



Pacific Island Landbird Monitoring Annual Report, Haleakalā National Park, 2012

Natural Resource Technical Report NPS/PACN/NRTR—2013/740



ON THE COVER

‘Alauahio (*Paroreomyza montana newtoni*)

Photograph by: Jack Jeffrey

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Abstract

Haleakalā National Park (HALE) was surveyed for landbirds and habitat characteristics from March 20 through July 26, 2012. This information provides data in the time-series of landbird monitoring for long-term trends in forest bird distribution, density, and abundance. The Kīpahulu District of eastern Haleakalā Volcano was surveyed using point-transect distance sampling to estimate bird abundance. We surveyed 160 stations and detected a total of 2,830 birds from 12 species. Half of the species were native and half were non-native. Numbers of detections per species ranged from 1 to 849. There were sufficient detections of seven species to allow density estimation. Āpapane (*Himatione sanguinea*) was the most widely distributed and abundant native species detected in the survey. ‘Alauahio (*Paroreomyza montana newtoni*), Maui ‘Amakihi (*Hemignathus virens wilsoni*), and I‘iwi (*Vestiaria coccinea*) were widespread and occurred in relatively modest densities. Only eight Kiwīkiu (*Pseudonestor xanthophrys*) and 20 ‘Ākohekohe (*Palmeria dolei*) were detected and were restricted to high elevation wet forest. We estimated an abundance of 495 ± 261 individuals of Kiwīkiu in a 2,036 ha inference area which likely includes the entire suitable habitat for this species in HALE. For ‘Ākohekohe, we estimated an abundance of $1,150 \pm 389$ individuals in the 1,458 ha inference area. There was a strong representation of non-native landbirds in the survey area. The Japanese White-eye (*Zosterops japonicus*), Japanese Bush-warbler (*Cettia diphone*), and Red-billed Leiothrix (*Leiothrix lutea*) accounted for nearly half of all landbird detections. Each species was common in predominantly native forests.

Vegetation and topographic characteristics were recorded on 160 landbird monitoring stations. HALE canopy and understory composition was predominantly native, especially at elevations above 1,100 m. Much of the forest canopy was comprised of `ohi`a (*Metrosideros polymorpha*) interspersed with mature olapa (*Cheirodendron platyphyllum*). This canopy class occurred at 92.5% of the stations surveyed. More than three-quarters (77.5%) of the monitoring stations had a dense canopy with most crowns interlocking (> 60% cover). More than half (52%) of the stations surveyed had trees taller than 10 m, while almost a third (31%) had trees 5-10 m. Only 17% of the stations had a canopy shorter than 5 m. The native shrubs *Vaccinium calycinum*, *Broussaisia arguta*, and *Leptecophylla tameiameae* were the most common understory plants recorded, occurring at more than 30% of the stations sampled. Native mosses and ferns were also common at stations, occurring at more than 90% of the stations sampled. The invasive *Psidium cattleianum*, *Clidemia hirta*, and *Hedychium gardnerianum* occurred at approximately 14% of the stations sampled, predominantly at elevations below 1,100 m.

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Introduction

The Hawaiian Islands are volcanic and relatively young, the first islands emerged from the Pacific Ocean almost 30 million years ago (Ziegler 2002). The “main” islands are younger and larger than the series of small islands and atolls to the northwest. Hawai‘i Island is still volcanically active, and nearby Maui is less than 2 million years old (Ziegler 2002). Maui was part of a much larger system called “Maui Nui”, which included the present landmasses of Lāna‘i, Kaho‘olowe, and Moloka‘i (Carson and Clague 1995). Because of their extreme isolation, colonization to the islands by plants and animals was slow. The more than 60 species of Hawaiian Honeycreepers evolved through adaptive radiation from a single ancestral colonizer, likely a Cardueline Finch (Lerner et al. 2011), approximately 4.5 million years ago.

Haleakalā National Park harbors critically important habitat for a number of Hawaiian Honeycreepers endemic to East Maui, including the ‘Ākohekohe (*Palmeria dolei*), Maui Parrotbill (Kiwikiu; *Pseudonestor xanthophrys*), and Maui ‘Alauahio (Creeper; *Paroreomyza montana newtoni*; Scott et al. 1986). Avian disease, habitat conversion, and introduced plants and animals have all had profound negative effects on populations of these birds. The avian community of east Maui suffered the recent extinction of the Po‘ouli (*Myadestes palmeri*; Powell 2008), and biologists fear that extinction may already be a reality for the Maui ‘Ākepa (*Loxops coccineus ochraceus*) and Maui Nukupu‘u (*Hemignathus lucidus affinis*) because each species has been seen fewer than 10 times in the last 100 years (Banko 1968, Pratt and Pyle 2000, Reynolds and Snetsinger 2001, Bailey 2007). Honeycreeper species that have so far fared better include the Āpapane (*Himatione sanguinea*) and Maui ‘Amakihi (*Hemignathus virens wilsoni*). These have a broad distribution in HALE and have even demonstrated some tolerance to avian malaria (Woodworth et al. 2005). The ‘I‘iwi (*Vestiaria coccinea*) is very vulnerable to the disease (Atkinson et al. 1995) and appears to be declining in many areas (Camp et al. 2009).

Efforts to effectively manage honeycreeper populations are often hampered by lack of knowledge of their current demography. A major reason for this lack of knowledge is that most of the remaining forest bird habitat is remote and very difficult to access by biologists. Repeated landbird surveys are an important tool for identifying temporal changes of populations (Skalski 1990) that may allow park managers to monitor population trends and determine the efficacy of management actions (Camp et al. 2011). The National Park Service (NPS) created the Inventory and Monitoring (I&M) Program following the National Park Omnibus Management Act of 1998 to acquire data needed to support effective management and protection of native habitats located on park lands. The role of the I&M Program is to collect, organize, and make available natural resource data and contribute to the National Park Service’s institutional knowledge by facilitating the transformation of data into information through analysis, synthesis and modeling (Fancy et al. 2009). In concordance with the stated role of the I&M Program, our objectives were to establish a baseline for monitoring long-term trends in forest bird distribution and abundance in HALE. Ultimately, this information will help to inform and implement management actions for bird conservation.

Methods

The landbird vital sign monitoring protocol conducted by the Pacific Islands Network (PACN) I&M Program surveys three parks on a rotating basis. Each park, or units therein, will be surveyed once every 5-years to determine landbird status and trends. The protocol was implemented in 2012 at HALE. Point-transect distance sampling was conducted according to a split panel design (1:1, fixed: random sampling stations). In a split panel design legacy transects are visited during each sampling occasion and newly, randomly located transects are visited only during one sampling occasion. This design optimizes trend detection while allowing for measuring and correcting for estimator bias. Both the fixed and random panel stations were surveyed for birds and habitat (see Camp et al. 2011 for details).

Study Sites

Haleakalā National Park

HALE is comprised of four districts: the Crater, Nu‘u, Ka‘āpahu, and Kīpahulu Districts (Figure 1). The Crater District encompasses the summit of Haleakalā Volcano (3,056 m), and the habitat, consists of predominantly native subalpine shrublands and the sparsely vegetated volcanic basin. A dominant feature of the Crater District is the stream-eroded Kaupō Gap, which extends to the Southeast and is primarily native shrubland, invaded forest, and invaded grassland (Gon et al. 2006). The Nu‘u District (approximately 1,700 ha) was a 2008 addition to HALE and supports remnants of dry native forest on the hot and windy south facing slopes of Haleakalā Volcano. The southeastern Ka‘āpahu District (598 ha) was acquired by the park in 1999; it represents rare mesic native plant communities but also hosts a number of invasive weeds and feral animals (Welton and Haus 2005).

Landbird surveys were conducted in the Kīpahulu District (4,200 ha) which covers the northeastern portions of HALE, including the much-visited ‘Ohe‘o Gulch where Palikea Stream spills into large freshwater pools. Landbird monitoring transects traversed seldom-visited upland rainforests of Kīpahulu Valley, Manawainui, and the spectacular bog ecosystems near the Northeast Rift of Haleakalā Volcano.

Kīpahulu Valley

Kīpahulu Valley is a dramatic landscape of large headwalls, escarpments, waterfalls, and dense rainforest. The valley is comprised of two large drainages, the Upper and Lower Plateau, which are separated by a steep Central Pali (pali is Hawaiian for cliff; Warner 1967). The Upper Plateau extends from the valley headwall (2,250 m) and descends in a southeasterly direction almost 12 km to the Pacific Ocean. Ko‘uko‘uai Stream is the major drainage of the Upper Plateau, but many small streams and waterfalls flow during wet periods. Landbird monitoring transect 17 descends 1,200 m and bisects 8 km of primarily undisturbed open ‘ōhi‘a forest and closed ‘ōhi‘a-koa (*Acacia koa*; Gon et al. 2006) forest within the upper plateau. Transect 16 descends 1,100 m in the Lower Plateau, parallels the base of the Central Pali, and ends at 840 m elevation. The upper portion of this transect is in exclusively native ‘ōhi‘a-olapa forest, and the lower portions are co-dominated by ‘ōhi‘a and koa along with weedy trees and shrubs. To the north, the Palikea Stream drains the Lower Plateau and sheer walls of Northeast Rift, rising 500 m in areas. Transect 10 is the highest landbird transect (1,660-2,100 m); it traverses montane bogs, ridges, and promontories of the Northeast Rift.

Kīpahulu Valley is a closed-entry reserve; access is permitted only to HALE management personnel and for select monitoring and research activities. The valley is mostly fenced, and divided into three feral ungulate exclosures. Feral ungulate removal and fence maintenance is ongoing and most of the valley is ungulate free, except at lower elevations where pigs (*Sus scrofa*) and goats (*Capra hircus*) destroy native understory and spread seeds of invasive plants. Native floral diversity is high in Kīpahulu Valley, with over 89 species of ferns, 209 species of flowering plants, and over 20 species of endemic lobelioids (Higashino et al. 1988, Anderson et al. 1992, Medeiros et al. 1998). Typical northeast tradewinds pervade the valley and precipitation is high, averaging more than 7,000 mm/year (Giambelluca et al. 2011).

Manawainui

Manawainui is a 526 ha parcel in the southeast portion of the park, it is often referred to as the “Manawainui Planeze” because the bench is isolated by lava flows older than adjacent Kaupo and Kīpahulu Valley (Peterson 1976). Kuiki is the highest point at approximately 2,300 m, the planeze tapers southward in a pyramid shape, forming steep cliffs on each side (Figure 1). Landbird monitoring transect 18 ranges from 1,500-1,800 m, in wet ‘ōhi‘a forest of this parcel. Manawainui is characterized by high precipitation (>5,000 mm/year; Stein 2007). Precipitation tapers off to the west and transitions to a dry-mesic ecotone (Stein 2007).

Northeast Rift

The Northeast Rift lies near the northern boundary of HALE and the Hana Reserve. Landbird monitoring stations on the Northeast Rift are the highest in the survey (1,640-2,100 m). The area is ‘ōhi‘a-dominated, wet-montane rainforest. It is also comprised of the spectacular montane bogs that harbor some of HALE’s rarest plants, such as *Geranium hanaense*, *Argyroxiphium gravanum* (greensword), *Viola maviensis* (pāmakani), and *Plantago pachyphylla* (Medeiros et al. 1998). The area ranks among the rainiest places in the world, averaging more than 10,000 mm/year (Giambelluca et al. 2011).

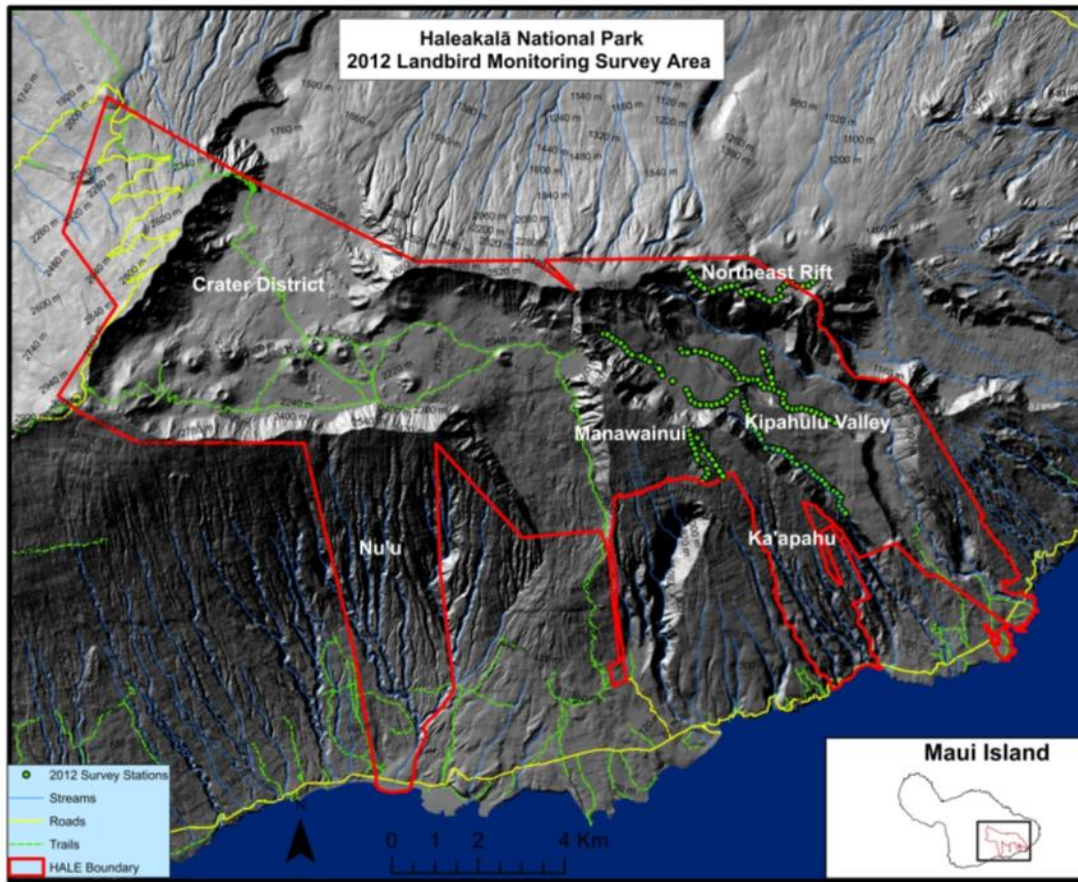


Figure 1. Haleakalā National Park and 2012 landbird monitoring survey stations.

Sampling

Surveys commenced March 20, 2012. We sampled for landbirds at 160 stations on 11 transects on the Upper and Lower Plateaus of Kīpahulu Valley, the Northeast Rift, and Manawainui. Appendix A summarizes the field methods and survey effort. Landbird counts began soon after dawn, or when the sunlight would strike treetops, and were concluded by 11:00 hrs. Stations, spaced 150 m apart, were surveyed using point-transect distance sampling methods lasting eight minutes. We recorded species, distance in meters from observer to each bird detected, and detection type (seen, heard or both). In addition, weather conditions were recorded at each station. Point-transect distance sampling methods allow for estimating detection probabilities by modeling a species-specific detection function to estimate absolute abundance (Buckland et al. 2001). This method thus accounts for individuals that go undetected, and produces unbiased absolute abundance. Robust estimates are reliant upon the critical assumptions that all birds are detected with certainty at the station center point, birds are detected prior to any responsive movement, and distances are measured without error. Details of landbird sampling can be found in Camp et al. (2011).

Landbird habitat data were also collected at each of the bird sampling stations. A 50-m radius plot was established at each point-transect station using the station as the center. At each plot, the dominant canopy species composition, canopy height and cover, dominant understory, and the species composition were described. In addition to habitat characteristics, topographical attributes were collected at each station. Habitat surveys were collected after completing bird counts (either after completing the station count, or after completing the daily counts). Details of landbird habitat sampling can be found in Camp et al. (2011).

Data Analysis

Indices

Indices of bird occurrence and abundance were calculated for each species. Percent occurrence was calculated as the number of stations occupied divided by the total number of stations sampled. Similarly, relative abundance (birds per station; BPS) was calculated as the number of individuals detected divided by the total number of station counts (adjusting the index for effort).

Species Richness

We used presence data by both the primary and secondary counters to estimate species richness – the total number of species. Naïve estimates of species richness, a simple tally, are biased because of imperfect and heterogeneous species detectability due to behavior and abundance. Detectability was accounted for by estimating species richness using program COMDYN (Hines et al. 1999). Because all of the extant native species on Maui were detected, we conducted this analysis only for non-native birds. Furthermore, we conducted this analysis only for the stratum below 1,280 m elevation (see below). Data were restricted to the 25 stations sampled by both counters in this stratum. From the point-transect counts the data recorded were reduced to simply a species list by station (i.e., dropping the distance and detection type information) and combined with the secondary counters' list of species at each station to create a detection history of four occasions (2 counts each by both counters). This detection history was entered into program COMDYN, and species richness was estimated using both the SPECRICH and COMDYN4 estimators. See Camp et al. (2011) for sampling and analysis details, and Hines et al. (1999) for analysis and model details.

Density Estimation

Density estimates (birds ha⁻¹) were calculated for each of seven species (the native 'Alauahio, Āpapane, Maui 'Amakihi, and 'I'iwi, and the non-native Japanese Bush-warbler, Japanese White-eye and Red-billed Leiothrix) that had sufficient detections to adequately characterize detectability (Buckland et al. 2001), using program DISTANCE, version 6.0, release 2 (Thomas et al. 2010). Detections of the endangered 'Ākohekohe and Kiwīkiu were low; therefore, detections for these birds were pooled with data from previous surveys to model detectability (2,172 and 261 additional detections, respectively). Preliminary analysis of 'Alauahio yielded unrealistic uncertainty (%CV > 80); therefore, the 2012 data were pooled with data from previous surveys similar to the endangered species (3,559 additional detections). The candidate detection function models were limited to half normal and hazard-rate detection functions with expansion series of order two (Buckland et al. 2001). Following

recommendations by Buckland et al. (2001), the half normal was paired with cosine and Hermite polynomial adjustments, and the hazard-rate was paired with cosine and simple polynomial adjustments. Model precision was improved by incorporating sampling covariates in the multiple covariate distance sampling (MCDS) engine of DISTANCE (Thomas et al. 2010). Covariates included cloud cover, rain, wind, gust, observer, time of detection, detection type, tree height, and elevation strata (above or below the 1,280 m counter). All covariates were treated as a factor, except time of detection, which was treated as a continuous covariate. Assessing time of detection as a continuous covariate helped to determine if the detection rate varied during the morning. Detection type 4, bird first detected aurally but later confirmed visually, was pooled with both detection type 1 and 2, and fitted independently. Pooling of covariates was used to increase sample size and increase the likelihood of model convergence. Covariates for survey and year were also assessed for the endangered birds and ‘Alauahio because of pooling, but tree height and elevation strata were not included for the endangered species because they were detected only in tall stature and high elevation stratum. Each detectability model in the candidate set was fit, and the model selected was that with the lowest 2nd-order Akaike’s Information Criterion corrected for small sample sizes (AICc) (Buckland et al. 2001, Burnham and Anderson 2002; Appendix B). Data were truncated at a distance where the detection probability was approximately 10%. This procedure facilitates modeling by deleting outliers and reducing the number of parameters needed to modify the detection function. Species-specific densities, variances and confidence intervals were derived by bootstrap methods in DISTANCE from 999 iterations (Thomas et al. 2010) from a global detection function using post-stratification procedures stratifying by elevation. For the endangered birds, species-specific densities by survey and year were estimated from the global detection function using the post-stratification procedure where density and precision were estimated using bootstrap methods. For these range-restricted species only stations sampled within their ranges were used for analytical purposes. Absolute abundance was calculated as mean density of unit estimates weighted by elevation strata area for each species.

Inference Areas

We used transect locations, the HALE boundary, geographical features, and the current and historical distribution of landbird species to determine the inference area for abundance estimates. Inference areas were mapped as a minimum convex polygon using ArcMap 9.3.1 (Environmental Systems Research Institute, CA, USA). We used the Editor Tool in ArcMap to adjust polygons using the park boundary, 20 m elevation contours, and the steep ridgeline of western Manawainui. The final inference areas were calculated in hectares using Xtools Pro. The 2,100 m elevation contour line forms the top boundary of each polygon. This coincides with the approximate elevation of the highest station surveyed (transect 10, station zero). The 720 m contour traces the lowest boundary, the approximate elevation of the lowest station surveyed (transect 17, station 71). The HALE boundary demarcates the northern and eastern edges of inference area. The inference area was 3,121 ha, which was used as the area for calculating species abundance estimates (density estimates times area). The Kiwikiu distribution is smaller; detections of the species have only been above 1,180 m during previous landbird surveys (Camp et al. 2009, USGS unpublished data). Using GIS, we established a minimum convex polygon around Kiwikiu detections, yielding a 2,036 ha polygon that was used to estimate Kiwikiu abundance in HALE. Similarly, we mapped a minimum convex polygon around ‘Ākohekohe detections. The distribution of ‘Ākohekohe is even smaller at 1,458 ha; the species was detected at elevations only above 1,500 m in Kīpahulu Valley during previous surveys (Camp et al. 2009, USGS unpublished data). We used a 3,121 ha inference area for ‘Alauahio, ‘Apapane, ‘I‘iwi, Maui ‘Amakihi, Japanese Bush-warbler, Japanese White-eye and Red-

billed *Leiothrix* because each species has been detected throughout the entire 2012 landbird survey area (Scott et al. 1986, Camp et al. 2009, Foster 2009).

