



Pacific Island Landbird Monitoring Annual Report, Hawaii Volcanoes National Park, Tract Group 1 and 2, 2010

Natural Resource Technical Report NPS/PACN/NRTR—2011/486



ON THE COVER

Male Hawaii Akepa (*Loxops coccineus*)

Photograph by: Jack Jeffrey

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Abstract

Hawaii Volcanoes National Park (HAVO) was surveyed for landbirds and landbird habitat from March through May, 2010. This information provides the first datum in the time-series of landbirds monitoring for long-term trends in forest bird distribution, density, and abundance. The entire survey area was comprised of eight tracts. Each was surveyed using point-transect distance sampling to calculate estimates of bird abundance and density. In addition to the permanent survey transects from past landbird surveys in these tracts, randomly generated point-transects were also surveyed, providing a split panel sampling design. Twenty-nine species were detected yielding 9,845 records (9,803 during counts). Of the 29 species, two-thirds were non-native (19 species) and 10 species were native. Half of the native birds were endangered species—the Hawaiian Goose (*Branta sandwicensis*), Hawaiian Hawk (*Buteo solitarius*), Akiapolaau (*Hemignathus munroi*), Hawaii Creeper (*Oreomystis mana*), and Hawaii Akepa (*Loxops coccineus*). The native Apapane (*Himatione sanguinea*) and Hawaii Amakihi (*Hemignathus virens*), and non-native Japanese White-eye (*Zosterops japonicus*) were detected throughout the tracts and had the highest relative abundances, whereas 10 species were detected less than 10 times and in only one or two tracts. Sufficient detections to allow density estimation were made for nine species (5 native and 4 non-native). Changes in species-specific densities by tract were assessed using two-sample z-tests in an equivalence testing framework to determine long-term trends. In general, most densities were not estimated well enough to obtain conclusive results. However, for those species and tracts that were conclusive most birds have increased with a few notable declines. For example, the Hawaii Amakihi and Apapane increased across all tracts, and the Japanese White-eye increased in all tracts except Northwest Kahuku and Papa. The most striking change in the native birds was that Omao (*Myadestes obscurus*), which was considered extirpated from the Southwest Flank of Mauna Loa since the 1970s was detected in the high elevation tracts (Northwest Kahuku and Papa) of the region. Conversely, Iiwi declined in the Northwest Kahuku tract and Omao declined in the Olaa tract. Lastly, there was relatively little difference between the quantile distributions of the fixed and random transects ($D=0.0568$), thus, the fixed transects appear to be a random sample and representative of the larger population.

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Introduction

Background and Objectives

The avifauna of Hawaii is characterized by a high level of endemism that is a result of adaptive radiation (Fleischer et al. 1998, Pratt 2005, Camp et al. 2011). Since human colonization of the Hawaiian Islands, the introduction of alien flora and fauna has caused the biota to become more continental in composition and ecology, almost invariably to the detriment of native birds. The decline of Hawaiian landbirds is often explained as the non-adaptive response of ecologically constrained or behaviorally naive species to the arrival of new diseases, parasites, predators, and competitors (Banko and Banko 1976, Atkinson 1977, Pratt 1994, van Riper and Scott 2001, Pratt et al. 2009). Only 42 of the once 113 species of native landbirds persist in the islands (Pyle 2002). Thirty of the remaining species are considered threatened or endangered and 10 of them have not been seen in the last 40 years. Over 170 species of birds have been introduced to the islands and 54 species have become naturalized.

During the late 1970s and early 1980s, the Fish and Wildlife Service (USFWS) conducted surveys of bird and plant communities on the main Hawaiian Islands as part of the Hawaii Forest Bird Survey (HFBS). A review of the status of native Hawaiian birds based on the extensive HFBS of the main islands (Scott et al. 1986, Scott and Kepler 1985) documented declining populations and decreasing ranges for most species, and the extinction of several species. The HFBS in 1976 (Kau) and 1978 (Kona) covered portions of the Kahuku unit of Hawaii Volcanoes National Park (HAVO), and the results from these surveys provided regional population estimates on Hawaiian forest bird species (Scott et al. 1986). They found that the Kahuku unit contained important populations of three endangered forest bird species: Akiapolaau (*Hemignathus munroi*), Hawaii Akepa (*Loxops coccineus*), and Hawaii Creeper (*Oreomystis mana*).

Many native bird species continue to decline throughout Hawaii (Jacobi and Atkinson 1995, Gorresen et al. 2009). Habitat management (e.g., predator, ungulate, and weed control) has resulted in stable or increasing populations over relatively small areas (Camp et al. 2010). Frequent monitoring is needed to track population changes and is important to monitor declines and document increases related to management (Camp et al. 2011). Population estimates and range maps of HAVO require updating as some of the surveyed areas have undergone habitat change and bird populations show evidence of change in size and distribution. In fact, many recovery plans propose population density target values that must be achieved before a population may be considered for delisting, such that population monitoring and estimates are integral to endangered species recovery (Tear et al. 1995, Doremus and Pagel 2001).

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 (<http://science.nature.nps.gov/im/index.cfm>). In concordance with the stated role of the I&M Program, the objectives of this survey were to provide information for monitoring long-term

trends in forest bird distribution, density, and abundance in HAVO. Ultimately, this information will help to inform and implement management actions to stabilize and/or increase bird populations.

While the scope of the Pacific Island Network (PACN) Inventory and Monitoring Program landbird survey spans several Pacific islands, this report focuses on bird species within HAVO on Hawaii Island. HAVO was first established in 1916, and the Kahuku unit (47,350 ha) was added to the park in 2003, resulting in the protection of over 134,750 ha. The park ranges from sea level to the summit of Mauna Loa (4,169 m) with a diverse array of habitat types, ranging from native rainforest to arid desert environments, with several active volcanic sites on Kilauea and Mauna Loa (Appendix A). The park harbors habitat that is critically important to native bird populations, and many of the island's other indigenous, endemic, and endangered flora and fauna (Tweed et al. 2007). This report documents the status of three endangered native Hawaiian honeycreepers: Akiapolaau, Hawaii Creeper, and Hawaii Akepa; five additional native species, Hawaii Elepaio (*Chasiempis sandwichensis*), Omao (*Myadestes obscurus*), Hawaii Amakihi (*Hemignathus virens*), Iiwi (*Vestiaria coccinea*) and Apapane (*Himatione sanguinea*), and four non-native passerines: Red-billed Leiothrix (*Leiothrix lutea*), Japanese White-eye (*Zosterops japonicus*), Northern Cardinal (*Cardinalis cardinalis*), and House Finch (*Carpodacus mexicanus*) in lands adjacent to and within HAVO.

Methods

Landbirds sampling conducted by the PACN I&M Program surveys five parks/units on a rotating basis where each park/unit will be surveyed once per rotation (i.e., each park/unit will be sampled once per 5-yr rotation cycle; Camp et al. 2011). The PACN I&M Landbirds Monitoring Protocol was implemented in 2010 at HAVO. Sampling protocol separated HAVO tracts into two groups (1 and 2), each were to be surveyed during disparate years; however, in 2010 time and resources available allowed for both groups to be completed. Point-transect distance sampling was conducted according to a split panel (1:1, fixed: random sampling unit [i.e., stations] allocation, respectively) design in eight tracts in HAVO (see Camp et al. 2011 for details). The fixed panel stations will be surveyed during each rotation cycle, whereas the random panel stations will not be resampled in future rotations. The number of sampling units was determined using observed density and variance estimates for native Hawaiian birds (Camp et al. 2011). This methodology was then used to correct abundance estimates for individuals that go undetected by modeling a species-specific detection function and calculating a probability of detection, which was subsequently used to estimate bird density (Buckland et al. 2001). 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 specific to the sampling design in this survey can be found in Camp et al. 2011. In addition, weather conditions and habitat parameters were recorded at each sampling unit (Camp et al. 2011) in order to provide a detection function with weather and habitat data as covariates.

Tract Descriptions

Bird point-transect counts and habitat data were collected from eight tracts located on Mauna Loa and Kilauea volcanoes (Figure 1). These tracts included the East Rift Zone, Honomalino, Kahuku, Mauna Loa South Flank, Mauna Loa Strip, Northwest Kahuku, Olaa, and Papa. The elevation of all tracts ranged between 731 m and 2,560 m, with a diversity of substrate ages ranging from < 200 to approximately 10,000 years old. Forest types included wet forest, mesic forest, sub-alpine woodland, shrub land, pioneer forest, and remnant older growth forest “islands” surrounded completely by lava, or “kipuka” in Hawaiian. Climate zones of tracts ranged from “moderately wet” to “very dry” with the majority of transects falling in the “seasonal mesic” category (see Price et al. 2007; Figure 3). While the majority of the tracts are within and managed by the National Park Service, exceptions include Honomalino (managed by The Nature Conservancy) and the Kau Forest Reserve section of Kahuku (managed by the State of Hawaii Division of Forestry and Wildlife).

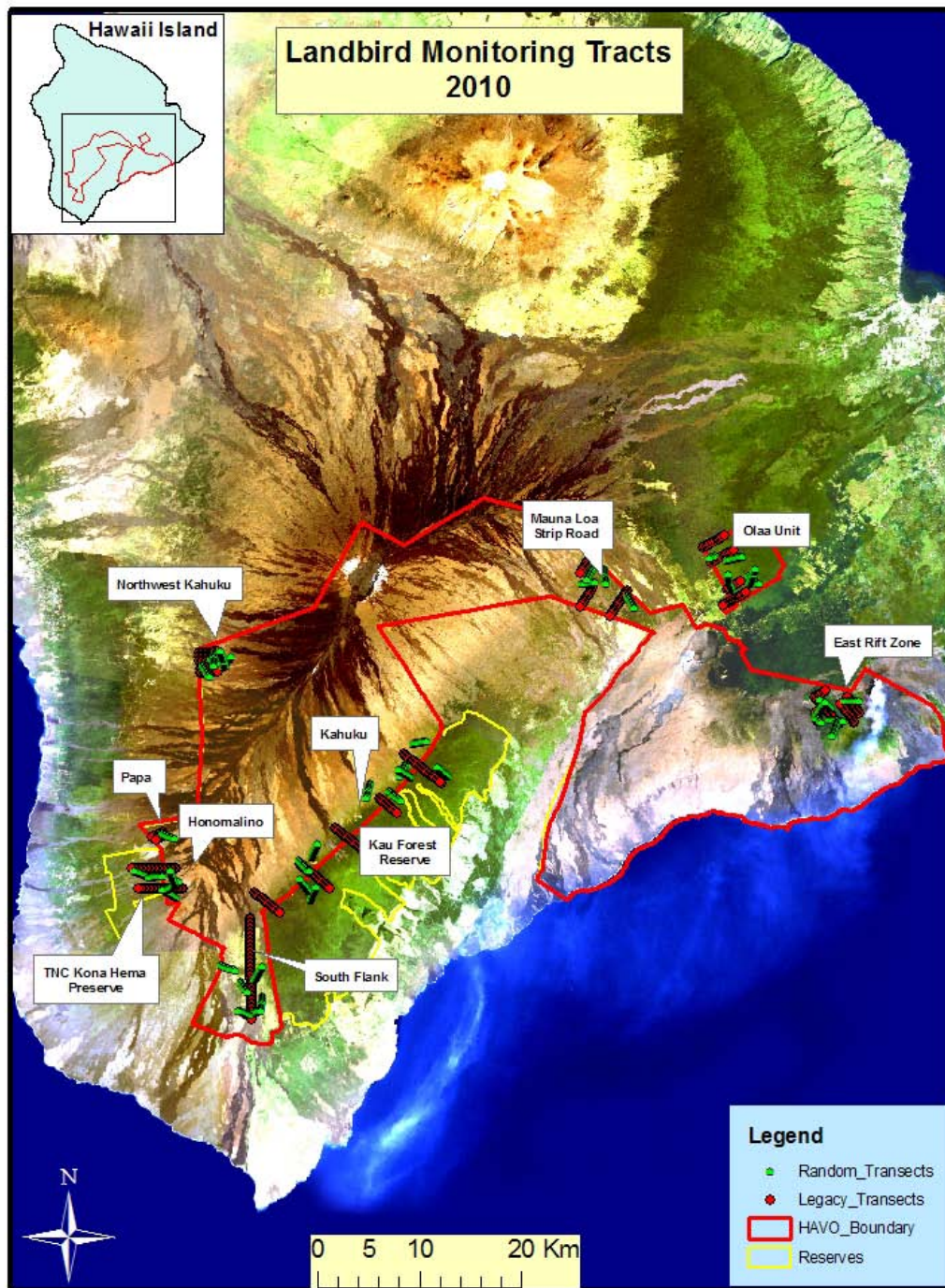


Figure 1. Southern portion of Hawaii Island indicating Hawaii Volcanoes National Park and landbird monitoring tracts.

East Rift Zone

The 2,254 ha East Rift Zone tract is located on the southeastern side of Kilauea volcano, adjacent to the cinder cone, Puu Oo, which has been erupting since 1983 (Figure 4). The tract is managed by the National Park Service, and has been primarily used for recreational activities such as hiking and camping as well as geological research. The moderately wet/moist mesic (Price et al. 2007), ungulate-free tract varies from bare recent lava flows to dense tree fern-dominated forests, with extensive craters and deep earth fissures throughout. Four fixed-panel transects, with stations spaced at 200 m apart and seven random transects, with stations spaced at 150 m intervals, were established in this tract between 731 m and 975 m elevation. Of the established transects, two fixed-panel transects were sampled, consisting of 29 stations.

Honomalino

The 1,688 ha Honomalino tract is located on the southwestern side of Mauna Loa and includes 597 ha within HAVO and a 1,091 ha area of forested land managed by The Nature Conservancy in their Kona Hema Unit (Figure 5). The vegetation ranges from dry sub-alpine ohia (*Metrosideros polymorpha*) woodland to mesic koa (*Acacia koa*)-ohia montane forest. Several lava flows fragment the habitat and form kipukas in the tract. The tract spans two climate zones, seasonal mesic and moist mesic (Price et al. 2007). The Nature Conservancy's successful ungulate control has left the reserve mostly ungulate-free. Two fixed-panel transects with stations spaced at 200 m intervals and five random transects with stations spaced at 150 m intervals, were established in this tract, between 1,371 m and 1,798 m elevation. Of the established transects, two fixed-panel transects (43 stations) and three random transects (31 stations) were sampled.

Kahuku

The 10,989 ha Kahuku tract is located on the eastern side of the Southwest Rift Zone on Mauna Loa. The study area includes about 4,936 ha of HAVO and an adjacent 6,053 ha in the Kau Forest Reserve, managed by the State of Hawaii (Figure 6). The vegetation is comprised of dry sub-alpine ohia woodland and mesic ohia-koa forest and the study area spans two climate zones; moist mesic and moderately wet (Price et al. 2007). The tract contains a well-established and growing population of mouflon sheep (*Ovis *gmellini musimon**; Hess et al. 2006). The Kau Forest Reserve section of the tract supports a well-established population of pigs (*Sus scrofa*), and damage and sign was widespread. Five fixed-panel transects with stations spaced at 200 m intervals and ten random transects with stations spaced at 150 m intervals, were established in the tract, between 1,524 m and 2,164 m elevation. Of the established transects, five fixed-panel transects (92 stations) and nine random transects (81 stations) were sampled.

Mauna Loa South Flank

The 4,593 ha South Flank tract is located in the southern portion of the Kahuku Unit, located just east of the Southwest Rift Zone, on Mauna Loa (Figure 7). Due to extensive vegetation clearing for cattle (*Bos taurus*) ranching and impacts by mouflon sheep, canopy cover and understory composition has been considerably altered from its original condition as mesic and wet koa-ohia forest (Tweed et al. 2007). Currently, the tract consists of open pasture with isolated trees and small stands of native forest, and spans three climate zones: seasonal mesic, moist mesic, and moderately wet (Price et al. 2007). One fixed-panel transect with stations spaced at 200 m intervals and six random transects with stations spaced at 150 m intervals were established

between 731 m and 1,584 m elevation. Of the established transects, one fixed-panel transect (50 stations) and six random transects (43 stations) were sampled.

Mauna Loa Strip

The 3,181 ha Mauna Loa Strip tract is located on the eastern flank of Mauna Loa (Figure 8). The tract is situated along an 18-km, paved access road. The seasonal mesic (Price et al. 2007) region varies greatly from historic lava flows to mesic, koa-dominated kipukas, and sub-alpine shrubland. The tract is currently ungulate-free, but was used historically for ranching. Kapapala Ranch lies adjacent to the tract's southern boundary, and Keauhou Ranch lies adjacent to the north. Three fixed-panel transects with stations spaced at 200 m intervals and four random transects with stations spaced at 150 m intervals were established between 1,433 m and 2,011 m elevation. Of the established transects, three fixed-panel transects (40 stations) and four random transects (38 stations) were sampled.

Northwest Kahuku

The 884 ha study tract is located in the northwest corner of HAVO and west of the Southwest Rift Zone of Mauna Loa (Figure 9). The dry sub-alpine woodland vegetation includes ohia, mamane (*Sophora chrysophylla*) and naio (*Myoporum sandwicensis*) trees, and spans two climate zones: moderately dry and very dry (Price et al. 2007). There was a well-established population of feral sheep (*Ovis aries*) in the tract, resulting in little understory throughout. Five fixed-panel transects with stations spaced at 200 m intervals and five random transects with stations spaced at 150 m intervals were established between 2,164 m and 2,560 m elevation. Of the established transects, five fixed-panel transects (48 stations) and five random transects (52 stations) were sampled.

Olaa

The 2,446 ha Olaa tract is located on the far eastern side of Mauna Loa (Figure 10). The moderately wet (Price et al. 2007) forest grows on deep ash soils and was dominated by ohia trees, with olapa (*Cheirodendron trigynum*) and akala (*Rubus hawaiensis*) prevalent. Koa was present in the northern region of the forest. The tract had been divided into smaller sections; most of them are fenced and free of ungulates. Five fixed-panel transects, four with stations spaced at 200 m intervals and the other with stations spaced at 150 m intervals, and six random transects with stations spaced at 150 m intervals were established in the tract between 1,067 m and 1,341 m elevation. Of the established transects, five fixed-panel transects (47 stations) and five random transects (40 stations) were sampled.

Papa

The 329 ha Papa tract is located 2.5 km north of the Honomalino tract on the western side of the Southwest Rift Zone of Mauna Loa (Figure 5). It was the smallest of the five tracts surveyed in HAVO. The tract spans two climate zones: seasonal mesic and moderately dry (Price et al. 2007). The vegetation is comprised of sub-alpine ohia woodland and small stands of ohia forest; both fragmented by several lava flows. The mostly ungulate-free tract was accessed through The Nature Conservancy's Kona Hema unit. Two fixed-panel transects with stations spaced at 200 m intervals and one random transect with stations spaced at 150 m intervals were established in the area between 1,738 m and 1,981 m elevation. Of the established transects, two fixed-panel transects (11 stations) and one random transect (10 stations) were sampled.

Tract Area Calculation

Tract areas were established using ArcMap 9.3.1 (Environmental Systems Research Institute, CA, U. S. A). A minimum convex polygon that enclosed all 2010 transects (fixed and random) was created using Editor Tool in ArcMap for each tract and was adjusted according to habitat coverage, terrain, adjacent boundaries, trails and roads. A 150 m buffer was then added to the adjusted polygon to create an inference area for each tract. The final inference areas were calculated in hectares individually using Xtools Pro.

Detailed guidelines for establishing tract boundaries were as follows: The East Rift Zone tract's eastern edge was extended 150 m to cover adjacent forest habitat within HAVO. The southern edge followed the Kalapana trail and the 700 m contour line. The northern and western tract edges were also extended 150 m to include adjacent forest habitat. The Napau and Makaopuhi Craters were excluded because they were not forested and therefore not bird habitat. The Kahuku tract's northeastern and southwestern edges were extended to the HAVO boundary. The upper edge of the Kahuku tract extended to the woodland-alpine ecotone, and the lower edge extended to about the 1,500 m contour line. The Mauna Loa South Flank tract's northwestern edge extended to the HAVO boundary. The southern and southwestern edges extended to the roads south and west of the tract. The eastern edge followed the HAVO boundary. The Mauna Loa Strip tract's northwestern and southeastern edges were extended to fence lines. Northeastern and southwestern edges followed the HAVO boundary. The Northwest Kahuku tract's northern and western edges were extended to the HAVO boundary. The Olaa Small Tract, Olaa Puu and Olaa Koa Units were combined to form one tract — the Olaa Tract. The north, west and south edges followed the HAVO boundary, whereas the east edge extended to the fence line. The Papa tract's southern edge followed the HAVO boundary, and the north, east and west edges were extended to cover the forested regions of the kipuka. The Honomalino tract's southern edge followed the HAVO boundary and extended down to below the 1,500 m contour line. The west, north, and east edges matched the study area defined by Tweed et al. (2007).

Geological Substrate Age and Climate Zone Assignment

Global positioning coordinates (way-points) were displayed in ArcMap 9.3.1 (ESRI) for all sampling units (stations). A layer containing geological substrate information (biogeology_utmz5.shp; derived from Wolfe and Morris 1996) was overlaid to determine the geological substrate age range within each tract. A layer containing climate zone information (climatezones08.shp; derived from Price et al. 2007) for Hawaii Island was overlaid to determine the climate zone(s) that span each survey tract area (Figure 2).

Point-Transect Sampling Methods

A total of 665 stations on 58 transects were surveyed (Table 1). Permanent (fixed panel) transects were staked with metal pins and marked with affixed pvc pipe over the pins (Camp et al. 2011). Bird surveys were conducted using point-transect sampling, which utilizes distance sampling to estimate abundance for individuals that are undetected as a function of the distance between the observer and birds (Buckland et al. 2001). Surveys were conducted from 19 March 2010 through 28 May 2010 (Table 1). Three primary and three secondary counters were trained to calibrate for distance estimation and learn bird vocalizations, thereby minimizing variability among observers and standardizing for local conditions (Camp et al. 2011) two weeks prior to the start of the survey.

Table 1. Survey sites with dates of survey, number of stations, climate zone categories, elevation range, and geological substrate age range. (following Price et al. 2007 and Wolfe and Morris 1996).

Tract	Dates Surveyed	# Stations Sampled	Climate Zone(s)	Elevation Range (m)	Geological Substrate Age Range(s) (y.a.)
East Rift Zone	19 May – 28 May	29	Moist Mesic and Moderately Wet	731 – 975	200 – 750
Honomalino	27 April – 28 April	74	Moist Mesic and Seasonal Mesic	1,371 – 1,798	< 200 and 1,500 – 3,000
Kahuku	6 April – 22 April	183	Moist Mesic and Moderately Wet	1,524 – 2,164	750 – 3,000
Mauna Loa South Flank	5 April – 6 May	93	Seasonal Mesic, Moist Mesic, and Moderately Wet	731 – 1,584	200 – 3,000 and 5,000 – 10,000
Mauna Loa Strip	22 March – 30 April	78	Seasonal Mesic	1,433 – 2,011	200 – 10,000
Northwest Kahuku	11 May – 13 May	100	Very Dry and Moderately Dry	2,164 – 2,560	1,500 – 3,000
Olaa	19 March – 22 April	87	Moderately Wet	1,067 – 1,341	5,000 - 10,000
Papa	7 May	21	Moderately Dry and Seasonal Mesic	1,738 – 1,981	<200 and 1,500 – 3,000

Detection type (heard, seen, or both) and horizontal distance from the station center point to individual birds detected was recorded during the 8-minute count. Birds only flying over or through the survey area were excluded. Detections of both male and female birds singing and calling were recorded, although the sex of individuals was not noted. Most of the birds encountered were adults because counts were timed during the breeding season and most juveniles had not yet fledged (Camp et al. 2011).

Observers also recorded cloud cover, rain, wind, gust, and time of day at each station (Camp et al. 2011). Sampling was conducted between dawn and 11:00 a.m. and halted when rain, wind, or gust exceeded prescribed levels (light rain and wind level 3 on the Beaufort scale). Weather variables and time of day were included as covariates in the analyses to account for possible differences in the detection probabilities due to the conditions when the count was conducted.

The detectability of forest birds varies throughout the year, due to changes in vocal activity associated with breeding (Best 1981), and birds may move in or out of the study area in response to phenology of food resources (Simon et al. 2002). To minimize biases associated with differences in sampling periods, density estimates were restricted to the breeding season only.

Habitat Survey Methods

Habitat data were collected following the methods described in Camp et al. 2011. A 50-m radius plot was established at each point-count station using the station as the center. At each plot, the dominant canopy species composition, canopy height and cover, dominant understory species composition, and the horizontal vegetation profile were described. In addition to habitat data, physical attributes such as slope and aspect were collected at each station. Habitat surveys were

collected at the point-count stations after completing bird counts (either after completing the station count, or after completing the daily counts).

Computer Data Entry and Verification Methods

Microsoft Access was used as the primary software environment for landbird data and the associated metadata. Three separate Access databases with front-end, back-end configuration were developed for the landbirds monitoring data: (1) Avian Monitoring Entry Database, (2) Hawaii Forest Birds Monitoring Database, and (3) Habitat Monitoring Database.

Raw data was compared to the electronic version on a line-by-line basis to correct transcription errors. After line-by-line proofing was completed, individual data sets were spot-checked for errors. Lastly, field books (copies and originals) and digital data were archived according to NPS standards (Camp et al. 2011).

Data Analysis

Density Estimation

Species-specific density estimates (birds ha⁻¹) were calculated for the nine species that had sufficient detections to adequately characterize detectability (Table 4; Buckland et al. 2001) using program DISTANCE, version 5.0, release 2 (Thomas et al. 2005; retrieved September 11, 2006, from <http://www.ruwpa.st-and.ac.uk/distance/>). 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 (Marques and Buckland 2004, Thomas et al. 2005). Covariates included cloud cover, rain, wind, gust, observer, time of detection, canopy cover, canopy height, and tract (Appendix B). All covariates were treated as a factor, except time of detection, which was treated as both a factor and a continuous covariate. Assessing time of detection as a continuous covariate helped to determine if the detection rate varied during the morning. Each detectability model in the candidate set was fit to data pooled across tracts for each species, and the model selected was that with the lowest 2nd-order Akaike's Information Criterion corrected for small sample sizes (AICc) and where the proportion of variance in the model due to variability in the detection function was less than 70% (Buckland et al. 2001; Burnham and Anderson 2002; K. Burnham, pers. comm.; Appendix C). An upper limit was set of 70% of the variation in density to be attributed to the detection function because there was considerable spatial variation in the counts. Data were truncated at a distance where detection probability was <10%. This procedure facilitates modeling by deleting outliers and reducing the number of parameters needed to modify the detection function. Species-specific densities by tract were estimated from the global detection function using the post-stratification approach, and variances and confidence intervals were derived by bootstrap methods in DISTANCE from 999 iterations (Appendix D; Thomas et al. 2005). The total absolute abundance was calculated as mean density of tract estimates weighted by tract area for each species (this is referred to as the global density estimate in DISTANCE).

Population Trend

Change in population densities between the 2010 survey and the most recent survey (either 1994 or 2005) were compared using end-point z-test by tract. The standard two-sample z-test was modified to incorporate testing for differences within and outside an equivalence region (see Camp et al. 2008 for details). Equivalence tests allowed for distinguishing between cases where there was not a trend from the inability to statistically detect a trend (Dixon and Pechmann 2005, Camp et al. 2008). Equivalence bounds were set to identify a 50% change in the population over 25 years, or a -0.0285 and 0.0170 annual rate of change. Changes in population density, or trends, were defined as increasing, decreasing, negligible trend (i.e., stable population), or an inconclusive result. A biologically meaningful trend occurred when the difference in density estimates was greater than the equivalence region. A negligible trend occurred when the difference lay within the equivalence region. An inconclusive result occurred when the densities were imprecise and precluded obtaining conclusive results (Dixon and Pechmann 2005). Note that the areas sampled, and, therefore, densities compared may be from different sampling frames. Thus, the end-point comparisons should be viewed with caution.

Comparison of Panel Data

Panel designs possess several major advantages over conventional time-series or cross-sectional data sets (Hsiao 2003). Panel designs improve the efficiency of estimates through large degrees of freedom and reduce the co-linearity among explanatory variables. Time-series data refer to observations of a given unit made over time, and are often referred to as longitudinal data. Cross-sectional data refer to observations of many individuals (subjects, objects) at a given time. Longitudinal data analysis was not possible at this point because only one temporal measurement has been made. Instead, we assessed selection bias from the cross-sectional data by comparing the distribution of bird densities between the fixed and random transects (data pooled across species and tracts) using a quantile-quantile (q-q) plot and Kolmogorov-Smirnov test in program R (version 2.7.0; R Foundation for Statistical Computing). Density per station estimates above the 95th percentile was dropped. This procedure facilitated convergence of the Kolmogorov-Smirnov test. In addition, the jitter function was used to eliminate ties while calculating p-values. Those procedures had little effect on the overall distributions (Kolmogorov-Smirnov test: $D_{Full}=0.0526$; $D_{Reduced\&Jittered}=0.0568$), and the test yielded reliable p-values.

Results

Landbird Summaries

A total of 9,845 birds of 29 species (19 non-native and 10 native) were detected (Table 2). Apapane and Hawaii Amakihi were the most abundant native birds in HAVO. The endangered Akiapolaau, Hawaii Akepa, and Hawaii Creeper were detected in low numbers (4, 20, and 26 individuals, respectively). Omao, Iiwi, and Hawaii Elepaio were detected in modest densities in most tracts. Non-native birds showed a wide range of abundances with the Japanese White-eye being most abundant and occurring in all tracts.

Table 2. List of species detected during the 2010 Landbird survey of HAVO. Abbreviated species code, and origin (E-endemic and N-non-native) of birds are presented.

Species Name	Scientific Name	Species Code	Origin
Akiapolaau	<i>Hemignathus munroi</i>	AKIP	E
Apapane	<i>Himatione sanguinea</i>	APAP	E
California Quail	<i>Callipepla californica</i>	CAQU	N
Common Myna	<i>Acridotheres tristis</i>	COMY	N
Common Peafowl	<i>Pavo cristatus</i>	COPE	N
Erckel's Francolin	<i>Francolinus erckelii</i>	ERFR	N
Hawaii Akepa	<i>Loxops coccineus</i>	HAAC	E
Hawaii Amakihi	<i>Hemignathus virens</i>	HAAM	E
Hawaii Creeper	<i>Oreomystis mana</i>	HCRE	E
Hawaii Elepaio	<i>Chasiempis sandwichensis</i>	HAEL	E
Hawaiian Goose	<i>Branta sandvicensis</i>	HAGO	E
House Finch	<i>Carpodacus mexicanus</i>	HOFI	N
Hwamei	<i>Garrulax canorus</i>	MELT	N
Iiwi	<i>Vestiaria coccinea</i>	IIWI	E
Io	<i>Buteo solitarius</i>	HWAH	E
Japanese Bush-Warbler	<i>Cettia diphone</i>	JABW	N
Japanese White-eye	<i>Zosterops japonicus</i>	JAWO	N
Kalij Pheasant	<i>Lophura leucomelanos</i>	KAPH	N
Northern Cardinal	<i>Cardinalis cardinalis</i>	NOCA	N
Northern Mockingbird	<i>Mimus polyglottos</i>	NOMO	N
Nutmeg Mannikin	<i>Lonchura punctulata</i>	NUMA	N
Omao	<i>Myadestes obscurus</i>	OMAO	E
Red-billed Leiothrix	<i>Leiothrix lutea</i>	RBLE	N
Saffron Finch	<i>Sicalis flaveola</i>	SAFI	N
Sky Lark	<i>Alauda arvensis</i>	SKLA	N
Spotted Dove	<i>Streptopelia chinensis</i>	SPDO	N
Wild Turkey	<i>Meleagris gallopavo</i>	WITU	N
Yellow-fronted Canary	<i>Serinus mozambicus</i>	YFCA	N
Zebra Dove	<i>Geopelia striata</i>	ZEBD	N

The eight tracts in the sampling design occur within five of the eight climate zones on Hawaii Island (Table 1; Figure 3). Native species percent occurrence was highest in mesic and wet climate zones (Table 3). This pattern was also observed for alien species, with the exception of California Quail, Northern Mockingbird, and Sky Lark which had highest percent occurrences in dry climate zones (Table 4).

In general, landbird abundance was greater in the 2010 surveys, higher than almost all previous surveys (Tables 5-6). Inference areas were estimated in GIS to determine abundance of a species (Figures 4-10). Summary indices of species that were detected in low numbers were calculated by tract (Table 7). Notable patterns densities and occurrences are discussed in the species accounts below.

Table 3. Native species occurrence (%) within climate zones.

Species Code	Total Number of Species Detections	Very Dry	Moderately Dry	Seasonal Mesic	Moist Mesic	Moderately Wet
AKIP	4	0	0	0	50%	50%
APAP	4358	3.53%	2.25%	25.59%	43.14%	25.49%
HAAC	20	0	0	5%	60%	35%
HAAM	2286	17.76%	11.07%	37.31%	29.22%	4.64%
HAEL	104	2.88%	6.73%	66.35%	2.88%	21.15%
HAGO	2	0	0	100	0	0
HCRE	26	0	0	19.23%	23.08%	57.69%
HWAH	9	0	0	55.56%	11.11%	33.33%
IIWI	173	0	0.58%	26.59%	18.50%	54.34%
OMAO	292	4.79%	1.03%	11.64%	36.99%	45.55%

Table 4. Non-native species occurrence (%) within climate zones.

