



Pacific Island Landbird Monitoring Report, Hawai‘i Volcanoes National Park, 2015-2016

Tract Groups 1 and 2

Natural Resource Report NPS/PACN/NRR—2017/1407



C

ON THE COVER

‘Ōma’o (*Myadestes obscurus*)

Photograph by: Jack Jeffrey Photography

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Abstract

Hawai‘i Volcanoes National Park (HAVO) was surveyed for landbirds and landbird habitat from February through April 2015 and February through April 2016. This information provides the second datum in the time-series of Pacific Island Network (PACN) monitoring for long-term trends in landbird distribution, density, and abundance. Initial PACN surveys were conducted in 2010 and are repeated every five years.

The entire survey area was comprised of eight tracts in forest, woodland, and shrub habitat, totaling 26,364 ha. Each tract was surveyed using point-transect distance sampling to calculate estimates of bird abundance and density. In addition to the permanent PACN survey transects, randomly generated point-transects were also surveyed, allowing for a split panel sampling design.

A total of 14,061 bird detections of twenty-eight species were recorded during point counts; 8 species were native to Hawai‘i and 20 species were non-native. ‘Apapane (*Himatione sanguinea*) and Hawai‘i ‘Amakihi (*Chlorodrepanis virens virens*) were the most abundant and widely distributed native species detected. ‘Ōma‘o (*Myadestes obscurus*), ‘I‘iwi (*Drepanis coccinea*), and Hawai‘i Elepaio (*Chasiempis sandwichensis*) occurred at fewer than 30% of the 757 stations surveyed, and were absent from some tracts. Three species of native birds detected during surveys were endangered—‘Io (*Buteo solitarius*), Hawai‘i Creeper (*Loxops mana*), and Hawai‘i ‘Akepa (*Loxops coccineus*). Two additional endangered species were detected incidentally on transects—Nēnē (*Branta sandwicensis*) and ‘Akiapola‘au (*Hemignathus wilsoni*). Non-native Japanese White-eye (*Zosterops japonicus*), Northern Cardinal (*Cardinalis cardinalis*), Japanese Bush Warbler (*Horornis diphone*), and Yellow-fronted Canary (*Crithagra mozambica*) were detected throughout most tracts and had the highest relative abundances among non-natives. The remaining species detected occurred at less than 10% of stations surveyed.

Sufficient detections to allow density estimation were made for 11 species (5 native and 6 non-native). Changes in species-specific densities by tract were assessed between the initial and current surveys using two-sample z-tests in an equivalence testing framework to determine long-term trends. Differences between densities were highly variable for native species; including increasing, decreasing and stable trends. There were notable increases of ‘I‘iwi and ‘Ōma‘o densities in some tracts. However there were also declines of ‘Ōma‘o in three tracts, including leeward Northwest Kahuku where birds were detected in 2010 for the first time in over 30 years, but not during this recent survey. ‘I‘iwi densities increased in the high elevation Pāpā tract; however, they declined in the Mauna Loa Strip tract where the species may be vulnerable to avian malaria.

Trend results for Hawai‘i ‘Akepa were inconclusive, but the species occurred at more survey stations than in 2010, and we estimate a density of 0.31 ± 0.34 birds/ha in the 10,989 ha Kahuku tract. Hawai‘i Creeper had in an increasing trend in the Kahuku tract with a density of 0.16 ± 0.07 birds/ha and an inconclusive trend in Honomalino, where there was only one detection in 2016. There was a large expansion in the distribution and abundance of the non-native Yellow-fronted Canary and Japanese Bush Warbler. The Lavender Waxbill (*Estrilda caerulea*) was detected in HAVO for the first time. Trend results were variable for other non-native species, but generally maintained

stable densities when compared to previous landbird surveys. Several habitat variables were sampled at monitoring stations in each tract. Canopy and understory species were predominantly native, especially in tracts where ungulates have been excluded.

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Introduction

Background and Objectives

The avifauna of Hawai'i 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 birds 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 (species that occupy terrestrial habitat) persist in the islands (Pyle 2002). Thirty-five of the remaining species are considered threatened or endangered and 11 of them have not been seen in the last 45 years (Banko and Banko 2009, Elphick et al. 2010). Over 170 species of birds have been introduced to the islands and 54 species have become naturalized (Pyle 2002, Pyle 2003, Foster 2009).

During the late 1970s and early 1980s, the US Fish and Wildlife Service (USFWS) conducted surveys of bird and plant communities on the main Hawaiian Islands as part of the Hawai'i 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) documented declining populations and decreasing ranges for most species, and the extinction of several species. The HFBS in Ka'u (1976) and Kona (1978) covered portions of the Kahuku unit of Hawai'i Volcanoes National Park (HAVO), and the results from these surveys provided regional population estimates of Hawaiian forest bird species (Scott et al. 1986). They found that the Kahuku unit contained important populations of three endangered forest bird species: 'Akiapola'au (*Hemignathus wilsoni*), Hawai'i 'Akepa (*Loxops coccineus*), and Hawai'i Creeper (*Loxops mana*). Trends of common native landbirds in Kahuku have been variable (Tweed et al. 2007, Gorreson et al. 2009); but densities of endangered honeycreepers remained low and trends were difficult to establish without repeated survey efforts.

Many native bird species continue to decline throughout Hawai'i (Jacobi and Atkinson 1995, Gorreson 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 document declines and 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 landbird populations show evidence of change in size and distribution. Many recovery plans propose population density target values that must be achieved before a population may be considered for downlisting and 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 Pacific Island Network (PACN) 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 conserve native bird populations.

While the scope of the PACN landbird survey spans several Pacific islands, this report focuses on surveys within HAVO on Hawai'i 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. 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.

Landbirds were first sampled in HAVO for PACN in 2010. Additionally, portions of landbird monitoring tracts were surveyed in 1992, 1993, 1994 and 2005 (referred to as legacy transects; Gorreson et al. 2005, Tweed et al. 2007). The current landbird monitoring results allow for tract abundance and trends of both native and non-native populations of birds in HAVO; as well as adjacent protected lands in Ka'ū Forest Reserve and The Nature Conservancy's Kona Hema Unit. This report documents the status of three endangered native Hawaiian Honeycreepers, 'Akiapola'au, Hawai'i Creeper, and Hawai'i 'Akepa; five additional native species, Hawai'i Elepaio (*Chasiempis sandwichensis*), 'Ōma'o (*Myadestes obscurus*), Hawai'i 'Amakihi (*Chlorodrepanis virens virens*), 'I'iwi (*Drepanis coccinea*), and 'Apapane (*Himatione sanguinea*); and six non-native passerines: House Finch (*Haemorhous mexicanus*), Japanese Bush Warbler (*Horornis diphone*), Japanese White-eye (*Zosterops japonicus*), Northern Cardinal (*Cardinalis cardinalis*), Red-billed Leiothrix (*Leiothrix lutea*), and Yellow-fronted Canary (*Crithagra mozambica*).

Methods

Landbird sampling conducted by the PACN I&M Program surveys five distinct areas of core landbird habitat within three Pacific island parks on a rotating basis, where each area or park is surveyed once every five years (Camp et al. 2011). The PACN Landbird Monitoring Protocol was implemented in 2010 at HAVO. Sampling protocol separated HAVO tracts into two groups based on their location (Old HAVO and Kahuku Unit); Old HAVO was surveyed in 2015 and the Kahuku Unit in 2016. Both tracts were surveyed in 2010 with a crew of six and then the effort was split into two years with a crew of two in 2015 and 2016. 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 be relocated/not resampled in future survey rotations. The number of sampling stations 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 with low 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 in order to provide a detection function with weather and habitat data as covariates (Camp et al. 2011).

Tract Descriptions

Landbird point-transect counts and habitat data were collected from eight tracts located on Mauna Loa and Kīlauea volcanoes (Figure 1). These tracts included the East Rift Zone, Honomalino, Kahuku, Mauna Loa South Flank, Mauna Loa Strip, Northwest Kahuku, ‘Ōla’a, and Pāpā (see Appendix D for maps of each tract). 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 (Wolfe and Morris 1996). 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 (Jacobi 1989). Climate zones of tracts ranged from “moderately wet” to “very dry” with the majority of transects falling in the “seasonal mesic” category (Price et al. 2007). The majority of the tracts are within HAVO and managed by the National Park Service. Landbird transects are also surveyed in The Nature Conservancy’s Kona Hema Unit and within portions of the Ka‘ū Forest Reserve (managed by the State of Hawai‘i Division of Forestry and Wildlife).

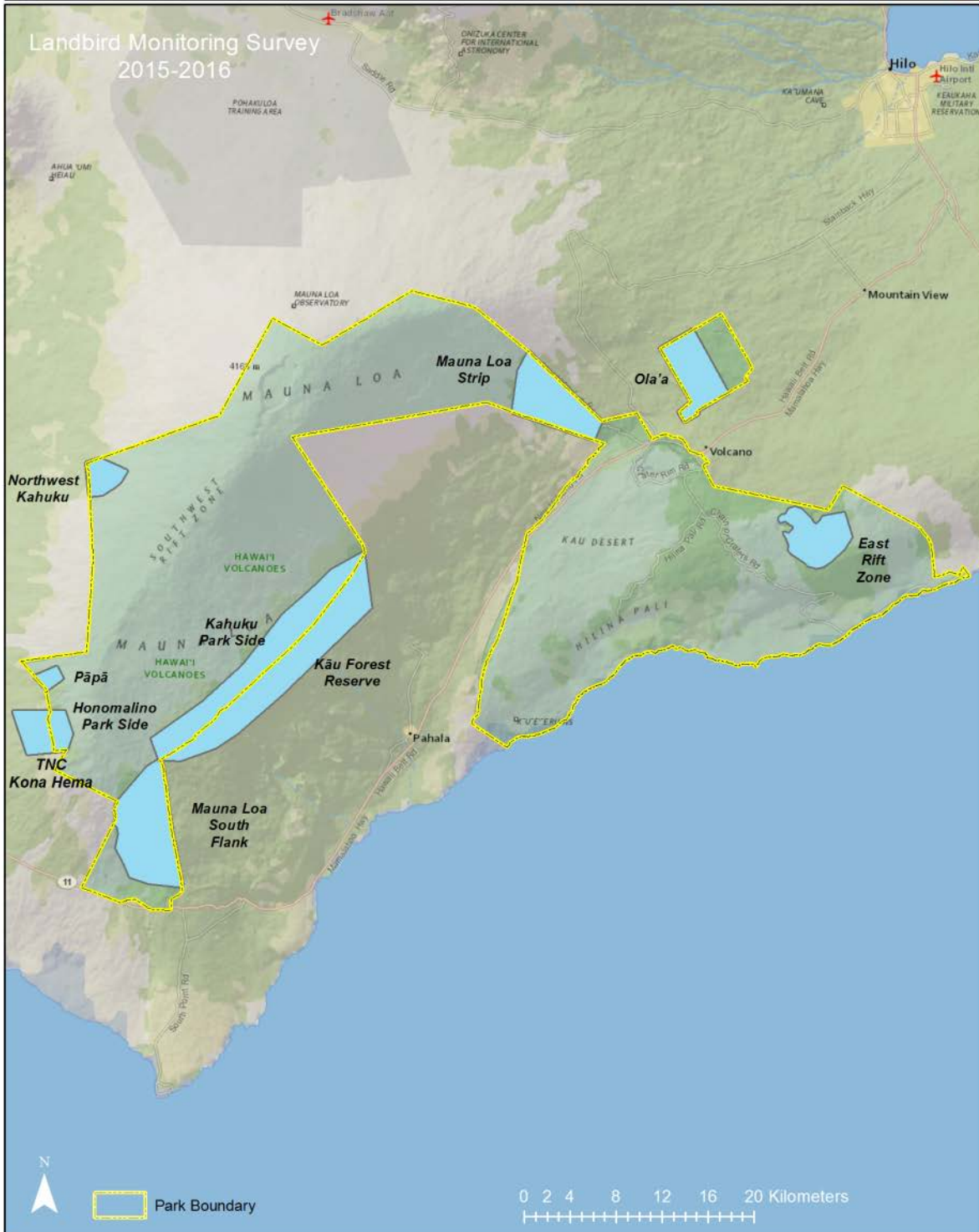


Figure 1. Hawai'i Volcanoes National Park and landbird monitoring tracts surveyed in 2015-2016.

East Rift Zone

The 2,254 ha East Rift Zone tract is located on the southeastern side of Kīlauea volcano, adjacent to the cinder cone, Pu‘u ‘Ō‘ō, which has been erupting since 1983. 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) 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 (totaling 67 stations) with stations spaced at 150 m and 200 m intervals were surveyed in 2015. Randomly prescribed transects were abandoned because of safety concerns.

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. The vegetation ranges from dry sub-alpine ‘ōhi‘a (*Metrosideros polymorpha*) woodland to mesic koa (*Acacia koa*)-‘ōhi‘a 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 surveyed in 2016. A total of 100 stations were sampled in 2016.

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 4,936 ha of HAVO and 6,053 ha in the adjacent Ka‘ū Forest Reserve. The vegetation is comprised of dry sub-alpine ‘ōhi‘a woodland and mesic ‘ōhi‘a-koa forest and the study area spans two climate zones; moist mesic and moderately wet (Price et al. 2007). The tract contains a population of mouflon sheep (*Ovis gmelini musimon*; Hess et al. 2006). The Ka‘ū Forest Reserve section of the tract supports a well-established population of pigs (*Sus scrofa*) and damage was widespread. Five fixed-panel transects with stations spaced at 200 m intervals and 10 random transects with stations spaced at 150 m intervals, were sampled in 2016. A total of 193 stations were sampled in 2016.

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. 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-‘ōhi‘a 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 sampled. A total of 117 stations were sampled in 2016.

Mauna Loa Strip

The 3,181 ha Mauna Loa Strip tract is located on the eastern flank of Mauna Loa. The tract is situated along the paved 18-km Mauna Loa summit trail 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 sampled. A total of 80 stations were sampled in 2015.

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 'ōhi'a, māmane (*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 domestic sheep (*Ovis aries*) in the tract, resulting in little native 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 (47 stations) and four random transects (39 stations) were sampled.

'Ōla'a

The 2,446 ha 'Ōla'a 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 'ōhi'a trees, with 'ōlapa (*Cheirodendron trigynum*) and 'ākala (*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 (46 stations) were sampled.

Pāpā

The 329 ha Pāpā 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 eight 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 'ōhi'a woodland and small stands of 'ōhi'a 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 (11 stations) were sampled.

Geological Substrate Age and Climate Zone Assignment

Global positioning coordinates (way-points) were displayed in ArcMap 10.2.2 (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 Hawai‘i Island was overlaid to determine the climate zone(s) that span each survey tract.

Point-Transect Sampling Methods

A total of 757 stations on 62 transects were surveyed during the 2015–2016 landbird survey (Table 1). 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 in the Old HAVO tracts (Mauna Loa Strip Road, ‘Ōla’a, and East Rift Zone) were conducted from 3 March 2015 through 23 April 2015. Surveys in the Kahuku Unit tracts (Mauna Loa South Flank, Kahuku, Honomalino, Pāpā, and Northwest Kahuku) were conducted from 8 February 2016 through 13 April 2016 (Table 1). Two weeks prior to the start of the survey, two primary surveyors 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).