Elevation Strata

The study area was divided into two strata: high elevation (above 1,280 m) and low elevation (below 1,280 m). We based the division on three factors: the presence and absence of koa (koa is more abundant at low elevations), the upper range of mosquitoes and transmission of avian malaria (Aruch et al. 2007), and the approximate high elevation where weeds have encroached upon Kīpahulu Valley (S. Anderson pers. comm.). Differences in densities by elevation strata were compared using a two-sample z-test (Buckland et al. 2001:353).

We also summarize landbird distribution and habitat characteristics by 200 m elevation increments. The presence of species and habitat composition was identified at each landbird monitoring station, with increments between 700 m and 2,100 m elevation. This method is similar to how Scott et al. (1986) summarized their data.

Comparison of Panel Data

The Protocol prescribes monitoring using a panel design (Camp et al. 2011). Panel designs possess several major advantages over conventional time-series data sets (Hsiao 2003), including improved efficiency of estimates through large degrees of freedom and reduced collinearity among explanatory variables. Time-series data refer to observations of a given unit made over time, and are often referred to as longitudinal data. Longitudinal data analysis was not possible at this point because only one temporal measurement has been made. Selection and placement of the legacy transects may not be representative of current landbird populations resulting in biased estimates. Panel designs allow for assessing selection bias by comparing the distribution of bird densities between the fixed and random transects (data pooled across species) using a quantile-quantile (q-q) plot and Kolmogorov-Smirnov test in program R (version 2.15.1; R Foundation for Statistical Computing). The jitter function was used to eliminate ties while calculating p-values, which have little effect on the overall distributions and yielded reliable p-values (Judge et al. 2011).

Results

Landbird Results

Indices

A total of 2,830 birds of 12 landbird species was detected during the 2012 HALE survey (Table 1). Half of the species detected during the survey were endemic to Maui or the Hawaiian Archipelago, and half of the species have been introduced to the islands. Indices of bird occurrence and relative abundance were calculated for all species detected (Table 2). The ‘Apapane was the most widely distributed and abundant species, occurring on almost all stations (92.5%), at just over five birds per station (BPS). The Maui ‘Amakihi and ‘I‘iwi were also broadly distributed, occurring at more than 70% of the stations sampled. The ‘I‘iwi had a high relative abundance of 2.46 BPS and the Maui ‘Amakihi averaged 2.06 BPS. ‘Alauahio occurred at 35% of the stations sampled and averaged 0.88 BPS. The endangered Kiwiku and ‘Ākohekohe were the rarest native birds detected in the survey, occurring at only 3.1% and 8.1% of the stations sampled, respectively. Each endangered species occurred at less than 0.20 BPS. The Japanese Bush-warbler, Japanese White-eye, and the Red-billed Leiothrix accounted for more than half of all detections. Each species occurred on more than 70% of the stations sampled and at greater than 2 BPS. The Japanese Bush-warbler was the most widely distributed non-native species, occurring at 86.9% of the stations sampled. The Melodious Laughing-thrush (*Garrulax canorus*), Northern Cardinal (*Cardinalis cardinalis*), and House Finch (*Carpodacus mexicanus*) were relatively uncommon, occurring at less than 10% of the stations with less than 0.1 BPS (Table 2). Occurrence maps displaying extent and number of detections of each species are presented in Appendix C.

Species Richness

Of the 14 terrestrial native bird species on Maui, four have not been observed in decades and four are non-forest species (i.e., associated with water or open country habitats; Camp et al. 2011). We detected the remaining six native forest birds on Maui, thus species richness estimates were not calculated for the native birds. Within the sampled area below 1,280 m we detected six of the 33 non-native bird species on Maui. Results from the species richness analysis indicate that one additional non-native species may occur at this elevation (SPECRICH; $N = 7$; $SE = 1.41$). This estimate was corroborated using COMDYN4, which yielded a species richness estimate of 7.19 ($SE = 1.73$, 95% CI = 6.00—12.32). Based on previous forest bird surveys, there are four additional non-native birds that could occur in the forest of HALE, and we speculate on the most likely bird in the Discussion.

Table 1. List of species detected during the 2012 Landbird survey in HALE. Abbreviated species code and origin (N=Native, I=introduced) of birds are presented.

Species Name	Scientific Name	Species Code	Origin
'Ākohekohe, Crested Honeycreeper	<i>Palmeria dolei</i>	CRHO	N
'Alauahio, Maui Creeper	<i>Paroreomyza montana newtoni</i>	MAAL	N
'Apapane	<i>Himatione sanguinea</i>	APAP	N
House Finch	<i>Carpodacus mexicanus</i>	HOFI	I
'I'iwi	<i>Vestiaria coccinea</i>	IIWI	N
Japanese Bush-Warbler	<i>Cettia diphone</i>	JABW	I
Japanese White-eye	<i>Zosterops japonicus</i>	JAWE	I
Kiwikiu, Maui Parrotbill	<i>Pseudonestor xanthophrys</i>	MAPA	N
Maui 'Amakihi	<i>Hemignathus virens wilsoni</i>	MAAM	N
Melodious Laughing Thrush, Hwamei	<i>Garrulax canorus</i>	MELT	I
Northern Cardinal	<i>Cardinalis cardinalis</i>	NOCA	I
Red-billed Leiothrix	<i>Leiothrix lutea</i>	RBLE	I

Table 2. Number of birds detected, indices of bird occurrence (Percent Occurrence), and relative abundance (BPS) in HALE.

Species Name	# Birds Detected	# Stations Occupied	Percent Occurrence	BPS
‘Ākohekohe	20	13	8.1	0.12
‘Alauahio	142	56	35.0	0.88
‘Apapane	849	148	92.5	5.24
House Finch	1	1	0.6	0.01
‘I‘iwi	399	114	71.3	2.46
Japanese Bush-warbler	354	139	86.9	2.19
Japanese White-eye	357	118	73.8	2.20
Kiwikiu, Maui Parrotbill	8	5	3.1	0.05
Maui ‘Amakihi	334	124	77.5	2.06
Melodious Laughing Thrush	17	14	8.8	0.10
Northern Cardinal	3	2	1.3	0.02
Red-billed Leiothrix	346	129	80.6	2.14

Landbird Density and Abundance

There were sufficient detections of seven species to determine densities (Table 3). Densities were also calculated for the endangered ‘Ākohekohe and Kiwīkiu, as well as the ‘Alauahio, by pooling their data with previous surveys. The ‘Apapane was the most abundant bird with abundances about twice that of the other birds (Figure 2).

Table 3. Densities and abundances of landbirds in the 2012 landbird study area.

Species	Density (birds/ha $\pm$ SE & 95%CI)	Abundance
‘Alauahio	9.97 $\pm$ 1.92	31,109 $\pm$ 6,004
	7.41—12.75	23,134—39,790
‘Ākohekohe	0.79 $\pm$ 0.27	1,150 $\pm$ 389
	0.39—1.41	561—2,059
‘Apapane	20.52 $\pm$ 3.05	64,055 $\pm$ 9,531
	15.11—26.88	47,150—83,880
‘Iiwi	7.00 $\pm$ 1.11	21,850 $\pm$ 3,452
	5.26—9.68	16,407—30,227
Japanese Bush-warbler	2.91 $\pm$ 0.22	9,081 $\pm$ 680
	2.47—3.35	7,723—10,453
Japanese White-eye	10.19 $\pm$ 1.22	31,792 $\pm$ 3,802
	7.95—12.56	24,817—39,201
Kiwīkiu	0.24 $\pm$ 0.13	495 $\pm$ 261
	0.06—0.56	114—1,132
Maui ‘Amakihi	7.10 $\pm$ 0.76	22,172 $\pm$ 2,370
	5.50—8.48	17,175—26,459
Red-billed Leiothrix	4.00 $\pm$ 0.53	12,495 $\pm$ 1,649
	3.08—5.06	9,615—15,807

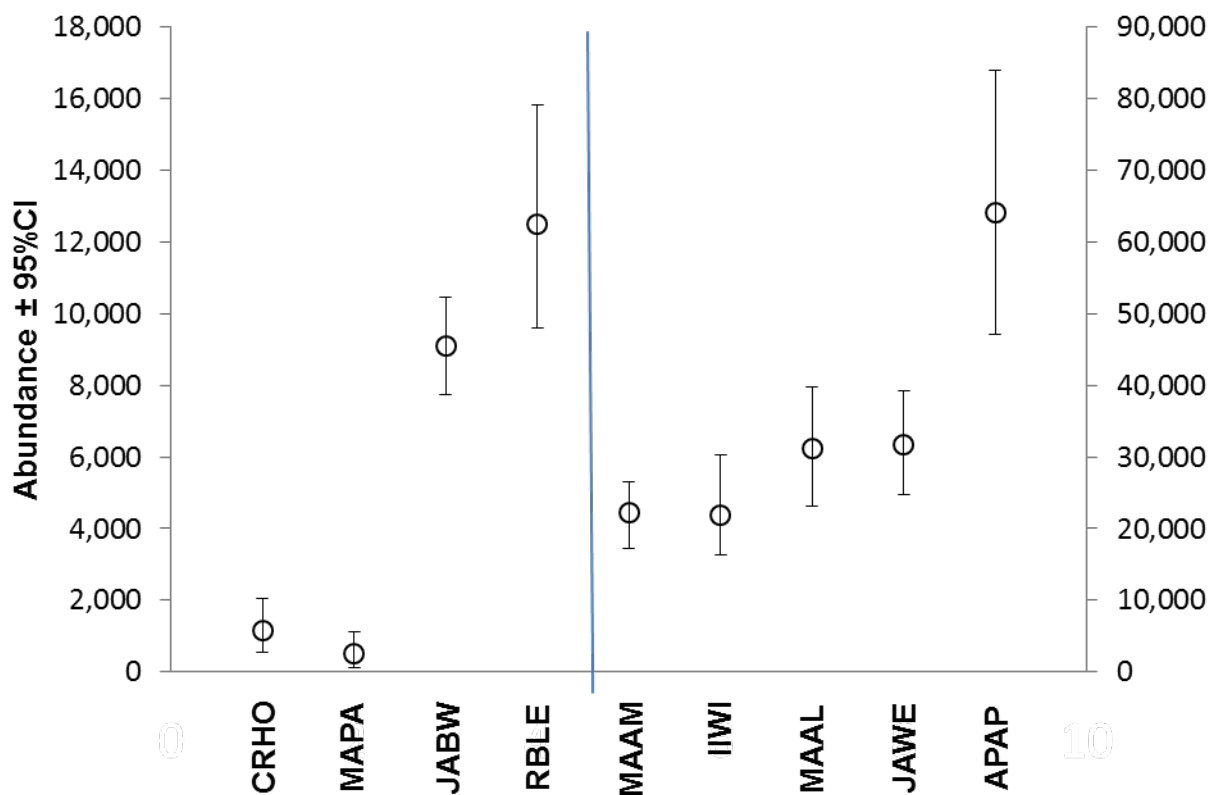


Figure 2. Population abundance and 95% confidence intervals for birds in HALE. Species abbreviations are: ‘Ākohekohe – CRHO; Kiwīkiu – MAPA; Japanese Bush-Warbler – JABW; Red-billed Leiothrix – RBLE; Maui ‘Amakihi – MAAM; ‘I‘iwi – IIWI; Maui ‘Alauahio – MAAL; Japanese White-eye – JAWE; ‘Apapane – APAP. Maui ‘Amakihi, ‘I‘iwi, Maui ‘Alauahio, Japanese White-eye, and ‘Apapane estimates use the right-hand y-axis.

Landbird Density by Elevation Strata

We compared densities of landbirds between the two strata. Remarkably, the difference in occurrence between strata was less than 15% for all but two of the species—‘Alauahio and Japanese White-eye. Densities of two natives (‘Alauahio and ‘Apapane) were significantly greater above 1,280 m, whereas the density of Japanese White-eyes was significantly greater at low elevations (Table 4).

Table 4. Densities above and below 1,280 m elevation of landbirds in HALE. A two-sample z-test was used to compare densities.

Species	Density (birds/ha $\pm$ SE) High elevation (>1,280 m)	Density (birds/ha $\pm$ SE) Low elevation (<1,280 m)	z-test (statistic, p-value)
‘Alauahio	14.40 $\pm$ 2.76	3.50 $\pm$ 1.28	3.578, 0.0002
‘Apapane	24.89 $\pm$ 3.87	14.15 $\pm$ 2.30	2.389, 0.008
‘I‘iwi	7.65 $\pm$ 1.32	6.05 $\pm$ 1.06	0.949, 0.17
Japanese Bush-warbler	2.68 $\pm$ 0.24	3.25 $\pm$ 0.28	-1.533, 0.063
Japanese White-eye	6.97 $\pm$ 0.87	14.88 $\pm$ 2.20	-3.336, 0.0004
Maui ‘Amakihi	7.31 $\pm$ 0.88	6.81 $\pm$ 0.93	0.390, 0.35
Red-billed Leiothrix	3.69 $\pm$ 0.57	4.47 $\pm$ 0.62	-0.928, 0.18

Native Species Summaries

‘Ākohekohe, (Crested Honeycreeper)

A total of 20 of the endangered ‘Ākohekohe was detected. Occurrence was highest above 1,600 m in mesic and montane ‘ōhi‘a dominated rainforest (Appendix C—Figure 5). Most detections occurred near the Northeast Rift. Density was low at 0.79 $\pm$ 0.27 birds/ha (SE), and we estimate an abundance of 1,150 $\pm$ 389 individuals in the 1,458 ha inference area. This large honeycreeper is known to be aggressive towards ‘Apapane and ‘I‘iwi when competing for foraging resources (Perkins 1903), and its rarity may result in a shift in interspecies relationships among Hawaiian honeycreepers. ‘Ākohekohe rely on understory flowers when ‘ōhi‘a is not in bloom; thus, any reduction or degradation of understory quality may negatively impact this species (Scott et al. 1986).

‘Alauahio, (Maui Creeper)

Density of the ‘Alauahio was modest at 9.97 $\pm$ 1.92 birds/ha. The species was broadly distributed at elevations above 1,200 m (Appendix C—Figure 6), and their very high susceptibility to avian malaria may limit populations below 1,200 m (Atkinson et al. 2001). We estimate there to be 31,109 $\pm$ 6,004 individuals in the 3,121 ha inference area. The species was once common on Lāna‘i Island and West Maui, but is now extirpated there (Perkins 1903, Munro 1944). Populations have remained stable on East Maui (Camp et al. 2009). Scott et al. (1986) reported an abundance of 35,000 $\pm$ 5,000 individuals. ‘Alauahio feed on insects and nectar and the species can occupy a variety of habitats such as savanna and scrubland, but are most common in wet-mesic ‘ōhi‘a forests (Perkins 1903, Scott et al. 1986).

‘Apapane

‘Apapane were the most abundant and widely distributed species detected in the survey (Appendix C—Figure 7). Density was relatively high (20.52 ± 3.05 birds/ha), and we estimated $64,055 \pm 9,531$ individuals in the 3,121 ha inference area. A gregarious species, ‘Apapane occur in small to large flocks as a defense to larger and more aggressive birds, as well as social coordination for finding roosting and foraging sites (Ward 1964, Pimm and Pimm 1982). Dependent on nectar and foliar arthropods, the species appears to be thriving in the ‘ōhi‘a dominated forests of HALE.

‘I‘iwi

‘I‘iwi were widespread and occurred at more than 70% of the stations sampled (Appendix C—Figure 8). Density was modest at 7.00 ± 1.11 birds/ha, and we estimated $21,850 \pm 3,452$ individuals in the 3,121 ha inference area. Detections ranged between 860 m and 2,000 m elevation, a wide range for this honeycreeper that is extremely vulnerable to avian malaria (Atkinson et al. 1995). The long decurved bill of the ‘I‘iwi is adapted for nectar feeding from the curved flowers of native lobelioids (Perkins 1903, Spieth 1966, Scott et al. 1986); however, their main source of nectar is ‘ōhi‘a flowers. The species may be limited by nectar abundance throughout HALE and the presence of avian malaria at lower elevations.

Kiwikiu, (Maui Parrotbill)

The endangered Kiwikiu was the rarest bird detected in the survey. Only eight individuals were documented. Detections ranged between 1,440 m and 2,400 m elevation and occurrence was highest near the Northeast Rift (Appendix C—Figure 9). Density was very low (0.24 ± 0.13 birds/ha). We estimated 495 ± 261 individuals in the 2,036 ha inference area. Kiwikiu previously occupied a wide range of habitats, including dry forests and lowland habitat (Olson and James 1982). Henshaw (1902) and Perkins (1903) reported that the species was strongly associated with koa forests. Kiwikiu, however, were not detected in koa dominated or co-dominated forests in HALE and appear to be restricted to high elevation, wet, ‘ōhi‘a dominated forests.

Maui ‘Amakihi

Maui ‘Amakihi occurred at nearly 78% of the stations sampled (Appendix C—Figure 10). Densities were modest at 7.10 ± 0.76 birds/ha, and the species was relatively abundant in the 3,121 ha inference area at $22,172 \pm 2,370$ individuals. Generalist foragers, Maui ‘Amakihi occur in a wide variety of native habitats and can even exploit introduced resources (Scott et al. 1986, Camp et al. 2009). The Hawai‘i Island subspecies of ‘Amakihi appears to be resistant to avian malaria (Woodworth et al. 2005). In Kīpahulu, this subspecies occupies lower elevations where avian malaria can be transmitted by mosquitoes.

Non-Native Species Summaries

House Finch

Only one House Finch (*Carpodacus mexicanus*) was detected in Kīpahulu Valley near an elevation of 880 m (Appendix C—Figure 11). The detection was likely a transient individual as House Finches are rare in Hawaiian wet forests and often strongly associated with rural and urban developments (Scott et al. 1986, Judge et al. 2011). This finch naturalized Hawai‘i in the 1960s and has demonstrated interisland dispersal (Foster 2005).

Japanese Bush-warbler

Japanese Bush-warblers were widely distributed and occurred at nearly 87% of the stations sampled (Appendix C—Figure 12). At a density of 2.91 ± 0.22 birds/ha, we estimated an abundance of $9,081 \pm 680$ individuals in the 3,121 ha inference area. Native to Japan and parts of Asia, the species was first recorded on Maui in 1980 (Carothers and Hansen 1982). The species was sparsely distributed on East Maui during landbird surveys by Scott et al. (1986), and has been slowly spreading across the island (Foster 2009). Our findings mark a substantial increase in distribution and abundance.

Japanese White-eye

The Japanese White-eye was one of the most common non-native species detected (Appendix C—Figure 13). It occurred at nearly 74% of the stations sampled and at a relatively high density (10.19 ± 1.22 birds/ha). We estimated an abundance of $31,792 \pm 3,802$ individuals in the 3,121 ha inference area. The species is ubiquitous throughout the main Hawaiian Islands and can occupy almost any habitat (Scott et al. 1986, Judge et al. 2011).

Melodious Laughing Thrush, (Hwamei)

The Melodious Laughing-thrush (*Garrulax canorus*) was detected at almost 9% of the stations sampled. Occurrence was highest below 1,200 m elevation, but it was also detected near 2,000 m (Appendix C—Figure 14). The species forages for insects and fruits in both native and introduced understory. Introduced to Hawai‘i in 1929 (Locey 1937, Foster 2005), the species is naturalized in both native and non-native forests. Capable of seed dispersal (Foster and Robinson 2007), this thrush may be spreading invasive non-native plants in Kīpahulu Valley.

Northern Cardinal

The Northern Cardinal (*Cardinalis cardinalis*) occurred at < 2% of the stations sampled. Detections in Kīpahulu Valley were below 900 m elevation in weed invaded habitat (Appendix C—Figure 15). Northern Cardinals were first introduced to the Hawaiian Islands in 1929 (Caum 1933) and are relatively common in disturbed and open habitats (Scott et al. 1986).

Red-billed Leiothrix

The Red-billed Leiothrix was widely distributed, occurring at 81% of the stations sampled (Appendix C—Figure 16). Density was modest at 4.00 ± 0.53 birds/ha and we estimated an abundance of $12,495 \pm 1,649$ individuals in the 3,121 ha inference area. This babbler is capable of seed dispersal (Foster and Robinson 2007) and may contribute to the spread of invasive non-native shrubs in Kīpahulu Valley. The species was intentionally and accidentally released on separate occasions in the early 20th century (Fisher and Baldwin 1947), and occurs throughout native and alien-dominated forests.

Incidentally Observed and Undetected Bird Species

A‘o (Newell’s Shearwater)

The federally endangered A‘o (*Puffinus newelli*) was heard calling at night from the Delta Shelter on June 5 and 6. Calls came from the direction of the Northeast Rift, a steep pali rising from the Palikea Stream. Individuals were presumably nesting on the pali. The finding is encouraging for one of Hawai‘i’s rarest seabirds.

