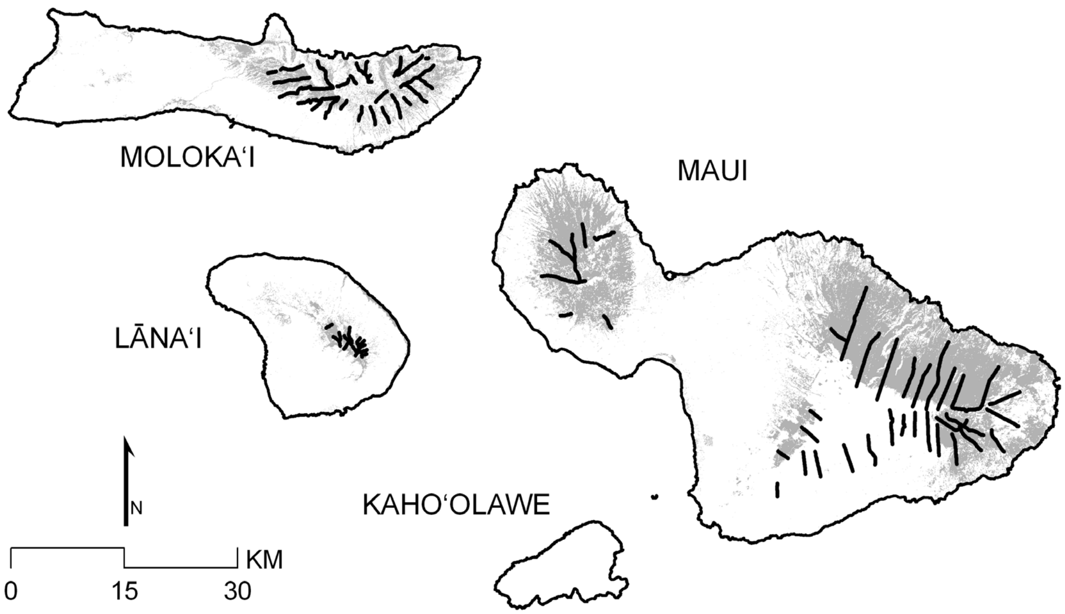


Figure 1 continued.

A)



B)

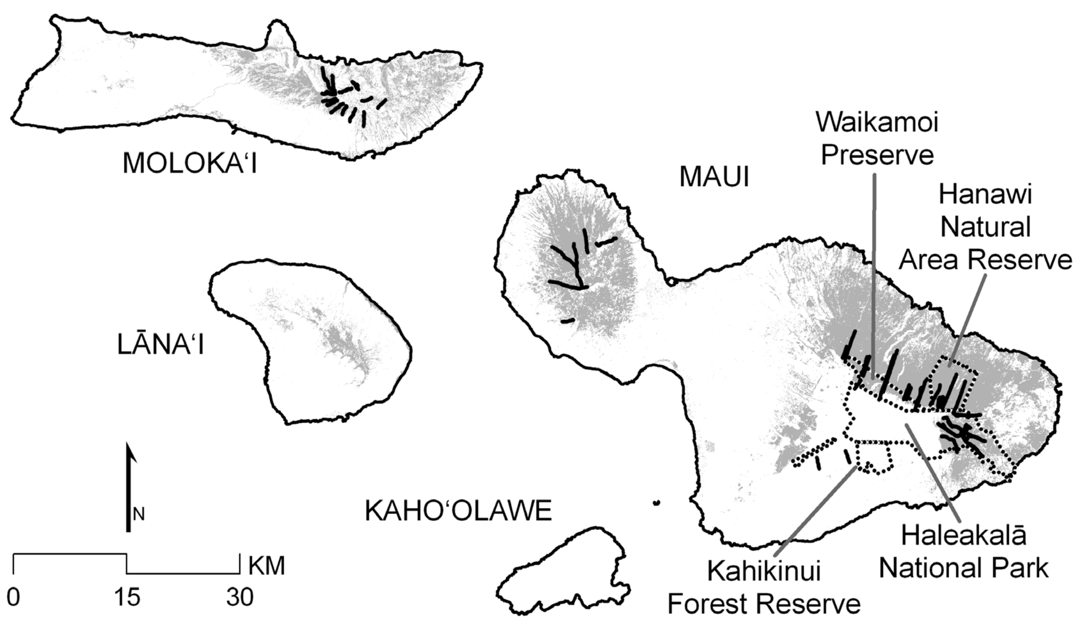


Figure 2. Location of forest bird survey transects (heavy lines), region names, and native and exotic forests and woodlands (shaded area) on the islands of Maui, Lāna`i, and Moloka`i for (A) Hawaii Forest Bird Surveys (HFBS; Scott *et al*. 1986) and (B) subsequent surveys. The HFBS was conducted between 1979 and 1980 with transect coverage closely matching forest extent. Spatial extent and coverage of subsequent surveys was generally more restricted and of limited use for broad scale, range-wide monitoring. Lāna`i has not been sampled subsequent to the HFBS. West and East Maui are referenced by the numbers 4 and 5 in trend summary Figures 20–23.

A)

B)

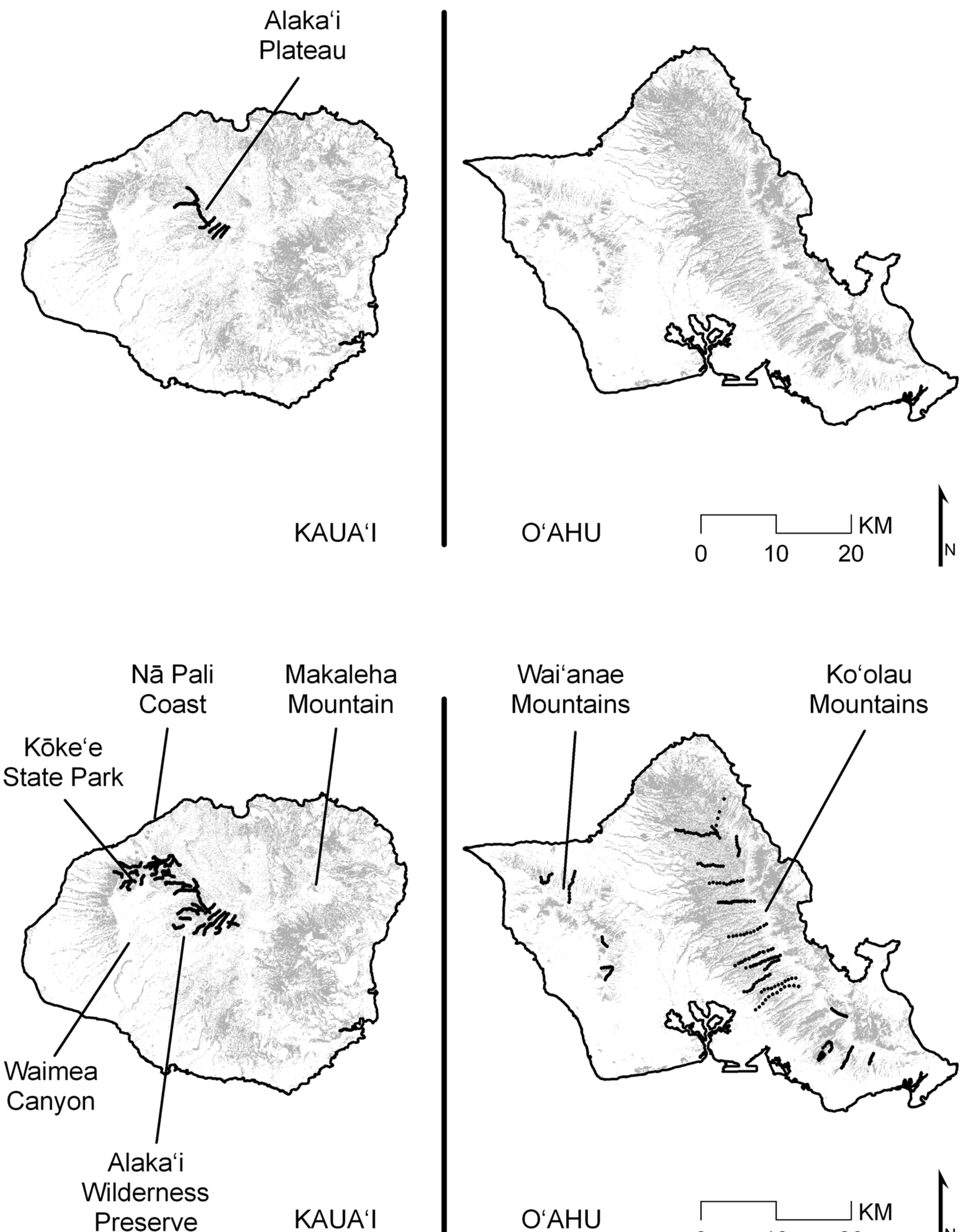


Figure 3. Location of forest bird survey transects (heavy lines), region names, and native and exotic forests and woodlands (shaded area) on the islands of Kaua`i and O`ahu for (A) Hawaii Forest Bird Surveys (HFBS; Scott *et al*. 1986) and (B) subsequent surveys. The HFBS survey on Kaua`i was conducted in 1981. The HFBS did not sample on O`ahu, however, it was sampled in 1991. The Wai`anae and Ko`olau Mountains are jointly referenced by the number 2 in trend summary Figures 20–23.

Monitoring subsequent to the HFBS has in most cases resampled only a portion of the HFBS transects (Figures 1, 2, and 3). For example, only HFBS stations above 1,200 m along six to 13 of 31 transects have been resampled on northern Haleakalā Volcano, east Maui (Figure 2; Appendix 1). On Kaua`i, however, the number of transects has been substantially increased since the HFBS, so that a larger proportion of the habitat suitable to forest birds has been covered (Foster *et al*. 2004). In a few areas, such as at Hakalau Forest National Wildlife Refuge (NWR), a new set of transects has replaced the HFBS transects to provide denser sampling (Camp, Pratt *et al*. 2009). Additional surveys have also been added in high elevation mamane-naio habitat on Mauna Kea in order to improve monitoring of the Palila (Figure 1; Johnson *et al*. 2006, Leonard *et al*. 2008)

In addition to spatial inconsistencies between the HFBS and subsequent surveys, many of the subsequent surveys have not completely resampled study areas annually. For example, annual surveys in the Kūlani-Keauhou study area commenced in 1990; however, the study area was not completely surveyed until 1995. These spatial and temporal inconsistencies necessitated restricting our trend analysis to smaller study areas delineated by transects that have been sampled across the sampling period (see "Study Areas for Evaluating Bird Trends", and Appendix 2).

Bird Sampling

Counts of Hawaiian forest birds (Appendix 1) were conducted following methods for point transect distance sampling described by Scott *et al*. (1986). Trained and calibrated observers recorded the species, detection type (heard, seen, or both), and distance from survey station center-point to birds detected during eight-minute counts. Counts on Mauna Kea, Hawai`i Is., lasted six minutes because the woodland habitat is more open than the `ōhi`a (*Metrosideros polymorphia*) forests allowing for easier and more rapid detection. Time of sampling and weather conditions (cloud cover, rain, wind, and gust) were also recorded, and surveying was halted when conditions hindered the ability to detect birds (wind and gust > 20 kph or heavy rain).

Study Areas for Evaluating Bird Trends

Variations in spatial and temporal sampling necessitated subsetting the surveys to delineate the area that was coincident to all of the surveys. This process identified the Trend Study Area within each region and ensured that the analyses were not biased by the inclusion of inconsistently sampled sites. For each annual survey, the sampled transects were plotted and a minimum convex polygon with a 150-m buffer was generated to delineate the area sampled (i.e., a survey polygon). In the situation when the area sampled was not completely surveyed during a given year, two or more years were pooled together and designated as a survey period (e.g., East Maui survey period 1: 1992-1996; survey period 2: 1997-2001; sampling effort was adjusted by the number of surveys pooled together when estimating densities for each period). This procedure provided the greatest extent of survey coverage and maximized use of the available survey data. The area delineated from the coincident survey polygons defined the Trend Study Area for a particular region. Information from transects that were not sampled during all years or periods was dropped. Stations within the Trend Study Areas were identified and used to calculate population density.

Many Hawaiian forest bird species are restricted in habitat and elevation (e.g., `Akiapōlā`au is restricted to koa [*Acacia koa*] forests above 1,300 m; Table 2). For these species, we refined the Trend Study Areas using vegetation maps (Jacobi 1989) and elevation contours to produce Habitat Restricted Areas for calculating population density. This procedure produces a more precise estimate of density (Thompson 2002).

Table 2. Habitat and elevation requirements used in defining Habitat Restricted Areas for Threatened and Endangered Hawaiian forest birds.

Species	Habitat	Minimum Elevation (m)
Hawai`i: Ka`ū		
Hawai`i Creeper	Forest habitat	1,200
Hawai`i `Ākepa	Forest habitat	1,200
Hawai`i: Central Windward		
Hawai`i `Elepaio	Forest habitat	1,500
`Akiapōlā`au	Koa habitat	1,500
Hawai`i Creeper	Forest habitat	1,500
Hawai`i `Ākepa	Forest habitat	1,500
Hawai`i: Kona – Pu`u Wa`awa`a		
Hawai`i Creeper	Forest habitat*	1,500
Hawai`i `Ākepa	Forest habitat*	1,500
Maui: East		
Maui Parrotbill	Forest habitat	1,220
Maui `Alauahio	Forest habitat	1,220
Maui `Ākepa	Forest habitat	1,200
`Ākohekohe	Forest habitat	1,220

* Forest habitat within the Pu`u Wa`awa`a Forest Bird Sanctuary.

Description of Trend Study Areas

Although our goal was to provide current bird status and trend through 2008, density and trend analyses take time and were conducted as a series of projects with partner agencies. The analyses were done in a geographical sequence starting with Central Windward (Gorresen et al. 2005), and ending with Hakalau Forest NWR (Camp, Pratt *et al.* 2009) and Kaua`i (VanderWerf *et al.* in prep.). Therefore, in cases where data had already been analyzed, some of the most recent surveys were not included in our analyses, and bird status and trend information therefore spans different time periods for different areas. Details of the Trend Study Areas including descriptions of surveys, any required pooling, and references and publications are provided in Appendix 2.

Determining Proportion Forested and Area Surveyed

The maximum extent of areas surveyed was determined by arbitrarily delineating a one-km buffer around survey stations. A one-km buffer was also added to the Trend Study Areas to determine the area repeatedly surveyed. The one-km buffer was sufficiently large to encompass an area of inference around survey stations. The proportion forested of each maximum extent surveyed and Trend Study Area was calculated using the NOAA C-CAP (1995) land cover classification, where forest cover included both the forest and woodland cover types.

Delineating Species' Ranges

Species' ranges were manually delineated using a two-stage approach: (1) plotting the distribution of species occurrence by station and (2) drawing a polygon encompassing the stations with occurrences. In some cases species' ranges were refined by removing outlier occurrences, accounting for elevation limits, and interpolating to eliminate unsuitable land cover types and include expert knowledge from the authors and other sources.

Estimating and Comparing Population Density

Species-specific densities (birds/km^2) were calculated from the point transect data using program Distance 4.2 (Thomas *et al*. 2001). Except for the Hakalau Forest NWR and Kaua`i analyses, data were post-stratified by study area (Survey Area or Habitat Restricted Area) for each year or survey period using the global detection function calculated across pooled strata. Density estimates for Hakalau Forest NWR birds were estimated from a global detection function applied to each annual survey (post-filtering approach; see Camp, Pratt, *et al*. 2009). Kaua`i bird densities were estimated from survey specific detection functions, except for `Akikiki and `Akeke`e whose species-specific detections were pooled to attain sufficient sample sizes (see VanderWerf *et al*. in prep). Variance was calculated using analytic methods, except for the Palila, Hakalau Forest NWR, and Kaua`i analyses where bootstrap methods were used to determine variance. Results of simulation studies reveal that bootstrap methods compare well with analytic methods; however, bootstrap methods better reflect the uncertainty in the confidence limits (Buckland et al. 2001).

Observations from all surveys conducted between December and July in each survey region were pooled together to calculate global detection functions by species following methods described by Buckland *et al*. (2001, 2004) and Thomas *et al*. (2001). All data were treated as exact measures and modeled accordingly, except the O`ahu survey where distances were recorded in 10, 25, 50, and 100 ft intervals, and thus analyzed as binned data. *A priori* model selection was restricted to half normal and hazard-rate detection functions with expansions series of two orders and covariate variables (observer, time of day, cloud cover, rain, wind, gust, year, and month), and followed methods described by Buckland *et al*. (2001, 2004), Burnham and Anderson (1998, 2002), and Thomas *et al.* (2001). Model and covariate parameters are presented in Appendices 3 and 4 for analyses conducted for this report, and see Camp, Pratt *et al*. (2009) for Hakalau Forest NWR and VanderWerf *et al*. (in prep.) for Kaua`i modeling parameters.

We assessed change in population by three methods—end-point *z*-test, log-linear regression within a frequentist framework, and log-linear regression model within a Bayesian framework—depending on the number of surveys conducted during the time series. End-point *z*-tests were applied to time series with fewer than five surveys. Log-linear regression was applied to most time series with more than five surveys, with the exception of surveys of the Hakalau Forest NWR, Hawai`i Island, and a 25-km$^2$ core area in the eastern half of the Alaka`i Wilderness Preserve, Kaua`i Island which was analyzed with the Bayesian log-linear regression.

The HFBS and most recent survey results served as the two-sample end-points from which to compare changes in density. We applied one modification to the standard two-sample *z*-test which entailed testing for differences in density estimates within and outside an equivalence region (see Camp *et al*. 2008 for details). The approach used under classical hypothesis testing is to examine whether a significant difference in the population density has occurred between time T_i and T_{i+t}. It is unreasonable, however, to suppose that the population densities would be exactly the same, even in the absence of trends. Instead, a more appropriate approach is to consider the parameters to be equivalent within some pre-specified bounds and test for evidence to falsify this—an equivalence-testing approach (Manly 2001). Equivalence tests allowed us to distinguish between cases in which there was not a trend from the inability to statistically detect a trend or were intrinsically variable (Dixon and Pechmann 2005, Camp *et al*. 2008).

We chose conservative equivalence bounds equal to a 50% change in the population over 25 years, or a -0.0285 and 0.0170 annual rate of change. We defined changes in population density, or trends, as increasing, decreasing, negligible trend (i.e., stable population), or an inconclusive result. An ecologically meaningful trend occurred when the slope lay outside the equivalence region, whereas a negligible trend occurred when the slope lay within the equivalence region. An inconclusive result occurred when the sample size was insufficient to produce precise variation estimates (Dixon and Pechmann 2005).

Density estimates from subsequent surveys were compared to HFBS with end-point analyses (*z*-tests), except for the Hakalau Forest NWR, Mauna Kea and Mauna Loa Strip study areas on Hawai`i Island, and 25-$km^2$ area in the eastern half of the Alaka`i Wilderness Preserve on Kaua`i Island. End-point comparisons ignore the estimates from any intervening surveys that were conducted. Although this analytical approach filters out 'noise' associated with the intervening surveys, end-point comparison differences may result from chance alone. Continued monitoring will allow analyses that use multiple surveys and evaluation of short-term fluctuations and long-term trends.

Comparisons of densities were made using variance weighted log-linear regression for all species in Mauna Kea, Mauna Loa Strip, and above 1,500 m in the Kona Forest Unit of the Hakalau Forest NWR study areas on Hawai`i Island. Data for regression analyses were log-transformed to account for variance heteroscedasticity, and variance-weighted methods provide the best unbiased linear estimates. The slope coefficient of the linear regression was used to characterize the direction of trend, and the slope and standard error of the slope were used in the equivalence tests following methods described by Dixon and Pechmann (2005) and Camp *et al*. (2008). We interpret the trend as defined above.

Bayesian regression was used to assess population trends in the Hakalau Forest NWR, Hawai`i Island, and within the 25-$km^2$ area in the eastern half of the Alaka`i Wilderness Preserve, Kaua`i Island. The calculated evidence of a trend was derived from the posterior probability of the slope using a log-link regression model, and we used a 25% change of a population in 25 years (annual rate of change equal to -0.0119 and 0.0093) as the equivalence threshold for those two study areas. Detailed methods are provided in Camp, Pratt, *et al*. (2009) and VanderWerf *et al*. (in prep.).

RESULTS

Survey Coverage

From 1976 to 2008, 592 forest bird surveys were conducted on the main Hawaiian Islands using point transect methods. There are approximately 4,500 km^2 of forest on the main Hawaiian Islands (NOAA C-CAP 1995), of which approximately 1,900 km^2 (42%) have been surveyed for forest birds using quantitative sampling methods at least once (Table 3). Approximately 600 km^2 (13% of forests) have been sampled two or more times, allowing for the analysis of population trends (Table 3).

HFBS surveyed more habitat on each island than any survey since, with the exception of Kaua`i, where a USGS/State of Hawai`i Division of Forestry and Wildlife (DOFAW) survey in 2000 added 28 transects and 434 stations, expanding coverage from 32 to 51 km^2. In proportion to its area, Moloka`i has received the most extensive coverage, with 61 $km^2$ (59%) of forests surveyed, whereas Kaua`i has the least area covered with just 51 km^2 (16%) of forest surveyed.

Tracking population trends is most efficiently determined from the repeated sampling of the same survey transects and stations over time. About 30% of the original HFBS transects and stations have been resampled. Resampling effort has varied greatly, with Lāna`i not being resampled at all, to Maui, where 55% of the survey area has been resampled (120 of 218 km^2; Table 3).

Many Hawaiian forest birds are very rare (Table 1). Recovery plans have been written for 22 taxa (U.S. Fish and Wildlife Service 2003, 2006), more than half (12) of which have been observed infrequently during the point transect surveys subsequent to HFBS prior to their disappearances, including: Kaua`i `Ō`ō or `Ō`ō`ā`ā; Bishop's `Ō`ō; `Alalā or Hawaiian Crow; Kāma`o or Large Kaua`i Thrush; Oloma`o or Moloka`i Thrush; `Ō`ū; Kaua`i `Akialoa; Maui Nukupu`u; Kaua`i Nukupu`u; O`ahu `Alauahio or O`ahu Creeper; Kākāwahie or Moloka`i Creeper; and Po`ouli. However, this is not surprising given the amount of survey effort that must be invested to detect very rare species (Scott *et al*. 2008).

Bart *et al*. (2004) proposed that at least two-thirds of a species' range be repeatedly sampled for trends. All of the USFWS-designated endangered species are currently the subjects of monitoring programs using point transect, rare bird searches, surveillance of banded birds, or spot-mapping. However, these programs frequently cover only a small portion of the species' range (Table 4) or are conducted infrequently (e.g., rare bird searches; Reynolds and Snetsinger 2001). Species with ranges < 100 km^2 have been well surveyed on all islands, except O`ahu (Table 4). On Maui, more than two-thirds of the ranges of Maui Parrotbill, Maui `Alauahio, and `Ākohekohe have been repeatedly sampled. On Kaua`i, Puaiohi and `Akikiki ranges have received between 50 – 60% sampling for trends. Two of five species with ranges between 100 – 350 $km^2$, Palila and Hawai`i `Ākepa, have received more than 50% repeated sampling coverage, with the Palila receiving more than 66% coverage. In contrast, ranges of `Akiapōlā`au, Hawai`i Creeper, and `Akeke`e have not been repeatedly sampled as well (proportion of coverage = 46, 43, and 19%, respectively).

As expected for broadly distributed species, species with ranges > 350 km^2 have been less well sampled (Table 4). `Elepaio on Hawai`i and Kaua`i, `Ōma`o, and Kaua`i `Amakihi have received between six and 13% repeated sampling coverage. Although this coverage does not meet the two-thirds standard sampling coverage, the core populations of these species have been repeatedly sampled, and species' range trends may be inferred from extrapolating patterns observed in the core populations. In summary, only Palila on Mauna Kea and the rare Maui forest birds meet the two-thirds sampling coverage objective, and all other species are inadequately sampled for trends by the Bart et al. standard.

Table 3. Comparison of total area of forest bird habitat and the proportion surveyed using variable circular plot methods on the main Hawaiian Islands. Forest cover was derived from NOAA C-CAP (1995) and includes forest and woodland cover types. Maximum survey extent includes all areas sampled at least once. Trend study area includes only areas sampled two or more times, allowing for analysis of trends. Percent coverage provided in parentheses. Area was determined by arbitrarily delineating a one-km buffer around survey stations and summing the amount of forest within the buffer. The one-km buffer approximates the area to which bird habitat models have been applied to infer occurrence and density.

Island	Area Forested (km^2)
Hawai`i	3,141
Maximum Survey Extent	1,493 (48%)
Trend Study Area	456 (15%)
Maui	552
Maximum Survey Extent	218 (39%)
Trend Study Area	120 (22%)
Moloka`i	104
Maximum Survey Extent	61 (59%)
Trend Study Area	13 (13%)
Lāna`i	27
Maximum Survey Extent	13 (48%)
Trend Study Area	na
O`ahu	337
Maximum Survey Extent	76 (23%)
Trend Study Area	na
Kaua`i	327
Maximum Survey Extent	51 (16%)
Trend Study Area	14 (4%)

Table 4. Comparison of species' ranges and the area and proportion of ranges repeatedly surveyed using variable circular plot methods on the main Hawaiian Islands. Species' ranges were determined by manually delineating records of species occurrence. A minimum convex polygon around coincident surveys was used to delineate the area repeatedly surveyed.

Island	Species	Species Range (km^2)	Area of Range Repeatedly Surveyed (km^2)	Proportion of Range Repeatedly Surveyed (%)
Hawai`i	Hawai`i `Elepaio	3,942	473	12%
	`Ōma`o	2,303	294	13%
	Palila	131	105	80%
	Hawai`i `Amakihi	5,319	473	9%
	`Akiapōlā`au	277	128	46%
	Hawai`i Creeper	339	147	43%
	Hawai`i `Ākepa	226	140	62%
	`I`iwi	2,260	441	19%
	`Apapane	4,821	473	10%
Maui	Maui Parrotbill	51	48	94%
	Hawai`i `Amakihi	778	91	12%
	Maui `Alauahio	98	67	68%
	`I`iwi	182	91	50%
	`Ākohekohe	60	55	92%
	`Apapane	729	91	12%
Moloka`i	Hawai`i `Amakihi	65	10	15%
	`I`iwi	18	10	54%
	`Apapane	164	10	6%
O`ahu	O`ahu `Elepaio	93	0	0%
	O`ahu `Amakihi	273	0	0%
	`Apapane	236	0	0%
Kaua`i	Kaua`i `Elepaio	379	25	7%
	Puaiohi	40	25	63%
	Kaua`i `Amakihi	379	25	7%
	`Anianiau	127	25	20%
	`Akikiki	39	21	54%
	`Akeke`e	127	25	20%
	`I`iwi	101	25	25%
	`Apapane	379	25	7%

Species Accounts

Distribution and density estimates were produced for 29 species and subspecies of native Hawaiian forest birds observed on point transect surveys (Table 1). For these species, we present a brief description of range, habitat associations, density estimates, and patterns in density for each survey area in a species-account format. We also present population estimates from the literature to facilitate drawing conclusions of population trends. We did not provide analyses for the Nihoa Millerbird, Nihoa Finch, or Laysan Finch because point transect sampling surveys are not conducted on Nihoa or Laysan. Gorresen *et al*. (2009) provide the species accounts for those three species.

Kaua`i `Ō`ō

The `Ō`ō`ā`ā (Kaua`i `Ō`ō, *Moho braccatus*) was the last of five species of an endemic family (Mohoidae) to persist and the only one endemic to Kaua`i (Scott *et al*. 1986, Sykes *et al*. 2000). The Kaua`i `Ō`ō was once common in lowland and montane native forests but disappeared from the lowlands in the early 1900s and was rare and restricted to the interior of the Alaka`i Plateau by the 1930s (Munro 1960). Surveys between 1968 and 1973 resulted in a population estimate of 36 ± 22 (U.S. Fish and Wildlife Service 1983), but only one breeding pair was located during the 1981 HFBS survey (Scott *et al*. 1986). The species was last seen in 1985 and last heard in 1987 (Pyle 1985, 1987). Intensive surveys during 1995–1996 and ongoing fieldwork have failed to detect the species (Reynolds and Snetsinger 2001, Foster *et al*. 2004, VanderWerf *et al*. in prep.). It is presumed extinct.

Bishop's `Ō`ō

Endemic to Moloka`i, Bishop's `Ō`ō (*Moho bishopi*) was last recorded there in 1904 (Scott *et al*. 1986, Sykes *et al*. 2000). A few observations of `ō`ō-like birds in the upland forests of windward Maui were made in the 1970s and 1980s and may have been of this species (Sabo 1982, Sykes *et al*. 2000). However, the HFBS and numerous subsequent surveys did not confirm these reports. The species is presumed extinct (Reynolds and Snetsinger 2001).

`Alalā

The `Alalā (Hawaiian Crow, *Corvus hawaiiensis*) is a large, omnivorous crow that once ranged widely in old-growth `ōhi`a and koa forests of western and southeastern Hawai`i Island (Banko 2009). It underwent a dramatic decline in numbers and is now extinct in the wild. The HFBS yielded a population estimate of 76 ± 9 birds (Scott *et al*. 1986), and demographic studies at that time by Banko and Banko (1980) indicated that there were at least 53 birds in the core breeding population in central Kona. By 1992, the species existed as a single population of 11 birds (Banko *et al*. 1992), and intensive searches and surveys between 1992 and 2003 failed to detect additional `Alalā (Reynolds and Snetsinger 2001). Twenty-seven captive-raised birds released between 1993 and 1999 bolstered the population temporarily (Kuehler *et al*. 1995, Banko 2009). However, because of a high rate of mortality, the remaining captive-raised birds were removed from the wild in 1999. The last wild birds were seen in 2002. Sixty birds were managed in captivity as of 2009 (A. Lieberman, pers. comm.).

`Elepaio

The `Elepaio (*Chasiempis sandwichensis*) is an insectivorous monarch flycatcher locally common on the islands of Hawai`i and Kaua`i, and uncommon to rare on O`ahu. Five subspecies are currently recognized, three of which occur on Hawai`i Island (*C. s. sandwichensis*, *C. s.*

ridgwayi, *C. s. bryani*) and one each on Kaua`i (*C. s. sclateri*) and O`ahu (*C. s. ibidis*). The three island populations are likely to be elevated to species status based on new genetic and behavioral evidence (VanderWerf *et al*. 2009). `Elepaio are found in a wide variety of habitats and range in elevation from near sea level to about 3,000 m (Figure 4; Scott *et al*. 1986, VanderWerf *et al*. 2001). On Hawai`i Island, density is highest in closed canopied and high statured dry and mesic `ōhi`a and koa forest at upper elevations. The species also occurs at low to moderate densities in subalpine `ōhi`a shrublands, māmane (*Sophora chrysophylla*) and naio (*Myoporum sandwicense*) woodlands, disturbed forests with an exotic plant component, and forests almost entirely comprised of alien plants. `Elepaio had sizeable populations on Kaua`i and Hawai`i islands during HFBS, and its densities appear stable on Kaua`i and in upper-elevation habitats on windward Hawai`i Island. However, its densities have decreased on leeward and mid-elevation windward Hawai`i since the HFBS. Moreover, the small fragmented population on O`ahu is rapidly declining and has been listed as an endangered subspecies (VanderWerf *et al*. 2001, U.S. Fish and Wildlife Service 2006).

`Elepaio occur throughout much of Hawai`i Island, and Scott *et al*. (1986) estimated the population at 207,270 $\pm$ 7,962 (SE) birds. The most numerous of the island's subspecies, *C. s. ridgwayi*, is dispersed in three somewhat disjunct populations—Kohala, Windward, and Ka`ū. The Kohala population was the smallest population and was estimated at 13,642 $\pm$ 1,030 birds based on the 1979 HFBS. This isolated population occurred in 79-km^2 of forest habitat at elevations over 900 m and at densities upwards of 254/km^2. The current status and population trend in this region is unknown. DOFAW Natural Areas Reserve (NAR) staff working on Kohala Mountain in 2008 noted that `Elepaio are locally common and occur in isolated pockets in various parts of the forest (N. Agorastos and L. Hadway, pers. comm.).

The largest population of *C. s. ridgwayi* was found on windward Hawai`i Island (Scott *et al*. 1986). Assessment of trends for this widespread population was divided into several regions in this account, and the status of `Elepaio varied somewhat among these regions. Densities within the Hakalau Forest NWR increased between 1987 and 2007 (Tables 5 and 6), and the 2007 abundance within the refuge was 15,347 birds (95% CI = 12,030 – 19,560; Camp, Pratt *et al*. 2009). Trends elsewhere in the North Windward region are not known.

In the Central Windward region of the island, `Elepaio abundance appears to have increased at the drier leeward edge of upper elevation habitat. Densities of 76/$km^2$ were detected in koa-`ōhi`a kipuka forest and pioneer `ōhi`a scrub between 1,500 and 2,100 m during a 1972-1975 survey of the Mauna Loa Strip tract in the Hawai`i Volcanoes NP (Conant 1975). The 1977 and 1979 HFBS of the same area also recorded a density of 76/km^2, and an average of 183/km^2 was observed for surveys between 1986 and 1994 (Table 5; Gorresen *et al*. 2005). Although statistically inconclusive, the stable or positive trend in density may be a result of regenerating forest cover in the area (Table 6).