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	31 March – 23 April 2015	67	Moist Mesic and Moderately Wet	731 – 975	200 – 750
Honomalino	25 March – 28 April 2016	100	Moist Mesic and Seasonal Mesic	1,371 – 1,798	< 200 and 1,500 – 3,000
Kahuku	16 Feb–30 March 2016	193	Moist Mesic and Moderately Wet	1,524 – 2,164	750 – 3,000
Mauna Loa South Flank	8 Feb–23 March 2016	117	Seasonal Mesic, Moist Mesic, and Moderately Wet	731 – 1,584	200 – 3,000 and 5,000 – 10,000
Mauna Loa Strip	9–19 March 2015	79	Seasonal Mesic	1,433 – 2,011	200 – 10,000
Northwest Kahuku	14–17 March 2016	86	Very Dry and Moderately Dry	2,164 – 2,560	1,500 – 3,000
‘Ōla’a	3–25 March 2015	93	Moderately Wet	1,067 – 1,341	5,000 - 10,000
Pāpā	5 April 2016	22	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 which are treated as covariates (Camp et al. 2011). Sampling was conducted between dawn and 11:00 a.m. and halted when rain, wind strength, 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 and dominant understory species composition. 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) Hawai'i Forest Birds Monitoring Database, and (3) Habitat Monitoring Database.

Raw data was verified by comparing data sheets 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 certified by checking 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 thirteen species that had sufficient detections to adequately characterize detectability (Table 2; Buckland et al. 2001) using program DISTANCE, version 6.0, release 2 (Thomas et al. 2010; retrieved September 11, 2015, 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. 2010). Covariates included cloud cover, rain, wind, gust, observer, time of detection, canopy cover, canopy height, and tract (Table 2; Appendix C). 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) (Buckland et al. 2001; Burnham and Anderson 2002). 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 C; Thomas et al. 2010). 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).

Table 2. Models and parameters used to derive population densities by species for the 2015-2016 landbird survey.

Species	Model	Series expansion	Covariate	Truncation (m)
'Apapane	Hazard Rate	Cos(2,3)	Cover	69.6
Hawai'i 'Akepa	Hazard Rate	Key	None	60.0
Hawai'i 'Amakihi	Hazard Normal	Cos(2)	24Detect	59.5
Hawai'i Elepaio	Hazard Rate	Key	24Detect	59.9
Hawai'i Creeper	Hazard Normal	Key	None	57.0
House Finch ¹	Hazard Rate	Key	Year	89.0
'Iiwi	Hazard Rate	Key	24Detect	68.6
Japanese Bush Warbler	Hazard Rate	Key	Cover	95.0
Japanese White-eye	Hazard Normal	Key	Obs	45.9
Northern Cardinal	Hazard Rate	Key	Tract	131.0
'Ōma'o	Hazard Rate	Key	Year	69.3
Red-billed Leiothrix	Hazard Rate	Key	Year	79.0
Yellow-fronted Canary ¹	Hazard Rate	Key	Obs	69.0

¹ Bootstrap model failed to converge; used next best-fit model to estimate abundance and variance.

Population Trend

Change in population densities between the 2010 survey and these surveys (2015-2016) 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 greater than a -0.0285 or 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).

Comparison of Split 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 collinearity among explanatory variables. Time-series data refer to observations of a given unit made over time, and are often referred to as longitudinal data. 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 two temporal measurements have been made. Instead, we assessed selection bias from the cross-sectional data by comparing the 2015-2016 distribution of bird densities between the panel members, fixed and random transects (data pooled across species and tracts, and sorted ascending) using a quantile-quantile plot and Kolmogorov-Smirnov test in program R (version 3.2.3, 2015; R Core Team).

Results

Landbird Summaries

A total of 14,061 birds of 29 species (20 non-native and 9 native) was detected during the 2015-2016 HAVO landbird surveys (Table 3; Table 4). ‘Apapane and Hawai‘i ‘Amakihi were the most abundant and widely distributed native birds detected (Table 5). ‘Ōma‘o, ‘I‘iwi, and Hawai‘i Elepaio were detected in modest densities in some tracts (Table 5), but each had a limited distribution and ‘I‘iwi in particular were restricted to high elevation mesic and montane forests. Furthermore, Hawai‘i Elepaio were not detected in the Mauna Loa South Flank, Pāpā, or East Rift Zone tracts. Three endangered species were detected during surveys: Hawai‘i ‘Akepa, Hawai‘i Creeper, and ‘Io were detected in low numbers (55, 26, and 6 individuals, respectively). Two endangered species were detected incidentally in low numbers on survey transects: the ‘Akiapola‘au and Nēnē. When compared to previous surveys, trends of native landbirds were highly variable. Because of relatively small density changes and uncertain estimates, many species trends within tracts were inconclusive. Notable changes in densities of native landbirds include an increasing trend of Hawai‘i Creeper in Kahuku and a small but stable population in Honomalino. Hawai‘i ‘Akepa did not demonstrate a significant increase in densities, but did occur over a broader area and at more survey stations than in 2010. There were declines in ‘Ōma‘o densities in the East Rift Zone, Northwest Kahuku and Pāpā tracts, but increases in the large Kahuku tract and the heavily managed ‘Ōla‘a tract. There was a significant decline in ‘I‘iwi densities within the Mauna Loa Strip tract and a slight increase in the small Pāpā tract. Populations of Hawai‘i ‘Amakihi were similarly variable, with increases in Mauna Loa South Flank and Kahuku, and decreases in Honomalino and Northwest Kahuku.

Table 3. List of species detected during the 2015-2016 PACN landbird survey. Abbreviated species alpha code, and origin (E-endemic, N-non-native and I-indigenous) of each species are presented.

Species Name	Scientific Name	Species Code	Origin
‘Akiapola‘au	<i>Hemignathus wilsoni</i>	AKIP	E
‘Apapane	<i>Himatione sanguinea</i>	APAP	E
Barn Owl	<i>Tyto alba</i>	BNOW	N
California Quail	<i>Callipepla californica</i>	CAQU	N
Chukar Partridge	<i>Alectoris chukar</i>	CHUK	N
Common Myna	<i>Acridotheres tristis</i>	COMY	N
Erckel's Francolin	<i>Francolinus erckelii</i>	ERFR	N
Hawai‘i ‘Akepa	<i>Loxops coccineus</i>	HAAC	E
Hawai‘i ‘Amakihi	<i>Chlorodrepanis virens virens</i>	HAAM	E
Hawai‘i Creeper	<i>Loxops mana</i>	HCRE	E

Table 3 (continued). List of species detected during the 2015-2016 PACN landbird survey. Abbreviated species alpha code, and origin (E-endemic, N-non-native and I-indigenous) of each species are presented.

Species Name	Scientific Name	Species Code	Origin
Hawai'i Elepaio	<i>Chasiempis sandwichensis</i>	HAEL	E
Nēnē	<i>Branta sandvicensis</i>	HAGO	E
'Io	<i>Buteo solitarius</i>	HWAH	E
House Finch	<i>Haemorhous mexicanus</i>	HOFI	N
'I'iwi	<i>Drepanis coccinea</i>	IIWI	E
Japanese Bush Warbler	<i>Horornis diphone</i>	JABW	N
Japanese White-eye	<i>Zosterops japonicus</i>	JAWE	N
Kalij Pheasant	<i>Lophura leucomelanos</i>	KAPH	N
Lavender Waxbill	<i>Estrilda caerulescens</i>	LAVW	N
Hwamei	<i>Garrulax canorus</i>	MELT	N
Northern Cardinal	<i>Cardinalis cardinalis</i>	NOCA	N
Northern Mockingbird	<i>Mimus polyglottos</i>	NOMO	N
'Ōma'o	<i>Myadestes obscurus</i>	OMAO	E
Pacific Golden Plover	<i>Pluvialis fulva</i>	PAGP	I
Red-billed Leiothrix	<i>Leiothrix lutea</i>	RBLE	N
Saffron Finch	<i>Sicalis flaveola</i>	SAFI	N
Scaly-breasted Munia	<i>Lonchura punctulata</i>	SBMU	N
Skylark	<i>Alauda arvensis</i>	SKLA	N
Spotted Dove	<i>Streptopelia chinensis</i>	SPDO	N
Yellow-fronted canary	<i>Crithagra mozambica</i>	YFCA	N
Zebra Dove	<i>Geopelia striata</i>	ZEBD	N

Table 4. List of birds detected during 2015–2016 surveys, number of stations occupied, indices of percent occurrence and birds per station.

Species Name	# of Birds Detected	Stations Occupied	Stations Sampled	Percent Occurrence	Bird Per Station
'Apapane	5778	669	757	88.38	7.63
Barn Owl	3	2	757	0.26	0.00
California Quail	25	19	757	2.51	0.03

Table 4 (continued). List of birds detected during 2015–2016 surveys, number of stations occupied, indices of percent occurrence and birds per station.

Species Name	# of Birds Detected	Stations Occupied	Stations Sampled	Percent Occurrence	Bird Per Station
Chukar	2	1	757	0.13	0.00
Common Myna	1	1	757	0.13	0.00
Erckel's Francolin	249	151	757	19.95	0.33
Skylark	96	69	757	9.11	0.13
Hawai'i 'Akepa	55	30	757	3.96	0.07
Hawai'i 'Amakihi	2978	585	757	77.28	3.93
Hawai'i Elepaio	95	63	757	8.32	0.13
Hawai'i Creeper	26	15	757	1.98	0.03
House Finch	374	146	757	19.29	0.49
'Io	6	5	757	0.66	0.01
'Iiwi	276	128	757	16.91	0.36
Japanese bush-warbler	186	106	757	14.00	0.25
Japanese White-eye	2262	531	757	70.15	2.99
Kalij Pheasant	28	16	757	2.11	0.04
Lavender Waxbill	39	11	757	1.45	0.05
Hwamei	15	10	757	1.32	0.02
Northern Cardinal	443	250	757	33.03	0.59
Northern Mockingbird	31	26	757	3.43	0.04
'Ōma'o	466	221	757	29.19	0.62
Red-billed Leiothrix	216	103	757	13.61	0.29
Saffron Finch	6	3	757	0.40	0.01
Scaly-breasted Munia	87	14	757	1.85	0.11
Spotted Dove	3	3	757	0.40	0.00
Yellow-fronted Canary	294	130	757	17.17	0.39
Zebra Dove	21	14	757	1.85	0.03

Table 5. Density and abundance of native forest birds in Hawai'i Volcanoes National Park. Population density estimates (birds/ha $\pm$ SE and confidence intervals) for previous surveys were from Gorresen et al. (2005), Tweed et al. (2007), and the 2010 NPS I&M survey (Judge et al. 2011). Estimates from the 2015-2016 landbird survey are highlighted. Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	APAP	HAAM	HAEL	IIWI	OMAO
East Rift Zone	1992	4.23 $\pm$ 0.47 (3.31—5.16)	0	0	0	0.24 $\pm$ 0.06 (0.13—0.36)
	1993 (Jan)	7.13 $\pm$ 0.33 (6.48—7.78)	0.01 $\pm$ 0.01 (0—0.03)	0	0	0.76 $\pm$ 0.08 (0.61—0.92)
	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)	0	1.01 $\pm$ 0.04 (0.94—1.09)
	2010	17.35 $\pm$ 1.75 (13.71—20.11)	0.78 $\pm$ 0.46 (0.09—1.97)	0	0	1.89 $\pm$ 0.28 (1.42—2.50)
	2015-2016	15.86 $\pm$ 1.49 (12.98—18.27)	0.38 $\pm$ 0.14 (0.12—0.73)	0	0	0.93 $\pm$ 0.14 (0.68—1.26)
	Tract Abundance	28,249 (23,123—32,532)	672 (222—1,301)	0	0	1,661 (1,209—2,246)
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)	0.39 $\pm$ 0.05 (0.29—0.54)	0
	2010	16.03 $\pm$ 1.52 (12.98—18.60)	15.77 $\pm$ 1.34 (13.88—19.30)	0.19 $\pm$ 0.09 (0.06—0.46)	0.35 $\pm$ 0.13 (0.12—0.57)	0
	2015-2016	17.38 $\pm$ 1.78 (13.87—20.39)	10.91 $\pm$ 1.07 (9.39—13.66)	0.58 $\pm$ 0.24 (0.28—1.34)	0.43 $\pm$ 0.13 (0.18—0.63)	0
	Tract Abundance	29,343 (23,407—34,418)	18,423 (15,859—23,056)	986 (470—2,257)	723 (303—1,061)	0
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)	0.89 $\pm$ 0.08 (0.73—1.08)	1.03 $\pm$ 0.06 (0.90—1.16)
	2010	26.25 $\pm$ 2.11 (21.55—29.66)	4.24 $\pm$ 0.39 (3.67—5.30)	0.20 $\pm$ 0.09 (0.09—0.47)	1.07 $\pm$ 0.26 (0.53—1.44)	0.85 $\pm$ 0.10 (0.68—1.09)

Table 5 (continued). Density and abundance of native forest birds in Hawai'i Volcanoes National Park. Population density estimates (birds/ha $\pm$ SE and confidence intervals) for previous surveys were from Gorresen et al. (2005), Tweed et al. (2007), and the 2010 NPS I&M survey (Judge et al. 2011). Estimates from the 2015-2016 landbird survey are highlighted. Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	APAP	HAAM	HAEL	IIWI	OMAO
Kahuku (continued)	2015-2016	26.62 $\pm$ 2.24 (22.10—30.59)	6.86 $\pm$ 0.55 (6.14—8.30)	0.19 $\pm$ 0.07 (0.09—0.44)	1.79 $\pm$ 0.34 (0.99—2.14)	1.40 $\pm$ 0.13 (1.19—1.69)
	Tract Abundance	292,570 (242,870—336,200)	75,376 (67,442—91,173)	2,129 (1,043—4,847)	19,620 (10,892—23,564)	15,374 (13,127—18,609)
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	0.33 $\pm$ 0.04 (0.26—0.46)
	2010	8.64 $\pm$ 1.29 (6.04—11.01)	9.54 $\pm$ 0.88 (8.35—11.81)	0	0	0.26 $\pm$ 0.07 (0.14—0.43)
	2015-2016	6.36 $\pm$ 0.91 (4.64—8.02)	9.67 $\pm$ 0.79 (8.60—11.74)	0	0	0.31 $\pm$ 0.08 (0.17—0.48)
	Tract Abundance	29,232 (21,296—36,817)	44,432 (39,481—53,905)	0	0	1,445 (780—2,225)
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)	0.54 $\pm$ 0.09 (0.37—0.72)	0
	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)	0.32 $\pm$ 0.07 (0.19—0.46)	0.01 $\pm$ 0.01 (0—0.03)
	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)	1.12 $\pm$ 0.16 (0.81—1.44)	0.01 $\pm$ 0.01 (0—0.03)
	1991	2.92 $\pm$ 0.29 (2.36—3.49)	4.50 $\pm$ 0.50 (3.52—5.48)	1.18 $\pm$ 0.33 (0.54—1.83)	1.07 $\pm$ 0.15 (0.78—1.37)	0.02 $\pm$ 0.01 (0.01—0.04)
	1992	3.05 $\pm$ 0.30 (2.47—3.64)	5.29 $\pm$ 0.41 (4.49—6.10)	1.69 $\pm$ 0.29 (1.13—2.26)	0.74 $\pm$ 0.10 (0.55—0.94)	0.03 $\pm$ 0.02 (0—0.07)
	1993	2.47 $\pm$ 0.21 (2.06—2.89)	3.28 $\pm$ 0.49 (2.32—4.25)	1.68 $\pm$ 0.30 (1.10—2.27)	0.59 $\pm$ 0.10 (0.40—0.79)	0.01 $\pm$ 0.01 (0.01—0.02)