Species Code	Total Number of Detections	Very Dry	Moderately Dry	Seasonal Mesic	Moist Mesic	Moderately Wet
CAQU	7	28.57%	57.14%	14.29%	0	0
COMY	12	0	0	8.33%	91.67%	0
COPE	3	0	0	0	100	0
ERFR	39	17.95%	12.82%	51.28%	17.95%	0
HOFI	231	6.49%	9.09%	36.80%	46.75%	0.87%
JABW	5	0	0	0	0	100%
JAWF	1669	0.18%	0.54%	22.89%	30.92%	45.48%
KAPH	15	0	0	6.67%	13.33%	80%
MELT	15	0	0	53.33%	33.33%	13.33%
NOCA	269	1.49%	6.32%	36.06%	29.37%	26.77%
NOMO	13	46.15%	53.85%	0	0	0
NUMA	36	0	0	0	100%	0
RBLE	167	0	0	17.96%	14.97%	67.07%
SAFI	3	0	0	0	100%	0
SKLA	53	35.85%	56.60%	3.77%	3.77%	0
SPDO	8	0	0	100%	0	0
WITU	9	0	0	22.22%	77.78%	0
YFCA	15	0	0	13.33%	86.67%	0
ZBDO	1	0	0	0	0	100%

Table 5. Density and abundance of native forest birds. Population density and abundance estimates by tract for native forest birds in Hawaii Volcanoes National Park. Density (birds/ha $\pm$ SE) and confidence intervals for previous surveys were from Gorresen et al. (2005) and Tweed et al. (2007), and the most recent 2010 NPS I&M survey (highlighted rows). Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	APAP	HAAM	HAEL	OMAO	IIWI
East Rift Zone	1992	4.23 $\pm$ 0.47 (3.31—5.16)	0	0	0.24 $\pm$ 0.06 (0.13—0.36)	0
	1993 (Jan)	7.13 $\pm$ 0.33 (6.48—7.78)	0.01 $\pm$ 0.01 (0—0.03)	0	0.76 $\pm$ 0.08 (0.61—0.92)	0
	1993-1994	6.44 $\pm$ 0.31 (5.84—7.05)	0.04 $\pm$ 0.02 (0.01—0.08)	0.21 $\pm$ 0.06 (0.10—0.33)	1.01 $\pm$ 0.04 (0.94—1.09)	0
	2010	19.53 $\pm$ 2.13 (15.79—24.14)	0.93 $\pm$ 0.56 (0.09—2.30)	0	2.37 $\pm$ 0.33 (1.74—3.03)	0
	Tract Abundance	44,030 (35,591—54,404)	2,094 (191—5,186)	0	5,344 (3,911—6,834)	0
Honomalino	2005	3.48 $\pm$ 0.26 (2.98—3.99)	4.53 $\pm$ 0.23 (4.07—5.04)	0.32 $\pm$ 0.12 (0.08—1.35)	0	0.39 $\pm$ 0.05 (0.29—0.54)
	2010	18.24 $\pm$ 1.81 (15.20—22.20)	19.71 $\pm$ 2.57 (15.64—26.08)	0.18 $\pm$ 0.08 (0.05—0.35)	0	0.45 $\pm$ 0.16 (0.19—0.81)
	Tract Abundance	30,795 (25,656—37,472)	33,272 (26,407—44,029)	298 (86—583)	0	767 (328—1,367)
Kahuku	2005	7.98 $\pm$ 0.58 (6.85—9.12)	1.65 $\pm$ 0.13 (1.40—1.94)	0.14 $\pm$ 0.03 (0.08—0.28)	1.03 $\pm$ 0.06 (0.90—1.16)	0.89 $\pm$ 0.08 (0.73—1.08)
	2010	30.99 $\pm$ 2.65 (26.06—35.91)	5.49 $\pm$ 0.73 (4.27—7.16)	0.19 $\pm$ 0.07 (0.07—0.35)	1.10 $\pm$ 0.13 (0.85—1.34)	1.37 $\pm$ 0.29 (0.86—2.02)
	Tract Abundance	331,800 (286,330—394,620)	60,279 (46,889—78,722)	2,077 (813—3,884)	12,042 (9,295—14,718)	15,078 (9,461—22,156)
Mauna Loa South Flank	2005	0.92 $\pm$ 0.18 (0.66—1.29)	0.83 $\pm$ 0.09 (0.65—1.07)	0	0.33 $\pm$ 0.04 (0.26—0.46)	0
	2010	9.77 $\pm$ 1.50 (7.07—12.97)	11.88 $\pm$ 1.57 (9.41—15.41)	0	0.35 $\pm$ 0.10 (0.18—0.56)	0
	Tract Abundance	44,889 (32,476—59,586)	54,543 (43,228—70,795)	0	1,620 (810—2,578)	0
Mauna Loa Strip	1986	2.96 $\pm$ 0.25 (2.47—3.45)	4.04 $\pm$ 0.40 (3.26—4.83)	1.80 $\pm$ 0.35 (1.12—2.49)	0	0.54 $\pm$ 0.09 (0.37—0.72)
	1987	1.91 $\pm$ 0.23 (1.46—2.37)	3.89 $\pm$ 0.38 (3.15—4.64)	1.89 $\pm$ 0.27 (1.37—2.42)	0.01 $\pm$ 0.01 (0—0.03)	0.32 $\pm$ 0.07 (0.19—0.46)
	1990	3.67 $\pm$ 0.34 (3.01—4.34)	4.35 $\pm$ 0.37 (3.63—5.08)	2.55 $\pm$ 0.34 (1.89—3.22)	0.01 $\pm$ 0.01 (0—0.03)	1.12 $\pm$ 0.16 (0.81—1.44)

Table 5. Density and abundance of native forest birds (continued).

	1991	2.92 ± 0.29 (2.36—3.49)	4.50 ± 0.50 (3.52—5.48)	1.18 ± 0.33 (0.54—1.83)	0.02 ± 0.01 (0.01—0.04)	1.07 ± 0.15 (0.78—1.37)
	1992	3.05 ± 0.30 (2.47—3.64)	5.29 ± 0.41 (4.49—6.10)	1.69 ± 0.29 (1.13—2.26)	0.03 ± 0.02 (0—0.07)	0.74 ± 0.10 (0.55—0.94)
	1993	2.47 ± 0.21 (2.06—2.89)	3.28 ± 0.49 (2.32—4.25)	1.68 ± 0.30 (1.10—2.27)	0.01 ± 0.01 (0.01—0.02)	0.59 ± 0.10 (0.40—0.79)
	1994	2.83 ± 0.31 (2.23—3.44)	4.18 ± 0.51 (3.19—5.18)	1.99 ± 0.36 (1.29—2.70)	0.01 ± 0.01 (0—0.03)	0.44 ± 0.08 (0.29—0.60)
	2010	10.14 ± 1.24 (7.96—12.91)	8.35 ± 1.21 (6.40—11.05)	1.53 ± 0.36 (0.93—2.33)	0.32 ± 0.07 (0.19—0.46)	0.64 ± 0.21 (0.29—1.08)
	Tract Abundance	32,257 (25,009—40,247)	26,558 (20,350—35,159)	4,861 (2,972—7,406)	1,007 (605—1,475)	2,043 (922—3,449)
Northwest Kahuku	2005	2.80 ± 0.33 (2.15—3.65)	4.72 ± 0.38 (3.98—5.60)	0.10 ± 0.04 (0.01—0.70)	0	0.61 ± 0.12 (0.37—1.00)
	2010	3.57 ± 0.58 (2.59—4.94)	15.40 ± 2.15 (11.86—20.15)	0.20 ± 0.08 (0.07—0.36)	0.16 ± 0.05 (0.07—0.26)	0.03 ± 0.03 (0—0.09)
	Tract Abundance	3,158 (2,264—4,176)	13,614 (10,483—17,808)	179 (62—322)	140 (62—227)	22 (0—78)
Olaa	1992	2.00 ± 0.30 (1.42—2.59)	0	0.02 ± 0.02 (0—0.06)	0.21 ± 0.04 (0.14—0.29)	0.17 ± 0.08 (0.02—0.33)
	1993	7.46 ± 0.61 (6.27—8.66)	0	0.09 ± 0.04 (0.02—0.17)	1.20 ± 0.14 (0.93—1.48)	0.28 ± 0.10 (0.09—0.48)
	1994	6.92 ± 0.83 (5.30—8.55)	0.02 ± 0.02 (0—0.06)	0	0.91 ± 0.11 (0.70—1.13)	0.23 ± 0.09 (0.06—0.41)
	2010	13.14 ± 1.52 (10.37—16.27)	0.10 ± 0.06 (0—0.25)	0.20 ± 0.09 (0.06—0.39)	0.34 ± 0.10 (0.17—0.57)	0.33 ± 0.16 (0.07—0.69)
	Tract Abundance	32,146 (25,376—39,796)	253 (0—602)	485 (151—948)	842 (420—1,384)	816 (177—1,685)
Papa	2005	3.64 ± 0.75 (2.17—4.87)	4.71 ± 0.73 (3.28—6.78)	0	0	0
	2010	12.36 ± 2.60 (8.16—18.04)	13.55 ± 2.47 (9.44—18.98)	0	0.50 ± 0.22 (0.13—1.01)	0.23 ± 0.23 (0—0.84)
	Tract Abundance	4,066 (2,684—5,936)	4,458 (3,105—6,244)	0	166 (41—333)	77 (0—276)
Total Abundance		$523,140 \pm 44,362$ (451,080—627,840)	$195,070 \pm 23,545$ (156,870—248,360)	$7,901 \pm 1,774$ (5,009—11,828)	$21,160 \pm 1,911$ (17,419—24,786)	$18,804 \pm 3,676$ (12,230—27,197)

Table 6. Density and abundance of non-native forest birds. Population density and abundance estimates by tract for non-native forest birds in Hawaii Volcanoes National Park. Density (birds/ha $\pm$ SE) and confidence intervals for previous surveys were from Gorresen et al. (2005) and Tweed et al. (2007), and the most recent 2010 NPS I&M survey (highlighted rows). Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	HOFI	JAWE	NOCA	RBLE
East Rift Zone	1992	0.07 $\pm$ 0.05 (0—0.17)	7.25 $\pm$ 0.95 (5.39—9.12)	0.01 $\pm$ 0.01 (0—0.03)	0
	1993 (Jan)	0	17.33 $\pm$ 0.95 (15.47—19.20)	0.05 $\pm$ 0.02 (0.02—0.09)	0
	1993-1994	0.03 $\pm$ 0.02 (0—0.07)	11.90 $\pm$ 0.49 (10.94—12.87)	0.04 $\pm$ 0.01 (0.03—0.06)	0
	2010	0	23.82 $\pm$ 3.67 (17.87—32.50)	0.23 $\pm$ 0.13 (0—0.53)	0.14 $\pm$ 0.15 (0—0.48)
	Tract Abundance	0	53,691 (40,280—73,264)	509 (0—1,186)	315 (0—1,071)
Honomalino	2005	0.74 $\pm$ 0.10 (0.54—1.00)	1.91 $\pm$ 0.16 (1.60—2.28)	0.83 $\pm$ 0.11 (0.61—1.12)	0
	2010	1.06 $\pm$ 0.31 (0.53—1.72)	7.15 $\pm$ 1.25 (5.04—10.02)	0.57 $\pm$ 0.13 (0.36—0.86)	0.09 $\pm$ 0.06 (0—0.23)
	Tract Abundance	1,790 (887—2,899)	12,063 (8,507—16,913)	964 (603—1,452)	148 (0—385)
Kahuku	2005	0	2.36 $\pm$ 0.17 (2.02—2.76)	0.03 $\pm$ 0.01 (0.01—0.05)	0.33 $\pm$ 0.05 (0.24—0.45)
	2010	0.03 $\pm$ 0.02 (0—0.08)	3.04 $\pm$ 0.50 (2.20—4.16)	0.02 $\pm$ 0.02 (0—0.05)	0.80 $\pm$ 0.15 (0.53—1.10)
	Tract Abundance	280 (0—827)	33,411 (24,141—45,681)	181 (0—508)	8,750 (5,810—12,160)
Mauna Loa South Flank	2005	0.60 $\pm$ 0.10 (0.40—0.89)	3.25 $\pm$ 0.21 (2.85—3.71)	0.49 $\pm$ 0.05 (0.39—0.60)	0
	2010	1.73 $\pm$ 0.42 (1.08—2.71)	22.33 $\pm$ 3.01 (17.54—29.21)	0.80 $\pm$ 0.13 (0.58—1.08)	0.24 $\pm$ 0.09 (0.08—0.42)
	Tract Abundance	7,929 (4,973—12,435)	102,570 (80,552—134,140)	3,673 (2,643—4,939)	1,120 (378—1,917)
Mauna Loa Strip	1986	0.73 $\pm$ 0.19 (0.36—1.11)	4.78 $\pm$ 0.54 (3.73—5.84)	0.20 $\pm$ 0.03 (0.15—0.26)	0.96 $\pm$ 0.13 (0.71—1.22)
	1987	0.97 $\pm$ 0.14 (0.70—1.25)	6.73 $\pm$ 0.72 (5.32—8.15)	0.29 $\pm$ 0.04 (0.22—0.37)	1.22 $\pm$ 0.13 (0.97—1.48)
	1990	1.46 $\pm$ 0.31 (0.86—2.07)	7.27 $\pm$ 0.81 (5.69—8.86)	0.26 $\pm$ 0.03 (0.21—0.32)	0.29 $\pm$ 0.07 (0.16—0.43)
	1991	1.36 $\pm$ 0.27 (0.84—1.89)	8.45 $\pm$ 0.91 (6.67—10.24)	0.32 $\pm$ 0.04 (0.25—0.40)	0.06 $\pm$ 0.03 (0.01—0.12)

Table 6. Density and abundance of non-native forest birds (continued).

	1992	0.59 ± 0.16 (0.28—0.91)	7.98 ± 0.63 (6.75—9.22)	0.22 ± 0.03 (0.17—0.28)	0.29 ± 0.06 (0.18—0.41)
	1993	0.78 ± 0.14 (0.51—1.06)	9.72 ± 0.92 (7.92—11.53)	0.22 ± 0.03 (0.17—0.28)	0.25 ± 0.07 (0.12—0.39)
	1994	0.83 ± 0.21 (0.42—1.25)	10.83 ± 0.93 (9.01—12.66)	0.30 ± 0.04 (0.23—0.38)	0.50 ± 0.10 (0.31—0.70)
	2010	0.08 ± 0.04 (0.02—0.17)	12.08 ± 1.97 (8.78—16.51)	0.15 ± 0.05 (0.06—0.26)	0.60 ± 0.20 (0.25—1.04)
	Tract Abundance	243 (51—534)	38,417 (27,916—52,531)	475 (191—816)	1,919 (806—3,299)
Northwest Kahuku	2005	0.53 ± 0.14 (0.25—1.14)	1.88 ± 0.31 (1.27—2.79)	0.10 ± 0.03 (0.04—0.23)	0
	2010	0.33 ± 0.13 (0.12—0.62)	0.44 ± 0.28 (0—1.10)	0.12 ± 0.04 (0.05—0.20)	0
	Tract Abundance	289 (102—549)	390 (0—970)	106 (48—180)	0
Olaa	1992	0.03 ± 0.02 (0—0.07)	4.46 ± 0.47 (3.54—5.39)	0.08 ± 0.02 (0.05—0.12)	0
	1993	0.16 ± 0.05 (0.07—0.26)	15.57 ± 0.81 (13.99—17.16)	0.33 ± 0.06 (0.22—0.45)	0.16 ± 0.06 (0.05—0.28)
	1994	0.10 ± 0.04 (0.03—0.18)	17.44 ± 0.81 (15.86—19.03)	0.42 ± 0.06 (0.31—0.54)	0.24 ± 0.07 (0.11—0.38)
	2010	0	32.46 ± 4.27 (25.78—42.91)	0.65 ± 0.13 (0.42—0.96)	1.13 ± 0.26 (0.67—1.67)
	Tract Abundance	0	79,398 (63,057— 104,960)	1,582 (1,035—2,348)	2,757 (1,633—4,096)
Papa	2005	0.56 ± 0.21 (0.15—2.14)	2.86 ± 0.46 (1.96—4.16)	0.58 ± 0.13 (0.33—0.99)	0
	2010	0.34 ± 0.19 (0—0.79)	0.74 ± 0.40 (0—1.64)	0.09 ± 0.09 (0—0.32)	0
	Tract Abundance	112 (0—259)	243 (0—541)	30 (0—104)	0
Total Abundance		$10,642 \pm 2,222$ (7,166-15,910)	$320,190 \pm 40,184$ (258,840- 412,530)	$7,520 \pm 1,126$ (5,785-10,232)	$15,010 \pm 2,274$ (10,793-19,758)

Table 7. List of birds detected, number of transects and stations sampled (# Trans and # Stns, respectively), number of stations occupied (# Ocpd), and number of birds detected (# Det) by tract during the 2010 Landbird survey of HAVO. Indices of percent occurrence (% Occ) and birds per station (BPS) were calculated. Species names can be found for each species code in Table 2.

TRACT	Species Code	# Trans	# Stns	# Ocpd	# Det	% Occ	BPS
Kahuku	AKIP	14	173	3	4	1.73	0.02
East Rift Zone	APAP	2	29	29	211	100.00	7.28
Honomalino	APAP	5	74	74	562	100.00	7.59
Kahuku	APAP	14	173	173	2025	100.00	11.71
Mauna Loa South Flank	APAP	7	93	61	387	65.59	4.16
Mauna Loa Strip	APAP	7	78	76	404	97.44	5.18
Northwest Kahuku	APAP	10	100	80	205	80.00	2.05
Olaa Koa Unit	APAP	7	56	50	184	89.29	3.29
Olaa Puu Unit	APAP	2	24	24	201	100.00	8.38
Olaa Small Tract Unit	APAP	1	7	7	31	100.00	4.43
Papa	APAP	3	21	21	148	100.00	7.05
Mauna Loa Strip	CAQU	7	78	1	1	1.28	0.01
Northwest Kahuku	CAQU	10	100	5	6	5.00	0.06
Mauna Loa South Flank	COMY	7	93	7	12	7.53	0.13
Mauna Loa South Flank	COPE	7	93	3	3	3.23	0.03
Honomalino	ERFR	5	74	11	16	14.86	0.22
Kahuku	ERFR	14	173	1	1	0.58	0.01
Mauna Loa South Flank	ERFR	7	93	2	2	2.15	0.02
Mauna Loa Strip	ERFR	7	78	6	7	7.69	0.09
Northwest Kahuku	ERFR	10	100	12	12	12.00	0.12
Papa	ERFR	3	21	1	1	4.76	0.05
Kahuku	HAAC	14	173	12	19	6.94	0.11
Mauna Loa South Flank	HAAC	7	93	1	1	1.08	0.01
East Rift Zone	HAAM	2	29	4	9	13.79	0.31
Honomalino	HAAM	5	74	74	514	100.00	6.95
Kahuku	HAAM	14	173	134	356	77.46	2.06
Mauna Loa South Flank	HAAM	7	93	87	408	93.55	4.39
Mauna Loa Strip	HAAM	7	78	69	267	88.46	3.42
Northwest Kahuku	HAAM	10	100	88	615	88.00	6.15
Olaa Koa Unit	HAAM	7	56	1	1	1.79	0.02
Olaa Puu Unit	HAAM	2	24	2	2	8.33	0.08
Papa	HAAM	3	21	20	114	95.24	5.43
Honomalino	HAEL	5	74	7	7	9.46	0.09
Kahuku	HAEL	14	173	11	15	6.36	0.09
Mauna Loa Strip	HAEL	7	78	37	64	47.44	0.82
Northwest Kahuku	HAEL	10	100	8	10	8.00	0.10
Olaa Koa Unit	HAEL	7	56	1	1	1.79	0.02
Olaa Puu Unit	HAEL	2	24	6	7	25.00	0.29
Kahuku	HAGO	14	173	1	2	0.58	0.01
Honomalino	HCRE	5	74	3	3	4.05	0.04
Kahuku	HCRE	14	173	13	22	7.51	0.13
Papa	HCRE	3	21	1	1	4.76	0.05
Honomalino	HOFI	5	74	20	61	27.03	0.82
Kahuku	HOFI	14	173	2	3	1.16	0.02
Mauna Loa South Flank	HOFI	7	93	45	119	48.39	1.28

Table 7. List of birds detected, number of transects and stations sampled (continued).

Mauna Loa Strip	HOFI	7	78	5	7	6.41	0.09
Northwest Kahuku	HOFI	10	100	17	35	17.00	0.35
Papa	HOFI	3	21	4	6	19.05	0.29
Honomalino	HWAH	5	74	1	1	1.35	0.01
Mauna Loa Strip	HWAH	7	78	3	5	3.85	0.06
Olaa Koa Unit	HWAH	7	56	2	3	3.57	0.05
Honomalino	IIWI	5	74	13	17	17.57	0.23
Kahuku	IIWI	14	173	48	109	27.75	0.63
Mauna Loa Strip	IIWI	7	78	19	31	24.36	0.40
Northwest Kahuku	IIWI	10	100	1	1	1.00	0.01
Olaa Koa Unit	IIWI	7	56	1	1	1.79	0.02
Olaa Puu Unit	IIWI	2	24	7	12	29.17	0.50
Papa	IIWI	3	21	1	2	4.76	0.10
Kahuku	JABW	14	173	2	5	1.16	0.03
East Rift Zone	JAWF	2	29	27	152	93.10	5.24
Honomalino	JAWF	5	74	46	110	62.16	1.49
Kahuku	JAWF	14	173	66	120	38.15	0.69
Mauna Loa South Flank	JAWF	7	93	89	472	95.70	5.08
Mauna Loa Strip	JAWF	7	78	65	242	83.33	3.10
Northwest Kahuku	JAWF	10	100	4	12	4.00	0.12
Olaa Koa Unit	JAWF	7	56	56	381	100.00	6.80
Olaa Puu Unit	JAWF	2	24	24	137	100.00	5.71
Olaa Small Tract Unit	JAWF	1	7	7	40	100.00	5.71
Papa	JAWF	3	21	3	3	14.29	0.14
Honomalino	KAPH	5	74	1	1	1.35	0.01
Kahuku	KAPH	14	173	4	5	2.31	0.03
Olaa Koa Unit	KAPH	7	56	5	5	8.93	0.09
Olaa Puu Unit	KAPH	2	24	2	2	8.33	0.08
Olaa Small Tract Unit	KAPH	1	7	1	2	14.29	0.29
East Rift Zone	MELT	2	29	1	1	3.45	0.03
Mauna Loa South Flank	MELT	7	93	7	7	7.53	0.08
Mauna Loa Strip	MELT	7	78	5	6	6.41	0.08
Olaa Koa Unit	MELT	7	56	1	1	1.79	0.02
East Rift Zone	NOCA	2	29	3	7	10.34	0.24
Honomalino	NOCA	5	74	34	56	45.95	0.76
Kahuku	NOCA	14	173	2	3	1.16	0.02
Mauna Loa South Flank	NOCA	7	93	55	99	59.14	1.06
Mauna Loa Strip	NOCA	7	78	15	19	19.23	0.24
Northwest Kahuku	NOCA	10	100	16	21	16.00	0.21
Olaa Koa Unit	NOCA	7	56	25	47	44.64	0.84
Olaa Puu Unit	NOCA	2	24	7	11	29.17	0.46
Olaa Small Tract Unit	NOCA	1	7	3	4	42.86	0.57
Papa	NOCA	3	21	1	2	4.76	0.10
Northwest Kahuku	NOMO	10	100	11	13	11.00	0.13
Mauna Loa South Flank	NUMA	7	93	10	36	10.75	0.39
East Rift Zone	OMAO	2	29	25	51	86.21	1.76
Kahuku	OMAO	14	173	85	142	49.13	0.82
Mauna Loa South Flank	OMAO	7	93	16	28	17.20	0.30
Mauna Loa Strip	OMAO	7	78	20	26	25.64	0.33
Northwest Kahuku	OMAO	10	100	13	14	13.00	0.14

Table 7. List of birds detected, number of transects and stations sampled (continued).

Olaa Koa Unit	OMAO	7	56	4	4	7.14	0.07
Olaa Puu Unit	OMAO	2	24	10	17	41.67	0.71
Olaa Small Tract Unit	OMAO	1	7	1	1	14.29	0.14
Papa	OMAO	3	21	6	9	28.57	0.43
East Rift Zone	RBLE	2	29	1	2	3.45	0.07
Honomalino	RBLE	5	74	2	3	2.70	0.04
Kahuku	RBLE	14	173	34	71	19.65	0.41
Mauna Loa South Flank	RBLE	7	93	11	15	11.83	0.16
Mauna Loa Strip	RBLE	7	78	15	27	19.23	0.35
Olaa Koa Unit	RBLE	7	56	10	14	17.86	0.25
Olaa Puu Unit	RBLE	2	24	12	24	50.00	1.00
Olaa Small Tract Unit	RBLE	1	7	4	11	57.14	1.57
Mauna Loa South Flank	SAFI	7	93	2	3	2.15	0.03
Kahuku	SKLA	14	173	1	2	0.58	0.01
Mauna Loa South Flank	SKLA	7	93	1	1	1.08	0.01
Northwest Kahuku	SKLA	10	100	30	44	30.00	0.44
Papa	SKLA	3	21	6	7	28.57	0.33
Mauna Loa South Flank	SPDO	7	93	5	8	5.38	0.09
Kahuku	WITU	14	173	2	2	1.16	0.01
Mauna Loa South Flank	WITU	7	93	3	5	3.23	0.05
Mauna Loa Strip	WITU	7	78	2	2	2.56	0.03
Mauna Loa South Flank	YFCA	7	93	13	15	13.98	0.16
Olaa Koa Unit	ZEBD	7	56	1	1	1.79	0.02

Native Species Summaries

Akiapolaau

The federally and state listed endangered Akiapolaau were only detected four times during the survey. Detections were between 1,600 and 2,100 m in elevation near the edges of moist mesic and moderately wet climate zones (Figure 11). The detections were all within the Kahuku tract, two within HAVO and two within the Kau Forest Reserve. The koa long-horned beetle larvae (*Megopis reflexa*) are the Akiapolaau's primary food source and are only found in koa trees. Koa was relatively sparse in the region and may be the limiting factor in Akiapolaau populations.

Apapane

Apapane were the most abundant native bird in the survey, the species was detected at nearly every station in every tract (Table 8; Figures 12 and 13). Densities were highest in the Kahuku, East Rift Zone, and Honomalino tracts at 30.99, 19.53, and 18.24 birds/ha, respectively. Apapane density was lowest at the dry sub-alpine forest in the Northwest Kahuku tract (3.57 birds/ha) where the birds were detected at 80% of the stations sampled. The relatively sparse forest within the tract is co-dominated by mamane, naio, and ohia. Trends are very positive for the species, as its abundance is increasing in nearly every tract (Table 8).

Table 8. Apapane abundance, densities, and trends.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Inference Area	Percent Occurrence within Tract
APAP	East Rift Zone	Increasing	19.53 ± 2.13 (15.79—24.14)	44,030 (35,591—54,404)	2253.86 ha	100.00
	Honomalino	Increasing	18.24 ± 1.81 (15.20—22.20)	30,795 (25,656—37,472)	1688.04 ha	100.00
	Kahuku	Increasing	30.99 ± 2.65 (26.06—35.91)	331,800 (286,330—394,620)	10989.33 ha	100.00
	Mauna Loa South Flank	Increasing	9.77 ± 1.50 (7.07—12.97)	44,889 (32,476—59,586)	4592.74 ha	65.59
	Mauna Loa Strip	Increasing	10.14 ± 1.24 (7.96—12.91)	32,257 (25,009—40,247)	3180.75 ha	97.44
	Northwest Kahuku	Inconclusive	3.57 ± 0.58 (2.59—4.94)	3,158 (2,264—4,176)	883.86 ha	80.00
	Olaa	Increasing	13.14 ± 1.52 (10.37—16.27)	32,146 (25,376—39,796)	2445.89 ha	93.10
	Papa	Increasing	12.36 ± 2.60 (8.16—18.04)	4,066 (2,684—5,936)	329.25 ha	100.00
Total				523,140 ± 44,362 (451,080—627,840)	26363.72 ha	

Hawaii Akepa

Hawaii Akepa were detected in low numbers in the Kahuku tract (19 individuals at 6.94% of stations surveyed; Table 7). The detections straddled the HAVO and Kau Forest Reserve boundary near the 1600-1900 m elevations (Figure 14). The species was detected in both sub-alpine woodlands and lower mature montane ohia forests. A single anomalous detection occurred within the Mauna Loa South Flank tract in an area where the species has not been detected in previous surveys (Figure 14). It is unusual to detect Akepa in pastureland but this tract is dominated by mature koa and ohia that may offer foraging opportunities.

Hawaii Amakihi

Hawaii Amakihi were abundant and widespread throughout most tracts (Figures 15 and 16). Densities were highest in the seasonally mesic leeward Honomalino, Northwest Kahuku, and Papa tracts with 19.71, 15.40, and 13.55 birds/ha, respectively. Hawaii Amakihi occurred in lower densities in the wetter windward tracts. The species was detected at 13.79% of the stations sampled in the East Rift Zone tract estimated at 0.93 birds/ha, and 3.73% of the stations sampled in the Olaa tract for an estimated density of 0.10 birds/ha. Point transect count data from previous surveys indicate an increasing trend for Hawaii Amakihi densities at all tracts except the East Rift Zone tract and Olaa tract where data are inconclusive (Table 9).

Table 9. Hawaii Amakihi abundance, densities, and trends.

Species	Tract	Trend	Density (Birds/Hectare)	Abundance	Inference Area	Percent Occurrence within Tract
HAAM	East Rift Zone	inconclusive	0.93 ± 0.56 (0.09—2.30)	2,094 (191—5,186)	2253.86 ha	13.79
	Honomalino	increasing	19.71 ± 2.57 (15.64—26.08)	33,272 (26,407—44,029)	1688.04 ha	100.00
	Kahuku	increasing	5.49 ± 0.73 (4.27—7.16)	60,279 (46,889—78,722)	10989.33 ha	77.46
	Mauna Loa South Flank	increasing	11.88 ± 1.57 (9.41—15.41)	54,543 (43,228—70,795)	4592.74 ha	93.55
	Mauna Loa Strip	increasing	8.35 ± 1.21 (6.40—11.05)	26,558 (20,350—35,159)	3180.75 ha	88.46
	Northwest Kahuku	increasing	15.40 ± 2.15 (11.86—20.15)	13,614 (10,483—17,808)	883.86 ha	88.00
	Olaa	inconclusive	0.10 ± 0.06 (0—0.25)	253 (0—602)	2445.89 ha	3.45
	Papa	increasing	13.55 ± 2.47 (9.44—18.98)	4,458 (3,105—6,244)	329.25 ha	95.24
Total				$195,070 \pm 23,545$ (156,870—248,360)	26363.72 ha	

Hawaii Creeper

The federally and state listed endangered Hawaii Creeper was detected in small numbers in the Kahuku, Honomalino, and Papa tracts (22, 3, and 1, respectively; Figure 17). Occupancy was highest in the ohia, koa, and olapa co-dominated moderately wet montane forests of the Kahuku tract where the species forages for insects in the bark of large stature trees. The Honomalino and Papa detections were the first since the Hawaii Forest Bird Survey began in the late 1970s and may mark an expansion of the species' range.

Hawaii Elepaio

Hawaii Elepaio were detected at five of the eight tracts (Honomalino, Kahuku, Mauna Loa Strip, Northwest Kahuku, and the Olaa Unit; Figures 18 and 19). Densities were highest in the Mauna Loa Strip tract (1.53 birds/ha) occurring at nearly half of all the stations surveyed (Table 10). Detections were highest on transects within seasonal mesic forests dominated by koa. The birds were not detected in the East Rift Zone, Mauna Loa South Flank, or Papa tracts. Trend information in HAVO is inconclusive because of insufficient density estimates.

Table 10. Hawaii Elepaio abundance, densities, and trends.

Species	Tract	Trend	Density (Birds/Hectare)	Abundance	Inference Area	Percent Occurrence within Tract
HAEL	East Rift Zone	n/a	0	0	2253.86 ha	0.00
	Honomalino	inconclusive	0.18 ± 0.08 (0.05—0.35)	298 (86—583)	1688.04 ha	9.46
	Kahuku	inconclusive	0.19 ± 0.07 (0.07—0.35)	2,077 (813—3,884)	10989.33 ha	6.36
	Mauna Loa South Flank	n/a	0	0	4592.74 ha	0.00
	Mauna Loa Strip	inconclusive	1.53 ± 0.36 (0.93—2.33)	4,861 (2,972—7,406)	3180.75 ha	47.44
	Northwest Kahuku	inconclusive	0.20 ± 0.08 (0.07—0.36)	179 (62—322)	883.86 ha	8.00
	Olaa	n/a	0.20 ± 0.09 (0.06—0.39)	485 (151—948)	2445.89 ha	9.20
	Papa	n/a	0	0	329.25 ha	0.00
Total				$7,901 \pm 1,774$ (5,009—11,828)	26363.72 ha	

Hawaiian Goose

Two Hawaiian geese (Nene; *Branta sandvicensis*) were detected during surveys in the Kahuku Tract near 2,100 m elevation in a small stature ohia dominated seasonal mesic forest (Figure 20). Nene occur more commonly in mid-elevation seasonally dry ohia and shrublands on Kilauea (S. Judge pers. obs). Feral dogs were sighted within the Kahuku tract, and may pose a threat to the ground nesting Nene, a federally and state listed endangered species.

Hawaiian Hawk

Nine Hawaiian Hawks (Io; *Buteo solitarius*), a federally and state listed endangered species, were detected in the Olaa, Mauna Loa Strip, and Honomalino tracts (Figures 21 and 22). Occurrence was low in each of the tracts (<4%), the highest within a seasonal mesic ohia dominated forest near 1,500 m. Densities were not calculated because of limited detections among tracts. Furthermore, point transect count methods alone may miss the often quiet hawks. Applying appropriate methods, Gorresen et al. (2008) reported 0.54 ± 0.05 birds/km² in a 575,516 ha breeding range which included much of HAVO.

Iiwi

Iiwi densities were highest at the Kahuku, Mauna Loa Strip, Honomalino, and Olaa tracts, with 1.37, 0.64, 0.45, and 0.33 birds/ha, respectively (Table 11; Figures 23 and 24). Occurrence ranged from 17-27% of the stations sampled at those tracts. The Kahuku tract, where densities were highest, supports large stature ohia and koa trees and a native understory. Aside from the downward trend in density at the Northwest Kahuku tract, trend data is inconclusive at all other tracts because of insufficient density estimates.

Table 11. Iiwi abundance, densities, and trends.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Inference Area	Percent Occurrence within Tract
IWI	East Rift Zone	n/a	0	0	2253.86 ha	0.00
	Honomalino	inconclusive	0.45 ± 0.16 (0.19—0.81)	767 (328—1,367)	1688.04 ha	17.57
	Kahuku	inconclusive	1.37 ± 0.29 (0.86—2.02)	15,078 (9,461—22,156)	10989.33 ha	27.75
	Mauna Loa South Flank	n/a	0	0	4592.74 ha	0.00
	Mauna Loa Strip	inconclusive	0.64 ± 0.21 (0.29—1.08)	2,043 (922—3,449)	3180.75 ha	24.36
	Northwest Kahuku	decreasing	0.03 ± 0.03 (0—0.09)	22 (0—78)	883.86 ha	1.00
	Olaa	inconclusive	0.33 ± 0.16 (0.07—0.69)	816 (177—1,685)	2445.89 ha	9.20
	Papa	n/a	0.23 ± 0.23 (0—0.84)	77 (0—276)	329.25 ha	4.76
Total				$18,804 \pm 3,676$ (12,230—27,197)	26363.72 ha	

Omao

Omao were detected in variable densities among tracts, from zero birds in Honomalino to 2.37 birds/ha in the East Rift Zone where the birds occurred at 86% of the stations sampled (Table 12; Figures 25 and 26). Densities were highest in moist mesic and moderately wet climates co-dominated by ohia, koa, olapa (*Cheirodendron trigynum*), kawau (*Ilex anomala*) and olomea (*Perrottetia sandwicensis*). Large hapuu tree ferns (*Cibotium* spp.) and native shrubs (pilo [*Coprosma rhynchocarpa*], *Vaccinium* spp, kanawao [*Broussaisia arguta*] etc.) dominated the understory and mid-canopy of tracts where Omao were most abundant. However, Omao appear to range across a wide variety of habitats and climates and can even be found above tree line in the arid and sparse native shrublands of alpine Mauna Loa (Wakelee and Fancy 1999; Judge pers. obs.)

Omao populations were increasing in the East Rift Zone and Mauna Loa Strip tracts compared to previous survey data (Table 12). Data was inconclusive at the Kahuku and Mauna Loa South Flank tracts because of insufficient density estimates. The Olaa tract population was in significant decline; down from 0.91 birds/ha in 1994 to 0.34 birds/ha in 2010. Omao were detected in modest densities at the Northwest Kahuku and Papa tracts (0.16 birds/ha and 0.50 birds/ha, respectively).