`Elepaio abundance has apparently diminished in wetter habitats and at lower elevations elsewhere in the Central Windward region. For example, forest habitat at 1,700 m supported an average density of 382/km^2 during a 1972-1975 survey of the Keauhou Ranch and the Kīlauea FR (Conant 1975). The 1977 HFBS and subsequent surveys through 2003 detected lower densities (261 and 222/km^2, respectively; Table 5; Gorresen *et al*. 2005). Although not significantly different, the most recent estimate is 40% less than during the 1970s. More alarmingly, surveys in the adjacent `Ōla`a tract of the Hawai`i Volcanoes NP (1,300 m) have shown `Elepaio densities to have decreased from 164/km^2 in 1977 to zero in 1994 (Gorresen *et al*. 2005).

The mid-elevation `Elepaio population within the East Windward region (i.e., upper Puna) has also undergone a severe decline. Based on a 1973-1974 assessment of sites surveyed in the 1940s, Banko and Banko (1980) determined that `Elepaio had disappeared from much of the mid-elevation (800-1,200 m) habitat within Hawai`i Volcanoes NP. A 1972-1975 survey east of the

Kīlauea Caldera revealed densities of only 43/km^2 in `ōhi`a forest at 1,100 m elevation (Conant 1975). Moreover, `Elepaio densities at 700-900 m decreased from 60/km$^2$ during the 1979 HFBS to only 21/km$^2$ in 1993-1994 within the Kahauale`a NAR and an adjacent area in Hawai`i Volcanoes NP (Tables 5 and 6; Gorresen *et al*. 2005). Turner *et al*. (2006) detected no `Elepaio in 2005 within mid-elevation woodland and shrubland habitats in Hawai`i Volcanoes NP. Reynolds *et al*. (2003) suggested the regional population may be declining and undergoing range contraction.

`Elepaio in the Ka`ū region are currently estimated at 14,621 $\pm$ 4,279 birds (Gorresen *et al*. 2007), and this population is separated from the Central Windward region by about 10 km of degraded woodland and pasture. `Elepaio are relatively uncommon in the region (<100/km$^2$; Table 5), and few detections were made in the southern-most portion of its Ka`ū range in 2005, possibly indicating declining numbers or extirpation in a portion of the range in which the species was moderately widespread in 1976 (Gorresen *et al*. 2007). Densities above 1,500m declined 68% to 34/km^2 in 2003, whereas densities below 1,500m remained stable (Tables 5 and 6). Notably, about two-thirds of the Ka`ū population is predicted to occur below 1,500 m, and `Elepaio continue to be detected down to forest habitats between 700 and 800 m elevation. Despite the apparent northeastward contraction of the species' range, `Elepaio persist at low elevations.

On leeward Hawai`i Island, the subspecies *C. s. sandwichensis* is distributed from southern Kona to the northern slope of Hualālai Volcano, and the population was estimated at 62,782 $\pm$ 1,698 birds (Pratt 1980, Scott *et al*. 1986). However, `Elepaio numbers appear to have declined throughout Kona since the 1978 HFBS (Tables 5 and 6). Surveys in south Kona revealed that densities halved between 1978 and 2003. Densities in the KFU-Hakalau Forest NWR at elevations $\geq$1,500 m declined almost three fold between 1978 and 2001. Densities in the lower part of the refuge (500-1,500 m) were variable and did not show evidence of a decline, and `Elepaio densities are lower below 1,500 m than above 1,500 m. A decrease in the northern Hualālai region within the Pu`u Wa`awa`a Forest Bird Sanctuary is also evident (e.g., declining from 42/km^2 in 1978 to 17/km^2 in 2003), although the trend was not statistically significant.

The subspecies *C. s. bryani* occupies a small 60 to 90-km^2 remnant of dry, subalpine, māmane-naio woodland habitat on the western slope of Mauna Kea. Although statistically inconclusive, surveys conducted in 1983 and between 1997 and 2003 tentatively indicate the population is stable (Tables 5 and 6).

Kaua`i `Elepaio are widely distributed in native forest above 600 m (Scott *et al*. 1986). Reanalysis of the 1981 HFBS yielded a population of 4,150 $\pm$ 3,208 birds within a 25-km^2 area in the eastern Alaka`i Wilderness Preserve, which is comparable to numbers estimated from surveys between 1968 and 1973 (5,000 ± 1,000 [95% CI]; Scott *et al*. 1986). Subsequent surveys of the region indicate that the population has increased nearly three-fold since 1981 (Tables 5 and 6). VanderWerf *et al*. (in prep) estimate `elepaio density on the Alaka`i Plateau in 2008 at 401/km^2, and extrapolation of this density to the 379-km^2 area comprising the species' range yields a population size of 151,865 birds (95% CI = 75,522 – 195,337).

The `Elepaio on O`ahu are listed as endangered (U.S. Fish and Wildlife Service 2006), and the subspecies' declining trend has been evident from Christmas Bird Counts since 1940 (Williams 1987). The current range totals to 55 km^2 (4% of its original area) and is down from about 215 km^2 in 1975 (VanderWerf *et al*. 2001). The subspecies is presently distributed in six large and 11 small populations spanning the Wai`anae and central and southern parts of the Ko`olau mountain ranges (VanderWerf *et al*. 1997, VanderWerf *et al*. 2001). Based on surveys between 1992 and 2000, the island-wide population was estimated at 1,974 individuals, of which 1,768 were breeding birds (VanderWerf *et al*. 2006).

A)

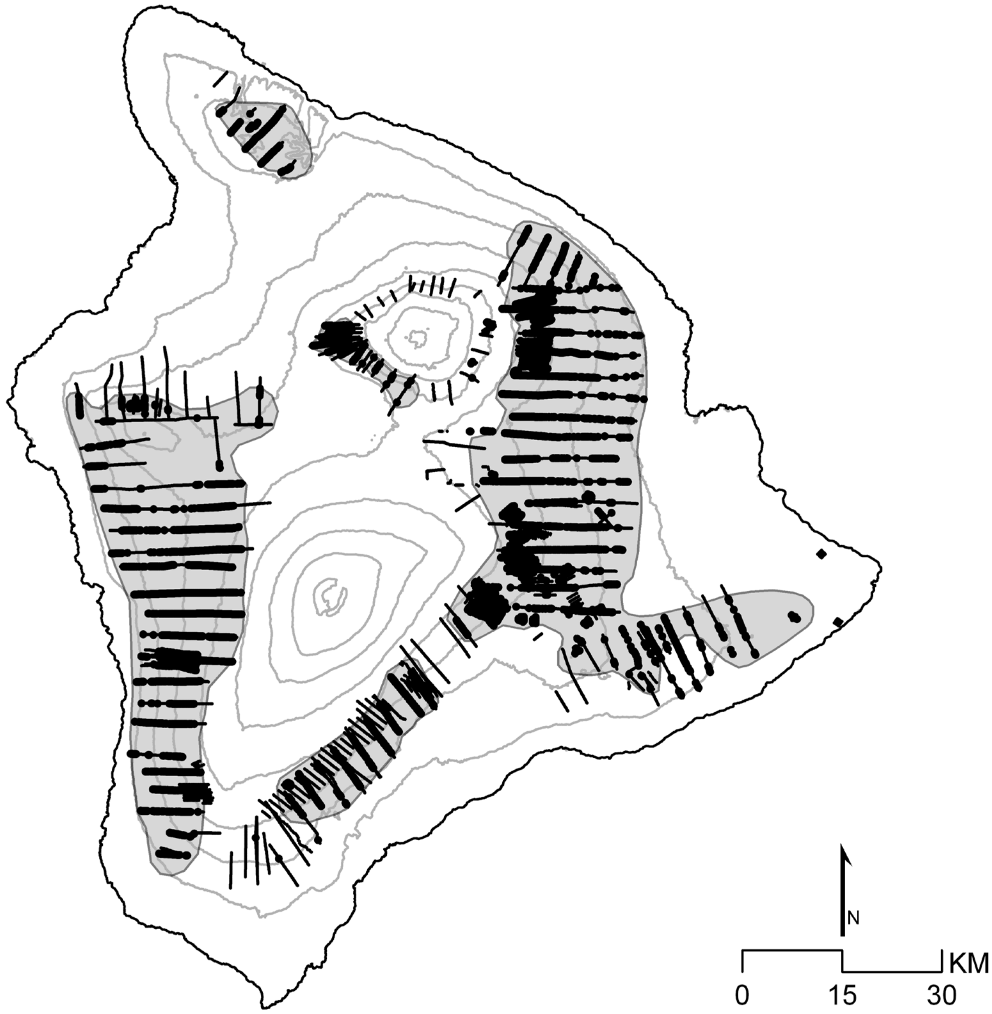
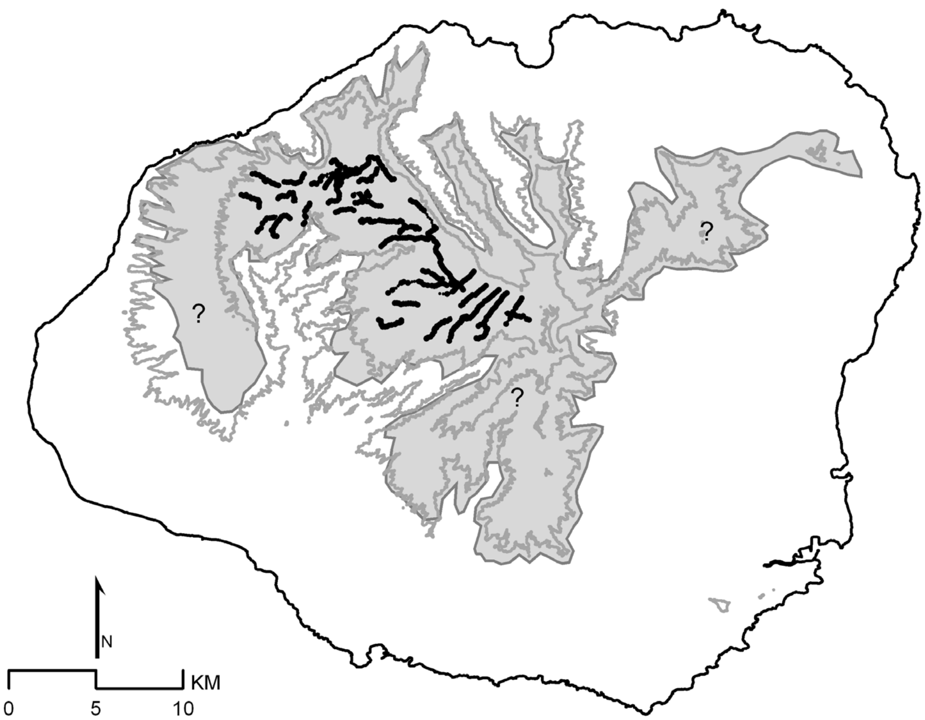


Figure 4. Survey detections (large points), locations with no detections (small points), and current range (shaded) of `Elepaio on (A) Hawai`i, (B) Kaua`i and C) O`ahu Islands. Elevation in 500 m contours. Current range and distribution on O`ahu in part from VanderWerf et al. (2001).

B)



C)

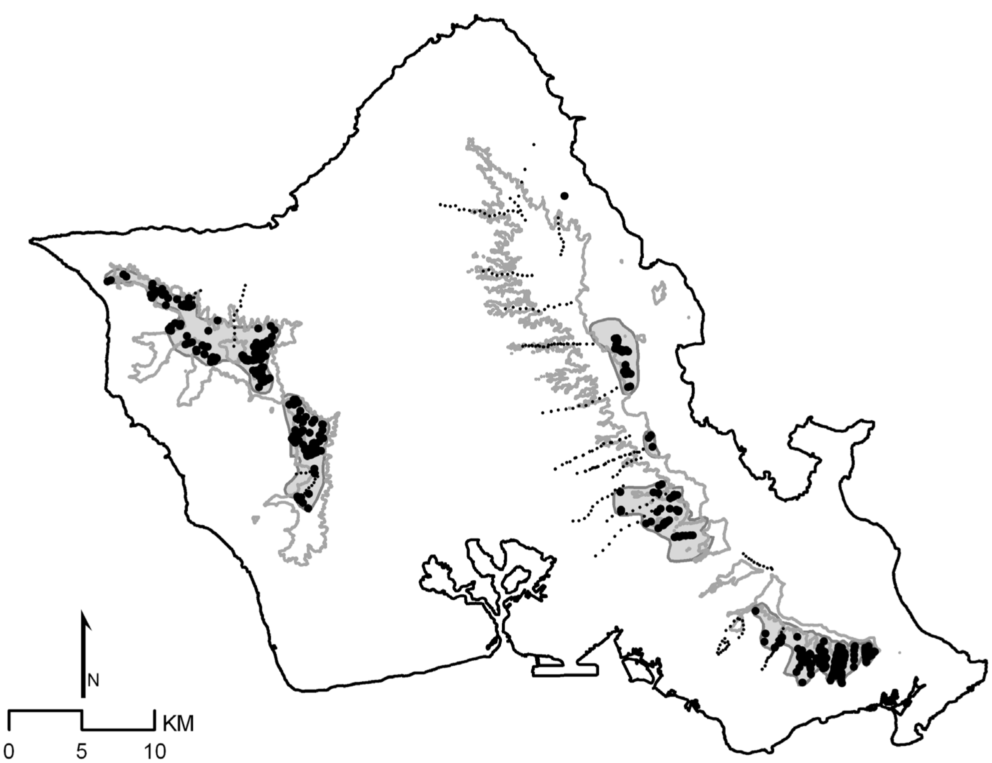


Figure 4 continued.

Table 5. `Elepaio population density (birds/km^2) and standard error (SE) estimates by region and time period. Sampling effort (number of stations sampled) and number of birds used to estimate densities are presented.

Survey	Year	Density	SE	No. Stations	No. Birds
Hawai`i					
Ka`ū >1,500m					
	1976	57.2	11.83	162	39
	1993	37.9	11.58	94	15
	2002	29.4	9.88	88	11
	2005	33.2	7.63	213	30
Ka`ū <1,500m					
	1976	68.2	10.17	234	67
	1993	76.0	14.35	138	44
	2002	69.5	13.13	126	37
Mauna Loa Strip					
	1977-1979	76.3	19.10	79	42
	1986	180.4	35.26	39	37
	1987	189.3	27.01	43	64
	1990	255.1	33.86	65	97
	1991	118.2	33.39	51	30
	1992	169.2	28.58	59	83
	1993	168.1	29.69	61	96
	1994	199.1	36.17	53	102
Kūlani-Keauhou					
	1977	260.9	33.64	80	67
	1995-1998*	229.3	11.23	267	790
	2001-2003	221.9	15.52	214	423
`Ōla`a					
	1977	164.0	30.70	54	30
	1992	2.2	2.24	141	1
	1993	8.9	4.41	142	4
	1994	0.0	0.00	142	0
East Rift					
	1979	59.9	10.64	99	49
	1993-1994	20.5	5.64	158	23
Hakalau Forest NWR					
	1977	364.0	34.55	78	132
	1987	274.8	32.10	194	143
	1988	186.6	17.89	194	238
	1989	209.4	23.08	198	155
	1990	197.2	22.39	197	167
	1991	114.9	14.43	197	106
	1992	264.8	33.81	197	139
	1993	215.1	25.62	194	152
	1994	205.7	21.82	194	158
	1995	271.2	25.14	195	175
	1996	224.6	21.65	198	182
	1997	270.5	29.15	193	125
	1998	197.4	22.60	197	135

Table 5. `Elepaio population density cont.

Survey	Year	Density	SE	No. Stations	No. Birds
	1999	246.0	23.84	195	152
	2000	321.6	34.32	198	150
	2001	305.0	33.03	196	182
	2002	269.5	31.26	195	150
	2003	293.8	30.21	199	174
	2004	261.6	27.10	198	168
	2005	269.7	36.36	165	133
	2006	293.8	36.35	162	154
	2007	205.1	26.04	147	144
Pu`u Wa`awa`a Forest Bird Sanctuary					
	1978	41.7	14.63	37	10
	1990-1991	20.8	6.64	74	17
	1996	15.4	6.46	95	9
	2003	16.9	6.43	77	8
Kona Forest NWR >1,500m					
	1978	456.2	50.88	21	63
	1995	266.1	25.15	72	118
	1999	171.8	19.22	69	73
	2000	141.5	16.82	70	61
	2001	160.1	19.96	70	69
Kona Forest NWR <1,500m					
	1978	117.1	24.36	43	32
	1995	58.2	10.92	106	38
	1999	79.4	10.71	138	68
	2000	75.4	10.07	140	65
South Kona					
	1978	147.3	16.25	135	130
	2003	71.0	10.93	135	59
Mauna Kea					
	1983	11.0	2.29	321	52
	1997	12.6	4.68	260	16
	1998	9.2	3.17	313	14
	1999	19.6	5.60	324	31
	2000	11.1	3.07	314	17
	2001	17.2	4.77	310	26
	2002	10.8	3.24	324	17
	2003	11.8	3.15	312	18
Kaua`i					
	1981	166.0	128.30	140	449
	1989	218.8	30.85	129	161
	1994	177.1	29.40	112	127
	2000	227.6	16.91	139	281
	2005	427.7	49.57	144	131
	2007	455.0	60.14	92	141
	2008	435.4	162.96	150	200

Table 6. Trends in regional `Elepaio densities. The null hypothesis that density in each region has not changed over time was tested with a z-test or, for the Mauna Loa Strip and Mauna Kea regions, with a regression test. Equivalence tests were used to determine if the difference/slope (slope in italics) was within the threshold bounds (-0.0285, 0.0170) of a 50% change in density. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LEL and UEL = Lower and Upper Equivalence Level *p*-values. Trends at Hakalau Forest NWR and Kaua`i were assessed from Bayesian posterior probabilities using a 25% change in densities over 25 years, corresponding to an annual rate of change with a threshold lower bound of $\varphi_l = -0.0199$ and upper bound of $\varphi_u = 0.0093$. Trends were interpreted as increasing, decreasing, stable or increasing, stable or decreasing, stable, or inconclusive.

Survey	Years	Diff/Slope	SE	LCL	UCL	LEL	UEL	LEL *p*	UEL *p*	Result
Hawai`i										
Ka`ū >1,500m										
	29	-23.97	14.08	-47.13	-0.82	-31.72	34.60	1.000	0.775	stable or decreasing
Ka`ū <1,500m										
	26	1.33	16.61	-25.99	28.65	-35.07	35.84	0.986	0.981	stable
Mauna Loa Strip										
	17	*0.03*	0.02	-0.01	0.06	-0.03	0.03	0.995	0.582	inconclusive
Kūlani-Keauhou										
	25	-38.98	37.05	-99.93	21.97	-130.43	130.43	1.000	0.993	stable
`Ōla`a										
	17	-163.96	30.70	-214.46	-113.45	-60.67	50.88	1.000	0.000	decreasing
East Rift										
	15	-39.33	12.05	-59.14	-19.51	-19.91	15.97	1.000	0.026	decreasing
Pu`u Wa`awa`a Forest Bird Sanctuary										
	25	-24.82	15.98	-51.11	1.46	-20.85	20.84	0.998	0.402	inconclusive
Kona Forest NWR >1,500m										
	23	-0.04	0.00	-0.05	-0.04	-0.03	0.03	0.000	1.000	decreasing
Kona Forest NWR <1,500m										
	22	-41.67	26.36	-85.04	1.69	-53.23	49.85	1.000	0.622	inconclusive
South Kona										
	25	-76.38	21.40	-111.59	-41.17	-73.67	73.67	1.000	0.450	decreasing
Mauna Kea										
	20	*0.01*	0.02	-0.02	0.04	-0.03	0.03	0.968	0.826	inconclusive

Survey	$\hat{\beta}$ (95% credible interval)	Declining $P\ \hat{\beta} < \varphi_l$	Negligible P $\varphi_l < \hat{\beta} < \varphi_u$	Increasing $P\ \hat{\beta} > \varphi_u$	Result
Hakalau Forest NWR	*0.0134* (0.0070—0.0197)	0	0.108	0.892	increasing
Kaua`i	*0.0378* (0.0330—0.0427)	0	0	1.000	increasing

Table 7. \`Ōma\`o population density (birds/km^2) and standard error (SE) estimates by region and time period. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented.

Survey	Year	Density	SE	No. Stations	No. Birds
Ka\`ū >1,500m					
	1976	213.4	14.55	162	314
	1993	321.5	19.55	94	276
	2002	411.7	23.92	88	331
	2005	189.1	10.36	213	367
Ka\`ū <1,500m					
	1976	314.7	14.57	234	673
	1993	296.4	16.12	138	373
	2002	239.1	17.04	126	275
Mauna Loa Strip					
	1977-1979	17.2	3.98	79	52
	1986	0.0	0.00	39	0
	1987	0.3	0.34	43	1
	1990	1.4	0.78	65	3
	1991	2.3	1.40	51	4
	1992	3.0	1.67	59	9
	1993	0.7	0.41	61	3
	1994	1.1	0.88	53	4
Kūlani-Keauhou					
	1977	281.8	9.87	95	318
	1995-1998*	279.1	6.22	284	3,345
	2001-2003	202.2	5.83	229	1,435
\`Ōla\`a					
	1977	117.4	14.80	54	79
	1992	20.5	4.28	141	34
	1993	119.6	13.52	142	202
	1994	91.1	11.31	142	152
East Rift					
	1979	139.9	7.90	99	310
	1993-1994	101.2	4.92	158	329
Hakalau Forest NWR					
	1977	113.9	8.87	78	138
	1987	266.9	16.71	194	402
	1988	162.3	13.39	194	469
	1989	144.8	9.14	198	411
	1990	137.5	9.10	197	392
	1991	72.6	5.65	197	236
	1992	159.7	11.16	197	346
	1993	97.0	5.67	194	339
	1994	161.7	8.28	194	395
	1995	132.4	7.79	195	348
	1996	123.1	6.57	198	355
	1997	258.1	15.00	193	358
	1998	146.1	7.19	197	367
	1999	173.2	9.13	195	362

Survey	Year	Density	SE	No. Stations	No. Birds
	2000	196.0	10.94	198	361
	2001	205.3	10.68	196	393
	2002	192.3	11.40	195	370
	2003	170.4	10.97	199	314
	2004	228.5	10.51	198	470
	2005	149.4	10.34	165	306
	2006	237.7	13.88	162	398
	2007	111.6	9.52	147	332

Kāma`o

A frugivorous solitaire, the Kāma`o (*Myadestes myadestinus*) was considered the most common forest bird on Kaua`i during the late 1800s but declined drastically in range and numbers in the early 1900s (Richardson and Bowles 1964). Surveys between 1968 and 1973 yielded a population estimate of 337 ± 243 birds (U.S. Fish and Wildlife Service 1983). By the time of the 1981 HFBS survey, the Kāma`o population had declined to 24 ± 20 (Scott *et al*. 1986). Kāma`o were reliably sighted until 1985, and unconfirmed sightings were reported until 1991 (Pyle 1985a, 1985b, 1993). None has since been detected during intensive searches or surveys, and the species is most likely extinct (Reynolds *et al*. 1997, Foster *et al*. 2004, VanderWerf *et al*. in prep.).

Oloma`o

The Oloma`o (*Myadestes lanaiensis*) was once ubiquitous throughout the mesic and wet forests of Moloka`i, Lāna`i, and possibly Maui (Wakelee and Fancy 1999). It was likely extirpated from Maui by the late 1800s and from Lāna`i by the early 1900s and was presumed extinct on Moloka`i shortly thereafter. Following its rediscovery on Moloka`i in 1963 (Pekelo 1963), there were two or three sightings in 1975 (Scott *et al*. 1977), three detections during the 1980 HFBS survey (Scott *et al*. 1986), and an unconfirmed report in 1988 (Reynolds and Snetsinger 2001). These records have all been from the same small area of dense rain forest above 1,000 m. Surveys in 1988, 1995, and 2004 did not encounter Oloma`o, and although the remote Oloku`i Plateau has remained unsurveyed since the HFBS, the species is likely extinct (Reynolds and Snetsinger 2001).

`Ōma`o

The `Ōma`o (*Myadestes obscurus*) is a locally common Hawaiian solitaire endemic to the island of Hawai`i. The `Ōma`o consumes a mixed diet of fruit and invertebrates (van Riper and Scott 1979, Wakelee and Fancy 1999). Once found throughout much of the island, the species presently occurs only from the Hāmākua region south to Ka`ū and is absent from the Kohala and Kona regions, except in alpine habitat on Mauna Loa (Figure 5; Wakelee and Fancy 1999). The species had a contiguous and sizeable population in the 1970s (Scott *et al*. 1986), and its densities remain stable in the larger upper-elevation tracts of forest habitat in Ka`ū and within the Hakalau Forest NWR. It is worth noting, however, that `Ōma`o densities have decreased in the Central and East Windward regions (eastern Mauna Loa and Kīlauea Volcano) since the 1977 and 1979 HFBS surveys. Nonetheless, the `Ōma`o is one of the few native species that persists at middle elevations and has been observed as low < 250 m in elevation (Reynolds *et al*. 2003, Spiegel *et al*. 2006).

Scott *et al*. (1986) estimated the entire island population at 170,452 ± 3,499 individuals, of which about half were distributed in windward habitats on the eastern slopes of Mauna Kea and Mauna Loa. \`Ōma\`o trends varied among the different regions and study areas. \`Ōma\`o densities within the Hakalau Forest NWR in the North Windward region are generally stable or increasing and have averaged about 168/km^2 since 1987 (Tables 7 and 8; Camp, Pratt *et al*. 2009). Trends are more mixed in the Central Windward region. Year-round surveys at 1,700 m in the Keauhou Ranch and Kīlauea FR from 1972 to 1975 observed a combined density of 345/km^2 (Conant 1975). Surveys in the same area between 1977 and 2003 may indicate a decline in \`Ōma\`o densities from 282 to 202/km^2 (Tables 7 and 8; Gorresen *et al*. 2005).

Surveys along the relatively drier, leeward edge of the Central Windward region indicate that the \`Ōma\`o now occurs where it once had been absent or rare between 1940 and the early 1970s, although at very low numbers (Banko and Banko 1980). Surveys in the Mauna Loa Strip (MLS) tract of Hawai\`i Volcanoes NP between 1940 and 1949 and from 1960 to 1961 recorded no \`Ōma\`o (Dunmire 1962, Banko and Banko 1980). Moreover, a 1972-1975 survey (Conant 1975) at upper elevations (1,500 to 2,100 m) detected only a single \`Ōma\`o in an area described as "koa savanna" (i.e., relict koa stands with few understory fruiting plants as a result of fire and heavy grazing preceding ungulate exclusion of the MLS tract). However, a 1973 survey of the same sites detected a modest number of \`Ōma\`o (10-25 birds; Banko and Banko 1980), and more thorough surveys during the 1977-1979 HFBS detected \`Ōma\`o at low densities (Table 7). Subsequent surveys between 1986 and 1994 detected birds at very low densities (Gorresen *et al*. 2005), and the population appears to have declined since HFBS (Table 8). The \`Ōma\`o trend in the nearby \`Ōla\`a tract of the Hawai\`i Volcanoes NP was inconclusive. Densities at this wet mid-elevation (1,300 m) site fluctuated widely, and are lower than that observed in the Keauhou-Kīlauea area (Tables 7 and 8; Gorresen *et al*. 2005).

Contiguous with the species' range in the Central Windward region, the East Windward population was estimated at 15,509 ± 503 birds (Scott *et al*. 1986). Densities recorded at elevations between 700 and 900 m in the Kahauale\`a NAR and an adjacent area within Hawai\`i Volcanoes NP declined 39% between 1979 and 1993-1994 (Tables 7 and 8; Gorresen *et al*. 2005). It is not apparent however that the \`Ōma\`o distribution has changed in this region. \`Ōma\`o were observed at elevations between 300-500 m during the 1979 HFBS (Camp *et al*. 2002), and recent surveys detected \`Ōma\`o <250 m elevation in northeastern Puna (Reynolds *et al*. 2003, Spiegel *et al*. 2006).

The Ka\`ū population, currently estimated at 82,378 ± 7,493 birds (Gorresen *et al*. 2007), is separated from the Central Windward population by about 10 km of degraded woodland and pasture. \`Ōma\`o are common in the Ka\`ū region, ranging in density from 200 to 400/km^2 both above and below 1,500 m, and trends appear stable (Tables 7 and 8). Remarkably, two-thirds of the Ka\`ū population is estimated to occur at 700-1,500 m, and \`Ōma\`o remain fairly abundant down to the lower reaches of native forest at about 700 m (Gorresen *et al*. 2007).

Once common in Kona (Wakelee and Fancy 1999), the \`Ōma\`o is now extirpated from forests in the region, and the 1978 HFBS recorded only four detections in subalpine \`ōhi\`a shrubland. Scott *et al*. (1986) estimated a regional population of 732 ± 55 birds; however, most of these birds were distributed contiguously with the population located in southern Ka\`ū and were not located in Kona. Two birds seen in 2006 at the top of Manukā NAR (1,650 m) (F. Duvall, DOFAW, pers. comm.) could represent immigration from the Ka\`ū population. A 1996 reintroduction and translocation program released 41 \`Ōma\`o in the Pu\`u Wa\`awa\`a Forest Bird Sanctuary (Fancy *et al*. 2001); however, only four birds were detected in the area in 1999, and no \`Ōma\`o were observed since 2003.

The population on Kohala Mountain was reported as extirpated by van Riper and Scott (1979) and Scott *et al*. (1986). There have been no surveys in the region since 1979 to determine if the `Ōma`o have recolonized the area, and recently NAR staff have not detected `Ōma`o on Kohala Mountain (N. Agorastos and L. Hadway, pers. comm.).

Puaiohi

The Puaiohi (*Myadestes palmeri*) is an endangered solitaire endemic to the Alaka`i Plateau on the island of Kaua`i. Predominantly frugivorous, this secretive, cliffnesting species occupies high-elevation (1,000–1,280 m) riparian habitats of native rain forests dominated by `ōhi`a and a dense understory of mostly native shrubs and ferns. About 75% of the breeding population is concentrated within an area of about 20 km2 (Snetsinger *et al*. 1999). The early naturalists considered Puaiohi very rare (Munro 1960), and by 1970s the species was thought to be nearly extinct (Banko 1980). The population was estimated at 177 ± 96 from surveys conducted between 1968 and 1973 (U.S. Fish and Wildlife Service 1983). Scott *et al*. (1986) estimated that there were 97 ± 129 individuals within their 25 km2 study area in the eastern Alaka`i Wilderness Preserve. Intensive searches in 1995–1996 identified 145 ± 19 individuals from six of eight river drainages surveyed (Reynolds *et al*. 1997). As a result of more extensive targeted searches from 1999 to 2004, the entire population is currently thought to number 300–500 individuals (Figure 6; Snetsinger *et al*. 1999, Woodworth *et al*. 2009), but the population trend is unknown.

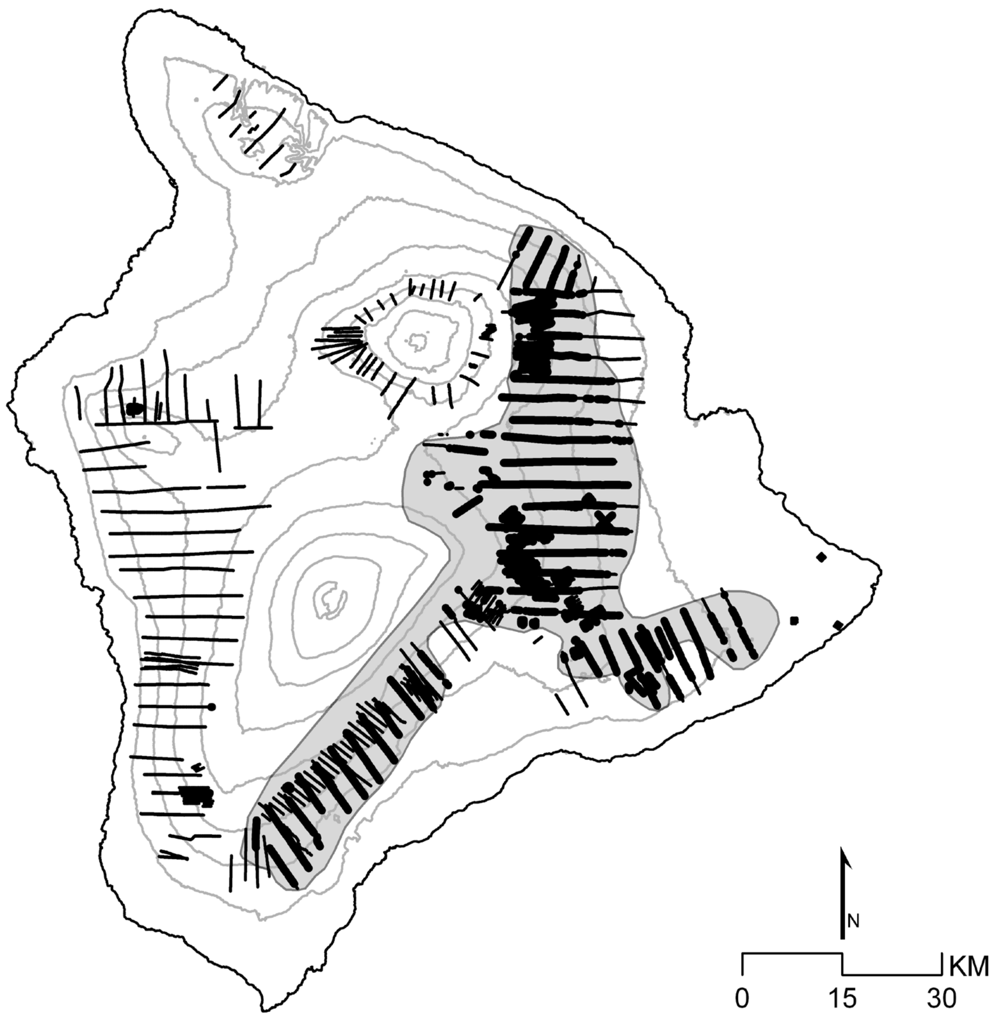


Figure 5. Survey detections (large points), locations with no detections (small points), and current range (shaded) of `Ōma`o on Hawai`i Island. Elevation in 500 m contours.