Table 5 (continued). Density and abundance of native forest birds in Hawai'i Volcanoes National Park. Population density estimates (birds/ha $\pm$ SE and confidence intervals) for previous surveys were from Gorresen et al. (2005), Tweed et al. (2007), and the 2010 NPS I&M survey (Judge et al. 2011). Estimates from the 2015-2016 landbird survey are highlighted. Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	APAP	HAAM	HAEL	IIWI	OMAO
Mauna Loa Strip (continued)	1994	2.83 $\pm$ 0.31 (2.23—3.44)	4.18 $\pm$ 0.51 (3.19—5.18)	1.99 $\pm$ 0.36 (1.29—2.70)	0.44 $\pm$ 0.08 (0.29—0.60)	0.01 $\pm$ 0.01 (0—0.03)
	2010	8.68 $\pm$ 0.96 (6.73—10.33)	6.50 $\pm$ 0.72 (5.38—8.31)	1.64 $\pm$ 0.50 (1.08—3.22)	0.51 $\pm$ 0.18 (0.18—0.76)	0.23 $\pm$ 0.06 (0.12—0.36)
	2015-2016	10.86 $\pm$ 1.20 (8.38—12.87)	9.34 $\pm$ 0.94 (7.97—11.85)	0.80 $\pm$ 0.30 (0.47—1.78)	0.07 $\pm$ 0.05 (0—0.17)	0.24 $\pm$ 0.07 (0.12—0.42)
	Tract Abundance	34,550 (26,658—40,942)	29,705 (25,357—37,692)	2,541 (1,481—5,660)	225 (0—534)	764 (391—1,328)
Northwest Kahuku	2005	2.80 $\pm$ 0.33 (2.15—3.65)	4.72 $\pm$ 0.38 (3.98—5.60)	0.10 $\pm$ 0.04 (0.01—0.70)	0.61 $\pm$ 0.12 (0.37—1.00)	0
	2010	3.02 $\pm$ 0.53 (2.05—4.02)	11.82 $\pm$ 1.35 (9.79—15.31)	0.23 $\pm$ 0.11 (0.07—0.57)	0.02 $\pm$ 0.02 (0—0.06)	0.11 $\pm$ 0.04 (0.05—0.20)
	2015-2016	3.07 $\pm$ 0.56 (2.01—4.08)	8.28 $\pm$ 0.81 (7.03—10.35)	0.03 $\pm$ 0.03 (0—0.11)	0	0
	Tract Abundance	2,712 (1,778—3,610)	7,323 (6,210—9,151)	24 (0—95)	0	0
'Ōla'a	1992	2.00 $\pm$ 0.30 (1.42—2.59)	0	0.02 $\pm$ 0.02 (0—0.06)	0.17 $\pm$ 0.08 (0.02—0.33)	0.21 $\pm$ 0.04 (0.14—0.29)
	1993	7.46 $\pm$ 0.61 (6.27—8.66)	0	0.09 $\pm$ 0.04 (0.02—0.17)	0.28 $\pm$ 0.10 (0.09—0.48)	1.20 $\pm$ 0.14 (0.93—1.48)
	1994	6.92 $\pm$ 0.83 (5.30—8.55)	0.02 $\pm$ 0.02 (0—0.06)	0	0.23 $\pm$ 0.09 (0.06—0.41)	0.91 $\pm$ 0.11 (0.70—1.13)
	2010	11.71 $\pm$ 1.25 (9.21—13.93)	0.06 $\pm$ 0.04 (0—0.16)	0.21 $\pm$ 0.10 (0.07—0.51)	0.26 $\pm$ 0.12 (0.06—0.48)	0.27 $\pm$ 0.08 (0.13—0.47)

Table 5 (continued). Density and abundance of native forest birds in Hawai'i Volcanoes National Park. Population density estimates (birds/ha $\pm$ SE and confidence intervals) for previous surveys were from Gorresen et al. (2005), Tweed et al. (2007), and the 2010 NPS I&M survey (Judge et al. 2011). Estimates from the 2015-2016 landbird survey are highlighted. Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	APAP	HAAM	HAEL	IIWI	OMAO
‘Ōla’a (continued)	2015-2016	17.13 $\pm$ 1.64 (13.80—19.85)	0.03 $\pm$ 0.03 (0—0.09)	0.23 $\pm$ 0.11 (0.05—0.56)	0.22 $\pm$ 0.12 (0.03—0.45)	0.59 $\pm$ 0.11 (0.40—0.83)
	Tract Abundance	41,893 (33,748—48,563)	66 (0—222)	553 (125—1,370)	539 (83—1,091)	1,438 (968—2,039)
Pāpā	2005	3.64 $\pm$ 0.75 (2.17—4.87)	4.71 $\pm$ 0.73 (3.28—6.78)	0	0	0
	2010	10.92 $\pm$ 2.31 (6.91—15.55)	10.35 $\pm$ 1.72 (7.57—14.35)	0	0.18 $\pm$ 0.18 (0—0.56)	0.37 $\pm$ 0.16 (0.11—0.73)
	2015-2016	12.10 $\pm$ 1.88 (8.42—15.68)	8.96 $\pm$ 1.37 (6.75—12.22)	0	1.35 $\pm$ 0.52 (0.41—2.17)	0
	Tract Abundance	3,982 (2,769—5,159)	2,947 (2,219—4,021)	0	446 (136—714)	0
Total Abundance		462,531 $\pm$ 38,853 (395,575—550,237)	178,944 $\pm$ 13,278 (156,005—205,617)	6,233 $\pm$ 2,003 (3,679—10,982)	21,553 $\pm$ 3,949 (14,136—29,403)	20,682 $\pm$ 1,801 (17,343—24,342)

Non-native birds showed a wide range of distributions and densities (Table 6), with the Japanese White-eye being most abundant and occurring in all tracts. The Red-billed Leiothrix and House Finch occurred in modest densities in most tracts; each species had a stable or increasing trend in tracts where they were detected. There were large increases in the distribution of both the Japanese Bush Warbler and Yellow Fronted-canary. Each species was only detected in in the Kahuku tract in 2010; but in 2015-2016 they were recorded in six of the eight tracts surveyed. The Lavender Waxbill was detected for the first time in HAVO, but only in the Mauna Loa South Flank tract. Several other species occurred in low densities and occurrence. Each species’ occurrence is described in sections below; as well as densities, abundances, and trends for species with sufficient detections to statistically provide estimates.

Table 6. Density and abundance of non-native forest birds in Hawai'i Volcanoes National Park. Density estimates (birds/ha ± SE and confidence intervals) for previous surveys were from Gorresen et al. (2005), Tweed et al. (2007), and the 2010 NPS I&M survey (Judge et al. 2011). Estimates from the 2015-2016 landbird survey are highlighted. Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	HOFI	JABW	JAWF	NOCA	RBLE	YFCA
East Rift Zone	1992	0.07 ± 0.05 (0—0.17)	0	7.25 ± 0.95 (5.39—9.12)	0.01 ± 0.01 (0—0.03)	0	0
	1993 (Jan)	0	0	17.33 ± 0.95 (15.47—19.20)	0.05 ± 0.02 (0.02—0.09)	0	0
	1993-1994	0.03 ± 0.02 (0—0.07)	0	11.90 ± 0.49 (10.94—12.87)	0.04 ± 0.01 (0.03—0.06)	0	0
	2010	0	0	19.25 ± 2.15 (15.21—23.47)	0.14 ± 0.08 (0—0.35)	0.10 ± 0.10 (0—0.38)	0
	2015-2016	0	0.65 ± 0.10 (0.46—0.84)	20.05 ± 1.42 (17.33—22.78)	0.32 ± 0.07 (0.21—0.51)	0	0.04 ± 0.04 (0—0.13)
	Tract Abundance	0	1,149 (812—1,491)	35,706 (30,861—40,573)	574 (370—907)	0	63 (0—234)
Honomalino	2005	0.74 ± 0.10 (0.54—1.00)	0	1.91 ± 0.16 (1.60—2.28)	0.83 ± 0.11 (0.61—1.12)	0	0
	2010	0.69 ± 0.20 (0.34—1.18)	0	5.60 ± 0.82 (4.09—7.31)	0.44 ± 0.09 (0.30—0.65)	0.06 ± 0.04 (0—0.17)	0
	2015-2016	0.47 ± 0.17 (0.19—0.89)	0.04 ± 0.02 (0.01—0.08)	4.10 ± 0.53 (3.02—5.11)	0.59 ± 0.09 (0.45—0.80)	0.14 ± 0.06 (0.05—0.28)	0.27 ± 0.09 (0.13—0.50)
	Tract Abundance	796 (323—1,509)	68 (18—133)	6,920 (5,095—8,628)	992 (756—1,354)	243 (80—476)	463 (218—848)
Kahuku	2005	0	0	2.36 ± 0.17 (2.02—2.76)	0.03 ± 0.01 (0.01—0.05)	0.33 ± 0.05 (0.24—0.45)	0
	2010	0.02 ± 0.01 (0—0.04)	0	2.34 ± 0.29 (1.77—2.93)	0.01 ± 0.01 (0—0.03)	0.59 ± 0.14 (0.39—0.97)	0

Table 6 (continued). Density and abundance of non-native forest birds in Hawai'i Volcanoes National Park. Density estimates (birds/ha ± SE and confidence intervals) for previous surveys were from Gorresen et al. (2005), Tweed et al. (2007), and the 2010 NPS I&M survey (Judge et al. 2011). Estimates from the 2015-2016 landbird survey are highlighted. Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	HOFI	JABW	JAWE	NOCA	RBLE	YFCA
Kahuku (continued)	2015-2016	0.06 ± 0.03 (0.02—0.13)	0.01 ± 0.01 (0—0.03)	7.30 ± 0.56 (6.28—8.46)	0.02 ± 0.01 (0.01—0.06)	0.68 ± 0.12 (0.48—0.98)	0.43 ± 0.13 (0.24—0.76)
	Tract Abundance	659 (170—1,408)	164 (29—346)	80,206 (69,023—93,002)	273 (66—627)	7,468 (5,321—10,805)	4,681 (2,679—8,389)
Mauna Loa South Flank	2005	0.60 ± 0.10 (0.40—0.89)	0	3.25 ± 0.21 (2.85—3.71)	0.49 ± 0.05 (0.39—0.60)	0	0
	2010	1.07 ± 0.23 (0.72—1.67)	0	18.76 ± 1.46 (16.12—21.87)	0.62 ± 0.10 (0.47—0.87)	0.19 ± 0.06 (0.08—0.33)	0
	2015-2016	1.19 ± 0.20 (0.87—1.73)	0.05 ± 0.02 (0.01—0.10)	11.29 ± 0.79 (9.83—12.99)	0.29 ± 0.06 (0.20—0.42)	0.09 ± 0.06 (0—0.23)	1.54 ± 0.30 (1.12—2.26)
	Tract Abundance	5,485 (4,013—7,936)	249 (62—460)	51,875 (45,157—59,660)	1,342 (913—1,951)	396 (0—1,057)	7,062 (5,125—10,376)
Mauna Loa Strip	1986	0.73 ± 0.19 (0.36—1.11)	0	4.78 ± 0.54 (3.73—5.84)	0.20 ± 0.03 (0.15—0.26)	0.96 ± 0.13 (0.71—1.22)	0
	1987	0.97 ± 0.14 (0.70—1.25)	0	6.73 ± 0.72 (5.32—8.15)	0.29 ± 0.04 (0.22—0.37)	1.22 ± 0.13 (0.97—1.48)	0
	1990	1.46 ± 0.31 (0.86—2.07)	0	7.27 ± 0.81 (5.69—8.86)	0.26 ± 0.03 (0.21—0.32)	0.29 ± 0.07 (0.16—0.43)	0
	1991	1.36 ± 0.27 (0.84—1.89)	0	8.45 ± 0.91 (6.67—10.24)	0.32 ± 0.04 (0.25—0.40)	0.06 ± 0.03 (0.01—0.12)	0
	1992	0.59 ± 0.16 (0.28—0.91)	0	7.98 ± 0.63 (6.75—9.22)	0.22 ± 0.03 (0.17—0.28)	0.29 ± 0.06 (0.18—0.41)	0
	1993	0.78 ± 0.14 (0.51—1.06)	0	9.72 ± 0.92 (7.92—11.53)	0.22 ± 0.03 (0.17—0.28)	0.25 ± 0.07 (0.12—0.39)	0

Table 6 (continued). Density and abundance of non-native forest birds in Hawai'i Volcanoes National Park. Density estimates (birds/ha ± SE and confidence intervals) for previous surveys were from Gorresen et al. (2005), Tweed et al. (2007), and the 2010 NPS I&M survey (Judge et al. 2011). Estimates from the 2015-2016 landbird survey are highlighted. Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	HOFI	JABW	JAWF	NOCA	RBLE	YFCA
Mauna Loa Strip (continued)	1994	0.83 ± 0.21 (0.42—1.25)	0	10.83 ± 0.93 (9.01—12.66)	0.30 ± 0.04 (0.23—0.38)	0.50 ± 0.10 (0.31—0.70)	0
	2010	0.05 ± 0.02 (0.01—0.11)	0	9.97 ± 1.10 (8.03—12.20)	0.13 ± 0.04 (0.07—0.22)	0.45 ± 0.16 (0.21—0.85)	0
	2015-2016	0.14 ± 0.05 (0.05—0.26)	0.05 ± 0.02 (0.02—0.09)	9.88 ± 1.29 (7.56—12.49)	0.66 ± 0.10 (0.52—0.88)	0.44 ± 0.16 (0.19—0.82)	0.03 ± 0.03 (0—0.11)
	Tract Abundance	430 (146—826)	162 (60—284)	31,433 (24,062—39,724)	2,101 (1,653—2,801)	1,393 (598—2,614)	96 (0—346)
Northwest Kahuku	2005	0.53 ± 0.14 (0.25—1.14)	0	1.88 ± 0.31 (1.27—2.79)	0.10 ± 0.03 (0.04—0.23)	0	0
	2010	0.28 ± 0.09 (0.14—0.48)	0	0.38 ± 0.23 (0—0.88)	0.10 ± 0.03 (0.05—0.17)	0	0
	2015-2016	0.86 ± 0.16 (0.62—1.29)	0	0.20 ± 0.12 (0—0.49)	0.16 ± 0.04 (0.09—0.25)	0	0.07 ± 0.04 (0.01—0.16)
	Tract Abundance	759 (547—1,139)	0	179 (0—436)	142 (79—221)	0	61 (12—146)
‘Ōla’a	1992	0.03 ± 0.02 (0—0.07)	0	4.46 ± 0.47 (3.54—5.39)	0.08 ± 0.02 (0.05—0.12)	0	0
	1993	0.16 ± 0.05 (0.07—0.26)	0	15.57 ± 0.81 (13.99—17.16)	0.33 ± 0.06 (0.22—0.45)	0.16 ± 0.06 (0.05—0.28)	0
	1994	0.10 ± 0.04 (0.03—0.18)	0	17.44 ± 0.81 (15.86—19.03)	0.42 ± 0.06 (0.31—0.54)	0.24 ± 0.07 (0.11—0.38)	0
	2010	0	0	27.72 ± 1.45 (24.85—30.53)	0.42 ± 0.09 (0.28—0.65)	0.81 ± 0.22 (0.46—1.37)	0

Table 6 (continued). Density and abundance of non-native forest birds in Hawai'i Volcanoes National Park. Density estimates (birds/ha ± SE and confidence intervals) for previous surveys were from Gorresen et al. (2005), Tweed et al. (2007), and the 2010 NPS I&M survey (Judge et al. 2011). Estimates from the 2015-2016 landbird survey are highlighted. Total abundance was calculated as mean density of tract estimates weighted by tract area for each species.