Table 12. Omao abundance, densities, and trends.

Species	Tract	Trend	Density (Birds/Hectare)	Abundance	Inference Area	Percent Occurrence within Tract
OMAO	East Rift Zone	increasing	2.37 ± 0.33 (1.74—3.03)	5,344 (3,911—6,834)	2253.86 ha	86.21
	Honomalino	n/a	0	0	1688.04 ha	0.00
	Kahuku	inconclusive	1.10 ± 0.13 (0.85—1.34)	12,042 (9,295—14,718)	10989.33 ha	49.13
	Mauna Loa South Flank	inconclusive	0.35 ± 0.10 (0.18—0.56)	1,620 (810—2,578)	4592.74 ha	17.20
	Mauna Loa Strip	increasing	0.32 ± 0.07 (0.19—0.46)	1,007 (605—1,475)	3180.75 ha	25.64
	Northwest Kahuku	n/a	0.16 ± 0.05 (0.07—0.26)	140 (62—227)	883.86 ha	13.00
	Olaa	decreasing	0.34 ± 0.10 (0.17—0.57)	842 (420—1,384)	2445.89 ha	25.28
	Papa	n/a	0.50 ± 0.22 (0.13—1.01)	166 (41—333)	329.25 ha	28.57
Total				$21,160 \pm 1,911$ (17,419—24,786)	26363.72 ha	

Non-Native Species Summaries

California Quail

California Quail (*Callipepla californica*) were only detected in the Mauna Loa Strip and Northwest Kahuku tracts (Figures 27 and 28). Percent occurrence was highest (5% of stations surveyed) in the disturbed habitat of Northwest Kahuku. The quail subsist on introduced grasses, which flourish in areas damaged by intense grazing by introduced cattle, goats (*Capra hircus*) and sheep.

Common Myna

The Common Myna (*Acridotheres tristis*) was detected near forest edges at 7.53% of the stations surveyed in the Mauna Loa South Flank tract (Figure 29). The Mauna Loa South Flank tract was formerly a large cattle ranch with a long history of grazing. Mynas are not typical of dense intact forests and usually occur in disturbed habitat near human habitations.

Common Peafowl

Common Peafowl (*Pavo cristatus*) were detected at 3.23% of the stations surveyed in the Mauna Loa South Flank tract (Figure 30). Peafowl are a common domestic pet and may be released or escaped birds within HAVO.

Erckel's Francolin

The Erckel's Francolin (*Francolinus erckelii*) was detected at six of the eight tracts surveyed in 2010 (Figures 31 and 32). Percent occurrence was highest in the higher elevations of Honomalino and Northwest Kahuku (0.22 and 0.12 birds/station, respectively) in open canopy forests where native and exotic grasses persist.

House Finch

The House Finch was detected in six of the eight tracts surveyed (Figures 33 and 34). The birds were absent in the moderately wet Olaa and East Rift Zone tracts. Densities were highest in the pasturelands of the large stature open canopy ohia forests of the Mauna Loa South Flank tract (1.73 birds/ha). Many birds were not counted during surveys because they were usually seen flying over sampling areas.

Japanese Bush-Warbler

The Japanese Bush-Warbler (*Cettia diphone*) was detected in the Kahuku tract and heard incidentally in the Honomalino tract (Figure 35). The species has been expanding throughout Hawaii Island since it's colonization in 1997 (Nelson and Vitts 1998).

Japanese White-eye

The Japanese White-eye was the most abundant and widespread of the non-native species (Figures 36 and 37). Densities were highest in the moderately wet and moist mesic climates of the Olaa, East Rift Zone, and Mauna Loa South Flank tracts (32.46, 23.82, and 22.33 birds/ha, respectively). Densities were far lower in the leeward mamane and naio dominated Northwest Kahuku tract (0.44 bird/ha). Comparison of previous survey data indicates the species is increasing in the majority of tracts except in the Northwest Kahuku and Papa tracts where there is an apparent decline (Table 13).

Table 13. Japanese White-eye abundance, densities, and trends.

Species	Tract	Trend	Density (Birds/Hectare)	Abundance	Inference Area	Percent Occurrence within Tract
JAWE	East Rift Zone	increasing	23.82 ± 3.67 (17.87—32.50)	53,691 (40,280—73,264)	2253.86 ha	93.10
	Honomalino	increasing	7.15 ± 1.25 (5.04—10.02)	12,063 (8,507—16,913)	1688.04 ha	62.16
	Kahuku	inconclusive	3.04 ± 0.50 (2.20—4.16)	33,411 (24,141—45,681)	10989.33 ha	38.15
	Mauna Loa South Flank	increasing	22.33 ± 3.01 (17.54—29.21)	102,570 (80,552—134,140)	4592.74 ha	95.70
	Mauna Loa Strip	inconclusive	12.08 ± 1.97 (8.78—16.51)	38,417 (27,916—52,531)	3180.75 ha	83.33
	Northwest Kahuku	decreasing	0.44 ± 0.28 (0—1.10)	390 (0—970)	883.86 ha	4.00
	Olaa	increasing	32.46 ± 4.27 (25.78—42.91)	79,398 (63,057—104,960)	2445.89 ha	100.00
	Papa	decreasing	0.74 ± 0.40 (0—1.64)	243 (0—541)	329.25 ha	14.29
Total				320,190 ± 40,184 (258,840—412,530)	26363.72 ha	

Kalij Pheasant

Kalij Pheasants (*Lophura leucomelanos*) were detected in the Honomalino, Kahuku, and Olaa tracts and only in low numbers (Figures 38 and 39). The species is restricted to the understory and is cryptic in nature, potentially causing underestimates of densities.

Hwamei, or Melodious Laughing Thrush

Hwamei (*Garrulax canorus*) were absent from most tracts and detected in low numbers in the East Rift Zone, Mauna Loa South Flank, and Mauna Loa Strip tracts (0.03, 0.08, 0.08 birds/station, respectively; Figures 40 and 41). The bird forages in the understory and seems wary of observers. However, the song of the Hwamei is loud and conspicuous so it seems unlikely that many birds were undetected. Scott et al. in 1986 reported the species as having a “dynamic” range and fluctuations in presence may be expected.

Northern Cardinal

The Northern Cardinal (*Cardinalis cardinalis*) was detected in every tract in low densities (Table 14; Figures 42 and 43). Densities were highest in the moderately wet ohia dominated Olaa tract (0.65 birds/ha). Trend data is mostly inconclusive except in the Mauna Loa South Flank and Papa tracts where the population is increasing and decreasing, respectively. Northern Cardinals were introduced to the islands in 1929 (Scott et al. 1986), and occur in both native and alien-dominated forests.

Table 14. Northern Cardinal abundance, densities, and trends.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Inference Area	Percent Occurrence within Tract
NOCA	East Rift Zone	inconclusive	0.23 ± 0.13 (0—0.53)	509 (0—1,186)	2253.86 ha	10.34
	Honomalino	inconclusive	0.57 ± 0.13 (0.36—0.86)	964 (603—1,452)	1688.04 ha	45.95
	Kahuku	inconclusive	0.02 ± 0.02 (0—0.05)	181 (0—508)	10989.33 ha	1.16
	Mauna Loa South Flank	increasing	0.80 ± 0.13 (0.58—1.08)	3,673 (2,643—4,939)	4592.74 ha	59.14
	Mauna Loa Strip	stable or decreasing	0.15 ± 0.05 (0.06—0.26)	475 (191—816)	3180.75 ha	19.23
	Northwest Kahuku	inconclusive	0.12 ± 0.04 (0.05—0.20)	106 (48—180)	883.86 ha	16.00
	Olaa	inconclusive	0.65 ± 0.13 (0.42—0.96)	1,582 (1,035—2,348)	2445.89 ha	12.64
	Papa	decreasing	0.09 ± 0.09 (0—0.32)	30 (0—104)	329.25 ha	4.76
Total				$7,520 \pm 1,126$ (5,785—10,232)	26363.72 ha	

Northern Mockingbird

The Northern Mockingbird (*Mimus polyglottos*) was only detected in the Northwest Kahuku tract, occurring at 11% of the stations sampled (Figure 44). The species’ presence in the tract is an apparent expansion of range as no birds were detected there in 2005 or in previous survey years. The species was heard “mocking” Hawaii Elepaio, Apapane, and Hawaii Amakihi. Both aural and visual sightings of the bird are recommended to confirm identification.

Nutmeg Mannikin

Nutmeg Mannikins (*Lonchura punctulata*) were only detected in the pastures of the Mauna Loa South Flank tract, occurring at 10.75% of the stations surveyed (Figure 45). The species is typical of grasslands and usually forage in small flocks.

Red-billed Leiothrix

The Red-billed Leiothrix (*Leiothrix lutea*) was the second most abundant and widespread non-native species detected in the survey (Table 15; Figures 46 and 47). The species was found in relatively similar densities among windward tracts, the highest in the Olaa tract (1.13 birds/ha). The species was absent from the leeward Papa and Northwest Kahuku tracts, and only 0.09 birds/ha were estimated in the Honomalino tract. Trend data was available in the Kahuku, Mauna Loa Strip, and Olaa tracts where populations are increasing, inconclusive, and increasing, respectively. The species was intentionally and accidentally released on separate occasions in the early 20th century (Fisher and Baldwin 1947), and occur throughout native and alien-dominated forests.

Table 15. Red-billed Leiothrix abundance, densities, and trends.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Inference Area	Percent Occurrence within Tract
RBLE	East Rift Zone	n/a	0.14 ± 0.15 (0—0.48)	315 (0—1,071)	2253.86 ha	3.45
	Honomalino	n/a	0.09 ± 0.06 (0—0.23)	148 (0—385)	1688.04 ha	2.70
	Kahuku	increasing	0.80 ± 0.15 (0.53—1.10)	8,750 (5,810—12,160)	10989.33 ha	19.65
	Mauna Loa South Flank	n/a	0.24 ± 0.09 (0.08—0.42)	1,120 (378—1,917)	4592.74 ha	11.83
	Mauna Loa Strip	inconclusive	0.60 ± 0.20 (0.25—1.04)	1,919 (806—3,299)	3180.75 ha	19.23
	Northwest Kahuku	n/a	0	0	883.86 ha	17.86
	Olaa	increasing	1.13 ± 0.26 (0.67—1.67)	2,757 (1,633—4,096)	2445.89 ha	29.89
	Papa	n/a	0	0	329.25 ha	0.00
Total				15,010 ± 2,274 (10,793—19,758)	26363.72 ha	

Saffron Finch

Three Saffron Finches (*Sicalis flaveola*) were detected foraging in the pastures of the Mauna Loa South Flank tract (Figure 48). The species was first documented on Hawaii Island in 1966 (Berger 1981). The species is readily seen foraging in grass closer to human habitations on the windward and leeward side (S. Judge pers. obs.)

Sky Lark

The Sky Lark (*Alauda arvensis*) was only detected in open grasslands (Figure 49). Percent occupancy was highest in Northwest Kahuku (0.44 birds/station) in sub-alpine sparse ohia forests with open and grassy understory. The species is most often observed singing high in the air, often in a hovering position.

Spotted Dove

The Spotted Dove (*Streptopelia chinensis*) was only detected in the Mauna South Flank tract in low percent occurrence (5.38% of stations surveyed; Figure 50). The detection is likely representative of the proximity to human settlements where the species is common.

Wild Turkey

The Wild Turkey (*Meleagris gallopavo*) was detected in small numbers in the Mauna Loa South Flank, Mauna Loa Strip, and Kahuku tracts, occurring at less than 4% of the stations surveyed at each tract (Figures 51 and 52). The Wild Turkey is a popular game bird and is rarely found in dense mature forests.

Yellow-fronted Canary

The Yellow-fronted Canary (*Serinus mozambicus*) was only detected in the Mauna Loa South Flank (Figure 53). The species was detected at 13.98% of the stations surveyed at the tract in a moist mesic ohia dominated forest near 1,600 m. The species was first recorded on leeward Hawaii Island in 1977 (Van Riper 1978). Scott et al. (1986) documented an expansion of the species' range. Tweed et al. (2007) detected the species at the Mauna Loa South Flank tract in 2005 and the species was also sighted in the windward Keauhou Ranch in 2011 (S. Judge pers. obs.).

Zebra Dove

One Zebra Dove (*Geopelia striata*) was detected in the Olaa Tract during the survey (Figure 54). The species was found in a moderately wet ohia dominated forest. The species is common in lower elevation areas (<1,000 m) outside the range of the HAVO landbird study areas.

Habitat Surveys

Of the 616 stations that were surveyed for habitat, 423 stations were surveyed for slope (473 for slope variability; or unevenness of terrain), 544 stations for aspect (467 for aspect variability), 611 stations for canopy composition, 601 stations for canopy cover, 585 stations for canopy height, 613 stations for understory vegetation, and 319 for horizontal vegetation density.

Slope

The mean for the slope percent grade for all tracts combined was 11.30 ± 8.64 . Fifty-five percent of the stations surveyed for slope had a percent grade between 0 to 10%, 32% of the stations had a slope between 11 to 20%, 9% of the stations had a slope between 31 to 40%, <1% of the stations had a slope between 41 to 50%, and <1% of the stations had a slope greater than 50% (Table 16).

The mean for the slope percent grade for individual tracts ranged from 4% (SE = 5.24) to 16% (SE = 10.25), with Olaa having the most gradual slopes and Papa the steepest. Seven out of the eight tracts had slopes greater than 10%. Honomalino, Kahuku, Mauna Loa Strip, Olaa, and Papa had low slope variability in the majority (>50%) of their stations. Mauna Loa South Flank and Northwest Kahuku had medium slope variability in the majority of their stations (Table 17).

Table 16. Slope percent grade. Slope grade of stations sampled and percent of total stations of given slope grade.

Slope % grade	Count	%
0-10	233	55.08
11-20	134	31.68
21-30	39	9.22
31-40	12	2.84
41-50	4	0.95
>50	1	0.23
Total	423	

Table 17. Slope by tracts. Mean slope and slope variability of each tract sampled.

Tract	Slope (mean)	Slope Variability (% stations)
East Rift Zone	10.67±6.15	Not surveyed
Honomalino	12.60±8.81	Low (77.36%)
Kahuku	13.76±9.83	Low (80.33%)
ML South Flank	10.37±7.63	Med (51.61%)
ML Strip	12.34±7.87	Low (49.35%)
NW Kahuku	11.67±7.24	Med (50.88%)
Olaa	4.31±5.24	Low (92.11%)
Papa	16.09±10.25	Low (90%)

Aspect

Twelve percent of all stations surveyed for aspect faced from north to east (1-90°), 41% faced from east to south (91-180°), 34% faced from south to west (181-270°), and 14% faced from west to north (271-360°; Table 18). Honomalino had an aspect mean of 232° (SE = 49.27) and faced primarily southwest, Kahuku had an aspect mean of 145° (SE = 64.18) and faced primarily southeast, Mauna Loa South Flank had an aspect mean of 179° (SE = 49.99) and faced primarily south, Mauna Loa Strip had an aspect mean of 132° (SE = 54.77) and faced primarily southeast, Northwest Kahuku had an aspect mean of 266° (SE = 25.12) and faced primarily west, and Olaa had an aspect mean of 153° (SE = 93.31) and faced primarily southeast. Northwest Kahuku had medium aspect variability, and all other tracts had low aspect variability (Table 19). East Rift did not have enough stations surveyed for the summary.

Table 18. Aspect of stations sampled. Total number of stations sampled and percent of stations with given aspect are presented.

Aspect (degrees)	Count	%
North to East (1-90)	65	11.95
East to South (91-180)	224	41.18
South to West (181-270)	182	33.46
West to North (271-360)	73	13.42
Total	544	

Table 19. Aspect by tracts. Mean aspect of tracts and variability of aspect at stations within tract are presented.

Tract	Aspect (degree)	Aspect Variability (% stations)
East Rift Zone	Not surveyed	Not surveyed
Honomalino	231.65±49.27	Low (83%)
Kahuku	145.03±64.18	Low (80%)
ML South Flank	178.62±49.99	Low (62%)
ML Strip	131.74±54.77	Low (56%)
NW Kahuku	265.92±25.12	Med (63%)
Olaa	152.89±93.31	Low (100%)
Papa	224.00±60.01	low (89%)

Canopy

Native canopy species included ohia, olapa, koa, kolea (*Myrsine sp.*), naio, soapberry (*Sapindus saponaria*), and mamane. Ohia was the dominant canopy species at 65% of the count stations (Table 20) and in all tracts, except in the Mauna Loa Strip, Northwest Kahuku, and Olaa tracts. Eucalyptus (*Eucalyptus deglupta*) was the only dominate introduced canopy species.

Most stations had between 5 and 25% cover (Table 21), and the canopy height at most stations was greater than 10 m (Table 22). Canopy cover and height varied among the tracts (Table 23; see Supplemental Figures SM1-SM25).

Table 20. Canopy composition of plots at stations sampled (611 stations).

Canopy composition	Station count	%
Ohia dominant	400	65.47
Koa dominant	56	9.17
Mamane dominant	43	7.04
Olapa dominant	29	4.75
No canopy	22	3.60
Ohia-koa co-dominant	19	3.11
Ohia-olapa co-dominant	16	2.62
Ohia-mamane co-dominant	6	0.98
Mamane-naio co-dominant	6	0.98
Other Native trees dominant	5	0.82
Naio dominant	3	0.49
Ohia-native trees co-dominant	3	0.49
Ohia-introduced trees co-dominant	1	0.16
Olapa-koa co-dominant	1	0.16
Introduced tree dominant	1	0.16

Table 21. Canopy cover of stations sampled (601 stations).

Canopy cover class	Station count	%
Scattered (5-25% cover)	191	31.78
Closed (>60% cover)	152	25.29
Open (25-60% cover)	146	24.29
Very scattered (<5% cover)	90	14.98
No canopy (0% cover)	22	3.66

Table 22. Canopy height of stations sampled (585 stations).

Canopy height class	Station count	%
3 (> 10 m tall)	375	64.10
2 (5-10 m tall)	195	33.33
1 (2-5 m tall)	15	2.56

Table 23. Canopy types by tract, including canopy cover class, and canopy height where: 1 = <5m, 2 = 5-10m, 3 = >10m (Jacobi, 1989) and composition of canopy at landbird monitoring tracts.

Tract	Canopy cover class	Canopy height	Canopy composition	% stations
East Rift Zone	Closed	3	Ohia dominant	67.86
Honomalino	Open or scattered	2-3	Ohia dominant	67.65
Kahuku	Closed, open or Scattered	2-3	Ohia dominant	77.14
ML South Flank	Open, scattered or very scattered	2-3	Ohia dominant	47.67
ML Strip	Scattered or very scattered	2-3	Ohia dominant	39.19
	Open, closed or scattered	2-3	Koa dominant	35.14
NW Kahuku	Scattered	2	Mamane dominant	29.63
	Scattered or very scattered	2	Ohia dominant	25.93
Olaa	Closed	3	Olapa dominant	25.61
	Closed	3	Olapa-ohia	10.98
	Open or closed	3	Ohia dominant	39.02
Papa	Scattered	2-3	Ohia dominant	61.11

Understory vegetation

Species composition of the understory included the native aalii (*Dodonaea viscosa*), amau (*Sadleria* spp), kanawao, pilo, pukiawe (*Leptecophylla tameiameia*), and uluhe (*Dicranopteris linearis*). Introduced understory species included bamboo grass (*Microstegium vimineum*), banana poka (*Passiflora mollissima*), and blackberry (*Rubus* spp). Native shrubs and bare ground were found at more than two-thirds of the stations (Table 24; see Supplemental Figures SM26-SM65). Pig damage was observed at 3% of all stations; however, pig damage was observed at 10 of the 284 (4%) stations designated as bare ground.

Horizontal Vegetation Density

Out of the 319 stations surveyed for horizontal vegetation density 174 (55%) stations contained 0-25% understory vegetation cover. Equal percentages, 18%, of the stations contained 26-50% vegetation cover and 76-100% vegetation cover. Only 31 (10%) stations contained 51-75% vegetation cover.

Table 24. Understory classes of stations sampled.

Class	Description	Station count for the vegetation type	%
mf	Matted ferns: <i>Dicranopteris spp.</i> , <i>Hicriopteris spp.</i> , <i>Sticherus spp.</i>	144	23.49
mg	Mixed native-introduced grasses, sedges, or rushes	69	11.26
ng	Native grasses	109	17.78
ns	Native shrubs	416	67.86
pm	<i>Passiflora mollissima</i> (banana poka)	3	0.49
sp	<i>Sphagnum sp.</i>	73	11.91
tf	Native tree ferns: <i>Cibotium spp.</i>	114	18.60
xg	Introduced grasses, sedges, or rushes	147	23.98
xh	Introduced herbaceous species	4	0.65
xs	Introduced shrubs	18	2.94
xx	Bare ground (at least 25% of the area without vegetation)	284	46.33
lichen	Lichen	6	0.98
pig	Pig damage	16	2.61

Comparison of Panel Data

The q-q plot indicates that there was little difference between the two quantile distributions, fixed and random transects (Figure 2). This was supported by the small D-statistic from the two-sample Kolmogorov-Smirnov test ($D=0.0568$). Although this negligible difference was statistically significant ($p=0.003$), there was no evidence that this difference was biologically meaningful.

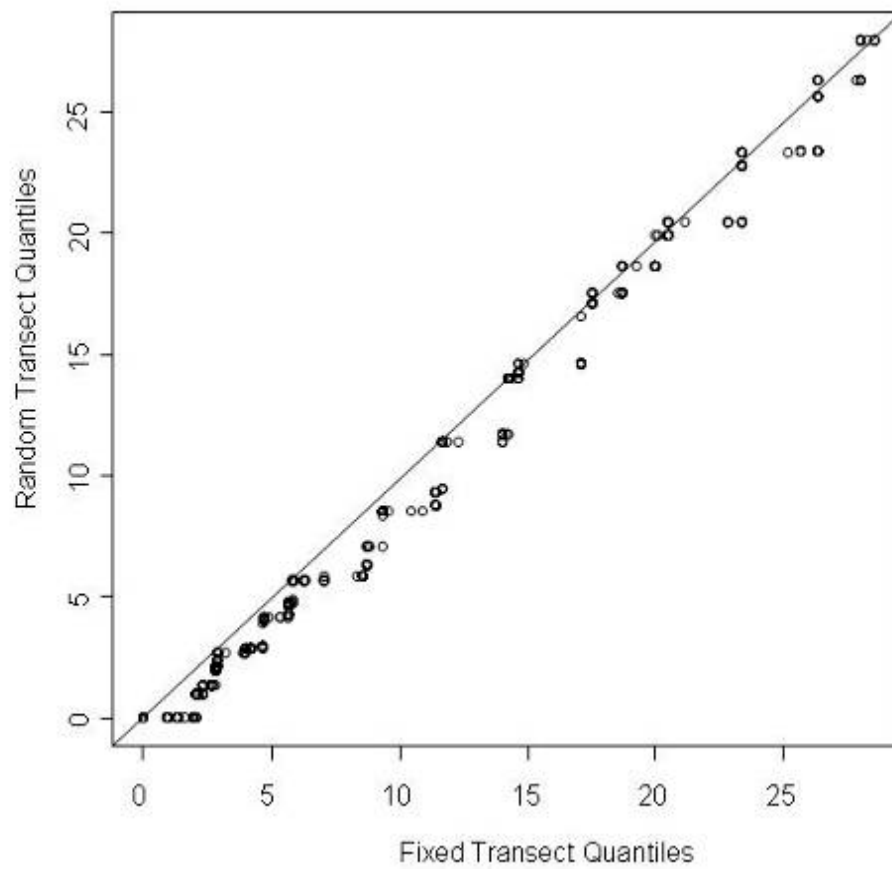


Figure 2. Plot of the fixed transect quantile against those of the random transects to compare their distributions.

Discussion

Landbirds

The 2010 landbird survey within HAVO produced estimates of distribution, occurrence, abundance and density of 10 native and 19 non-native forest bird species. Hawaii Amakihi and Apapane were the most abundant and widespread native species documented in the survey. Both species exhibited a general upward trend in density when compared to the 1994 and 2005 survey data. The ubiquity of Apapane throughout our tracts is likely an indicator of resistance to avian malaria, which has restricted the range of many other native forest bird species (Woodworth et al. 2005). Apapane in the Kahuku tract occurred in densities much higher than any other tract, and were nearly twice as dense as the populations of HFNW, a region that has benefited from intense ungulate removal, fencing and restoration efforts. This may be attributable to the relatively lower densities of Iiwi, which compete for similar food resources (Carpenter 1976).

Iiwi occurred only in tracts above 1,500 m and had low densities relative to most species. Trend data is inconclusive in tracts where Iiwi were documented except in the Northwest Kahuku tract where there is a significant decline. Avian malaria restricts Iiwi to elevations above 1,500 m where the disease vector-mosquito (*Culex quinquefasciatus*) presence drops due to cold temperature intolerance (Atkinson et al. 2000). Iiwi were not detected at the East Rift Zone and Mauna Loa South Flank tracts, both are low elevation areas where avian malaria is likely widespread. Only one individual was detected at the Northwest Kahuku tract; malaria does not explain the low density because the tract is well above 2,000 m. The tract was surveyed in 2005 and Iiwi were detected at relatively high densities. Seasonal fluctuations in food resources may account for their absence. The flower nectar of the ohia is the Iiwi's primary food resource and seasonal peaks of ohia bloom affect the birds' density and distribution (Perkins 1903, Baldwin 1953, Pimm and Pimm 1982, Ralph and Fancy 1995). Ohia bloom peaks between April and June and bottoms out October through November (Ralph and Fancy 1994, 1995). The 2005 survey was conducted in September, presumably when ohia bloom was in a downtrend. Mamane and naio are co-dominant trees in the Northwest Kahuku tract and their flowers and fruits may be an additional food source for Iiwi when ohia bloom is low (Hess et al. 2001). The 2010 Northwest Kahuku survey was conducted in May, possibly when Iiwi were in ohia dominated forests. A similar occurrence was observed on the eastern slopes of Mauna Kea when Iiwi capture rates were higher in September-November in mamane dominated forests (Scott et al. 1986; Pratt et al. 1997).

Omao were also widespread among tracts and were generally found in densities similar to historical records. However, Omao were detected in leeward regions of HAVO where the species was considered extirpated since 1978 (van Riper and Scott 1979, Scott et al. 1986). The reappearance of Omao is perhaps the most significant finding of the 2010 survey. Omao are dispersers of native seeds (Wakelee and Fancy 1999) and may be important to the restoration of native forests. Trend data for Omao in general was increasing or inconclusive except in the Olaa tract where there may be a decline in densities. The decline in population size may be attributed to disease or introduced predators such as cats and rats. The Olaa tract is adjacent to Volcano Village, which may serve as a source of predator ingress. It is also possible that birds were not as easily detectable during our survey. In addition, the majority of the Olaa tract surveyed has been

fenced and nearly all of the ungulates have been removed. Thus, the recovering vegetation may provide adequate resources, but may also have hindered Omao detectability.

Hawaii Elepaio were most abundant in the moderately dry native montane forest of the Mauna Loa Strip tract, but were absent or detected in low densities in all other tracts. Hawaii Elepaio trend data are inconclusive in all tracts and warrants further monitoring to detect a potential population decline. Additional survey information from leeward and mid-elevation windward tracts on Hawaii Island indicates a decline in Elepaio densities (Gorresen et al. 2005, Camp et al 2009).

The endangered honeycreepers Akiapolaau, Hawaii Akepa and Hawaii Creeper were detected in the mature montane and sub-alpine forests of the Kahuku tract above 1,300 m elevation. Each species is restricted in range and percent occurrence is very low. The Hawaii Creeper was the most abundant endangered species in the Kahuku tract and was also detected in small numbers in the Honomalino and Papa tracts for the first time since the Hawaii Forest Bird Survey began. Only four Akiapolaau were detected in the survey, all within a small area of mature ohia and koa forests within the Kahuku tract. The Hawaii Akepa was most common near the edge of mature montane and sub-alpine ohia dominated forests.

The Japanese White-eye was the most widespread and abundant non-native species detected in the survey. Densities were increasing for the majority of the tracts but were conspicuously small and in decline in the mamane and naio forests of Northwest Kahuku. It is interesting that Japanese White-eye densities in the Olaa tract were much higher than any other tract surveyed (32.46 birds/ha). In addition, the species' density was much higher than any other species in the tract, most notably the Hawaii Amakihi (0.10 birds/ha). The Northern Cardinal and House Finch were detected in all tracts but trends are inconclusive for these species. Red-billed Leiothrix densities were highest in the wetter Kahuku and Olaa tracts where the species forages in the diverse understory. Other non-native species were detected in relatively low abundance and densities. Occurrence of rare non-natives was higher in disturbed habitat or areas close to roads and human settlements.

The Kahuku tract had the highest numbers of native forest bird species as well as the largest stands of mature native forest. However, forest restoration and ungulate removal may be essential for the enhancement and expansion of forest bird habitat there. Range expansion of native species in leeward areas highlights the need for cooperation between land management agencies. Such is the case of the Omao and the potential expansion of the species from HAVO to TNC and HFNWR lands. The species is a vital seed disperser of native trees (Wakelee and Fancy 1999) and its expansion into these areas may greatly facilitate restoration efforts.

Trend data is positive for the majority of species documented in the survey. While endangered species were detected within HAVO and adjacent lands, each species still occurs in densities too low to detect a significant expansion of populations. Restoration efforts will help facilitate recovery of endangered species and continued monitoring will assist in identifying shifts in populations as well as habitat critical for species survival.

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. For example, the model for Hawaii Amakihi included canopy cover as a covariate, indicating that canopy cover strongly influenced Hawaii Amakihi detectability. The models for Iiwi and House Finch included canopy height as a covariate, indicating that canopy height strongly influenced their detectability. Incorporating covariates reduces estimator variability, thus increasing confidence in the density and abundance estimates.

Habitat surveys are an important component of the landbird monitoring effort because the information can be used to better understand the dynamics of bird populations and habitat structures. Habitat conditions such as canopy cover and density influence food availability, which may affect foraging bird population densities in the area (Fretz 2002). If we detect changes in bird populations, having long-term habitat information may allow better resolution of the reason behind those changes. Furthermore, the information gathered from the habitat surveys serves as an overview and provided general descriptions of habitat conditions at our study plots. The vegetation maps we created provide information on the major canopy types, compositions and height, and understory vegetation compositions and densities for each tract. Over time, park managers and researchers may use the information to determine habitat changes at these remote locations where people infrequently visit. For example, we mapped feral pig damage at our survey transects and noticed that most of the pig damage occurred outside of HAVO boundaries (see Supplemental Figures 45 and 46). Pig activity not only causes destruction to the vegetation and habitat, the holes and depressions they create in tree ferns also harbor mosquitoes, a vector for avian malaria (*Plasmodium relictum*) and pox (*Poxvirus avium*) that are detrimental to native Hawaiian birds (La Pointe, Atkinson and Jarvi 2009). Our surveys were not a complete assessment for pig damage, but the information was enough to show the effectiveness of pig control in the National Park, where we found very few signs of pig damage. With continuous monitoring, habitat surveys provide the needed clues for future ungulate control. 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 Hawaii for the preservation of native ecosystem and bird habitats (Loope et al. 2001). Our habitat surveys cover a wide range of areas in the HAVO and may detect invasive plants such as banana poka (*Passiflora mollissima*) at their incipient stage before a major infestation strikes.

Panel Data

It is usually not possible to make direct observations of every individual in a population, thus a subset of individuals—a sample—is used to make inference about the entire population. Random selection of the sample ensures that the sample is representative of the larger population. The random-panel-members met this probability sampling criteria because all transect locations were equally likely to be selected. However, the fixed panel members were a

carryover from previous surveys, and were initially established under a different sampling frame. Therefore, including them in the current I&M survey may have introduced a bias in estimates of density and variance. Testing for this difference between the fixed and random panel members was important for three reasons: 1) there were differences, although minor, in the sampling frames among the earlier surveys and the 2010 I&M survey; 2) probabilistic sampling required sampling units, transects and stations, be randomly located within the sampling frame (Thompson 2002); and 3) estimation in distance sampling required placement of transects and stations that were chosen with an equal coverage design, i.e., randomly placed within the tracts (Buckland et al. 2001, Fewster et al. 2009).

There was no evidence that the distribution of bird densities from the fixed and random transects were different. The q-q plot revealed that most points were close to the line and there was little systematic departure. Although the distributions were statistically different from each other, an artifact of the large sample size, the very small difference was not biologically meaningful. The sampling frames of the earlier surveys and the 2010 I&M survey were approximately the same for most of the HAVO tracts. The 2005 and 2010 Honomalino, Kahuku, Northwest Kahuku, Papa and South Flank tracts had the same sampling frames, for example. The sampling frames for the East Rift Zone, Mauna Loa Strip, and Olaa tracts were less similar but the differences were marginal. In addition to maintaining similar sampling frames, a random subset of the fixed-panel transects were selected and sampled for the fixed-member panel. Those two approaches minimized the differences between the fixed and random-member-panels. The later approach, randomly selecting a subset of the fixed-panel transects, also ensured that the probabilistic sampling and distance sampling criteria were met.

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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HAVO Landbird Survey Tracts with Climate Zones

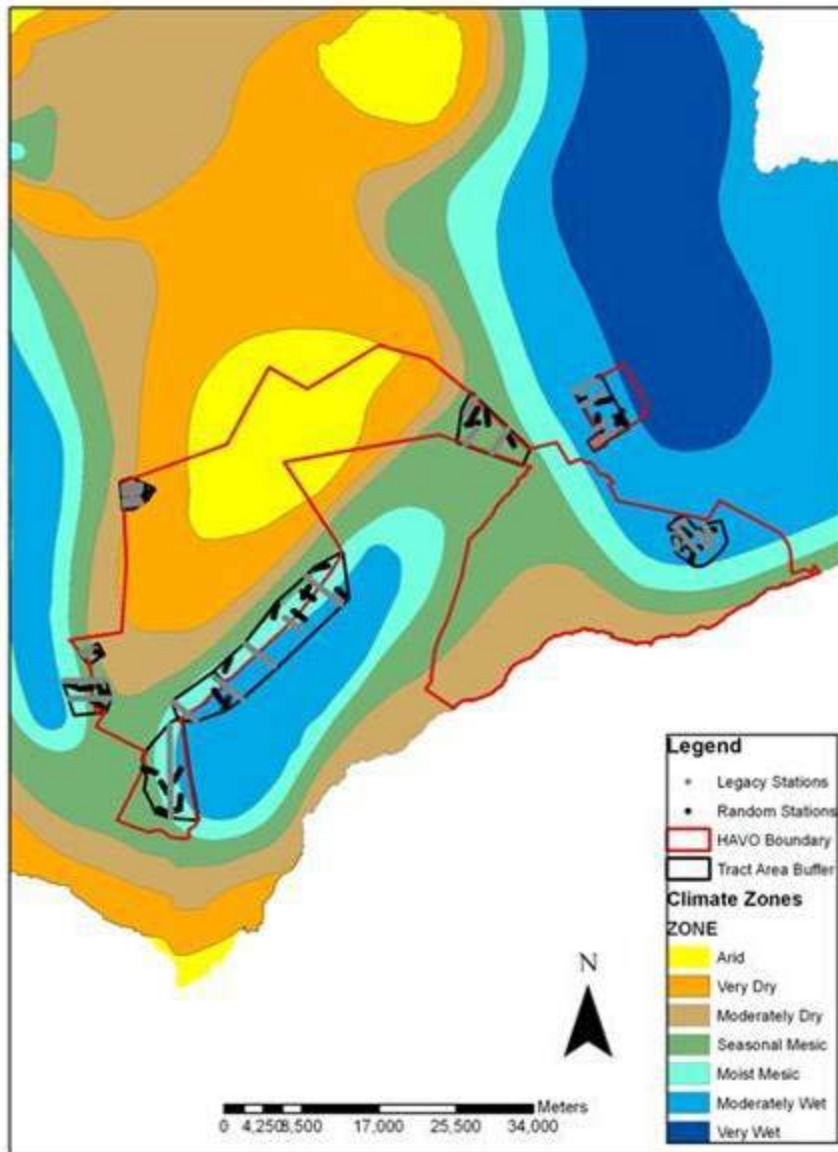


Figure 3. Climate zones of landbird survey tracts. Transects (fixed-panel [termed legacy] in gray, random in black) by tract with 150 m buffers around the perimeter of the survey area, displayed with climate zones (from Price et al. 2007). The red line denotes the HAVO boundary.