Maui ‘Ākepa

The endangered Maui ‘Ākepa was not detected during the 2012 landbird survey. The species was last seen in 1994 (Reynolds and Snetsinger 2001). Eight individuals were detected during the 1980 Hawai‘i Forest Bird Survey (Scott et al. 1986), and there are documented sightings in 1988 (Reynolds and Snetsinger 2001). Any surviving birds would be on the Northeastern slopes of Haleakalā between 1,700 m and 2,000 m and in Kīpahulu Valley (USFWS 2006). Detections of Maui ‘Ākepa require visual and aural confirmation because of possible confusion with the Kiwīkiu. Targeted surveys in HALE would help determine if the species is extant or extinct.

Maui Nukupu‘u

The endangered Maui Nukupu‘u is presumed extinct (Pratt and Pyle 2000). The species was not detected during the survey. First records of the species are from mixed koa and ‘ōhi‘a forest from 1,220 meters to tree line (Perkins 1903, USFWS 2006). Banko (1968) had three sightings in Kīpahulu Valley between 1,800 m and 2,000 m in mixed forest. The most recent detections were in Hanawī Natural Area Reserve in 1996 (Reynolds and Snetsinger 2001). Prior reports were of a single male in the same area in 1994 and 1995. Point-counts in Kīpahulu Valley in 2005 and 2008 yielded no detections and the species has not been seen on the Northeast slope of Haleakalā during survey efforts (C. Bailey pers. comm.). Furthermore, Maui Nukupu‘u have not been detected in research conducted by the Maui Forest Bird Recovery Project in the Hanawī and Waikamoi areas (H. Mounce pers. comm.). Targeted surveys in HALE would help determine if the species is extant or extinct.

Nēnē (Hawaiian Goose)

The Nēnē (*Branta sandvicensis*) is often seen in native shrublands of the Crater District. They are conspicuous at visitor areas and cabins in HALE. On May 15, surveyors at the West Camp in Kīpahulu Valley heard distant calls from shrublands above the camp (at approximately 2,100 m elevation).

Habitat

Canopy Composition

We sampled 160 stations for canopy composition in HALE. *M. polymorpha* and *C. platyphyllum* were the most dominant tree species and nine other native and invasive species were conspicuous at stations surveyed (Table 5). We documented 22 canopy classes of varying levels of dominance, co-dominance, and sub-dominance of tree species (Table 6). The combination of *M. polymorpha* interspersed with mature *C. platyphyllum* was the most common canopy class documented, occurring at 92.5% of the stations surveyed. Most monitoring stations had a dense canopy: 77.5% had most crowns interlocking (> 60% cover), and the remaining stations sampled had an open canopy of some or no interlocking crowns (25-60% cover). More than half (52%) of the stations surveyed had trees taller than 10m, while almost a third (31%) had trees 5-10m, and the remaining (17%) were dominated by trees shorter than 5m.

Table 5. Canopy tree species recorded at landbird monitoring stations (50-m radius plot).

Common Name	Scientific Name	% stations sampled	Range (m)	Class	Abbreviation
ōhi'a lehua	<i>Metrosideros polymorpha</i>	92.50	700-2100	native tree	Me
‘ōlapa	<i>Cheirodendron platyphyllum</i>	80.00	700-2100	native tree	Ch
koa	<i>Acacia koa</i>	28.75	700-1300	native tree	Ac
kōlea	<i>Myrsine</i> spp.	8.13	900-2100	native tree/shrub	Myr
olomea	<i>Perrottetia sandwicensis</i>	8.13	700-1100	native tree/shrub	Olo
pilo	<i>Coprosma</i> spp.	8.13	1100-2100	native tree/shrub	pilo
strawberry guava	<i>Psidium cattleianum</i>	7.50	700-900	invasive tree	PC
kopiko	<i>Psychotria</i> spp.	4.38	1900-2100	native tree/shrub	psy
ho'awa	<i>Pittosporum</i> spp.	1.88	1900-2100	native tree/shrub	pitt
kāwa'u	<i>Ilex anomala</i>	1.88	700-2100	native tree/shrub	ilex
hapu'u	<i>Cibotium glaucum</i>	1.25	700-900	tree fern	TF

Table 6. Canopy composition classes documented at landbird monitoring stations (50-m radius plot). The species listed first is the most dominant, co-dominant species are separated by a hyphen, and sub-dominant species are separated by commas (Jacobi 1989). Percent of stations sampled and elevation of canopy class is noted in 200 m intervals (Range). Abbreviations are found in Table 5.

Canopy Composition	Range (m)	Station Count	%
Me, Ch	700-2100	83	51.88
Me, Ac, Ch	900-1300	19	11.88
Me	900-1900	18	11.25
Me, Ac	900-1300	5	3.13
Me, Ch, Kopiko	1900-2100	5	3.13
Ac, Ch	700-1100	4	2.50
Me, Ch, Kolea	1300-1500	4	2.50
Me-Ac, Ch	900-1300	4	2.50
PC, Ac	700-900	3	1.88
Me, Ac-Ch	900-1300	2	1.25
PC, AC, Olo, Ch	700-900	2	1.25
Ac	900-1100	1	0.63
Ac, Ch, Olo	900-1100	1	0.63
Me, Ac, PC	900-1100	1	0.63
Me, Ch, Cyanea	1100-1300	1	0.63
Me, PC, Ac, Ilex	700-900	1	0.63
Me, Pilo	1300-1500	1	0.63
Me-Ac-Olo-PC	700-900	1	0.63
PC	700-900	1	0.63
PC, AC, Me, Ch	700-900	1	0.63
PC, AC, Olo, Ch	700-900	1	0.63
PC, Ch, Ac, TF	700-900	1	0.63

Understory Composition

We sampled 160 stations for understory composition in HALE. We identified 8 understory classes of both native and introduced shrubs, ferns, grasses, mosses, sedges, and vines (Table 7). Native shrubs and native ferns were the most common understory vegetation, occurring at 100% and 99% of stations sampled, respectively. Invasive shrubs and grasses were predominant at lower elevations (below 1,700 m). Native sedges, native vines, and introduced grasses were recorded at relatively few stations (< 15%).

We documented 24 understory composition classes at 160 landbird monitoring stations (Table 8). The combination of native ferns, native shrubs, and native mosses (pooled group including native and non-native mosses and liverworts) was the most common composition class recorded, occurring at 83 of the stations sampled (52%) and ranging throughout the entire sampling area (700-2100 m elevation). The remaining classes each occurred at less than 13% of the stations sampled (Table 8).

The most common native shrubs recorded were *Vaccinium calycinum*, *Broussaisia arguta*, and *Leptecophylla tameiameae*; each occurring at more than 34% of the stations sampled (Table 9). The most common native ferns were *Dicranopteris linearis*, *Diplazium sandwichianum*, and *Sadleria* spp. (Table 9). Invasive species *Psidium cattleianum*, *Clidemia hirta*, and *Hedychium gardnerianum* occurred at approximately 14% of the stations sampled, predominantly at elevations below 1,100 m.

Table 7. Understory classes at landbird monitoring stations (50-m radius plot).

Class	% stations sampled	Range (m)	Abbreviation
native shrubs	100.00	700-2100	NS
native ferns	99.40	700-2100	NF
native mosses	78.10	700-2100	NM
invasive shrubs	14.38	700-1700	IS
native grasses	9.40	1300-2100	NG
native sedges	7.50	1100-2100	NSD
native vines	3.80	1100-1500	NV
introduced grasses	3.80	700-2100	IG

Table 8. Understory composition classes at landbird monitoring stations in 2012. Abbreviations are found in Table 7.

Understory Composition	Elevation Range (m)	Station Count	%
NF, NS, NM	700-2100	83	51.88
NS, NF, NM, NSED	900-2100	20	12.50
NF, NS, IS	700-1700	10	6.25
NF, NS, IS, BG	700-900	6	3.75
NF, NS, NM, NSED	1100-2100	5	3.13
BG, IS, NF, NS	700-900	4	2.50
NG, NF, NM, NS, NSED	1100-1700	4	2.50
NF, NS, NM, NG	1100-1700	3	1.88
NS, NF, NG	1500-1900	3	1.88
IG, IS, NF, NS	700-1100	2	1.25
IS, NF, NS	900-1100	2	1.25
NS, NF, NG, IG	1500-1900	2	1.25
NS, NF, NG, NM	1300-1700	2	1.25
NS, NG, NF, NM	1500-1700	2	1.25
NF, NS, NG	1300-1500	1	0.63
NF, NS, NG, NSED, IG	1900-2100	1	0.63
NF, NS, NM NSED, BG	1900-2100	1	0.63
NF, NS, NM, BG	900-1100	1	0.63
NF, NS, NM, IS	900-1100	1	0.63
NF, NS, NM, NV	1100-1300	1	0.63
NG, NSED, NS, IS	1500-1700	1	0.63
NS, NF, NG, IG, IS	1700-1900	1	0.63
NS, NF, NM, NSED, IG	1300-1500	1	0.63
NS, NF, NV, NM	1300-1500	1	0.63

Table 9. Understory species documented at HALE landbird monitoring stations (50-m radius plot).

Common Name	Scientific Name	% stations sampled	Range (m)	Class	Abbr.
‘ōhelo	<i>Vaccinium calycinum</i>	45.00	900-2100	native shrub	NS
kanawao	<i>Broussaisia arguta</i>	44.38	900-2100	native shrub	NS
pūkiawe	<i>Leptecophylla tameiameae</i>	34.38	1100-2100	native shrub	NS
‘uluhe	<i>Dicranopteris linearis</i>	14.38	900-1900	native fern	NF
‘ākala	<i>Rubus hawaiensis</i>	14.38	900-2100	native shrub	NS
Koster's curse	<i>Clidemia hirta</i>	10.63	700-1100	invasive shrub	IS
lāukahi nunui	<i>Elaphoglossum</i> spp.	8.13	900-2100	native shrub	NS
‘ala‘ala wai nui	<i>Peperomia</i> spp.	8.13	1100-2100	native shrub	NS
kahili ginger	<i>Hedychium gardnerianum</i>	5.00	700-1300	invasive shrub	IS
poholi	<i>Diplazium sandwichianum</i>	5.00	900-1100	native fern	NF
hāhā	<i>Cyanea</i> spp.	4.38	900-1700	native shrub	NS
alani	<i>Melicope</i> spp.	3.75	1300-1900	native shrub	NS
manono	<i>Kadua affinis</i>	3.13	700-2100	native shrub	NV
māmaki	<i>Pipturus albidus</i>	2.50	900-1500	native shrub	NS
‘ama‘u	<i>Sadleria</i> spp.	1.88	1500-1700	native fern	NF
āle	<i>Plantago pachyphylla</i>	1.88	1500-1700	native shrub	NS
greensword	<i>Argyroxiphium virescens</i>	1.88	1500-1700	native shrub	NS
lobelia	<i>Lobelia gloria-montis</i>	1.88	1500-1700	native shrub	NS
oha wai	<i>Clermontia</i> spp.	1.88	1100-1700	native shrub	NS
maile	<i>Alyxia oliviformis</i>	1.88	900-1100	native vine	NV
pa‘iniu	<i>Astelia menziesiana</i>	1.88	1700-1900	native shrub	NS
glory-bush	<i>Tibouchina</i> spp.	1.25	700-1700	invasive shrub	IS
thimbleberry	<i>Rubus rosifolius</i>	1.25	700-900	invasive shrub	IS

Slope

Slope measurements were taken at all 160 stations in HALE. The majority of stations were of a medium grade slope—29% of the stations were a 11-20 slope percent grade, 14% were 21-30 percent grade, and 18% of the stations sampled were 31-40 percent grade. Only a handful of stations were on steeper slopes, 11% of the stations sampled were on > 60 degree slopes (Table 10). Most of the stations were classed as medium variability and there were very few stations in the low and high variability classes (11% and 7%, respectively; Table 11).

Table 10. Slope grade and percent of total stations of given slope.

Slope % grade	Count	Percent
0-10	19	12%
11-20	46	29%
21-30	23	14%
31-40	28	18%
41-50	17	11%
51-60	9	6%
>60	18	11%

Table 11. Slope variability of stations sampled.

Slope Variability	Stations Sampled	Percentage
high	11	7%
med	131	82%
low	18	11%

Aspect

Kīpahulu Valley generally slopes down in an easterly direction and southward at lower elevations. Aspect for a majority of the stations ranged 45°-225°, or east to south (Table 12). Most of the stations had a medium variability of aspect measurements (Table 13). The slopes of the Upper and Lower Plateaus are gradual, except in areas where transects cross gulches and ridge tops. Transect 18, in Manawainui, descended in a more southerly direction.

Table 12. Aspect of stations sampled.

Aspect (degrees)	Stations Sampled	Percentage
North (45-315°)	16	10%
East (45-115°)	66	41%
South (115-225°)	71	44%
West (225-315°)	7	4%

Table 13. Aspect variability of stations sampled in HALE

Aspect Variability	Stations Sampled	Percent
high	11	7%
med	131	82%
low	18	11%

Comparison of Panel Data

As evidenced by the quantile-quantile (q-q) plots, distributions of bird densities differed between the fixed and random member panels (Figure 3). This difference was statistically significant (two-sample Kolmogorov-Smirnov test: $D=0.166$, $p=0.026$). This result should be viewed with caution as the samples were uneven and there were very few random panel stations sampled. However, given the current data we conclude that bird densities from the fixed and random transects were different. Because of these differences between the panel members, abundance estimates from the legacy transects may be biased, thus transects from both panels should be sampled during subsequent surveys.

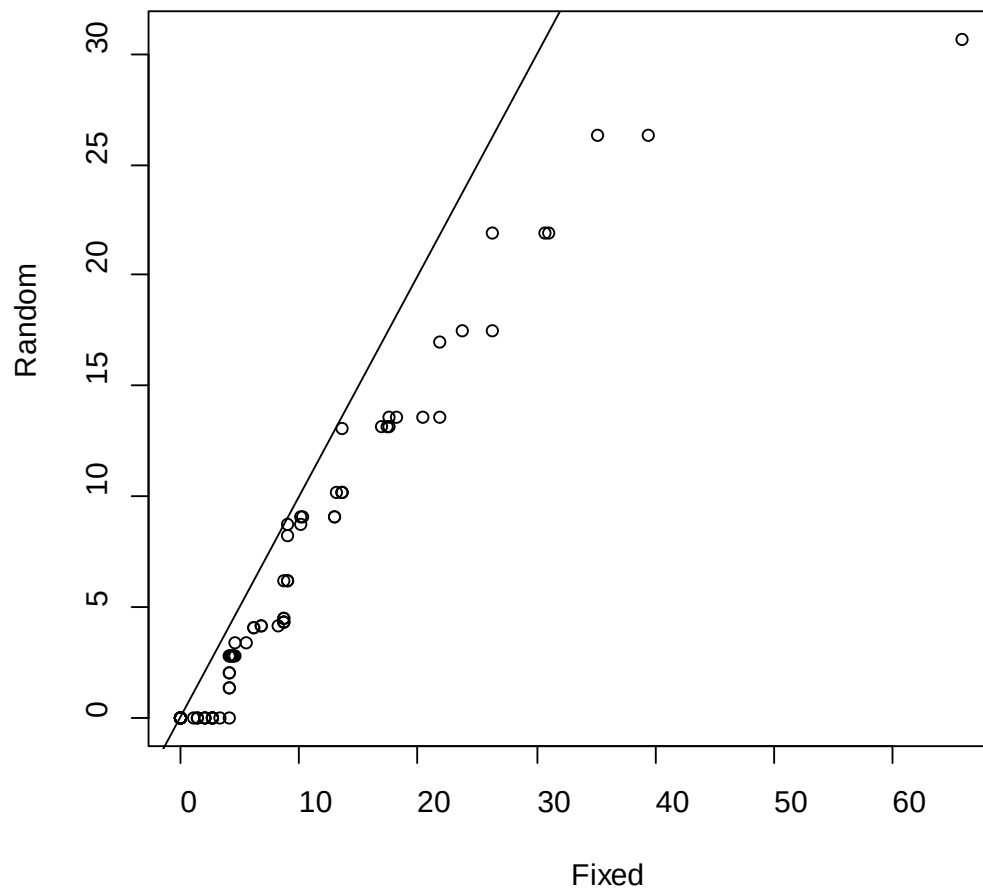


Figure 3. Q-Q plot of panel design member densities. Distribution of station-specific density estimates for the legacy transects (x-axis) plotted against estimates from the random transects (y-axis). The line represents a 1:1 relationship. There was evidence of a difference between the member distributions ($p=0.026$). Therefore, given the current data both panels should be sampled during subsequent surveys.

Discussion

Landbirds

The 2012 HALE Landbird survey produced estimates of distribution, abundance, and density of six native and six non-native species. The ‘Apapane was the most abundant species detected in the survey. The Maui ‘Amakihi, Maui ‘Alauahio, and ‘I‘iwi were detected at modest densities and each was relatively abundant in the study area. Of the six introduced landbirds detected, the Japanese White-eye, Red-billed Leiothrix, and Japanese Bush Warbler were the most abundant and widely distributed. Future surveys in HALE will help determine population trends of native and non-native species, as well as the distribution of Hawai‘i’s rarest species.

HALE harbors habitat critical for the endangered Kiwikiu. Prior island-wide estimates of Kiwikiu varied widely ranging from 400 to 1,100 individuals (Brinck et al. 2012). We estimated 495 ± 261 SE individuals in HALE, in an inference area that likely includes all suitable habitats inside the National Park. In 2011, the State of Hawai‘i Division of Forestry and Wildlife conducted surveys outside the Park in the Northeast Maui portion of Kiwikiu range and estimated there to be 421 birds (95% CI 209—674). The combined estimates yielded a point-estimate of 916 birds (95% CI 238—1,317). It is likely that the uncertainty about the point estimates could be reduced if repeat visits were conducted (Brinck et al. 2012). Perkins (1903) reported the species preferred to forage in the branches of Koa trees. Since 1980, there have been few detections of Kiwikiu in koa forests of Kīpahulu (Camp et al. 2009), and this is taken as evidence that the species’ range has contracted from preferred habitat, perhaps because of avian malaria.

The Hawaii Forest Bird Survey (HFBS; Scott et al. 1986) estimated the island-wide population for ‘Ākohekohe at $3,753 \pm 373$ (SE) individuals. Subsequent surveys indicated that ‘Ākohekohe may be increasing and the most recent range-wide estimate for the period 1997-2001 was $6,728 \pm 812$ birds (Camp et al. 2009). We estimated a population of $1,150 \pm 389$ individuals in the 1,458 ha inference area within the park (about 25% of the species 60 km² range; Camp et al. 2009). HALE therefore hosts a sizeable portion of the ‘Ākohekohe population and at densities similar to those during the HFBS.

It is notable that all observations of Kiwikiu and ‘Ākohekohe were at elevations above 1,500 m, indicating that disease likely plays an important role in the current distribution of these birds in HALE. Other potential factors include introduced predators such as cats (*Felis catus*) and rats (*Rattus* spp.), and introduced avian competitors such as the Japanese White-eye. Rats are known nest predators on Hawaiian forest birds, and two species of rats (*Rattus exulans* and *R. rattus*) are common and widespread in ‘ōhi‘a dominated rainforest within HALE (Stone et al. 1984, Bailey 2007), thus it is quite likely that rats are having some impact on reproductive success of most bird species in the park. Rats, along with Japanese White-eyes and possibly introduced yellowjacket wasps (*Vespula pensylvanica*) may also be competing with native birds for arthropod food resources in HALE. Freed et al. (2008) have demonstrated that Japanese White-eye outbreaks at Hakalau Forest National Wildlife Refuge on Hawai‘i Island are correlated with decreases in abundance of Hawai‘i ‘Ākepa, a native insectivore. However, the idea that introduced competitors may be reducing arthropod food availability for native birds in Kīpahulu requires further study.

Both the 'Alauahio and Maui 'Amakihi were widespread and abundant, occurring throughout the inference area. The surveyed portion of HALE lies well within the elevational range of both these species, and there was no indication of changes in their ranges. The dramatic difference in 'Alauahio densities above and below 1,280 m elevation was also documented by Scott et al. (1986) and is likely due to their very high susceptibility to malaria (Atkinson et al. 2001) and may also be indicative of differences in habitat suitability or increased threats at the lower elevation. Interestingly, Scott et al. (1986) estimated the total 'Alauahio population at 35,000 birds. Although direct comparisons between HFBS and subsequent surveys should be viewed with caution because the HFBS was conducted past the period of peak vocalization, our estimate in HALE was 31,100 birds, or almost 90% of the historical population. Thus, there has been a large increase in abundance within HALE, which was also documented elsewhere in the 'Alauahio population (Camp et al. 2009, Brinck et al. 2012). Similarly, the 'Amakihi population has increased on Maui (Camp et al. 2009) and the current HALE population was more than 50% of the historical population (22,200 and 43,900 birds, respectively; Scott et al. 1986).