Tract	Survey Year	HOFI	JABW	JAWF	NOCA	RBLE	YFCA
‘Ōla’a (continued)	2015-2016	0.02 ± 0.02 (0—0.07)	0.38 ± 0.07 (0.25—0.52)	28.98 ± 1.98 (25.21—33.39)	0.43 ± 0.08 (0.30—0.62)	1.04 ± 0.23 (0.68—1.66)	0.01 ± 0.01 (0—0.04)
	Tract Abundance	47 (0—163)	940 (613—1,273)	70,887 (61,657—81,661)	1,041 (737—1,524)	2,540 (1,660—4,058)	31 (0—108)
Pāpā	2005	0.56 ± 0.21 (0.15—2.14)	0	2.86 ± 0.46 (1.96—4.16)	0.58 ± 0.13 (0.33—0.99)	0	0
	2010	0.25 ± 0.13 (0.04—0.54)	0	0.62 ± 0.33 (0—1.29)	0.06 ± 0.06 (0—0.20)	0	0
	2015-2016	0.57 ± 0.25 (0.13—1.18)	0	2.78 ± 0.94 (1.20—4.78)	0.85 ± 0.21 (0.50—1.34)	0.20 ± 0.19 (0—0.63)	0.92 ± 0.35 (0.41—1.82)
	Tract Abundance	186 (43—387)	0	913 (396—1,571)	278 (165—441)	65 (0—209)	303 (134—599)
Total Abundance		8,362 ± 1,159 (6,534-10,903)	2,732 ± 362 (2,041-3,467)	278,119 ± 16,103 (247,803-309,481)	6,743 ± 814 (5,355-8,551)	12,105 ± 1,968 (8,826-16,144)	12,760 ± 2,509 (8,634-18,399)

Native Species Summaries

‘Akiapola‘au

The federally and state listed endangered ‘Akiapola‘au were not detected during the survey effort. Two individuals were incidentally recorded on legacy transect 22—station 16 within the Ka‘ū Forest Reserve in the Kahuku tract. The sightings were near 1,600 m in elevation near the edges of moist mesic ‘ōhi‘a and koa co-dominated forest. Larvae of the koa long-horned beetle (*Megopis reflexa*) are the ‘Akiapola‘au’s primary food source and are only found in koa trees. Koa was relatively sparse in the Kahuku tract and may be the limiting factor for ‘Akiapola‘au populations in this area.

‘Apapane

‘Apapane were the most abundant native bird in the survey: the species was detected at nearly every station in every tract (Table 7; Figures A-1 and A-2). Densities were highest in the Kahuku, Honomalino, and East Rift Zone tracts at 26.6, 17.4, and 15.9 birds/ha, respectively. ‘Apapane density was lowest at the dry sub-alpine woodland in the Northwest Kahuku tract (3.07 birds/ha). Trends were statistically inconclusive in most tracts, but occurrence remained high and density was increasing in the ‘Ōla’a tract (Table 7).

Table 7. ‘Apapane trends, density (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
APAP	East Rift Zone	Inconclusive	15.86 ± 1.49 (12.98—18.27)	28,249 (23,123—32,532)	100
	Honomalino	Inconclusive	17.38 ± 1.78 (13.87—20.39)	29,343 (23,407—34,418)	100
	Kahuku	Inconclusive	26.62 ± 2.24 (22.10—30.59)	292,570 (242,870—336,200)	95.85
	Mauna Loa South Flank	Inconclusive	6.36 ± 0.91 (4.64—8.02)	29,232 (21,296—36,817)	66.67
	Mauna Loa Strip	Inconclusive	10.86 ± 1.20 (8.38—12.87)	34,550 (26,658—40,942)	100
	Northwest Kahuku	Inconclusive	3.07 ± 0.56 (2.01—4.08)	2,712 (1,778—3,610)	77.91
	‘Ōla’a	Increasing	17.13 ± 1.64 (13.80—19.85)	41,893 (33,748—48,563)	76.34
	Pāpā	Inconclusive	12.10 ± 1.88 (8.42—15.68)	3,982 (2,769—5,159)	100
Total		—	—	462,531 ± 38,853 (395,575—550,237)	88.38

Hawai'i 'Akepa

Hawai'i 'Akepa were detected in low numbers in the Kahuku tract (55 individuals at 15.5% of stations surveyed; Table 8). The detections straddled the HAVO and Ka'ū Forest Reserve boundary near the 1,600-1,900 m elevations (Figure A-3). The species was detected in both sub-alpine woodlands and lower mature montane 'ōhi'a forests. The abundance estimate was 3,407 (2,308—44,287) birds in the tract, however we consider the high end biologically unrealistic and advise a conservative interpretation. Trends were inconclusive, but the distribution was greater than detected in 2010.

Table 8. Hawai'i 'Akepa trends, density (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
HAAK	East Rift Zone	N/A	0	0	0
	Honomalino	N/A	0	0	0
	Kahuku	Inconclusive	0.31 ±0.34 (0.21—4.03)	3,407 (2,308—44,287)	15.54
	Mauna Loa South Flank	N/A	0	0	0
	Mauna Loa Strip	N/A	0	0	0
	Northwest Kahuku	N/A	0	0	0
	'Ōla'a	N/A	0	0	0
	Pāpā	N/A	0	0	0
Total		–	–	3,407 (2,308—44,287)	3.96

Hawai'i 'Amakihi

Hawai'i 'Amakihi were abundant and widespread throughout most tracts (Table 9; Figures A-4 and A-5). Densities were highest in the seasonally mesic leeward Honomalino tract, Mauna Loa South Flank tract, and Mauna Loa Strip tract with 10.91, 9.67, and 9.34 birds/ha, respectively. Hawai'i 'Amakihi occurred in lower densities in the wetter windward tracts, particularly 'Ōla'a where there were only 10 detections, estimated at 0.03 birds/ha. Density was also low in the East Rift Zone tract, estimated at 0.38 birds/ha. Point transect count data from previous surveys indicate an increasing trend in the Kahuku and Mauna Loa Strip tracts. There was a declining trend in the sub-alpine Northwest Kahuku tract. Densities were stable or inconclusive in the remaining tracts (Table 9).

Table 9. Hawai‘i ‘Amakihi trends, density (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
HAAM	East Rift Zone	Inconclusive	0.38 ± 0.14 (0.12—0.73)	672 (222—1,301)	10.45
	Honomalino	Decreasing	10.91 ± 1.07 (9.39—13.66)	18,423 (15,859—23,056)	99
	Kahuku	Increasing	6.86 ± 0.55 (6.14—8.30)	75,376 (67,442—91,173)	92.23
	Mauna Loa South Flank	Inconclusive	9.67 ± 0.79 (8.60—11.74)	44,432 (39,481—53,905)	97.44
	Mauna Loa Strip	Increasing	9.34 ± 0.94 (7.97—11.85)	29,705 (25,357—37,692)	98.73
	Northwest Kahuku	Decreasing	8.28 ± 0.81 (7.03—10.35)	7,323 (6,210—9,151)	100
	‘Ōla’a	Stable	0.03 ± 0.03 (0—0.09)	66 (0—222)	1.08
	Pāpā	Inconclusive	8.96 ± 1.37 (6.75—12.22)	2,947 (2,219—4,021)	100
Total		–	–	178,944 ± 13,278 (156,005—205,617)	–

Hawai‘i Creeper

The federally and state listed endangered Hawai‘i Creeper was detected in small numbers in the Kahuku and Honomalino tracts (25 and 1, respectively; Table 10; Figure A-6). Occupancy was highest in the ‘ōhi’a, koa, and ‘ōlapa co-dominated moderately wet montane forests of the Kahuku tract where the species forages for insects in the bark of large statured trees. Fortunately, the densities of this rare honeycreeper are increasing in Kahuku. The single Honomalino detection was consistent with our low Hawai‘i Creeper detections in 2010 (3 individuals).

Table 10. Hawai'i Creeper trends, density (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
HACR	East Rift Zone	N/A	0	0	0
	Honomalino	Stable	0.01 (0.00—0.05)	17 (0.00—84.4)	1
	Kahuku	Increasing	0.16 ± 0.07 (0.06—0.34)	1,758 (659—3,736)	7.25
	Mauna Loa South Flank	N/A	0	0	0
	Mauna Loa Strip	N/A	0	0	0
	Northwest Kahuku	N/A	0	0	0
	‘Ōla’a	N/A	0	0	0
	Pāpā	N/A	0	0	0
	Total	–	–	1,773 ± 849 (616—3,888)	–

Hawai'i Elepaio

Hawai'i Elepaio were detected at five of the eight tracts (Table 11; Figures A-7 and A-8). Densities were highest in the Mauna Loa Strip tract (0.80 birds/ha) occurring at 34.2% of all the stations surveyed. 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 Pāpā tracts. Trends are stable or inconclusive in the remaining tracts (Table 11).

Table 11. Hawai'i Elepaio trends, density, (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
HAEL	East Rift Zone	N/A	0	0	0
	Honomalino	Inconclusive	0.58 ± 0.24 (0.28—1.34)	986 (470—2,257)	16
	Kahuku	Stable	0.19 ± 0.07 (0.09—0.44)	2,129 (1,043—4,847)	6.74
	Mauna Loa South Flank	N/A	0	0	0
	Mauna Loa Strip	Inconclusive	0.80 ± 0.30 (0.47—1.78)	2,541 (1,481—5,660)	34.18
	Northwest Kahuku	Stable	0.03 ± 0.03 (0—0.11)	24 (0—95)	2.33
	‘Ōla’a	Stable	0.23 ± 0.11 (0.05—0.56)	553 (125—1,370)	5.38
	Pāpā	N/A	0	0	0
Total		–	–	6,233 ± 2,003 (3,679—10,982)	–

Nēnē

Two Nēnē (Hawaiian Goose; *Branta sandvicensis*) were recorded incidentally in the Mauna Loa South Flank tract near 2,100 m elevation in a small stature ‘ōhi’a dominated seasonal mesic forest. Nēnē occur more commonly in mid-elevation seasonally dry ‘ōhi’a and shrublands on Kīlauea (Leopold and Hess 2013). Feral dogs were sighted within the Kahuku tract, and may pose a threat to the ground nesting Nēnē, a federally and state listed endangered species.

‘Io

Only six ‘Io (Hawaiian Hawk; *Buteo solitarius*), a federally and state listed endangered species, were detected in the East Rift Zone, ‘Ōla’a, Mauna Loa South Flank, and Kahuku tracts (Figures A-9 and A-10). Occurrence was low in each of the tracts (<2%); the highest was within a seasonal mesic ‘ōhi’a dominated Mauna Loa South Flank tract near 1,500 m. Densities were not calculated because of limited detections among tracts. 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, Pāpā, Honomalino, and ‘Ōla’a tracts with 1.79, 1.35, 0.43, and 0.22 birds/ha, respectively (Table 12; Figures A-11 and A-12). The Kahuku tract, where densities were highest, supports large stature ‘ōhi’a and koa trees and a predominantly native

understory. There was an increasing trend in the Pāpā population. Densities were low in the Mauna Loa Strip tract (0.07 birds/ha) and that population exhibited a decreasing trend. Zero birds were detected in the East Rift Zone tract where mosquitoes are common and temperatures allow avian malaria to persist. Similarly, zero birds were detected in the Northwest Kahuku tract where ‘ōhi‘a and māmane were relatively sparse. Densities were stable in the ‘Ōla’a tract and inconclusive at all other tracts because of relatively high levels of uncertainty in the density estimates (Table 12).

Table 12. ‘Iiwi trends, density, (birds/ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
IIWI	East Rift Zone	N/A	0	0	0
	Honomalino	Inconclusive	0.43 ± 0.13 (0.18—0.63)	723 (303—1,061)	22
	Kahuku	Inconclusive	1.79 ± 0.34 (0.99—2.14)	19,620 (10,892—23,564)	45.08
	Mauna Loa South Flank	N/A	0	0	0
	Mauna Loa Strip	Decreasing	0.07 ± 0.05 (0—0.17)	225 (0—534)	5.06
	Northwest Kahuku	Stable	0	0	0
	‘Ōla’a	Stable	0.22 ± 0.12 (0.03—0.45)	539 (83—1,091)	5.38
	Pāpā	Increasing	1.35 ± 0.52 (0.41—2.17)	446 (136—714)	45.45
Total		—	—	21,553 ± 3,949 (14,136—29,403)	—

‘Ōma’o

‘Ōma’o were detected in variable densities among tracts, from zero birds in three tracts to 1.40 birds/ha in the Kahuku tract where the birds occurred at 56% of the stations sampled (Table 13; Figures A-13 and A-14). Densities were highest in moist mesic and moderately wet climates co-dominated by ‘ōhi‘a, koa, ‘ōlapa, kawau (*Ilex anomala*) and olomea (*Perrottetia sandwicensis*). Large hapuu tree ferns (*Cibotium* spp.) and native shrubs (pilo [*Coprosma rhynchocarpa*], ohelo [*Vaccinium* spp], kanawao [*Broussaisia arguta*] etc.) dominated the understory and mid-canopy of tracts where ‘Ōma’o were most abundant. However, ‘Ōma’o 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 et al. 2012).

Table 13. ‘Ōma’o trends, density, (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
OMAO	East Rift Zone	Decreasing	0.93 ± 0.14 (0.68—1.26)	1,661 (1,209—2,246)	55.22
	Honomalino	N/A	0	0	0
	Kahuku	Increasing	1.40 ± 0.13 (1.19—1.69)	15,374 (13,127—18,609)	55.96
	Mauna Loa South Flank	Stable	0.31 ± 0.08 (0.17—0.48)	1,445 (780—2,225)	28.21
	Mauna Loa Strip	Stable	0.24 ± 0.07 (0.12—0.42)	764 (391—1,328)	26.58
	Northwest Kahuku	Decreasing	0	0	0
	‘Ōla’a	Increasing	0.59 ± 0.11 (0.40—0.83)	1,438 (968—2,039)	23.66
	Pāpā	Decreasing	0	0	0
	Total	—	—	20,682 ± 1,801 (17,343—24,342)	—

‘Ōma’o populations were only increasing in the Kahuku and ‘Ōla’a tracts. There was a steep decline in ‘Ōma’o densities within the East Rift Zone; where we estimated a density of 1.89 birds/ha in 2010, and estimated approximately half that figure in 2015 (0.93 birds/ha). There were also declining trends in the Northwest Kahuku and Pāpā tracts. Densities were stable in the Mauna Loa South Flank and Mauna Loa Strip tracts (Table 13).