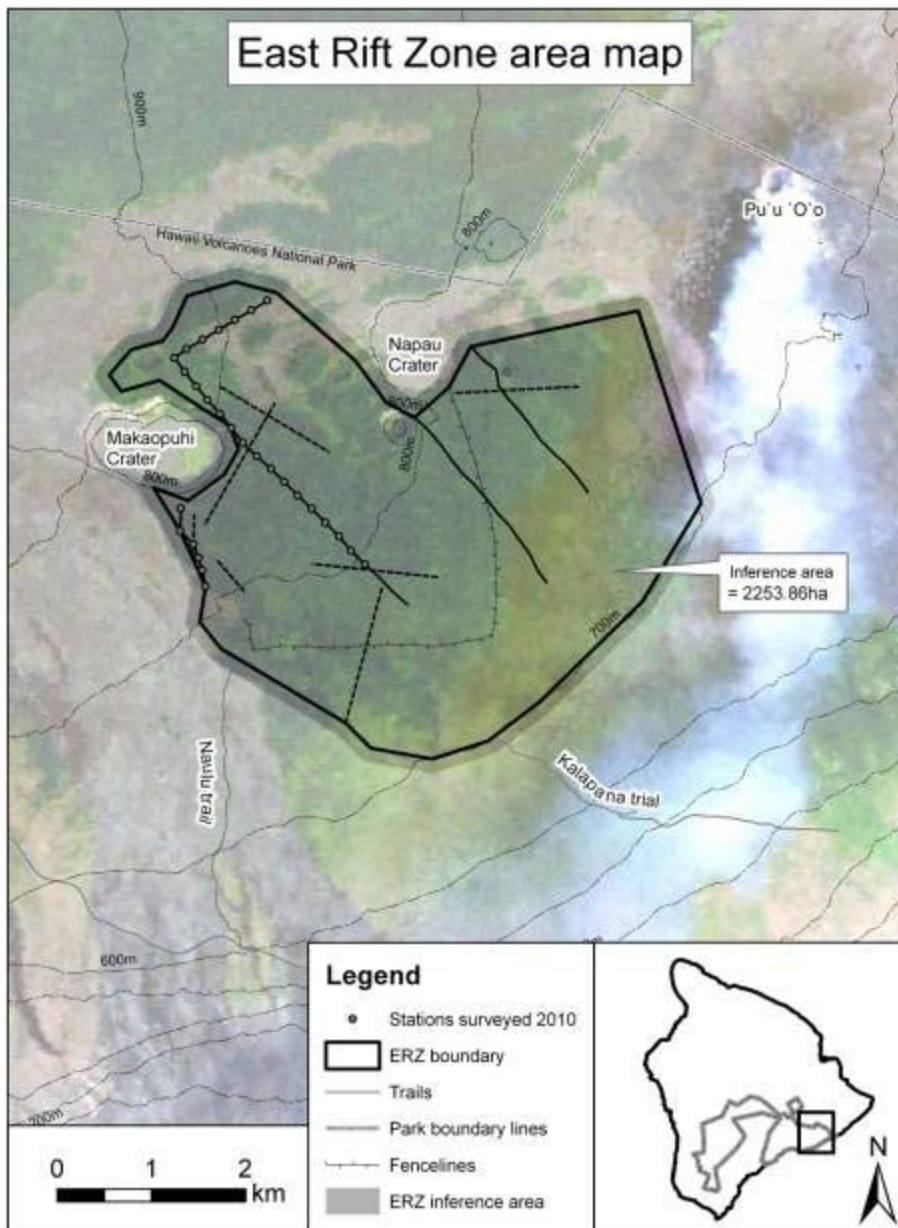


Figure 4. East Rift Zone tract area and boundary (with 150 m buffer).

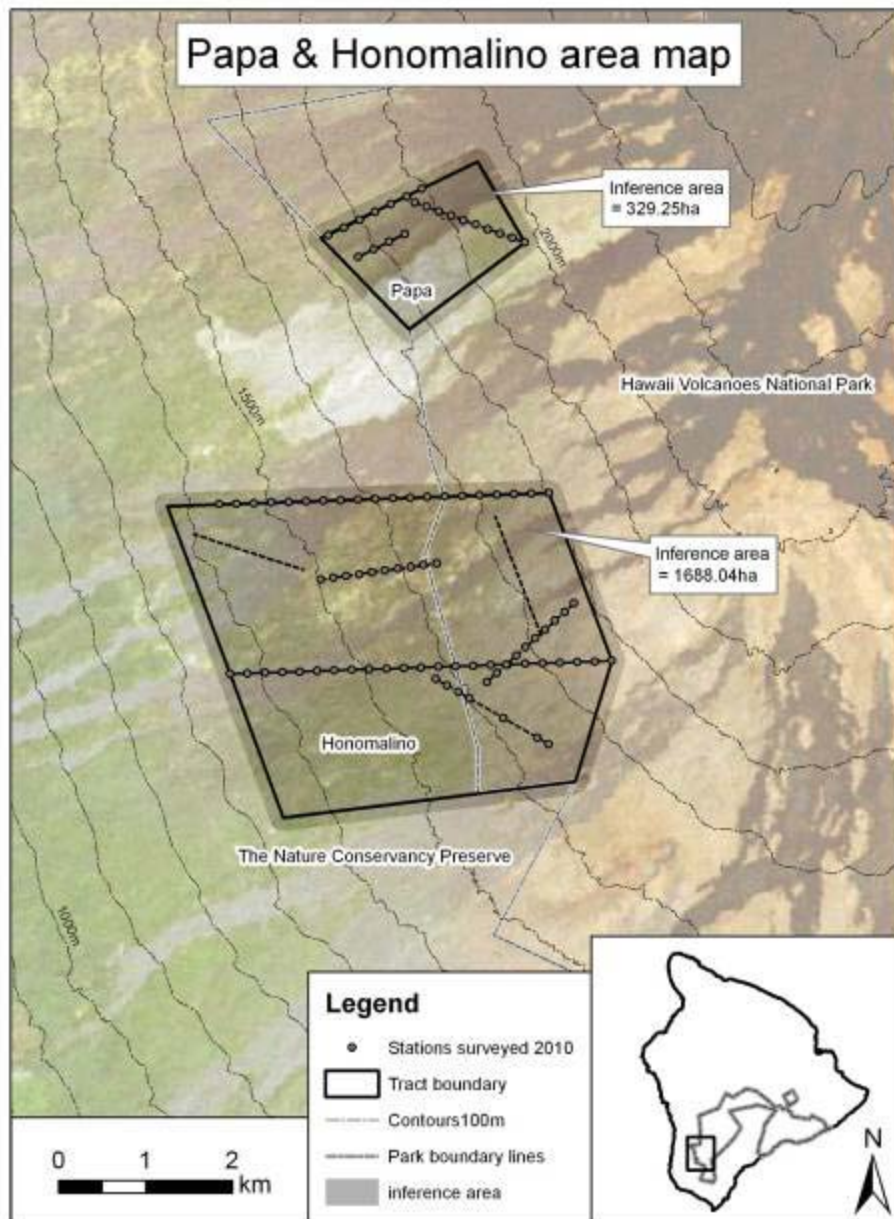


Figure 5. Honomalino and Papa tract inference areas and boundaries (with 150 m buffer).

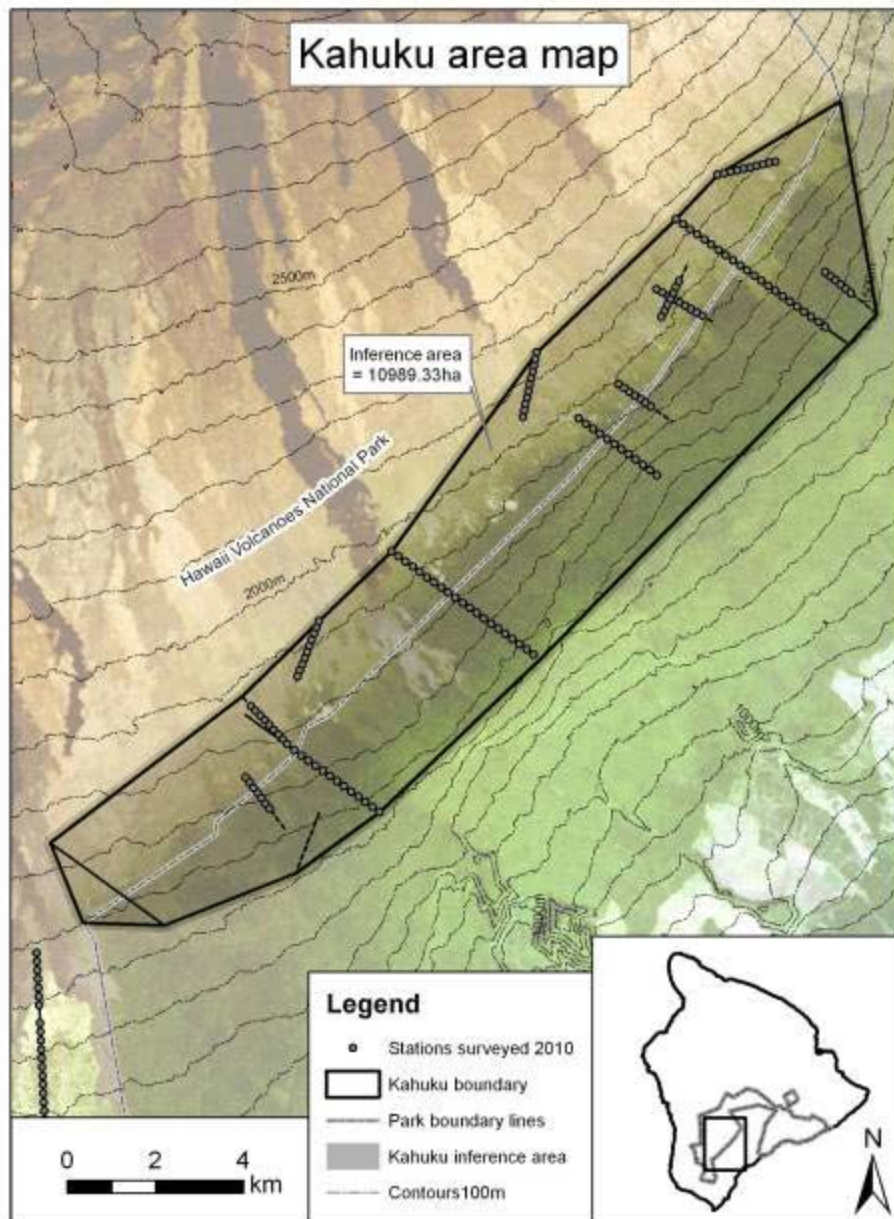


Figure 6. Kahuku Tract inference area and boundary (with 150 m buffer).

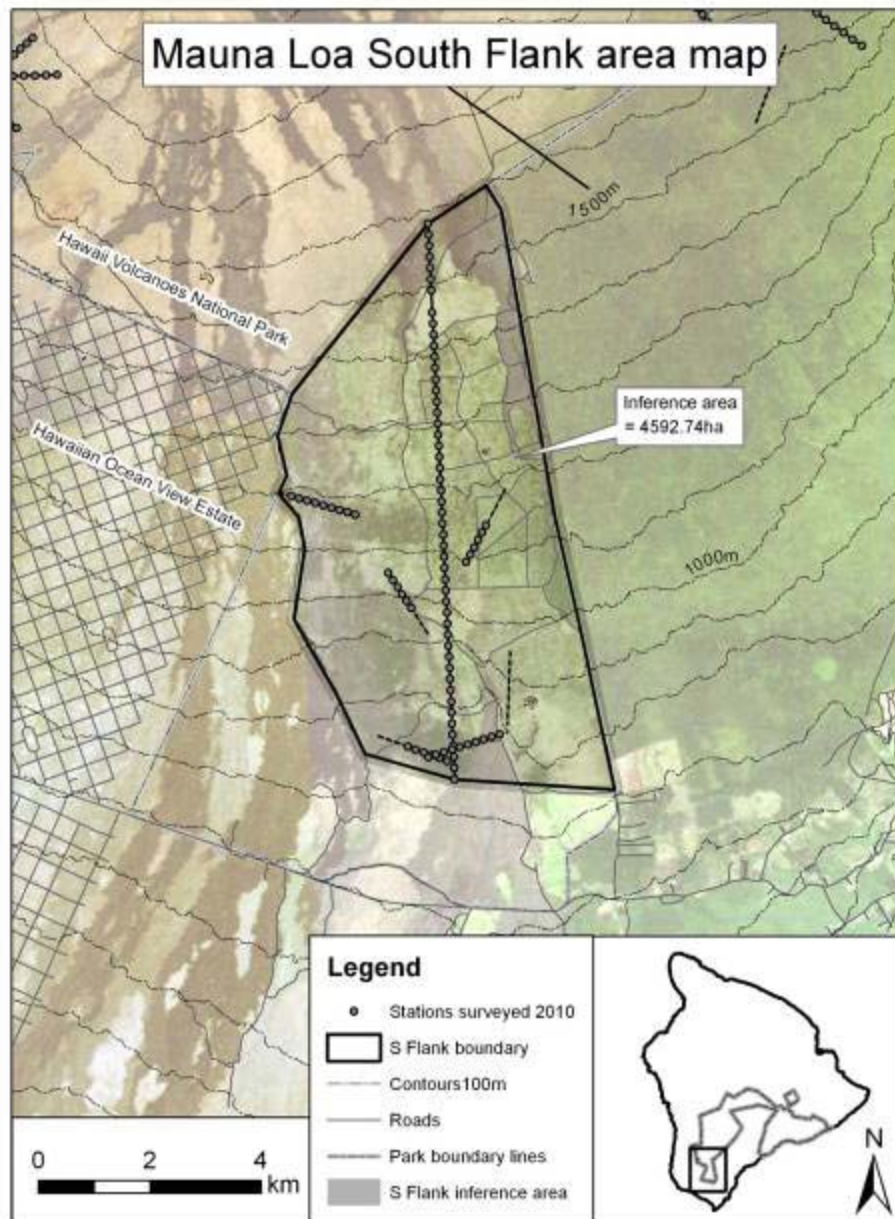


Figure 7. Mauna Loa South Flank tract inference area and boundary (with 150 m buffer).

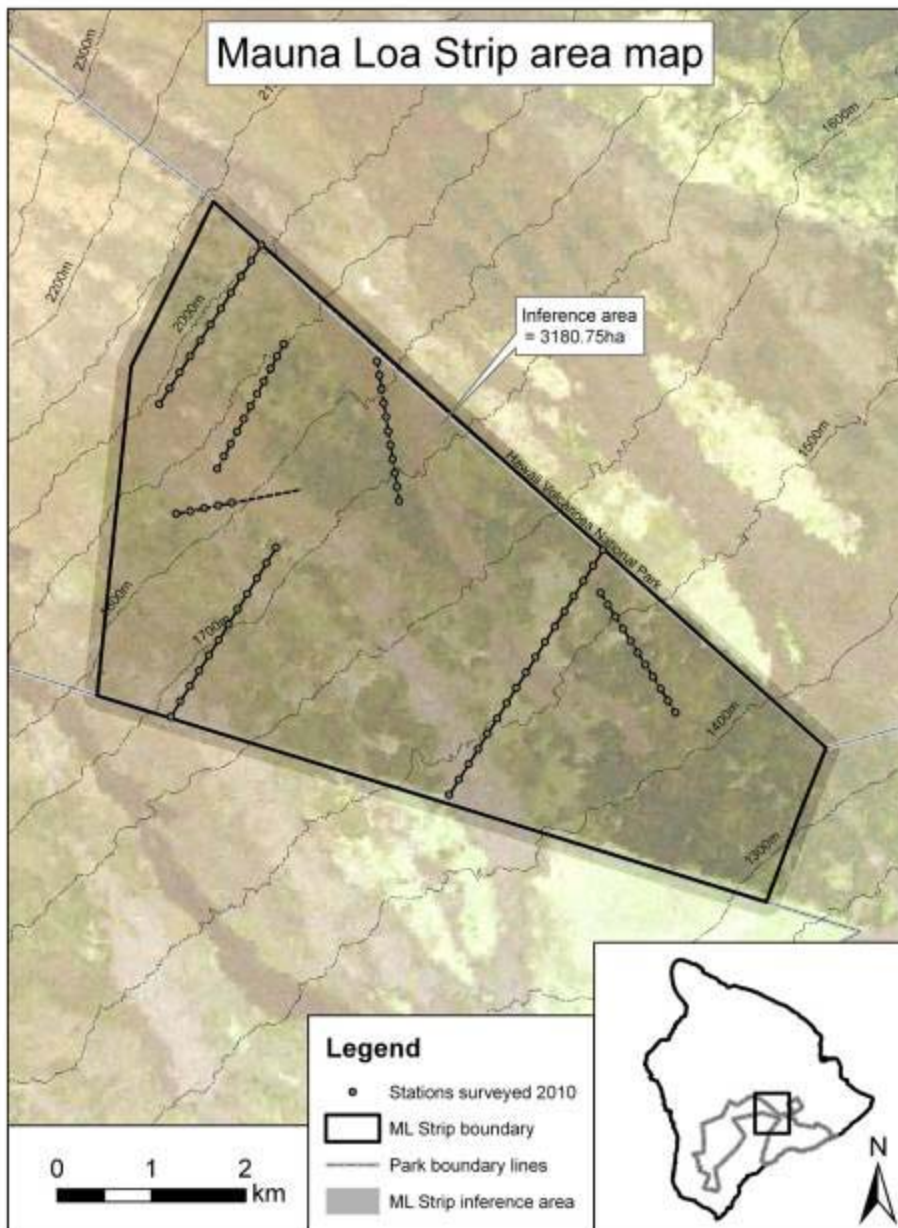


Figure 8. Mauna Loa Strip tract inference area and boundary (with 150 m buffer).

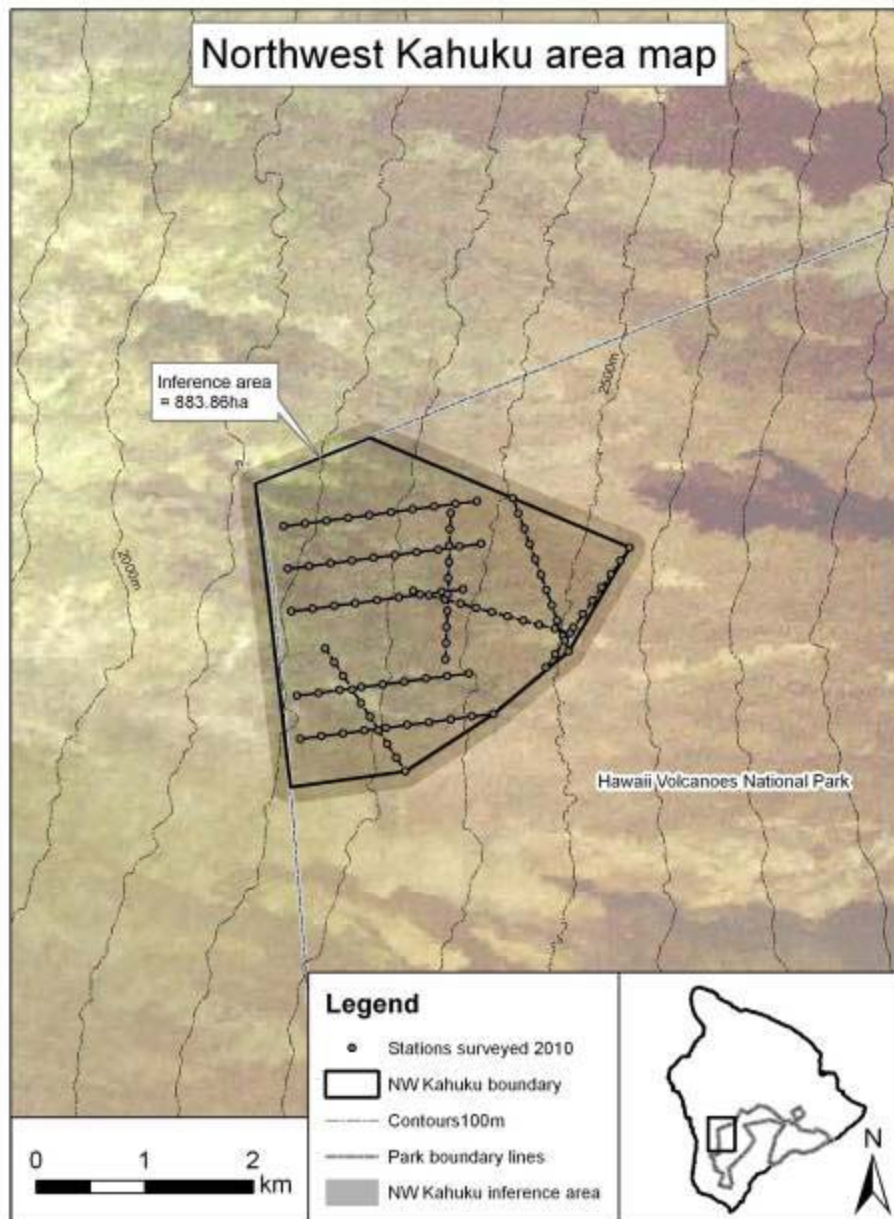


Figure 9. Northwest Kahuku inference area and boundary (with 150 m buffer).

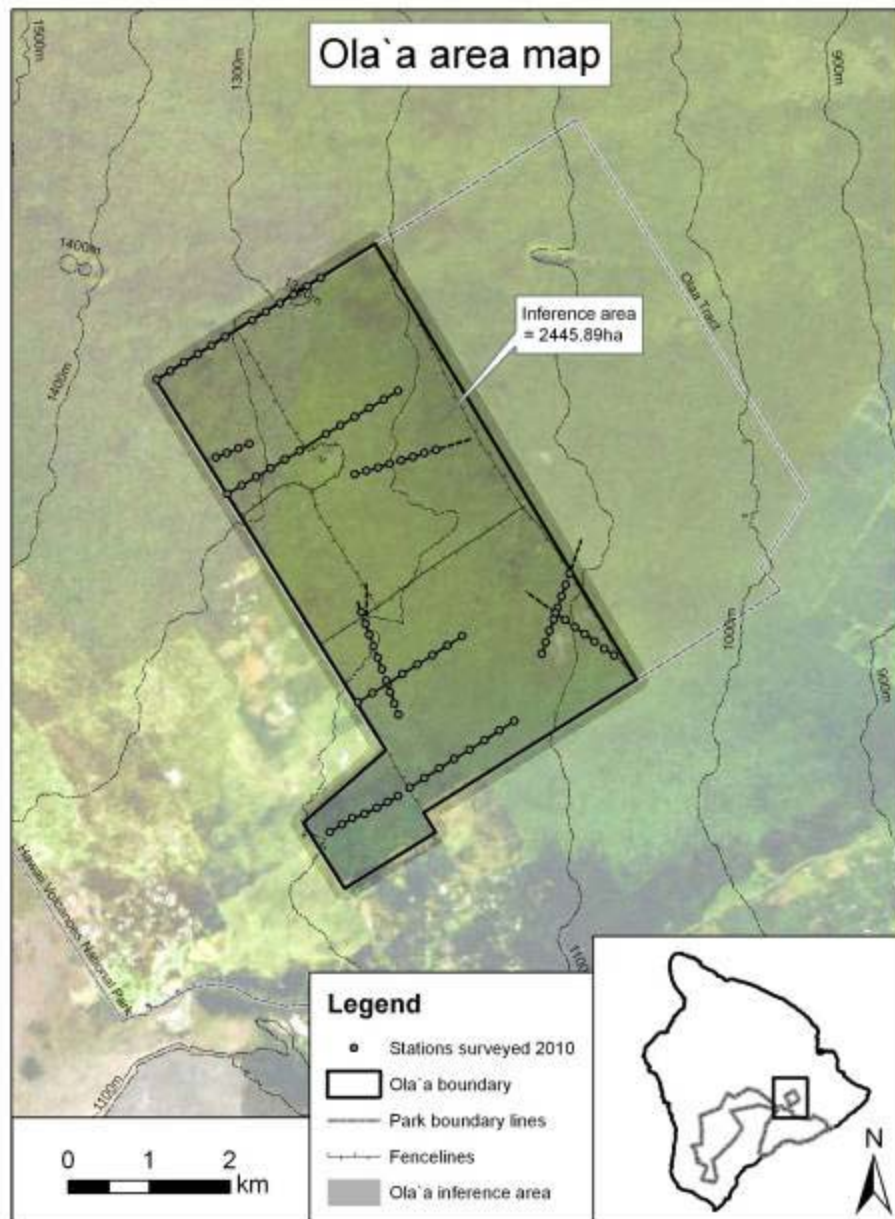


Figure 10. Olaa tract inference area and boundary (with 150 m buffer).

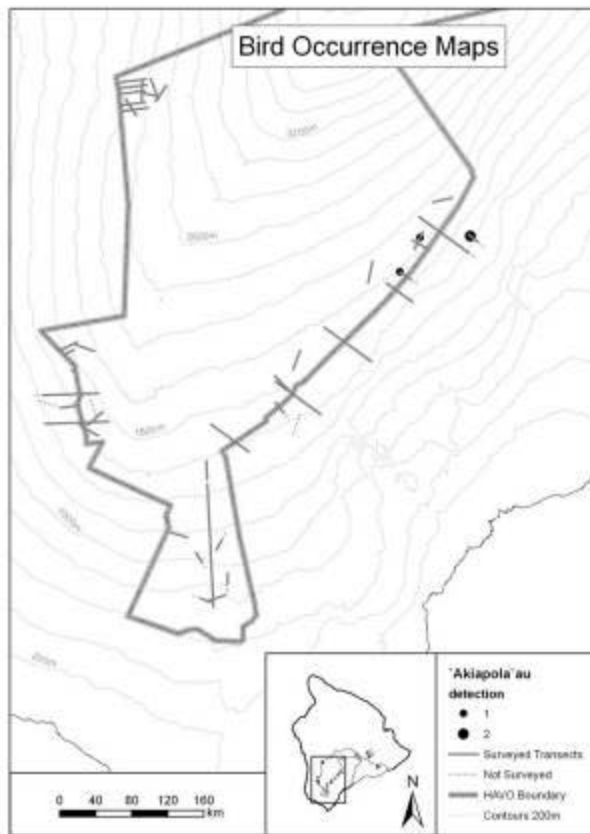


Figure 11. Akiapolaau occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

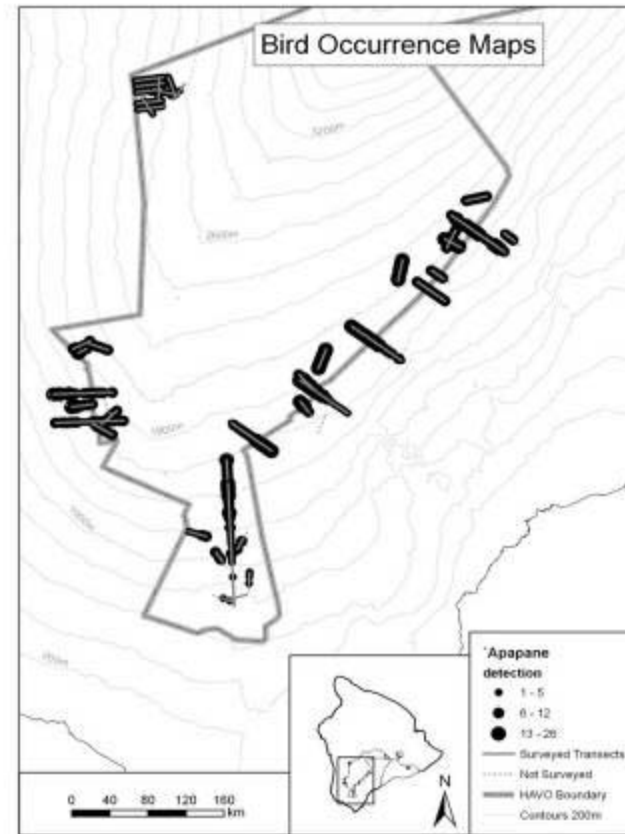


Figure 12. Apapane occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

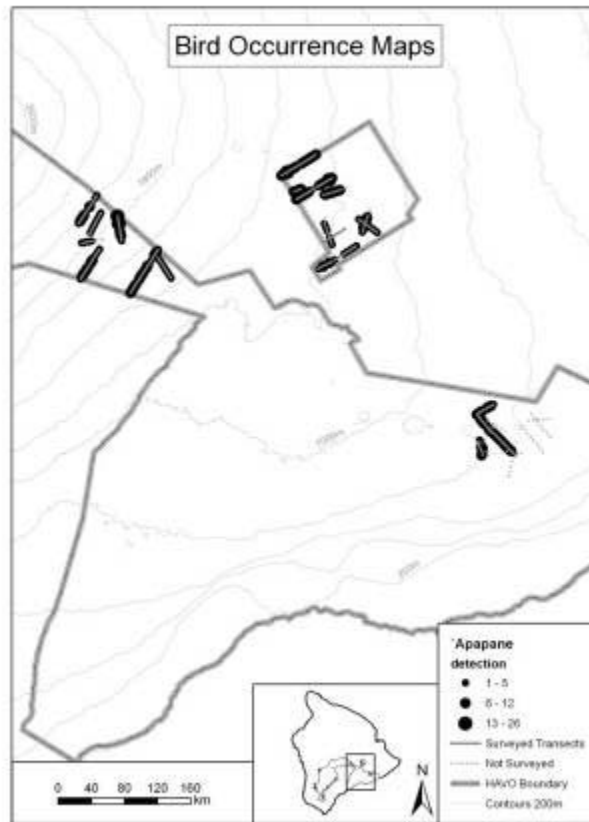


Figure 13. Apapane occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

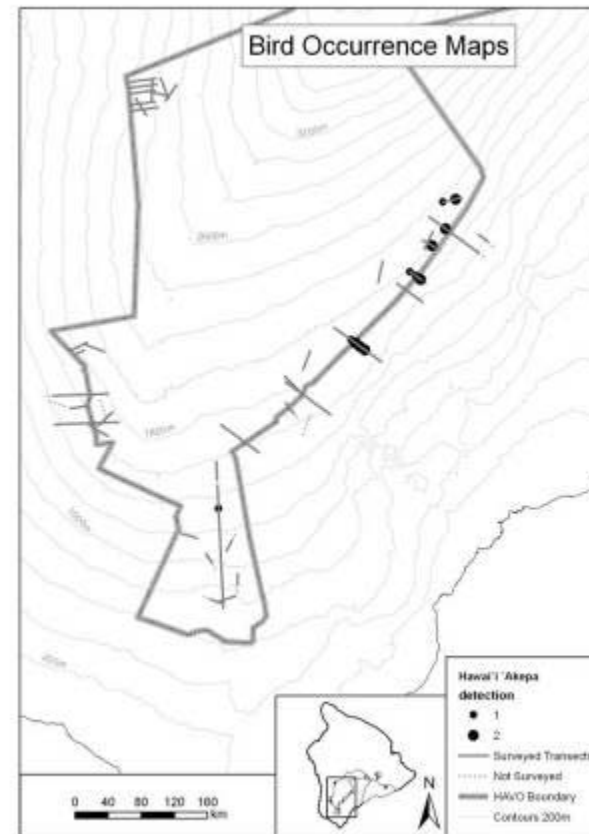


Figure 14. Hawaii Akepa occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

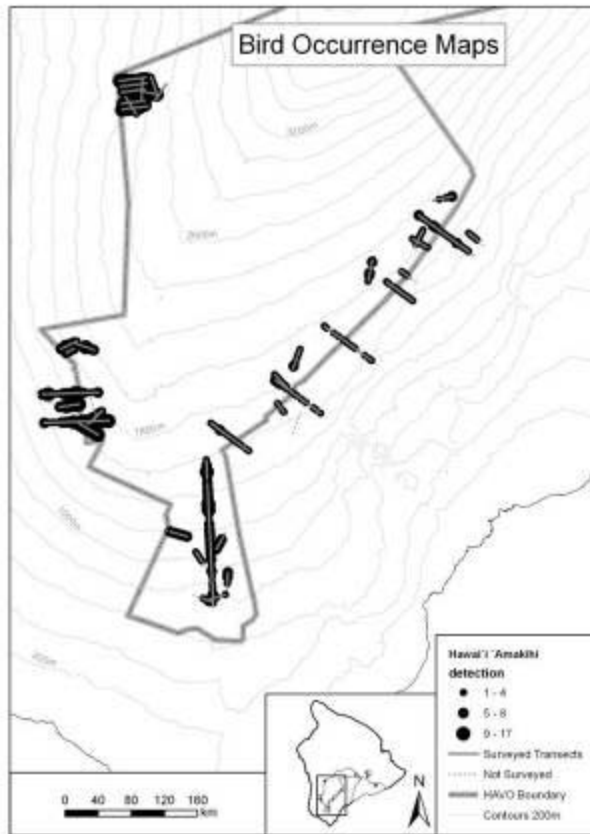


Figure 15. Hawaii Amakihi occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

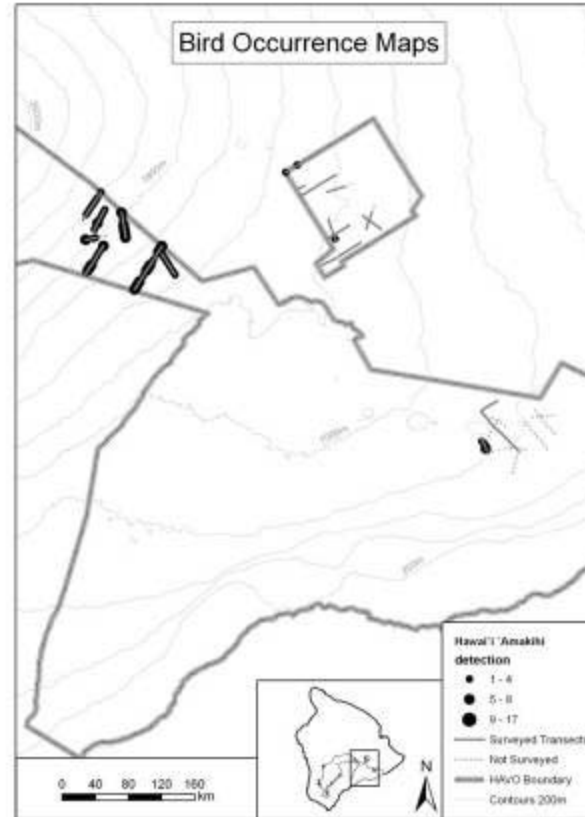


Figure 16. Hawaii Amakihi occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

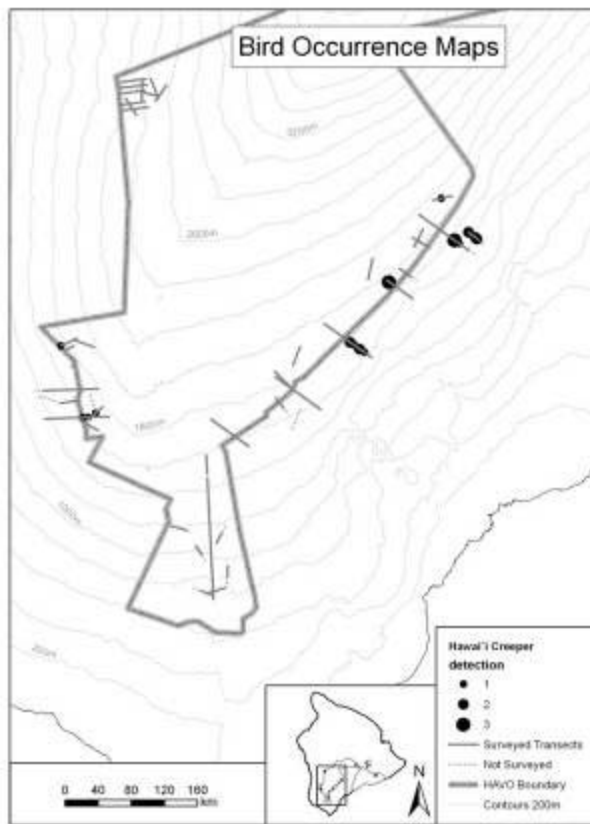


Figure 17. Hawaii Creeper occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

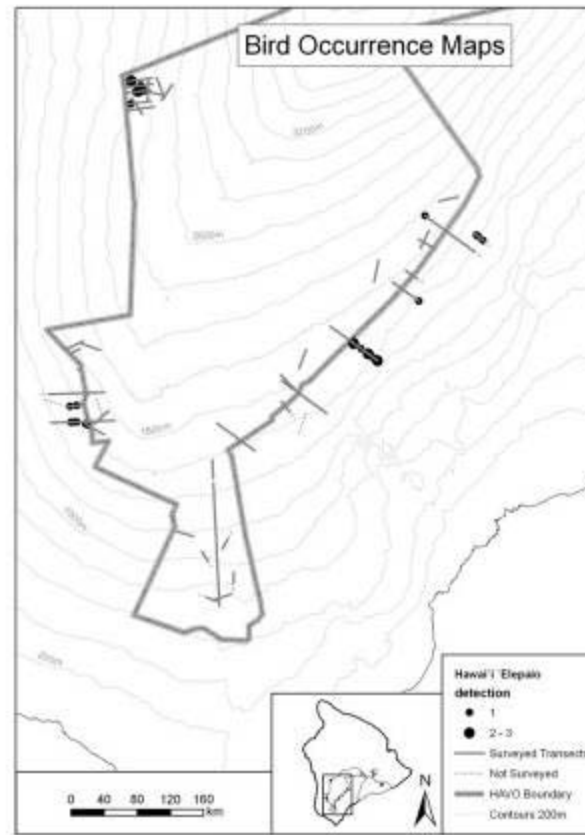


Figure 18. Hawaii Elepaio occurrence during the 2010 landbird survey (part1). Graduated symbols display the abundance of individuals detected at each station.