Table 8. Trends in regional \`Ōma\`o densities. The null hypothesis that density in each region has not changed over time was tested with a z-test or, for the Mauna Loa Strip region, with a regression test. Equivalence tests were used to determine if the difference/slope (slope in italics) was within the threshold bounds (-0.0285, 0.0170) of a 50% change in density. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LEL and UEL = Lower and Upper Equivalence Level *p*-values. Trends at Hakalau Forest NWR were assessed from Bayesian posterior probabilities using a 25% change in densities over 25 years, corresponding to an annual rate of change with a threshold lower bound of $\varphi_l = -0.0199$ and upper bound of $\varphi_u = 0.0093$. Trends were interpreted as increasing, decreasing, stable or increasing, stable or decreasing, stable, or inconclusive.

Survey	Years	Diff/Slope	SE	LCL	UCL	LEL	UEL	LEL *p*	UEL *p*	Result
\`Ōma\`o										
Hawai\`i										
Ka\`ū >1,500m										
	29	-24.30	17.87	-53.69	5.09	-118.34	129.07	1.000	1.000	stable
Ka\`ū <1,500m										
	26	-75.65	22.42	-112.54	-38.76	-161.83	165.38	1.000	1.000	stable or decreasing
Mauna Loa Strip										
	17	*-0.16*	0.02	-0.18	-0.13	-0.03	0.03	0.000	1.000	decreasing
Kūlani-Keauhou										
	25	-79.65	11.46	-98.51	-60.80	-140.91	140.90	1.000	1.000	stable or decreasing
\`Ōla\`a										
	17	-26.32	18.62	-56.96	4.31	-43.46	36.45	1.000	0.707	inconclusive
East Rift										
	15	-38.71	9.31	-54.02	-23.40	-46.53	37.33	1.000	0.441	stable or decreasing

Survey	$\hat{\beta}$ (95% credible interval)	Declining $P(\hat{\beta} < \varphi_l)$	Negligible $P(\varphi_l < \hat{\beta} < \varphi_u)$	Increasing $P(\hat{\beta} > \varphi_u)$	Result
Hakalau Forest NWR	0.0098 (0.0057—0.0139)	0	0.411	0.589	stable or increasing

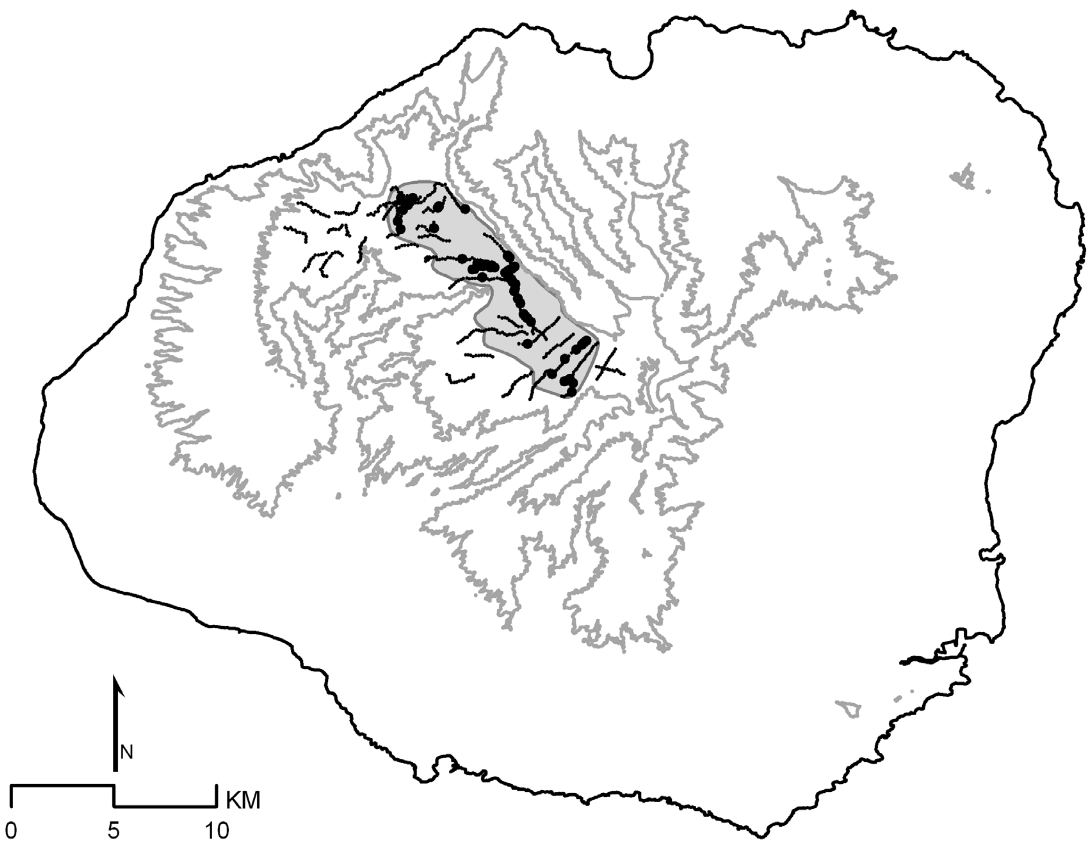


Figure 6. Survey detections (large points), locations with no detections (small points), and current range (shaded) of Puaiohi on Kaua`i Island. Elevation in 500 m contours.

`Ō`ū

The `Ō`ū (*Psittirostra psittacea*) is a finch-billed honeycreeper once common and widespread in the main Hawaiian islands (Snetsinger *et al*. 1998). Primarily frugivorous, the species used a wide range of habitats but was most abundant in mid-elevation `ōhi`a forests with `ie`ie vines (*Freycinetia arborea*), from which it sought much of its food. The `Ō`ū was extirpated from O`ahu, Moloka`i, and Maui by the early 1900s and from Lāna`i by the 1930s (Banko 1986). With only 33 detections, the `Ō`ū was the rarest species detected on Hawai`i Island during the HFBS survey (Scott *et al*. 1986). At that time, the population was reduced to an estimated 394 ± 166 birds, mostly restricted to the forested slopes of northeastern Mauna Loa. Despite occasional unconfirmed reports, subsequent surveys and intensive rare bird searches failed to detect `Ō`ū, and the last confirmed sighting was made in the `Ōla`a Forest Tract of Hawai`i Volcanoes NP in 1987 (Snetsinger *et al*. 1998, Reynolds and Snetsinger 2001).

Already imperiled on Kaua`i by the 1960s (Richardson and Bowles 1964), the `Ō`ū was found by an island-wide survey between 1968 and 1973 to be restricted to the Alaka`i Plateau and to number 62 ± 41 birds (U.S. Fish and Wildlife Service 1983). The 1981 HFBS survey detected only three birds and confirmed the species' catastrophic decline (Scott *et al*. 1986). Two `Ō`ū were seen on Kaua`i in 1989 prior to the extensive habitat loss caused by Hurricane Iniki in 1992

(Pyle 1989). No confirmed sightings have been made since, and the species is probably extinct (Reynolds and Snetsinger 2001, Foster *et al*. 2004, VanderWerf *et al*. in prep.).

Palila

The Palila (*Loxioides bailleui*) is an endangered, seed-eating, finch-billed honeycreeper dependent on māmane for all aspects of its biology (van Riper *et al*. 1978, Lindsey *et al*. 1995, Banko *et al*. 2009). Palila were historically distributed on Hawai`i Island from 1,200 to 3,000 m on Mauna Kea, Hualālai, and western Mauna Loa. However, by 1975 the species was restricted to Mauna Kea on only 10% of its former range and was estimated at 1,595 birds (95% CI = 1,146 – 2,049; van Riper *et al*. 1978). Palila are now found only above 2,000 m in 136-km^2 of subalpine and dry-forests fringing Mauna Kea (Figure 7; Banko *et al*. 2002). Of this area, 30-km^2 on the western and southwestern slope harbors 96% of the total population. Annual population estimates for the period between 1980 and 2007 have varied widely for reasons that may be partly attributable to habitat changes, drought, predators, insect competitors, annual variation in pod production (Banko *et al*. 2009), as well as measurement error (Table 9; Johnson *et al*. 2006). The overall, long-term trend indicates Palila densities have marginally increased since 1980 (Table 9), and the population size peaked in 1996 at 6,878 birds (95% CI = 6,184 – 7,573). However, Leonard *et al*. (2008) identified a recent short-term declining trajectory, between 2003 and 2007, that may indicate a downward shift in the population trend. Moreover, Jacobi *et al*. (1996) detected a decreasing number of birds at the margins of the species' range on eastern Mauna Kea which suggests that the species' range is contracting. Subsequent surveys confirm that the species is now absent from the eastern slope of Mauna Kea (USGS-PIERC, unpubl. data).

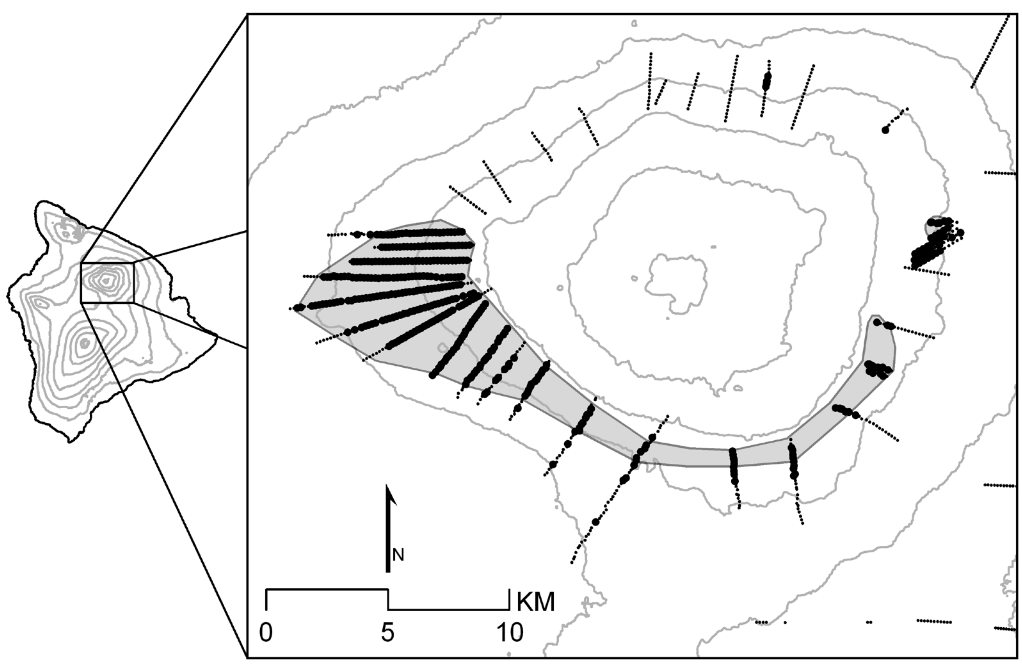


Figure 7. Survey detections (large points), locations with no detections (small points), and current range (shaded) of Palila on Hawai`i Island. Elevation in 500 m contours.

Table 9. Palila population density (birds/km^2; panel A) and standard error (SE) estimates by year. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented. Density and SE values derived from surveys of original 15 transects (transects 101-115). Trends in Palila densities (panel B). Palila densities are for the core population only. The null hypothesis that density in each region has not changed over time was tested with a regression test. Equivalence tests were used to determine if the slope was within the threshold bounds (-0.0285, 0.0170) of a 50% change in density. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LEL and UEL = Lower and Upper Equivalence Level *p*-values. Trends were interpreted as increasing, decreasing, stable or increasing, stable or decreasing, stable, or inconclusive.

A)

Survey	Year	Density	SE	No. Stations	No. Birds
Mauna Kea					
	1980	48.3	5.69	321	136
	1981	81.9	4.80	312	225
	1982	45.7	5.83	326	138
	1983	30.5	6.80	321	189
	1984	36.4	6.39	328	164
	1985	25.7	7.13	325	108
	1986	35.6	6.45	321	195
	1987	50.9	5.55	329	283
	1988	66.6	4.96	323	330
	1989	43.6	5.95	324	148
	1990	74.2	4.82	326	344
	1991	36.1	6.41	292	21
	1992	20.8	7.50	321	39
	1993	47.1	5.75	222	100
	1994	42.5	6.01	293	96
	1995	34.1	6.55	242	67
	1996	106.8	5.50	134	141
	1997	53.0	5.45	260	96
	1998	83.6	9.21	355	330
	1999	92.6	8.86	414	390
	2000	48.2	5.18	418	235
	2001	86.2	8.92	414	350
	2002	79.1	7.38	416	339
	2003	103.0	9.48	404	458
	2004	86.9	7.90	397	380
	2005	82.9	8.45	402	338
	2006	71.4	7.37	386	304
	2007	60.0	6.37	387	236

Table 9. Palila population density (birds/km^2; panel A) and standard error (SE) estimates by year cont.

B)

Survey	Years	Slope	SE	LCL	UCL	LEL	UEL	LEL *p*	UEL *p*	Result
Palila										
Mauna Kea	27	0.03	0.01	0.02	0.04	-0.03	0.03	1.000	0.389	Increasing[1]

[1] However, Leonard *et al*. (2008) identified a recent short-term declining trajectory, between 2003 and 2007, that may indicate a shift in the population trend.

Maui Parrotbill

The Maui Parrotbill (*Pseudonestor xanthophrys*) is an endangered Hawaiian honeycreeper with a massive parrot-like beak which it uses to bite open bark and wood in pursuit of insect prey (Simon *et al*. 1997). Decreasing densities indicate that the parrotbill population may be in decline, although statistical analyses were inconclusive. The parrotbill is now restricted to a single population occupying 50 km^2 of rainforest above 1,200 m on Haleakalā Volcano (Figure 8; Simon *et al*. 1997). The current range may be constrained to sub-optimal habitat because of the relative scarcity of koa, a favored foraging substrate (Simon *et al*. 1997, Stein 2007). Scott *et al*. (1986) estimated the population at 502 ± 116 individuals over the species' entire range. Subsequent surveys indicate that Maui Parrotbill roughly persists over the same area identified by Scott et al. (1986) but a small, upslope contraction of 100 m has probably occurred (from 1,100 m up to 1,200 m elevation). A study from 1995-1997 at Hanawī, a site located in the core of the species' range, showed that Maui Parrotbill occurred at approximately the same density (40/km^2) as in 1980 (Simon *et al*. 2002). Range-wide surveys between 1980 and 2001 yielded very similar densities (17/km^2 and 12/km^2; Table 10), although the trend assessment was statistically inconclusive (Table 11). Extrapolation of the 2001 density to the species' 50 km^2 range produces a population estimate of 590 ± 208 birds.

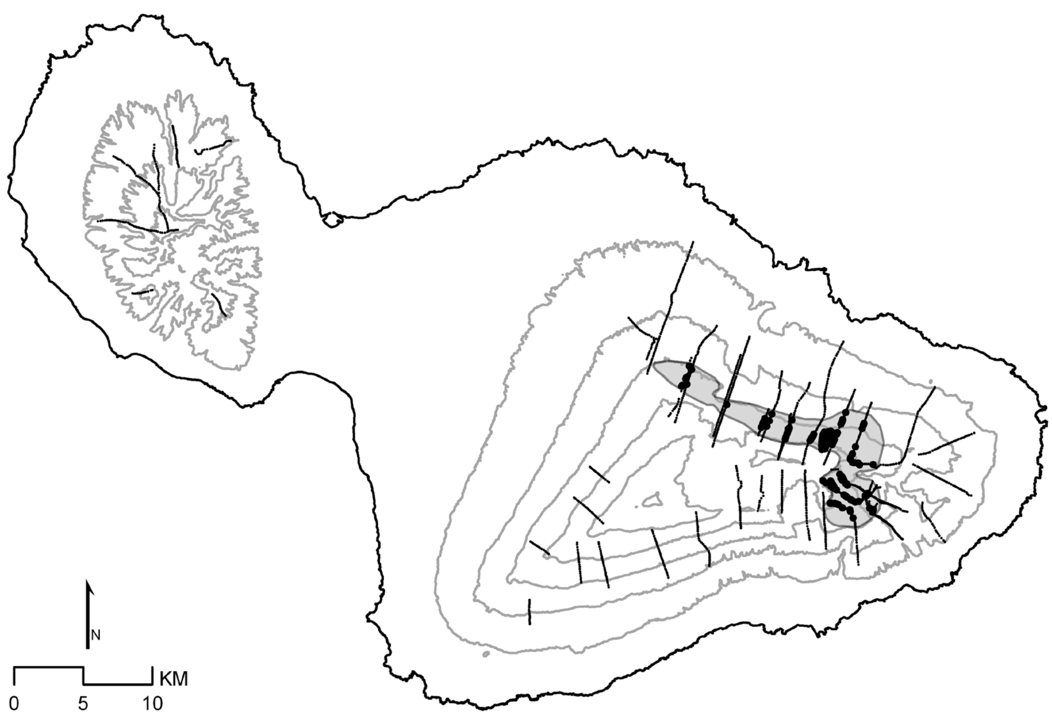


Figure 8. Survey detections (large points), locations with no detections (small points), and current range (shaded) of Maui Parrotbill on Maui Island. Elevation in 500 m contours.

Table 10. Maui Parrotbill, Maui `Alauahio, and `Akohekohe population density (birds/km^2) and standard error (SE) estimates by time period. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented.

Species	Year	Density	SE	No. Stations	No. Birds
Maui Parrotbill					
	1980	17.2	4.16	306	22
	1992-1996	17.0	4.24	497	47
	1997-2001	11.8	2.55	258	29
Maui `Alauahio					
	1980	730.6	64.43	306	264
	1992-1996	1483.5	76.51	497	1,099
	1997-2001	1166.9	73.54	258	838
`Ākohekohe					
	1980	80.8	10.11	306	157
	1992-1996	98.4	11.33	497	411
	1997-2001	116.3	13.60	258	382

Hawai`i `Amakihi

The `amakihi are a closely related group of endemic Hawaiian honeycreepers common to all the main islands. Omnivorous and generalized in foraging behavior, `amakihi are found in a wide range of native and non-native habitat types, although densities are highest in drier `ōhi`a, koa-`ōhi`a, and māmane-naio forests above 1,500 m (Figure 9; Scott *et al*. 1986, Lindsey *et al*. 1998). The Hawai`i `Amakihi (*Hemignathus virens*) occurs on Hawai`i, Maui, and Moloka`i, and formerly on Lāna`i island; two other `amakihi species are endemic to O`ahu and Kaua`i (see separate accounts below). Overall, Hawai`i `Amakihi densities are stable to increasing throughout its range. Only densities in one region were in decline on Hawai`i Island—Central Windward; however, recent low-elevation (<250 m) detections on Hawai`i, Maui, and Moloka`i islands may indicate evolving resistance to malaria (Atkinson and LaPointe 2009) and a larger range than previously realized.

Hawai`i `Amakihi occur in most forested areas of Hawai`i Island, including the Kona, Ka`ū, Mauna Kea, Kohala, and windward regions (Scott *et al*. 1986). With the exception perhaps of the Kohala Mountain population, the species is distributed as a single, relatively contiguous population. Scott *et al*. (1986) estimated an island-wide population of 869,868 ± 26,771 birds.

The leeward Hawai`i region (i.e., Kona and Hualālai) contained the largest number of `Amakihi, estimated at 348,879 ± 5,324 individuals (Scott *et al*. 1986). `Amakihi in this region has exhibited variable densities during the past several decades (Table 12). `Amakihi trends both above and below 1,500 m in the KFU-Hakalau Forest NWR were statistically inconclusive although densities appear to have increased slightly (Table 13). `Amakihi numbers in the Pu`u Wa`awa`a Forest Bird Sanctuary have significantly increased 57% since 1978 (Table 13). Surveys in south Kona indicate that the `amakihi is stable in this area (Table 13).

Table 11. Trends in regional Maui Parrotbill, Maui `Alauahio, and `Ākohekohe densities. The null hypothesis that density in each region has not changed over time was tested with a z-test. Equivalence tests were used to determine if the difference was within the threshold bounds (-0.0285, 0.0170) of a 50% change in density. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LEL and UEL = Lower and Upper Equivalence Level *p*-values. Trends were interpreted as increasing, decreasing, stable or increasing, stable or decreasing, stable, or inconclusive.

Species	Years	Diff	SE	LCL	UCL	LEL	UEL	LEL *p*	UEL *p*	Result
Maui Parrotbill	19	-5.33	4.88	-13.36	2.70	-6.95	6.10	0.994	0.562	inconclusive
Maui `Alauahio	19	436.30	97.77	275.46	597.13	-296.16	259.63	1.000	0.035	increasing
`Ākohekohe	19	35.52	16.95	7.64	63.39	-32.75	28.71	1.000	0.344	increasing

The `amakihi abundance for an 870-km$^2$ area encompassing the island's North Windward and Central Windward regions was estimated at 172,741 $\pm$ 4,920 (Scott *et al*. 1986). Within the Hakalau Forest NWR, density has increased almost three fold since 1977 (Table 12). `Amakihi density from 1987 to 2007 has been stable (Table 13), and the 2007 refuge population was 27,206 birds (95% CI = 22,490 – 32,931; Camp, Pratt *et al*. 2009).

A stable trend in `amakihi numbers was also observed in the high elevation forests of the Central Windward region (Tables 12 and 13; Gorresen *et al*. 2005). A 1972-1975 survey of upper elevation (1,700 m) forest habitat in the Keauhou Ranch and the Kīlauea FR recorded an average density of 243/km^2 (Conant 1975). Surveys in the same region between 1977 and 2003 indicate a stable population and densities have increased to 401/km^2.

`Amakihi abundance in the relatively drier leeward edge of the Central Windward region is somewhat higher than in wet forest. A 1972-1975 survey of the Mauna Loa Strip in the Hawai`i Volcanoes NP noted densities of 520/km^2 in koa-`ōhi`a kipuka forest and pioneer `ōhi`a scrub between 1,500 and 2,100 m (Conant 1975). The 1977 and 1979 HFBS in the same area detected `amakihi at a density of 652/km^2, and surveys between 1986 and 1994 revealed variable but somewhat lower densities (Table 12; Gorresen *et al*. 2005). The population appears stable since the 1970s (Table 13).

Sustained by the prevalence of host reservoirs and the mosquito vector, avian malaria appears to most adversely affect `amakihi in mid-elevation wet forest (Woodworth *et al*. 2005), particularly in areas near residential–agricultural landscapes (Reiter and LaPointe 2007). Surveys at 1,300 m in the `Ōla`a tract of the Hawai`i Volcanoes NP have shown `amakihi densities to have decreased to zero or near zero by 1992-1994 (Tables 12 and 13; Gorresen *et al*. 2005). Although trends were inconclusive, areas of very low abundance also appear to extend throughout the neighboring East Windward region. For instance, the 1979 HFBS and surveys from 1993 to 1994 at 700-900 m in the Kahauale`a NAR and an adjacent area within Hawai`i Volcanoes NP recorded very low densities of `amakihi (<five/km$^2$). In contrast, a nearby survey in 2005 (Turner *et al*. 2006) observed `amakihi at somewhat higher densities in drier habitats less likely to support mosquitoes (woodland: 48/km^2 and shrubland: seven/km^2). Moreover, `amakihi numbers appear to be rebounding in the wet lowland forest (<300 m elevation) of the East Windward region, specifically northeast Puna District (Spiegel *et al*. 2006). These individuals appear to have survived prior malaria infections, as evidenced by resident breeding birds that harbor avian malaria, and may indicate evolving resistance and the recolonization of native habitats (Jarvi *et al*. 2001, Woodworth *et al*. 2005). Forest bird surveys have not been conducted in the mid-elevation portion of the East Windward region (300-1,000 m) since the mid-1990s; however, `amakihi presence was documented throughout much of this area during a 2007 `Io survey (Gorresen *et al*. 2008; USGS-PIERC, unpubl. data).

The `amakihi in Ka`ū is contiguous with birds in the Central Windward and southern Kona regions, and the Ka`ū abundance is estimated at 154,749 $\pm$ 9,393 birds (Gorresen *et al*. 2007). Densities above 1,500 m in 2005 were lower than in 1976 (Tables 12 and 13), but may reflect the species' highly variable annual densities (e.g., `amakihi trends in Hakalau Forest NWR; Camp, Pratt *et al*. 2009). Notably, as much as a third of the birds were predicted to occur below 1,500 m (Gorresen *et al*. 2007). Although less abundant than at upper elevations, densities below 1,500 m are fairly high (e.g., 260/km^2 in 2002) and stable, and `amakihi occurrence extends down to about 700 m in this region.

On Mauna Kea, subalpine māmane-naio woodland supported an estimated 87,624 ± 3,777 `amakihi (Scott *et al*. 1986). Although the overall mean density from 1997 to 2003 was greater than that observed during the 1983 HFBS, the upward trend was not conclusive and the regional population appears stable (Tables 12 and 13).

The disjunct `amakihi population on Kohala Mountain was estimated at 29,175 ± 7,377 individuals, and densities >600/km$^2$ were observed in `ōhi`a and exotic forest (Scott *et al*. 1986). The area has not been surveyed since and the population status and trend is not known. The Kohala `amakihi population remains fairly common above 1,200 m (N. Agorastos and L. Hadway, pers. comm.).

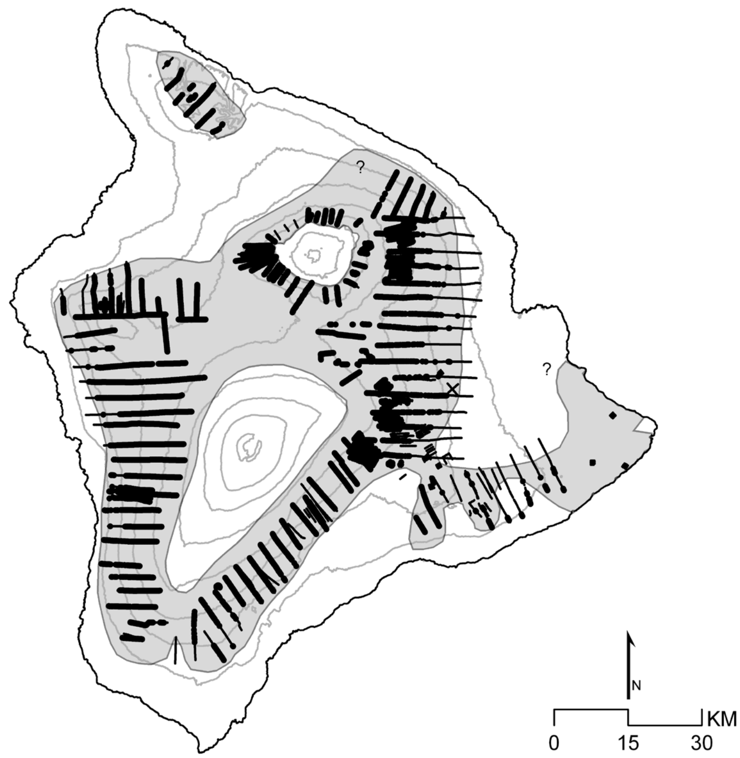
Hawai`i `Amakihi are distributed in two disjunct populations on west and east Maui and were estimated to number 2,762 ± 421 and 43,930 ± 1,725 birds, respectively (Scott *et al*. 1986). The west Maui population occurs in 36-km^2 of habitat centered on northwest Pu`u Kukui and is about 30 km distant from the eastern population. Surveys have detected increasing densities although the trend was inconclusive (Tables 12 and 13). The eastern population is distributed in a 340-km^2 area spanning the wet windward and dry southern slopes of Haleakalā Volcano, with seasonal occurrences in Haleakalā Crater during periods of māmane flowering (Scott *et al*. 1986). Densities in east Maui have increased more than two fold and number 1,007/km^2 (Tables 12 and 13).

The Hawai`i `Amakihi range on Moloka`i is limited to a 37-km$^2$ area in the upper Kamakou range, the adjacent Pu`u Ali`i and Oloku`i plateaus, and Pelekunu watershed. The population was estimated at 1,834 ± 363 based on the 1979 HFBS (Scott *et al*. 1986). Although Lindsey *et al*. (1998) believed that the population may be declining on Moloka`i; `amakihi densities have increased, yet trends were inconclusive (Tables 12 and 13), and extrapolation of the 1995 density (35/km^2) to the species' 37-km^2 range produces a population estimate of 1,291 ± 427 birds.

O`ahu `Amakihi

O`ahu `Amakihi (*Hemignathus flavus*) are distributed as two disjunct populations in the Wai`anae and Ko`olau mountain ranges (Lindsey *et al*. 1998), and densities may be increasing. Honolulu Christmas bird counts between 1958 and 1985 showed a decline in numbers (Williams 1987). However, recent surveys have detected `amakihi at elevations lower than previously noted, and this expansion may be a sign of resistance to avian malaria, an increasing population trend, and reoccupation of low elevation, non-native habitat (Conry 1991, VanderWerf 1997, Lindsey *et al*. 1998, Shehata *et al*. 2001). A 1991 survey recorded the species at moderate densities and noted detections as low as 100 m in the Ko`olau range (Figure 9; Table 12). `Amakihi were absent from the northern Wai`anae Mountains but were found in the southern part of the range above 500 m. Extrapolation of the observed densities to occupied habitat on the Ko`olau range and south Wai`anae region yields estimated populations of about 49,500 ± 4,400 and 2,300 ± 900, respectively.

A)



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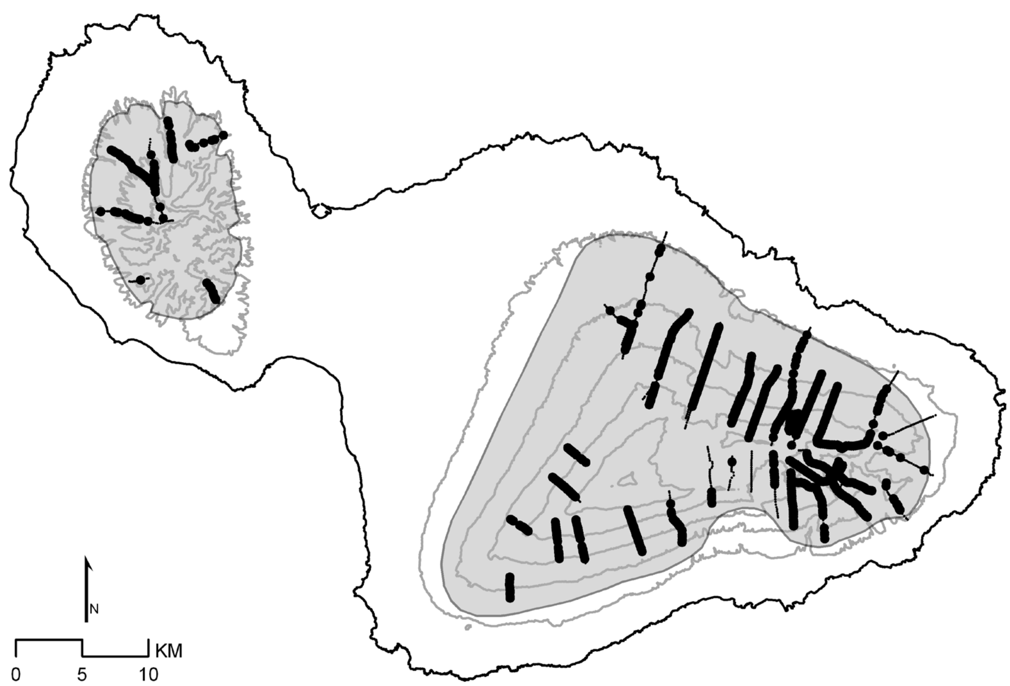
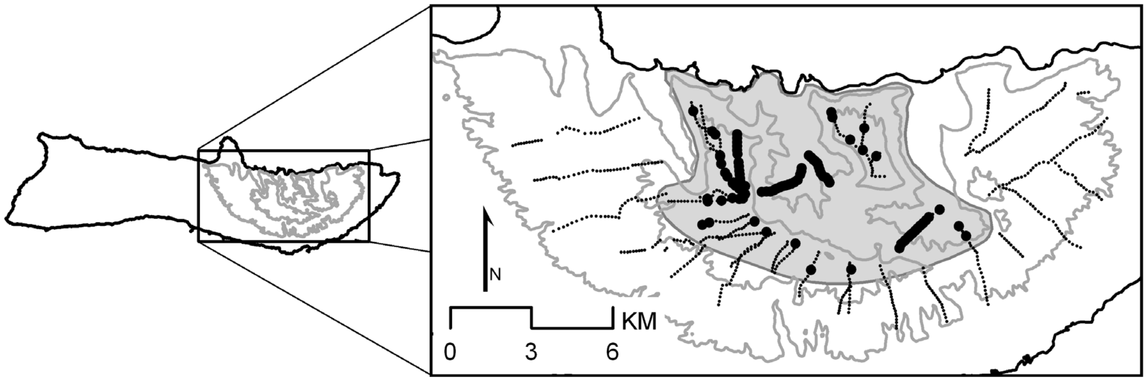


Figure 9. Survey detections (large points), locations with no detections (small points), and current range (shaded) of Hawai`i `Amakihi on (A) Hawai`i, (B) Maui, and (C) Moloka`i Islands, and (D) O`ahu `Amakihi and (E) Kaua`i `Amakihi. Elevation in 500 m contours.