Pacific Golden Plover

Three indigenous Pacific Golden Plovers (Kōlea; *Pluvialis fulva*) were recorded incidentally in the Mauna Loa South Flank tract near 1,250 m elevation. This tract is characterized by former pasturelands dominated by non-native grasses, one of the preferred wintering habitats of the migratory plover.

Non-Native Species Summaries

Barn Owl

Three Barn Owls (*Tyto alba*) were detected during sampling in the Mauna Loa Strip tract in 2015 (Figure A-15). The primarily nocturnal predator is cryptic in the daytime and often detected when disturbed in daylight hours.

California Quail

California Quail (*Callipepla californica*) were only detected in the Mauna Loa Strip and Northwest Kahuku tracts (A-16). Percent occurrence was highest (0.28 birds per station) 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 1.08% of the stations surveyed in the ‘Ōla’a tract (A-17). Mynas are not typical of dense intact native forests and usually occur in disturbed habitat near human habitations.

Erckel’s Francolin

The Erckel’s Francolin (*Francolinus erckelii*) was detected at six of the eight tracts surveyed in 2015 and 2016 (Figures A-18 and A-19). Percent occurrence was highest in the upper elevations of Honomalino and Northwest Kahuku (0.77 and 1.19 birds/station, respectively) in open canopy forests where native and exotic grasses persist.

Skylark

The Skylark (*Alauda arvensis*) was only detected in open grass and shrublands in the Mauna Loa South Flank, Mauna Loa Strip, Northwest Kahuku, and Pāpā tracts (96 total detections; Figures A-20 and A-21). Percent occupancy was highest in Northwest Kahuku (0.44 birds/station) in sub-alpine sparse ‘ōhi’a forests with open and grassy understory. The species is most often observed singing high in the air, often in a hovering position.

Hwamei

The Hwamei (Melodious Laughing Thrush; *Garrulax canorus*) was absent from most tracts and detected in low numbers in the East Rift Zone and Mauna Loa Strip tracts (1.32% occurrence combined; Figure A-31). 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. (1986) reported the species as having a “dynamic” range, and fluctuations in presence may be expected.

House Finch

The House Finch was detected in seven of the eight tracts surveyed (Table 14; Figures A-22 and A-23). Densities were highest in the pasturelands of the large stature open canopy ‘ōhi’a forests of the Mauna Loa South Flank tract (1.19 birds/ha). The birds were absent in the moderately wet East Rift Zone tract. Many birds were not counted during surveys because they were usually seen flying over sampling areas. Trends were predominantly stable or inconclusive, except in the Northwest Kahuku tract where densities were increasing (Table 14).

Table 14. House Finch trends, density, (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
HOFI	East Rift Zone	N/A	0	0	0
	Honomalino	Inconclusive	0.47 ± 0.17 (0.19—0.89)	796 (323—1,509)	20
	Kahuku	Stable	0.06 ± 0.03 (0.02—0.13)	659 (170—1,408)	3.11
	Mauna Loa South Flank	Inconclusive	1.19 ± 0.20 (0.87—1.73)	5,485 (4,013—7,936)	52.99
	Mauna Loa Strip	Stable	0.14 ± 0.05 (0.05—0.26)	430 (146—826)	11.39
	Northwest Kahuku	Increasing	0.86 ± 0.16 (0.62—1.29)	759 (547—1,139)	47.67
	‘Ōla’a	Stable	0.02 ± 0.02 (0—0.07)	47 (0—163)	1.08
	Pāpā	Inconclusive	0.57 ± 0.25 (0.04—0.54)	186 (43—387)	31.82
Total		–	–	8,362 ± 1,159 (6,534-10,903)	–

Japanese Bush Warbler

The Japanese Bush Warbler was detected in six of the eight tracts surveyed and ranged from zero to 56.7% occurrence (Table 15; Figures A-24 and A-25). Densities were highest in the wet mesic East Rift Zone and ‘Ōla’a tracts (0.65 birds/ha and 0.38 birds/ha, respectively). Zero birds were detected in the drier Pāpā and Northwest Kahuku tracts. The species has been expanding throughout Hawai‘i Island since colonizing in 1997 (Nelson and Vitts 1998), and trends were increasing in the majority of tracts the species was detected (Table 15). This species is extremely vocal during the breeding season but stops vocalizing shortly after and becomes virtually non-detectable. Therefore, caution is advised when assessing the distribution and abundance of this species and when comparing between surveys.

Table 15. Japanese Bush Warbler trends, density, (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
JABW	East Rift Zone	Increasing	0.65 ± 0.10 (0.46—0.84)	1,149 (812—1,491)	56.72
	Honomalino	Increasing	0.04 ± 0.02 (0.01—0.08)	68 (18—133)	14
	Kahuku	Stable	0.01 ± 0.01 (0—0.03)	164 (29—346)	2.07
	Mauna Loa South Flank	Increasing	0.05 ± 0.02 (0.01—0.10)	249 (62—460)	5.13
	Mauna Loa Strip	Increasing	0.05 ± 0.02 (0.02—0.09)	162 (60—284)	8.86
	Northwest Kahuku	N/A	0	0	0
	‘Ōla’a	Increasing	0.38 ± 0.07 (0.25—0.52)	940 (613—1,273)	39.78
	Pāpā	N/A	0	0	0
	Total	—	—	2,732 ± 362 (2,041-3,467)	—

Japanese White-eye

The Japanese White-eye was the most abundant and widespread of the non-native species (Table 16; Figures A-26 and A-27). Densities were highest in the moderately wet and moist mesic climates of the ‘Ōla’a, East Rift Zone and Mauna Loa South Flank tracts (29.0, 20.1, and 11.3 birds/ha, respectively). Densities were far lower in the leeward māmane and naio dominated Northwest Kahuku tract (0.20 bird/ha). Trend results were variable with a notable increasing trend in the Kahuku and Pāpā tracts. Despite a 97% occurrence in the Mauna Loa South Flank tract, there was a decreasing trend in densities there, down from 18.8 birds/ha in 2010 to 11.3 birds/ha in 2015. The remaining tracts were stable or inconclusive because of relatively high uncertainty in density estimates (Table 16).

Table 16. Japanese White-eye trends, density, (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	Percent Occurrence within Tract
JAWE	East Rift Zone	Inconclusive	20.05 ± 1.42 (17.33—22.78)	35,706 (30,861—40,573)	100
	Honomalino	Inconclusive	4.10 ± 0.53 (3.02—5.11)	6,920 (5,095—8,628)	55
	Kahuku	Increasing	7.30 ± 0.56 (6.28—8.46)	80,206 (69,023—93,002)	72.02
	Mauna Loa South Flank	Decreasing	11.29 ± 0.79 (9.83—12.99)	51,875 (45,157—59,660)	97.44
	Mauna Loa Strip	Inconclusive	9.88 ± 1.29 (7.56—12.49)	31,433 (24,062—39,724)	79.75
	Northwest Kahuku	Stable	0.20 ± 0.12 (0—0.49)	179 (0—436)	9.30
	‘Ōla’a	Inconclusive	28.98 ± 1.98 (25.21—33.39)	70,887 (61,657—81,661)	76.34
	Pāpā	Increasing	2.78 ± 0.94 (1.20—4.78)	913 (396—1,571)	63.64
Total		—	—	278,119 ± 16,103 (247,803-309,481)	—

Kalij Pheasant

Kalij Pheasants (*Lophura leucomelanos*) were detected in six of the eight tracts, though only in low numbers (28 detections; Figures A-28 and A-29). The species is restricted to the understory and is cryptic in nature, potentially causing underestimates of occurrence.

Lavender Waxbill

The Lavender Waxbill was detected for the first time during HAVO landbird surveys. The species was only detected in the Mauna Loa South Flank tract (Figure A-30). There were 39 total detections averaging 0.05 birds/station, a 1.45% occurrence in the tract.

Northern Cardinal

The Northern Cardinal was detected in every tract in low densities (Table 17; Figures A-33 and A-34). Densities were highest in the open canopy sub-alpine woodland Pāpā tract (0.85 birds/ha). Trend data was variable with increasing densities in the Mauna Loa Strip and Pāpā tracts. Densities were decreasing only in the Mauna Loa South Flank and stable or inconclusive in the remaining tracts (Table 17). Northern Cardinals were introduced to the islands in 1929 (Scott et al. 1986), and occur in both native and non-native forests.

Table 17. Northern Cardinal trends, density, (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	% Occurrence within Tract
NOCA	East Rift Zone	Inconclusive	0.32 ± 0.07 (0.21—0.51)	574 (370—907)	35.82
	Honomalino	Inconclusive	0.59 ± 0.09 (0.45—0.80)	992 (756—1,354)	60
	Kahuku	Stable	0.02 ± 0.01 (0.01—0.06)	273 (66—627)	2.59
	Mauna Loa South Flank	Decreasing	0.29 ± 0.06 (0.20—0.42)	1,342 (913—1,951)	30.77
	Mauna Loa Strip	Increasing	0.66 ± 0.10 (0.52—0.88)	2,101 (1,653—2,801)	64.56
	Northwest Kahuku	Stable	0.16 ± 0.04 (0.09—0.25)	142 (79—221)	22.09
	‘Ōla’a	Stable	0.43 ± 0.08 (0.30—0.62)	1,041 (737—1,524)	40.86
	Pāpā	Increasing	0.85 ± 0.21 (0.50—1.34)	278 (165—441)	77.27
Total		–	–	6,743 ± 814 (5,355–8,551)	–

Northern Mockingbird

The Northern Mockingbird (*Mimus polyglottos*) was only detected in the Northwest Kahuku tract, occurring at 3.4% of the stations sampled (Figure A-34). The species was first detected in 2010 after several previous surveys failed to detect it. Its continued presence indicates a stable and naturalized population in the dry sub-alpine sparse woodland of the Northwest Kahuku tract. The species was heard “mocking” Hawai‘i Elepaio, Hawai‘i ‘Apapane, Hawai‘i ‘Amakihi, and Skylarks. Both aural and visual sightings of the bird are recommended to confirm identification.

Red-billed Leiothrix

The Red-billed Leiothrix was the second most abundant and widespread non-native species detected in the survey (Table 18; Figures A-35 and A-36). The species was found in relatively similar densities among windward tracts, the highest in the ‘Ōla’a tract (1.0 birds/ha). The species was absent from the East Rift Zone and Northwest Kahuku tracts, and only 0.14 birds/ha were estimated in the Honomalino tract. Trend data was either stable or inconclusive in the remaining tracts (Table 18). The species was both intentionally and accidentally released on separate occasions in the early 20th century (Fisher and Baldwin 1947) and occurs throughout native and non-native forests.

Table 18. Red-billed Leiothrix trends, density, (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within each tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	% Occurrence within Tract
RBLE	East Rift Zone	Inconclusive	0	0	0
	Honomalino	Inconclusive	0.14 ± 0.06 (0.05—0.28)	243 (80—476)	8
	Kahuku	Stable	0.68 ± 0.12 (0.48—0.98)	7,468 (5,321—10,805)	20.73
	Mauna Loa South Flank	Stable	0.09 ± 0.06 (0—0.23)	396 (0—1,057)	1.71
	Mauna Loa Strip	Stable	0.44 ± 0.16 (0.19—0.82)	1,393 (598—2,614)	25.32
	Northwest Kahuku	N/A	0	0	0
	‘Ōla’a	Inconclusive	1.04 ± 0.23 (0.68—1.66)	2,540 (1,660—4,058)	34.41
	Pāpā	Inconclusive	0.20 ± 0.19 (0—0.63)	65 (0—209)	4.55
Total		—	—	12,105 ± 1,968 (8,826-16,144)	—

Saffron Finch

The Saffron Finch (*Sicalis flaveola*) was only detected in the Mauna Loa South Flank tract in low numbers (6 detections; 0.4% occurrence). The species is strongly associated with disturbed habitat, roadsides and proximity to human settlements. The species was first documented on Hawai‘i Island in 1966 (Berger 1981). We observed the species in former pasturelands in the lower elevations of the tract (Figure A-37).

Scaly-breasted Munia

Scaly-breasted Munia (*Lonchura punctulata*) were only detected in the pastures of the Mauna Loa South Flank tract, occurring at 1.9% of the stations surveyed (Figure A-38). The species is typical of grasslands and usually forage in small flocks.

Spotted Dove

The Spotted Dove (*Streptopelia chinensis*) was detected in the Honomalino and ‘Ōla’a tracts in low numbers (3 total individuals; Figure A-39 and A-40). The detections are likely representative of the proximity to human settlements where the species is common.

Yellow-fronted Canary

The Yellow-fronted Canary was detected in all eight tracts during 2015–2016 surveys (Table 19; Figures A-40 and A-41) but was only detected in the Mauna Loa South Flank tract in 2010. The

species was detected at 17.2% of all stations surveyed. Densities were highest in the Mauna Loa South Flank and Pāpā tracts (1.5 birds/ha and 0.9 birds/ha, respectively). The species was first recorded on leeward Hawai‘i 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 we observed a large expansion since the 2010 landbird survey, as indicated by increasing trends in 5 of the 8 tracts (Table 19).

Table 19. Yellow-fronted canary trends, density, (birds/Ha and 95% CI), abundance (including 95% CI), and occurrence within tract.

Species	Tract	Trend	Density (Birds/Ha)	Abundance	% Occurrence within Tract
YFCA	East Rift Zone	Inconclusive	0.04 ± 0.04 (0—0.13)	63 (0—234)	1.49
	Honomalino	Increasing	0.27 ± 0.09 (0.13—0.50)	463 (218—848)	14
	Kahuku	Increasing	0.43 ± 0.13 (0.24—0.76)	4,681 (2,679—8,389)	14.51
	Mauna Loa South Flank	Increasing	1.54 ± 0.30 (1.12—2.26)	7,062 (5,125—10,376)	59.83
	Mauna Loa Strip	Increasing	0.03 ± 0.03 (0—0.11)	96 (0—346)	2.53
	Northwest Kahuku	Stable	0.07 ± 0.04 (0.01—0.16)	61 (12—146)	5.81
	‘Ōla’a	Stable	0.01 ± 0.01 (0—0.04)	31 (0—108)	1.08
	Pāpā	Increasing	0.92 ± 0.35 (0.41—1.82)	303 (134—599)	40.91
Total		—	—	12,760 ± 2,509 (8,634-18,399)	—

Zebra Dove

The Zebra Dove (*Geopelia striata*) was detected in low numbers in the Mauna Loa South Flank tract during the survey (21 individuals at 11.97% of stations surveyed; Figure A-43). The species was found in a moderately wet ‘ōhi’a dominated forest. The species is common in lower elevation areas (<1,000 m) outside the range of the HAVO landbird study areas (S. Judge pers. obs.).

Habitat Surveys

Habitat variables were measured at a total of 736 landbird monitoring stations in 2015 and 2016. Canopy height, canopy cover, slope, aspect, slope variability, dominant understory classes of plants and/or substrate; as well as canopy classes were measured at each station. Each tract exhibited unique characteristics dependent on geographic position, elevation, rainfall levels and management history

(Table 20; Appendix B). ‘Ōhi‘a was the most commonly occurring tree species recorded at stations, followed by koa, ‘ōlapa, māmane, naio, *Myrsine* sp., and soapberry (*Sapindus saponaria*). Non-native trees did not dominate canopy in any plot, but several species were recorded at landbird stations, such as *Eucalyptus deglupta*, *Schinus terebinthifolius*, *Psidium cattleianum*, and *Myrica faya*. Canopy height and cover tended to decrease at higher elevations, such as in the montane/sub-alpine Northwest Kahuku tract. Slope and aspect were dependent on geographic position and were variable within each tract (Table 20, Appendix B). Understory classes were highly variable among tracts, ranging from bare lava to dense tangles of native shrubs and ferns (Appendix B). Species composition of the understory included the native a‘ali‘i (*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). Exotic grasses were common in both the Mauna Loa South Flank and Northwest Kahuku tracts where there was a history of ungulate grazing.