The abundance of 'Apapane was not surprising, given that they are common in middle to high elevation forests on most Hawaiian Islands (Camp et al. 2009). In addition, they were found at all elevations sampled in HALE. However, the large elevational range of 'I'iwi was notable, as they are known to be extremely vulnerable to avian malaria and the species is rarely detected below 1,500 m in Hawai'i (Atkinson et al. 2000, Atkinson and LaPointe 2009). 'I'iwi were relatively common throughout the HALE survey area and were detected at elevations as low as 860 m. Landbird surveys in Hawai'i Volcanoes National Park did not detect 'I'iwi below 1,500 m (Judge et al. 2011), and 'I'iwi on Kaua'i Island are becoming relatively rare and occur only above 1,000 m (Camp et al. 2009). It is possible that the low elevation 'I'iwi detected in this survey were making daily foraging flights from higher elevations where they nest and roost, which could afford some protection from the night-biting *C. quinquefasciatus* mosquitoes. Simon et al. (2002) documented seasonal movements of 'I'iwi where birds migrated to lower elevations during the summer, which may account for the detections at low elevations. Another possibility is that wet and cool weather conditions in Kīpahulu Valley may limit the cold intolerant mosquito. Aruch et al. (2007) found very low prevalence of malaria in Kīpahulu in the east region of Maui. This area receives typical tradewind weather, 2—6m annual precipitation and heavy rainfall associated with orographic effects. They attributed low malaria rates in Kīpahulu to high rainfall events that flush larval mosquito habitats in stream drainages, and relatively cool temperatures even at low elevations that limit mosquito and malaria development. In addition, the National Park Service has actively managed this area to control weeds and eradicated feral pigs. In wet forest habitats feral pigs create standing water sources suitable for mosquito breeding (Atkinson et al. 1995). Thus, the control and eradication of pigs from Kīpahulu may have limited larval habitat, and Aruch et al. (2007) failed to find *Culex* larvae in 12 km of terrestrial transects. There is currently no evidence to suggest that 'I'iwi have developed resistance to avian malaria on Maui.

There has been a dynamic shift in Maui's avian community during the last 40 years. Many native species that filled specific ecological niches have disappeared, and introduced birds have expanded into the isolated rainforests of HALE. We did not detect either the endangered Maui 'Ākepa or Maui Nukupu'u. The recent extinction of the Po'ouli was a sobering reminder of the fragility of native birds. The Po'ouli, an insectivore, wasn't discovered until 1973 (Casey and Jacobi 1974). However, this mysterious

honeycreeper declined quickly, and the species was last detected in 2004 and is feared extinct (Groombridge 2009).

There was a strong representation of non-native passerines in the study area, accounting for more than half of all the detections. The degree to which non-natives compete for resources with honeycreepers is not known, but there is evidence of a negative correlation of Japanese White-eye populations with that of 'I'iwi (Mountainspring and Scott 1985). Furthermore, non-native species may disperse seeds of invasive plants in Kipahulu Valley and thus could facilitate the degradation of native forests (Foster 2009).

The non-native avifauna on Maui is rich at 33 species but only 11 species are associated with forest habitats (Camp et al. 2011). In the middle portion of HALE we detected six non-native species and our analysis to determine species richness indicated that one or possibly two additional species could occur in HALE. Of the five possible species, only the Red-crested Cardinal (*Paroaria coronata*) is restricted to lower elevations and not likely to occur in the forested portions of HALE. Thus, four non-native forest bird species could occur in HALE (Red Junglefowl, *Gallus gallus*; Spotted Dove, *Streptopelia chinensis*; Zebra Dove, *Geopelia striata*; and White-rumped Shama, *Copsychus malabaricus* [unsubstantiated occurrence]). Only the Spotted Dove has been detected in proximity to HALE, in Waikamoi, Makawao, and Hanawi (USGS unpublished data), and is the most likely species to expand into middle and high elevation portions of HALE.

Habitats

Our habitat survey was derived from the methods developed by Jacobi (1989). For the purpose of this study, the information from the habitat surveys was mainly used for identifying influencing factors (covariates) in modeling detection functions for estimating bird densities. There was little influence, however, of habitat factors on bird detectability (see Appendix B).

Habitat surveys are an important component of the landbird monitoring because the information can be used to better understand the dynamics of bird populations. Habitat conditions such as canopy cover and density influence food availability, which may affect bird population densities in the area (Fretz 2002). If bird populations change over time, having long-term habitat information may allow for identifying potential reasons behind those changes. Furthermore, the information gathered from the habitat surveys serves as an overview of habitat conditions at our study plots. Over time, park managers and researchers may use the information to determine habitat changes at these remote locations where people infrequently visit. Lastly, the habitat information can also be incorporated into other programs of vital signs monitoring. Canopy information may complement satellite imagery to improve knowledge of the vegetation composition in an area. Understory vegetation information may reveal habitat structures that cannot be surveyed using remote sensing methods. Canopy and understory vegetation information may help to locate and monitor the spread of invasive plants. Introduced plants have already become an acute problem in Hawai'i for the preservation of native ecosystem and bird habitats (Loope and Medeiros 1995). Our habitat surveys cover a wide range of areas in the HALE and may detect invasive plants, such as *Miconia calvescens*, at their incipient stage before a major infestation strikes.

Panel Data

Random selection of transect and station placement ensures that the sample is representative of the larger population, and is a requirement of distance sampling, i.e., randomly placed within the Units (Buckland et al. 2001, Fewster et al. 2009). The PACN landbirds vital sign monitoring protocol prescribes sampling using a panel design: legacy transects assigned to the fixed member and new transects assigned to the random member (Camp et al. 2011). The fixed panel members were a carryover from previous surveys and were initially established under a different sampling frame (island-wide versus park unit). A random subset of the fixed-panel transects was selected and sampled for the fixed member panel to maximize the representativeness to the park unit sampling frames. However, including them in the current I&M survey may have introduced a bias in estimates of density and variance. This bias may yield a systematic error in the estimates as a result of non-random sampling of the population, and the estimates may not be representative of the entire population. Testing for this difference between the fixed and random panel members was therefore necessary to determine if the fixed panel member remains representative of the sampling frame. There was strong evidence that the distribution of bird densities from the fixed and random transects were different.

Future investigation of the bird distributions is warranted when additional data are available. Our analytical approach investigating the cross-sectional data set is more appropriate for examining precision than for examining bias. The random panel provides the necessary information to allow for bias assessment. That is, the random members' panel data is independent of the survey data of the fixed members' panel. With continuing surveys, bias, precision and other sources of non-sampling error (e.g., panel conditioning) can be investigated (O'Muircheartaigh 1989, Hsiao 2003). Moreover, evaluation for non-sampling error early in the monitoring program will provide an enormous potential to identify, treat and correct for errors, and with continuing surveys further evaluation can identify necessary modifications of field procedures.

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Appendix A. Field Report: Summary of Field Efforts in 2012

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Abstract

This abstract summarizes the field methods and survey effort for the 2012 landbird survey within Haleakalā National Park (HALE). This study was conducted under a cooperative agreement between the National Park Service and the Hawaii-Pacific Islands Cooperative Ecosystems Studies Unit (HPI-CESU), joint agreement H8080090008. Fieldwork preparation and data collection methods were followed as prescribed in the Landbird Vital Sign Monitoring Protocol (Camp et al. 2011), except where noted.

A total of 160 stations on seven transects were surveyed for landbirds and landbird habitat in Kīpahulu Valley, Manawainui and Northeast Rift. Surveys began on March 20 and concluded July 26, 2012. Three primary counters surveyed the stations over 19 survey days. A total of 2,830 bird detections of 12 different species was recorded. Each station was surveyed for landbird habitat characteristics.

Introduction

The PACN landbird vital sign monitoring protocol (hereafter Protocol) field season of 2012 was conducted in Haleakalā National Park (HALE). The park was surveyed to estimate species-specific bird abundance, density and distribution, as well as to describe landbird habitat. Training and sampling procedures followed the Protocol (Camp et al. 2011). This report documents the field effort and describes the logistical needs and considerations for future sampling of each unit. In addition, this report identified deviations from the procedures prescribed in the Protocol.

Three primary point counters and three secondary counters (Appendix A—Table 1) conducted the field work, including field preparation, training, data collection, and data management. Joy Tamayose, of HALE endangered species management, provided much expertise in landbird identification and habitat characteristics. Seth Judge, the Project Field Lead, conducted the majority of the data collection and coordinated the field effort. Patrick Hart (Department of Biology, University of Hawai‘i at Hilo) served as the project Principal Investigator and assisted with planning, preparations, and reporting. Richard Camp (Hawai‘i Cooperative Studies Unit, University of Hawai‘i at Hilo) assisted with data analysis and reporting, and issues pertaining to the Protocol. HALE Resource Management Chief Matt Brown provided logistical assistance. HALE Aviation Manager Timothy Bailey assisted with helicopter operations. Greg Kudray (PACN Inventory and Monitoring Program) offered further support with project and permitting needs. Invaluable field assistance was provided by HALE vegetation management personnel, each of whom provided much effort in establishing transects through dense forests and identifying rare plant species.

Appendix A—Table 1. List of observers for landbird monitoring field data collection. Primary point counters are in bold.

Observer	Observer Code	Contact information
Patrick J. Hart	PJH	pjhart@hawaii.edu
Seth W. Judge	SWJ	sjudge@hawaii.edu
Lindsay E. Moore	LEM	Lindsay_Moore@nps.gov
Steven P. Orwig	SPO	Steven_Orwig@nps.gov
Joy A. Tamayose	JAT	Joy_Tamayose@nps.gov
Patty C. Welton	PCW	Patty_Welton@nps.gov

Methods

Training

Bird Identification

Field ornithologists knowledgeable in the identification of Hawaiian forest birds participated in 20 days of training to learn species- and region-specific bird vocalizations. Identification skills were improved through rigorous training in the field and by practice with Hawaiian bird recordings (Cornell Laboratory of Ornithology 1995) and *Voices of Hawai‘i’s Birds* (Pratt 1996). The field crew studied historical references and bird guides (Perkins 1903, Munro 1944, Berger 1981, Pratt et al. 1987).

Distance Measurement Training

In addition to bird identification, the crew practiced estimating distances from observer to flagging. Distance calibration training followed the Protocol procedures (Camp et al. 2011). Training for distance measurements were conducted repeatedly within HALE. Between 3 and 20 strips of colored flagging were tied to objects about the station, typically trees, and each counter estimated the distance, in meters, from the station center-point to the flagging. The differences between the actual and estimated distance were calculated and recorded in field books. Calibration continued until each crewmember obtained an accuracy of less than 10% difference between the actual and estimated distances for more than 80% of all measurements. It was important to practice distance measurements in a variety of habitats, such as open shrubland or dense forest. Distance measurements varied by habitat, thus requiring counters to make mental adjustments to accommodate for the surrounding habitats.

Habitat Identification

Training for habitat data collection focused on field methods outlined in the Protocol (Camp et al. 2011). Plant guides by Herat (1981), Hoe (1979), Medeiros et al. (1998), Stemmermann et al. (1981), and Wagner (1990) were used to accurately identify species in the field.

Establishing Transects and Stations

Transects were navigated to using GPS units and magnetic compasses as prescribed in the Protocol (Camp et al. 2011). East Maui is a Universal Transverse Mercator projection, North American Datum 1983, Zone 4N. Each legacy transect in the Protocol was surveyed, but only a portion of the random stations prescribed in the Protocol were surveyed because of safety concerns and logistical difficulties.

Legacy transects were marked with blue flagging for ease of navigation by future surveyors. Flag spacing depended on the density of the forest and understory, but typically was placed five-20 m apart so that the next or previous flag was always visible. Orange flagging was placed approximately five and 10 m away from the station to prevent surveyors from accidentally missing the station. Stations were marked with pink and white flagging, and a metal tag with the transect and station number. The method deviated from the Protocol as HALE Resource Management preferred to tie flagging to trees on the legacy transects, rather than stake each station with a pole.

Data Collection

Point-transect distance sampling methods were used to survey landbirds and followed techniques described in the Protocol (Camp et al. 2011). Surveys were conducted at sampling stations spaced 150 m apart on transects. All birds seen or heard at each station were recorded during an 8-minute sampling period. The species, method of detection, and distance between observer and bird measured to the nearest meter was recorded. Rounding of measurements to the nearest five or 10 m was strictly avoided to eliminate “heaping.” Unnecessary noise and movement was avoided during counts to prevent altering bird activity. Binoculars were used to facilitate species identification. Counts were temporarily stopped when wind gusts or disturbances (e.g., helicopters, barking dogs, etc.) interrupted counts. There were no deviations between the Protocol prescribed and applied sampling methods. Data necessary to calculate unbiased species composition were collected.

Habitat data was collected as described in the Protocol (Camp et al. 2011). Slope was determined using a clinometer. Aspect of sampling stations was determined by compass. Topographic position in each station

was gauged by relative slope or geographic position on mountainside, from sea level to summit or ridge top areas. Canopy cover was estimated using a spherical densitometer. Percent canopy cover fell into four classes: closed canopy (>60% cover), open canopy (25-60% cover), scattered trees (5-25% cover) or very scattered (<5% cover). Canopy height was visually estimated into three classes: low stature trees (2-5 m tall), moderate stature (5-10 m tall) and tall stature (>10 m tall). Tree species composing more than 25% of the total crown cover at each 50 m radius plot was recorded to determine canopy tree composition. Understory composition was also documented as prescribed in the Protocol (Camp et al. 2011).

Field Effort Summary

HALE was surveyed for birds and habitat during the 2012 field season. Four legacy transects and three random transects were established in areas of Kīpahulu Valley, Manawainui, and Northeast Rift. HALE vegetation management personnel had flagged and “brushed” each transect prior to the arrival of the landbird monitoring team. Field efforts were scheduled according to helicopter readiness, weather considerations, and observer availability. Field operations were based out of NPS built shelters in the restricted access Scientific Reserve. Work load was quantified by “survey days,” or the number of primary point counters available per day.

Helicopter Operations

All flights to and from Kīpahulu Valley were executed by Windward Aviation. Scheduling, training, and support were kindly provided by the HALE Aviation Manager and Resource Management Division Chief. Each passenger was, as required, an interagency training certified crewmember or flight manager. All helicopter protocols were followed as described in the Interagency Helicopter Operations Guide (IHOG). The personal protection equipment, entering and exiting procedures, and emergency procedures were strictly adhered to using IHOG requirements. Each passenger was briefed on safety procedures before each flight and a post flight debriefing was conducted to address concerns and operational successes. Most flights were based out of the ‘Ohe‘o Helispot, which is a short drive from the Kīpahulu visitor center. A HALE flight plan was prepared and accepted by several safety and administrative personnel days before operations commenced. Flight plans detailed destinations, contingency plans, dates, and daily locations of monitoring teams. Shuttles to field sites from ‘Ohe‘o took 5-10 minutes plus another 10 minutes for crews to enter and exit the helicopter. Most week long field excursions required approximately 50-100 kg of gear; thus, sling loads of gear were flown to and from field landing zones. An hour or more of flight time was usually needed for flights to or from field sites.

Transect Descriptions

Transect 10

Legacy transect 10 traverses the Northeast Rift and the spectacular montane bogs near the Northeastern boundary of HALE. The transect is 28 stations long, station zero is the highest point (2,100 m) and the transect ends at station 27 (1,640 m; Appendix A—Figure 4). The transect crosses the HALE boundary near station 23 and stations 24-27 fall inside the Hana Reserve. Field and helicopter operations were based out of the Smith camp which is near station 22. Surveyors Judge and Orwig were dropped off via helicopter at the shelter on July 23. The transect crosses a large bog and rises over a large pu‘u (hill) and skirts the top edge of the Northeast Rift. The bogs are fragile and care should be taken when hiking through sensitive areas. The 2012 team surveyed stations 21 through eight on July 24. Surveyors hiked to

station seven the following day, departing the Smith shelter at 05:15 hours in order to arrive at the station and finish the transect (stations 0-7) before 11:00 hours. Surveyors should return to Smith camp via the transect, and avoid the strenuous hike along the northern boundary fence. On July 25 the remaining stations, 22-27, were surveyed in less than two hours and the crew was extracted by helicopter that afternoon.

Transect 16

Legacy transect 16 traverses the Lower Plateau of Kīpahulu Valley. The transect is 43 stations, it begins at station zero (1,980 m) and ends at station 42 (860 m; Appendix A—Figure 4). Field operations were based out of the Palikea and Delta camps. Surveyors accessed the highest stations via the “MAPA trail,” a challenging hike uphill from Palikea camp. Stations 0-6 lie on a very steep ridge. Surveyors would have to depart Palikea camp at the predawn hours to survey all the way up to station zero. Alternatively, a team can be dropped off via helicopter (“bumped”) early in the morning at the Mauka Ridge; there, surveyors can walk down to station zero, survey approximately 10 stations, and continue on to the Palikea shelter via the MAPA trail. In 2012, surveyors were not able to get that bump scheduled and only had time to survey stations 6-42. On June 4, surveyors Judge, Hart, and secondary counter Orwig were dropped off at the Palikea Shelter. Surveys began the following day at station 14. Hart surveyed uphill to station six and Judge surveyed downhill to station 19. The following day Judge surveyed random transect 1R (stations 1-6) as well as stations 28-29 on transect 16, and Hart surveyed stations 20-27. The team then continued to Delta shelter, where they based field operations. Additional camping gear was dropped by helicopter on June 5. Surveyors finished the transect on June 7. Judge surveyed stations 30-36, and Hart surveyed 38-42. The crew was extracted from Delta shelter via helicopter the morning of June 8.

There was a problem with the station numbering on transect 16. There are two stations marked “station 9” on the transect. We surveyed the lower elevation station nine and the upper elevation station nine should be marked “station 8.” Each station number lower than “station 9” needs to be remarked. To account for the additional station, station one heretofore will be referred to as station zero. Future surveyors need to be prepared to replace the station tags with the proper numbers.

Transect 17

Legacy Transect 17 is the longest transect in HALE. The transect traverses nearly the entire length of the Upper Plateau, starting at station one (2,020 m; Appendix A—Figure 4) and ending at station 75 (720 m). Field operations were based out of the West, Charlie, Ohē, and Ginger camps. From the West camp, the transect can be reached by a 30-minute hike to station one. A blue flagged trail leads south towards the Ko‘uko‘uai Stream. Primary point counter Judge and secondary counter Moore surveyed stations 1-12 on May 5 and returned to West Camp that afternoon. On May 6 the counters surveyed stations 13-18 and then continued to Charlie camp where some supplies were dropped off via helicopter on May 4. The transect follows close to the stream and then enters the stream bed near station 23. There are numerous crossings and walking in the stream can be especially hazardous on the wet and slippery rocks. The stream may be impassable during heavy rain and we suggest surveyors return to the nearest camp in that event. Foot travel to and from Charlie and West camp may not be possible in heavy rain and an alternative route that avoids stream crossings is advisable. Near station 26, the transect meets a large waterfall known casually as “end of the world,” which appeared to drop 150 m. From there, the transect turns north towards a fence and then to the Charlie LZ near station 32. The shelter is a 5-minute hike

uphill on a blue flagged trail. Judge and Moore surveyed stations 31-21 on May 7; there was not enough time to finish stations 19 and 20 unfortunately. The team was extracted from the Charlie LZ the following morning.

The middle portions of Transect 17 may be accessed from the Charlie, Ohe, and Ginger camps. On March 19, Judge and Tamayose were flown from Oheo Helipad to the Charlie LZ where they based fieldwork for one night. They surveyed stations 30-40 on March 20 and hiked to Ohe Camp where they overnighted. On March 21 the team surveyed stations 41-60 and overnighted at Ginger Camp. On March 22, the team was to survey the lower stations (61-75) and get picked up by an NPS off road vehicle near the Palikea Flats. While hiking to the transect, Tamayose hurt her knee and the team scheduled an immediate helicopter extraction. Tamayose was driven to the hospital, she was released that day, but had to undergo a knee operation months later. The HALE Resource Management division scheduled a “safety stand down” and two weeks were devoted to safety procedures.

Judge and Welton flew to Ginger Camp on June 26 to finish stations 61-75. Field work was hampered by rain and the team was only able to survey stations 61-71. The team had planned to hike from the bottom of the transect (station 75) to Palikea Flats, but were not able to cross the fast flowing stream below station 71. The team returned to Ginger Camp and was flown out the morning of June 29.