C)



D)

Figure 9. Survey detections (large points), locations with no detections (small points), and current range (shaded) of Hawai`i `Amakihi continued.

Table 12. Hawai`i `Amakihi, O`ahu `Amakihi, and Kaua`i `Amakihi population density (birds/km^2) and standard error (SE) estimates by region and time period. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented.

Survey	Year	Density	SE	No. Stations	No. Birds
Hawai`i `Amakihi—Hawai`i Island					
Ka`ū >1,500m					
	1976	424.4	37.00	162	291
	1993	510.6	36.76	94	203
	2002	577.4	44.35	88	215
	2005	311.6	22.53	213	280
Ka`ū <1,500m					
	1976	294.2	23.83	234	291
	1993	178.3	23.00	138	104
	2002	259.9	33.63	126	138
Mauna Loa Strip					
	1977-1979	651.9	65.20	79	470
	1986	403.8	40.22	39	105
	1987	389.2	38.07	43	186
	1990	435.4	37.20	65	210
	1991	450.4	50.05	51	151
	1992	528.6	41.13	59	260
	1993	328.0	49.39	61	161
	1994	417.7	50.60	53	186
Kūlani-Keauhou					
	1977	358.0	27.72	95	148
	1995-1998*	322.3	13.83	284	1,483
	2001-2003	401.1	18.69	229	1,081
`Ōla`a					
	1977	21.5	11.09	54	5
	1992	0.0	0.00	141	0
	1993	0.0	0.00	142	0
	1994	1.6	1.63	142	1
East Rift					
	1979	1.5	1.08	99	2
	1993-1994	4.3	2.29	158	9
Hakalau Forest NWR					
	1977	369.7	42.45	78	125
	1987	1439.4	83.63	194	551
	1988	454.3	33.30	194	585
	1989	1026.6	54.72	198	661
	1990	1243.2	68.13	197	838
	1991	858.0	38.52	197	805
	1992	1491.2	72.02	197	848
	1993	1166.8	52.27	194	916
	1994	710.3	33.38	194	626
	1995	824.6	41.81	195	640
	1996	1523.7	71.16	198	1,109
	1997	1466.8	70.41	193	737

Table 12. Hawai`i `Amakihi, O`ahu `Amakihi, and Kaua`i `Amakihi population density cont.

Survey	Year	Density	SE	No. Stations	No. Birds
	1998	1177.3	57.33	197	818
	1999	878.2	55.68	195	712
	2000	1272.4	66.55	198	601
	2001	1297.7	56.19	196	807
	2002	1163.3	50.25	195	821
	2003	1260.3	73.10	199	743
	2004	1168.5	62.28	198	738
	2005	990.4	59.52	165	845
	2006	1090.4	61.50	162	584
	2007	358.6	28.94	147	598
Pu`u Wa`awa`a Forest Bird Sanctuary					
	1978	939.4	77.29	37	159
	1990-1991	2374.3	60.38	74	1,060
	1996	2107.6	65.98	95	841
	2003	2189.1	77.12	77	708
Kona Forest NWR >1,500 m					
	1978	578.2	74.51	21	55
	1995	1795.5	69.84	72	543
	1999	1463.0	67.80	69	424
	2000	1234.6	47.04	70	363
	2001	1098.6	58.60	70	323
Kona Forest NWR <1,500 m					
	1978	160.6	32.40	43	29
	1995	444.7	53.12	106	198
	1999	217.4	28.82	138	129
	2000	197.3	25.99	140	116
South Kona					
	1978	703.7	46.34	135	414
	2003	768.9	61.98	135	436
Mauna Kea					
	1983	382.0	18.47	321	1,228
	1997	1541.7	49.55	260	1,625
	1998	1502.1	44.78	313	1,912
	1999	1255.5	46.39	324	1,676
	2000	991.8	31.60	314	1,291
	2001	1194.4	42.11	310	1,501
	2002	1488.4	44.81	324	1,955
	2003	935.3	28.70	312	1,183
Hawai`i `Amakihi—Maui Island					
East	1980	358.3	23.15	306	305
	1992-1996	1133.8	37.23	497	1,908
	1997-2001	1007.3	37.98	258	1,627
West					
	1980	88.9	16.95	162	44
	1997	130.0	25.37	156	62
Hawai`i `Amakihi—Moloka`i Island					
	1979	19.6	8.54	87	5

Table 12. Hawai`i `Amakihi, O`ahu `Amakihi, and Kaua`i `Amakihi population density cont.

	Density	SE	No. Stations	No. Birds
1988-1989	40.2	10.47	120	26
	34.9	11.54	122	13
O`ahu `Amakihi				
Ko`olau Range				
	206.1	18.39	200	259
North Wai`anae Range				
	-	-	21	0
South Wai`anae Range				
	208.9	83.14	10	13
Kaua`i `Amakihi				
	17.3	2.63	140	139
	109.8	16.58	129	161
	238.0	51.02	112	156
	146.6	14.37	139	216
	159.1	24.83	144	93
	137.5	24.07	92	58
	132.0	19.91	150	85

Kaua`i `Amakihi

Kaua`i `Amakihi (*Hemignathus kauaiensis*) were distributed throughout forests above 600 m, including a population in the Makaleha Mountains (Figure 9; Scott *et al*. 1986). Recent surveys reveal that the population has increased, although it is unknown if their range has changed. The island-wide population was estimated at 10,743 ± 970 birds for the 1968-1973 period (USFWS 1983). Reanalysis of the 1981 HFBS data produced a lower density estimate for Kaua`i `Amakihi (Table 12) than that originally calculated by Scott *et al*. (1986) for a 25-km^2 area of the eastern Alaka`i Wilderness Preserve. Subsequent surveys of the same area since 1981 have yielded increasing densities (Tables 12 and 13). A survey in 2008 across a more extensive area comprising the entire Alaka`i Plateau recorded a density of 134/km^2 (VanderWerf *et al*. in prep), and its extrapolation to the species' 379-km^2 range produces a population estimate of 50,900 (95% CI = 39,830 – 62,690 birds).

Table 13. Trends in regional Hawai`i `Amakihi, O`ahu `Amakihi, and Kaua`i `Amakihi densities. The null hypothesis that density in each region has not changed over time was tested with a z-test or, for the Mauna Loa Strip and Mauna Kea regions, with a regression test. Equivalence tests were used to determine if the difference/slope (slope in italics) was within the threshold bounds (-0.0285, 0.0170) of a 50% change in density. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LEL and UEL = Lower and Upper Equivalence Level *p*-values. Trends at Hakalau Forest NWR and Kaua`i were assessed from Bayesian posterior probabilities using a 25% change in densities over 25 years, corresponding to an annual rate of change with a threshold lower bound of $\varphi_l = -0.0199$ and upper bound of $\varphi_u = 0.0093$. Trends were interpreted as increasing, decreasing, stable or increasing, stable or decreasing, stable, or inconclusive.

Survey	Years	Diff/Slope	SE	LCL	UCL	LEL	UEL	LEL *p*	UEL *p*	Result
Hawai`i `Amakihi—Hawai`i Island										
Ka`ū >1,500m										
	29	-112.72	43.32	-183.99	-41.45	-235.32	256.66	1.000	1.000	stable or decreasing
Ka`ū <1,500m										
	26	-34.36	41.22	-102.16	33.44	-151.30	154.63	1.000	0.998	Stable
Mauna Loa Strip										
		-0.03	0.01	-0.04	-0.02	-0.03	0.03	0.996	0.994	Stable
Kūlani-Keauhou										
	25	43.19	33.43	-11.81	98.19	-178.97	178.97	1.000	1.000	Stable
`Ōla`a										
	17	-19.86	11.21	-38.30	-1.41	-7.95	6.67	0.993	0.120	decreasing
East Rift										
	15	2.80	2.53	-1.37	6.97	-0.51	0.41	0.904	0.173	inconclusive
Pu`u Wa`awa`a Forest Bird Sanctuary										
	25	1249.64	109.19	1070.02	1429.25	-469.71	469.69	1.000	0.000	increasing
Kona Forest NWR >1,500m										
	23	0.03	0.02	0.00	0.05	-0.03	0.03	1.000	0.568	inconclusive
Kona Forest NWR <1,500m										
	22	36.70	41.53	-31.62	105.02	-73.01	68.38	0.996	0.777	inconclusive
South Kona										
	25	65.25	77.38	-62.04	192.55	-351.82	351.80	1.000	1.000	stable
Mauna Kea										
	20	*0.02*	0.02	-0.01	0.05	-0.03	0.03	0.996	0.629	inconclusive

Table 13. Trends in regional Hawai`i `Amakihi, O`ahu `Amakihi, and Kaua`i `Amakihi densities cont.

Survey	Years	Diff/Slope	SE	LCL	UCL	LEL	UEL	LEL *p*	UEL *p*	Result
Hawai`i `Amakihi—Maui Island										
East										
	19	648.95	44.48	575.78	722.12	-145.26	127.34	1.000	0.000	increasing
West										
	17	41.17	30.51	-9.02	91.36	-32.88	27.58	0.992	0.328	inconclusive
Hawai`i `Amakihi—Moloka`i Island										
	16	15.31	14.35	-8.30	38.92	-6.87	5.64	0.939	0.250	inconclusive

Survey	$\hat{\beta}$ (95% credible interval)	Declining $P\ \hat{\beta} < \varphi_l$	Negligible $P\ \varphi_l < \hat{\beta} < \varphi_u$	Increasing $P\ \hat{\beta} > \varphi_u$	Result
Hakalau Forest NWR	*-0.0053* (-0.0084—-0.0021)	<0.001	1.000	0	stable
Kaua`i `Amakihi	*0.0465* (0.0401—0.0533)	0	0	1.000	increasing

`Anianiau

The `Anianiau (*Magumma parva*) is a common Hawaiian honeycreeper endemic to Kaua`i that feeds on nectar and arthropods on flowers and foliage of trees and shrubs. Although it is not known if the species' range has changed, `Anianiau densities across the Alaka`i Plateau have increased. `Anianiau occurred in greatest numbers in native forest above 450 m but historically were found in native and nonnative forests in drainages along the northwest coast down to 100 m (Figure 10; Richardson and Bowles 1964, U.S. Fish and Wildlife Service 1983, Lepson 1997). The main population occurs on the Alaka`i Plateau, Na Pali Coast valleys, and Kōke`e State Park, with possibly a small isolated population on Makaleha Mountains (U.S. Fish and Wildlife Service 1983, Scott *et al*. 1986, Lepson 1997, Foster *et al*. 2004). U.S. Fish and Wildlife Service (1983) estimated an island-wide population of 24,230 ± 1,514 `Anianiau. HFBS abundance within the 25-$km^2$ area of the eastern Alaka`i Wilderness Preserve was estimated at 6,077 ± 277 birds and is comparable to the 5,500 ± 900 birds derived from a 1968-1973 survey of the same area (Scott *et al*. 1986). Since the 1981 HFBS, densities have increased more than three-fold to 473/km^2 within the 25-km^2 area of the eastern Alaka`i Wilderness Preserve (Tables 14 and 15). Surveys across a more extensive area comprising the entire Alaka`i Plateau from 2000-2008 recorded an average density of 293/km^2 (VanderWerf *et al*. in prep), and extrapolation of the 2008 density (296/km^2) to the species' 127-km^2 range produces a population estimate of 37,529 (95% CI = 30,340 – 44,615) birds.

Kaua`i Greater `Akialoa

The Kaua`i Greater `Akialoa (*Hemignathus ellisianus stejnegeri*) is one of three subspecies of the Greater `Akialoa, which also includes the O`ahu Greater `Akialoa (*H. e. ellisianus*) and the Maui-nui Greater `Akialoa (*H. e. lanaiensis*), both extinct. This `akialoa is a large-bodied Hawaiian honeycreeper with a dramatically long and decurved bill used to probe for arthropods and take nectar from `ōhi`a and lobelia flowers (Lepson and Johnston 2000). Once common and widespread on Kaua`i, the subspecies occupied all forest types above 200 m. Following population declines in the 1800s, the Kaua`i `Akialoa was rare by the 1920s, although accounts indicate that it persisted in the interior of the Alaka`i Plateau as late as the 1960s (Munro 1960, Richardson and Bowles 1964, Conant *et al*. 1998). Intensive surveys in the region since then have not resulted in any additional detections. The Kaua`i Greater `Akialoa is presumed extinct (Reynolds and Snetsinger 2001).

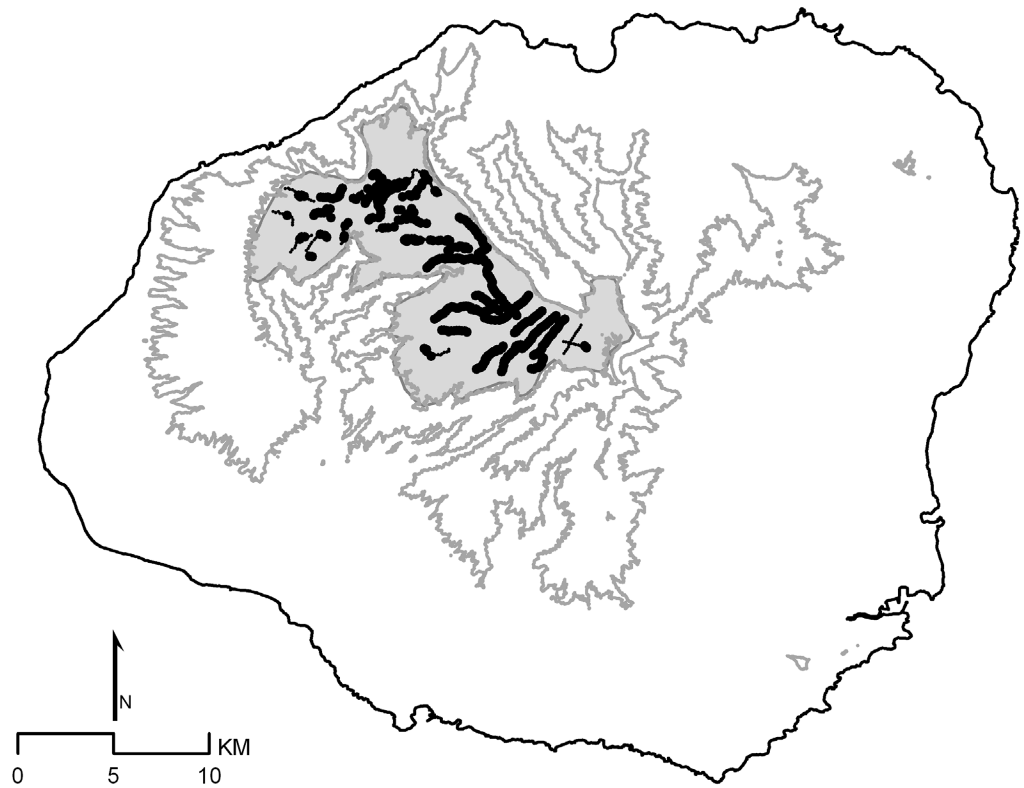


Figure 10. Survey detections (large points), locations with no detections (small points), and current range (shaded) of `Anianiau on Kaua`i Island. Elevation in 500 m contours.

Nukupu`u

Equipped with long, decurved bills, the three subspecies of Nukupu`u (*Hemignathus lucidus*) primarily fed on insects and spiders, and the species historically occupied montane forests (Pratt *et al*. 2001). The O`ahu subspecies (*H. l. lucidus*) has been extinct since at least the late 1800s. Known historically only from leeward mesic and wet forests above 600 m, Kaua`i Nukupu`u (*H. l. hanapepe*) have been extremely rare since 1900. Unconfirmed sightings were made from 1960 to 1996; however, intensive rare bird searches and surveys since then have failed to detect the subspecies (Pratt and Pyle 2000, Reynolds and Snetsinger 2001), and it is very likely extinct. Only one Maui Nukupu`u (*H. l. affinis*) was detected during the 1980 HFBS survey (Scott *et al*. 1986), and one bird was found in the Hanawī Natural Area Reserve on the northeastern slope of Haleakalā during the 1994–1996 Hawai`i Rare Bird Search (Reynolds and Snetsinger 2001). Despite considerable ongoing survey effort in the region, the last sighting was made in 1996, and this subspecies also is likely extinct (Pratt and Pyle 2000).

Table 14. \`Anianiau, \`Akikiki, and \`Akeke\`e population density (birds/km^2) and standard error (SE) estimates by year. Estimates are for the population within the 25-km^2 area of the eastern Alaka\`i Wilderness Preserve only, not the entire Alaka\`i Plateau or across the species ranges. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented.

Species	Year	Density	SE	No. Stations	No. Birds
\`Anianiau					
	1981	129.8	8.85	140	625
	1989	260.7	28.00	129	265
	1994	376.1	50.96	112	217
	2000	435.9	30.99	139	359
	2005	409.2	40.76	144	181
	2007	316.9	42.02	92	89
	2008	473.2	49.40	150	218
\`Akikiki					
	1981	84.6	12.59	140	139
	1989	152.9	27.02	129	66
	1994	179.4	36.13	112	44
	2000	31.4	8.09	139	28
	2005	63.1	21.92	144	15
	2007	70.8	31.04	92	11
	2008	155.2	32.19	150	41
\`Akeke\`e					
	1981	44.7	6.66	140	146
	1989	204.0	33.81	129	149
	1994	187.5	42.90	112	85
	2000	152.0	24.03	139	141
	2005	117.1	27.07	144	39
	2007	75.0	27.38	92	16
	2008	96.3	21.34	150	36

\`Akiapōlā\`au

The \`Akiapōlā\`au (*Hemignathus munroi*) is an uncommon insectivorous Hawaiian honeycreeper endemic to Hawai\`i Island. Its diet consists almost entirely on arthropods, and \`Akiapōlā\`au show a preference for foraging primarily on koa branches and stems (Pratt *et al*. 2001, Pratt 2005). The \`Akiapōlā\`au trends vary by region; however, overall this endangered bird is declining in both range and abundance.

Scott *et al*. (1986) estimated the species' population to be 1,496 ± 318 birds distributed in five disjunct populations located in the North and Central Windward, Ka\`ū, Kona, and Mauna Kea regions (Figure 11, Pratt *et al*. 2001). In the North Windward region, \`Akiapōlā\`au only inhabit high-elevation koa-\`ōhi\`a forests in and near Hakalau Forest NWR, and this may be the only region where \`Akiapōlā\`au are responding positively (Table 16). Although densities may have declined since 1999 at Hakalau Forest NWR, the species' long-term trend in the refuge has been increasing since 1987 (Table 17; Camp, Pratt *et al*. 2009). The 2007 estimate for the refuge was 410 birds (95% CI = 175 – 912; Camp, Pratt *et al*. 2009), and additional habitat immediately south of the refuge may harbor a comparable number of birds.

Populations in the North and Central Windward regions may no longer be connected as indicated by the absence of `Akiapōlā`au detections during a 2002 survey of the Upper Waiākea FR (Gorresen *et al*. 2005). The species' range in the Central Windward region excludes the Hawai`i Volcanoes NP, from which the species has been absent since at least the early 1970s (Conant 1975, Banko and Banko 1980). A 1972-1975 survey in Keauhou Ranch and the Kīlauea FR estimated densities of 48 and 50/km^2 (Conant 1975). Subsequent surveys from 1977 to 2003 recorded densities averaging 10/km^2 (Tables 16 and 17; Gorresen *et al*. 2005). Although density appears to have declined since the 1972-1975 survey, the trend assessment was statistically inconclusive because of imprecise estimates (Table 17). More encouraging is the recent observation that young, regenerating koa supports moderate densities of `Akiapōlā`au (Pratt *et al*. 2001, Pejchar *et al*. 2005, Camp, Jacobi *et al*. in press).

`Akiapōlā`au estimates vary widely among surveys in Ka`ū. For example, the population was estimated at 533 $\pm$ 163 birds within the 60 km$^2$ species' range in 1976 (Scott *et al*. 1986). However, Tweed *et al*. (2007) estimated the 2005 `Akiapōlā`au population at 1,073 birds (95% CI = 616 – 1,869). Densities from the 1993 and 2002 surveys were very low (<two/km^2) and may have increased to 10/km^2 by 2005 (Table 16). Given the species usually only produces one chick per year (Pratt *et al*. 2001), an increase from the lowest estimate to that estimated from Tweed's surveys would not have been possible. The differences among the estimates are instead more likely to be a reflection of sampling error related to year-to-year variability in vocalization and detectability (Ralph and Fancy 1996, Pratt *et al*. 2001). Despite the recent observations of relatively high densities in young koa groves, the range of the Ka`ū population appears to have contracted upslope since 1976. At that time `Akiapōlā`au were detected as low as 1,300 m, but all detections since have been above 1,450 m, and the range in Ka`ū in 2005 was estimated to be about 56 km^2 (Gorresen *et al*. 2007).

A small, relictual population in central Kona may still exist on the KFU-Hakalau Forest NWR. Based on the 1978 HFBS, Scott *et al*. (1986) estimated this area harbored only 22 $\pm$ 9 birds. However, subsequent surveys between 1995 and 2001 detected only one bird, and there have been none detected since (Table 16). Surveys on Hualālai between 1990 and 2003 have not detected `Akiapōlā`au in areas for which historical records exist (van Riper 1973), and indicate that the Kona population is nearly extirpated.

Until recently, a scattered population existed in subalpine woodland of Mauna Kea. This population was concentrated in two clusters on the western (Pu`u Lā`au) and eastern (Kanakaleonui) slopes of the mountain at a combined population of 50 $\pm$ 50 (95% CI) birds (Scott *et al*. 1986). Most of the remaining birds were banded by 1991, yielding a direct count at that time of less than 20 birds and indicating a rapid decline over a ten-year period. On-going surveys for Palila intermittently detected a few `Akiapōlā`au on the western and southern slopes; for example, three males were observed in 2000 (Pratt *et al*. 2001). However, `Akiapōlā`au have not been observed in Pu`u Lā`au since 2004, and are likely extirpated from western Mauna Kea (Banko and Banko 2009; USGS unpubl. data). Despite its proximity (five km) to a population in the upper elevation forest in the Hakalau Forest NWR, the birds in the Kanakaleonui area of eastern Mauna Kea also appear to have disappeared (Pratt *et al*. 2001).

Table 15. Trends in regional `Anianiau, `Akikiki, and `Akeke`e densities within the 25-km^2 area of the eastern Alaka`i Wilderness Preserve only, not the entire Alaka`i Plateau or across the species ranges. Trends were assessed from Bayesian posterior probabilities using a 25% change in densities over 25 years, corresponding to an annual rate of change with a threshold lower bound of $\varphi_l = -0.0199$ and upper bound of $\varphi_u = 0.0093$. Trends were interpreted as increasing, decreasing, stable or increasing, stable or decreasing, stable, or inconclusive.

Species	$\hat{\beta}$ (95% credible interval)	Declining $P\ \hat{\beta} < \varphi_l$	Negligible $P\ \varphi_l < \hat{\beta} < \varphi_u$	Increasing $P\ \hat{\beta} > \varphi_u$	Result
`Anianiau	*0.0411* (0.0374—0.045)	0	0	1.000	increasing
`Akikiki	*-0.0057* (-0.0170—0.0053)	0.135	0.861	0.004	stable
`Akeke`e	*0.0228* (0.0153—0.0304)	0	<0.001	1.000	increasing

`Akikiki

The `Akikiki (*Oreomystis bairdi*), or Kaua`i Creeper, is a warbler-like Hawaiian honeycreeper that gleans insects mainly from tree trunks and branches and appears to be dependent on tall trees upon which to forage (Foster *et al*. 2000, VanderWerf and Roberts 2008). Once common and widely distributed (Scott *et al*. 1986), this Kaua`i endemic is now limited to native montane forests above 800 m (Figure 12). The `Akikiki is undergoing rapid range contraction and number less than 5,000 individuals.

The `Akikiki population was estimated at 6,832 ± 966 birds in 1973, and the species' 88-km$^2$ range extended from Kōke`e State Park to the Alaka`i Plateau, with a small isolated population on the Lā`au Ridge. `Akikiki had disappeared from the Kōke`e region by the time of the 1981 HFBS (Scott *et al*. 1986), and by 2000 Foster *et al*. (2004) determined that `Akikiki were limited to a 36-km$^2$ area in the Alaka`i Wilderness Preserve (the Lā`au Ridge population was assumed extinct). `Akikiki counts are characterized by a low number of detections and high variability, making density estimation and trend assessment problematic. Within the species' range across the Alaka`i Plateau, `Akikiki densities ranged between 29 and 99 birds/km^2, and as of 2008 the population was estimated at 3,568 birds (95% CI = 2,369 – 5,011; VanderWerf *et al*. in prep). Densities within the 25-km^2 area of the eastern Alaka`i Wilderness Preserve have fluctuated widely, and there is mixed evidence of stable to declining densities (Tables 14 and 15). Rapid range contraction and low densities indicate that the `Akikiki is threatened with extinction (U.S. Fish and Wildlife Service 2006, VanderWerf *et al*. in prep).

Table 16. `Akiapōlā`au population density (birds/km^2) and standard error (SE) estimates by region and time period. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented.

Survey	Year	Density	SE	No. Stations	No. Birds
Ka`ū >1,500m					
	1976	0.0	0.00	162	0
	1993	1.2	1.33	94	1
	2002	1.2	1.32	88	1
	2005	10.3	4.21	213	20
Ka`ū <1,500m					
	1976	4.3	2.56	234	9
	1993	0.8	0.95	138	1
	2002	0.9	1.01	126	1
Kūlani-Keauhou					
	1977	9.7	6.34	52	5
	1995-1998*	10.3	1.45	247	96
	2001-2003	9.5	1.61	195	53
Hakalau Forest NWR					
	1977	11.4	4.64	78	10
	1987	11.5	3.55	194	20
	1988	10.5	2.68	194	18
	1989	3.5	2.24	198	6
	1990	6.5	3.46	197	12
	1991	6.3	3.56	197	11
	1992	5.1	2.97	197	9
	1993	2.7	1.09	194	9
	1994	5.5	1.85	194	18
	1995	3.1	1.27	195	9
	1996	10.5	2.39	198	31
	1997	8.7	3.41	193	14
	1998	8.5	2.60	197	14
	1999	6.6	2.53	195	10
	2000	11.8	3.71	198	18
	2001	19.6	7.48	196	22
	2002	11.6	4.72	195	13
	2003	25.2	11.82	199	27
	2004	12.2	5.92	198	13
	2005	11.8	4.26	165	18
	2006	8.1	3.09	162	10
	2007	7.6	2.35	147	17
Kona Forest NWR >1,500m					
	1978	-	-	21	0
	1995	-	-	72	0
	1999	-	-	69	1
	2000	-	-	70	0
	2001	-	-	70	0

Table 17. Trends in regional `Akiapōlā`au, Hawai`i Creeper, and Hawai`i `Ākepa densities. The null hypothesis that density in each region has not changed over time was tested with a z-test. Equivalence tests were used to determine if the difference was within the threshold bounds (-0.0285, 0.0170) of a 50% change in density. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LEL and UEL = Lower and Upper Equivalence Level *p*-values. Trends at Hakalau Forest NWR were assessed from Bayesian posterior probabilities using a 25% change in densities over 25 years, corresponding to an annual rate of change with a threshold lower bound of $\varphi_l = -0.0199$ and upper bound of $\varphi_u = 0.0093$. Trends were interpreted as increasing, decreasing, stable or increasing, stable or decreasing, stable, or inconclusive.

Survey	Years	Diff	SE	LCL	UCL	LEL	UEL	LEL *p*	UEL *p*	Result
`Akiapōlā`au										
Ka`ū >1,500m										
	29	10.27	4.21	3.34	17.20	0.00	0.00	0.993	0.007	increasing
Ka`ū <1,500m										
	26	-3.35	2.75	-7.87	1.18	-2.19	2.23	0.978	0.343	inconclusive
Kūlani-Keauhou										
	25	-0.22	6.55	-10.99	10.55	-4.84	4.84	0.780	0.760	inconclusive
Hawai`i Creeper										
Ka`ū >1,500m										
	29	-4.19	19.24	-35.84	27.45	-20.87	22.77	0.904	0.833	inconclusive
Ka`ū <1,500m										
	26	-3.73	2.75	-8.26	0.79	-1.92	1.96	0.980	0.260	inconclusive
Kūlani-Keauhou										
	25	9.63	8.04	-3.60	22.86	-6.78	6.78	0.979	0.361	inconclusive
Pu`u Wa`awa`a Forest Bird Sanctuary										
	25	-52.69	24.29	-92.64	-12.73	-27.99	27.99	1.000	0.155	decreasing
Kona Forest NWR >1,500 m										
	23	-0.01	0.01	-0.02	0.00	-0.03	0.03	0.996	1.000	stable
Kona Forest NWR <1,500 m										
	22	1.46	1.46	-0.94	3.86	0.00	0.00	0.841	0.159	inconclusive

Table 17. Trends in regional `Akiapōlā`au, Hawai`i Creeper, and Hawai`i `Ākepa densities cont.

Survey	Years	Diff	SE	LCL	UCL	LEL	UEL	LEL p	UEL p	Result
Hawai`i `Ākepa										
Ka`ū >1,500m										
	29	0.62	14.56	-23.34	24.57	-19.02	20.74	0.911	0.917	inconclusive
Ka`ū <1,500m										
	26	-7.78	3.64	-13.76	-1.80	-4.00	4.09	0.999	0.155	decreasing
Kūlani-Keauhou										
	25	-15.24	13.55	-37.53	7.06	-19.16	19.16	0.994	0.614	inconclusive
Pu`u Wa`awa`a Forest Bird Sanctuary										
	25	-74.79	26.06	-117.65	-31.92	-40.96	40.95	1.000	0.097	decreasing
Kona Forest NWR >1,500 m										
	23	0.02	0.14	-0.21	0.24	-0.03	0.03	0.630	0.538	inconclusive
Kona Forest NWR <1,500 m										
	22	1.58	1.58	-1.02	4.17	0.00	0.00	0.841	0.159	inconclusive

Survey	$\hat{\beta}$ (95% credible interval)	Declining $P\ \hat{\beta} < \varphi_l$	Negligible $P\ \varphi_l < \hat{\beta} < \varphi_u$	Increasing $P\ \hat{\beta} > \varphi_u$	Result
Hakalau Forest NWR					
`Akiapōlā`au	*0.0414* (0.0191—0.0647)	<0.001	0.003	0.997	increasing
Hawai`i Creeper	*0.0167* (0.0064—0.0271)	0	0.081	0.919	increasing
Hawai`i `Ākepa	*0.0088* (-0.0007—0.0185)	<0.001	0.542	0.458	stable or increasing

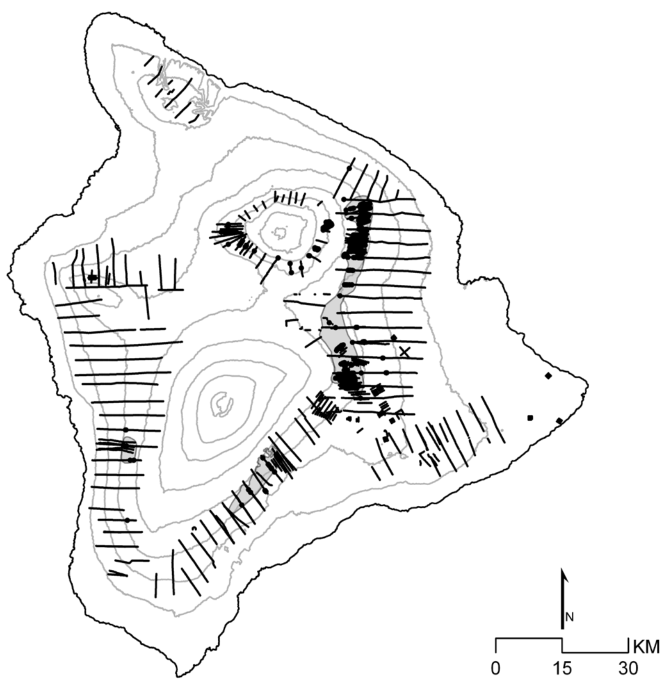


Figure 11. Survey detections (large points), locations with no detections (small points), and current range (shaded) of `Akiapōlā`au on Hawai`i Island. Elevation in 500 m contours.