Table 20. Habitat variables most commonly recorded within each landbird monitoring tract. See Appendix B for occurrence of each habitat class recorded in each tract.

Tract	Mean Slope ± SE	Predominant Aspect	Dominant Understory	Dominant Canopy	Canopy Height	Canopy Cover
East Rift Zone	9 ± 1.38	West	Native Fern, Native Shrubs	‘ōhi‘a	> 10 m tall	>60% cover
Honomalino	13.2 ± 1.94	West	Exotic Grasses	‘ōhi‘a, koa	> 10 m tall	25-60% cover
Kahuku	15.7 ± 1.67	East	Native Shrubs, Native Grasses, Bare Ground	‘ōhi‘a	> 10 m tall	>60% cover
Mauna Loa South Flank	10.7 ± 2.23	West	Exotic Grasses	‘ōhi‘a	> 10 m tall	<5% cover
Mauna Loa Strip	11.3 ± 1.57	South	Bare Ground, Native Shrubs	‘ōhi‘a	5-10 m tall	0% cover
Northwest Kahuku	17.47 ± 2.07	West	Bare ground	māmane	5-10 m tall	0% cover
‘Ōla‘a	8.64 ± 1.57	West	Exotic Shrubs, Native Fern, Native Shrubs	‘ōhi‘a, ‘ōlapa	> 10 m tall	>60% cover
Pāpā	17.9 ± 2.99	West	Bare Ground	‘ōhi‘a	5-10 m tall	<5% cover

Comparison of Panel Data

A quantile-quantile (q-q) plot and Kolmogorov-Smirnov test were used to compare the distribution of bird densities between the panel members – fixed and random transects. The q-q plot indicated that there was little difference and no discernable systematic departures between the two quantile distributions (Figure 2). This was supported by the small D-statistic from the two-sample Kolmogorov-Smirnov test (D=0.0166), which was not statistically significant (p=0.61).

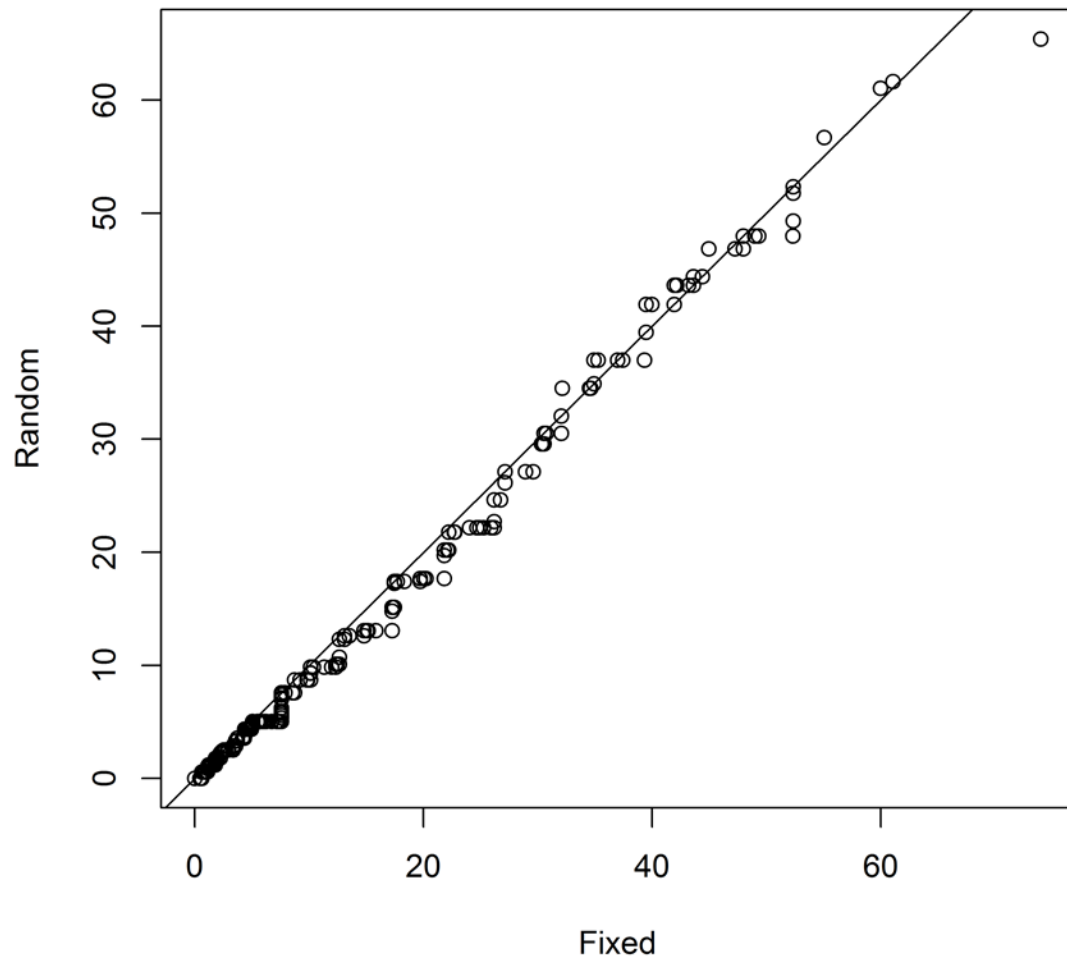


Figure 2. Q-Q plot of fixed transect to random transect quantiles indicate that there is little difference between the distributions.

Discussion

Landbirds

The 2015-2016 landbird survey within HAVO produced estimates of distribution and occurrence for all forest birds, and abundance and density of 5 native and 6 non-native forest bird species. Hawai‘i ‘Amakihi and ‘Apapane were the most abundant and widespread native species documented in the survey. Both species exhibited a general stable trend in density when compared to previous survey data; however, ‘Amakihi were rare or absent from the East Rift Zone and ‘Ōla’a tracts where avian malaria and very wet conditions may limit their populations. ‘Apapane in the Kahuku tract occurred in densities much higher than any other tract, and were nearly twice as dense as the populations of Hakalau National Wildlife Refuge (Gorreson et al. 2009, Camp et al. 2016). This may be partially attributable to the relatively lower densities of ‘I‘iwi, which can aggressively defend and competitively exclude other species of Hawaiian honeycreepers (Carpenter 1976).

‘I‘iwi occurred only in high elevation tracts, and trend data is mostly inconclusive, except in the Mauna Loa Strip tract where there was a significant decline. Avian malaria restricts ‘I‘iwi to elevations above 1,500 m where the presence of the disease and its vector-mosquito (*Culex quinquefasciatus*) drops due to cold temperature intolerance (Atkinson et al. 2000). ‘I‘iwi were not detected at the East Rift Zone and Mauna Loa South Flank tracts, both low elevation areas where avian malaria is likely prevalent. Interestingly, no birds were detected in the Northwest Kahuku tract, an area where they occurred at relatively high densities in 2005 (Tweed et al. 2007). Seasonal fluctuations in food resources may account for this absence, as the high elevation of this tract (>2000m) reduces the likelihood that avian malaria has played a significant role. The flower nectar of the ‘ōhi‘a is the ‘I‘iwi’s primary food resource, and seasonal peaks of ‘ōhi‘a bloom affect the birds’ density and distribution (Ralph and Fancy 1995, Hart et al. 2011). Māmane and naio are co-dominant trees in the Northwest Kahuku tract, and their flowers and fruits may be an additional food source for ‘I‘iwi when ‘ōhi‘a bloom is low (Hess et al. 2001). ‘Ōhi‘a bloom peaks from late winter through spring in most forests on Kilauea and Mauna Loa volcanoes (Hart et al. 2011). The 2016 Northwest Kahuku survey was conducted in May, possibly when most ‘I‘iwi were elsewhere in ‘ōhi‘a dominated forests. A similar occurrence was observed on the eastern slopes of Mauna Kea when ‘I‘iwi capture rates were higher in September-November in māmane dominated forests (Scott et al. 1986, Pratt et al. 1997).

‘Ōma’o were increasing in density only in the windward ‘Ōla’a and Kahuku tracts. There were no detections in any of the three leeward tracts. This species was detected in low numbers in the Pāpā tract in 2010 and represented the first sighting in leeward forests since 1978 (van Riper and Scott 1979, Scott et al. 1986). The reappearance of ‘Ōma’o in 2010 was significant because the species disperses native seeds and may be important to the restoration of native forests (Wakelee and Fancy 1999). The apparent population expansion could have been sourced from sup-alpine scrublands on Mauna Loa, or from lower elevation mesic windward forests (Judge et al. 2012). The species’ absence in 2016 may suggest that ‘Ōma’o have not become established in leeward mesic forests, and may instead be using the leeward forests periodically. Increasing trends in the Kahuku and particularly the ‘Ōla’a tract may be attributed to NPS management actions. Ungulate control efforts

have contributed to an increased abundance of native fruit-bearing trees and shrubs (Cole et al 2012), and thus may have led to an increase in ‘Ōma’o density since 2010.

Hawai‘i Elepaio were most abundant in the moderately dry native montane forest of the Mauna Loa Strip tract. The species was absent from the wet mesic East Rift Zone tract, the dry sub-alpine woodlands of the Pāpā tract, as well as the former pasturelands of Mauna Loa South Flank tract where there was little native understory. Hawai‘i Elepaio trend data are inconclusive in the remaining tracts and warrant further monitoring to detect any potential population changes. Previous surveys from leeward and mid-elevation windward tracts on Hawai‘i Island reported a decline in Elepaio densities (Gorresen et al. 2005, Camp et al 2009).

The endangered honeycreepers ‘Akiapola‘au, Hawai‘i ‘Akepa and Hawai‘i Creeper were concentrated in the mature montane ‘ōhi‘a and koa forests and sub-alpine woodlands of the Kahuku tract above 1,500 m elevation. We computed density estimates of Hawai‘i Akepa for the first time since PACN landbird monitoring began, and we expect to provide valuable trend data for this rare endangered honeycreeper with future surveys. More information is needed regarding the small population of Hawai‘i Creeper in the Kahuku and Honomalino tracts. There was only a single detection in Honomalino, and it is uncertain if that small population is stable or in decline. Similarly, there were only 25 detections in the Kahuku tract. All of the detections were within the Ka‘ū Forest Reserve where invasive weeds and ungulates are still a management concern. Only two ‘Akiapola‘au were observed during the survey effort (not during point counts), all within a small area of mature ‘ōhi‘a and koa forest within the Ka‘ū Forest Reserve. The standard PACN landbird point-transect survey may not be sufficient to provide an updated status of ‘Akiapola‘au in Kahuku. We suggest a coordinated and focused survey effort in HAVO and Ka‘ū Forest Reserve which would require a partnership with the State of Hawaii Department of Land and Natural Resources to determine the distribution and abundance of this rare and unique honeycreeper. The survey effort could include established HFBS transects and localized searches that identify specific areas vital for the species’ survival. Furthermore, more frequent landbird surveys would help determine if native species are rare or absent from some tracts because of seasonal variation or because of population decline.

Trends were primarily stable for non-native species that subsist in native forest. The Japanese White-eye remained the most widespread and abundant non-native species detected in the survey. The Red-billed Leiothrix and Northern Cardinal were also widespread in native forests. We observed notable changes in the assemblage of landbirds across the study area. For example, there was a very large expansion in distribution and densities of the Japanese Bush Warbler and Yellow-fronted Canary. In less than six years, both species established populations in almost all of the tracts surveyed. In addition, there was a large increase of occurrence of the Northern Mockingbird within the Northwest Kahuku tract. Finally, Lavender Waxbill was detected for the first time in our study area. The potential range of this species is unknown and will be monitored through future PACN landbird surveys.

Habitats

Our habitat survey followed 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 Hawai'i 'Amakihi included canopy cover as a covariate, indicating that canopy cover strongly influenced 'Amakihi detectability. The models for 'I'iwi 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.

Additionally, 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. Over time, park managers and researchers may use the information to determine habitat changes at these remote locations that are infrequently visited. With continuous monitoring, habitat surveys provide the needed clues for future management, such as ungulate and alien grass 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 Hawai'i 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 within each tract. However, the fixed panel members were a carry-over from previous surveys, and were initially established under a different sampling frame. Therefore, including them in the current I&M survey may have induced a bias in population parameters 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 and 2015-2016 I&M surveys; 2) probabilistic sampling required sampling units, transects and stations, be randomly located within the sampling frame (Thompson 2002); and 3) distance sampling required random placement of transects and stations 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 depicting a one-to-one

relationship in densities of the panel members and there was little systematic departure, which was supported by the non-significant Kolmogorov-Smirnov test. The sampling frames of the earlier surveys and I&M surveys were approximately the same for most of the HAVO tracts. The Honomalino, Kahuku, Northwest Kahuku, Pāpā and South Flank tracts had the same sampling frames, for example. The sampling frames for the East Rift Zone, Mauna Loa Strip, and ‘Ōla’a tracts were less similar but the differences were minor. In addition to maintaining similar sampling frames, a random subset of the legacy transects were selected and sampled for the fixed member panel. Those two approaches, maintaining consistent sampling frames and randomly selecting a subset of the legacy transects, minimized the differences between the fixed and random member panels. The later approach, randomly selecting a subset of the legacy transects, also ensured that the probabilistic sampling and distance sampling criteria were met.

Future investigation of the bird distributions is warranted when additional data is available. Our analytical approach investigating the cross-sectional data set is more appropriate for examining precision than they are for examining bias. The random members 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 nonsampling error can be fully investigated (O’Muircheartaigh 1989, Hsiao 2003). Moreover, evaluation for nonsampling error early in the monitoring program will provide an enormous potential to identify, treat and correct for errors, and with continuing surveys further assess modifications of field procedures.