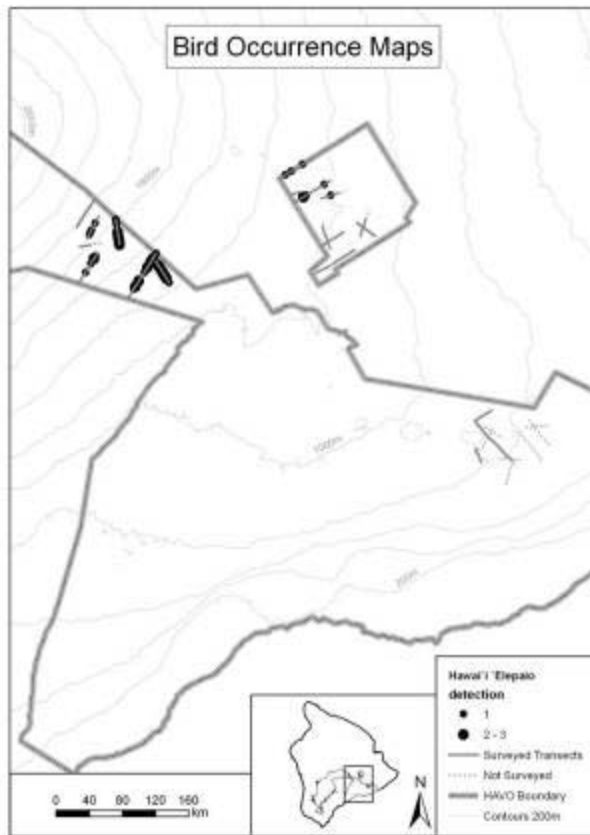


Figure 19. Hawaii Elepaio occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

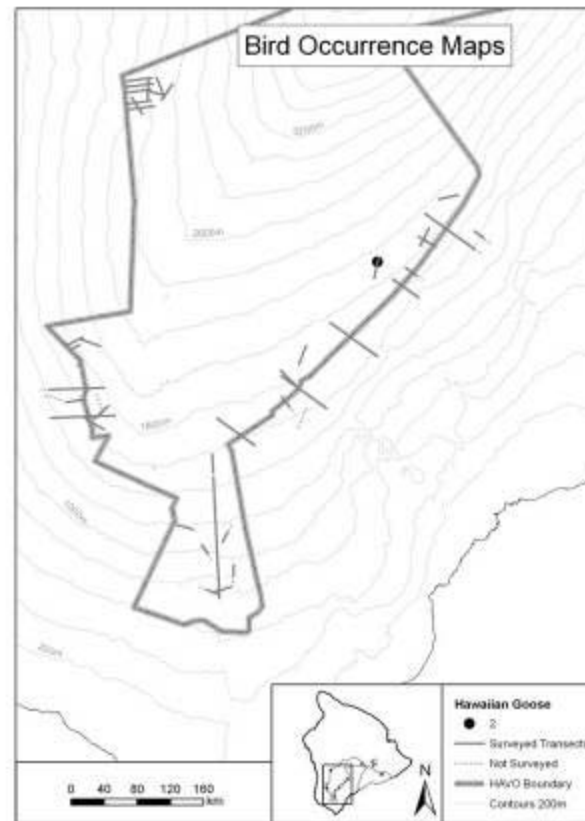


Figure 20. Hawaiian Goose occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

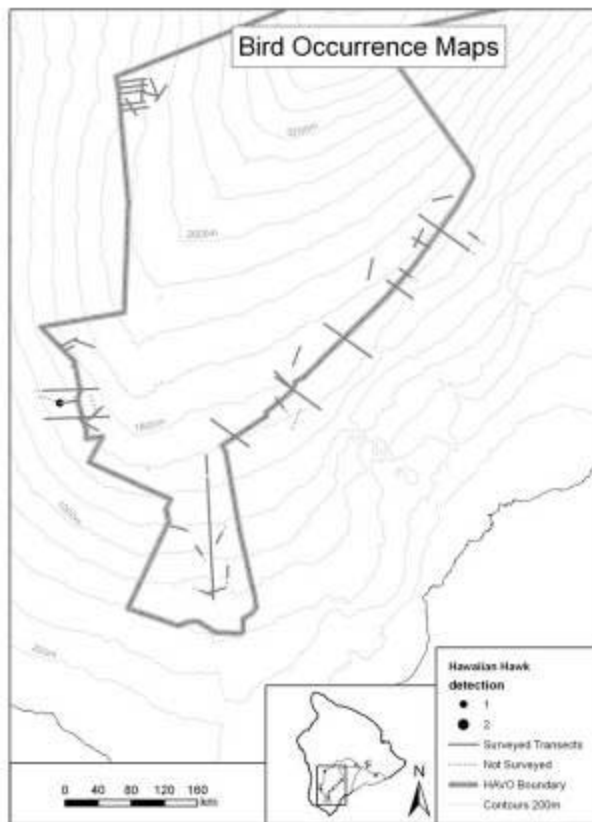


Figure 21. Hawaiian Hawk occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

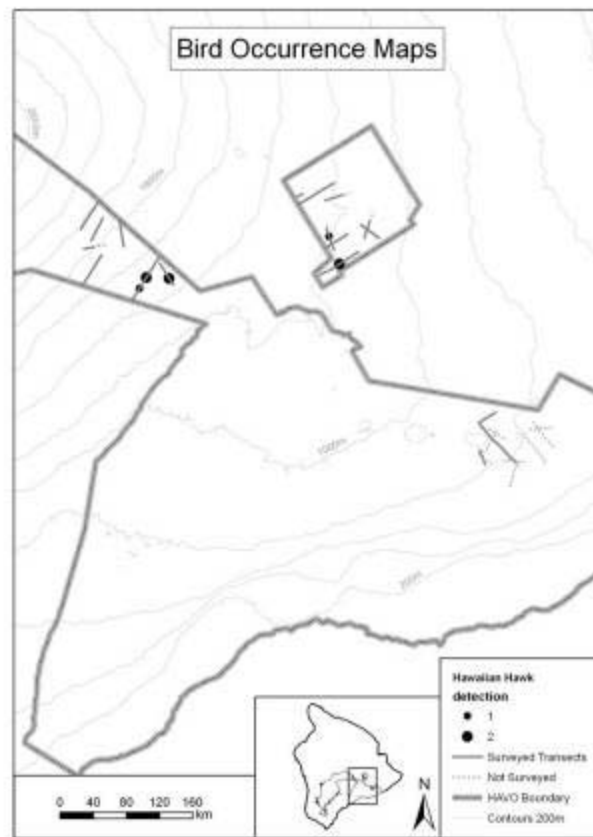


Figure 22. Hawaiian Hawk occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

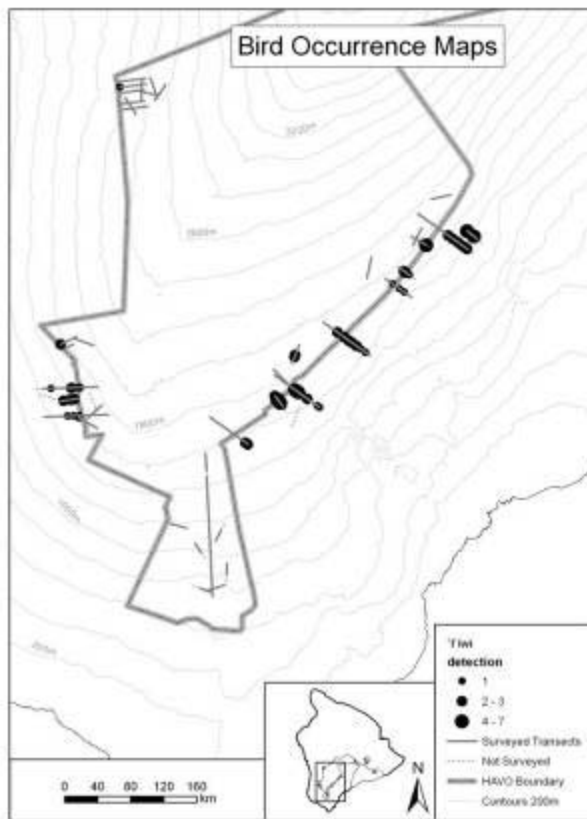


Figure 23. liwi occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

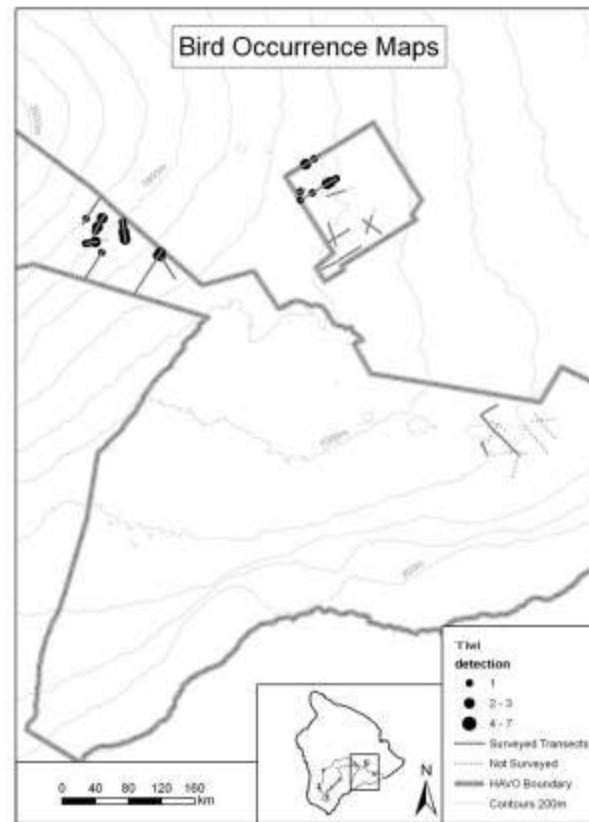


Figure 24. liwi occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

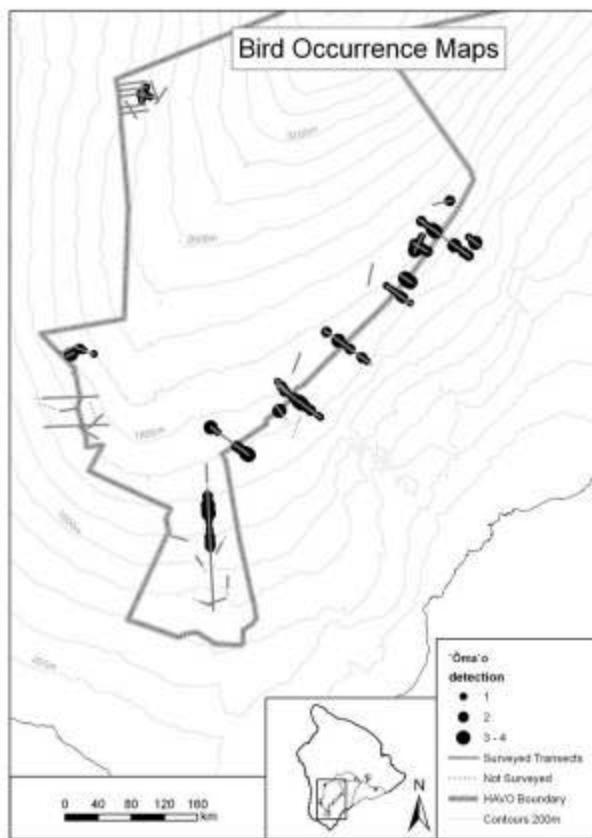


Figure 25. Omao occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

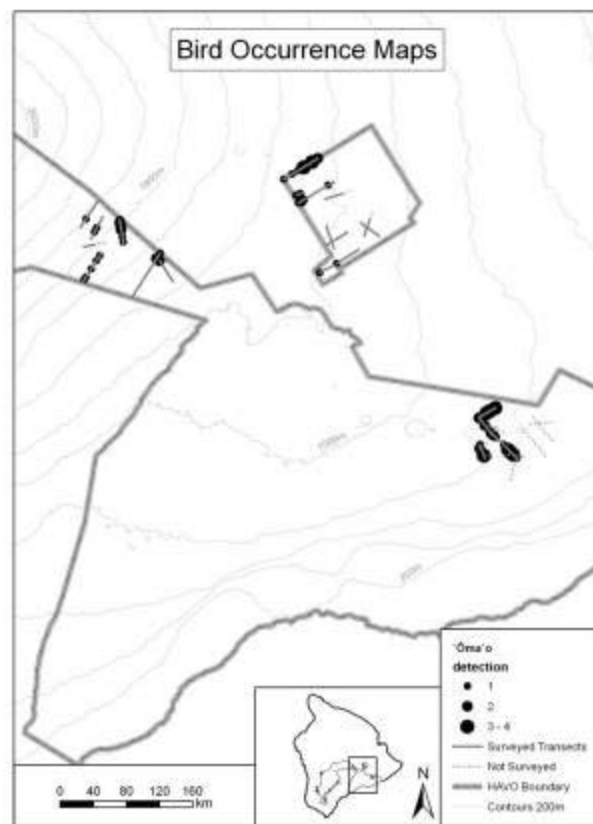


Figure 26. Omao occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

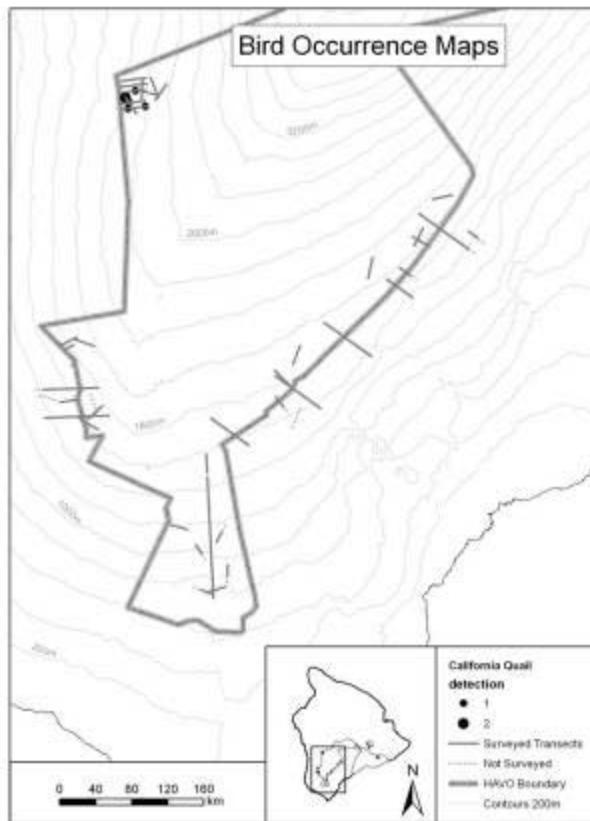


Figure 27. California Quail occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

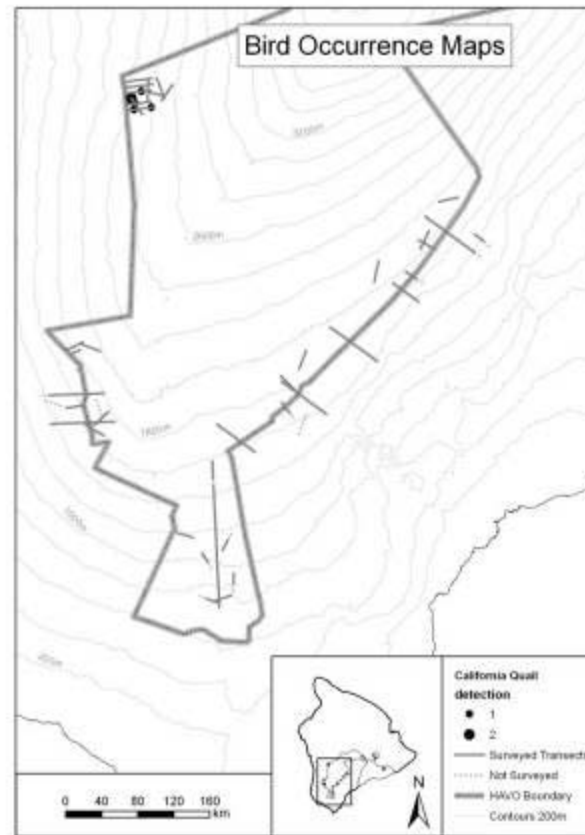


Figure 28. California Quail occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

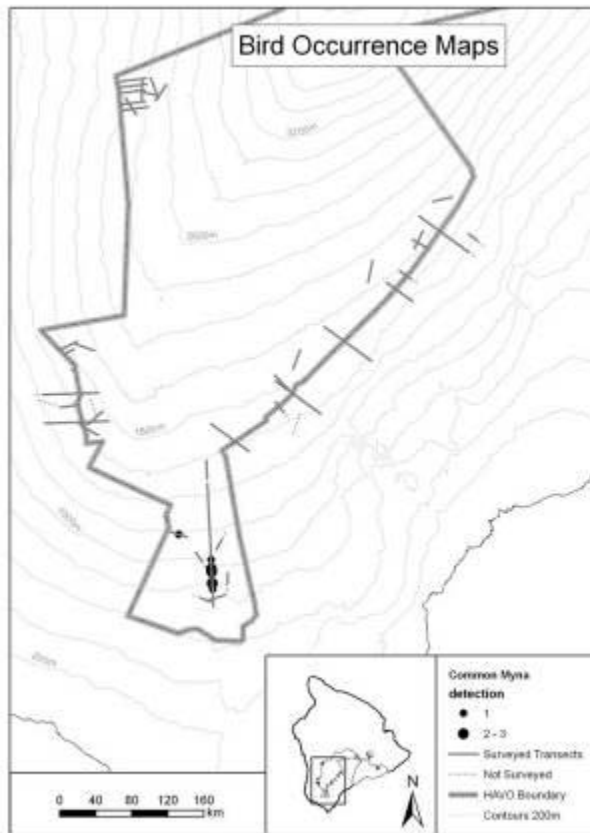


Figure 29. Common Myna occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

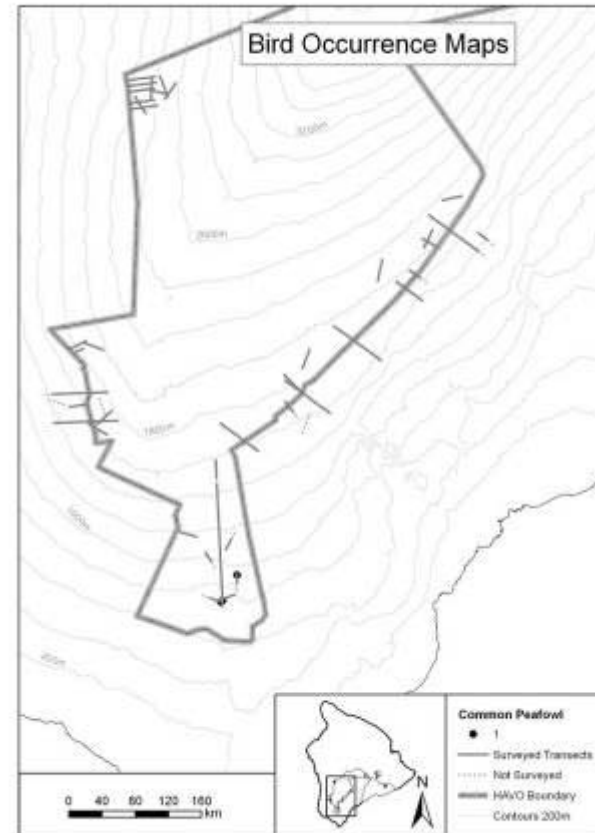


Figure 30. Common Peafowl occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

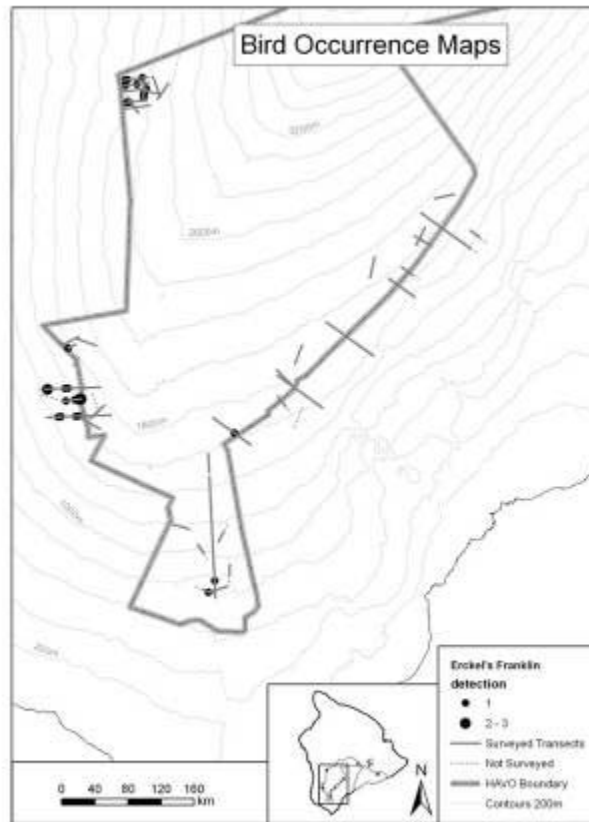


Figure 31. Erckel's Francolin occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

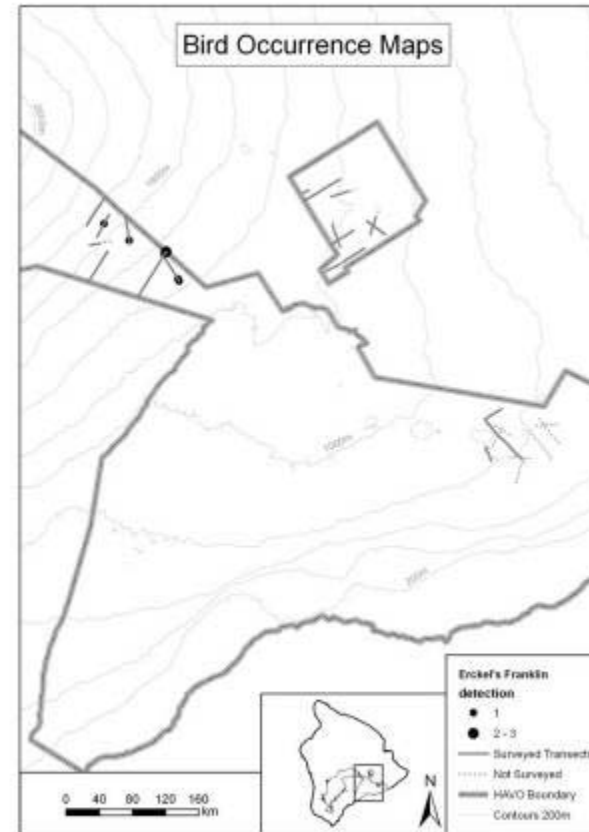


Figure 32. Erckel's Francolin occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

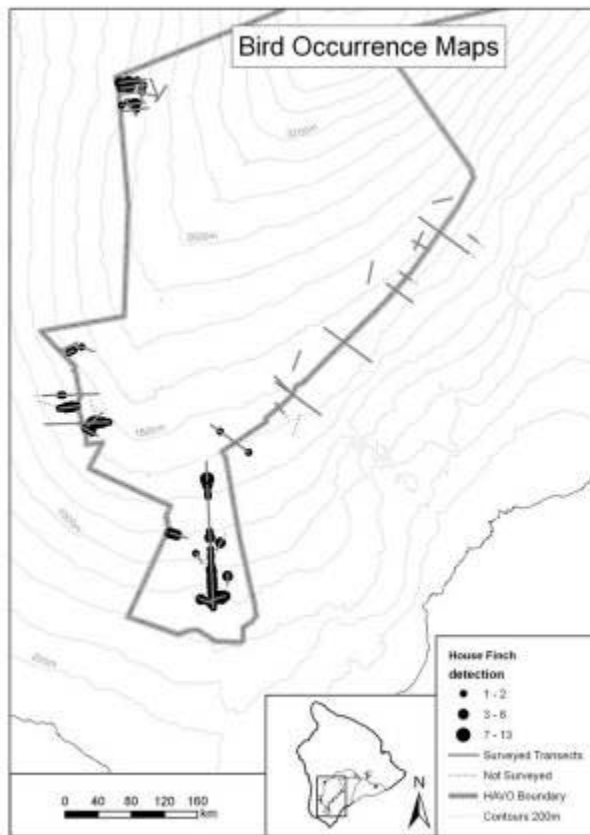


Figure 33. House Finch occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

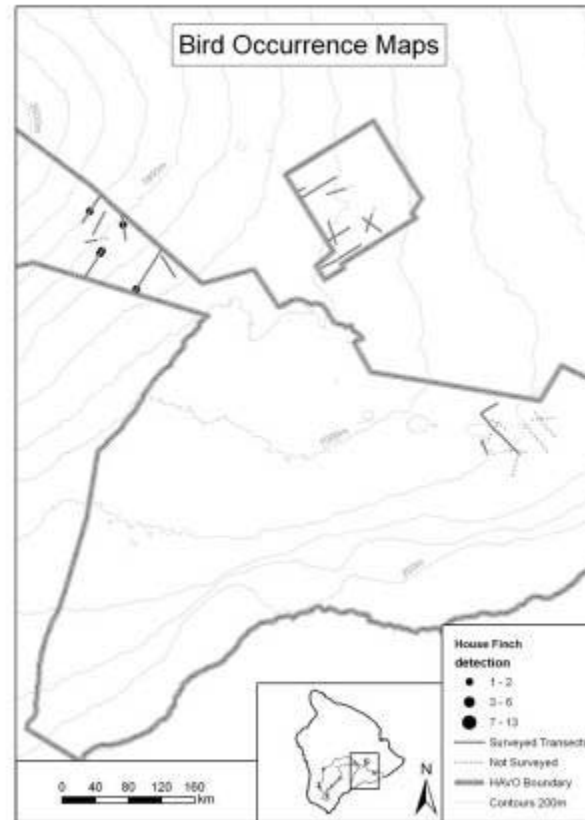


Figure 34. House Finch occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

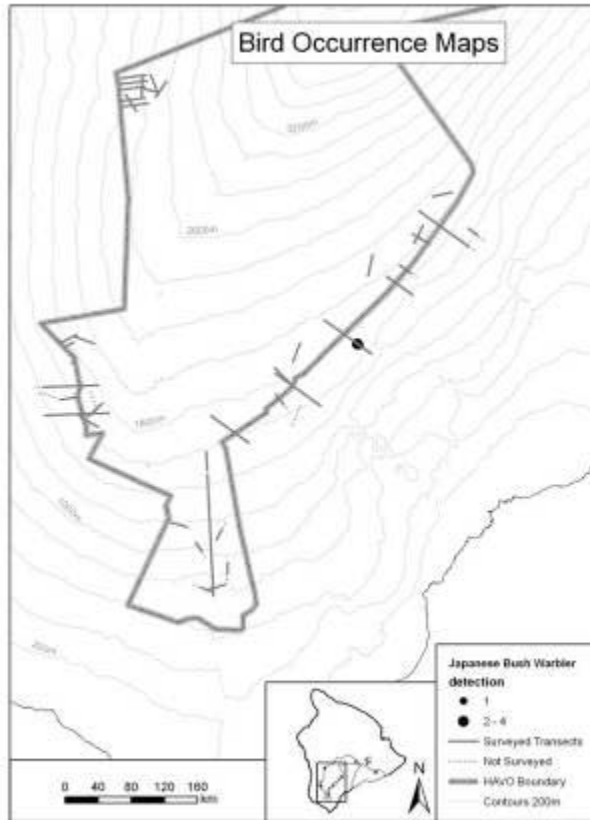


Figure 35. Japanese Bush-Warbler occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

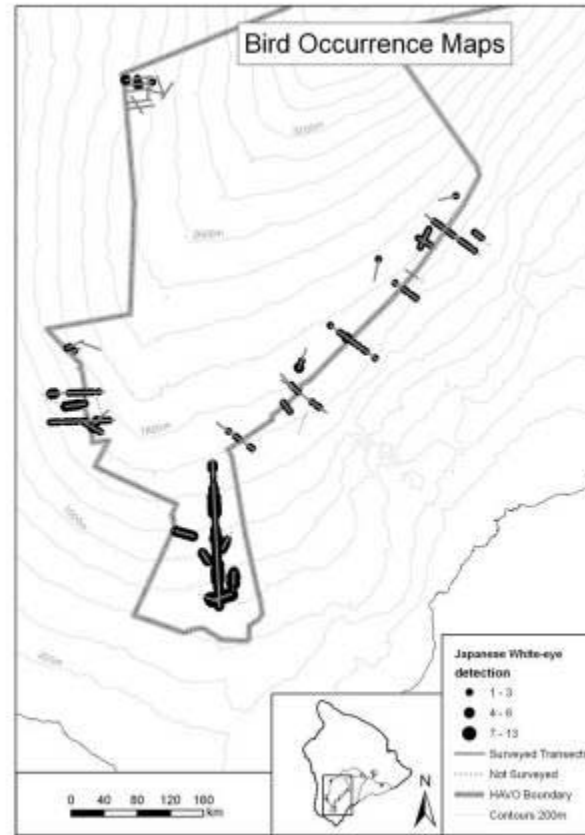


Figure 36. Japanese White-eye occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

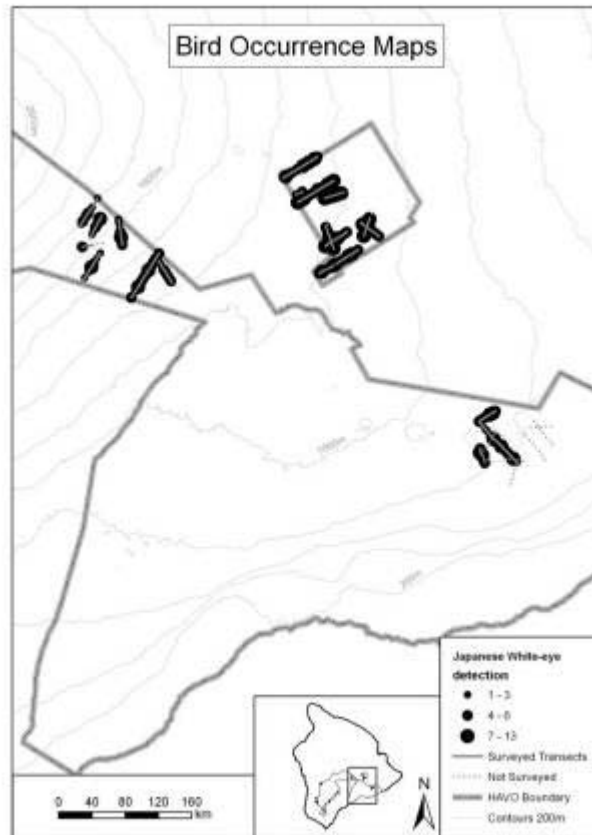


Figure 37. Japanese White-eye occurrence during the 2010 landbird survey (part 2). Graded symbols display the abundance of individuals detected at each station.