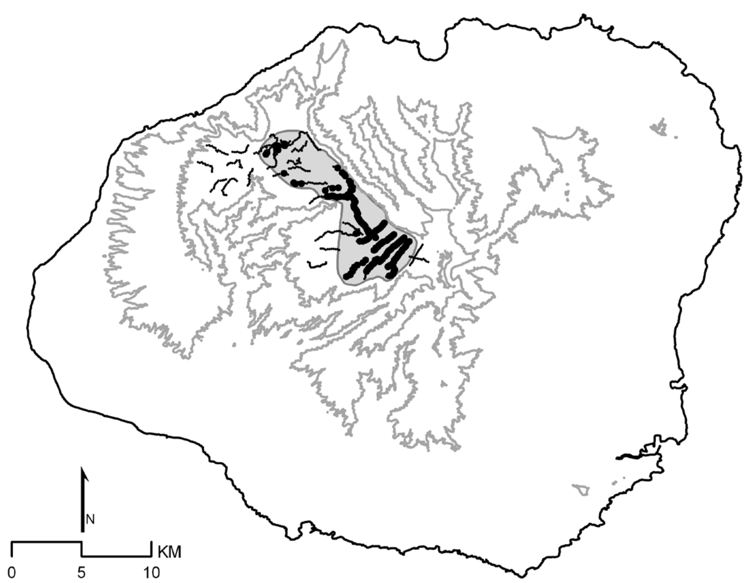


Figure 12. Survey detections (large points), locations with no detections (small points), and current range (shaded) of `Akikiki on Kaua`i Island. Elevation in 500 m contours.

Hawai`i Creeper

The Hawai`i Creeper (*Oreomystis mana*) is an uncommon, insectivorous, warbler-like Hawaiian honeycreeper endemic to Hawai`i Island (Scott *et al*. 1986, Lepson and Woodworth 2002). Creepers feed primarily on tree branches and stems and are most abundant in closed-canopied, high-stature, `ōhi`a and koa-`ōhi`a forests above 1,500 m. This species' range continues to contract and, with the exception of the population in the Hakalau Forest NWR, overall its densities are declining.

The species is distributed in four disjunct populations in the Ka`ū, Hualālai, Kona, and windward regions of the island (Figure 13; Scott *et al*. 1986, Lepson and Woodworth 2002). Scott *et al*. (1986) estimated the species' entire population at 12,501 $\pm$ 1,440 birds, with most birds (10,102 $\pm$ 827) restricted to the North and Central Windward regions. Creeper densities in Hakalau Forest NWR have increased since 1987 (Tables 17 and 18). Recent estimates for the Hakalau Forest NWR project a population of 5,956 birds (95% CI = 3,621 – 9,818; Camp, Pratt *et al*. 2009), and additional habitat immediately south of the refuge may support a comparable number of birds. Increasing density in the North Windward region may have been offset by contractions upslope in the species' range. Scott *et al*. (1986) recorded creeper at 1,000 m elevation and projected their range down to 700 m. It is now believed that the species persists only above about 1,500 m, although a few incidental individuals have been observed in mid-elevation forests (USGS unpubl. data).

Surveys between 1972 and 1975 in the Keauhou Ranch and the adjacent Kīlauea FR resulted in an average density of 31/km^2 (Conant 1975). Subsequent surveys between 1977 and 2003 demonstrated variable densities resulting in an inconclusive trend (Tables 17 and 18; Gorresen *et al*. 2005). The species' range in the region excludes the Hawai`i Volcanoes NP and the district of Puna from which creepers have been extirpated since the early 1970s (Conant 1975, Banko and Banko 1980, Scott *et al*. 1986).

The second largest creeper population is concentrated in Ka`ū and was estimated at 2,102 $\pm$ 540 birds in 1976 (Scott *et al*. 1986). This and subsequent surveys of central Ka`ū above 1,500 m between 1993 and 2005 detected variable densities (Table 18; Gorresen *et al*. 2007). Although there was no significant difference between the 1976 and 2005 densities, the highly variable estimates make conclusive trend assessment difficult (Table 17). With the exception of a single bird, all detections since 1976 have occurred at or above 1,500 m, and the current range is estimated at 64 km^2. Given this range size and the density observed in 2005, the current population of Hawai`i Creeper in Ka`ū was estimated by Tweed *et al*. (2007) at 2,268 birds (95% CI = 1,159 – 4,438 birds).

The populations on Hualālai and central Kona were estimated by the HFBS to number about 220 and 75 individuals, respectively (Scott *et al*. 1986). However, creeper detections have declined in leeward Hawai`i Island over the past several decades, and subsequent surveys of Pu`u Wa`awa`a Forest Bird Sanctuary and the KFU-Hakalau Forest NWR recorded very few birds (Table 18). These relict populations may be nearly extirpated.

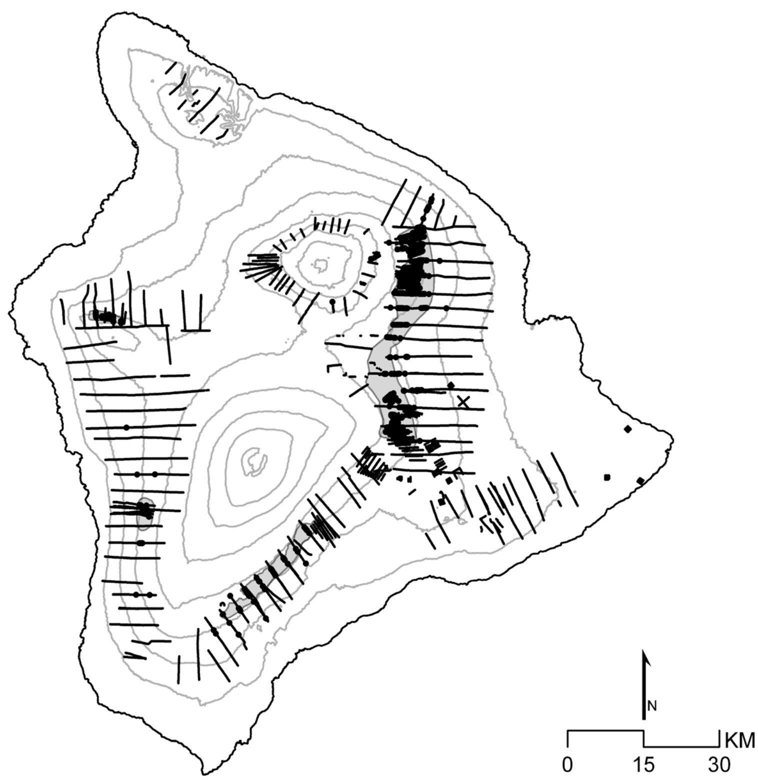


Figure 13. Survey detections (large points), locations with no detections (small points), and current range (shaded) of Hawai`i Creeper on Hawai`i Island. Elevation in 500 m contours.

O`ahu `Alauahio

The O`ahu `Alauahio (*Paroreomyza maculata*), or O`ahu Creeper, is another warblerlike insectivorous Hawaiian honeycreeper (Baker and Baker 2000). Common in the late 1800s, the O`ahu endemic was rare by the 1930s (Munro 1960). Only nine credible sightings were reported from 1941 to 1975 (Shallenberger and Pratt 1978), and all were from mixed introduced and koa-`ōhi`a forests in the middle to upper elevations of the Ko`olau Mountains (Baker and Baker 2000). Intensive surveys from 1976 to 1978 detected only three birds (Shallenberger and Pratt 1978). Several unconfirmed sightings were made between 1985 and 1990 (Baker and Baker 2000), but a 1991 survey did not detect O`ahu `Alauahio (USGS-PIERC unpubl. data), and the species may be extinct.

Kākāwahie

The Kākāwahie (*Paroreomyza flammea*), or Moloka`i Creeper, was a brilliant scarlet (males) or rusty brown (females) honeycreeper endemic to Moloka`i (Baker and Baker 2000). This curious and active bird picked over trunks, branches, and leaves in search of insects. Once widely distributed at both low and high elevations, it was still common as late as 1907 but declined rapidly thereafter and became rare by the 1930s (Perkins 1903, Munro 1960). The last sightings of Kākāwahie were from 1961 to 1963 (Pekelo 1963). The 1979–1980 HFBS survey and subsequent surveys yielded no further records, and the species is presumed extinct (Scott *et al.* 1986, Reynolds and Snetsinger 2001, U.S. Fish and Wildlife Service 2006).

Table 18. Hawai`i Creeper population density (birds/km^2) and standard error (SE) estimates by region and time period. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented.

Survey	Year	Density	SE	No. Stations	No. Birds
Ka`ū >1,500m					
	1976	37.6	14.32	162	14
	1993	60.1	21.31	94	13
	2002	138.7	32.56	88	28
	2005	33.4	12.85	213	16
Ka`ū <1,500m					
	1976	3.7	2.75	234	2
	1993	3.3	3.33	138	1
	2002	0.0	0.00	126	0
Kūlani-Keauhou					
	1977	13.6	6.50	80	6
	1995-1998*	33.8	4.47	267	144
	2001-2003	23.2	4.73	214	66
Hakalau Forest NWR					
	1977	38.9	31.70	78	46
	1987	130.9	31.34	194	67
	1988	33.4	22.21	194	59
	1989	54.3	25.62	198	48
	1990	127.3	44.82	197	112
	1991	46.0	32.08	197	70
	1992	182.1	43.09	197	93
	1993	28.9	13.79	194	44
	1994	158.7	29.90	194	86
	1995	83.2	23.55	195	45
	1996	234.2	51.86	198	148
	1997	185.6	36.49	193	113
	1998	153.2	30.27	197	75
	1999	67.3	20.42	195	84
	2000	140.4	37.76	198	102
	2001	104.5	14.13	196	130
	2002	237.1	42.61	195	183
	2003	143.1	30.69	199	90
	2004	111.0	30.66	198	122
	2005	150.7	34.09	165	81
	2006	83.3	29.61	162	95
	2007	67.0	17.33	147	106
Pu`u Wa`awa`a Forest Bird Sanctuary					
	1978	56.0	24.06	31	10
	1990-1991	21.8	8.97	61	9
	1996	17.2	9.39	83	7
	2003	3.3	3.29	62	1
Kona Forest NWR >1,500 m					
	1978	19.4	19.44	21	2
	1995	19.8	10.81	72	7
	1999	17.8	8.15	68	6

Table 18. Hawai`i Creeper population density cont.

Survey	Year	Density	SE	No. Stations	No. Birds
	2000	5.8	4.09	70	2
	2001	17.5	10.79	70	6
Kona Forest NWR <1,500 m					
	1978	0.0	0.00	43	0
	1995	0.0	0.00	106	0
	1999	1.5	1.48	138	1
	2000	1.5	1.46	140	1

Maui `Alauahio

The Maui `Alauahio (*Paroreomyza montana*), or Maui Creeper, is a warbler-like Hawaiian honeycreeper that occupies both native and alien forests and ranges into sub-alpine woodland and scrubland (Baker and Baker 2000). This species remains threatened by the encroachment of exotic plants, ungulates, and the upward spread of disease driven by global warming. Although Maui `Alauahio densities have increased substantially since the HFBS, this difference may be due to seasonality of sampling. Densities since the HFBS appear stable; however, the species' range continues to contract upslope.

Historically widespread on Maui and Lāna`i, the `Alauahio disappeared from low-elevation forests in the 1900s and is now restricted to three populations on east Maui. The largest contiguous population extends from Waikamoi Preserve eastward to Kīpahulu Valley on the north and east slopes of Haleakalā Volcano. The two other populations are small and isolated at Kahikinui FR and Polipoli State Park (Figure 14).

During the 1980 HFBS the `Alauahio population was estimated at 34,839 ± 2,723 birds (Scott *et al*. 1986). Subsequent surveys recorded `Alauahio at significantly higher densities (Tables 10 and 11), although this difference may be due to the 1980 survey being conducted past the period of peak vocalization. Similar densities to the HFBS were detected in 1995-1997 at the Hanawī Natural Area Reserve, an area of high quality habitat in the center of the species' range (Simon *et al*. 2002). The elevational range of the `Alauahio may be contracting upslope, with few individuals found below 1,600 m (Baker and Baker 2000). `Alauahio were not detected in the Kahikinui FR during a 1996 survey, and this local population may be extirpated. No bird surveys have occurred in Polipoli State Park since 1980. However, a population still exists there, even after a fire in 2007 destroyed much of the habitat (Mounce *et al*. 2008).

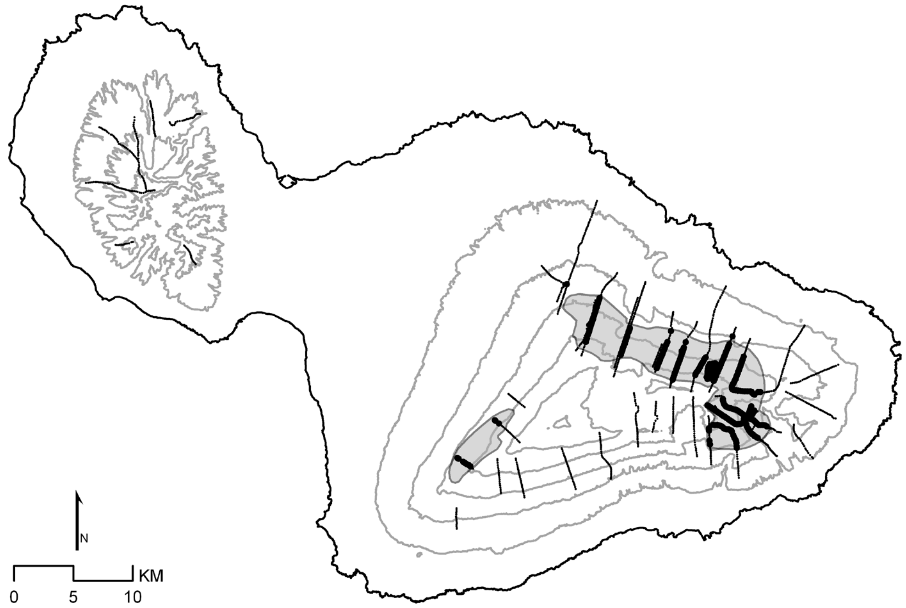


Figure 14. Survey detections (large points), locations with no detections (small points), and current range (shaded) of Maui `Alauahio on Maui Island. Elevation in 500 m contours.

`Akeke`e

The `Akeke`e (*Loxops caeruleirostris*), or Kaua`i `Ākepa, is a specialized honeycreeper that forages for insects in `ōhi`a canopy foliage (Lepson and Pratt 1997). Endemic to Kaua`i, the `Akeke`e species' range is contracting and densities have declined following two hurricanes.

When first comprehensively surveyed in 1968-1973, the `Akeke`e existed in two populations totaling 5,066 ± 840 birds: a main population extending from Kōke`e State Park to the Alaka`i Plateau, and a small, isolated population on the Makaleha Mountains (U.S. Fish and Wildlife Service 1983). Subsequent surveys have not been conducted in the Makaleha Mountains, and the status of that population is unknown. `Akeke`e have not been detected in Kōke`e State Park since 2000 indicating a range contraction (Figure 15). A reanalysis of the 1981 HFBS survey of a 25-$km^2$ area in the eastern Alaka`i Wilderness Preserve revealed a density of 45 birds/km^2. Estimates thereafter varied widely but seemed to have peaked in 1989 and have gradually decreased since (Tables 14 and 15). The HFBS estimate may be low because the survey was conducted later in the year than subsequent surveys and may have occurred after the period of peak vocalization. Hurricanes struck in 1982 and 1992 toppling much of the old growth forest. The regrowth of trees that followed has provided a flush of new `ōhi`a foliage, and it has been speculated that the `Akeke`e population initially grew in response to an increase in foraging substrate (Pratt 1994, Foster *et al*. 2004). `Akeke`e trends since the hurricanes have declined substantially (59% decline between 1989 and 2008; VanderWerf *et al*. in prep). Extrapolation of the density recorded in 2008 (62/km^2) within the species' 127-km^2 range across the Alaka`i Plateau produced a population estimate of 7,887 `Akeke`e (95% CI = 5,220 – 10,833; VanderWerf *et al*. in prep).

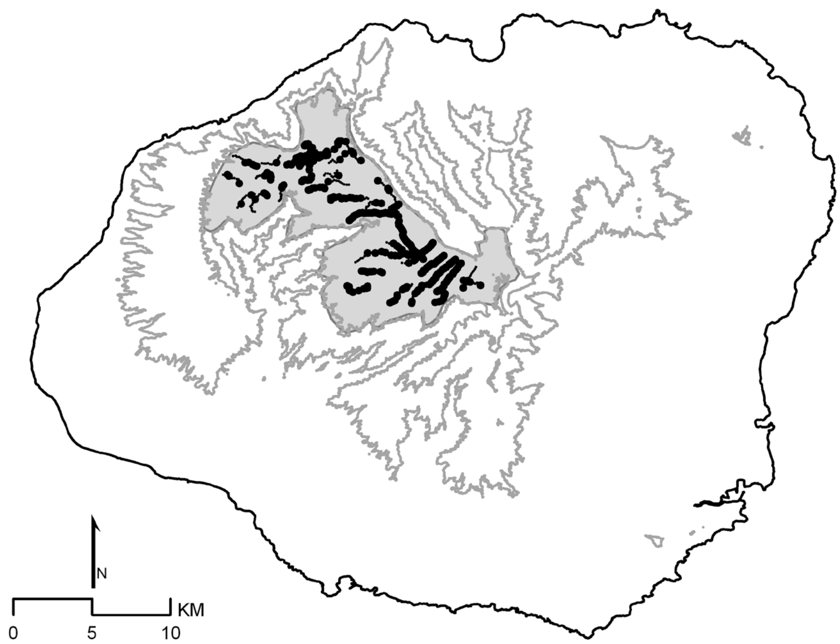


Figure 15. Survey detections (large points), locations with no detections (small points), and current range (shaded) of `Akeke`e on Kaua`i Island. Elevation in 500 m contours.

`Ākepa

Of the three subspecies of `Ākepa, both the O`ahu (*Loxops coccineus wolstenholmei*) and the Maui (*L. c. ochraceus*) subspecies are likely extinct (Reynolds and Snetsinger 2001, U.S. Fish and Wildlife Service 2006). The Hawai`i `Ākepa (*L. c. coccineus*) is most abundant in closed canopied, high stature `ōhi`a and koa-`ōhi`a forests and subalpine woodland above 1,300 m (Scott *et al*. 1986). Insectivorous in habit, `Ākepa forage almost entirely on the terminal leaf clusters of `ōhi`a and among koa leaves and pods (Lepson and Freed 1997). `Ākepa densities vary widely among the regions and annually; however, overall densities are decreasing and the species' range is contracting. A notable exception is the stable or increasing trend in Hakalau Forest NWR.

Hawai`i `Ākepa occur as five disjunct populations in the Ka`ū, Hualālai, Kona, and North and Central Windward regions (Figure 16; Scott *et al*. 1986, Lepson and Woodworth 2002). Scott *et al*. (1986) estimated the entire population in 1977-1979 at 13,892 $\pm$ 1,825 birds, with 7,938 $\pm$ 919 occurring in the Northern and Central Windward regions. However, recent estimates for Hakalau Forest NWR suggest a population of 6,839 birds (95% CI = 5,184 – 9,044; Camp, Pratt *et al*. 2009), and habitat immediately south of the refuge probably still supports additional birds. In Hakalau Forest NWR, the `Ākepa has increased over the past three decades (Tables 17 and 19).

Within the Central Windward region, the species' range has apparently contracted to the Kūlani-Keauhou area. Hawai`i `Ākepa have been absent from the nearby Hawai`i Volcanoes NP since at least the 1970s (Banko and Banko 1980). Moreover, no Hawai`i `Ākepa were detected in 2002 in the Upper Waiākea FR located between the Kūlani-Keauhou and Hakalau Forest NWR study areas, which may suggest that the Central and North Windward populations are no longer contiguous (Gorresen *et al*. 2005). Densities between 1972 and 1975 for Keauhou Ranch and the Kīlauea FR averaged 46/km^2 (Conant 1975). Subsequent surveys between 1977 and 2003 recorded Hawai`i `Ākepa densities between 38 and 23/km^2, respectively (Table 19; Gorresen *et al*. 2005). These data suggest that the population in the Central Windward region appears to be declining, although comparisons were statistically inconclusive (Table 17).

The Ka`ū region supports the island's second largest population of Hawai`i `Ākepa, which from the 1976 HFBS was estimated to number 5,293 $\pm$ 780 birds with a geographic range calculated at 180 km$^2$ (Scott *et al*. 1986). However, range contraction and highly variable density estimates complicate current population size projections. Whereas observations of `Ākepa during the HFBS occurred as low as 1,250 m, almost all subsequent detections have occurred above 1,500 m (Table 19; Gorresen *et al*. 2007). As of 2005, the range in Ka`ū was estimated at only 80 km$^2$. Estimated densities above 1,500 m in Ka`ū have varied widely between 1977 and 2005 (Table 19). Given the above range size and the density observed in 2005 (35/km^2), the 2005 population in Ka`ū was estimated by Tweed *et al*. (2007) at 2,556 birds (95% CI = 1,340 – 4,876).

Hawai`i `Ākepa occur as disjunct and relict populations on northern Hualālai and central Kona. Based on the 1978 HFBS, Scott *et al*. (1986) estimated a combined Hualālai-Kona population of 661 $\pm$ 126 birds. However, densities have drastically declined on leeward Hawai`i Island in the past several decades (Table 17), including within the Pu`u Wa`awa`a Forest Bird Sanctuary (Table 19). Only a single `Ākepa was detected during the 1978 HFBS in central Kona, although a 1988 survey by Pratt *et al*. (1989) encountered at least six birds in a 20 ha area within the KFU-Hakalau Forest NWR. Moreover, subsequent surveys in the forest unit at elevations $\geq$1,500 m have recorded very low densities (Table 19).

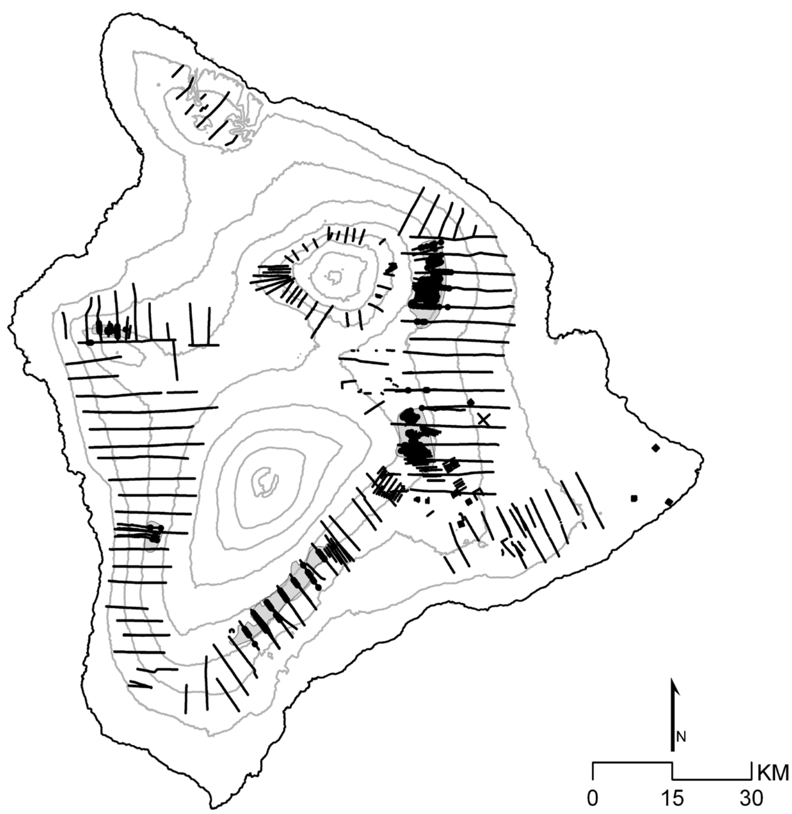


Figure 16. Survey detections (large points), locations with no detections (small points), and current range (shaded) of Hawai`i `Ākepa on Hawai`i Island. Elevation in 500 m contours.

Table 19. Hawai`i `Ākepa population density (birds/km^2) and standard error (SE) estimates by region and time period. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented.

Survey	Year	Density	SE	No. Stations	No. Birds
Ka`ū >1,500m					
	1976	34.3	11.20	162	30
	1993	155.8	30.30	94	81
	2002	106.7	29.09	88	50
	2005	34.9	9.30	213	40
Ka`ū <1,500m					
	1976	7.8	3.64	234	10
	1993	2.6	1.89	138	2
	2002	0.0	0.00	126	0
Kūlani-Keauhou					
	1977	38.3	12.93	80	12
	1995-1998*	30.0	4.55	267	113
	2001-2003	23.1	4.05	214	55
Hakalau Forest NWR					
	1977	44.5	10.56	78	29
	1987	146.2	25.14	194	93
	1988	84.3	12.49	194	110
	1989	80.9	15.44	198	82
	1990	77.3	16.18	197	71
	1991	69.6	15.17	197	65
	1992	117.9	19.03	197	106
	1993	79.9	10.91	194	133
	1994	74.3	12.55	194	92
	1995	73.5	13.14	195	100
	1996	229.9	33.31	198	183
	1997	168.3	23.04	193	135
	1998	132.8	20.28	197	114
	1999	89.9	13.56	195	96
	2000	172.5	24.94	198	137
	2001	153.9	20.96	196	133
	2002	118.6	14.67	195	165
	2003	143.8	26.58	199	105
	2004	155.6	21.51	198	147
	2005	88.7	19.55	165	56
	2006	61.8	11.61	162	48
	2007	92.4	13.61	147	146
Pu`u Wa`awa`a Forest Bird Sanctuary					
	1978	81.9	25.07	31	13
	1990-1991	57.9	25.63	61	22
	1996	34.6	12.83	83	13
	2003	7.1	7.12	62	2
Kona Forest NWR >1,500 m					
	1978	0.0	0.00	21	0
	1995	6.1	4.31	72	2
	1999	41.6	17.22	69	13

Table 19. Hawai`i `Ākepa population density cont.

Survey	Year	Density	SE	No. Stations	No. Birds
	2000	12.6	7.63	70	4
	2001	15.8	8.19	70	5
Kona Forest NWR <1,500 m					
	1978	0.0	0.00	43	0
	1995	0.0	0.00	106	0
	1999	0.0	0.00	138	0
	2000	1.6	1.58	140	1

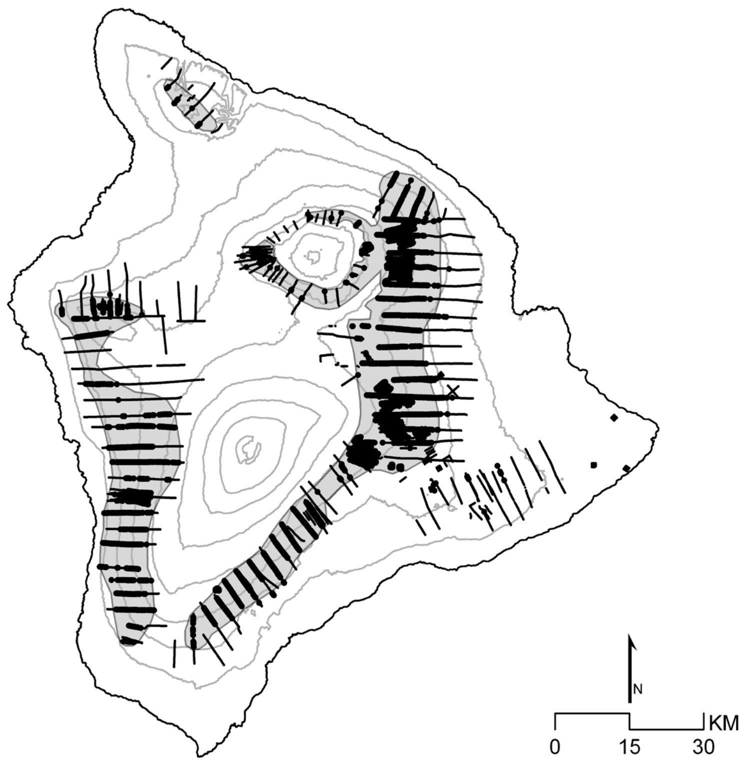
`I`iwi

The `I`iwi (*Vestiaria coccinea*) is a nectarivorous Hawaiian honeycreeper locally common on the islands of Hawai`i, Maui, and Kaua`i, and rare and listed by the state as endangered on O`ahu and Moloka`i (Figure 17; Fancy and Ralph 1998). It occurs at highest densities in closed-canopied, high-stature `ōhi`a and koa-`ōhi`a forests on windward slopes above 1,500 m. `I`iwi move in response to the seasonal and patchy distribution of `ōhi`a flowers, and local densities fluctuate accordingly (Fancy and Ralph 1998). Overall, `I`iwi numbers are declining and the species' range is contracting upslope. Hakalau Forest NWR is a notable exception to this pattern, and `I`iwi densities may also be stable in the upper elevation forests of Ka`ū.

With the possible exception of a population on Kohala Mountain, `I`iwi on Hawai`i Island occur as a single relatively contiguous population throughout the windward and leeward forested habitats (Scott *et al*. 1986, Lepson and Woodworth 2002). An estimated 802 $\pm$ 286 individuals on Kohala Mountain may be sustained by recruitment of migrants from nearby populations (Scott *et al*. 1986); however, the population trend in this region is not known. NAR staff occasionally detect `I`iwi in moderate to tall stature native forest above 1,300 m on Kohala Mountain (N. Agorastos and L. Hadway, pers. comm.).

On Mauna Kea, `I`iwi occur in subalpine woodland where they forage on flowering māmane (Scott *et al*. 1986, Ralph and Fancy 1995, Hess *et al*. 2001). This region was estimated to support a population of 2,821 $\pm$ 646 individuals (Scott *et al*. 1986). Although the 1983 HFBS and subsequent surveys (1997-2003) did not reveal a trend in density, an assessment of trend is difficult because their occurrence is highly irruptive and seems to be the result mainly of nonbreeding birds moving into the region to capitalize on mamane bloom ($\leq$five/km^2; Tables 20 and 21; USGS-PIERC, unpubl. data).