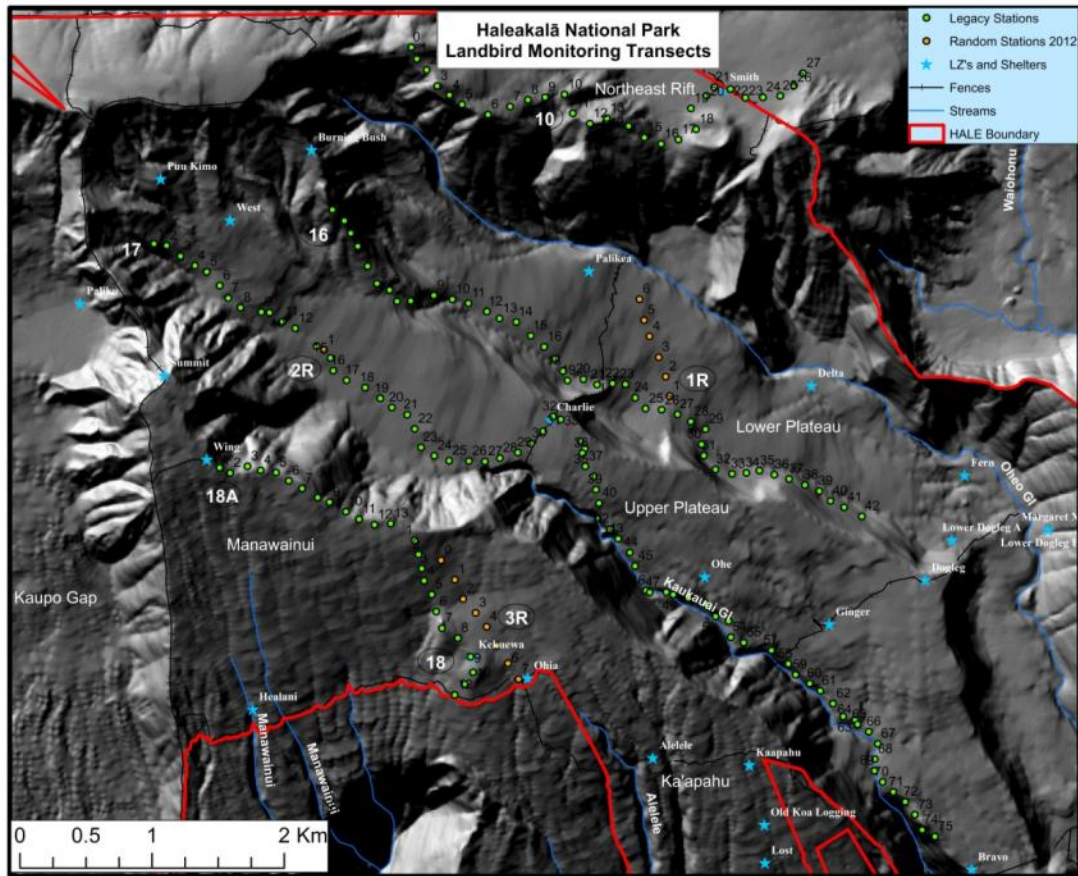
Transect 17 required seven days to survey 71 stations, an average of approximately 10 stations per day. However, access to West Camp is always limited because of inclement weather and surveys are often hampered by rain. Furthermore, surveys were limited to Tuesday through Thursday, because helicopter shuttles were scheduled on Mondays and Fridays and there wasn’t time for fieldwork on those days. Consequently, the transect may require well over 4 weeks of fieldwork to completely survey.

Transect 18

Legacy transect 18 was accessed from the ‘Ōhi‘a Camp in Manawainui (Appendix A—Figure 4). The transect was not designated in the Protocol, but was surveyed upon agreement with HALE resource managers and the monitoring team. The transect lies in habitat ideal for several species of rare honeycreepers. Surveyors Judge and Welton arrived at the shelter via helicopter on April 30. On May 1, the team surveyed random transect 3. It took the team two days to survey stations 1-12 on transect 18 and they finished the random transect in one day.

Transect 18A

There wasn’t enough time to survey transect 18A, which also bisects very good honeycreeper habitat. Surveyors would either need to be bumped up to the Wing LZ, or they would have to start hiking in the pre-dawn hours to reach station 13 from ‘Ōhi‘a Camp, there the team could survey uphill towards station 1. It’s unlikely the whole transect could be surveyed in one day, and it may take two weeks to finish transects 18 and 18A, as well as any random transects in the vicinity.



Appendix A - Figure 4. HALE landbird monitoring transects (2012). Legacy transects (10, 16, 17, and 18) are to be surveyed every five years, and random transects (1R, 2R, 3R) are one time only sites. Transect 18A was not sampled in 2012. The transect bisects critical endangered species habitat and should be surveyed in subsequent years. Most stations are spaced 150 m (± 10 m) apart.

Results

Landbird and landbird habitat surveys began on March 20, 2012 and concluded July 26, 2012. In total, three primary point counters required 19 survey days to conduct sampling. Travel to field sites was severely hampered by weather, helicopter availability, and logistical concerns. Teams were able to survey over a total of six weeks of field work. The first attempt to reach the valley was on February 27, that trip was cancelled because of rain. The cancellation was the first of many over a 16 week period. The Protocol specified surveys should be concluded by May 31, that date was unrealistic and we expect future HALE surveys may require several months to complete. In total, 160 stations (Appendix A—Table 1.) were surveyed for landbirds and habitat characteristics. A total of 2,830 birds of 12 species was detected in the survey.

Table 1. Landbird monitoring stations sampled in 2012.

Transect	First Station	Last Station	Number Stations Counted
10	0	27	28
16	6	42	37
17	1	71	69
18	1	12	12
1R	1	6	6
2R	1	1	1
3R	0	6	7

Discussion

The landbird monitoring team collected valuable data on the distribution, density, and abundance of Hawaiian honeycreepers and introduced species in HALE. We enumerated, ranked, and classified numerous habitat variables in order to describe the dominant plant community occupied by landbirds. Repeated surveys will provide data essential for determining the status and trends of Hawaiian honeycreepers and other landbirds in HALE.

The 2012 field effort was a collaborative process and the project wouldn't have been completed without the cooperation from HALE Resource Management personnel. The Vegetation Management division cleared and flagged most of the transects in fragile areas of the Kīpahulu Valley Scientific Reserve. Their effort saved the landbird monitoring team months of field work. Flagging and maintaining foot paths and transects in Kīpahulu Valley is an enormous challenge and only experienced field biologists knowledgeable in HALE plant communities and weed protocols should enter the reserve.

The weather in Kīpahulu Valley is unpredictable and heavy downpours can persist over several weeks. Field excursions were dependent on numerous factors, weather being the most pertinent concern for helicopter operations and landbird survey efforts. Field work in the Kīpahulu Valley requires last minute flexibility in planning and scheduling, as well as several contingency plans in the case of weather delays and potentially dangerous conditions.

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Appendix A

Appendix A—Table1. HALE landbird monitoring legacy transect number, stations, unique identifier, and location (Universal Transverse Mercator projection, North American Datum 1983, Zone 4N).

Transect	Station	Identifier	Latitude	Longitude	Y_Projection	X_Projection
10	0	10-00	20.73427799	-156.11663267	2295416.17	800289.24
10	1	10-01	20.73348009	-156.11624649	2295328.5	800331.06
10	2	10-02	20.73271238	-156.11555096	2295244.75	800405.06
10	3	10-03	20.73161283	-156.11480674	2295124.33	800484.79
10	4	10-04	20.73096972	-156.11392462	2295054.73	800577.99
10	5	10-05	20.73031147	-156.11302792	2294983.48	800672.74
10	6	10-06	20.72959384	-156.11114938	2294907.48	800869.93
10	7	10-07	20.73011736	-156.10953458	2294968.48	801037.18
10	8	10-08	20.73054904	-156.10823039	2295018.73	801172.24
10	9	10-09	20.73070642	-156.10698774	2295038.48	801301.43
10	10	10-10	20.73087587	-156.10556696	2295059.9	801449.16
10	11	10-11	20.72957542	-156.10498862	2294916.92	801512.01
10	12	10-12	20.7288588	-156.10376453	2294839.82	801641
10	13	10-13	20.72905728	-156.1025523	2294864.07	801766.94
10	14	10-14	20.72863891	-156.10094833	2294820.72	801934.93
10	15	10-15	20.72784493	-156.09983245	2294734.85	802052.8
10	16	10-16	20.72738358	-156.09861467	2294686.02	802180.63
10	17	10-17	20.72765723	-156.09735956	2294718.68	802310.89
10	18	10-18	20.72833843	-156.09606673	2294796.56	802444.27
10	19	10-19	20.72977079	-156.09640997	2294954.59	802405.65
10	20	10-20	20.73060352	-156.09526459	2295048.98	802523.36
10	21	10-21	20.73118686	-156.09467733	2295114.7	802583.4
10	22	10-22	20.73104215	-156.09350781	2295100.86	802705.57
10	23	10-23	20.73043057	-156.09244575	2295035.1	802817.47
10	24	10-24	20.73043596	-156.09116887	2295038.09	802950.53
10	25	10-25	20.73051103	-156.08990831	2295048.77	803081.75
10	26	10-26	20.7312138	-156.0888944	2295128.52	803186.01
10	27	10-27	20.7320291	-156.0882239	2295220.1	803254.26
16	0	16-00	20.7232927	-156.122575	2294188.25	799691.625

Appendix A—Table 1 cont.

Transect	Station	Identifier	Latitude	Longitude	Y_Projection	X_Projection
16	1	16-01	20.7225315	-156.1217235	2294105.5	799781.875
16	2	16-02	20.721673	-156.1212678	2294011.25	799831.0625
16	3	16-03	20.7207621	-156.1207776	2293911.25	799883.9375
16	4	16-04	20.7193988	-156.1200958	2293761.5	799957.6875
16	5	16-05	20.7182007	-156.1194354	2293630	800028.875
16	6	16-06	20.7177384	-156.1185274	2293580.48	800124.43
16	7	16-07	20.71696	-156.1180011	2293495.23	800180.81
16	8	16-08	20.7169772	-156.117009	2293498.98	800284.18
16	9	16-09	20.7173205	-156.1153238	2293540.13	800459.14
16	10	16-10	20.7170303	-156.1139813	2293510.48	800599.63
16	11	16-11	20.7167468	-156.1128209	2293481.24	800721.13
16	12	16-12	20.7161601	-156.1114852	2293418.73	800861.5
16	13	16-13	20.7156688	-156.1105812	2293365.98	800956.69
16	14	16-14	20.7154115	-156.1093724	2293339.73	801083.19
16	15	16-15	20.7144484	-156.108333	2293234.98	801193.43
16	16	16-16	20.7136765	-156.1073814	2293151.24	801294.13
16	17	16-17	20.7128597	-156.1065863	2293062.24	801378.62
16	18	16-18	20.7120062	-156.1060317	2292968.73	801438.12
16	19	16-19	20.7113533	-156.1057245	2292896.98	801471.43
16	20	16-20	20.7114332	-156.1045716	2292907.98	801591.44
16	21	16-21	20.7110353	-156.1035831	2292865.74	801695.25
16	22	16-22	20.7111002	-156.1024577	2292875.03	801812.42
16	23	16-23	20.71103	-156.1015158	2292869.01	801910.73
16	24	16-24	20.7101006	-156.1008263	2292767.35	801984.44
16	25	16-25	20.7093417	-156.1000943	2292684.64	802062.25
16	26	16-26	20.7092461	-156.0989262	2292676.24	802184.18
16	27	16-27	20.7089142	-156.0977757	2292641.62	802304.76
16	28	16-28	20.7083999	-156.0968199	2292586.43	802405.41
16	29	16-29	20.7078662	-156.0957691	2292529.28	802515.99
16	30	16-30	20.7068375	-156.0960759	2292414.74	802486.06
16	31	16-31	20.7060654	-156.0959275	2292329.49	802503.06
16	33	16-33	20.7047829	-156.0938886	2292191.24	802718.13

Appendix A—Table 1 cont.

Transect	Station	Identifier	Latitude	Longitude	Y_Projection	X_Projection
16	34	16-34	20.7048378	-156.0928587	2292199.24	802825.37
16	35	16-35	20.7049774	-156.0919038	2292216.49	802924.62
16	36	16-36	20.7046788	-156.0908236	2292185.44	803037.81
16	37	16-37	20.7043701	-156.089758	2292153.24	803149.49
16	38	16-38	20.7039334	-156.0886211	2292106.99	803268.87
16	39	16-39	20.7035061	-156.087576	2292061.62	803378.65
16	40	16-40	20.7028122	-156.0867783	2291986.24	803463.19
16	41	16-41	20.702369	-156.0857992	2291938.99	803566.12
16	42	16-42	20.7017292	-156.0845283	2291870.49	803699.87
17	1	17-01	20.7211838	-156.1355742	2293930.59	798341.02
17	2	17-02	20.7210446	-156.1346695	2293916.84	798435.58
17	3	17-03	20.7203131	-156.1336654	2293837.67	798541.66
17	4	17-04	20.7196462	-156.1326296	2293765.7	798650.92
17	5	17-05	20.719207	-156.1317846	2293718.61	798739.85
17	6	17-06	20.7182517	-156.1308576	2293614.51	798838.34
17	7	17-07	20.7173894	-156.1302536	2293520.1	798902.98
17	8	17-08	20.7167209	-156.1293816	2293447.66	798995.18
17	9	17-09	20.7163984	-156.1278712	2293414.73	799153.23
17	10	17-10	20.7163489	-156.1272823	2293410.34	799214.7
17	11	17-11	20.715719	-156.1263464	2293342.29	799313.48
17	12	17-12	20.7152479	-156.1254286	2293291.8	799410.07
17	13	17-13	20.7292021	-156.1025258	2294880.16	801769.41
17	14	17-14	20.7140134	-156.1238933	2293157.9	799572.51
17	15	17-15	20.7131843	-156.122898	2293067.9	799677.88
17	16	17-16	20.7123162	-156.1227238	2292972.05	799697.75
17	17	17-17	20.7116407	-156.1217651	2292899	799799
17	18	17-18	20.7111211	-156.1204328	2292843.92	799938.88
17	19	17-19	20.7103642	-156.1193418	2292762.09	800054.09
17	20	17-20	20.7097261	-156.1185108	2292692.95	800141.96
17	21	17-21	20.7092202	-156.1174088	2292638.95	800257.81
17	22	17-22	20.7082391	-156.1168787	2292531.26	800315

Appendix A—Table 1 cont.

Transect	Station	Identifier	Latitude	Longitude	Y_Projection	X_Projection
17	23	17-23	20.7069702	-156.1164507	2292391.49	800362.11
17	24	17-24	20.7063851	-156.1155027	2292328.43	800462.08
17	25	17-25	20.7060252	-156.1144287	2292290.56	800574.73
17	26	17-26	20.7059755	-156.1129825	2292287.74	800725.57
17	27	17-27	20.7059381	-156.1118309	2292285.74	800845.68
17	28	17-28	20.7061401	-156.1107317	2292310.16	800959.85
17	29	17-29	20.7065026	-156.1094288	2292352.74	801094.93
17	30	17-30	20.7071227	-156.1084564	2292423.24	801195.06
17	31	17-31	20.707929	-156.1075536	2292514.24	801287.56
17	32	17-32	20.7089121	-156.1068198	2292624.51	801362.1
17	33	17-33	20.7087085	-156.1062658	2292602.99	801420.25
17	34	17-34	20.707191	-156.1048687	2292437.49	801568.87
17	35	17-35	20.7067027	-156.1045536	2292383.99	801602.68
17	36	17-36	20.7063808	-156.1047367	2292347.99	801584.24
17	37	17-37	20.7054772	-156.1045486	2292248.24	801605.63
17	38	17-38	20.704781	-156.1039468	2292172.24	801669.74
17	39	17-39	20.7038804	-156.1038043	2292072.74	801686.38
17	40	17-40	20.7029518	-156.1036007	2291970.25	801709.44
17	41	17-41	20.7018926	-156.1037004	2291852.73	801701.14
17	42	17-42	20.7011623	-156.1028096	2291773.5	801795.44
17	43	17-43	20.7005001	-156.1022492	2291701.19	801855.17
17	44	17-44	20.6995459	-156.1014147	2291597.04	801944.05
17	45	17-45	20.6986167	-156.1010643	2291494.76	801982.41
17	46	17-46	20.6969303	-156.1002992	2291309.38	802065.51
17	47	17-47	20.6967975	-156.1000284	2291295.17	802094
17	48	17-48	20.6967937	-156.098827	2291296.99	802219.24
17	49	17-49	20.6966138	-156.098326	2291278	802271.82
17	50	17-50	20.6963471	-156.0972363	2291250.49	802385.94
17	51	17-51	20.6959898	-156.0959864	2291213.24	802516.93
17	52	17-52	20.6950814	-156.0952765	2291113.94	802592.74
17	53	17-53	20.6947358	-156.0943396	2291077.41	802691.09

Appendix A—Table 1 cont.

Transect	Station	Identifier	Latitude	Longitude	Y_Projection	X_Projection
17	54	17-54	20.6936428	-156.0941987	2290956.59	802707.95
17	55	17-55	20.6932593	-156.0932761	2290915.84	802804.88
17	56	17-56	20.6926897	-156.0912677	2290856.5	803015.37
17	57	17-57	20.6926928	-156.0912653	2290856.84	803015.62
17	58	17-58	20.6917592	-156.0900566	2290755.69	803143.47
17	59	17-59	20.6910063	-156.0895448	2290673.24	803198.32
17	60	17-60	20.6903845	-156.0885339	2290606.25	803304.94
17	61	17-61	20.6898727	-156.0877684	2290550.99	803385.75
17	62	17-62	20.6889863	-156.0868674	2290454.49	803481.44
17	63	17-63	20.6880983	-156.0861368	2290357.49	803559.37
17	64	17-64	20.6878513	-156.0852758	2290331.74	803649.62
17	65	17-65	20.6875416	-156.0851096	2290297.74	803667.56
17	66	17-66	20.687027	-156.0843029	2290242.25	803752.68
17	67	17-67	20.6861923	-156.0836588	2290150.99	803821.49
17	68	17-68	20.6851449	-156.0839048	2290034.5	803797.94
17	69	17-69	20.6843533	-156.0839402	2289946.75	803795.82
17	70	17-70	20.6835809	-156.0833687	2289862.25	803856.94
17	71	17-71	20.6828795	-156.0826033	2289785.99	803938.13
17	72	17-72	20.6821971	-156.0817502	2289712	804028.43
17	73	17-73	20.6813054	-156.0810669	2289614.5	804101.44
17	74	17-74	20.6802609	-156.0805552	2289499.75	804156.87
17	75	17-75	20.6797895	-156.079639	2289449.25	804253.32
18	1	18-01	20.7006381	-156.1170248	2291688.99	800314.77
18	2	18-02	20.6996672	-156.1167672	2291581.91	800343.53
18	3	18-03	20.6986963	-156.1165526	2291474.76	800367.81
18	4	18-04	20.6978648	-156.1164024	2291382.93	800385.11
18	5	18-05	20.6969206	-156.1158606	2291279.34	800443.45
18	6	18-06	20.6957458	-156.1155495	2291149.78	800478.19
18	7	18-07	20.6946086	-156.1151632	2291024.52	800520.7
18	8	18-08	20.6939166	-156.1140153	2290950	800641.73
18	9	18-09	20.6926291	-156.1131247	2290809.03	800737.1

Appendix A—Table 1 cont.

Transect	Station	Identifier	Latitude	Longitude	Y_Projection	X_Projection
18	10	18-10	20.6915609	-156.1129559	2290691.01	800756.81
18	11	18-11	20.6907638	-156.1136023	2290601.51	800691
18	12	18-12	20.6900445	-156.114318	2290520.5	800617.81
18A	1	18A-01	20.7058285	-156.1311019	2292237.888	798837.2739
18A	2	18A-02	20.7054554	-156.1303338	2292197.981	798918.0596
18A	3	18A-03	20.7058899	-156.1290732	2292248.444	799048.6025
18A	4	18A-04	20.7055993	-156.128125	2292218	799148
18A	5	18A-05	20.7054286	-156.1270078	2292201.158	799264.7754
18A	6	18A-06	20.7048523	-156.1260956	2292139	799361
18A	7	18A-07	20.7043127	-156.1251367	2292081	799462
18A	8	18A-08	20.7036744	-156.1240146	2292012.38	799580.2242
18A	9	18A-09	20.7033472	-156.123167	2291977.701	799669.2127
18A	10	18A-10	20.702682	-156.1219868	2291906.201	799793.534
18A	11	18A-11	20.7021456	-156.1210373	2291848.536	799893.5595
18A	12	18A-12	20.7017486	-156.1199322	2291806.611	800009.5263
18A	13	18A-13	20.7018077	-156.1187521	2291815.336	800132.4233

Appendix A—Table 2. HALE Landbird monitoring random stations sampled in 2012.

Transect	Station	Identifier	Latitude	Longitude	Y_Projection	X_Projection
1R	1	1R-01	20.71017725	-156.09832882	2292780.5	802244.6
1R	2	1R-02	20.71150196	-156.09858422	2292926.77	802215.35
1R	3	1R-03	20.71283038	-156.09906415	2293073.03	802162.69
1R	4	1R-04	20.71426721	-156.09971032	2293230.99	802092.49
1R	5	1R-05	20.71538256	-156.10008207	2293353.85	802051.53
1R	6	1R-06	20.71681381	-156.10039158	2293511.82	802016.43
2R	1	2R-01	20.713732	-156.12336095	2293127.71	799628.55
3R	0	3R-00	20.6992454	-156.11513917	2291538.21	800514.06
3R	1	3R-01	20.69790613	-156.11416036	2291391.67	800618.73
3R	2	3R-02	20.6965735	-156.11358312	2291245.12	800681.53
3R	3	3R-03	20.69561376	-156.1126975	2291140.45	800775.74
3R	4	3R-04	20.6946557	-156.1119123	2291035.78	800859.48
3R	5	3R-05	20.69336309	-156.11120261	2290893.91	800936.01
3R	6	3R-06	20.69213158	-156.11041676	2290758.95	801020.36

3R	7	3R-07	20.6910389	-156.10965765	2290639.32	801101.65
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Appendix B. Bird Modeling

Appendix B—Table 1. Factors for covariates for the 2012 HALE landbird survey. Pooling of covariates was used to increase sample size and increase the likelihood of model convergence.