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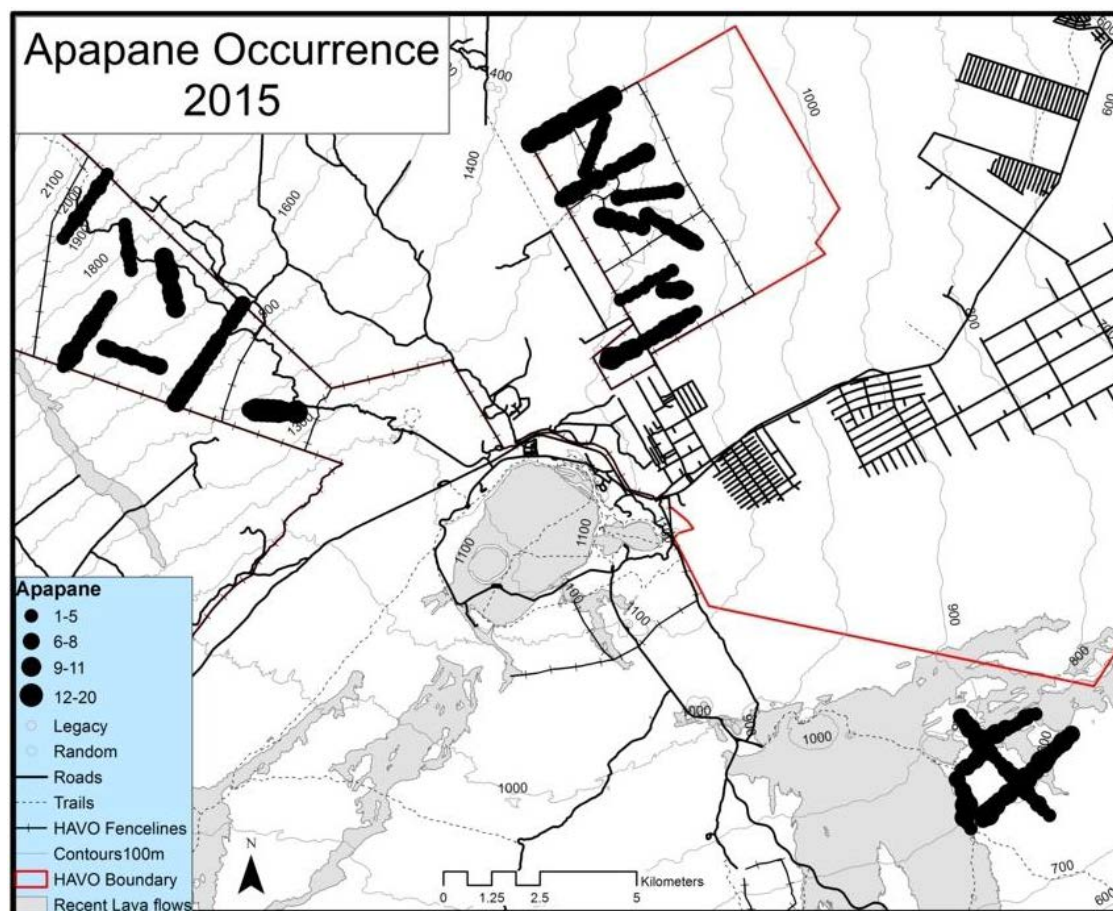


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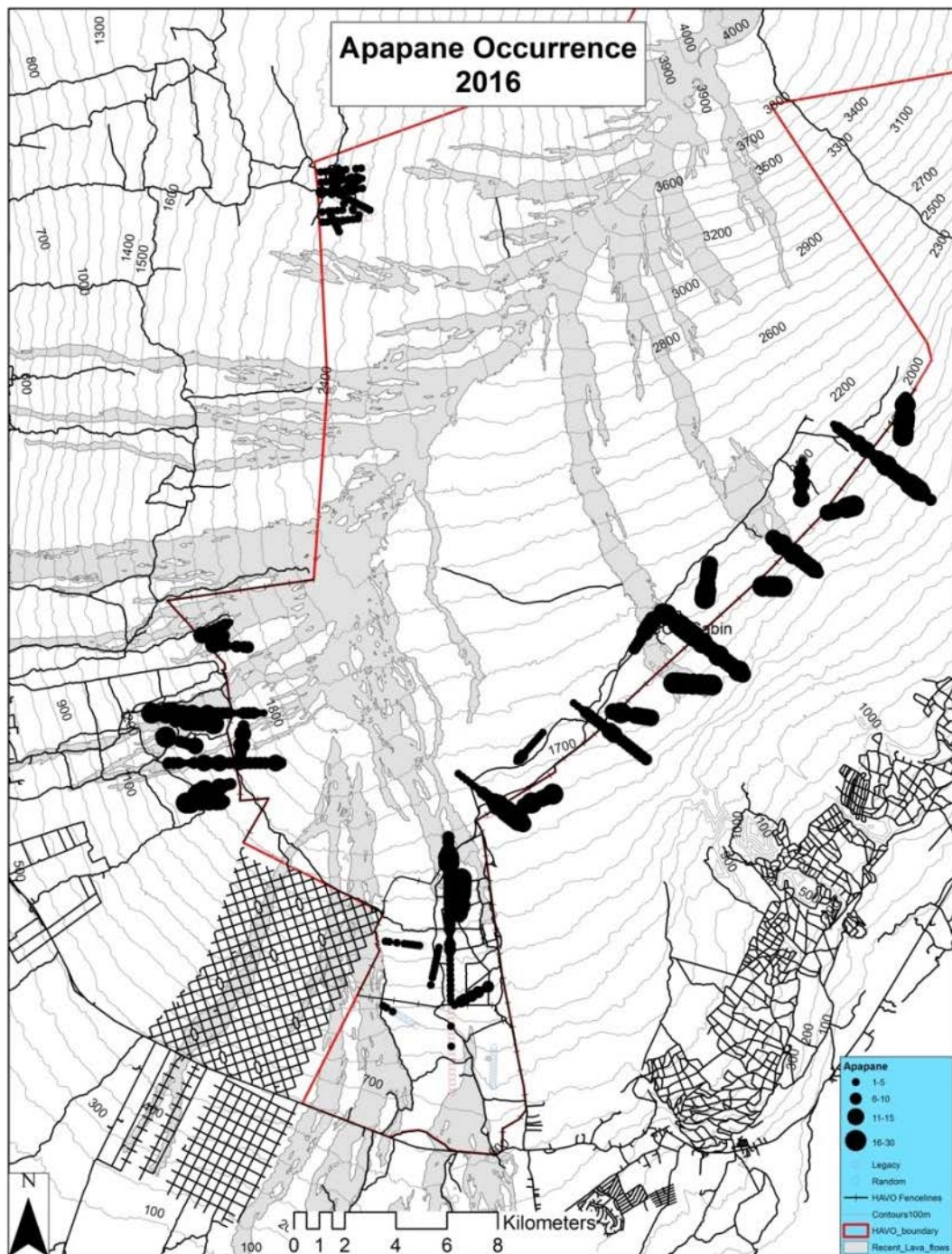


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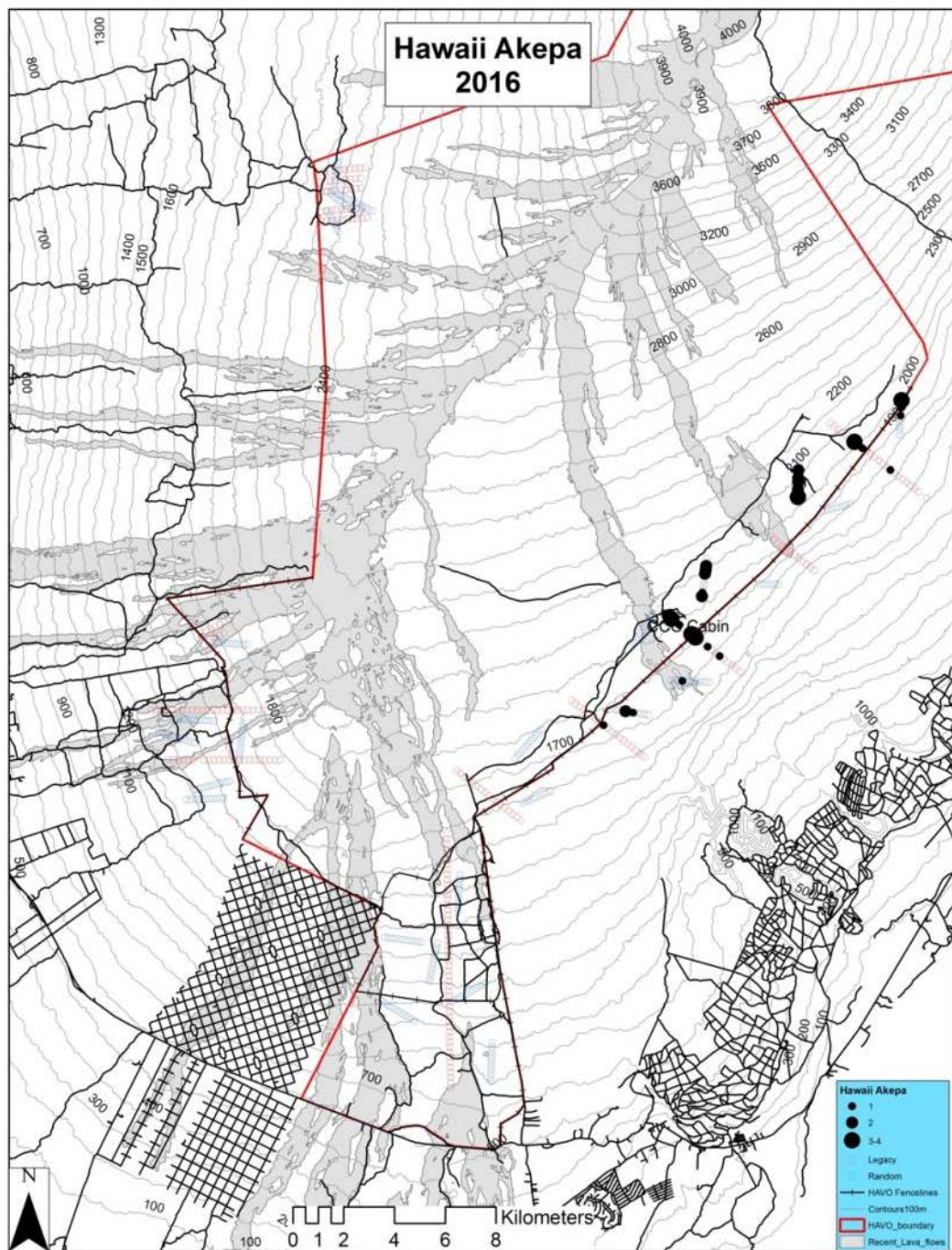


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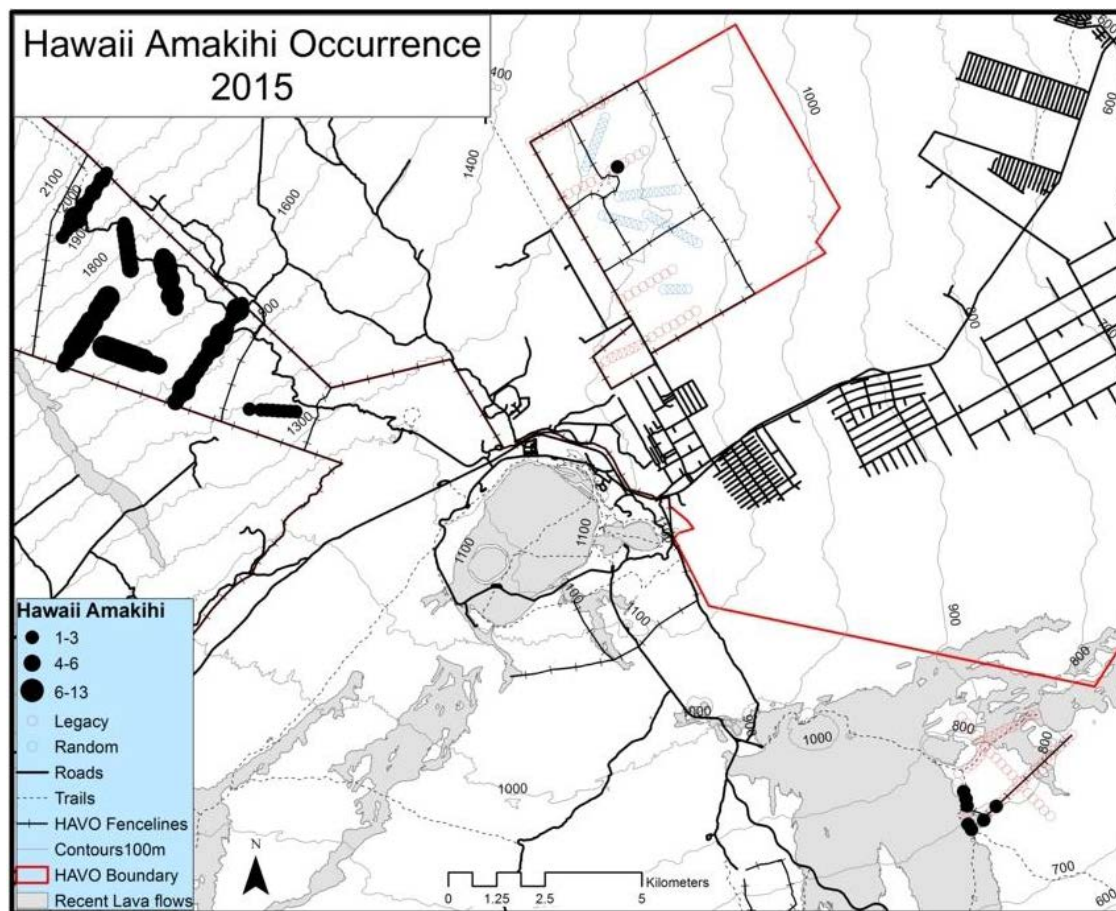


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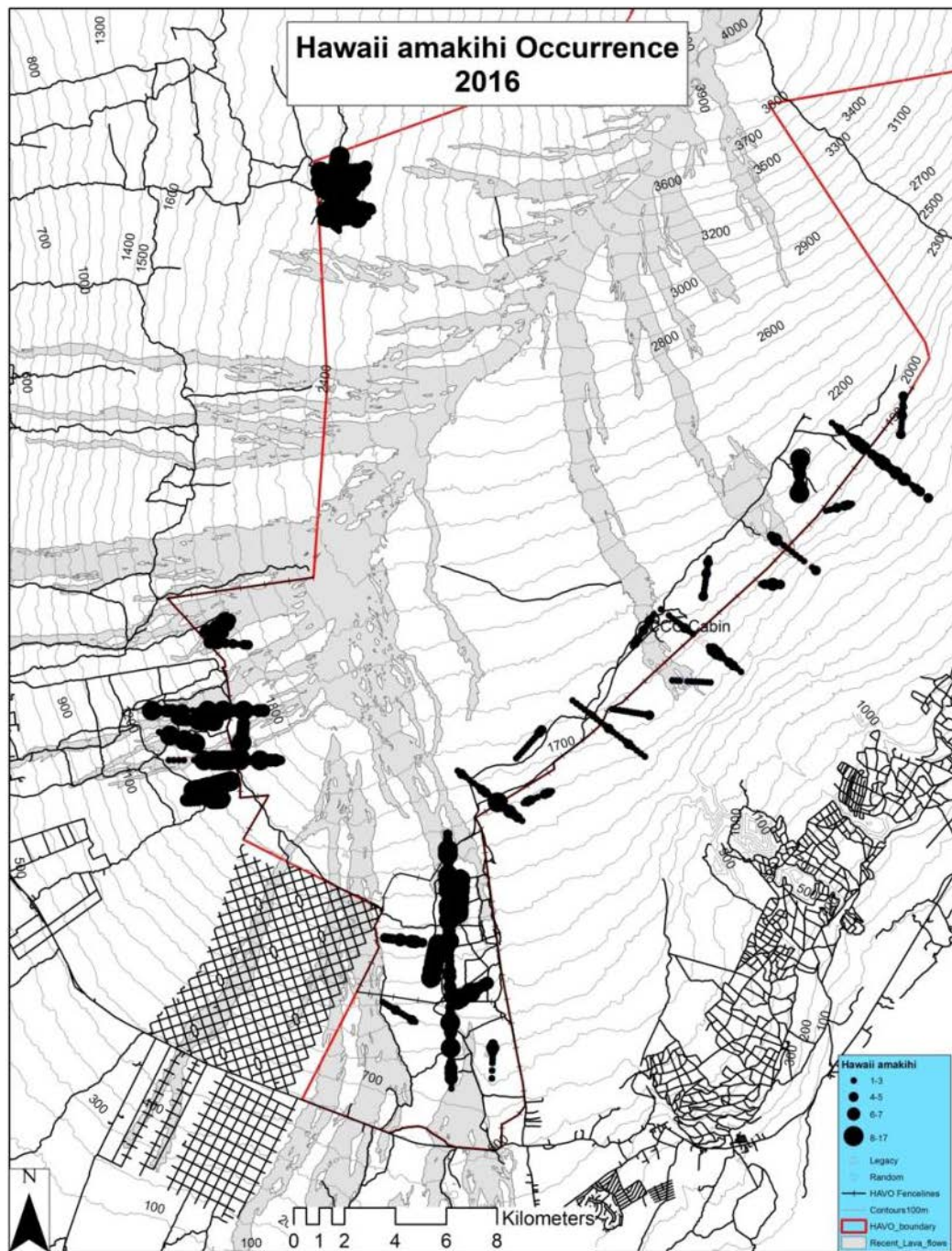