A)



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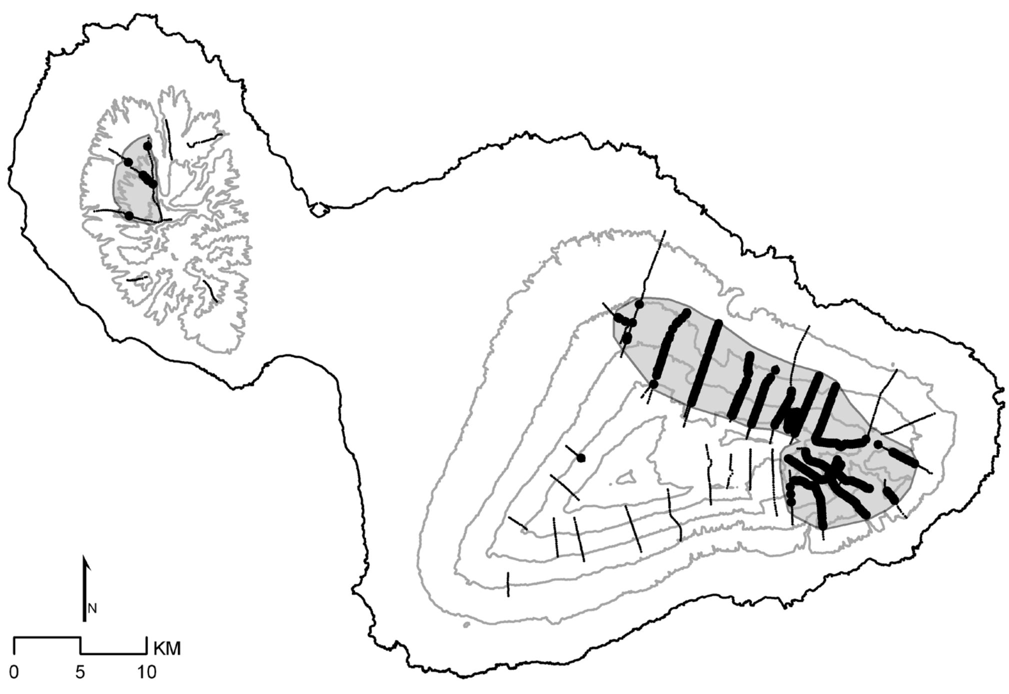
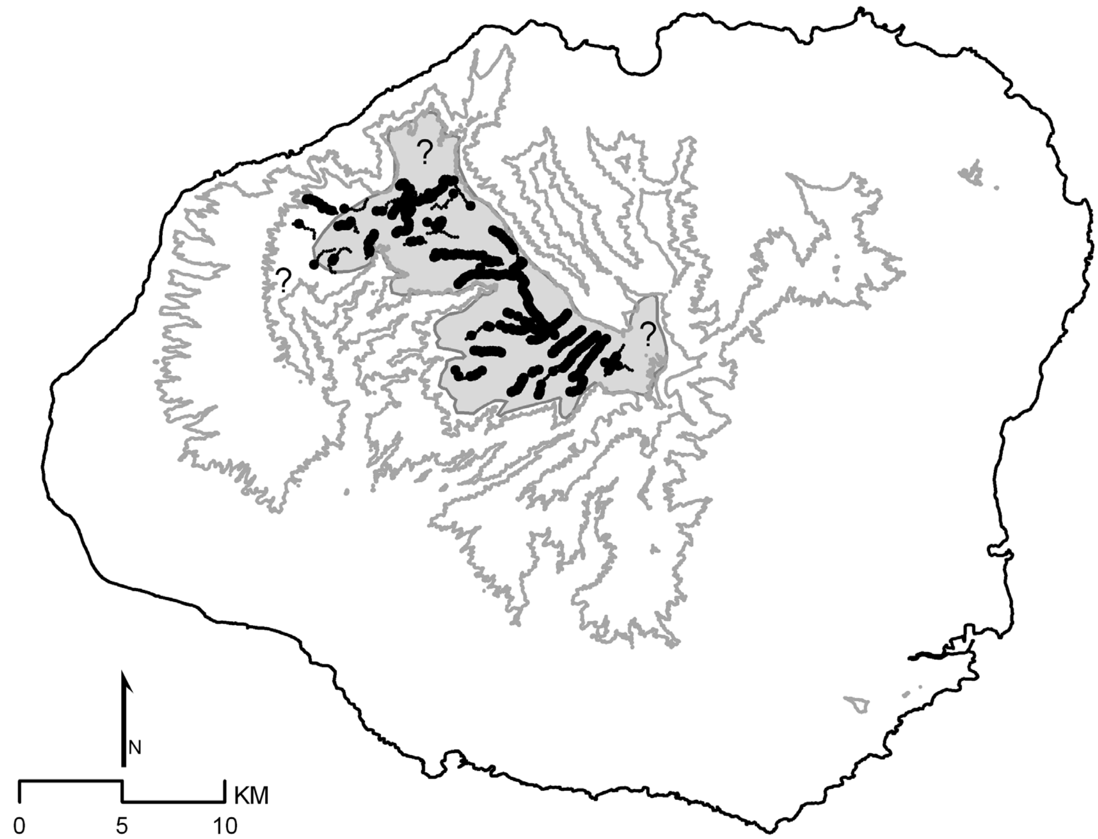


Figure 17. Survey detections (large points), locations with no detections (small points), and current range (shaded) of `I`iwi on (A) Hawai`i, (B) Maui, (C) Kaua`i and (D) Moloka`i Islands. Elevation in 500 m contours. `I`iwi distribution and range on O`ahu is described and mapped in USFWS (2006).

C)



D)

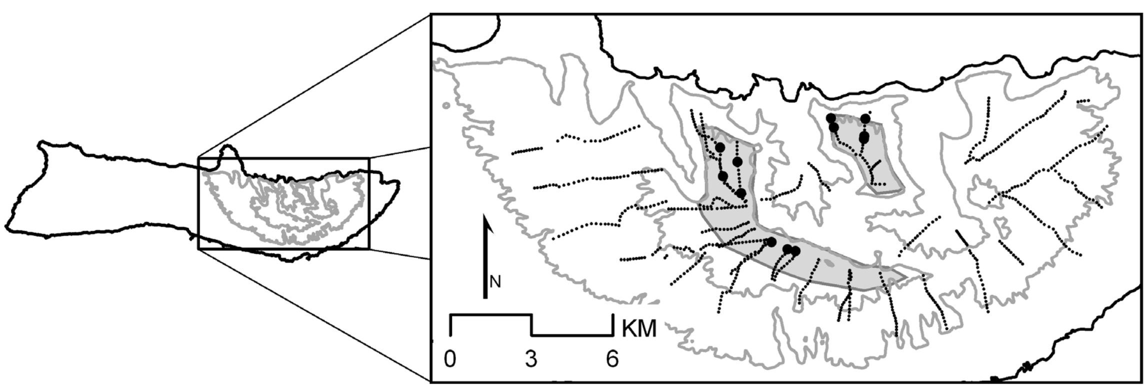


Figure 17 continued.

Table 20. \`I\`iwi population density (birds/km^2) and standard error (SE) estimates by region and time period. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented.

Survey	Year	Density	SE	No. Stations	No. Birds
Hawai\`i					
Ka\`ū >1,500m					
	1976	365.4	29.30	162	260
	1993	512.9	43.34	94	212
	2002	353.7	34.13	88	137
	2005	171.6	16.41	213	161
Ka\`ū <1,500m					
	1976	119.6	14.59	234	123
	1993	153.9	24.15	138	93
	2002	75.1	14.27	126	42
Mauna Loa Strip					
	1977-1979	51.7	9.48	79	81
	1986	54.0	8.86	39	34
	1987	32.4	6.83	43	39
	1990	112.4	15.52	65	134
	1991	106.9	15.03	51	88
	1992	73.6	10.19	59	91
	1993	59.4	9.72	61	72
	1994	44.4	8.28	53	48
Kūlani-Keauhou					
	1977	858.8	52.06	95	278
	1995-1998*	983.7	32.18	284	3,334
	2001-2003	848.8	28.46	229	1,772
\`Ōla\`a					
	1977	291.2	46.22	54	55
	1992	16.8	7.77	141	8
	1993	28.2	10.26	142	14
	1994	23.0	9.41	142	11
Hakalau Forest NWR					
	1977	1391.9	109.40	78	474
	1987	2521.9	130.63	194	747
	1988	855.8	69.15	194	999
	1989	2241.6	96.84	198	1,263
	1990	1274.1	70.20	197	1,030
	1991	1189.8	60.80	197	1,051
	1992	2135.8	96.11	197	1,329
	1993	1565.6	72.33	194	1,215
	1994	1551.1	57.39	194	1,095
	1995	1901.2	66.16	195	1,233
	1996	1616.8	59.66	198	1,120
	1997	2991.5	90.94	193	1,191
	1998	2361.5	71.79	197	1,380
	1999	1959.0	64.06	195	1,156
	2000	2379.7	89.00	198	1,247
	2001	1701.8	72.16	196	1,074

Table 20. `I`iwi population density cont.

Survey	Year	Density	SE	No. Stations	No. Birds
	2002	1611.1	68.79	195	964
	2003	1689.5	77.89	199	985
	2004	1758.4	69.81	198	1,034
	2005	1981.4	99.66	165	1,052
	2006	1592.3	76.59	162	909
	2007	777.4	63.36	147	919
Pu`u Wa`awa`a Forest Bird Sanctuary					
	1978	384.2	52.39	37	74
	1990-1991	306.6	36.78	74	153
	1996	271.7	42.76	95	128
	2003	196.4	28.87	77	75
Kona Forest NWR >1,500 m					
	1978	600.1	83.05	21	64
	1995	341.7	34.46	72	122
	1999	593.3	45.20	69	203
	2000	622.2	50.88	70	216
	2001	662.6	49.94	70	230
Kona Forest NWR <1,500 m					
	1978	323.6	52.04	43	72
	1995	218.8	42.06	106	115
	1999	111.1	19.46	138	76
	2000	134.0	22.26	140	93
South Kona					
	1978	212.1	24.64	135	144
	2003	41.8	10.41	135	28
Mauna Kea					
	1983	1.0	0.48	321	7
	1997	1.4	0.88	260	4
	1998	5.4	1.61	313	18
	1999	3.5	1.21	324	12
	2000	2.4	1.03	314	8
	2001	3.3	1.16	310	11
	2002	2.3	0.91	324	8
	2003	0.3	0.30	312	1
Maui					
East	1980	206.7	13.17	306	279
	1992-1996	556.6	22.31	497	1,505
	1997-2001	520.5	21.71	258	1,380
West					
	1980	-	-	162	7
	1997	-	-	156	4
Moloka`i					
	1979	-	-	87	12
	1988-1989	-	-	120	2
	1995	-	-	122	1

Table 20. `I`iwi population density cont.

Survey	Year	Density	SE	No. Stations	No. Birds
Kaua`i					
	1981	68.8	5.39	140	496
	1989	172.0	31.72	129	252
	1994	98.0	19.93	112	89
	2000	101.2	12.47	139	240
	2005	88.0	17.96	144	74
	2007	60.1	12.74	92	41
	2008	58.3	10.70	150	88

Based on the results of the 1977 HFBS, the population in the North and Central Windward regions (i.e., eastern Mauna Kea and northeastern Mauna Loa) was estimated at 228,034 $\pm$ 5,460 birds (Scott *et al*. 1986). Estimates for the Hakalau Forest NWR in 2007 indicate a population of 61,253 birds (95% CI = 52,437 – 72,859; Camp, Pratt *et al*. 2009). The 2007 estimate (777/km^2) is less than half that of the previous 20-year average (1,844/km^2). However, there is a wide range in observed densities that may be due to bird movement in response to nectar availability (Ralph and Fancy 1995). Extensive areas of forest habitat in the region surrounding the refuge may also harbor a large number of `I`iwi. Although the long-term trend at Hakalau Forest NWR appears stable, the species may be undergoing range contraction at low-elevation in this and other regions.

Surveys of the Kūlani-Keauhou study area in the Central Windward region detected similar densities between 1977 and 2003, and these indicate a stable population (Tables 20 and 21; Gorresen *et al*. 2005). At the drier leeward edge of the region, a 1972-1975 survey of Mauna Loa Strip in Hawai`i Volcanoes NP recorded a density of 139/km$^2$ in koa-`ōhi`a forest and scrubland between 1,500 and 2,100 m (Conant 1975). Densities between 1977 and 1994 were similar and no trends were apparent (Tables 20 and 21; Gorresen *et al*. 2005). However, surveys in the adjacent `Ōla`a tract of the Hawai`i Volcanoes NP at 1,300 m elevation have shown `I`iwi densities decreased from 291/km^2 in 1977 to less than 30/km^2 between 1992 and 1994.

`I`iwi density in forests east of Kīlauea Iki at 1,100 m was estimated at 40/km^2 in 1972-1975 (Conant 1975), but only two detections have been recorded in this area since the late 1970s (Camp *et al*. 2002; USGS-PIERC, unpubl. data). Scott *et al*. (1986) predicted densities of 10-50/km^2 down to 700 m within the Hawai`i Volcanoes NP. However, only intermittent detections have occurred below 1,100 m since the 1977 HFBS, and the species' range apparently no longer includes forest habitat below this elevation in the park and adjacent Kahauale`a NAR (Camp *et al*. 2002, Reynolds *et al*. 2003, Turner *et al*. 2006).

Based on surveys from 1976 (HFBS) to 2005, the Ka`ū region was predicted to support 78,154 $\pm$ 9,242 birds (Gorresen *et al*. 2007). `I`iwi were widespread in mid- and upper-elevation forest habitat in Ka`ū. Encouragingly, `I`iwi also occurred in moderate numbers at lower elevations, particularly in the drier northeastern part of the Ka`ū region. For example, density in 2002 was higher in forest above 1,500 m than below this elevation (Table 20), yet as many as 31,000 birds (40% of predicted total) were projected to occur below 1,500 m. Despite this, the `I`iwi densities both above and below 1,500 m were greater in 1976 compared to the most recent surveys (Table 21).

Table 21. Trends in regional `I`iwi densities. The null hypothesis that density in each region has not changed over time was tested with a z-test or, for the Mauna Loa Strip and Mauna Kea regions, with a regression test. Equivalence tests were used to determine if the difference/slope (slope in italics) was within the threshold bounds (-0.0285, 0.0170) of a 50% change in density. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LEL and UEL = Lower and Upper Equivalence Level *p*-values. Trends at Hakalau Forest NWR and Kaua`i were assessed from Bayesian posterior probabilities using a 25% change in densities over 25 years, corresponding to an annual rate of change with a threshold lower bound of $\varphi_l = -0.0199$ and upper bound of $\varphi_u = 0.0093$. Trends were interpreted as increasing, decreasing, stable or increasing, stable or decreasing, stable, or inconclusive.

Survey	Years	Diff/Slope	SE	LCL	UCL	LEL	UEL	LEL *p*	UEL *p*	Result
Hawai`i										
Ka`ū >1,500m										
	29	-193.75	33.58	-248.99	-138.51	-202.61	220.98	1.000	0.791	stable or decreasing
Ka`ū <1,500m										
	26	-44.44	20.40	-78.01	-10.88	-61.49	62.84	1.000	0.816	stable or decreasing
Mauna Loa Strip										
	17	*0.02*	0.03	-0.03	0.07	-0.03	0.03	0.958	0.599	inconclusive
Kūlani-Keauhou										
	25	-10.01	59.33	-107.60	87.58	-429.37	429.36	1.000	1.000	stable
`Ōla`a										
	17	-268.19	47.17	-345.79	-190.59	-107.74	90.37	1.000	0.000	decreasing
Pu`u Wa`awa`a Forest Bird Sanctuary										
	25	-187.81	59.82	-286.21	-89.41	-192.10	192.10	1.000	0.529	stable or decreasing
Kona Forest NWR >1,500m										
	23	0.00	0.01	-0.01	0.01	-0.03	0.03	1.000	1.000	stable
Kona Forest NWR <1,500m										
	22	-189.62	56.60	-282.73	-96.51	-147.14	137.79	1.000	0.180	decreasing
South Kona										
	25	-170.28	26.75	-214.28	-126.28	-106.05	106.04	1.000	0.008	decreasing
Mauna Kea										
	20	*0.02*	0.04	-0.05	0.08	-0.03	0.03	0.881	0.634	inconclusive

Table 21. Trends in regional `I`iwi densities cont.

Survey	Years	Diff/Slope	SE	LCL	UCL	LEL	UEL	LEL p	UEL p	Result
Maui East										
	19	313.72	25.39	271.95	355.48	-83.81	73.47	1.000	0.000	increasing

Survey	$\hat{\beta}$ (95% credible interval)	Declining $P\ \hat{\beta} < \varphi_l$	Negligible $P\ \varphi_l < \hat{\beta} < \varphi_u$	Increasing $P\ \hat{\beta} > \varphi_u$	Result
Hakalau Forest NWR	*-0.0011* (-0.0037—0.0015)	0	1.000	0	stable
Kaua`i	*0.0023* (-0.0021—0.0067)	0	0.999	0.001	stable

`I`iwi had a fairly continuous distribution spanning the Kona region and a population estimated at 52,008 ± 1,875 individuals (Scott *et al*. 1986). However, surveys between 1978 and 2003 indicate a decline in `I`iwi in the Pu`u Wa`awa`a Forest Bird Sanctuary (Tables 20 and 21). In central Kona, densities at upper elevations (≥1,500 m) in the KFU-Hakalau Forest NWR were stable between 1978 and 2001. In contrast, densities in the lower part of the refuge (500-1,500 m) have decreased since the 1978 HFBS. `I`iwi densities in south Kona have also shown a marked decline between 1978 and 2003.

On Maui, the species is found in two disjunct populations (Scott *et al*. 1986). Based on the 1980 HFBS, the west Maui population was estimated to number 176 ± 74 birds and was restricted to 16-km^2 of habitat on northwestern Pu`u Kukui about 30 km from the eastern population. Scott *et al*. (1986) noted that the prevalence of incidental observations over the previous 20 years suggests that the population was stable. However, detections in the 1990s were minimal and indicate a very small population that is unlikely to persist. The population on east Maui occurs on the windward slopes of Haleakalā and was estimated at 18,812 ± 1,006 in 1980 (Scott *et al*. 1986). Trends from 1980 to 2001 were equivocal and demonstrated either increasing densities or large-scale foraging movements (Tables 20 and 21). Extrapolating the current density to species' range (207-km^2) yields a population of 107,744 ± 4,451 birds.

The `I`iwi population on Kaua`i appears to be declining in the interior of the Alaka`i Plateau (Table 21). Based on surveys during 1968-1973, a population of 7,800 ± 2,300 birds was estimated for the 25-km^2 area in the eastern Alaka`i Wilderness Preserve (Scott *et al*. 1986). `I`iwi trends have been markedly negative following the 1981 HFBS survey, and as of 2008 densities were only 58/km^2 (Table 20) and the range of the island-wide population appeared to be contracting upslope (Foster *et al*. 2004). Projecting the 2008 density (41/km^2; VanderWerf *et al*. in prep.) to the species' 101-km^2 range produces a population estimate of 4,181 ± 646 birds.

Twelve `I`iwi were detected during the 1979 HFBS of Moloka`i, and based on these results, Scott *et al*. (1986) estimated 80 ± 33 birds distributed at low densities on the Kamakou Range and Oloku`i Plateau. However, surveys between 1988 and 2004 detected very few birds (for example, three in 2004; Table 20; USGS-PIERC unpubl. data), and indicate that the island population may be nearly extirpated (Reynolds and Snetsinger 2001).

The species' precipitous decline on O`ahu was evident by the early 1900s (Fancy and Ralph 1998). A 1991 survey failed to detect a single bird (Conry 1991), and surveys between 1994 and 1996 recorded only eight `I`iwi dispersed in three isolated areas in the Wai`anae and Ko`olau ranges (VanderWerf and Rohrer 1996, Fancy and Ralph 1998). Estimated to number <50 birds in 1991 (Ellis *et al*. 1992), the island population faces imminent extinction.

`Ākohekohe

The `Ākohekohe (*Palmeria dolei*), or Crested Honeycreeper, is an endangered, nectarivorous Hawaiian honeycreeper restricted to a 58 $km^2$ area of wet and mesic native forest above 1,100 m (Berlin and VanGelder 1999). Extirpated from Moloka`i, `Ākohekohe now occur only on the northeastern slope of Haleakalā on Maui (Figure 18). Although `Ākohekohe densities have increased since the HFBS, the species remains restricted to about five percent of its original range on Maui.

The population was estimated at 3,753 ± 373 individuals in 1980 (Scott *et al*. 1986). Subsequent surveys have covered the entire `Ākohekohe range and yielded higher densities (Tables 10 and 11). Extrapolating the 1997-2001 average density to the species' range yields a population of 6,745 ± 1,546 individuals. Surveys in the core of the species' range (i.e., Hanawī Natural Area Reserve) during 1980 and 1995-1997 also recorded increasing densities (183 and

289/km^2, respectively; Scott *et al*. 1986, Simon *et al*. 2002), and support the conclusion of range-wide increases in `Ākohekohe densities.

`Apapane

The `Apapane (*Himatione sanguinea*) is a nectarivorous Hawaiian honeycreeper found on all the major Hawaiian Islands. The species is common and widespread in native forests from near sea level to treeline, with the greatest densities found in koa-`ōhi`a forests (Figure 19; Scott *et al*. 1986, Fancy and Ralph 1997). `Apapane move extensively in response to seasonal and patchy distribution of `ōhi`a flowers, and local densities fluctuate accordingly (Fancy and Ralph 1997). `Apapane densities have markedly increased or remained stable throughout much of its range, and individuals are routinely detected at low-elevations (<250 m) on most islands.

`Apapane are distributed as a single fairly contiguous population on Hawai`i Island, with the exception of a disjunct population on Kohala Mountain (Scott *et al*. 1986) which was estimated at 20,374 ± 1,737 birds in 1979. The region has not been surveyed subsequently and the species' current status there is unknown. NAR staff routinely detect `Apapane above 1,200 m on Kohala Mountain and indicate that the species remains widespread and common in moderate to tall stature native forest but are virtually absent from the stunted lower stature forest and bogs (N. Agorastos and L. Hadway, pers. comm.). A small number of birds (~200) periodically forage in māmane woodland on Mauna Kea, and densities fluctuate widely (Table 22).

The forested windward slopes of eastern Mauna Loa and Mauna Kea were predicted to harbor 408,852 ± 8,881 individuals during the 1977-1979 HFBS (Scott *et al*. 1986). Although densities in the Hakalau Forest NWR have remained stable since 1987, the 1987-2007 average was twice that recorded during the 1977 HFBS (Tables 22 and 23). `Apapane density is almost twice as high in the Central Windward region (i.e., east Mauna Loa) than recorded during early surveys, and the population may now be sizeable. A 1972-1975 survey of forest habitat at 1,700 m in the Keauhou Ranch and Kīlauea FR recorded `Apapane at an average density of 1,651/km^2 (Conant 1975) and surveys between 1977 and 2003 in this area recorded increasing densities (Gorresen *et al*. 2005). In contrast, densities at 1,300 m in the adjacent `Ōla`a tract of the Hawai`i Volcanoes NP decreased between 1977 and 1994.

At the drier leeward edge of the Central Windward region in the Mauna Loa Strip tract of the Hawai`i Volcanoes NP, a 1972-1975 survey detected `Apapane densities of 365/km^2 in koa-`ōhi`a kipuka forest and pioneer `ōhi`a scrub between 1,500 and 2,100 m (Conant 1975). The 1977-1979 HFBS detected a density of 295/km^2, and surveys between 1986 and 1994 recorded similar densities and showed no apparent trend (Tables 22 and 23; Gorresen *et al*. 2005).

Based on the 1979 HFBS a population of 132,023 ± 3,452 `Apapane was predicted to occur in the East Windward region (i.e., Puna; Scott *et al*. 1986). During this period, `Apapane were detected at a density of 1,016/km^2 in the Kahauale`a NAR and adjacent Hawai`i Volcanoes NP (Table 22). Surveys from 1993 to 1994 detected birds at a lower density (Gorresen *et al*. 2005); however, this should be interpreted with caution because large-scale foraging movements may bias density estimates.

The Ka`ū population was estimated at 491,928 ± 23,966 birds as of 2005 (Gorresen *et al*. 2007), occurring at relatively high densities at both high- and mid-elevations. For example, the density in 2002 above and below 1,500 m was 1,778 and 1,059/km^2, respectively (Table 22). About 200,000 individuals (40%) of the predicted population size were projected to occur between 700-1,500 m. The densities observed above 1,500 m in 1976 and 2005 are not significantly different and abundance below 1,500 m appears to have increased (Table 23).

`Apapane are distributed on leeward Hawai`i Island from the north slope of Hualālai Mountain to south Kona. The Kona region was estimated to support 225,338 ± 5,125 birds in

1978 (Scott *et al*. 1986), but subsequent surveys have recorded higher densities. Nevertheless, only a small portion of this region has been resampled. Trends in density have been generally stable or increasing where resurveyed, and `Apapane appear abundant at both high and mid-elevations (Tables 22 and 23).

`Apapane populations on west and east Maui in 1980 were estimated at 15,825 ± 1,129 and 93,818 ± 3,511 birds, respectively (Scott *et al*. 1986). The west Maui population occurs in 41-km$^2$ of forest habitat on northwest Pu`u Kukui. Surveys on west Maui detected similar densities in 1980 and 1997 and indicate a stable population (Tables 22 and 23). Extrapolating the current density (501/km^2) to species' range yields a population of 20,521 ± 1,687 individuals. The eastern population is distributed in a 370-km^2 area spanning the wet windward and dry southern slopes of Haleakalā (Scott *et al*. 1986). Surveys of east Maui between 1980 and 2001 suggest that the population has increased. Extrapolating the current density (2,207/km^2) in east Maui to the species' range yields a population of 816,590 ± 19,477 individuals.

`Apapane still persist on Moloka`i, Lāna`i, and O`ahu despite the high rates of native bird extinction on those islands (Pratt 1994). Based on the 1979 HFBS, east Moloka`i was estimated to support 38,643 ± 2,360 individuals (Scott *et al*. 1986). Densities have increased in upland forest and recent detections below 250 m may indicate a larger range than previously realized (Atkinson and LaPointe 2009). The `Apapane is the only honeycreeper remaining on Lāna`i (Walther 2006), and the remnant population was estimated at 540 ± 213 birds in 1979 (Scott *et al*. 1986). Lāna`i has not been surveyed since and the current status, and population trend is unknown, although the species is still present (F. Duvall, pers. comm.). On O`ahu in 1991, `Apapane occurred at low densities but were fairly widespread, particularly at mid-elevations in the leeward Ko`olau range (Shallenberger and Vaughn 1978; Table 22). They were absent from the northern Wai`anae Range but present in the southern part of the range (Table 22). Extrapolation of the observed densities to occupied habitat in the Ko`olau range (~200 km$^2$) and the south Wai`anae region (~11 km^2) yielded estimated populations of about 24,000 ± 2,600 and 715 ± 385 birds, respectively.

`Apapane are widely distributed above 1,000 m on Kaua`i and were estimated at 163,147 ± 11,411 individuals from surveys conducted in 1968-1973 (USFWS 1983). Surveys in a 25-km^2 area in the eastern Alaka`i Wilderness Preserve detected significantly increasing trends since 1981 (HFBS; Tables 22 and 23). Foster *et al*. (2004) speculate that `Apapane were initially adversely affected by Hurricane Iniki in 1992 but now appear to be recovering. Projecting the 2008 density (859/km^2; VanderWerf *et al*. in prep.) to the species' 379-km^2 range produces a population estimate of 325,447 ± 15,6804 birds on Kaua`i.

Po`ouli.

The Po`ouli (*Melamprosops phaesoma*) is a critically endangered honeycreeper discovered a mere 36 years ago, at which time the species was rare and confined to a single area of wet `ōhi`a forest above 1,400 m on windward Haleakalā Volcano, Maui (Casey and Jacobi 1974). Po`ouli forage on tree branches of the subcanopy and understory and feed primarily on small snails, insects, and spiders (Pratt *et al*. 1997). Based on three birds detected during the 1980 HFBS survey, a population of 141 ± 141 individuals was estimated to occur within a range of 13 km^2 (Scott *et al*. 1986). However, the species has undergone a dramatic decline and now may be extinct. Six birds were detected during intensive searches in 1994–1995, and only three birds were located between 1997 and 2000 (Pratt *et al*. 1997; Reynolds and Snetsinger 2001). Attempts to bring these birds into captivity were unsuccessful. The species was last seen in 2004 (Groombridge 2009).

Table 22. `Apapane population density (birds/km^2) and standard error (SE) estimates by region and time period. Sampling effort (number of stations surveyed) and number of birds used to estimate densities are presented.

Survey	Year	Density	SE	No. Stations	No. Birds
Hawai`i					
Ka`ū >1,500m					
	1976	1329.0	61.67	162	993
	1993	2231.0	108.87	94	967
	2002	1778.4	79.67	88	721
	2005	1445.0	53.61	213	1,417
Ka`ū <1,500m					
	1976	505.8	32.12	234	545
	1993	1441.9	62.00	138	918
	2002	1058.9	55.59	126	614
Mauna Loa Strip					
	1977-1979	295.4	26.89	79	401
	1986	295.8	24.59	39	153
	1987	190.6	22.82	43	187
	1990	366.6	33.92	65	353
	1991	291.7	29.25	51	196
	1992	304.9	29.92	59	300
	1993	247.0	20.74	61	255
	1994	282.8	30.54	53	265
Kūlani-Keauhou					
	1977	1923.6	80.73	95	670
	1995-1998*	2443.0	51.63	284	8,764
	2001-2003	2834.6	56.26	229	6,214
`Ōla`a					
	1977	1869.9	126.53	54	386
	1992	200.4	29.86	141	103
	1993	745.9	61.40	142	392
	1994	691.8	82.71	142	358
East Rift					
	1979	1016.4	43.57	99	894
	1993-1994	643.7	31.31	158	848
Hakalau Forest NWR					
	1977	480.7	49.37	78	216
	1987	1440.5	69.14	194	907
	1988	384.0	46.00	194	448
	1989	1009.9	60.29	198	943
	1990	657.4	44.25	197	826
	1991	697.0	41.12	197	916
	1992	1337.1	54.82	197	1,317
	1993	762.3	56.87	194	982
	1994	478.5	30.57	194	688
	1995	590.2	31.10	195	799
	1996	599.3	32.54	198	775
	1997	1107.2	61.45	193	691

Table 22. `Apapane population density cont.

Survey	Year	Density	SE	No. Stations	No. Birds
	1999	1001.1	51.76	195	936
	2000	1162.5	54.41	198	971
	2001	972.2	48.51	196	879
	2002	982.0	51.95	195	899
	2003	1222.6	62.35	199	959
	2004	748.4	37.95	198	780
	2005	1005.8	73.02	165	751
	2006	788.9	43.23	162	760
	2007	482.2	36.99	147	718
Pu`u Wa`awa`a Forest Bird Sanctuary					
	1978	977.8	125.13	37	132
	1990-1991	1486.5	92.27	74	530
	1996	1236.6	92.71	95	401
	2003	1038.6	81.15	77	273
Kona Forest NWR >1,500 m					
	1978	258.1	72.82	21	19
	1995	1550.2	115.95	72	381
	1999	2984.7	130.74	69	703
	2000	2188.8	83.61	70	523
	2001	2490.1	127.68	70	595
Kona Forest NWR <1,500 m					
	1978	279.3	43.55	43	41
	1995	2252.4	88.98	106	815
	1999	3080.2	86.56	138	1,468
	2000	2370.8	56.26	140	1,133
South Kona					
	1978	1299.8	80.63	135	629
	2003	1382.3	76.74	135	637
Mauna Kea					
	1983	0.2	0.16	321	2
	1997	8.3	1.92	260	30
	1998	2.7	0.84	313	12
	1999	6.0	1.27	324	27
	2000	12.0	2.23	314	53
	2001	24.7	3.39	310	107
	2002	12.4	1.94	324	56
	2003	4.4	1.17	312	19
Maui					
East	1980	1088.1	46.99	306	936
	1992-1996	2745.9	73.23	497	4,712
	1997-2001	2207.4	52.64	258	3,451
West					
	1980	465.8	35.46	162	317
	1997	500.5	41.14	156	328

Table 22. `Apapane population density cont.

Survey	Year	Density	SE	No. Stations	No. Birds
Moloka`i					
	1979	778.4	60.41	87	202
	1988-1989	1444.3	70.37	120	759
	1995	1989.4	86.79	122	811
O`ahu					
Ko`olau Range					
	1991	121.4	13.16	210	200
North Wai`anae Range					
	1991	-	-	21	0
South Wai`anae Range					
	1991	65.2	35.04	10	5
Kaua`i					
	1981	498.5	35.09	140	2,340
	1989	610.8	40.80	129	1,170
	1994	520.0	75.55	112	562
	2000	910.5	31.96	139	1,441
	2005	1291.6	83.82	144	498
	2007	964.1	55.05	92	397
	2008	1015.3	58.89	150	656

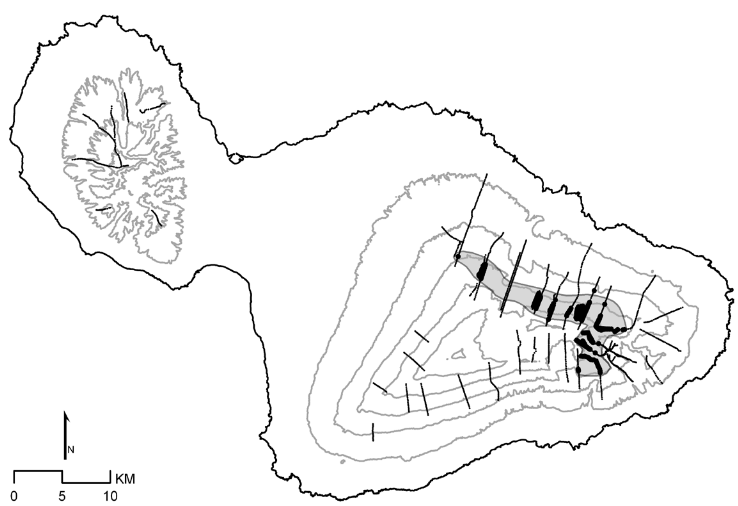


Figure 18. Survey detections (large points), locations with no detections (small points), and current range (shaded) of `Ākohekohe on Maui Island. Elevation in 500 m contours.