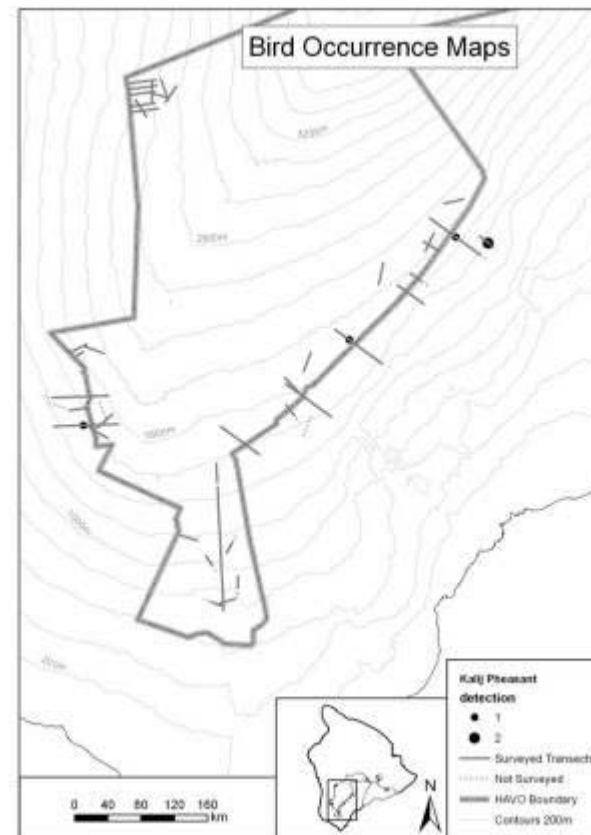


Figure 38. Kalij Pheasant occurrence during the 2010 landbird survey (part 1). Graded symbols display the abundance of individuals detected at each station.

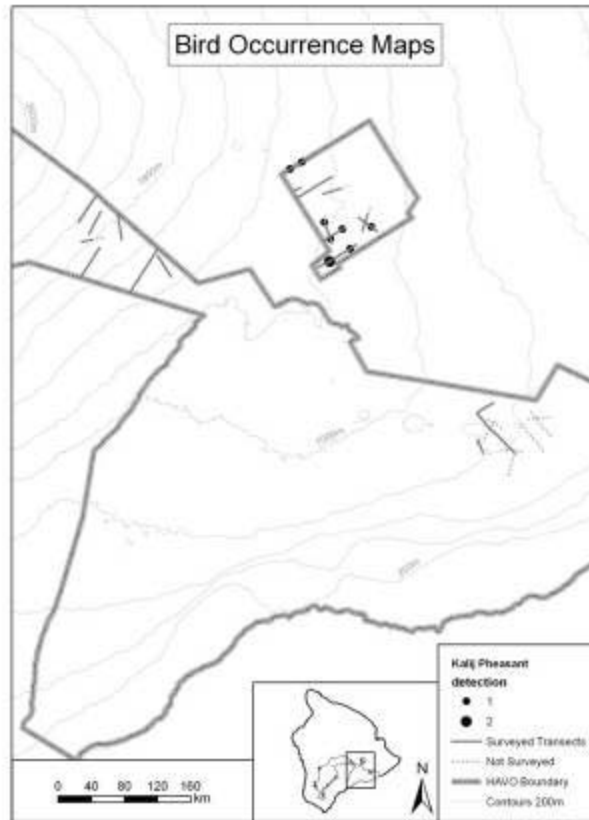


Figure 39. Kalij Pheasant occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

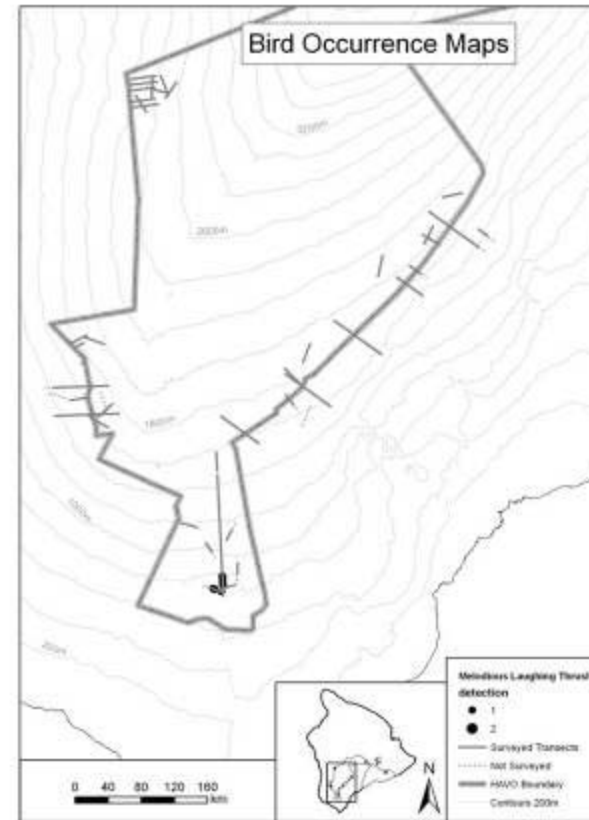


Figure 40. Hwamei, Melodious Laughing Thrush occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

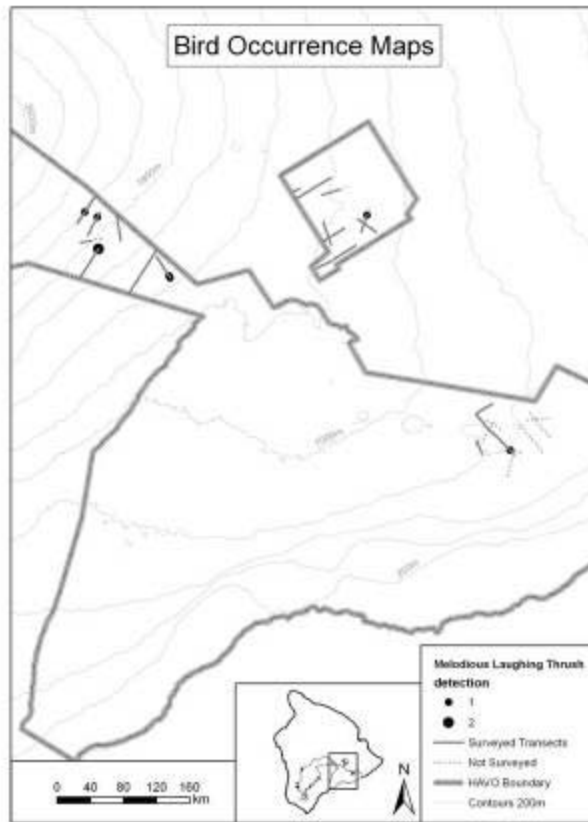


Figure 41. Hwamei, Melodious Laughing Thrush occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

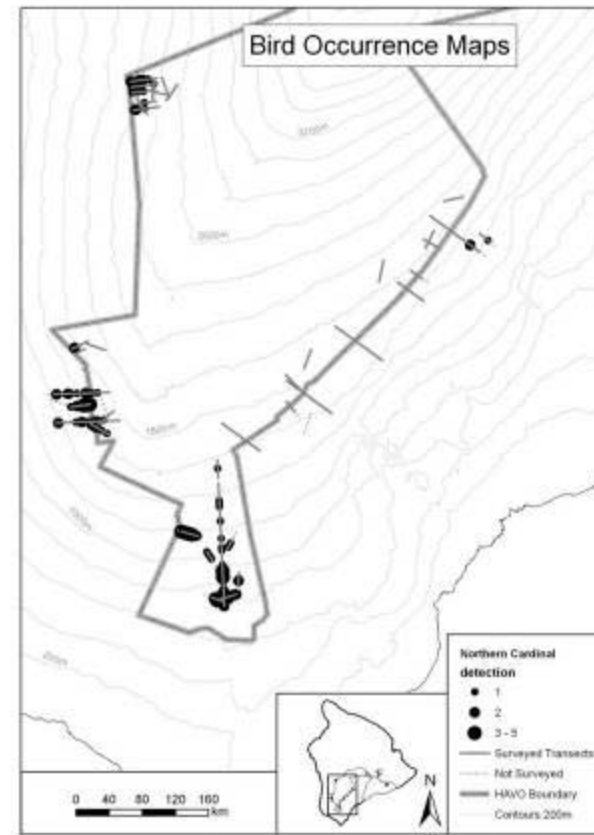


Figure 42. Northern Cardinal occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

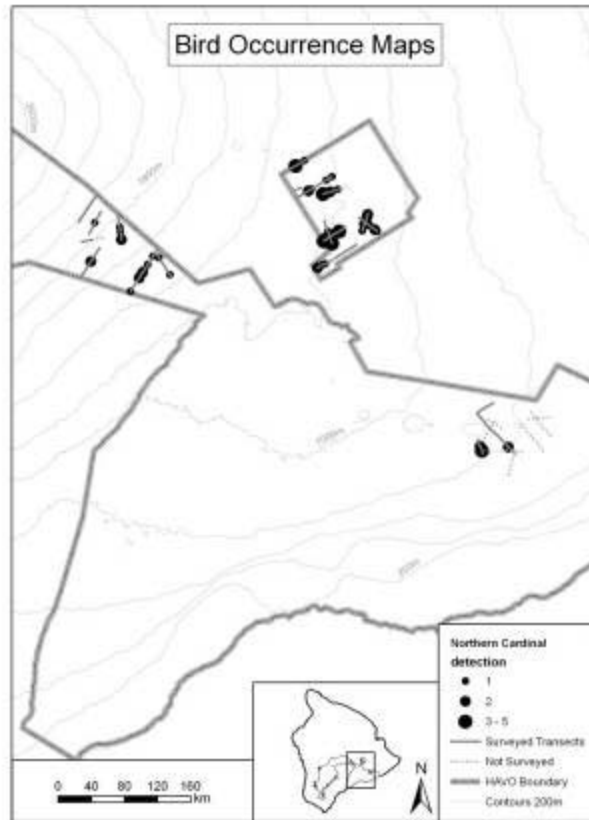


Figure 43. Northern Cardinal occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

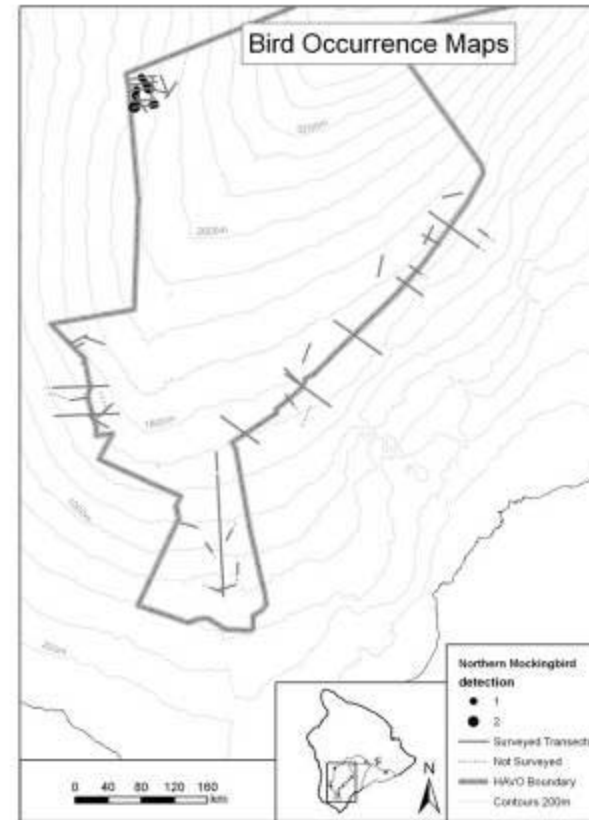


Figure 44. Northern Mockingbird occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

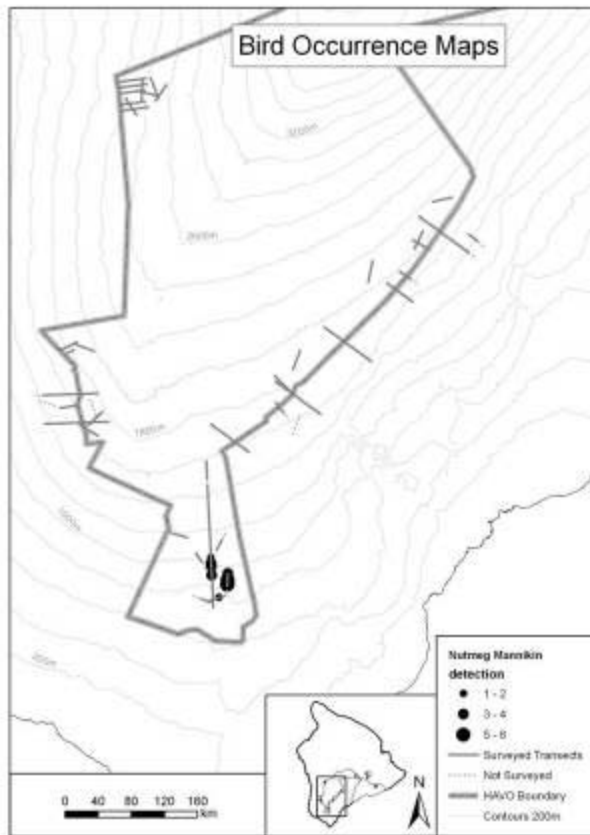


Figure 45. Nutmeg Mannikin occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

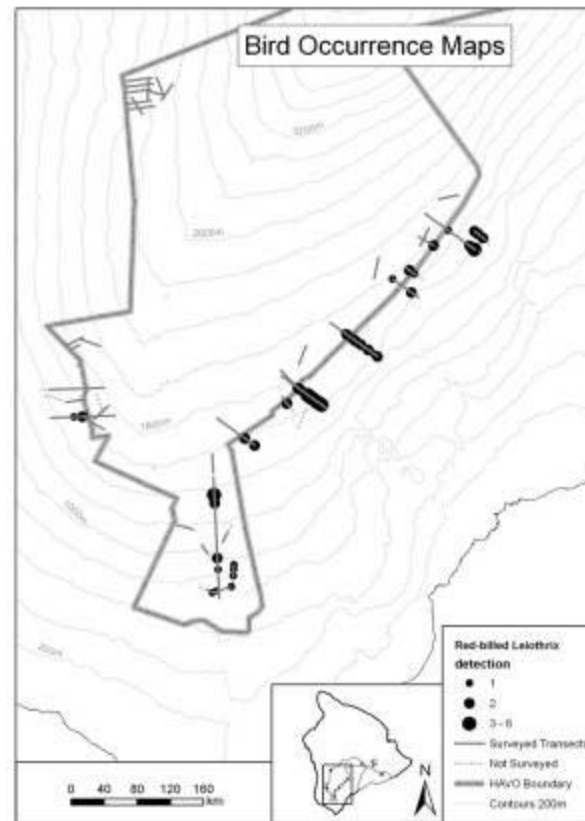


Figure 46. Red-billed Leiothrix occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

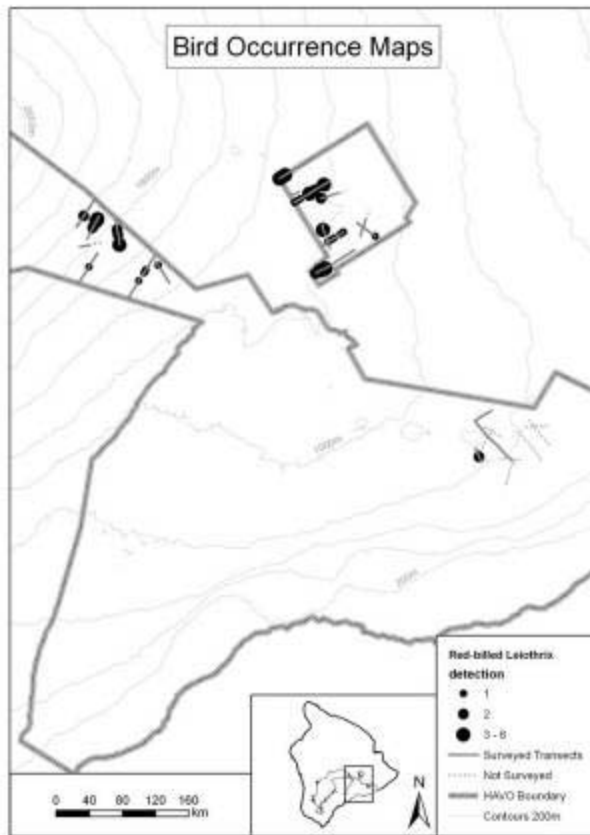


Figure 47. Red-billed Leiothrix occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

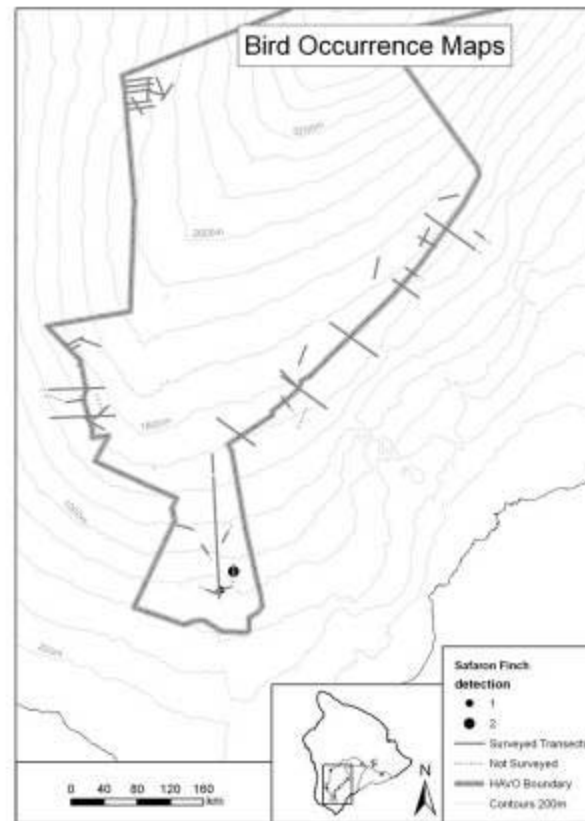


Figure 48. Saffron Finch occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

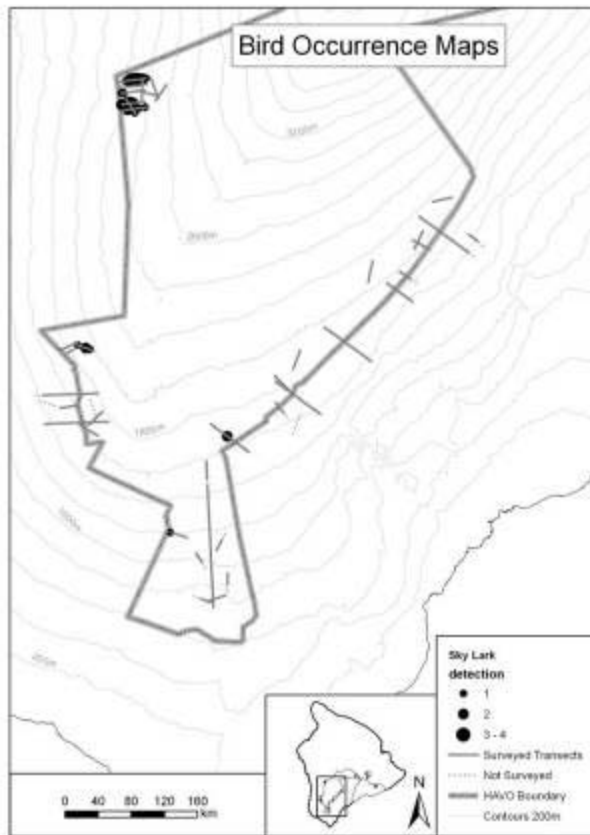


Figure 49. Sky Lark occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

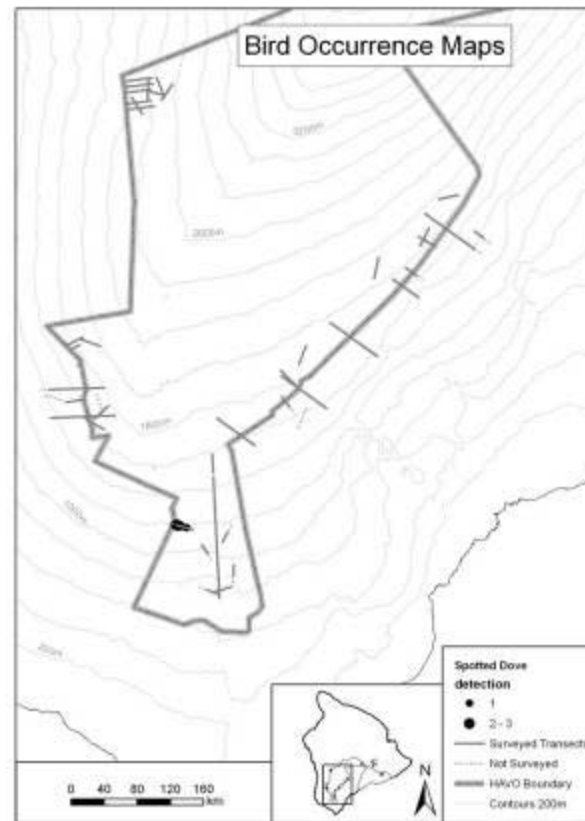


Figure 50. Spotted Dove occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

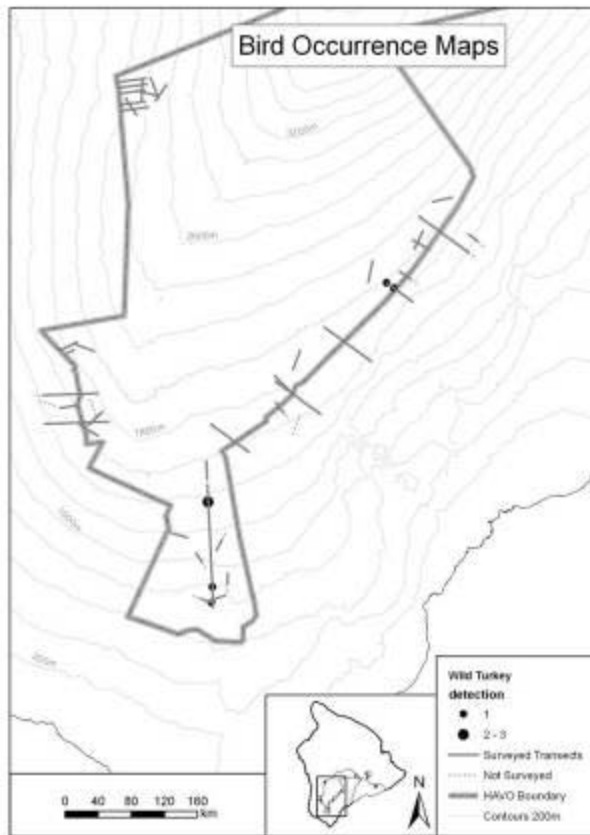


Figure 51. Wild Turkey occurrence during the 2010 landbird survey (part 1). Graduated symbols display the abundance of individuals detected at each station.

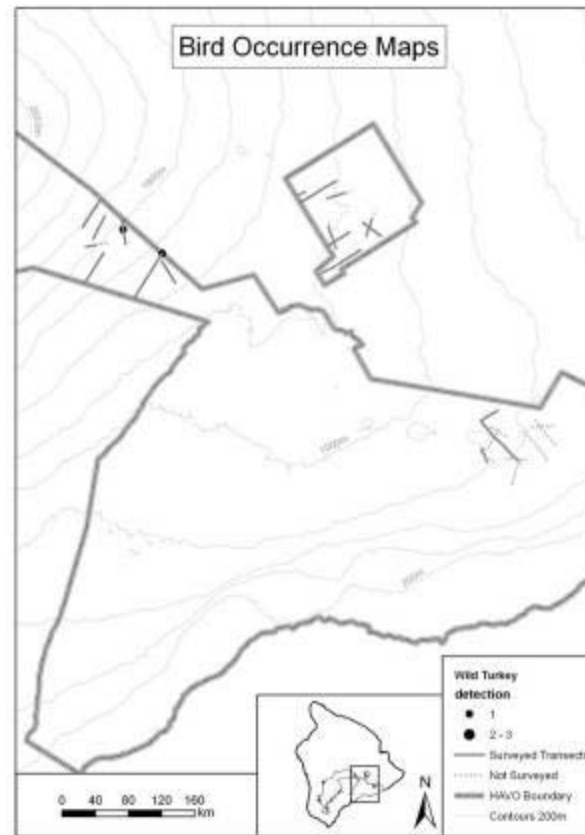


Figure 52. Wild Turkey occurrence during the 2010 landbird survey (part 2). Graduated symbols display the abundance of individuals detected at each station.

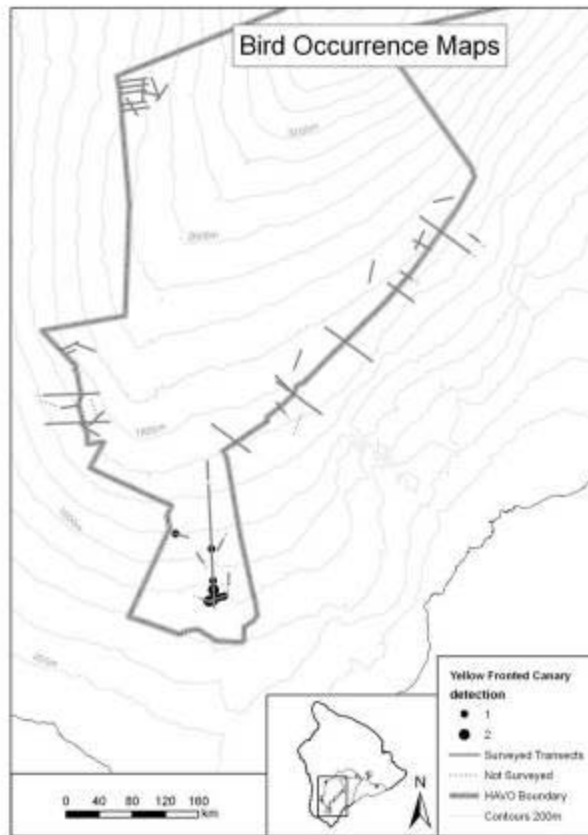


Figure 53. Yellow-fronted Canary occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

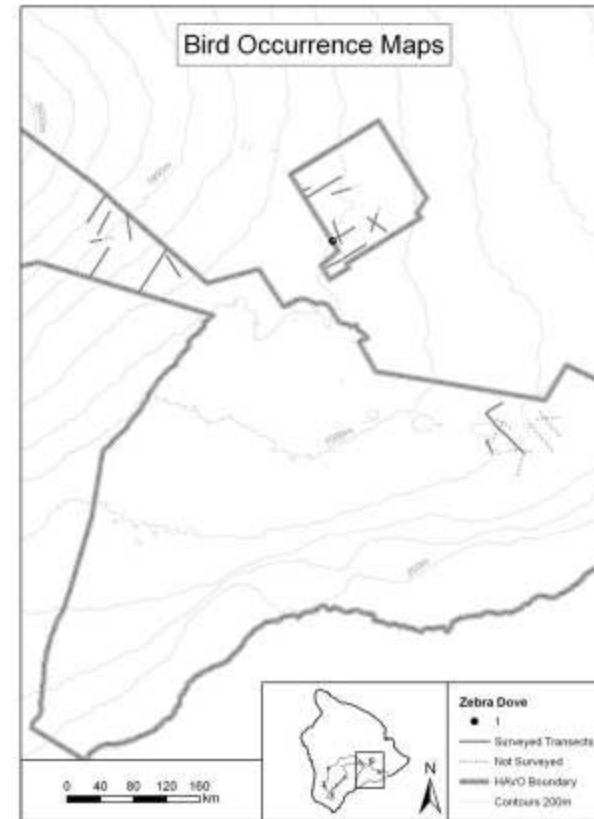


Figure 54. Zebra Dove occurrence during the 2010 landbird survey. Graduated symbols display the abundance of individuals detected at each station.

Appendix B: Covariates

Factors for covariates by species for the 2010 HAVO Landbird survey. Where applicable, additional pooling of covariates was used to increase sample size and increase the likelihood of model convergence.

Species Code	Cloud	Rain	Gust	Canopy Cover	Time	Observer	Tract
APAP	Cloud1	Rain1	Gust1	Cover1	Time1	Ob1	Tract1
HAAM	Cloud1	Rain1	Gust2	Cover1	Time1	Ob2	Tract1
HAEL	Cloud2	NM	Gust3	NM	Time2	Ob3	Tract1
HOFI	Cloud2	NM	Gust2	NM	Time2	Ob4	Tract1
IIWI	Cloud2	Rain2	Gust2	Cover2	Time2	Ob4	Tract2
JAWE	Cloud1	Rain1	Gust2	Cover1	Time1	Ob4	Tract3
NOCA	Cloud2	Rain2	Gust2	Cover3	Time2	Ob4	Tract1
OMAO	Cloud2	Rain2	Gust2	Cover2	Time2	Ob4	Tract1
RBLE	Cloud2	NM	Gust4	Cover2	Time2	Ob4	Tract1

Covariate Pooling Categories.

Rain	Rain1	Rain2	Wind	Wind1	Wind2
0	0	0	0	0	0
1	1	1	1	1	1
2	2	1	2	2	1
3	2	1	3	2	1
4	2	1	4	2	1
5	2	1	5	2	1
6	2	1	6	2	1
<>	2	1	<>	0	0
Gust	Gust1	Gust2	Gust3	Gust4	
0	0	0	1	1	
1	1	1	1	1	
2	2	2	2	2	
3	3	3	2	3	
4	4	3	2	3	
5	4	3	2	3	
6	4	3	2	3	
7	4	3	2	3	
<>	0	0	1	1	

CanopyHeight	Height		CanopyCover	Cover1	Cover2	Cover3
1	l		Closed	c	c	cm
2	l		Open	o	osvm	o
3	t		Sparse	s	osvm	sv
<>	l		Very Sparse	vs	osvm	sv
			<>	m	osvm	cm

Covariate Pooling Categories (continued).

Cloud	Cloud1	Cloud2		Time	Time1	Time2
0	0	1		500	1	1
10	1	1		530	1	1
20	1	1		600	1	1
30	1	1		630	1	1
40	1	1		700	1	1
50	1	1		730	2	1
60	2	2		800	3	1
70	2	2		830	4	1
80	2	2		900	5	2
90	2	2		930	6	2
100	3	2		1000	7	2
<>	0	1		1030	8	2
				1100	8	2

ObsCode	Ob1	Ob2	Ob3	Ob4
BHH	BHH	BHH	BHH	BHSJ
CMJ	JMG	CMJ	SWJ	JMG
JMG	JMG	JMG	SWJ	JMG
JXW	JXW	JXW	SWJ	JMG
NCC	NCC	SWJ	SWJ	BHSJ
SWJ	SWJ	SWJ	SWJ	BHSJ

Tract	Tract1	Tract2	Tract3
East Rift Zone	East Rift Zone	East Rift Zone	ERZMLS
Honomalino	Honomalino	HSFNWOP	HNWP
Kahuku	Kahuku	Kahuku	KahuSF
Mauna Loa South Flank	Mauna Loa South Flank	HSFNWOP	KahuSF
Mauna Loa Strip	Mauna Loa Strip	Mauna Loa Strip	ERZMLS
Northwest Kahuku	Northwest Kahuku	HSFNWOP	HNWP
Olaa Koa Unit	Olaa	HSFNWOP	Olaa
Olaa Puu Unit	Olaa	HSFNWOP	Olaa
Olaa Small Tract Unit	Olaa	HSFNWOP	Olaa
Papi	Papi	HSFNWOP	HNWP

Appendix C: Detection Function Models

Models and parameters used to derive population densities by species for the 2010 Landbird Survey.

Species	Truncation	Key Model	Adjustment Terms	Covariates
APAP	74.9	Hazard rate	Simple polynomial (4,6)	Detection type
HAAM	76.5	Hazard rate	None	Detection type, Cover1
HAEL	62.2	Hazard rate	None	Tract1
HOFI	75.1	Hazard rate	None	Height
IIWI	64.8	Hazard rate	None	Gust2, Height
Jawe	50.0	Hazard rate	Simple polynomial (4)	Tract2
NOCA	81.7	Hazard rate	None	Panel
OMAO	93.0	Hazard rate	None	None
RBLE	66.0	Hazard rate	None	None

Appendix D. Model Selection

Model Selection Based on AIC. † A model incorporating both panel and cover covariates was assessed and did not improve model fit (i.e., greater AICc value than best fit model).

Model	Variables	$\Delta AICc$	AICc	w_i	Comments
APAP					
H-rate S-poly DectType	6	0	31855	1.000	
H-rate S-poly Cover	8	28	31883	0.000	
H-rate S-poly Tract	11	40	31895	0.000	
H-rate S-poly Height	5	105	31960	0.000	
H-rate S-poly Panel	5	136	31991	0.000	
H-rate S-poly Rain	6	161	32016	0.000	
H-rate S-poly Observer	8	171	32026	0.000	
H-rate S-poly Cloud	7	187	32042	0.000	
H-rate S-poly Gust	8	192	32047	0.000	
H-rate S-poly	4	195	32050	0.000	
H-rate S-poly Time-cat	11	202	32057	0.000	
H-norm Cos	3	204	32059	0.000	
H-rate S-poly Time-con	5	207	32062	0.000	
H-rate S-poly Wind	6	208	32063	0.000	
H-rate Key	2	221	32076	0.000	
H-norm Key	1	276	32131	0.000	
H-norm H-poly					Parameters highly correlated
H-rate Cos					Threshold levels exceeded
HAAM					
H-rate Key DectType Cover	8	0	16326	1.000	
H-rate Key DectType	4	145	16471	0.000	
H-rate Key Cover	6	237	16563	0.000	
H-rate Key Observer	6	269	16595	0.000	
H-rate Key Gust	5	308	16634	0.000	
H-rate Key Wind	4	315	16641	0.000	
H-rate Key Tract	9	333	16659	0.000	
H-norm Cos	3	343	16669	0.000	
H-rate Key	2	346	16672	0.000	
H-rate Cos	3	346	16672	0.000	
H-rate S-poly	3	346	16672	0.000	
H-rate Key Height	3	353	16679	0.000	
H-rate Key Time-con	3	354	16680	0.000	
H-rate Key Panel	3	354	16680	0.000	
H-rate Key Rain	4	356	16682	0.000	
H-rate Key Cloud	5	357	16683	0.000	
H-rate Key Time-cat	9	365	16691	0.000	
H-norm Key	1	388	16714	0.000	
H-norm H-poly					Parameters highly correlated

Appendix D. Model Selection Based on AIC (continued).