Cloud	CloudPooled	Wind	WindPooled	Gust	GustPooled
0	1	0	0	0	0
10	1	1	1	1	1
20	1	2	1	2	1
30	1	3	1	3	1
40	1	4	1	4	1
50	1	5	1	5	1
60	2	6	1	6	1
70	2	<>	1	<>	1
80	2				
90	2				
100	2				
<>	2				

Appendix B—Table 2. Models and parameters used to derive population densities by species for the 2012 landbird survey.

Species Name	Model	Adjustment terms	Covariates	Truncation	k	-LogL	AICc	Justification
‘Ākohekohe	Hazard-rate	Cosine (2,3)	Detection 14	49.9	5	8282.78	16575.58	Selected using AICc methods
‘Alauahio	Hazard-rate	S-poly (4,6)	Detection	33	6	12237.62	24487.26	Selected using AICc methods
‘Apapane	Hazard-rate	Cosine (2)	Detection	45.8	5	2760.12	5530.33	Selected using AICc methods
‘I‘iwi	Hazard-rate	Key	Detection 24	52.1	3	1425.37	2856.8	Selected using AICc methods
Japanese Bush-warbler	Hazard-rate	Key	None	61	2	1288.7	2581.43	Selected using AICc methods
Japanese White-eye	Hazard-rate	Key	Observer	36	4	1098.17	2204.47	Selected using AICc methods
Kiwikiu	Half-normal	Key	Detection	60	3	1047.36	2100.81	Selected using AICc methods
Maui Amakihi	Hazard-rate	Key	Detection 24	37.8	3	966.01	1938.12	Selected using AICc methods
Red-billed Leiothrix	Hazard-rate	Key	None	55	4	1187.08	2382.29	Final model did not include covariates due to model errors using bootstrap methods

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
'Ā kohekohe	H-rate	Cos23	Dect14	5	8282.78	16575.58	0	1	
	H-rate	Cos23	SurveyArea	8	8306.26	16628.59	53.01	0	
	H-rate	Cos23	Gust	9	8316.01	16650.11	74.53	0	
	H-rate	Cos23	Obs	6	8383.29	16778.62	203.04	0	
	H-rate	Cos23	Cloud	8	8384.48	16785.02	209.44	0	
	H-rate	Cos23	Rain	7	8388.82	16791.69	216.11	0	
	H-rate	Cos	None	4	8398.04	16804.09	228.51	0	
	H-rate	Cos23	Time	5	8397.96	16805.95	230.37	0	
	H-norm	Cos	None	3	8401.36	16808.74	233.16	0	
	H-rate	Cos23	Wind	8	8397.3	16810.67	235.09	0	
	H-norm	Key	None	1	8413.28	16828.57	252.99	0	
	H-norm	H-poly	None						Invalid model fit
	H-rate	S-poly	None						Invalid model fit

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
'Ā kohekohe	H-rate	Key	None	2	8410.73	16825.46	249.88	0	
	H-rate	Cos23	Dect						Invalid model fit
	H-rate	Cos23	Dect24						Invalid model fit
	H-rate	Cos23	Year						Invalid model fit
'Alauahio	H-rate	S-poly46	Dect	6	12237.62	24487.26	0	1	
	H-rate	S-poly46	Dect24	5	12295.8	24601.62	114.36	0	
	H-rate	S-poly46	Dect14	5	12810.47	25630.9	1143.64	0	
	H-rate	S-poly46	Obs	25	12826.7	25703.75	1216.64	0	
	H-rate	S-poly46	Wind	8	12845.33	25706.71	1219.45	0	
	H-rate	S-poly46	Year	17	12837.95	25710.06	1222.8	0	
	H-rate	S-poly46	Gust	9	12847.84	25713.72	1226.46	0	
	H-rate	S-poly46	Rain	8	12849.58	25715.2	1227.94	0	
	H-rate	S-poly46	Cloud	15	12842.97	25716.08	1228.82	0	

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
'Alauahio	H-rate	S-poly46	Elev	7	12854.38	25722.79	1235.53	0	
	H-rate	S-poly46	None	4	12868.22	25744.45	1257.19	0	
	H-rate	S-poly46	Time	5	12873.91	25757.84	1270.58	0	
	H-norm	Cos	None	3	12877.25	25760.5	1273.24	0	
	H-norm	Key	None	1	12916.09	25834.18	1346.92	0	
	H-rate	Key	None	2	12919.24	25842.49	1355.23	0	
	H-norm	H-poly	None						Key model selected over more parameterized models
	H-rate	Cos	None						Invalid model fit
'Apapane	H-rate	Cos2	Dect	5	2760.12	5530.33	0	1	
	H-rate	Cos2	TreeHgt	5	2781.48	5573.04	42.71	0	
	H-rate	Cos2	None	3	2785.83	5577.69	47.36	0	
	H-norm	Key	None	1	2788.67	5579.35	49.02	0	

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
'Apapane	H-rate	Key	None	2	2788.1	5580.21	49.88	0	
	H-rate	Cos2	Obs	5	2785.57	5581.21	50.88	0	
	H-rate	Cos2	Elev	4	2787.21	5582.48	52.15	0	
	H-rate	Cos2	Time	4	2787.58	5583.22	52.89	0	
	H-rate	Cos2	Rain	6	2787.55	5587.2	56.87	0	
	H-rate	Cos2	Gust	7	2786.82	5587.79	57.46	0	
	H-rate	Cos2	Dect14	4	2786.87	5591.79	61.46	0	
	H-rate	Cos2	Cloud	13	2785	5597.1	66.77	0	
	H-norm	Cos2	None						Key model selected over more parameterized models
	H-norm	H-poly	None						Key model selected over more parameterized models

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
'Apapane	H-rate	S-poly	None						Key model selected over more parameterized models
	H-rate	Cos2	Dect24						Invalid model fit
	H-rate	Cos2	Wind						Invalid model fit
'I'iwi	H-rate	Key	Dect24	3	1425.37	2856.8	0	0.94037	
	H-rate	Key	Dect	4	1427.15	2862.4	5.6	0.05718	
	H-rate	Key	Obs	4	1430.3	2868.7	11.9	0.00245	
	H-rate	Key	None	2	1442.77	2889.58	32.78	0	
	H-norm	Key	None	1	1444.22	2890.45	33.65	0	
	H-rate	Key	Time	3	1442.79	2891.64	34.84	0	
	H-rate	Key	Dect14	3	1442.83	2891.73	34.93	0	
	H-rate	Key	Elev	3	1442.85	2891.76	34.96	0	
	H-rate	Key	Wind	4	1442.75	2893.61	36.81	0	

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
'I'iwi	H-rate	Key	TreeHgt	4	1442.86	2893.83	37.03	0	
	H-rate	Key	Rain	5	1442.23	2894.62	37.82	0	
	H-rate	Key	Gust	6	1442.76	2897.74	40.94	0	
	H-rate	Key	Cloud	12	1436.7	2898.27	41.47	0	
	H-norm	Cos	None						Key model selected over more parameterized models
	H-norm	H-poly	None						Key model selected over more parameterized models
	H-rate	Cos	None						Key model selected over more parameterized models
	H-rate	S-poly	None						Key model selected over more parameterized models

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
Japanese Bush-warbler	H-rate	Key	None	2	1288.7	2581.43	0	0.91422	
	H-rate	Key	Dect	3	1291.35	2588.77	7.34	0.02329	
	H-rate	Key	Dect24	3	1291.35	2588.77	7.34	0.02329	
	H-rate	Key	Time	3	1291.35	2588.77	7.34	0.02329	
	H-rate	Key	Elev	3	1291.35	2588.77	7.34	0.02258	
	H-rate	Key	Obs	4	1291.29	2590.7	9.27	0.00887	
	H-rate	Key	TreeHgt	4	1291.35	2590.82	9.39	0.0081	
	H-rate	Key	Rain	5	1291.35	2592.88	11.45	0.00298	
	H-rate	Key	Wind	5	1291.35	2592.88	11.45	0.00298	
	H-rate	Key	Gust	6	1291.35	2594.95	13.52	0.00106	
	H-rate	Key	Cloud	12	1291.35	2607.67	26.24	0	
	H-norm	Key	None	1	1311.98	2625.97	44.54	0	
	H-norm	Cos	None						Invalid model fit

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
Japanese Bush-warbler	H-norm	H-poly	None						Invalid model fit
	H-rate	Cos	None						Invalid model fit
	H-rate	S-poly	None						Invalid model fit
	H-rate	Key	Dect14						Invalid model fit
Japanese White-eye	H-rate	Key	Obs	4	1098.17	2204.47	0	1	
	H-rate	Key	None	2	1114.45	2232.94	28.47	0	
	H-rate	Key	Dect14	3	1115.35	2236.77	32.3	0	
	H-rate	Key	Dect24	3	1115.35	2236.77	32.3	0	
	H-rate	Key	Time	3	1115.35	2236.77	32.3	0	
	H-rate	Key	Elev	3	1115.35	2236.77	32.3	0	
	H-rate	Key	TreeHgt	4	1115.35	2238.82	34.35	0	
	H-rate	Key	Dect	4	1115.35	2238.82	34.35	0	
	H-norm	Key	None	1	1118.48	2238.98	34.51	0	

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
Japanese White-eye	H-rate	Key	Rain	5	1115.35	2240.88	36.41	0	
	H-rate	Key	Wind	5	1115.35	2240.88	36.41	0	
	H-rate	Key	Gust	6	1115.35	2242.96	38.49	0	
	H-rate	Key	Cloud	12	1115.35	2255.7	51.23	0	
	H-norm	Cos	None						Invalid model fit
	H-norm	H-poly	None						Invalid model fit
	H-rate	Cos	None						Key model selected over more parameterized models
Kiwikiu	H-rate	S-poly	None						Invalid model fit
	H-norm	Key	Dect	3	1047.36	2100.81	0	0.9831	
	H-norm	Key	Dect24	2	1052.45	2108.95	8.14	0.01679	
	H-norm	Key	Dect14	2	1057.48	2119	18.19	0.00011	
	H-norm	Key	Gust	6	1065.54	2143.4	42.59	0	

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
Kiwikiu	H-norm	Key	Obs	3	1070.19	2146.47	45.66	0	
	H-norm	Key	None	1	1078.7	2159.42	58.61	0	
	H-norm	Key	Wind	3	1076.96	2160.02	59.21	0	
	H-norm	Key	Time	2	1078.62	2161.28	60.47	0	
	H-rate	Key	None	2	1079.37	2162.78	61.97	0	
	H-norm	Key	Cloud	12	1068.86	2162.95	62.14	0	
	H-norm	Cos	None						Key model selected over more parameterized models
	H-norm	H-poly	None						Key model selected over more parameterized models
	H-rate	Cos	None						Key model selected over more parameterized models

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
Kiwikiu	H-rate	S-poly	None						Key model selected over more parameterized models
	H-norm	Key	Rain						Invalid model fit
	H-norm	Key	Year						Invalid model fit
	H-norm	Key	SurveyArea						Invalid model fit
Maui 'Amakihi	H-rate	Key	Dect24	3	966.01	1938.12	0	0.58715	
	H-rate	Key	Dect	4	965.41	1938.97	0.85	0.38386	
	H-rate	Key	Wind	4	968.19	1944.53	6.41	0.02381	
	H-rate	Key	None	2	972.6	1949.24	11.12	0.00226	
	H-rate	Key	Obs	4	971.2	1950.55	12.43	0.00117	
	H-rate	Key	Dect14	3	972.8	1951.68	13.56	0.00067	
	H-rate	Key	Time	3	972.8	1951.68	13.56	0.00067	
	H-rate	Key	Elev	3	972.8	1951.68	13.56	0.00067	

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
Maui 'Amakihi	H-rate	Key	TreeHgt	4	972.8	1953.74	15.62	0.00024	
	H-rate	Key	Cloud	12	964.47	1954.1	15.98	0.0002	
	H-rate	Key	Gust	6	971.42	1955.15	17.03	0.00012	
	H-rate	Key	Rain	5	972.8	1955.81	17.69	0.00008	
	H-norm	Key	None	1	983.82	1969.65	31.53	0	
	H-norm	Cos	None						Invalid model fit
	H-norm	H-poly	None						Invalid model fit
	H-rate	Cos	None						Invalid model fit
	H-rate	S-poly	None						Invalid model fit
Red-billed Leiothrix	H-rate	Key	Dect	4	1187.08	2382.29	0	0.52996	
	H-rate	Key	Dect24	3	1188.23	2382.53	0.24	0.47004	
	H-rate	Key	Dect14	3	1208.29	2422.66	40.37	0	
	H-rate	Key	Gust	6	1208.62	2429.51	47.22	0	

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

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Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
Red-billed Leiothrix	H-rate	Key	None	2	1213.49	2431.01	48.72	0	
	H-norm	Key	None	1	1214.69	2431.4	49.11	0	
	H-rate	Key	Time	3	1212.77	2431.61	49.32	0	
	H-rate	Key	Elev	3	1213.27	2432.63	50.34	0	
	H-rate	Key	Obs	4	1212.57	2433.26	50.97	0	
	H-rate	Key	Rain	5	1212.13	2434.67	52.38	0	
	H-rate	Key	Wind	5	1212.35	2434.89	52.6	0	
	H-rate	Key	TreeHgt	4	1213.5	2435.12	52.83	0	
	H-norm	Cos	None						Invalid model fit
	H-norm	H-poly	None						Key model selected over more parameterized models

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

Appendix B—Table 3. Model Selection Based on AIC.

Species Name	Model ¹	Adjustment Terms ^{2,3}	Covariates ⁴	No. Param ⁵	-LogL ⁶	AICc ⁷	Δ AICc ⁸	wi ⁹	Justification
Red-billed Leiothrix	H-rate	Cos	None						Key model selected over more parameterized models
	H-rate	S-poly	None						Key model selected over more parameterized models
	H-rate	Key	Cloud						Invalid model fit

¹ Models include half-normal = H-norm, and hazard-rate = H-rate.

² Adjustment terms include models without adjustment terms = Key, cosine adjustment = Cos, hermite polynomial = H-poly, and simple polynomial = S-poly.

³ Numbers following adjustment term is the adjustment order(s) .

⁴ Covariates include cloud cover = Cloud, rain = Rain, wind = Wind, gust = Gust, observer = Obs, time of detection = Time, detection type = Dect, detection type where types 1 and 4 were combined = Dect14, detection type where types 2 and 4 were combined = Dect24, survey year = Year, and location survey was conducted = SurveyArea.

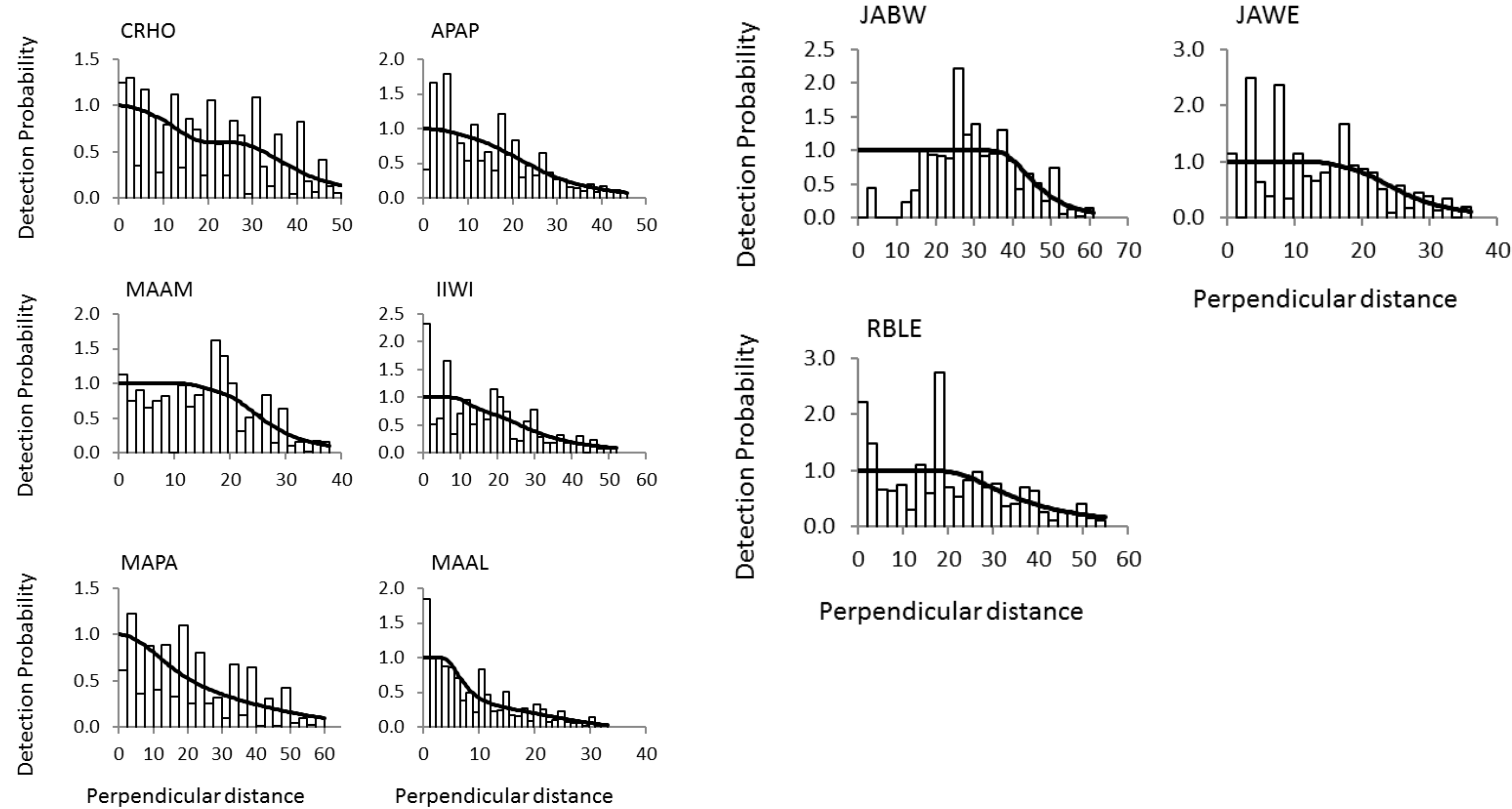
⁵ The number of estimated parameters.

⁶ Negative log-likelihood function.

⁷ Second-order Akaike's Information Criterion.

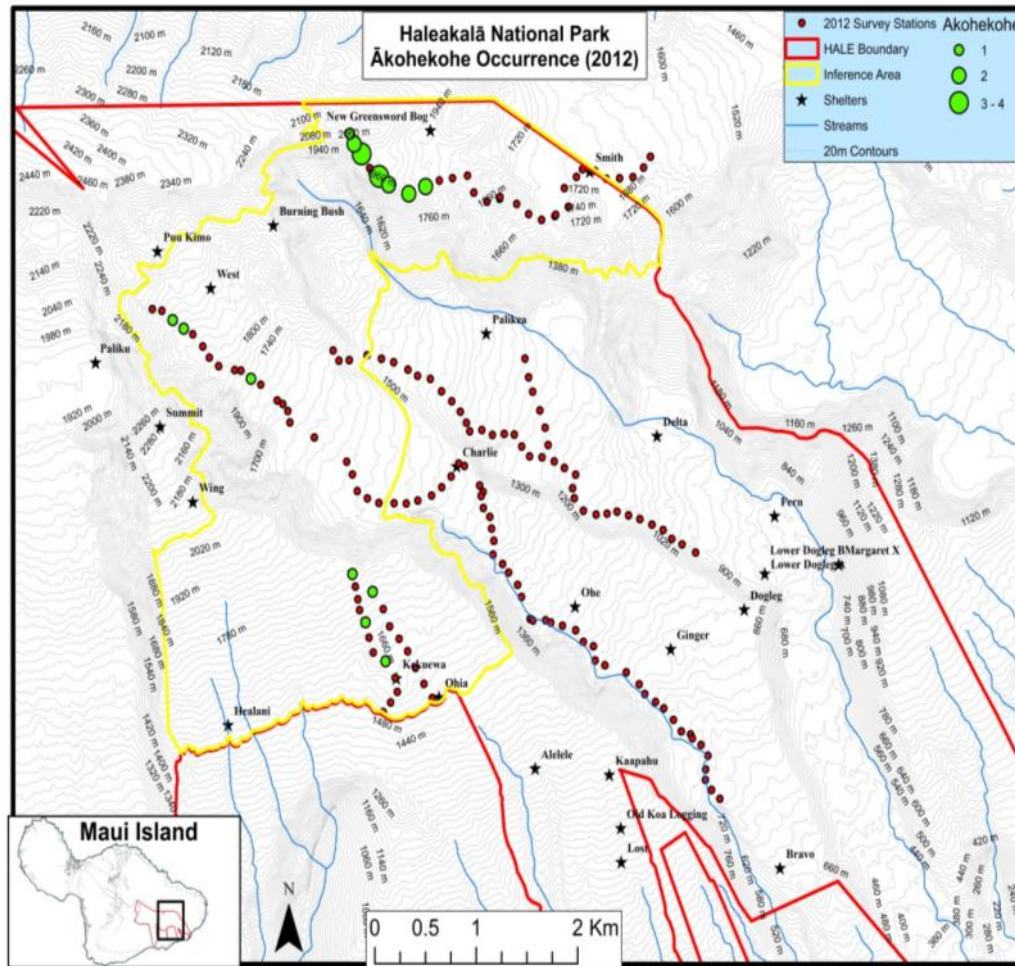
⁸ Differences in AICc values, relative to the smallest AICc value in the model set.