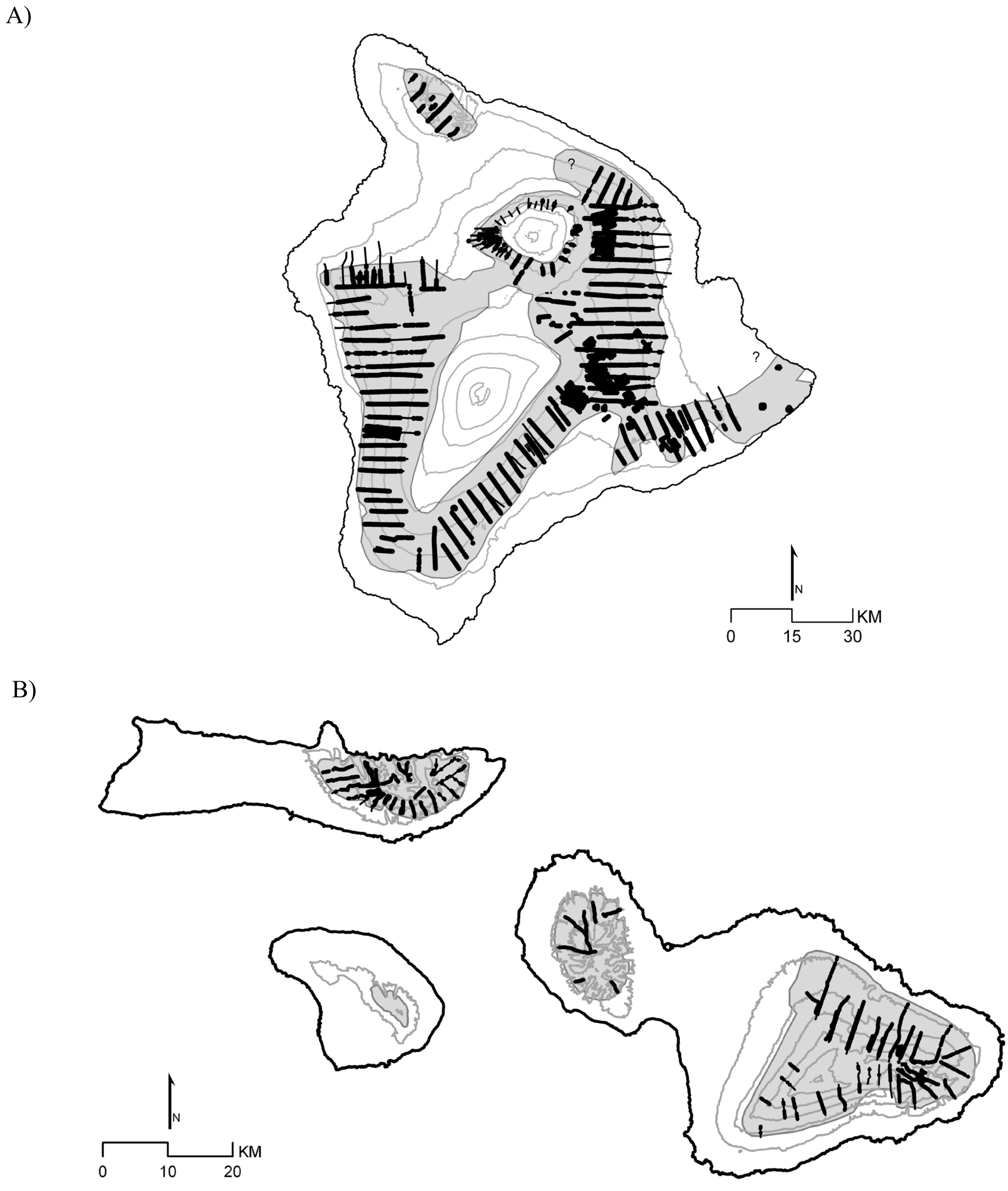
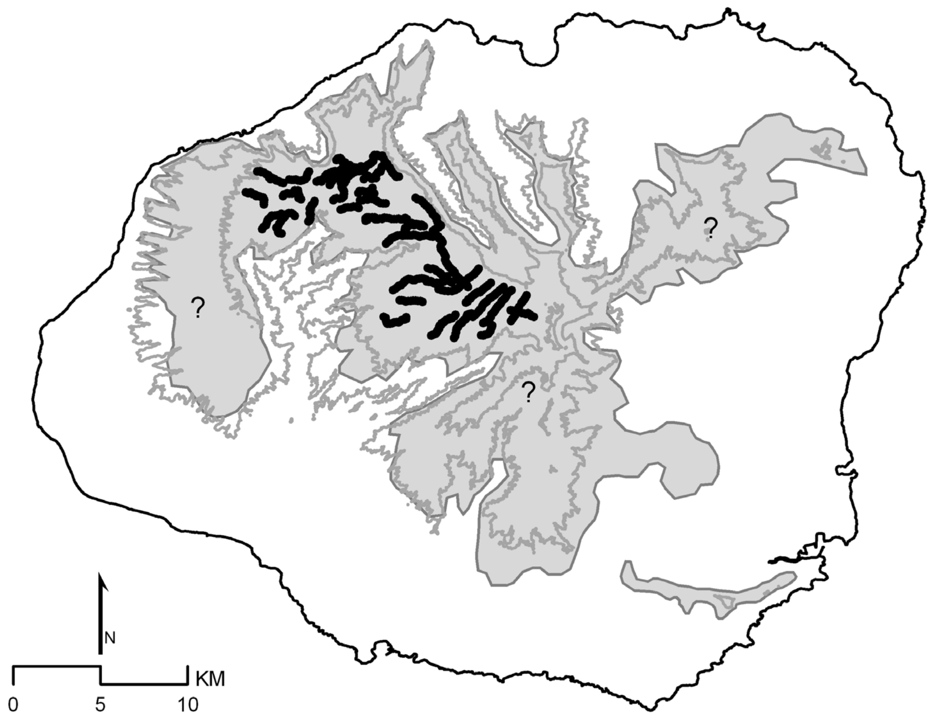


Figure 19. Survey detections (large points), locations with no detections (small points), and current range (shaded) of `Apapane on (A) Hawai`i, (B) Maui, Lāna`i and Moloka`i, (C) Kaua`i, and (D) O`ahu Islands. Elevation in 500 m contours.

C)



D)

Figure 19 continued.

Table 23. Trends in regional `Apapane densities. The null hypothesis that density in each region has not changed over time was tested with a z-test or, for the Mauna Loa Strip and Mauna Kea regions, with a regression test. Equivalence tests were used to determine if the difference/slope (slope in italics) was within the threshold bounds (-0.0285, 0.0170) of a 50% change in density. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LEL and UEL = Lower and Upper Equivalence Level *p*-values. Trends at Hakalau Forest NWR and Kaua`i were assessed from Bayesian posterior probabilities using a 25% change in densities over 25 years, corresponding to an annual rate of change with a threshold lower bound of $\varphi_l = -0.0199$ and upper bound of $\varphi_u = 0.0093$. Trends were interpreted as increasing, decreasing, stable or increasing, stable or decreasing, stable, or inconclusive.

Survey	Years	Diff/Slope	SE	LCL	UCL	LEL	UEL	LEL *p*	UEL *p*	Result
Hawai`i										
Ka`ū >1,500m	29	116	81.71	-18.41	250.41	-736.98	803.82	1	1	stable
Ka`ū <1,500m	26	553.07	64.2	447.45	658.69	-260.11	265.83	1	0	increasing
Mauna Loa Strip	17	*0*	0.01	-0.02	0.02	-0.03	0.03	0.996	0.994	stable
Kūlani-Keauhou	25	911.03	98.4	749.17	1072.9	-961.77	961.73	1	0.697	stable or increasing
`Ōla`a	17	-1178.12	151.17	-1426.8	-929.45	-691.91	580.32	1	0	decreasing
East Rift	15	-372.71	53.65	-460.96	-284.45	-338.02	271.19	1	0.029	decreasing
Pu`u Wa`awa`a Forest Bird Sanctuary	25	60.82	149.15	-184.52	306.17	-488.9	488.88	1	0.998	stable
Kona Forest NWR >1,500m	23	0.08	0.03	0.03	0.13	-0.03	0.03	1	0.039	increasing
Kona Forest NWR <1,500m	22	2091.49	71.15	1974.45	2208.53	-127.02	118.95	0	1	increasing
South Kona	25	82.46	111.31	-100.64	265.56	-649.9	649.88	1	1	stable
Mauna Kea	20	*0.09*	0.09	-0.07	0.24	-0.03	0.03	0.887	0.275	inconclusive
Maui										
East	19	1119.29	70.57	1003.2	1235.37	-441.09	386.68	0	1	increasing
West	17	34.7	54.31	-54.65	124.05	-172.36	144.56	0.994	1	stable
Moloka`i	16	1211.08	105.75	1037.12	1385.04	-273.65	224.48	1	0	increasing

DISCUSSION

Twenty-five years have elapsed since a complete status appraisal of the Hawaiian forest birds, while during that period much effort has been devoted to bird conservation. These accomplishments include management of forest bird habitat (Banko *et al*. 1992), revised recovery plans (U.S. Fish and Wildlife Service 2003, 2006), establishment of captive breeding facilities and reintroduction programs (Lieberman and Kuehler 2009), implementation of predator control (i.e., VanderWerf and Smith 2002, VanderWerf in press), and continued monitoring of forest bird populations (this study). How have native forest birds fared in these changing times? Have we done an adequate job measuring their populations, and if not, how can we improve monitoring?

Patterns in Status and Trends

When quantitative bird surveys were first begun in Hawai`i in the late 1960s, 14 forest bird species were considered at high risk of extinction, and probably most existed in populations of fewer than 500 individuals each. Their present status is, with a few exceptions, very disheartening. Eleven of these species—Kaua`i `Ō`ō, Bishop's `Ō`ō, Kāma`o, Oloma`o, `Ō`ū, Kaua`i Greater `Akialoa, Nukupu`u (both Kaua`i and Maui forms), O`ahu `Alauahio, Kākāwahie, Maui `Ākepa, and Po`o-uli—are almost certainly extinct. The hope for these birds is that they will be rediscovered in a remote corner of the Hawaiian wilderness through perseverance, targeted searches, and luck (Groombridge 2009). In preparation for such an event, a "Rare Bird Discovery Protocol" has been established that calls for intensive field data collection, multiple agency coordination, and immediate intervention (U.S. Fish and Wildlife Service 2006).

Two of the highest-risk bird species are still extant today, although their futures are by no means secure: the `Alalā and Puaiohi. Captive propagation has stabilized the `Alalā population following rapid decline and extirpation in the wild. `Alalā recovery exemplifies the need for captive propagation and reintroduction to be undertaken in the context of habitat conservation (Banko 2009). Finding and securing high-quality habitat is currently a significant challenge. On a brighter note, recent surveys for Puaiohi in their remote streamside habitat have shown that members of the species are more numerous and widespread than previously thought, though still fewer than 500 birds. Captive breeding and release are also improving the prospects for Puaiohi recovery (Woodworth *et al*. 2009).

The status of six other imperiled species or subspecies numbering between 500 and 5,000 individuals is mixed (Figure 20, Table 1). The O`ahu `Elepaio, Palila, Maui Parrotbill, `Akiapōlā`au, `Akikiki, and `Ākohekohe demonstrate some or all of the hallmarks of endangered species: small population size, declining densities and population size, restricted distribution, contracting range, and isolated subpopulations. These species are listed as endangered by the USFWS or the IUCN and are the focus of ongoing efforts at ameliorating threats and the risk of extinction. Experimental rat eradication to reduce nest predation rates appears effective at reducing demographic decline and stabilizing local populations of O`ahu `Elepaio (VanderWerf and Smith 2002, VanderWerf in press). The Palila population on west Mauna Kea appears to have benefited from ungulate control, habitat restoration, and predator reduction (Banko *et al*. 2001, 2009), although poorly understood recent declines in abundance are cause for concern (Leonard *et al*. 2008). Captive propagation, bird translocation, and the establishment of a resident group separate from the core population are being pursued as means of reducing the vulnerability of the species to catastrophic events such as fire (Banko *et al*. 2009). Maui Parrotbill and `Ākohekohe recovery centers on the protection of native high-elevation forests from the destructive effects of feral pigs, the reforestation of montane pastures on Maui, and the proposed establishment of additional populations by means of captive propagation and translocation (U.S. Fish and Wildlife

Service 2006). Recent observations of `Akiapōlā`au using young koa at the Hakalau Forest NWR and on plantations at the Kamehameha Schools' Keauhou Ranch indicate that forest restoration of pastures above 1,500 m and near existing `Akiapōlā`au populations may significantly contribute to the recovery of this species (Pratt *et al*. 2001, Pejchar *et al*. 2005, Camp, Pratt *et al*. 2009, Camp, Jacobi *et al*. in press). `Akikiki recovery is complicated by the fact that although the causes for its decline have not been identified, two hurricanes in the past 25 years have toppled much of the species' foraging substrate (Foster *et al*. 2004). However, the development of captive propagation and reintroduction techniques for the Hawai`i Creeper may serve as a model for use with the `Akikiki.

The Hawai`i Creeper, Maui `Alauahio, `Akeke`e, and Hawai`i `Ākepa have populations greater than 5,000 individuals (Figure 21, Table 1) but remain vulnerable to a variety of threats and are also listed as endangered by the USFWS or the IUCN. Hawai`i Creeper and Hawai`i `Ākepa populations are stable or increasing in the larger tracts of high-elevation forest habitat in north windward Hawai`i and Ka`ū but are diminishing in smaller, more fragmented, disturbed habitats in central Kona and Hualālai. Reducing disease transmission and restoring high-elevation forests would benefit these endangered species (U.S. Fish and Wildlife Service 2006). Densities of Maui `Alauahio and `Akeke`e appear stable, but the range of the `Akeke`e has contracted. Both continue to be threatened by the encroachment of exotic plants, ungulates, and the upward spread of disease driven by global warming (Lepson and Pratt 1997, Baker and Baker 2000, Benning *et al*. 2002). These species are expected to respond well to ungulate removal and habitat restoration above elevations harboring mosquitoes.

The Hawai`i `Elepaio, `Ōma`o, and `I`iwi are not listed as endangered by the USFWS but are nevertheless considered species of concern. These species have large populations but are experiencing range contraction and negative trends in many parts of their ranges (Figure 22, Table 1). The `I`iwi in particular, with its bright scarlet plumage and long, curved, orange beak, is the "poster child" for Hawaiian forest birds susceptible to malaria. Fully 90% of `I`iwi bitten by a single infected mosquito perish from the disease (Atkinson *et al*. 1995), and this susceptibility is widely considered the cause of the limited distribution and gradual decline in `I`iwi numbers (Atkinson and LaPointe 2009). The creation of high-elevation refugia may not be sufficient to safeguard the bird. `I`iwi, like the closely related `Apapane, make seasonal foraging flights over the landscape in search of nectar, and these flights often bring them into contact with mosquitoes at lower elevations. Furthermore, expansion of avian malaria into higher-elevation habitats through introduction of cold-tolerant mosquitoes, land-use changes, and global warming may well spell disaster for this familiar bird.

Six Hawaiian forest bird species with large populations show stable or improving trends (Figure 23, Table 1). These include the Kaua`i `Elepaio, three species of `amakihi, the `Anianiau, and the `Apapane. In contrast to the status of `Elepaio subspecies on O`ahu and parts of Hawai`i Island, the Kaua`i `Elepaio population appears to be increasing. The long-term prospects for this adaptable subspecies much depend on the degree to which it can withstand habitat degradation and the threats associated with alien introductions. Likewise, `Anianiau density has increased considerably on Kaua`i in the past several decades. The three `amakihi species share several traits that bode well for the long-term survival of this group, including generalized habitat requirements, flexible foraging behavior, and potential for further expansion into lowland areas. The `Apapane remains widespread and common in native forests, and the species exhibits increasing trends throughout much of its range.

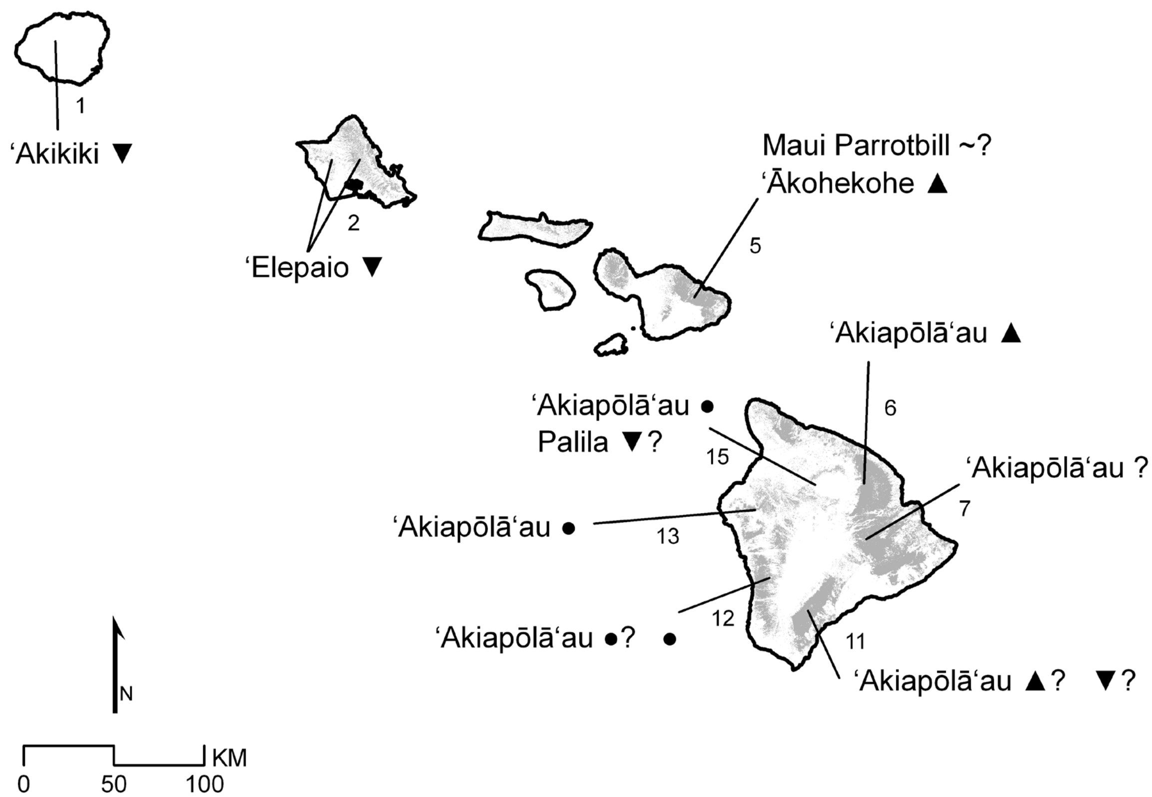


Figure 20. Population trends for forest bird species listed as endangered by either the USFWS or the IUCN (Bird Life International 2004) and with populations numbering between 500 and 5,000 individuals—O`ahu `Elepaio, Palila, Maui Parrotbill, `Akiapōlā`au, `Akikiki, and `Ākohekohe. Trends are based on current changes in estimated density, population size, and species' range. The symbols used indicate the following: ▲, increasing trend; ▼, decreasing trend; ●, absence; and ~, apparently stable population. A question mark refers to uncertainty in the trend assessment resulting from high variability in observed densities. The pair of symbols for central Kona and Ka`ū, Hawai`i Island, refer to trends below and above 1,500 m. Shading indicates areas designated as forest habitat by the National Oceanic and Atmospheric Administration, Coastal Change Analysis Program (1995). See Figures 1–3 for regional and local names and reference numbers for trend study areas.

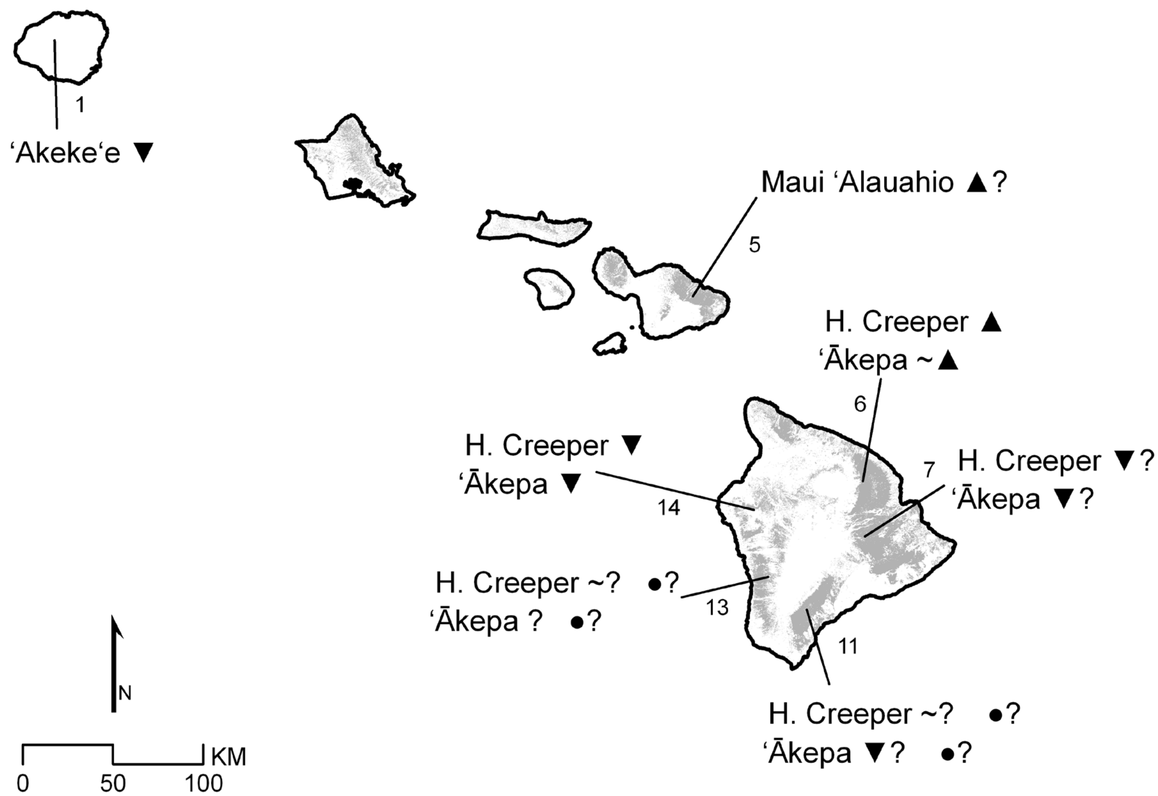


Figure 21. Population trends for forest bird species listed as endangered by either the USFWS or the IUCN (Bird Life International 2004) and with populations greater than 5,000 individuals—Hawai`i Creeper, Maui `Alauahio, `Akeke`e, and Hawai`i `Ākepa. See Figures 1–3 for regional and local names and reference numbers for trend study areas. See Figure 20 for an explanation of symbols used.

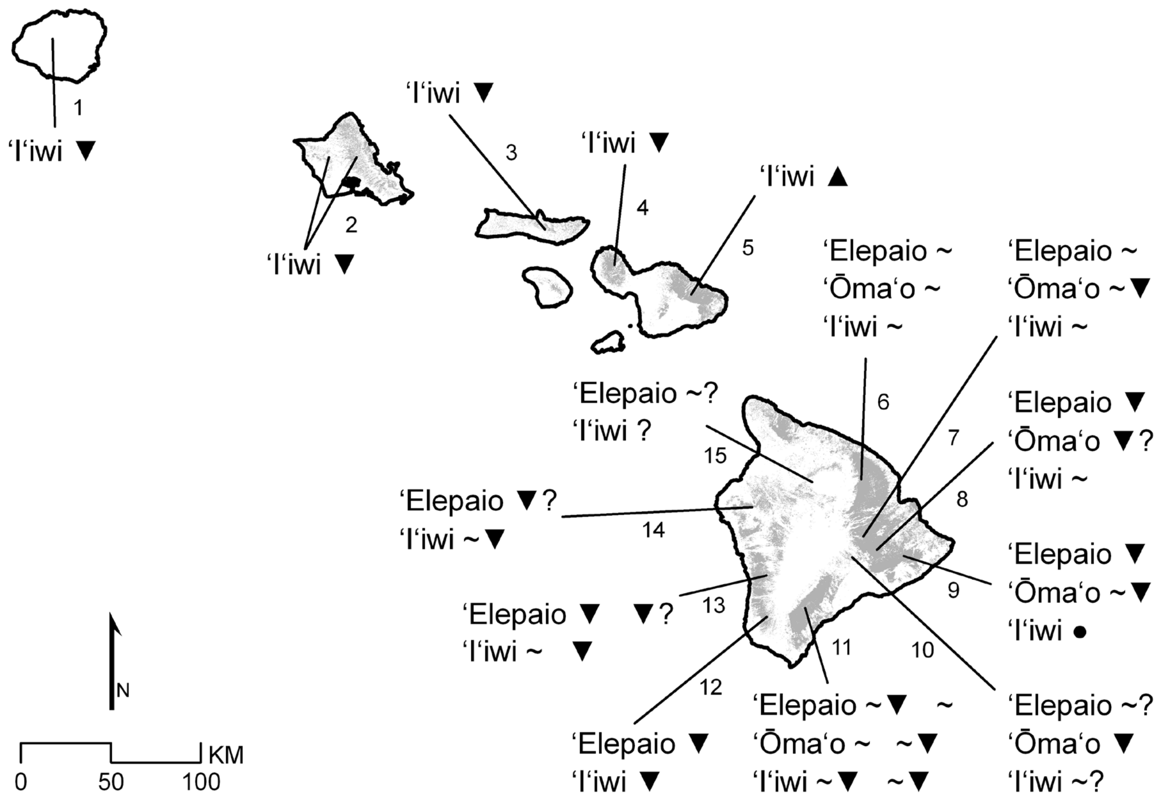


Figure 22. Population trends for forest bird species not listed as endangered by either the USFWS or the IUCN but that are nevertheless generally considered species of concern—Hawai`i `Elepaio, `Ōma`o, and `I`iwi. See Figures 1–3 for regional and local names and reference numbers for trend study areas. See Figure 20 for an explanation of symbols used.

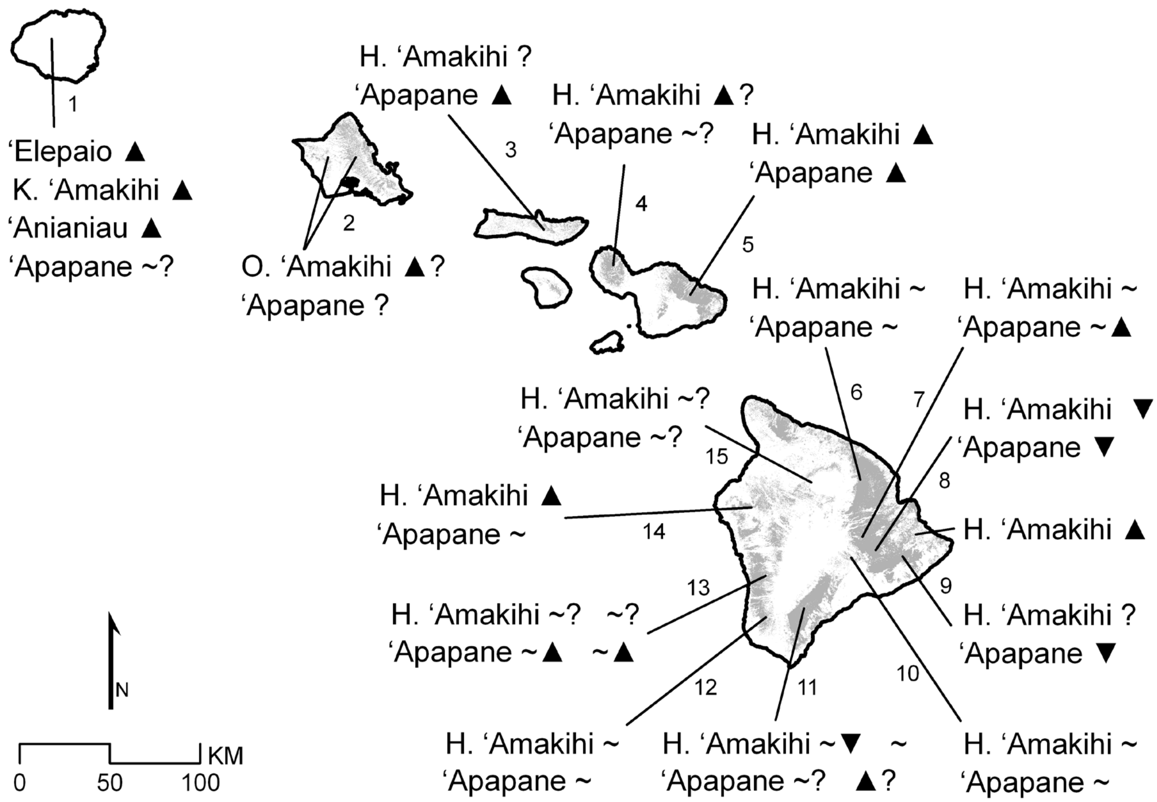


Figure 23. Population trends for forest bird species not listed as endangered by either the USFWS or the IUCN and that show stable or positive trends overall—Kaua`i `Elepaio, Hawai`i `Amakihi, O`ahu `Amakihi, Kaua`i `Amakihi, `Anianiau, and `Apapane. See Figures 1–3 for regional and local names and Figure 20 for an explanation of symbols used.

Prospects for the Future

A number of important generalities are evident from the multiplicity of species-specific trends. Notably, many native passerines, particularly endangered or special-concern species, appear to be stable or increasing in areas with large tracts of high-elevation native forest even while decreasing in more fragmented or disturbed areas at middle to low elevations. The overall result is that native birds are increasingly restricted to high-elevation forest and woodland refugia (Figures 4-19). It is these upland habitats that require intense, sustained efforts at conservation and restoration and from which long-term recovery strategies may be based. For example, the eight native species resident within the Hakalau Forest NWR—the Hawai`i `Elepaio, `Ōma`o, Hawai`i `Amakihi, `Akiapōlā`au, Hawai`i Creeper, `Ākepa, `I`iwi, and `Apapane—have shown significant increases in density or stable trends since 1987 (Camp, Pratt *et al*. 2009). The 13,252 ha refuge on windward Hawai`i was established specifically for the protection of native forest birds. Many of its management actions, particularly habitat protection, ungulate removal, and koa forest restoration, appear to be paying off.

A second notable development is the apparent persistence or recolonization of lowland forests by O`ahu `Amakihi and Hawai`i `Amakihi (Lindsey *et al*. 1998). The presence of O`ahu `Amakihi at low elevations, where avian malaria is presumably common, suggests that they may be evolving a resistance to the disease (Shehata *et al*. 2001, Atkinson and LaPointe 2009). The Hawai`i `Amakihi is breeding and even increasing in low-elevation Hawai`i despite the highest prevalence of malaria found anywhere in the islands (Woodworth *et al*. 2005), and individuals from low elevations survive the acute malaria challenge better than their high-elevation conspecifics (Atkinson and LaPointe 2009). This remarkable adaptation, however, may be eclipsed by the continued loss of much of the remaining areas of lowland native habitats to development and invasive plants. Efforts to protect high-elevation habitat must be coupled to the conservation of native habitat at lower elevations to ensure that the existing disease-tolerant genotypes evolve and retain the potential to survive as founders for recovering bird populations.

A Proposal to Improve Forest Bird Monitoring

The basis for long-term population monitoring in Hawai`i was established by the landmark Hawaii Forest Bird Survey (HFBS) of 1976-1983. It is evident that detecting meaningful population distribution, density and trends since has been difficult. These population parameters are best derived from long-term, large-scale, standardized monitoring programs. In contrast, most monitoring subsequent to the HFBS was characterized by intermittent, small-scale, and short-term surveys in most sites (a notable exception is the DOFAW surveys). In this section, we make recommendations to improve surveying of Hawaiian birds by adopting a unified, long-term monitoring program established at three levels of spatial scale (landscape, regional, and population).

Briker and Ruggiero (1998) have proposed sampling at three general levels of spatial scale. Level 1 surveys involve sampling across a species' entire regional distribution (landscape scale), which measures patterns across the entire range or region. This level is essential for understanding species' range contractions and expansions and for determining trends in species populations overall. Level 2 studies a subset of a region. Certain locations or habitats within a region may influence the region overall. For example, bird population fluctuations in Hakalau Forest NWR influence population patterns in the north windward region of Hawai`i Island. Measurements at this level are essential for understanding processes that occur at regional scales. Level 3 research, such as demography studies or monitoring response to management actions, intensively samples specific sites, providing information at a local scale. Measurements at this level are more likely to reveal the causes of changes detected at Levels 1 and 2.

In Hawai`i, Level 1 surveys include the DOFAW forest bird monitoring program with respect to endangered but not more widespread species. This program aims to survey the most important habitat, taking in the complete ranges of endangered species and the core range of common species, on all islands except Hawai`i Island, which has been only partially monitored due to its extensive size. A second example is the monitoring program for Palila, which completely surveys all of that species' range annually.

Spatial coverage by the current programs is inadequate at the landscape scale. Repeated surveying has met the criteria of Bart *et al*. (2004)—two-thirds sampling coverage—for only four of 22 Hawaiian birds (18%; see Table 4), these being the Palila, Maui Parrotbill, Maui `Alauahio, and `Ākohekohe. Increased coverage is required on all of the Hawaiian islands to sample across species' ranges.