IIWI					
H-rate Key Gust Height	6	0	1181	0.934	
H-rate Key Gust	5	6	1187	0.046	
H-rate Key Height	3	10	1191	0.006	
H-rate Key Cloud	3	10	1191	0.006	
H-rate Key	2	12	1193	0.002	
H-norm Key	1	13	1194	0.001	
H-rate Key Time-cat	3	14	1195	0.001	
H-rate Key Rain	3	15	1196	0.001	
H-rate Key Wind	4	15	1196	0.001	
H-rate Key Time-con	3	15	1196	0.001	
H-rate Key Cover	3	16	1197	0.000	
H-rate Key Observer	4	16	1197	0.000	
H-rate Key Panel	3	16	1197	0.000	
H-rate Key Tract	5	18	1199	0.000	
H-norm Cos					Key model selected
H-norm H-poly					Key model selected
H-rate Cos					Key model selected
H-rate S-poly					Key model selected
H-rate Key DectType					Model failed to converge
JAWE					
H-rate S-poly Tract	6	0	11121	1.000	
H-rate S-poly Cover	7	78	11199	0.000	
H-rate S-poly DectType	5	119	11240	0.000	
H-rate S-poly Observer	4	180	11301	0.000	
H-rate S-poly Time-con	4	197	11318	0.000	
H-rate S-poly Panel	4	205	11326	0.000	
H-rate S-poly Height	4	212	11333	0.000	
H-rate S-poly Rain	5	221	11342	0.000	
H-rate S-poly Wind	5	225	11346	0.000	
H-rate S-poly	3	230	11351	0.000	
H-rate S-poly Cloud	6	231	11352	0.000	
H-rate S-poly Gust	6	232	11353	0.000	
H-norm Key	1	237	11358	0.000	
H-rate Key	2	237	11358	0.000	
H-norm Cos					Threshold levels exceeded
H-norm H-poly					Parameters highly correlated
H-rate Cos					Threshold levels exceeded
H-rate S-poly Time-cat					Model failed to converge

Appendix D. Model Selection Based on AIC (continued).

Model	Variables	$\Delta AICc$	AICc	w_i	Comments
JAWE					
H-rate S-poly Tract	6	0	11121	1.000	
H-rate S-poly Cover	7	78	11199	0.000	
H-rate S-poly DectType	5	119	11240	0.000	
H-rate S-poly Observer	4	180	11301	0.000	
H-rate S-poly Time-con	4	197	11318	0.000	
H-rate S-poly Panel	4	205	11326	0.000	
H-rate S-poly Height	4	212	11333	0.000	
H-rate S-poly Rain	5	221	11342	0.000	
H-rate S-poly Wind	5	225	11346	0.000	
H-rate S-poly	3	230	11351	0.000	
H-rate S-poly Cloud	6	231	11352	0.000	
H-rate S-poly Gust	6	232	11353	0.000	
H-norm Key	1	237	11358	0.000	
H-rate Key	2	237	11358	0.000	
H-norm Cos					Threshold levels exceeded
H-norm H-poly					Parameters highly correlated
H-rate Cos					Threshold levels exceeded
H-rate S-poly Time-cat					Model failed to converge
OMAO					
H-rate Key	2	0	2310	0.771	
H-rate Key Tract	8	4	2314	0.104	
H-rate Key Cloud	3	8	2318	0.014	
H-rate Key Rain	3	8	2318	0.014	
H-rate Key Cover	3	8	2318	0.014	
H-rate Key Height	3	8	2318	0.014	
H-rate Key Time-cat	3	8	2318	0.014	
H-rate Key Time-con	3	8	2318	0.014	
H-rate Key Observer	3	8	2318	0.014	
H-rate Key Panel	3	8	2318	0.014	
H-rate Key Wind	4	10	2320	0.005	
H-rate Key DectType	4	10	2320	0.005	
H-rate Key Gust	5	12	2322	0.002	
H-norm Key	1	29	2339	0.000	
H-norm Cos					Threshold levels exceeded
H-norm H-poly					Parameters highly correlated
H-rate Cos					Threshold levels exceeded
H-rate S-poly					Threshold levels exceeded

Appendix D. Model Selection Based on AIC (continued).

Model	Variables	$\Delta AICc$	AICc	w_i	Comments
NOCA†					
H-rate Key Panel	3	0	1844	0.663	
H-rate Key Cover	4	3	1847	0.148	
H-rate Key Tract	9	4	1848	0.090	
H-rate Key	2	6	1850	0.033	
H-rate Key Cloud	3	8	1852	0.012	
H-rate Key Gust	5	8	1852	0.012	
H-rate Key Rain	3	9	1853	0.007	
H-rate Key Height	3	9	1853	0.007	
H-rate Key Time-cat	3	9	1853	0.007	
H-rate Key Time-con	3	9	1853	0.007	
H-rate Key Observer	3	9	1853	0.007	
H-norm Key	1	11	1855	0.003	
H-rate Key Wind	4	11	1855	0.003	
H-norm Cos					Threshold levels exceeded
H-norm H-poly					Parameters highly correlated
H-rate Cos					Key model selected
H-rate S-poly					Key model selected
H-rate Key DectType					Model failed to converge
HOFI					
H-rate Key Height	3	0	1600	0.975	
H-rate Key Gust	5	8	1608	0.018	
H-rate Key	2	12	1612	0.002	
H-rate Key Tract	7	13	1613	0.001	
H-rate Key Cloud	3	15	1615	0.001	
H-rate Key Time-cat	3	15	1615	0.001	
H-rate Key Time-con	3	15	1615	0.001	
H-rate Key Observer	3	15	1615	0.001	
H-rate Key Panel	3	15	1615	0.001	
H-rate Key Wind	4	17	1617	0.000	
H-rate Key DectType	4	17	1617	0.000	
H-norm Key	1	24	1624	0.000	
H-norm Cos					Threshold levels exceeded
H-norm H-poly					Parameters highly correlated
H-rate Cos					Threshold levels exceeded
H-rate S-poly					Threshold levels exceeded

Appendix D. Model Selection Based on AIC (continued).

Model	Variables	$\Delta AICc$	AICc	w_i	Comments
RBLE					
H-rate Key	2	0	1189	0.772	
H-norm Key	1	7	1196	0.023	
H-rate Key Cloud	3	7	1196	0.023	
H-rate Key Cover	3	7	1196	0.023	
H-rate Key Height	3	7	1196	0.023	
H-rate Key Time-cat	3	7	1196	0.023	
H-rate Key Time-con	3	7	1196	0.023	
H-rate Key Observer	3	7	1196	0.023	
H-rate Key DectType	3	7	1196	0.023	
H-rate Key Panel	3	7	1196	0.023	
H-rate Key Wind	4	9	1198	0.009	
H-rate Key Gust	4	9	1198	0.009	
H-rate Key Tract	7	15	1204	0.000	
H-norm Cos					Threshold levels exceeded
H-norm H-poly					Parameters highly correlated
H-rate Cos					Threshold levels exceeded
H-rate S-poly					Threshold levels exceeded
HAEL					
H-rate Key Tract	6	0	724	0.772	
H-rate Key Cloud	3	4	728	0.105	
H-rate Key DectType	4	5	729	0.063	
H-rate Key Height	3	7	731	0.023	
H-rate Key Panel	3	8	732	0.014	
H-rate Key Wind	3	10	734	0.005	
H-rate Key	2	10	734	0.005	
H-norm Key	1	10	734	0.005	
H-rate Key Gust	3	11	735	0.003	
H-rate Key Time-cat	3	13	737	0.001	
H-rate Key Time-con	3	13	737	0.001	
H-rate Key Observer	3	13	737	0.001	
H-norm Cos					Threshold levels exceeded
H-norm H-poly					Parameters highly correlated
H-rate Cos					Key model selected
H-rate S-poly					Key model selected

Appendix E. Summary of Field Efforts in 2010

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Abstract

This abstract summarizes the field methods and survey effort for the 2010 Landbird Monitoring Project on the Island of Hawaii. Bird and habitat surveys were conducted within the boundaries of Hawaii Volcanoes National Park, The Nature Conservancy's Kona Hema Unit, and the Kau State Forest Reserve. 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 Monitoring Protocol (hereafter Protocol; Camp et al. 2011) except where noted.

A total of 71 transects were designated for the 2010 bird surveys. Of those, 27 were legacy transects that will be repeatedly surveyed every 5 years. Stations on legacy transects were marked with permanent pins according to procedures in the Protocol (Camp et al. 2011). An additional 44 random transects were sampled, and in accordance with the Protocol were not marked and were not scheduled for future sampling.

Bird surveys for the Protocol began on March 19, 2010 and concluded May 28, 2010. The term "survey day" equals the effort of one primary point counter per day. Three primary point counters surveyed 655 stations on 58 transects across eight separate tracts totaling over 78 survey days. A total of 9,845 bird detections of 29 different species (10 native and 19 introduced) were recorded. Of the 655 stations surveyed for birds, 87% were sampled for canopy cover, 88% were sampled for canopy height, and 8% were not surveyed for habitat variables. An intern accompanied the primary counters.

Acknowledgments

On behalf of the National Park Service Pacific Island Network Inventory and Monitoring Landbird Monitoring Protocol, we would like to acknowledge the following for their invaluable assistance: Much appreciation to Rhonda Loh (HAVO Resource Management Chief) for logistical support and advice. A huge thank you to interns: Nicole Chatterson, Elyse Clifford, Caitlin Jensen, and Joanna Wu for their hard work in the field and in the office. Thanks to Mary Jo Chong for her prompt assistance with purchasing and payments. We would also like to helicopter pilot David Okita for his logistical advice and incomparable flying skills. Thank you to Allen Ramos (HAVO Pest Control Manager) for his advice regarding roads and access. We would also like to thank Ben Kawakame (HAVO Resource Management) for permission to use backcountry cabins and for equipment he and his crew graciously lent the project.

Introduction

The Landbird Monitoring field season of 2010 was conducted on the Island of Hawaii within Hawaii Volcanoes National Park (HAVO), Kau Forest Reserve, and The Nature Conservancy's (TNC) Kona Hema Unit. A total of eight tracts were surveyed to produce species-specific bird abundances, as well as to describe the habitats (Figure E-1). Training and sampling procedures followed the Pacific Island Network (PACN) Landbird Monitoring Protocol (Camp et al. 2011). This report documents the field effort and describes the logistical needs and considerations for future sampling of each tract.

A crew of six (Table E-1) conducted the field work including field preparation, training, data collection, and data management. Seth Judge, the Project Field Lead supervised the field crew and was a primary point counter. Two field technicians, Jackie Gaudio and Bobby Hsu, assisted with logistics and were primary point counters. Four internship positions were granted to Nicole Chattersen, Caitlin Jensen, Joanna Wu, and Elyse Clifford. Wu left the project in late April to pursue other job commitments and was replaced by Clifford. Patrick Hart (Assistant Professor- University of Hawaii at Hilo) served as the project Principal Investigator and assisted with planning and preparations. Richard Camp (Hawaii Cooperative Studies Unit, University of Hawaii at Hilo) assisted with the data analysis and answered questions pertaining to the protocol. Rhonda Loh (HAVO Resource Management Chief) was contacted frequently regarding permission and tract specific questions. Greg Kudray (PACN Inventory and Monitoring Program Manager) offered further assistance with project needs.

Table E-1. List of observers for Landbird Monitoring field data collection.

Observer	Observer Code	Contact information
Bobby H. Hsu	BHH	boppingshoester@gmail.com
Caitlin M. Jensen	CMJ	jensen.caitlin@gmail.com
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Jackie M. Gaudio	JMG	jgaudio@gmail.com
Joanna X. Wu	JXW	mojoxk@gmail.com
Nicole C. Chattersen	NCC	nikki2244@gmail.com
Seth W. Judge	SWJ	sethjudge@hotmail.com



Figure E-1. Map of Hawaii Volcanoes National Park and 2010 Landbird Monitoring tracts and transects. Tracts were located on the flanks of Mauna Loa and Kilauea Volcanoes on the southern half of the Island of Hawaii.

Methods

Training

Bird Identification

Training for bird identification and calibration for distance measurements were conducted according to the Protocol (Camp et al. 2011). Primary point counters—Bobby Hsu, Jackie Gaudioso, and Seth Judge—had multiple years of experience counting birds and conducting avian research on Hawaii Island. Nevertheless, the entire crew participated in the training and calibration to standardize bird identification and distance measurements. Training and calibration were conducted in HAVO. Experienced primary point counters paired with the field interns and explored areas of HAVO where forest birds could be readily seen and heard. Interns had little to no experience observing birds of the Island of Hawaii, which prompted a valuable dialogue between observers and facilitated the learning process. Common birds such as Apapane (*Himatione sanguinea sanguinea*), Hawaii Amakihi (*Hemignathus virens virens*), Japanese White-eye (*Zosterops japonicus*) and other common species were focused on until observers were comfortable identifying those species. Rarer species were then sought out in the field for observation. The entire crew volunteered for point counts in the USFWS Hakalau National Wildlife Refuge to gain experience surveying the rarest birds. Surveys did not commence until each primary counter was confident at identifying birds visually and aurally.

The interns became comfortable identifying birds at variable paces, some picking it up faster than others. The majority of their identification abilities came from actual surveys in the field over the course of the sampling period. Joanna Wu, Nicole Chatterson, and Caitlin Jensen became primary point counters after six to eight weeks in the field and after close observation by each primary counter. Primary and secondary counters discussed bird detections after each survey. These discussions allowed the primary counters to track and assess the intern sampling abilities and correct identification errors.

Distance Measurement Training

In addition to bird detections, 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 at six different sites within HAVO. Between 1- 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 was 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 surroundings.

Habitat Identification

Training for habitat data collection focused on field methods outlined in the Protocol (Camp et al. 2011). Hart joined the crew in the Olaa tract and assisted with plant identification and data collection methods, including use of clinometers and densiometers. Hart also lent the crew plant identification guides for study and reference. Each primary point counter also had several years field experience on Hawaii Island and already knew many of the dominant plants encountered in HAVO.

Field Preparation

Field gear was purchased according to the Protocol (Camp et al. 2011) with a few minor exceptions and additions. Field equipment not itemized in the Protocol such as backpacks, rubber boots, rain pants, and rain jackets were purchased. Essential camping gear was also purchased for extended stays in the field including kitchenware, a camp stove, camp chairs, tarpaulins, and a lantern. The crew used personal tents, sleeping bags, and pads for sleeping; however, it would be preferable in the future for project funds to be used for those items so personal items don't get damaged while at work.

Data collection equipment was either purchased or lent to the crew by HAVO personnel or by University of Hawaii cooperators. A measuring tape, used for distance estimates, was loaned to the crew by Hart. Hart also loaned three densimeters and three clinometers for habitat measurements. Power tools were borrowed from PACN Inventory and Monitoring to drill holes in the PVC pipe for permanently marking legacy stations. Thermometers were not purchased, thus, temperatures were not recorded during bird surveys.

Global Positioning System (GPS) units were purchased for the survey, but the units were not received in time for survey duties. Camp and Hart lent the crew three GPS units. Fieldwork would have been delayed for more than three weeks if those units were not made available. Camp also lent the crew three range finder units to assist with distance measurements during training and for survey work in the field.

Establishing Transects and Stations

Transects were navigated using GPS units and magnetic compasses as prescribed in the Protocol (Camp et al. 2011). The GPS units have a compass function, however, the crew found it to be more accurate in closed canopy forests to navigate to stations by reading the bearing in degrees from the GPS and following that bearing using a magnetic compass. The Garmin 60CSX units typically had an accuracy of three to six meters and stations were established one to two meters from the given position already loaded into the GPS.

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 on legacy transects were marked with a 1 m length of $\frac{3}{4}$ inch PVC pipe with a metal tag indicating transect and station number as prescribed in the Protocol (Camp et al. 2011). A strip of pink flagging was tied to the pipe and a few strips were also tied to the nearest tree. The pipes were drilled with a small hole and wire was used to attach the metal tag approximately 5 cm below the top. A PVC cap was placed on the exposed end to prevent rain from filling the hollow pipe. Steel stakes, 45 cm long, were hammered about halfway into the ground and Simpson High Strength Epoxy-Tie® Anchoring Adhesive was squeezed onto the base of the exposed stake to seal the PVC and stake together. The PVC pipe was hammered a few inches into the ground over the stake and epoxy. The epoxy at the base of the stake prevented the PVC pipe from filling with water from below and held the stake and PVC pipe together permanently.

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 established on transects. Stations were spaced either 150 or 200 m apart depending on location or the transect type (fixed or random). 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 was measured to the nearest meter were recorded. Rounding of measurements to the nearest 5 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 during wind gusts or disturbances (e.g., helicopters, barking dogs, etc.). There were no differences between the Protocol prescribed and applied sampling methods.

Habitat data was collected as described in the Protocol (Camp et al. 2011). A vegetation profile board (density board) was fashioned from 2 m length of $\frac{3}{4}$ inch PVC pipe. The PVC pipe was marked into four equal sections from 0–0.5, 0.5–1.0, 1.0–1.5 and 1.5–2.0 m. Each section was further divided into five 10 cm segments and marked alternately black and white with a sharpie pen. Thus, the density board was marked with a total of twenty 10 cm segments in four 50 cm sections. One counter held the density board up vertically 15 m away from the station center-point at azimuth 0°. The counter at the station recorded the number of segments covered by vegetation in each section. A segment was recorded as “covered” even if partially obscured by vegetation. It was felt that this method accurately quantified the understory density, while minimizing bias by not overestimating density. Furthermore, the PVC pipe was easy to carry through the forest and could serve as a probe when checking for holes and cracks in the lava.

Summary of Tracts

A total of eight tracts were surveyed for birds and habitat variables during the 2010 field season. Field efforts were scheduled according to tract location, landowner permission, and counter availability. Tracts differed substantially, ranging from 700 to 2,600 m in elevation, on substrates ranging from 200 to 10,000 years old, and across a moisture gradient from very dry to moderately wet (Table E-2). Each tract had unique considerations regarding access, ease of navigation, and overnight stays. Survey effort varied for each tract due to number of transects/stations (Table E-1-1), counter availability, and habitat characteristics. Workload was quantified by “survey days”, or the number of primary point counters available per day. On average, one primary point counter and intern could stake and survey 10 stations per day.

The tracts were accessed within HAVO boundaries with the exception of Honomalino, which was primarily within The Nature Conservancy’s Kona Hema unit. Two tracts—Northwest Kahuku and East Rift Zone—required helicopter assistance for transporting gear and crewmembers. Park dispatch assisted with helicopter operations and field communication. Employee backcountry permits were filed with HAVO Rangers at the Kilauea Visitors Center for overnight stays in Kahuku, Northwest Kahuku, and the East Rift Zone tracts. All HAVO gates were unlocked by a NPS issued key. Keys can be obtained by permission from PACN Inventory and Monitoring personnel. Field methods were identical for each tract, except where noted below in the tract descriptions.

Table E-2. Climate, elevation and age of substrate of landbird monitoring tracts.

Tract	Climate Zone(s)	Elevation Range (m)	Geological Substrate Age Range(s) (y.a.)
East Rift Zone	Moderately Wet	731 – 975	200 – 750
Honomalino	Moist Mesic and Seasonal Mesic	1,371 – 1,798	< 200 and 1,500 – 3,000
Kahuku	Seasonal Mesic, Moist Mesic, and Moderately Wet	1,524 – 2,164	750 – 3,000
Mauna Loa South Flank	Seasonal Mesic, Moist Mesic, and Moderately Wet	731 – 1,584	200 – 3,000 and 5,000 – 10,000
Mauna Loa Strip	Seasonal Mesic	1,433 – 2,011	200 – 10,000
Northwest Kahuku	Very Dry and Moderately Dry	2,164 – 2,560	1,500 – 3,000
Olaa	Moderately Wet	1,067 – 1,341	5,000-10,000
Papa	Moderately Dry	1,738 – 1,981	< 200 and 1,500 – 3,000

East Rift Zone

The East Rift Zone is a remote tract on the eastern flank of Kilauea Volcano (Figure E-2-1). The survey was reserved for the last two weeks of the sampling period in May. It was the lowest in elevation of all of the sites designated for the survey and the only tract on Kilauea Volcano. Some of the transects were near the Puu Oo vent, which has been volcanically active since 1983. The vent has spewed lava and volcanic gases almost constantly for the last 25 years. The tract was littered with earth cracks, steam vents, and large pit craters as well as dense matted fern, which make for difficult and hazardous hiking conditions. It was essential to have a fixed meeting time and place, means for communication, and a first aid kit, as well as plenty of water.

The crew camped for four and two nights at two different locations, respectively. The crew stayed at “Camp Area 1” (Figure E-2-1), which was a site near the Nalua and Kalapana Trail intersection approximately three km from the Kealakomo trailhead. The crew also camped at the established Napau campground at the end of the Napau Crater Trail and was designated “Camp Area 2 (Figure E-2-1). There were designated tent spaces and a composting toilet. Potable water was not available anywhere within the East Rift Zone tract. Approximately two gallons per person per day were needed in the field, which was too heavy to hike in. Therefore, 30 gallons and some field gear were flown to Camp Area 1 by helicopter on May 14, 2010. Camp Area 2 was within wilderness boundaries where helicopter operations require permission, thus water was not flown there.

Judge and Gaudioso met the helicopter and pilot at the Fire Escape Road staging area. The road was gated at the turnoff to the Mauna Ulu parking area and requires a HAVO key. The staging area was a short drive from the gate and was marked with signs. Judge and Gaudioso loaded the water into the helicopter (a sling load was not necessary) and flew approximately 15 km to Camp Area 1. The water and some equipment were unloaded there and Judge and Gaudioso were returned to the Fire Escape Road staging area. In total, the operation took 20 minutes to complete. The crew then hiked to Camp Area 1 the following week to flag and survey transects 1 and 2. Transects 3, 3001, and parts of transect 2 were closer to Camp Area 2 (Napau Campground), and were sampled the last week in May (Table E-1-1).

The tract proved to be too dangerous to survey Legacy transects 3 and 3001 (Figure E-2-1). On May 27, 2010, intern Elyse Clifford fell 7 m down into an earth crack and was fortunate enough to walk away with only cuts and bruises. The incident occurred only 20 m from Station 12 on Transect 3001. An incident report was submitted and filed as required. Surveyors on transect 3 encountered similar hazards and came to the determination that the area was too dangerous to survey. The crew was also set back by illness and non-work related injuries so there were not enough primary counters available to finish the tract before the end of the sampling period. None of the random transects were surveyed because of surveyor availability and field hazards. Legacy Transects 1 and 2 were completed and provided the only data for the tract. Transect 1 was very near the Naulu trail, when mapped the transect looks like it was supposed to fall directly on the trail as it curved through the forest because the points were not in a straight line like all of the other transects. Once on the trail however, it was apparent that the points were not directly on the trail as intended, perhaps because of a Geographic Information Systems (GIS) error. The counts were conducted at points on the trail closest to the loaded GPS points as possible, sometimes nearly 100 m away (Figure E-2-1). Survey points were documented and no flagging or stakes were placed because placing of markers of any kind on maintained trails was restricted in HAVO.

Honomalino

The Honomalino tract lies within HAVO and The Nature Conservancy's (TNC) Kona Hema unit on the southwest flank of Mauna Loa (Figure E-2-2). The tract was comprised of two legacy transects totaling 46 stations and 5 random transects of 52 stations. Sampling was conducted during the last week of April (Table E-1-1) and 7 survey days were dedicated to the tract.

The area was accessed through the Honomalino subdivision off of Highway 11 between the 88 and 89-mile markers. The crew stayed in the TNC cabin which was a short drive from the beginning of the transects. The majority of the transects lie in the TNC tract. A TNC research permit was arranged with Natural Resource Manager Laura Nelson and cabin arrangements and gate access were made with Kona Hema Field Coordinator Mel Johansen. The transects were in a mix of mesic forest and large lava flows and were fairly easy to navigate. There were two other transects in the Kona Hema unit that were surveyed for forest birds in 2008. There was some confusion by TNC personnel on whether or not those transects matched the HAVO landbird survey transects. Laura Nelson claimed that the transects were indeed the same after she looked over our maps. She said that the transects were already flagged, but when we navigated to the transects we found no flagging in the TNC tract. However, stations on the HAVO side were, probably from the 2005 bird survey effort. The crew surveyed the TNC stations without placing any flagging according to TNC requirements (Laura Nelson, pers. comm.). HAVO stations were reflagged and stations were established following protocol procedures. Future surveys in the TNC tract will have a degree of inaccuracy because the stations were not permanently established, thus position of point counts may vary from 5-20 m depending on GPS accuracy.

Kahuku

The Kahuku study area was the largest of the tracts and required the most time to survey. Five legacy transects totaling 95 stations and 10 random transects of 110 stations were designated for the landbird survey. The majority of the legacy stations were within the Kau Forest Reserve. Transects were approached at higher elevations inside HAVO by the upper Kahuku Road (Figure E-2-3). The tract required 19 survey days to sample according to the Protocol.

The tract was accessed through the lower HAVO Kahuku Ranch gate off Highway 11 between the 70 and 71-mile markers. Field operations were based out of the Nene Cabin, approximately an hour and half drive past the lower Kahuku gate. The cabin was small with three bunks so some of the crew slept outside in tents. The cabin was outfitted with a propane stove and some utensils, the crew brought all other camping gear including potable water and cookware. The cabin was reserved through Ben Kawakame (HAVO Resource Management Wildlife Manager). It was essential to coordinate with Kawakame and his hunting crew whom frequently control invasive ungulates in the area. Fieldwork was prohibited during hunting activities for safety reasons.

The transects in this tract were long and difficult to walk, especially the lower halves of the transect where vegetation was thick and slowed navigation. *Broussaisia arguta* (kanawao) in particular was especially dense in areas of the Kau Forest Reserve where it took a team of two an hour to hike only 600 m. Counters must double back on the transect to return to the road for pickup which also added a lot of time in the field. The crew rarely finished their daily duties in under eight hours. The road up to and past the Nene cabin required a 4x4 truck which was very slow going, especially in areas past (north of) the Nene cabin. It took more than an hour to drive to the furthest transect (transect 22; Figure E-2-3). Extended stays were necessary for survey work in the Kahuku tract.

Feral dogs were encountered near transect 17. Such dogs can be dangerous as they often have been wild for several generations and subsist by killing and scavenging large ungulates. Three dogs approached Gaudioso and Chatterson on April 7, 2010. It was uncertain what intention the dogs may have had, but should be treated as a threat. Consequently, the crew carried cans of pepper spray on subsequent trips.

Mauna Loa South Flank

The Mauna Loa South Flank tract (Figure E-2-4) was accessed through the lower Kahuku Ranch gate from Highway 11 between the 70 and 71-mile markers. The tract was surveyed opportunistically during the sampling period (Table E-1-1) and required repeat efforts because of high winds, which prevent counting. Transect 3 was the only legacy transect at the tract, but it was long at 51 stations. There were 6 random transects of 63 stations. The tract required 9 survey days (Table E-1-1) to complete.

Transect 3 was fairly easy to navigate because it runs through pasture lands, the flagging however, was often placed very far apart because of the lack of trees so it was necessary to navigate with a GPS. There was some remnant flagging near the top of the transect but nowhere else. There was little to no understory vegetation aside from exotic grasses and the occasional tree fern for the majority of the transect. The terrain changes quickly near the lower end of the transect where lava rock and dense matted ferns slow navigation. Camping was not required because it was feasible to get to the transect by 6 am to conduct the survey and return to the Field Station by 4 pm.

Mauna Loa Strip

The Mauna Loa Strip tract was surveyed opportunistically throughout the sampling period (Table E-1-1). The majority of the transects were accessed by the Mauna Loa Strip Road which connects to Highway 11 between the 30 and 31-mile markers and continues upslope to the Mauna Loa Summit trailhead (Figure E-2-5). There were three long legacy transects totaling 40 stations and four random transects of 43 stations. The tract required 15 survey days to complete.

The tract was very difficult to survey and establish permanent stations because of the habitat. The tract was a mixture of large lava flows and densely vegetated native forest. The understory in places had been invaded by blackberry and thick exotic grasses making it difficult to walk. Very dense thickets of native shrubs also made navigation difficult, thus this tract took several days to finish. Only small remnants of flagging were found so all of the stations in this tract were marked following protocol procedures. All transects were accessed from the Mauna Loa Strip Road except transect 14 which was accessed through the Kapapala Ranch. This transect can be reached by taking the power line road that connects to the strip road near the second cattle guard; approximately a 10 minute drive on a dirt road to the HAVO and Kapapala Ranch boundary fence and gate. This gate was keyed the same as the majority of the HAVO gates. Access continues upslope on a rough 4x4 road for about an hour to the end of the road. The transect beginning was approximately 850 m from this point, or a 20-30 minute walk. It was not effective to access Transect 14 from the Strip Road because of a dense forest and a large lava flow that must be navigated before reaching the closest station. Camping was not required because of the tract's close proximity to the HAVO field station.

Northwest Kahuku

Surveys in this tract were conducted during the week of May 10th. There were five legacy transects totaling 38 stations and five random transects of 52 stations. With a full crew including three primary point counters the tract was marked and surveyed over a four day period (10 survey days).

The tract was accessed by helicopter because of its isolation and adjacent private land (Figure E-2-6). The crew staged helicopter operations within the HAVO southwestern boundary above Hawaii Ocean

View Estates. This area was approximately 26 km from the Landing Zone at the field site, which was approximately a 15-minute flight. In total, the operation was approximately 80 minutes. David Okita, the helicopter pilot, suggested it would have been better to stage the flight closer to the tract, perhaps on the Kona Forest Unit on Hakalau Forest National Wildlife Refuge. Flight time and cost could be saved if a staging area was located closer to the tract.

Flight arrangements were made six weeks in advance and each crew member was required to take the online B3 Combination Helicopter and Airplane Safety module offered by the U.S. Government Interagency Aviation Training website: (<https://www.iat.gov/Training/pages/online.asp>)

The transport of the six member crew, water, camping gear, and field gear required three shuttles. Two shuttles with three crewmembers each (in addition to the pilot) plus a sling load without crewmembers. The helicopter retrieved us on Friday the 14th at 10 AM and returned us to our vehicle that was parked in HAVO above Hawaii Ocean View Estates. To save flight time the pilot transported the sling load back to the field station where it was retrieved later that afternoon.

Field equipment including flight suits, helmets, and a sling were borrowed from HAVO Resource Management. The sling serves as a net that hangs below the helicopter by a long wire. More weight and larger items were transported in a sling load and its use was often essential for extended camping trips. Approximately 220 kg of gear was transported in one trip. A flight manifest that lists items and weight for transport were provided to the pilot. Only essential items should be packed to keep sling load weight well below safe limits. The sling load was assembled on the road at the staging area. The pilot landed next to the load, checked the security of the sling and attached the sling load wire himself because none of the crewmembers had the required training for sling load attachment/detachment.

Olaa Unit

The Olaa Unit Tract was the easiest tract to access because of its close proximity to field station (Figure E-2-7). There were five legacy transects totaling 47 stations and six random transects of 50 stations. The crew required seven survey days to complete the bird surveys, but flagging and staking duties added an additional five survey days.

The tract was accessed by Wright Road which connects to Highway 11 between the 26 and 27-mile markers. Surveys occurred when convenient throughout the sampling period (Table E-1-1). The tract was a dense predominately native wet forest and difficult to navigate through. Blue flagging was already on the transects from either a vegetation project or previous bird surveys. The flagging did not identically match up to the points given in the protocol, but were only off 10-40 m. The crew followed the older flagging and marked the station at the point on the transect closest to the given GPS point which would be perpendicular to the already established transect. Thus, the transect may not be linear. In all likelihood the transect that was already present was established by compass and without the aid of GPS. If the landbird crew had used the loaded points for the stations there would have been two nearly parallel transects only 10-40 m apart, which would cause confusion and disturbance to the habitat. Station positions were recorded and the database was amended to show the more accurate placing of the transect (Table E-1-2).

Legacy transect 1 was located directly on the northwest fence line of the tract; a permanent and well maintained boundary fence. It was not necessary to place PVC pipes and stakes on the maintained fence. Instead, metal tags and pink flagging were attached directly onto the fence at the station points.

There were three separate units in the Olaa survey area—Olaa Puu Unit, Olaa Small Tract Unit, and the Olaa Koa Unit. Data from each unit will be pooled together for the tract data summaries. All units were fenced except for the northern half of the Olaa Puu Unit where feral pig damage was evident.

Papa

The Papa tract was entirely in HAVO and a short drive from the TNC cabin (Figure E-2-8), thus field logistics and camping arrangements were included with the Honomalino tract field efforts. The tract was small with only two legacy transects totaling 11 stations and one random transect of 10 stations. The survey was conducted and finished on May 7, 2010 (Table E-1-1).

The tract was accessed through the Honomalino subdivision off of Highway 11 between the 88 and 89-mile markers. The transects were accessed through the upper TNC gate into HAVO property. The gate had a TNC lock with a key available from TNC Property Manager Mel Johansen. It was approximately a half hour drive from the gate through large lava flows to the beginning of the Papa transects. There was some flagging already on the transects which was likely placed by a HAVO Resource Management vegetation survey crew. The transect coordinates closely matched the flagging for a short while and then diverged higher up the transect so surveyors should use a GPS to avoid confusion during the survey.

Results

Bird Survey Field Effort Summary

Landbird surveys began on March 19, 2010 and were concluded on May 28, 2010, totaling 30 field days (Table E-1-1). The number of primary point counters varied for each survey because of availability and work load. Survey effort was calculated as the number of “survey days” required in the field. One survey day was the effort of one primary point counter per day. In 2010, a total of 58 transects were surveyed over 78 survey days.

A total of 71 transects were designated in HAVO for landbird sampling in 2010 (Camp et al. 2011). Of the 71 transects, 27 were permanent legacy transects and 44 random transects. Each transect had a variable number of stations, ranging from four to 51 stations, and required variable effort. Legacy transects averaged 15 stations and required more time to set flagging and permanent station markers. Random transects averaged 10 stations, and also required a variable amount of effort depending on forest density and the isolation of the transect. A total of 394 legacy stations were designated for the survey, 360 (91%) of those stations were surveyed for birds during the field season (Table E-1-1). Approximately five survey days would be required to finish the remaining 34 legacy stations. The majority of the missed stations occurred at the East Rift Zone tract where dangerous field conditions and a reduced field crew hampered survey efforts. There were 440 random transect stations designated for the 2010 survey but only 295 (67%) of those stations were surveyed. The majority of the missing data was from the East Rift Zone, where field work was curtailed due to hazardous ground conditions. Also, a small number of stations at the ends of transects were missed in other tracts, generally because counters could not complete sampling them before 11 AM.

Habitat Sampling Summary

Habitat variables were measured and documented as outlined in the PACN Landbird Monitoring Protocol (Camp et al. 2011). Time restraints prevented observers from collecting habitat data from all of the stations surveyed for birds. Of the 655 stations surveyed for birds, eight percent were not surveyed for habitat. The proportion sampled for canopy cover and canopy height was not equal however; 87% were sampled for canopy cover and 88% were sampled for canopy height.

Permanent Stations Marking Summary

Stations were permanently marked as described in the Protocol (Camp et al. 2011). Transects 3 and 3001 in the East Rift Zone tract were not marked because of safety concerns. Transect 1 in the East Rift Zone tract was not marked because of HAVO regulations restricting marking on maintained trails. Transect 1 in the Olaa tract was not marked with PVC pipes because the transect was on the boundary fence line. Station tags and flagging were placed directly on the fence instead. All of the remaining stations on legacy transects within the tracts were permanently marked and this procedure will not need to be repeated.