⁹ Akaike weights.

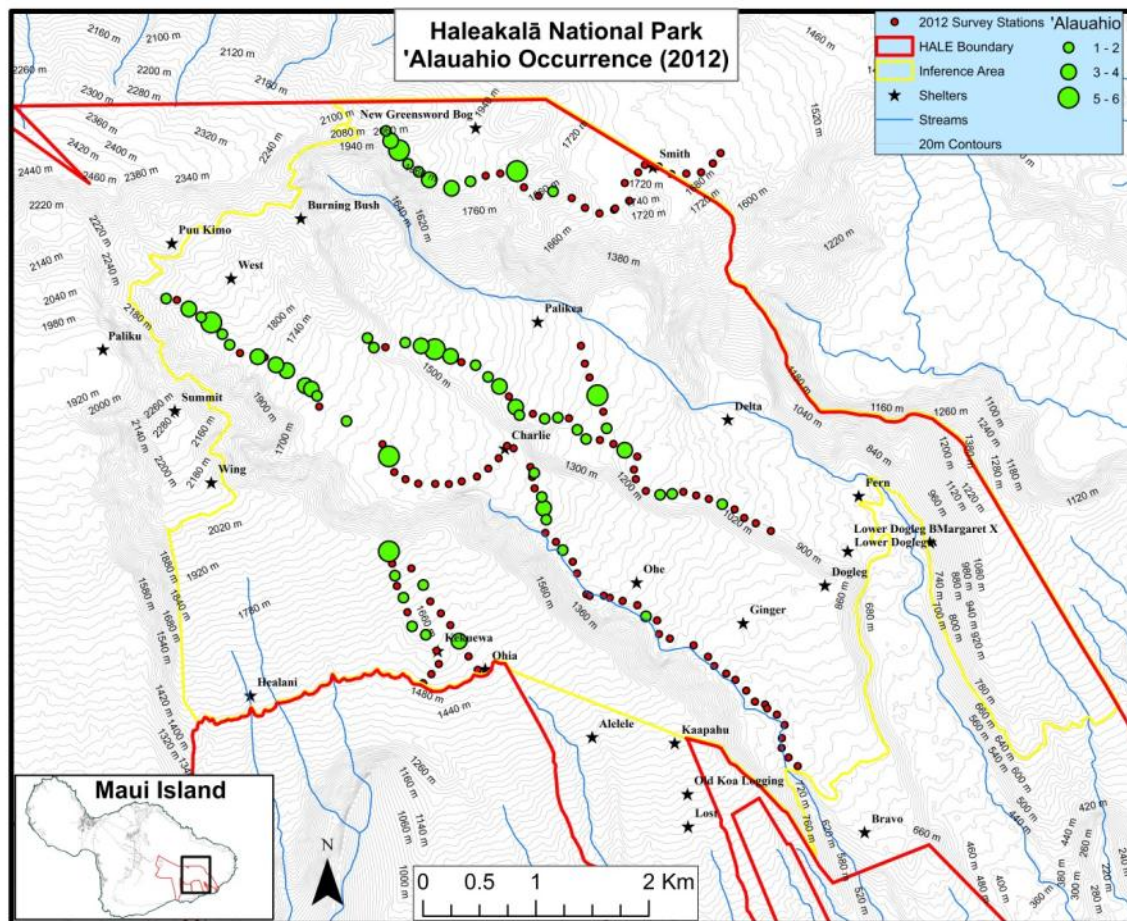


Appendix B—Figure 2. Detection histograms used to derive population densities for non-native species for the 2012 landbird survey. Species codes are: CRHO = ‘Ākohekohe; APAP = ‘Apapane; MAAM = Maui ‘Amakihi; IIWI = ‘Iiwi; MAPA = Kiwikiu; and MAAL = Maui ‘Alauahio. JABW = Japanese Bush-warbler; JAWE = Japanese White-eye; and RBLE = Red-billed Leiothrix.

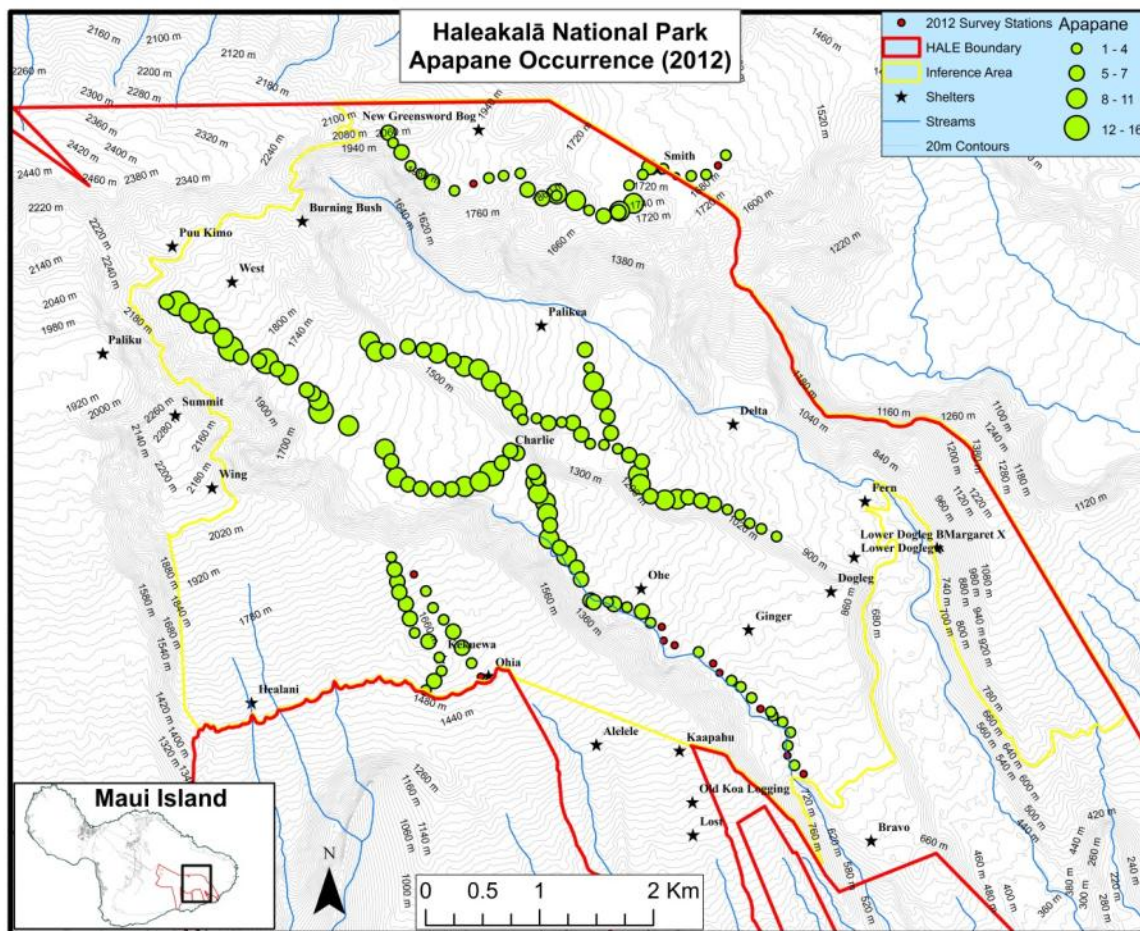
Appendix C. HALE Bird Occurrence Maps



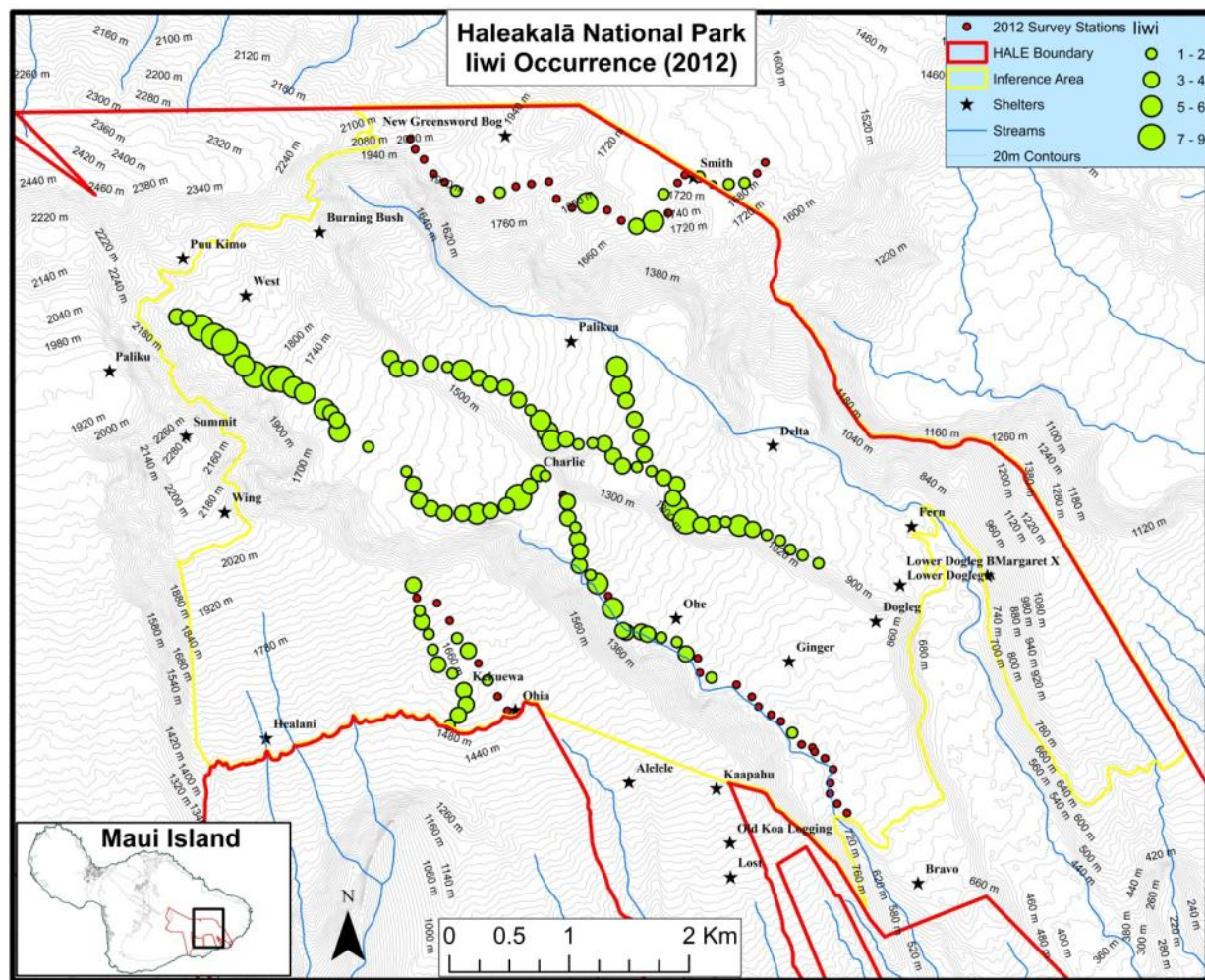
Appendix C—Figure 5. Ākohekohe occurrence in HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station.



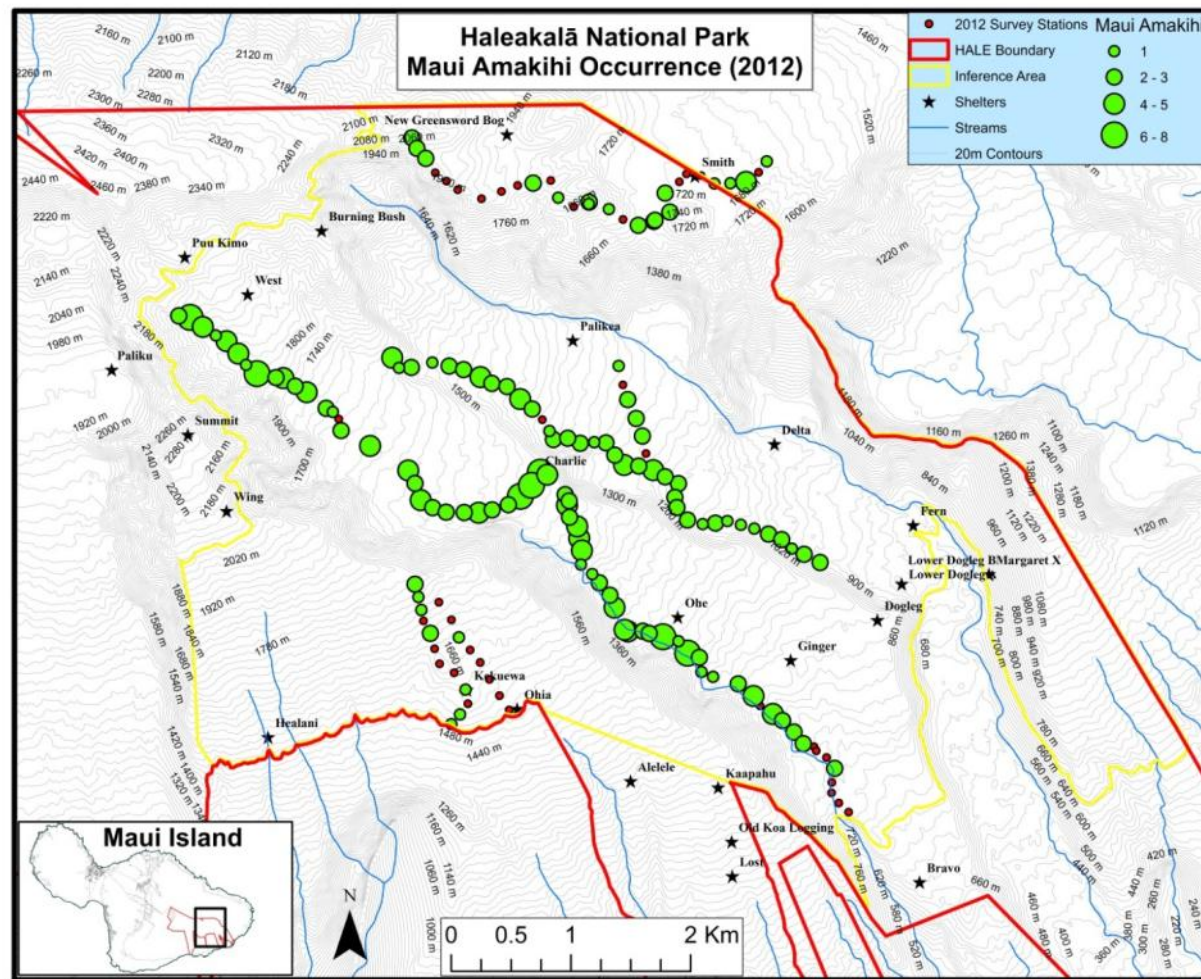
Appendix C—Figure 6. ‘Alauahio occurrence in the HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station.



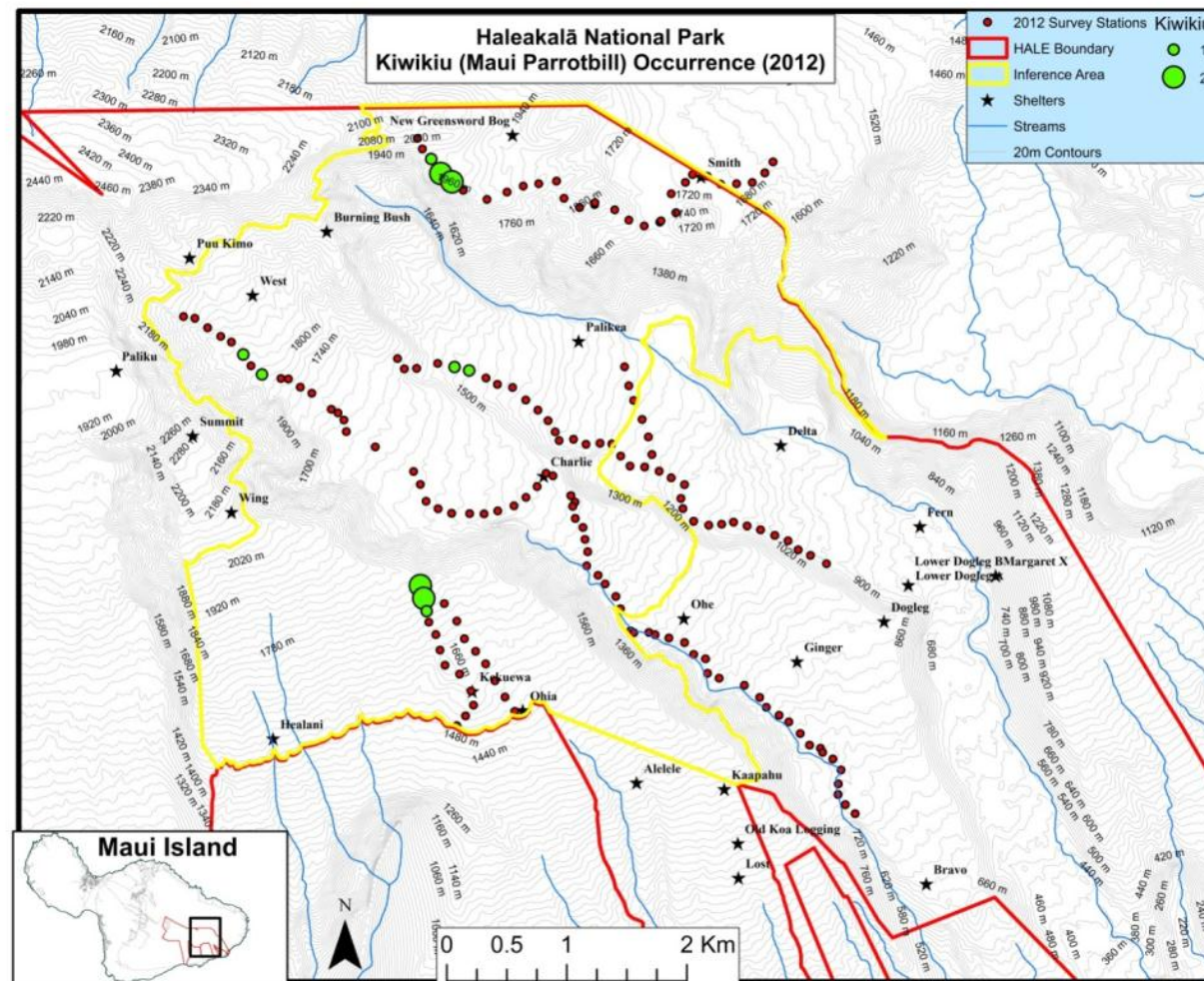
Appendix C—Figure 7. ‘Apapane occurrence in HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station.