Species that would most benefit from landscape scale surveys include the endangered Puaiohi, `Akiapōlā`au, `Akikiki, Hawai`i Creeper, `Akeke`e, and `Ākepa. Several of those birds are sampled near the two-thirds standard so expansion of the existing monitoring would be minimal. The more widespread species whose ranges appear to be declining—Hawai`i `Elepaio, `Ōma`o, and `I`iwi—or whose ranges are not currently known—O`ahu `Amakihi and `Apapane on O`ahu—could also benefit from periodic landscape scale surveys. To understand changes in the remaining widespread birds—the three species of `amakihi, `Anianiau, and `Apapane—would require sampling at much larger scales than even the HFBS. This is especially true for the `amakihi and `Apapane which are known to inhabit low-elevation native and mixed native forests. Thus, extending HFBS transects below the 600 m contour down to the coast would be required to track broad scale changes in those widespread birds.

Monitoring at the landscape scale is usually logistically constrained by limited funding and personnel; therefore, minimizing the sampling effort while maximizing the survey extent must be carefully evaluated. We suggest that surveys at the landscape scale follow a multiyear rotation scheme similar to that used by the DOFAW forest bird monitoring program. It has also been suggested that sampling for occupancy (e.g., proportion area occupied [PAO] analysis) be considered if sampling for density at the landscape scale is cost-prohibitive (MacKenzie *et al*. 2002, 2003).

Most surveys since the HFBS have covered a subset of a region with respect to each species' range on Hawai`i Island (except the Palila), and thus have been conducted at a Level 2 spatial scale. For monitoring at this scale, surveys should be conducted annually, especially if regional patterns fluctuate widely or are different. A notable Level 2 program is the one for the Hakalau Forest NWR, where annual surveys encompass the core populations (but not the range edges) of eight native forest birds. Existing and proposed monitoring programs at this level should be carefully evaluated for their contributions to understanding Level 1 processes and avian biology. A cautionary note is necessary for Level 2 monitoring: the core range needs to be delineated, and it should be unlikely to change over time.

Priorities for Level 2 monitoring would include continuation of the current programs at Hakalau Forest NWR and the Kūlani-Keauhou areas (Hawai`i) and continuation with increased frequency at Pu`u Wa`awa`a Forest Bird Sanctuary, Ka`ū and Kapāpala regions (Hawai`i), and Haleakalā National Park (Maui). We also recommend that this survey level be established to sample the remaining populations of all endangered species and species of concern (specific recommendations for survey areas appear in U.S. Fish and Wildlife Service 2006). Again, sampling across the entire range of a species, even for endangered Hawaiian birds, can be prohibitive. Urquhart and Kincaid (1999) and McDonald (2003) suggest a temporal sampling design (referred to as a panel design, where some stations are visited in some sampling occasions such as years, but not others) to optimize trend detection, spatial coverage, and sampling efficiency. This approach has merit for monitoring Hawaiian birds at the regional scale and for integrating population properties and patterns at the landscape scale.

Level 3 surveys illuminate specific population processes at a local scale and provide information on the causes of changes detected at Levels 1 and 2. Frequency of sampling is variable; however, most studies require annual or more frequent surveys. For example, Woodworth *et al*. (2001) studied the survival rate and other parameters of Hawai`i Creeper at three study sites within Hakalau Forest NWR during 1994–1999. This research provided information at Level 3 that was used to corroborate increases in population density within Hakalau Forest NWR (Level 2; Woodworth *et al*. 2001) and adjoining regions (Level 1; Camp, Pratt *et al*. 2009). Level 3 studies are most informative for rare species that cannot be effectively monitored by point transect studies for want of statistical power. Thus Level 3 studies would be very useful for monitoring any extant species listed in the Recovery Plan for Hawaiian Forest Birds (U.S. Fish and Wildlife Service 2006). However, because such ecological studies require high levels of funding and staffing, they have only been attempted in Hawai`i for a few species over short periods.

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Appendix 1. Surveys using point transect distance sampling conducted to monitor Hawaiian forest birds by island, region and survey area (NWR = National Wildlife Refuge) with years surveyed, and survey frequency. Survey organizers are Department of Defense (DOD), Division of Forestry and Wildlife (DOFAW), Hawaii Forest Bird Survey (HFBS), Kamehameha Schools (KS), National Park Service (NPS), The Nature Conservancy (TNC), U.S. Fish and Wildlife Service (USFWS), U.S. Forest Service (USFS), and U.S. Geological Service Pacific Island Ecosystems Research Center (USGS PIERC). Years surveyed conducted in perpetuity are denoted as 'year started – Present', and data not received are denoted as 'Unknown'. Numbers following survey area name reference trends summary results (Figures 20–23).

Island	Region	Survey Area	Survey Organizer	Years Surveyed	Survey Frequency
Kaua`i					
		Interior Alaka`i Plateau (1)	HFBS	1981	Annual
			DOFAW	1989, 1994	Annual
		Alaka`i Plateau (1)	USFS	Unknown	Unknown
			DOFAW / USGS PIERC	2000, 2005, 2007, 2008	Annual
O`ahu					
		Ko`olau Range (2)	DOFAW	1991	Annual
		Wai`anae Range (2)			
Moloka`i					
		HFBS (3)	USFWS	1979	Annual
		Moloka`i (3)	DOFAW	1981	Annual
			USGS PIERC	1989	Annual
		Moloka`i (3)	DOFAW	1988, 1995, 2004	Annual
Lāna`i					
		Lāna`i	HFBS	1979	Annual
Maui					
	East Maui				
		East Maui (5)	HFBS	1980	Annual
		Haleakalā	USGS PIERC	1993	Annual
		Haleakalā (Kīpahulu Valley) (5)	NPS	1996 - 2001, 2003	Annual
		Hanawī	USGS PIERC	1995 - 1997	Month
		Kahikinui	DOFAW	1996	Annual

Appendix 1. cont.

Island	Region	Survey Area	Survey Organizer	Years Surveyed	Survey Frequency
		Maui - East (5)	DOFAW	1992, 1996, 2001	Annual
		Waikamoi	TNC	1994, 1996	Annual
	West Maui				
		West Maui (4)	HFBS	1980	Annual
		Kapunakea (4)	TNC	1993, 1994, 1996, 1997	Annual
		Maui - West (4)	DOFAW	1997, 2004	Annual
Hawai`i					
	Hāmākua				
		Hāmākua (6-8)	HFBS	1977	Annual
		CJ Ralph Grid	USGS PIERC	2002 - 2004	Quarter
		Cooper's Center Grid	USGS PIERC	2002 - 2004	Quarter
		Hakalau Forest - Maulua Area	USGS PIERC	1994 - 1998	Quarter
		Hakalau Forest - Nauhi Area	USGS PIERC	1994 - 1999	Quarter
		Hakalau Forest - Pua Akala Area	USGS PIERC	1994 - 1998	Quarter
		Hakalau Forest NWR (6)	USFWS	1987 - Present	Annual
		Hāmākua Grid	USFS	Unknown	Unknown
		Hāmākua	DOFAW	2002	Annual
		Keauhou Ranch (7)	KS	1993 - Present	Biannual
		Keauhou `Akiapōlā`au Survey	KS	1999 - 2000	Quarter
		Keauhou Rat Control Survey	KS	1994 - 1998	Annual
		Keauhou Ranch Grid	USFS	Unknown	Unknown
		Keaukaha Military Reservation	DOD	1999 - 2000	Annual
		Kīlauea Forest	USFS	Unknown	Unknown
		Kūlani - Boys School (7)	USGS PIERC	1990 - 1992, 1995, 1997 - 1998, 2001 - Present	Annual[1]
		Kūlani - Pu`u Kīpū (7)	USGS PIERC	1990 - 1992, 1995, 1997 - 1998, 2001 - Present	Annual
		Kūlani - Safe Harbor	USGS PIERC	1996 - 1997	Annual
		Kūlani - Waiākea Area	USGS PIERC	1998	Annual
		Laupāhoehoe	DOFAW	1993	Annual
		`Ōla`a - Koa Unit (8)	NPS	1992 - 1994	Annual

Appendix 1 cont.

Island	Region	Survey Area	Survey Organizer	Years Surveyed	Survey Frequency
		\`Ōla\`a - Pu\`u Unit (8)	NPS	1992 - 1994	Annual
		\`Ōla\`a - Small Track Unit (8)	NPS	1992 - 1994	Annual
		\`Ōla\`a - Solid Waste Transfer Station	USGS PIERC	1995	Annual
		Pu\`u Unit Grid	USGS PIERC	2002 - 2004	Quarter
		Solomons Grid	USGS PIERC	2002 - 2004	Quarter
		Waiākea Grid	USGS PIERC	2002 - 2004	Quarter
		World Union Parcel	USGS PIERC	1999	Annual
	Ka\`ū				
		Ka\`ū (11)	HFBS	1976	Annual
		Kapapala (11)	USGS PIERC	1993, 1995, 2004	Annual
			DOFAW	1992, 1994	Annual
		Ka\`ū Forest	USFS	Unknown	Unknown
		Ka\`ū (11)	DOFAW	1993, 1994, 2002	Annual
		Kahuku (11)	NPS	2005	Annual
	Kīpukas				
		Kīpukas (10)	HFBS	1979	Annual
		Kīpuka Kī	NPS	1992 - 1994	Quarter
		Kīpuka Puaulu	NPS	1992 - 1994	Quarter
		Mauna Loa Strip (10)	NPS	1986 - 1994	Quarter
	Kohala				
		Kohala	HFBS	1979	Annual
	Kona				
		Kona (12-14)	HFBS	1978	Annual
		South Kona (12)	DOFAW	2003	Annual
		Kona Unit – Hakalau Forest NWR (13)	USFWS	1995, 1999 - 2001	Annual
		Pu\`u Wa\`awa\`a Forest Bird Sanctuary (14)	DOFAW	1990, 1991, 1996, 2003	Annual
			USGS PIERC	1996 - 1999	Quarter

Appendix 1. cont

Island	Region	Survey Area	Survey Organizer	Years Surveyed	Survey Frequency
	Mauna Kea				
		Mauna Kea (15)	HFBS	1983	Annual
		Kanakaleonui	USGS PIERC	1990 - 1992	Month
		Mauna Kea	USFS	Unknown	Unknown
		Palila Monitoring Project (15)	USGS PIERC	1980 - Present	Annual[2]
		Palila Translocation Project	USGS PIERC	1992 - 1996	Biannual
		Pōhakuloa Training Center	DOD	Unknown	Unknown
	Puna				
		Puna (9)	HFBS	1979	Annual
		Bryson Grid	USGS PIERC	2002 - 2004	Quarter
		Crater Rim Grid	USGS PIERC	2002 - 2004	Quarter
		East Rift Zone (9)	NPS	1992 - 1994	Annual
		Geothermal (9)	USGS PIERC	1993	Annual
		Malama Kī Grid	USGS PIERC	2002 - 2004	Quarter
		Nānāwale Grid	USGS PIERC	2002 - 2004	Quarter
		Thurston Lava Tube	NPS	1992 - 1994	Annual

[1] Survey frequency included quarter, biannual and annual, predominantly conducted as annual surveys.
[2] Survey frequencies were predominantly conducted as an annual survey; however, biannual surveys were conducted in nine years.

Appendix 2. Description of Trend Study Areas.

Hawai`i Is.

Scott *et al.* (1986) divided Hawai`i Island into seven regions; however, subsequent surveys have occurred in 10 smaller study areas. The subsequent surveys covered 1,493 km^2 and 456 km^2 was repeatedly sampled.

Ka`ū, Hawai`i Is.

Data from the 1976 HFBS and the 1993, 2002 and 2005 surveys by the DOFAW were included in the Ka`ū analyses. We excluded surveys conducted on the Kapāpala Ranch (DOFAW) and the C.J. Ralph Ka`ū Forest grid (U. S. Forest Service [USFS]) because those surveys were conducted outside the breeding season and the raw data were not available, respectively. We split the Ka`ū analyses into two data sets: those above 1,500 m and those below 1,500 m. No data required pooling to provide adequate spatial coverage for analyses. Status and trend of bird populations in this study area was previously published by Gorresen *et al*. (2007) and Tweed *et al*. (2007).

Mauna Loa Strip, Hawai`i Is.

The Mauna Loa Strip Trend Study Area was delineated using a different method because the 1977 and 1979 HFBS transects traversed the elevation gradient while the subsequent National Park Service (NPS) surveys (1986-1994) paralleled the elevation gradient. Therefore, we placed a 500-m buffer around the HFBS stations and identified the coincident subsequent survey stations for analyses. No data required pooling to provide adequate spatial coverage for analyses. Status and trend of bird populations in this study area was previously published by Gorresen *et al*. (2005).

Kūlani-Keauhou, Hawai`i Is.

We included survey data conducted between January and July from the 1977 HFBS and the 1995, 1997, 1998, 2001, 2002, and 2003 surveys on the Keauhou Ranch (administered by the Kamehameha Schools), the adjacent Kīlauea Forest Reserve (FR) and Kūlani Correctional Facilities (collectively referred to as "Kūlani-Keauhou"). We excluded surveys conducted by the USFS on the Keauhou Ranch and Kīlauea FR, and the Kūlani transects 1, 1A, 2, and 2A because the USFS raw data were not available and the Kūlani transects were not consistently sampled. Post HFBS data were pooled into survey periods for the 1990s (1995, 1997, and 1998) and 2000s (2001, 2002, and 2003). Status and trend of bird populations in this study area was previously published by Gorresen *et al*. (2005).

`Ōla`a, Hawai`i Is.

In 1977 the HFBS surveyed the `Ōla`a Forest Unit of Hawai`i Volcanoes National Park. Subsequently, the NPS sampled in 1992, 1993, and 1994. No data were excluded or required pooling to provide adequate spatial coverage for analyses. Status and trend of bird populations in this study area was previously published by Gorresen *et al*. (2005).

East Rift, Hawai`i Is.

Surveys within the East Rift Trend Study Area were located within the Kahauale`a Natural Area Reserve (NAR) and an adjacent area within the Hawai`i Volcanoes National Park, and included the 1979 HFBS, the December 1993 Puna Geothermal survey, and the January 1994 East Rift NPS survey. We excluded surveys conducted in 1992 and 1993 by the NPS because those surveys were conducted outside the breeding season. The Puna Geothermal and East Rift survey data were pooled to create a single survey period. Status and trend of bird populations in this study area was previously published by Reynolds *et al*. (2003) and Gorresen *et al*. (2005).

Appendix 2. Description of Trend Study Areas cont.

Hakalau Forest National Wildlife Refuge, Hawai`i Is.

The HFBS surveyed the Hakalau Forest National Wildlife Refuge Trend Study Area in 1977. Subsequently, the U.S. Fish and Wildlife Service sampled within Hakalau Forest National Wildlife Refuge (Hakalau Forest NWR) annually between 1987 and 2007. The U.S. Geological Service (USGS-PIERC) sampled three grids within Hakalau Forest NWR quarterly from 1994 – 1998, data from the first two quarters per annum were used for modeling species-specific detection functions but not used in calculating density estimates (Camp, Pratt *et al*. 2009). Analyses were limited to the open forest stratum from Camp, Pratt *et al*. (2009) instead of using the minimum convex polygon about the subsequent survey stations approach. No data required pooling to provide adequate spatial coverage for analyses. Status and trend of bird populations in this study area was previously published by Camp, Pratt *et al*. (2009).

Pu`u Wa`awa`a Forest Bird Sanctuary, Kona, Hawai`i Is.

The Kona region was surveyed by HFBS in 1978 and included the Pu`u Wa`awa`a Forest Bird Sanctuary on Hualālai Volcano. Within the sanctuary, DOFAW established 5 transects and resampled 2 HFBS transects in 1990, 1991, 1996, and 2003. Because of inconsistent sampling, we excluded data from 3 of the DOFAW transects (7, 8, and 10) and all USGS-PIERC `Ōma`o translocation surveys. The 1990 and 1991 DOFAW surveys were pooled into a single survey period to provide complete coverage of the Trend Study Area.

Kona Forest Unit of the Hakalau Forest National Wildlife Refuge, Kona, Hawai`i Is.

The Kona Forest Unit (KFU) of the Hakalau Forest NWR is located along the elevation gradient in central Kona. HFBS transect # 64 passed through the middle of the KFU. USFWS conducted subsequent surveys on four new transects in the refuge in 1995, 1999, and 2000. USFWS also surveyed KFU in 2001; however, this survey sampled only those stations above 1,500 m. Therefore, we split the KFU analyses into 2 data sets: those above 1,500 m and those below 1,500 m. No data required pooling to provide adequate spatial coverage for analyses.

South Kona, Kona, Hawai`i Is.

Portions of three 1978 HFBS transects, # 70, 71, and 73, in south Kona were resampled by DOFAW in 2003. Therefore, we did not define the Trend Study Area using our standard approach. Instead, we subset the HFBS transects to match the DOFAW stations surveyed (135 stations). No data required pooling for density estimate comparisons.

Mauna Kea, Hawai`i Is.

Surveys have been conducted on Mauna Kea since the mid-1970s to monitor Palila; however, all forest bird species were first surveyed in 1983 (HFBS) and subsequently surveyed between 1997 and 2007. Status and trend of Palila were assessed from annual surveys between 1980 and 2007. We included only HFBS transects, and excluded 8 subsequently established transects within the Trend Study Area, the Kanakaleonui surveys by T. Pratt, and all USGS-PIERC Palila translocation surveys. Those surveys were excluded because they did not span the entire time series or were located outside the Trend Study Area. No data required pooling to provide adequate spatial coverage for analyses. Status and trend of bird populations in this study area was previously published by Jacobi *et al*. (1996), Gray *et al*. (1999), Johnson *et al*. (2006), and Leonard *et al*. (2008).

Maui Is.

Scott *et al*. (1986) divided Maui Island into two regions. Many subsequent surveys have been conducted within both regions, and those surveys sampled 218 km^2 of which 120 km^2 was repeatedly surveyed.

Appendix 2. Description of Trend Study Areas cont.

East Maui, Maui Is.

East Maui was surveyed in 1980 by HFBS and subsequently surveyed between 1992 and 2001 by DOFAW and the NPS (surveys within the Kīpahulu Valley). We excluded geographically limited surveys conducted in the Hanawī Natural Area Reserve (Simon *et al*. 2001). Subsequent surveys did not completely sample the Trend Study Area; therefore, we pooled them into two survey periods, 1992-1996 and 1997-2001. The Trend Study Area lower extent was limited to 1,220 m elevation to generate a Habitat Restricted Area. The size of the East Maui study area was 174 km^2 of which 81 km^2 was repeatedly sampled.

West Maui, Maui Is.

West Maui was surveyed by HFBS in 1980, and comparable segments of transects were subsequently sampled in 1997 by DOFAW. We excluded surveys conducted by The Nature Conservancy from our analyses because they sampled only a portion of the Trend Study Area. No data required pooling to provide adequate spatial coverage for analyses. The size of the West Maui study area was 44 km^2 of which 39 km^2 was repeatedly sampled.

Moloka`i Is.

The HFBS surveyed Moloka`i in 1979. The DOFAW conducted subsequent surveys in 1988, 1989 and 1995. The Moloka`i Trend Study Area was manually adjusted to match the extent of the transects instead of using a minimum convex polygon. We pooled the 1988 and 1989 surveys into a survey period for analyses. The size of the Moloka`i study area was 61 km^2 of which 13 km^2 was repeatedly sampled.

O`ahu Is.

The DOFAW conducted point transect surveys between December 1990 and April 1991 in the Ko`olau and Wai`anae Mountains. No other point transect based surveys have been conducted on O`ahu. Density estimates for O`ahu `Amakihi and `Apapane, the only native forest birds with sufficient numbers of detections to model, were produced from data pooled across the survey period. The size of the O`ahu study area was 76 $km^2$ and has not been resampled. Status and trend of O`ahu `Elepaio was previously published by VanderWerf *et al*. (1997, 2001).

Kaua`i Is.

The 1981 HFBS survey on Kaua`i sampled 6 transects within a 25-$km^2$ area in the eastern half of the Alaka`i Wilderness Preserve, where five endangered bird species had last been reported. The DOFAW resurveyed these transects in 1989 and 1994 (except transect 4), and a combined

USGS-PIERC/DOFAW survey in 2000, 2005, 2007 and 2008 sampled all 6 HFBS transects and several additional transects. The size of the Kaua`i study area was 51 $km^2$ of which 14 $km^2$ was repeatedly sampled. Status and trend of bird populations in this study area was previously published by Foster *et al*. (2004), and current status and trend of bird populations within a 25-$km^2$ area in the eastern half of the Alaka`i Wilderness Preserve (1981 – 2008) and across the Alaka`i plateau-wide surveys (2000 – 2008) are being prepared by VanderWerf *et al*. (in prep.).

Appendix 3. Factors for each covariate are presented and where applicable additional pooling by species and region. Pooling increases sample size and increases the likelihood of model convergence. Covariate pooling are reported here only for the new analyses, and previously published status and trends reports and papers report covariate pooling for those regions (see Camp, Pratt *et al*. [2009] for Hakalau Forest NWR and VanderWerf *et al*. [in prep.] for Kaua`i modeling parameters).

	Covariate	Default factors	
	Cloud	0 – 100%, by tens & not recorded	
	Rain	0 – 3 & not recorded	
	Wind	0 – 3 & not recorded	
	Gust	0 – 4 & not recorded	
	Time	05:00 – 10:30 hrs by half hour, after 11:00 hrs pooled & not recorded	
	Observer	Observers with < 25 detections pooled	
Species	Region	Covariate	Factors
`Elepaio	Ka`ū, Hawai`i	Cloud	0 – 50 & 60 – 100
		Rain	0 – 1
		Wind	1 – 2
		Gust	1 – 4 & 0, not recorded
		Time	05:00 – 06:30 & hourly
	Mauna Loa Strip	Rain	2 – 3
		Time	05:00 – 07:00, 10:00 – 11:00 plus not recorded
		Year	1977 – 1979
	Kona	Wind	2 – 3
		Gust	2 – 3
	Mauna Kea	Cloud	10 – 30, 40 – 60 & 70 – 90
		Rain	0 – 2
		Gust	3 – 4
		Time	05:00 – 07:30 & hourly
		Year	1983 – 1986, 1987 – 1991, 1992 – 1995, 1996 – 1999 & 2000 – 2003
		Observers	Ob1 < 25 & Ob2 26 – 30
	Puna	Rain	1 – 3
		Wind	1 – 3
		Time	05:00 – 06:30, 07:00 – 07:30, 08:00 – 08:30 & 09:00 – 11:00
		Year	1993 – 1994
		Observer	Ob1 < 15 & Ob2 16 – 25
`Ōma`o	Ka`ū	Rain	1 – 2
		Wind	2 – 3
		Gust	1 – 2 & 3 – 4
	Mauna Loa Strip	Cloud	10 – 50 & 60 – 100
		Rain	1 – 2 plus not recorded
		Wind	0 – 1 & 2 – 3
		Gust	1 – 4
		Time	05:00 – 08:30 & 09:00 – 11:00 plus not recorded
	Puna	Cloud	10 – 30, 40 – 60 & 70 – 90
		Rain	2 – 3
		Wind	2 – 3
		Gust	1 – 2
		Time	10:00 – 11:00
		Year	1992 – 1994

Appendix 3. Factors for each covariate cont.

		Wind	0 – 1 & 2 – 3
		Gust	1 – 4

Species	Region	Covariate	Factors
Maui Parrotbill	East, Maui	Cloud	10 – 50 & 60 – 90
		Rain	1 – 3
		Wind	2 – 3
		Time	05:00 – 07:30, 08:00 – 09:30 & 10:00 – 11:00 plus not recorded
Hawai`i `Amakihi	Ka`ū	Cloud	10 – 30, 40 – 60 & 70 – 90
		Rain	1 – 2
		Wind	2 – 3
		Gust	3 – 4
	Mauna Loa Strip	Rain	2 – 3
		Time	05:00 – 06:00
	Kona	Wind	2 – 3
		Gust	3 – 4
	Mauna Kea	Rain	2 – 3
		Year	1987 – 1991
	Puna	Time	05:00 – 06:00 & 09:00 – 11:00 plus not recorded
	East, Maui	Time	05:00 – 06:30
		Observer	Ob1 < 100
	West, Maui	Cloud	0 – 50 & 60 – 100
		Rain	1 – 3
		Wind	1 – 3
		Gust	1 – 4
		Time	05:00 – 07:30, 08:00 – 09:30 & 10:00 – 11:00
	Moloka`i	Cloud	0 – 40 & 50 – 100
		Rain	1 – 3
		Wind	2 – 3
		Gust	1 – 4
		Time	05:00 – 07:30, 08:00 – 09:30 & 10:00 – 11:00
		Observer	Ob1 < 10 & Ob2 11 – 20
O`ahu `Amakihi	O`ahu	Cloud	0 – 50 plus not recorded & 60 – 100
		Rain	1 – 3 & 0 plus not recorded
		Wind	0 plus not recorded
		Time	05:00 – 08:30 & hourly
		Observer	Ob1 < 30
Maui `Alauahio	East, Maui	Time	05:00 – 06:00
`Ākepa	Ka`ū	Cloud	0 – 50 & 60 – 100
		Wind	2 – 3
		Gust	1 – 2 & 3 – 4
		Time	05:00 – 06:30 & hourly
`I`iwi	Ka`ū	Cloud	10 – 30, 40 – 60 & 70 – 90
		Rain	1 – 3
		Wind	2 – 3
	Mauna Loa Strip	Rain	2 –3
		Time	05:00 – 06:30
	Kona	Rain	0 – 2
		Wind	2 – 3
		Gust	3 – 4
	Mauna Kea	Cloud	10 – 100 plus not recorded
		Wind	0 plus not recorded
		Gust	0 plus not recorded
		Time	Hourly

Appendix 3. Factors for each covariate cont.

Species	Region	Covariate	Factors
		Wind	0 – 1 & 2 – 3
		Gust	1 – 4
`Apapane	Ka`ū	Rain	1 – 3
		Observer	Ob1 < 100
	Mauna Loa Strip	Rain	2 – 3
		Time	05:00 – 06:00
	Kona	Rain	1 – 3
		Gust	3 – 4
	Mauna Kea	Cloud	10 – 50, 60 – 100 & 0 plus not recorded
		Wind	0 plus not recorded
		Gust	0 plus not recorded
		Time	05:00 – 07:30
		Year	1983 – 1995
	Puna	Year	1992 – 1994
		Observer	Ob1 < 50
	East, Maui	Observer	Ob1 < 100
	West, Maui	Cloud	10 – 20, 30 – 40, 50 – 60, 70 – 80 & 90 – 100
`Apapane		Rain	2 – 3
		Time	05:00 – 06:30
	Moloka`i	Rain	2 – 3
		Time	05:00 – 06:00
		Observer	Ob1 < 40
	O`ahu	Cloud	0 – 50 plus not recorded & 60 – 100
		Rain	1 – 3 plus not recorded
		Wind	0 plus not recorded
		Time	05:00 – 08:30 & hourly

Appendix 4. Effective Detection Radius and variance estimates by species, island, and area, number of detections and number modeled, distance at which data were truncated, and models and covariate variables used to calculate population estimates. Model parameters are reported here only for the new analyses; previously published status and trends reports and papers report model parameters for those regions (see Camp, Pratt *et al*. [2009] for Hakalau Forest NWR and VanderWerf *et al*. [in prep.] for Kaua`i modeling parameters).

Species	Island	Area[1]	EDR	%CV	Number Observed	Number Modeled	Truncation[2]	Detection Function[3]	Covariates[4]
`Elepaio	Hawai`i	Cen	31.73	0.51	7,103	5,567	Rt 46.9 Lt 5.6	H-rate Key	R, G
		Ka`ū	35.38	2.91	406	345	Rt 48.6	H-rate Key	None
		MLS	39.79	1.67	1,119	974	Rt 76.0 Lt 5.2	H-rate Key	O
		Puna	47.49	3.77	241	216	Rt 76.0	H-rate Key	T, O
		Kona	44.28	1.37	2,897	2,165	Rt 87.7	H-norm Key	O, Y
		M Kea	39.40	1.54	744	629	Rt 53.8	H-rate Key	O, R, C, Y, W, M, G
`Ōma`o	Hawai`i	Cen	61.15	0.29	23,728	21,369	Rt 108.0	H-rate S-poly 1-adj	M, T
		Ka`ū	52.19	0.68	3,600	3,397	Rt 78.2	H-rate Key	O
		MLS	103.67	4.69	179	162	Rt 183.0	H-norm Key	None
		Puna	80.93	1.28	1,645	1,487	Rt 137.0	H-rate S-poly 2-adj	O
Maui Parrotbill	Maui	East	36.53	3.59	275	248	Rt 75.0	H-norm Key	M, Y
Hawai`i `Amakihi	Hawai`i	Cen	37.03	0.50	9,819	8,838	Rt 68.0	H-rate S-poly 1-adj	O
		Ka`ū	35.15	0.96	2,387	2,371	Rt 66.0	H-rate Key	O
		MLS	45.74	0.95	3,548	3,231	Rt 91.0	H-rate Key	O, Y
		Puna	64.67	2.15	553	500	Rt 143	H-rate Key	O
		Kona	36.57	0.47	17,086	14,657	Rt 89.9	H-rate S-poly 1-adj	R, C, M, T, G
		M Kea	35.92	0.30	25,562	23,072	Rt 66.0	H-rate Key	O, Y
	Maui	East	29.76	0.54	7,959	7,174	Rt 48.0	H-rate S-poly 1-adj	O, Y, C, R, W, M
		West	31.19	4.03	153	138	Rt 64.0	H-rate Key	O
	Moloka`i		30.59	4.34	154	127	Rt 63.8	H-norm Key	None
O`ahu `Amakihi	O`ahu		146.02	2.84	286	272	Rt 300.0	H-rate Key 5 eql int	T
`Akiapōlā`au	Hawai`i	Cen	56.21	2.05	670	603	Rt 96.0	H-rate Key	C, R, W, G

Appendix 4. Effective Detection Radius cont.

Species	Island	Area[1]	EDR	%CV	Number Observed	Number Modeled	Truncation[2]	Detection Function[3]	Covariates[4]
Hawai`i Creeper	Hawai`i	Cen	40.18	1.57	1,155	1,035	Rt 69.9	H-rate Key	O
		Ka`ū	29.65	4.35	148	142	Rt 60.0	H-norm Key	Y
		Kona	39.49	8.66	71	59	Rt 62.0 Lt 5.17	H-norm Key	None
	Maui	East	19.39	1.60	3,500	3,131	Rt 38.4	H-rate Key	None
`Ākepa	Hawai`i	Cen	35.30	1.32	1,159	1,044	Rt 57.0	H-rate Key	R, G, T, O
		Ka`ū	37.15	1.78	503	479	Rt 52.0	H-rate Key	M
		Kona	37.97	6.45	88	80	Rt 64.0	H-norm Key	None
`I`iwi	Hawai`i	Cen	32.76	0.41	18,599	16,655	Rt 74.9	H-rate Key	O, Y
		Ka`ū	37.19	1.03	1,887	1,787	Rt 59.2	H-rate Key	O
		MLS	71.70	1.37	1,274	1,163	Rt 122.0	H-rate Key	Y, O
		Kona	39.73	1.29	3,178	2,816	Rt 85.0 Lt 3.71	H-rate Key	O
		M Kea	58.28	2.93	205	184	Rt 87.0	H-norm Key	C
	Maui	East	37.27	0.70	5,383	4,921	Rt 60.0	H-rate Key	O, Y, M, G, C
`Ākohekohe	Maui	East	44.96	1.14	2,571	2,344	Rt 80.0	H-rate Key	O, Y, G
`Apapane	Hawai`i	Cen	34.06	0.19	59,488	53,555	Rt 67.0	H-norm Key	O
		Ka`ū	35.08	0.45	8,151	7,443	Rt 50.0	H-rate Key	O
		MLS	64.76	0.70	4,857	4,393	Rt 107.0	H-rate Key	O, Y
		Puna	51.52	0.69	4,470	4,032	Rt 98.0	H-rate S-poly 1-adj	M
		Kona	32.96	0.46	15,243	11,585	Rt 59.8	H-rate Key	O, Y, W, R
		M Kea	66.64	1.98	532	483	Rt 100.0	H-rate Key	O
	Maui	East	29.91	0.39	17,105	16,279	Rt 67.0	H-norm Key	O, Y
		West	36.57	1.55	1,092	867	Rt 59.8	H-rate Key	O, W
	Moloka`i		30.81	1.02	3,132	2,633	Rt 68.9	H-rate Key	O
	O`ahu		162.09	4.40	275	215	Rt 297.0	H-norm Key 6 eql int	O

[1] Area acronyms: Cen – Central Windward; M Kea – Mauna Kea; MLS – Mauna Loa Strip.
[2] Truncation acronyms: Rt – Right Truncation; Lt – Left Truncation.
[3] Detection Function acronyms: H-norm – Half-normal detection function; H-rate – Hazard-rate detection function; Key – Key detection function; S-poly – Simple polynomial of 1 or 2 terms (1-adj or 2-adj, respectively) to adjust the detection function; eql int – number of bins with approximately equal number of observations per interval.
[4] Covariate acronyms: C – cloud cover; G – gust; M – month; O – observer; R – rain; T – time; W – wind; Y – year.