Secondary Point Counter Progress

Secondary point count data was neither proficient nor consistent enough to collect bird species presence data, and, therefore, species composition could not be analyzed. Discussions among primary and secondary point counters were held after each count to identify bird detection progress. Interns Wu, Chatterson, and Jenson all became primary point counters on April 27th, May 7th, and May 13th, respectively, after they were confident enough in their own birding skills and by the approval of primary point counters Judge, Gaudioso, and Hsu. All counters should repeat the training and calibration procedures if they conduct surveys in the future.

Discussion

The 2010 Landbird Monitoring field season by and large was conducted smoothly and efficiently. The weather was good for the majority of the sampling period and did not hamper data collection. There was a severe drought during the winter of 2010, thus bird surveys were often conducted in clear conditions. The surveys began on March 19, 2010 but could have commenced in January according to the Protocol (Camp et al. 2011). More typical weather conditions may have hampered the sampling, and many of the transects may not have been surveyed because of rain. Thus, in the future it would be prudent to begin surveys earlier in the year if permissible. The late start date may have rushed training for the interns; however, they were able to develop their birding skills during the actual surveys.

The transects were marked clearly with flagging and the permanent stations were marked following protocol procedures. It should be noted that flagging often degrades in windy and sunny conditions. The next HAVO surveys were scheduled to occur in 2014, old unit, or 2015, new unit (Camp et al. 2011). By that time, much of the flagging could be degraded, so it will be essential for future counters to navigate by GPS. Future surveys should also expect to replace much of the flagging. The PVC pipes and stainless steel stakes should remain in position for many years, but the metal tag could corrode in the wet and vuggy conditions of HAVO. Counters should also expect to replace tags and rewrite transect and station numbers. The transects were not cleared during the flagging process. This decision was made to protect the crewmembers from injury and minimize disturbance to the habitat. Consequently, the transects were not easy to navigate, and as previously noted, navigating with a GPS unit was essential and will be necessary for future surveys.

Literature Cited

Camp, R. J., T. K. Pratt, C. Bailey, and D. Hu. 2011. Landbirds vital sign monitoring protocol – Pacific Island Network. Natural Resources Report NPS/PACN/NRR—2011/402. National Park Service, Fort Collins, Colorado.

Addendum E-1

Table E-1-1. Transects surveyed, field counter, and survey days.

<i>Date</i>	<i>Tract</i>	<i>Transects Surveyed</i>	<i>Number of Primary Counters</i>
19-Mar-10	Olaa Unit	28R, 30R, 32R	3
22-Mar-10	Mauna Loa Strip Road	34R, 35R	2
23-Mar-10	Olaa Unit	14L, 29R, 31R	3
24-Mar-10	Mauna Loa Strip Road	34R, 35R, 37R	3
25-Mar-10	Mauna Loa Strip Road	35R, 8L	2
29-Mar-10	Mauna Loa Strip Road	18L, 36R, 37R	3
30-Mar-10	Mauna Loa Strip Road	14L	2
5-Apr-10	South Flank	11R, 13R, 16R	3
6-Apr-10	Kahuku	5R, 6R, 8R	3
7-Apr-10	Kahuku	1R, 4R, 9R	3
8-Apr-10	Kahuku	2R, 4R, 9R	3
13-Apr-10	Mauna Loa Strip Road	8L	1
14-Apr-10	South Flank	12R, 14R, 15R	3
20-Apr-10	Kahuku	22L	2
21-Apr-10	Kahuku	17L, 22L	2
22-Apr-10	Olaa/Kahuku	1L, 12L	3
27-Apr-10	Honomalino	1L, 6L, 17R, 20R	4
28-Apr-10	Honomalino	1L, 6L, 19R	3
30-Apr-10	Mauna Loa Strip Road	14L	2
3-May-10	South Flank	3L	2
4-May-10	South Flank	2L	2
5-May-10	South Flank, Kahuku	2L, 7L	3
6-May-10	South Flank, Kahuku	2L, 3L	3
7-May-10	Papa	1L, 2L, 22R	3
11-May-10	Northwest Kahuku	3L, 4L, 5L	3
12-May-10	Northwest Kahuku	4L, 7L, 8L, 23R	3
13-May-10	Northwest Kahuku	24R, 25R, 26R, 27R	4
19-May-10	East Rift Zone	1L, 2L	2
20-May-10	East Rift Zone	2L	1
27-May-10	East Rift Zone	2L	1
28-May-10	East Rift Zone	2L	1
30 Days	8 Tracts	25 Random/ 25 Legacy Transects	78 Survey Days

Table E-1-2. List of station positions listed that differ from designated Landbird Protocol positions.

Transects and Stations Where Position Differed From Landbird Protocol			Coordinates of Stations as Designated in the Landbird Protocol		Coordinates of Actual Location of Stations in the Field	
Tract	Transect	Station	Easting	Northing	Easting	Northing
Olaa Unit	19	1	264230	2153159	264245	2153171
Olaa Unit	19	2	264418	2153269	264422	2153272
Olaa Unit	19	3	264607	2153380	264606	2153398
Olaa Unit	19	4	264795	2153490	264799	2153500
Olaa Unit	19	5	264984	2153601	264993	2153590
Olaa Unit	19	6	265172	2153711	265163	2153703
Olaa Unit	19	7	265361	2153821	265362	2153829
Olaa Unit	19	8	265549	2153932	265545	2153933
Olaa Unit	5	1	262107	2156857	262092	2156882
Olaa Unit	5	2	262288	2156957	262254	2156958
Olaa Unit	5	3	262470	2157057	262467	2157062
Olaa Unit	5	4	262652	2157157	262649	2157165
Olaa Unit	5	5	262834	2157257	262830	2157259
Olaa Unit	5	6	263016	2157357	263030	2157351
Olaa Unit	5	7	263347	2157555	263350	2157566
Olaa Unit	5	8	263529	2157655	263515	2157661
Olaa Unit	5	9	263711	2157755	263703	2157763
Olaa Unit	5	10	263893	2157855	263861	2157873
Olaa Unit	5	11	264075	2157955	264071	2157971
Olaa Unit	5	12	264257	2158055	264234	2158078
East Rift Zone	1	1	272515	2141171	272565	2141182
East Rift Zone	1	2	272554	2141354	272537	2141182
East Rift Zone	1	3	272583	2141537	272501	2141490
East Rift Zone	1	4	272522	2141698	272454	2141631
East Rift Zone	1	5	272480	2141884	272318	2141779
East Rift Zone	1	6	272427	2142067	272334	2142018

Addendum E-2: Maps of the HAVO tracts and transects.

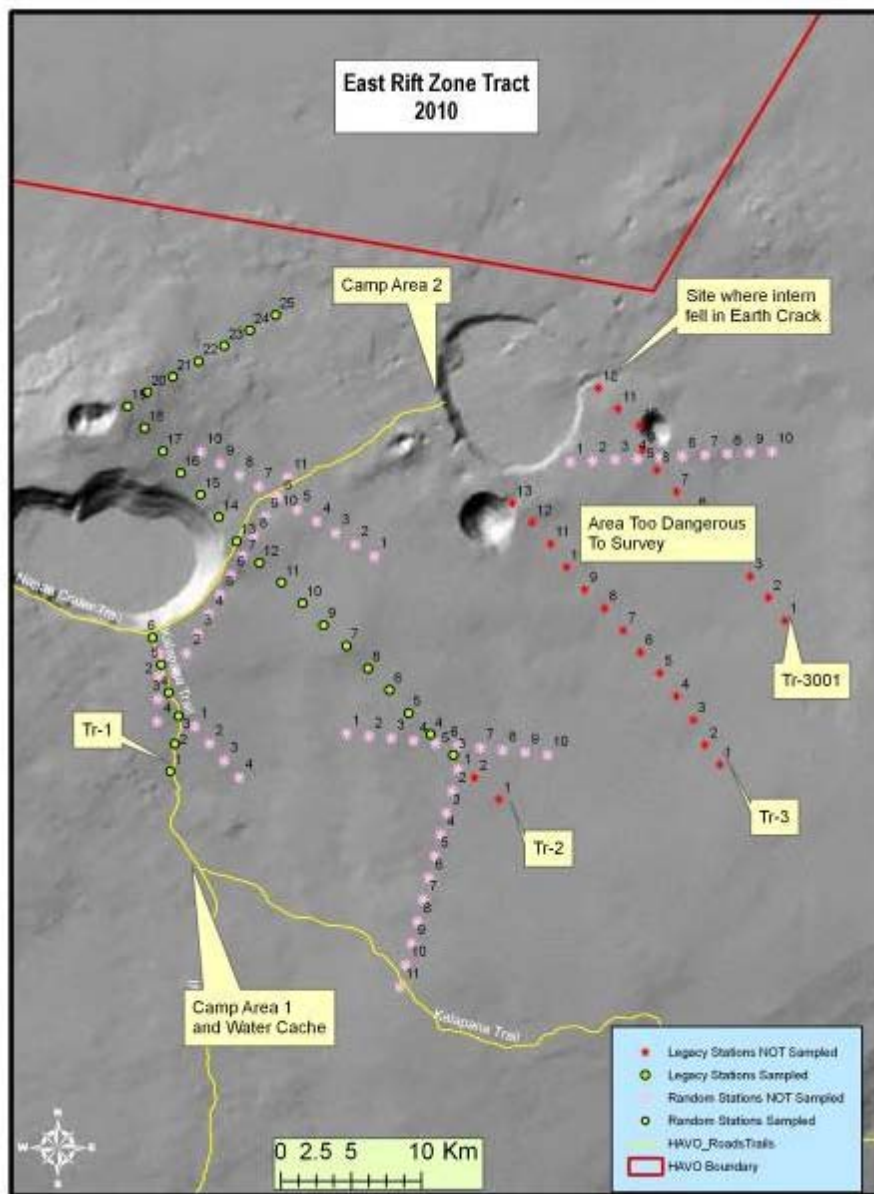


Figure E-2-1. Map of the East Rift Zone tract and stations sampled in 2010.

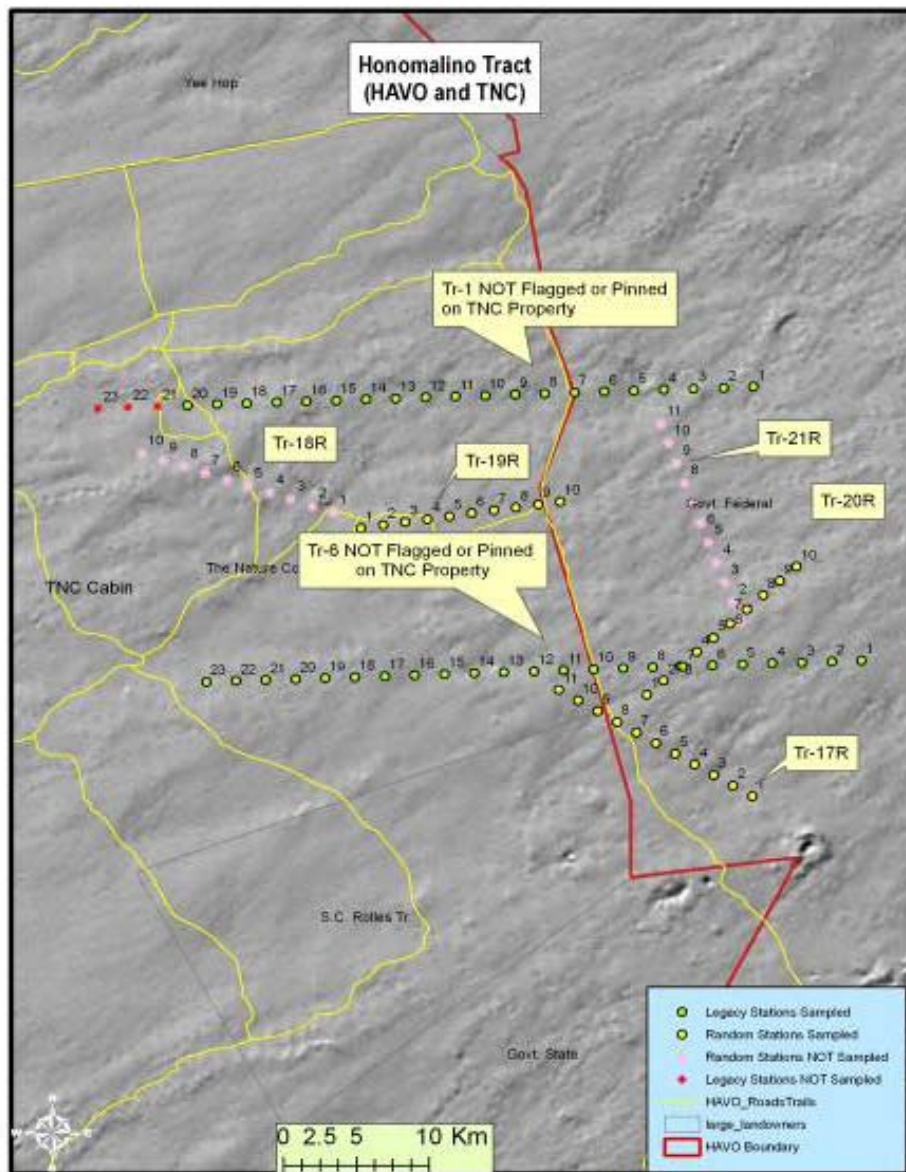


Figure E-2-2. Map of the Honomalino tract and stations sampled in 2010.

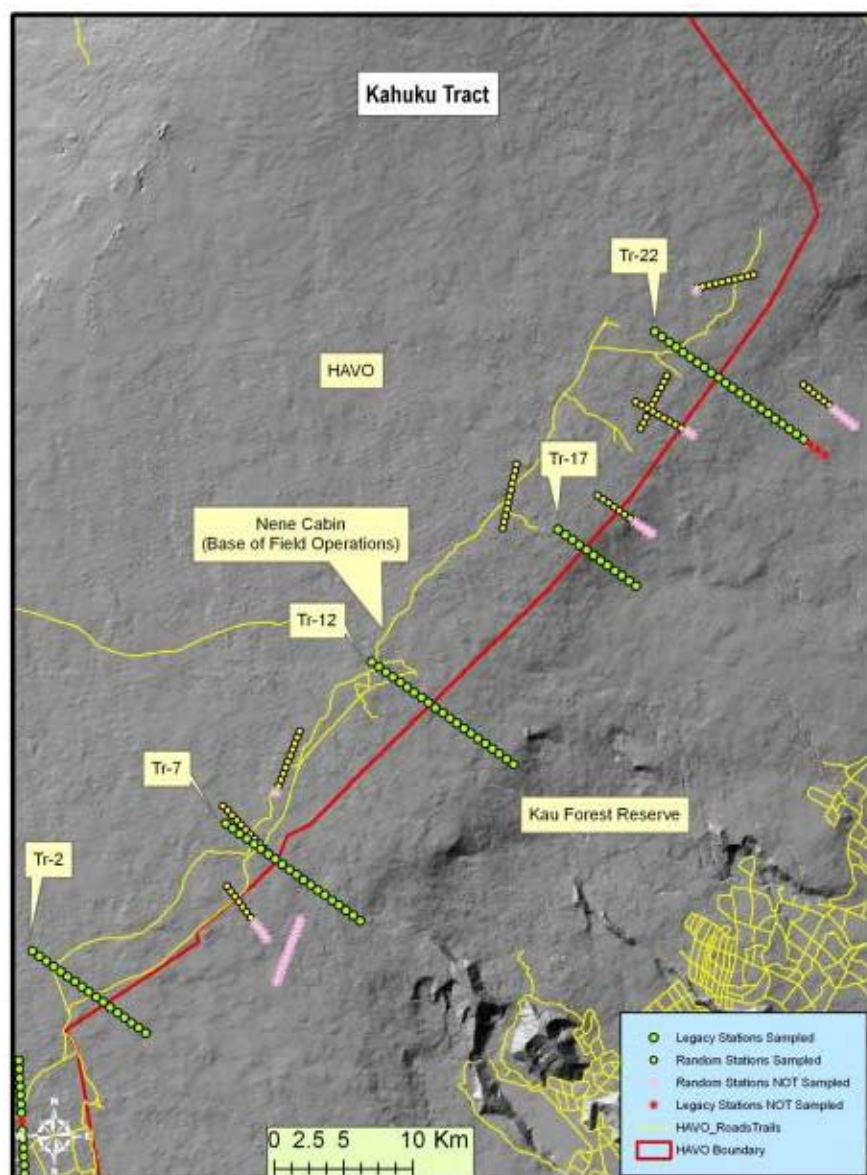


Figure E-2-3. Map of the Kahuku tract and stations sampled in 2010.

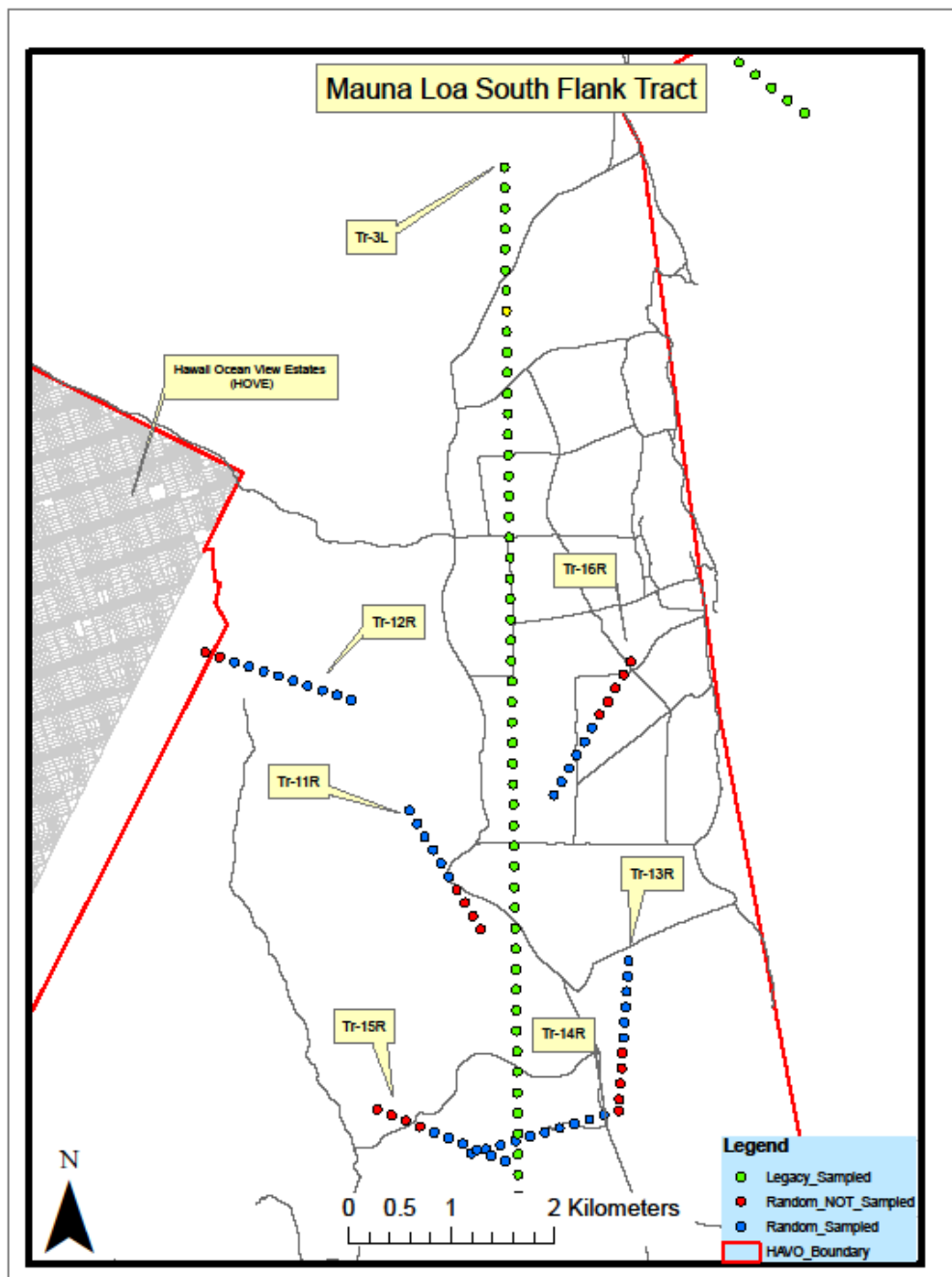


Figure E-2-4. Map of the Mauna Loa South Flank tract and stations sampled in 2010.

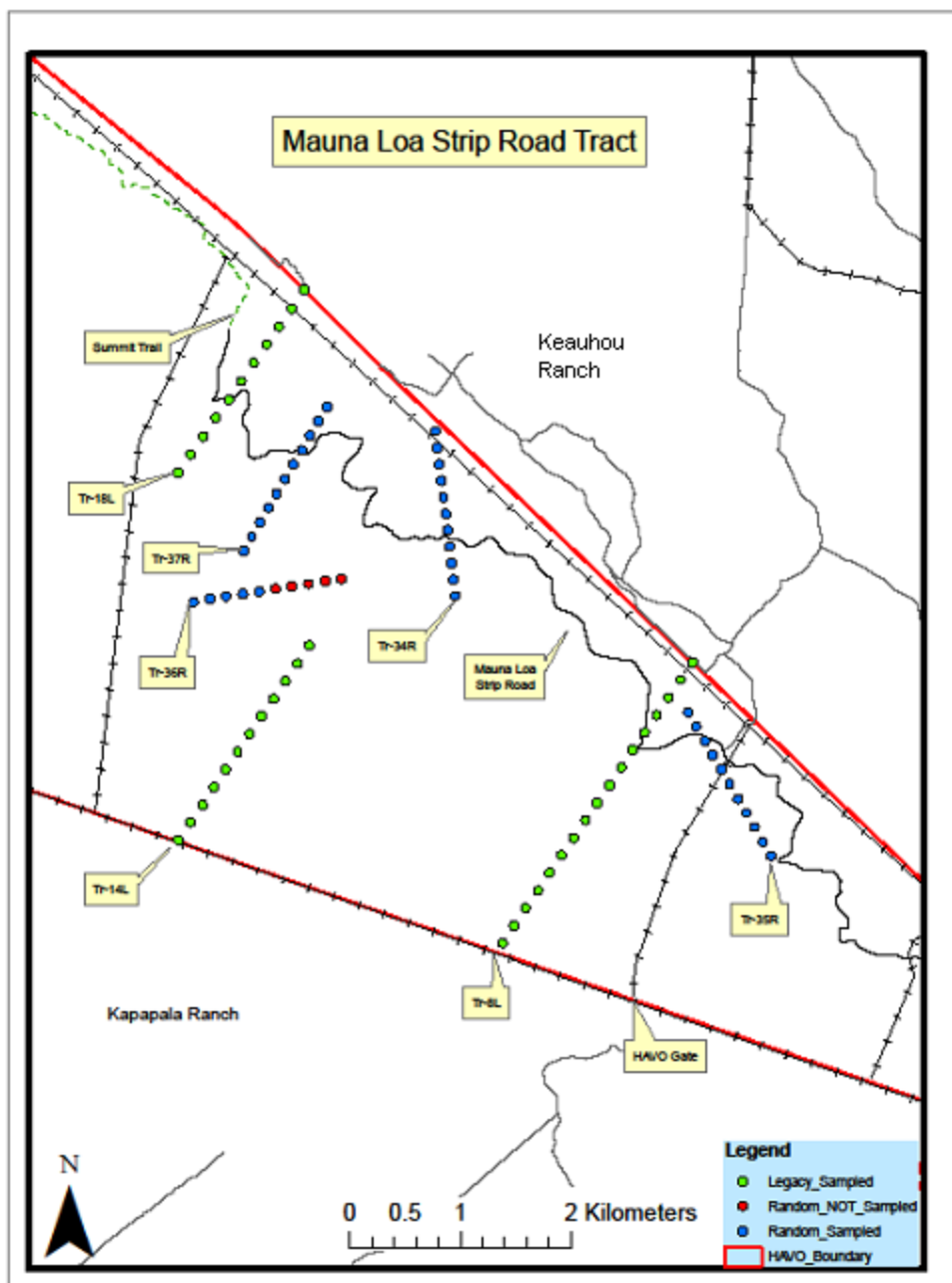


Figure E-2-5. Map of the Mauna Loa Strip Road tract and stations sampled in 2010.

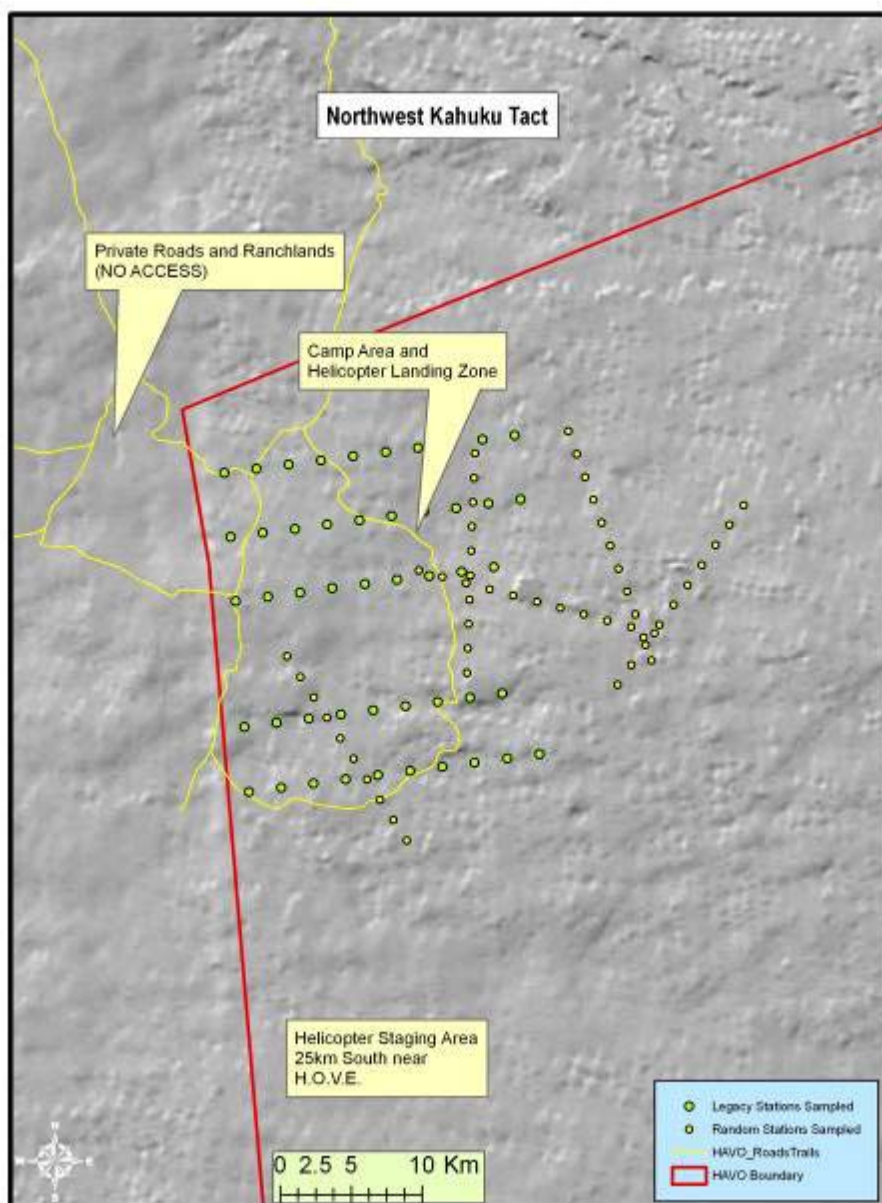


Figure E-2-6. Map of the Northwest Kahuku tract and stations sampled in 2010.

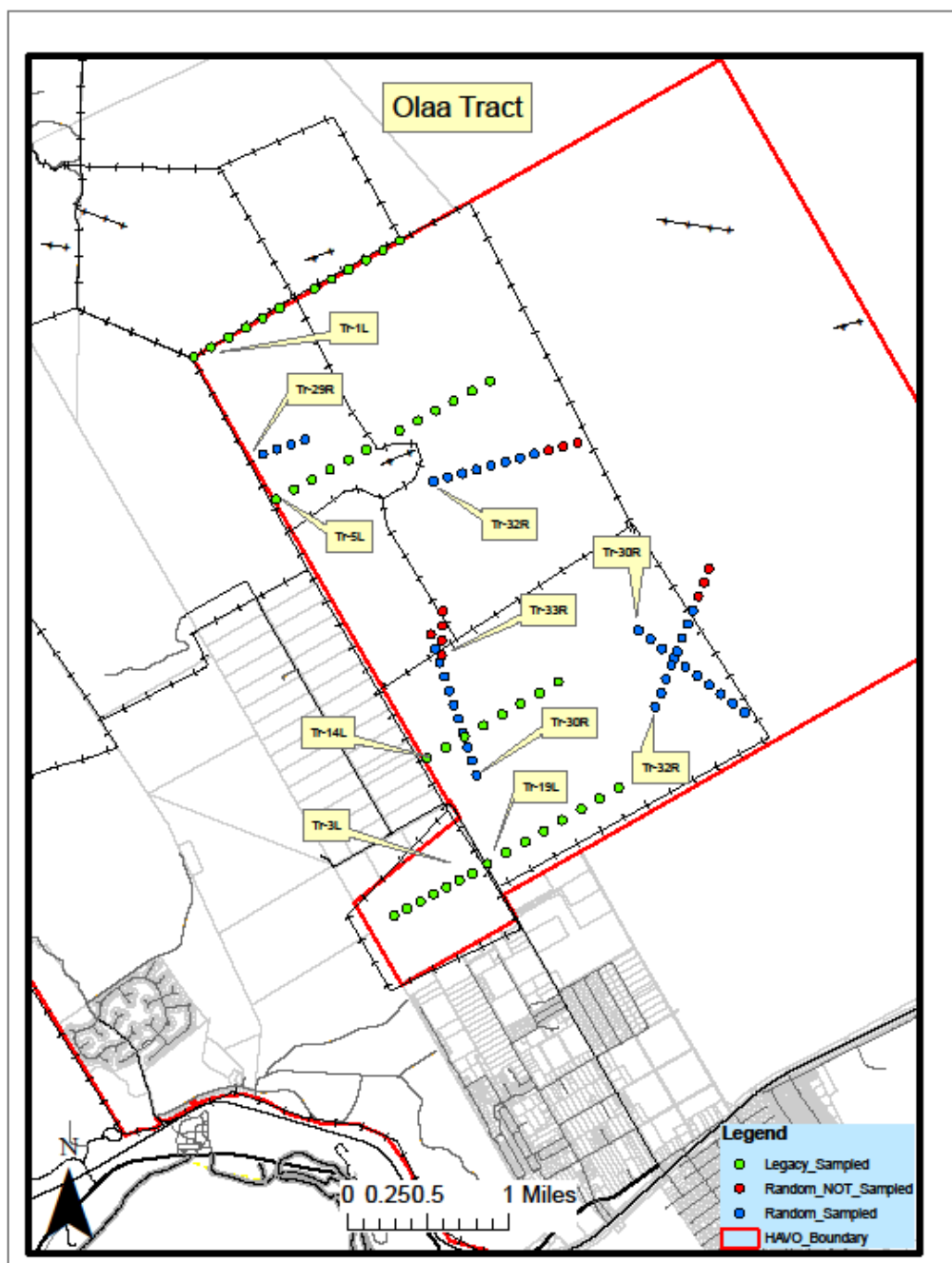


Figure E-2-7. Map of the Olaa Unit tract and stations sampled in 2010.

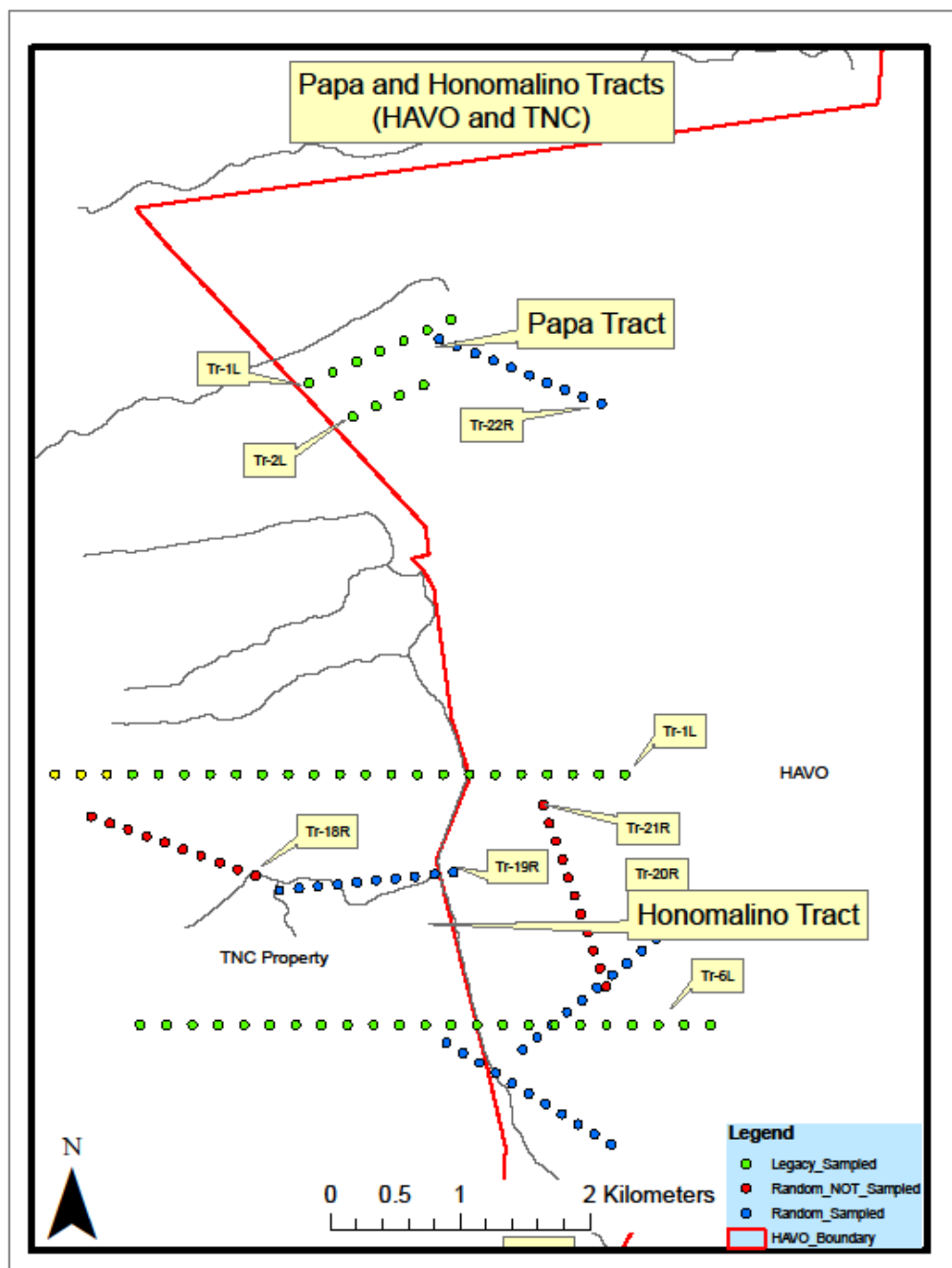


Figure E-2-8. Map of the Papa and Honomalino tracts and stations sampled in 2010.

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