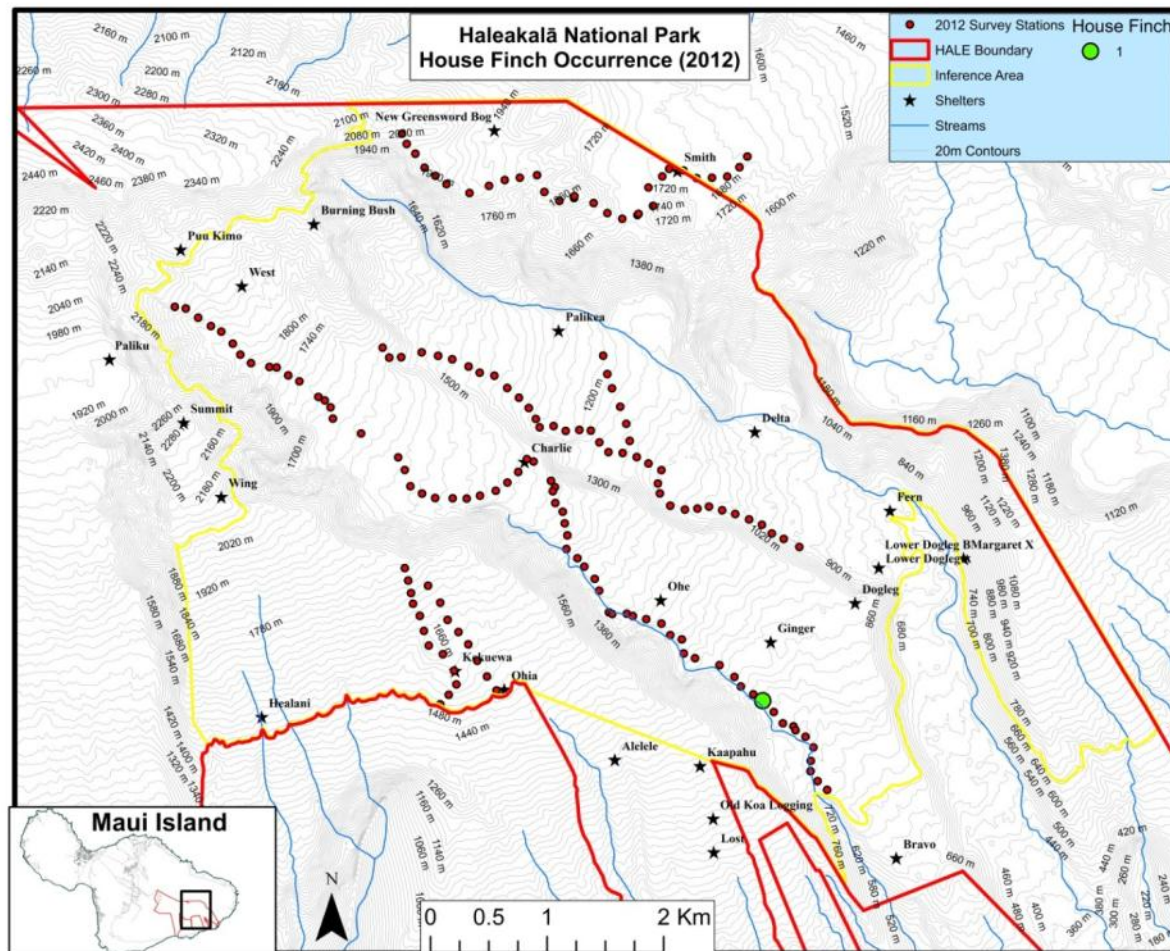
Appendix C—Figure 8. 'Iiwi occurrence in HALE during the 2012 landbird survey. Graded symbols display the abundance of individuals detected at each station.



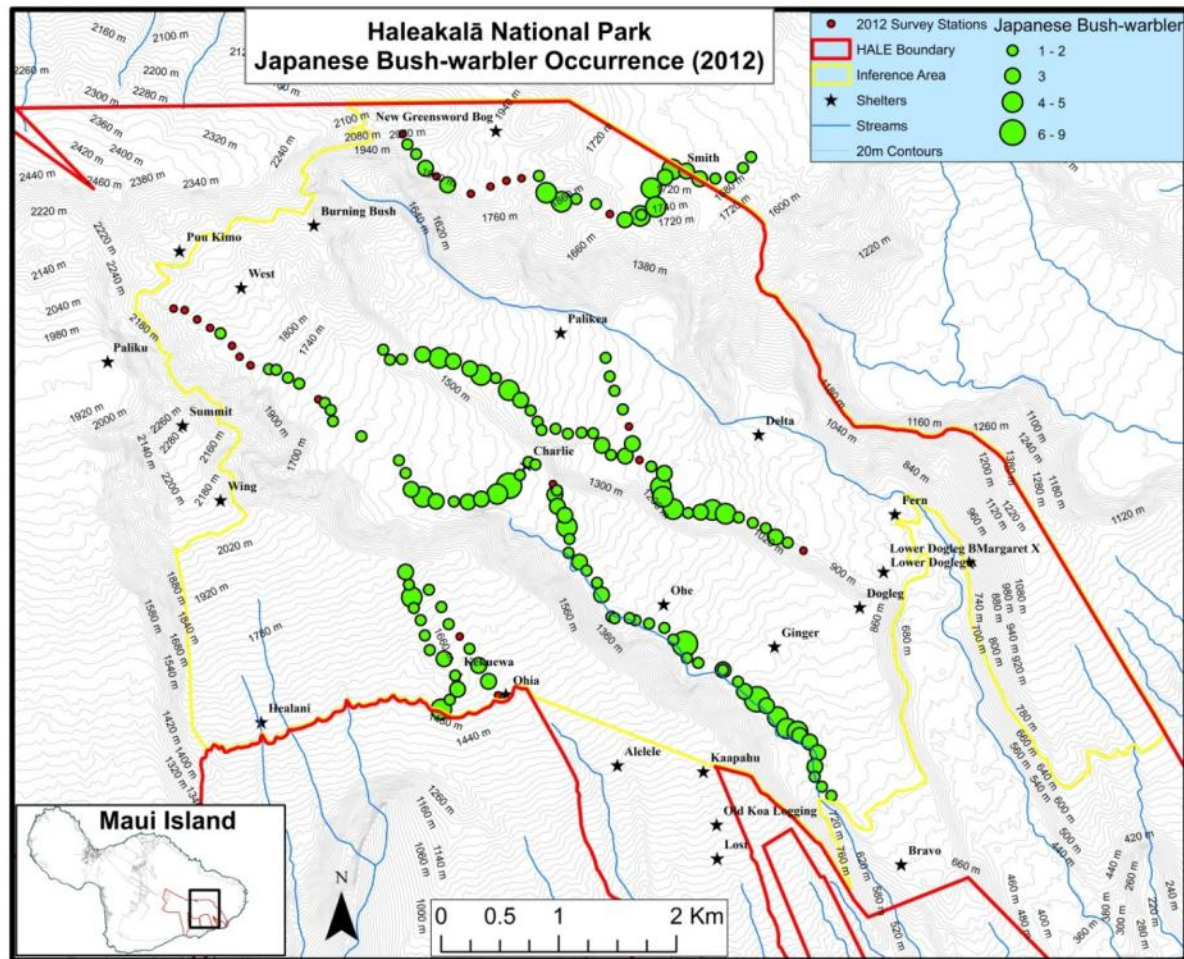
Appendix C—Figure 9. Maui ‘Amakihi occurrence in HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station.



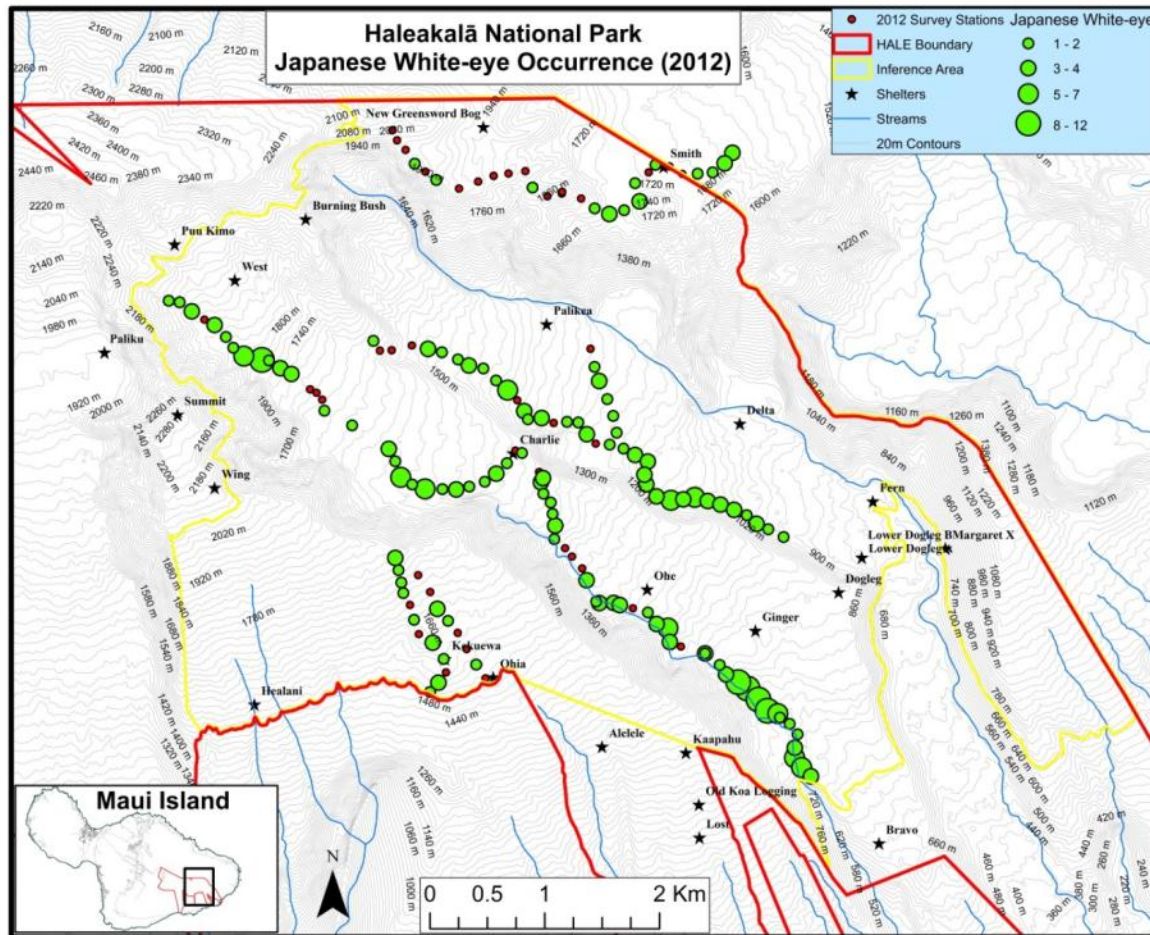
Appendix C—Figure 10. Kiwikiu (Maui Parrotbill) occurrence in HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station. The 2,036 ha inference area for Kiwikiu abundance is outlined in yellow.



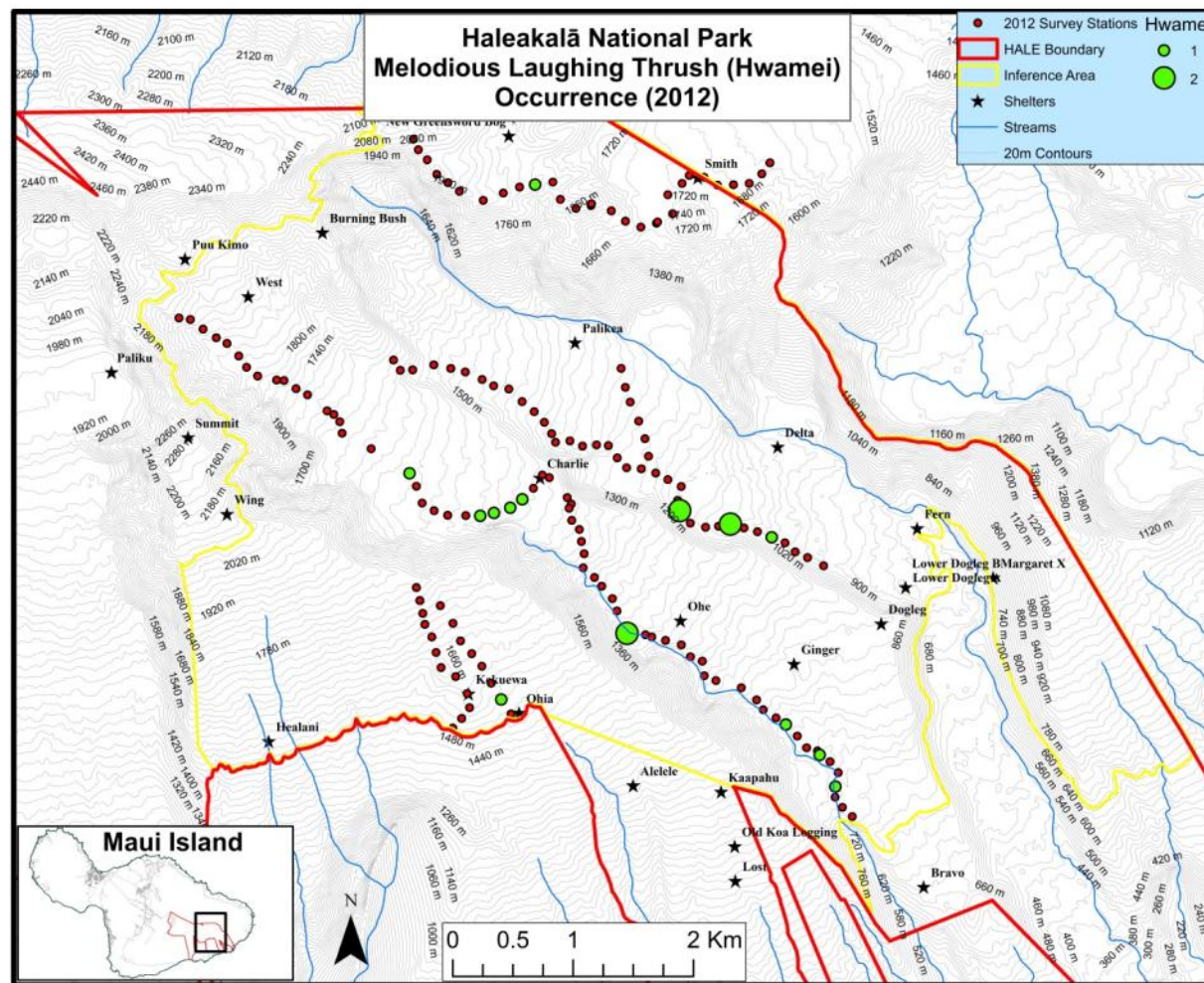
Appendix C—Figure 11. House Finch occurrence in HALE during the 2011 landbird survey. Graduated symbols display the abundance of individuals detected at each station.



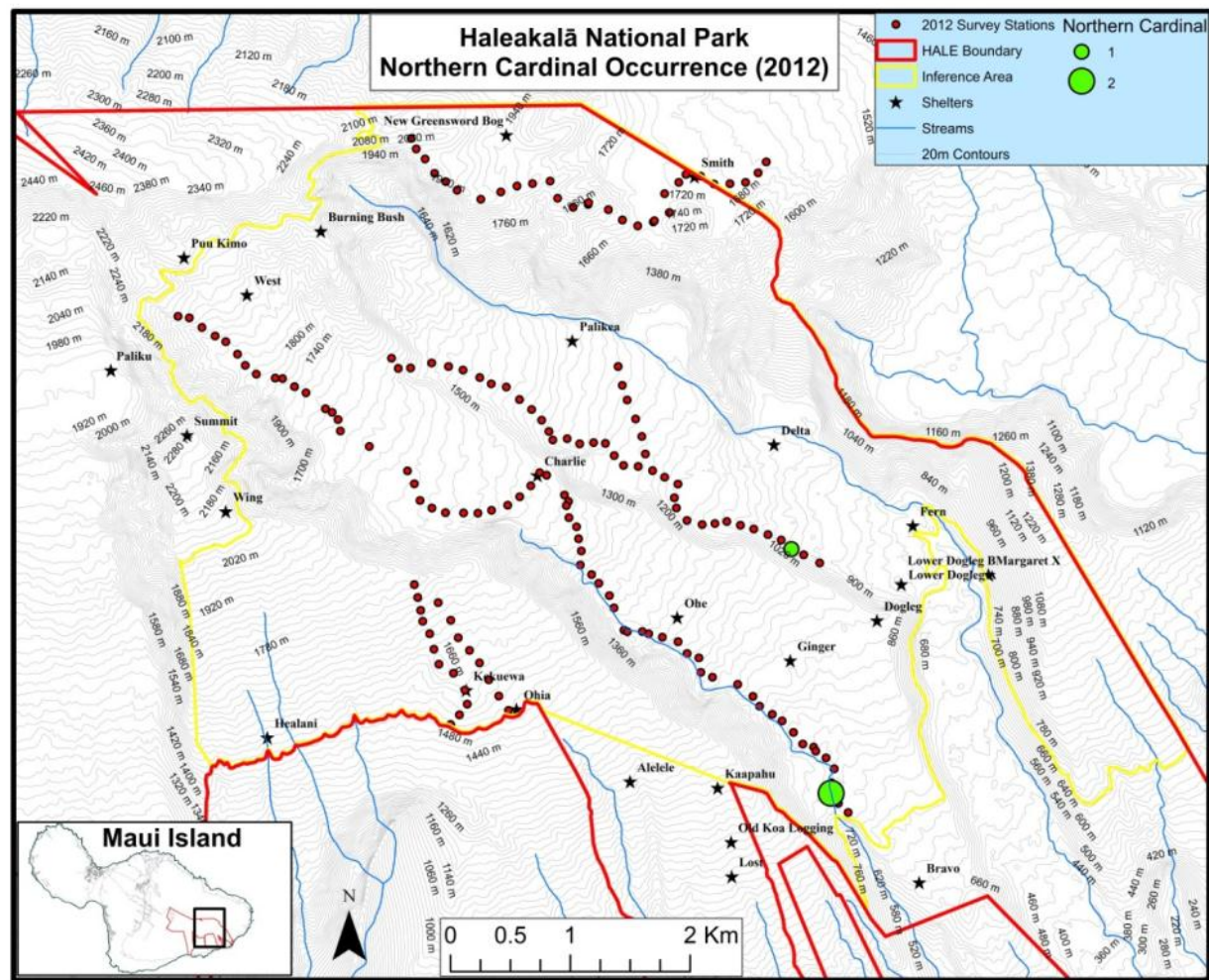
Appendix C—Figure 12. Japanese Bush-warbler occurrence in HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station.



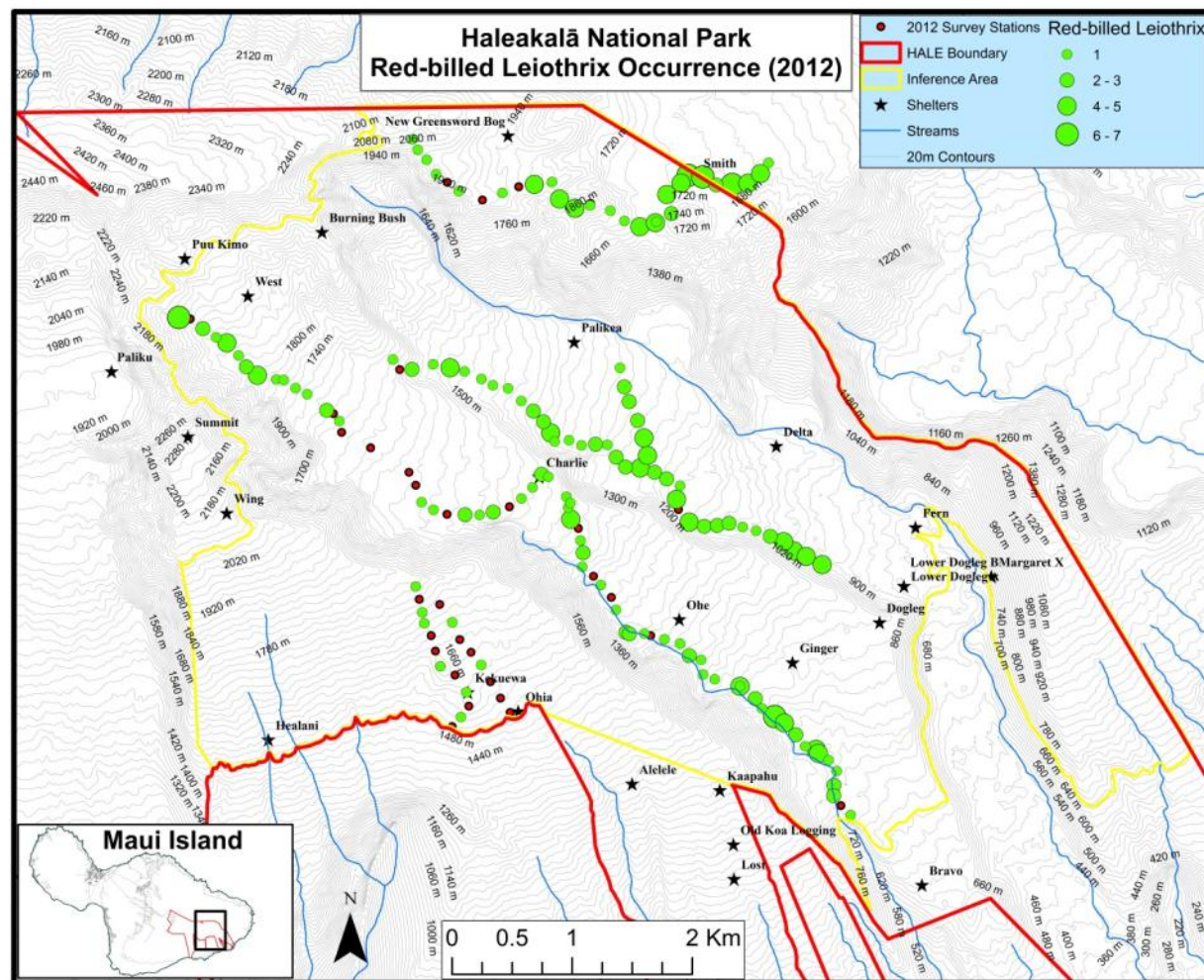
Appendix C—Figure 13. Japanese White-eye occurrence in HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station.



Appendix C—Figure 14. Melodious Laughing-thrush (Hwamei) occurrence in HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station.



Appendix C—Figure 15. Northern Cardinal occurrence in HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station.



Appendix C—Figure 16. Red-billed Leiothrix occurrence in HALE during the 2012 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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