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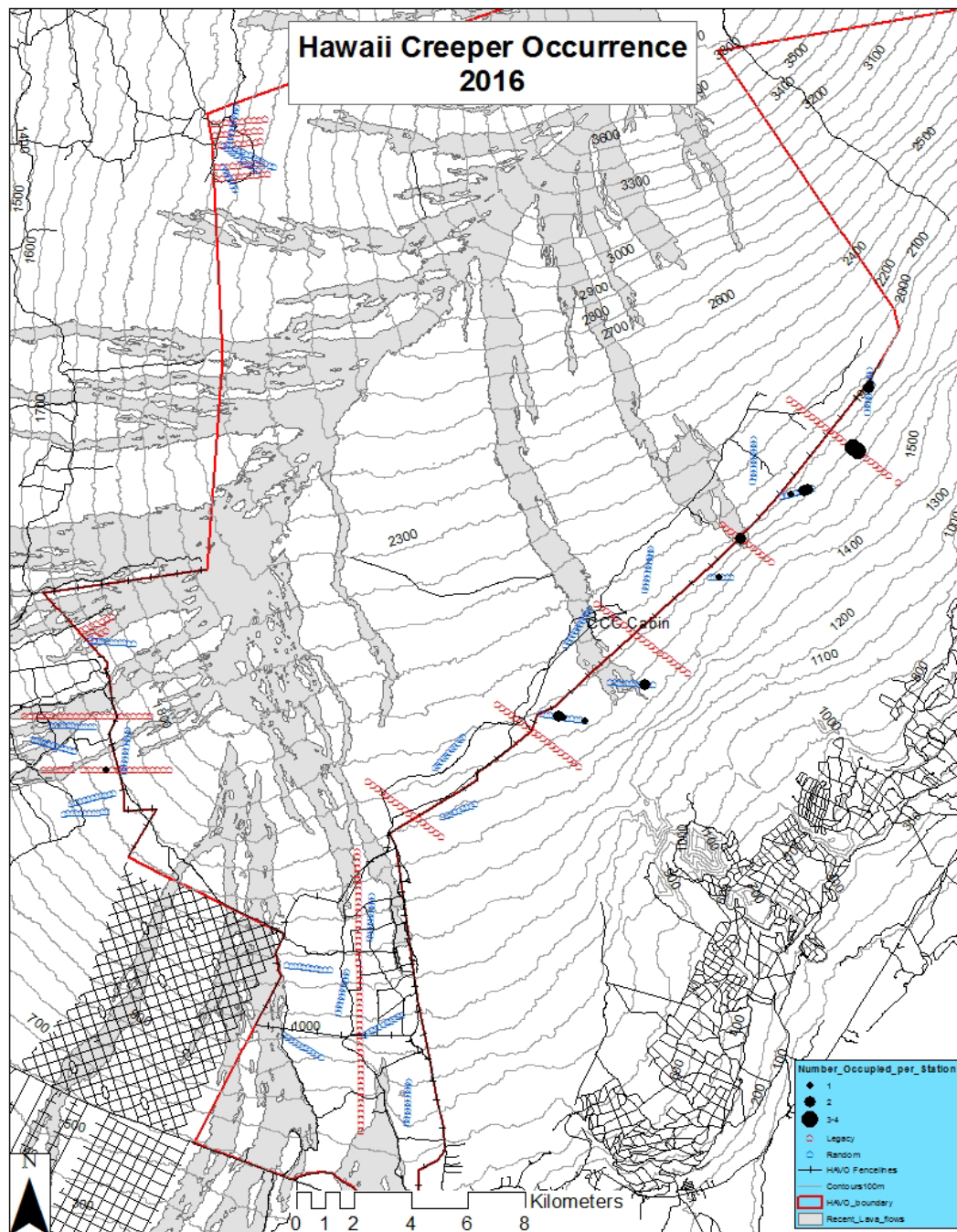


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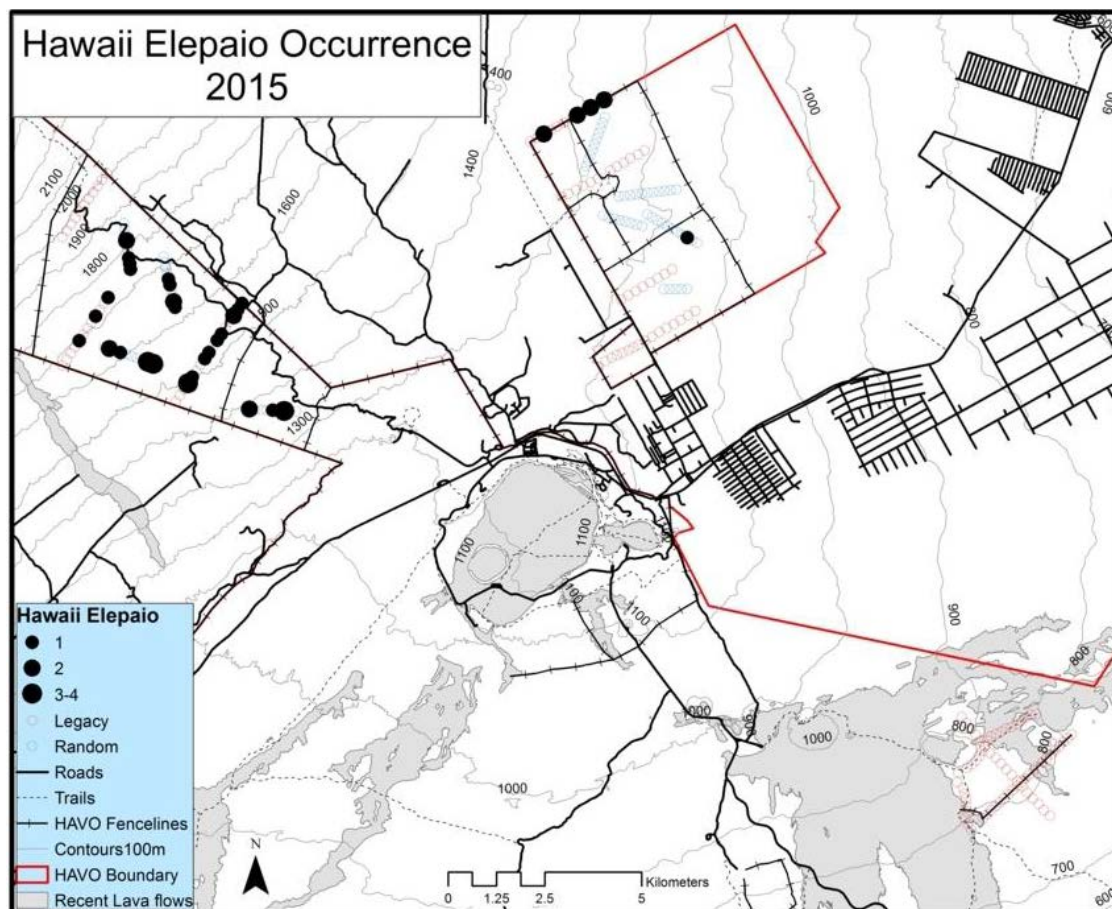


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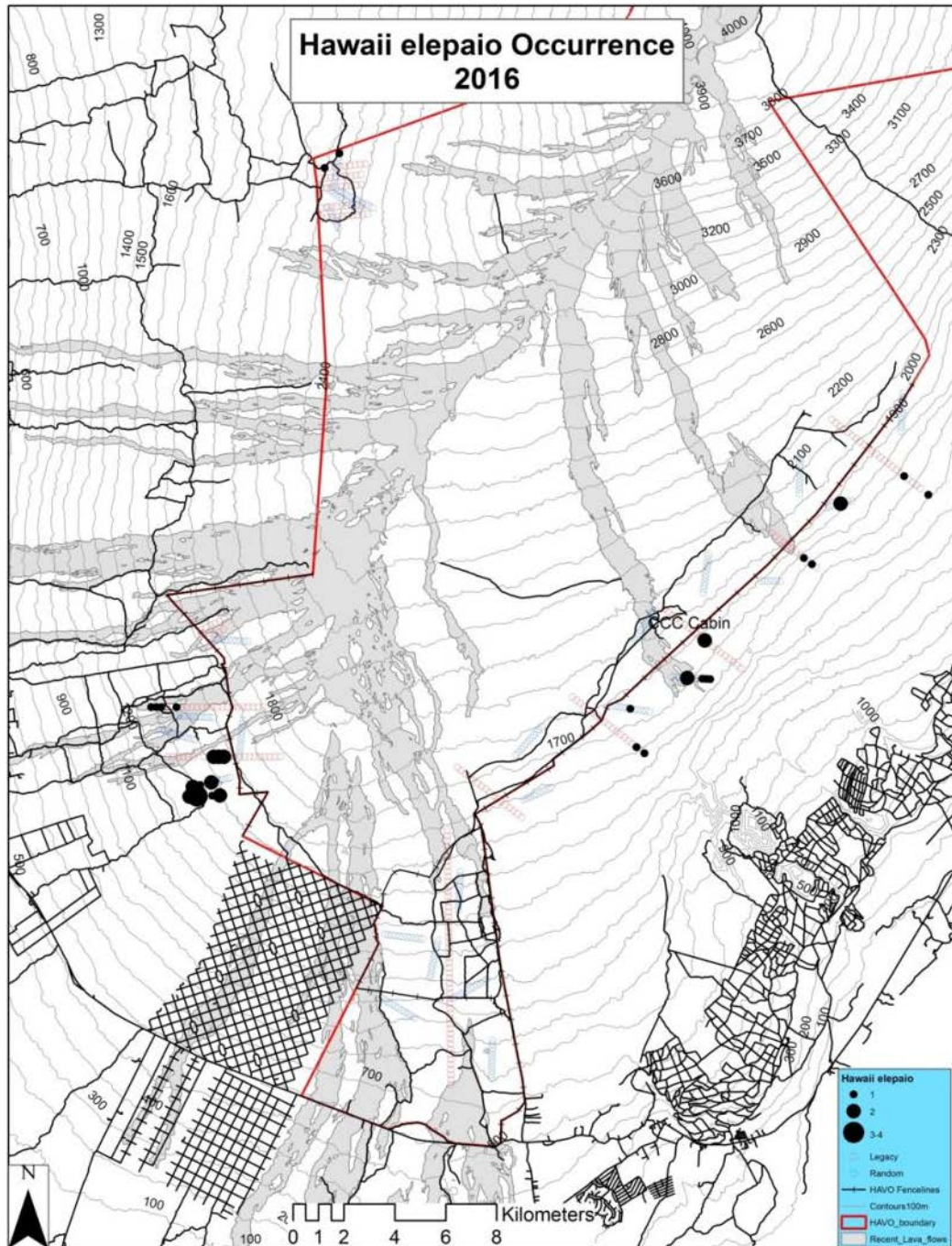


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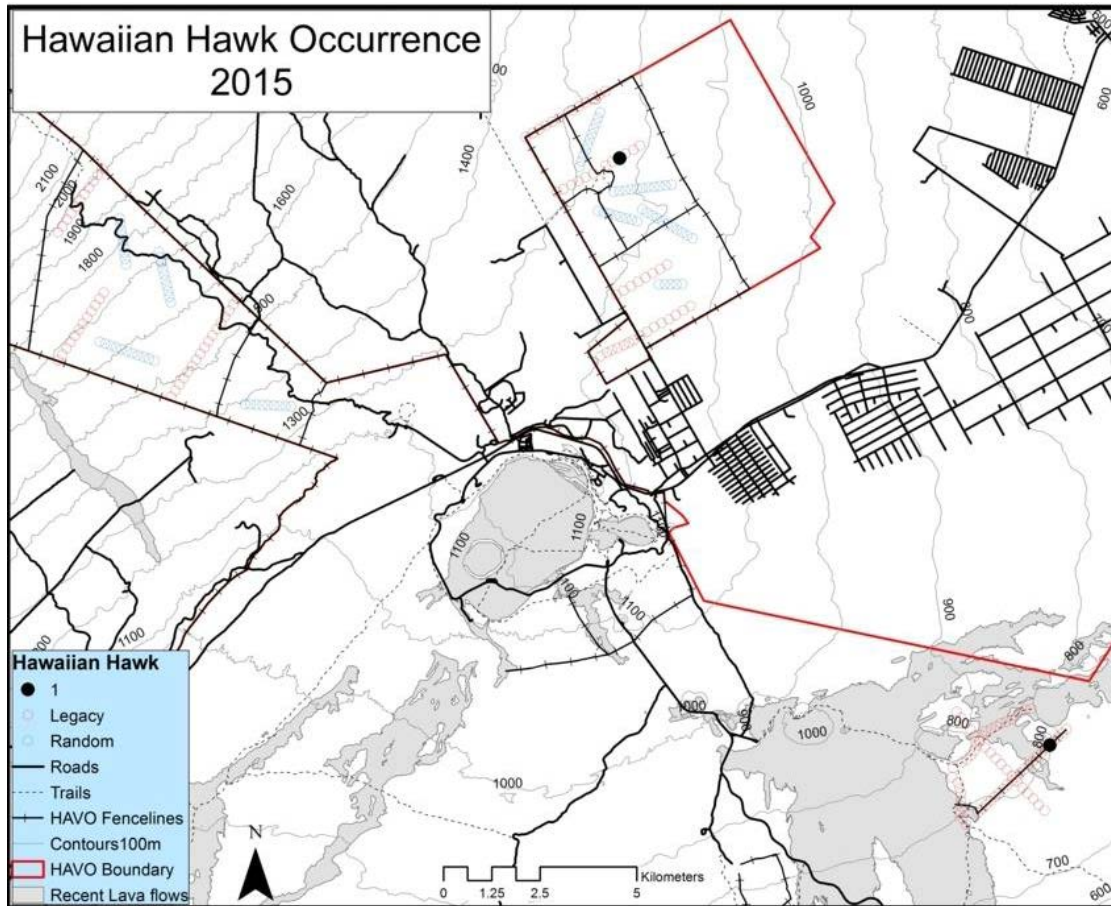


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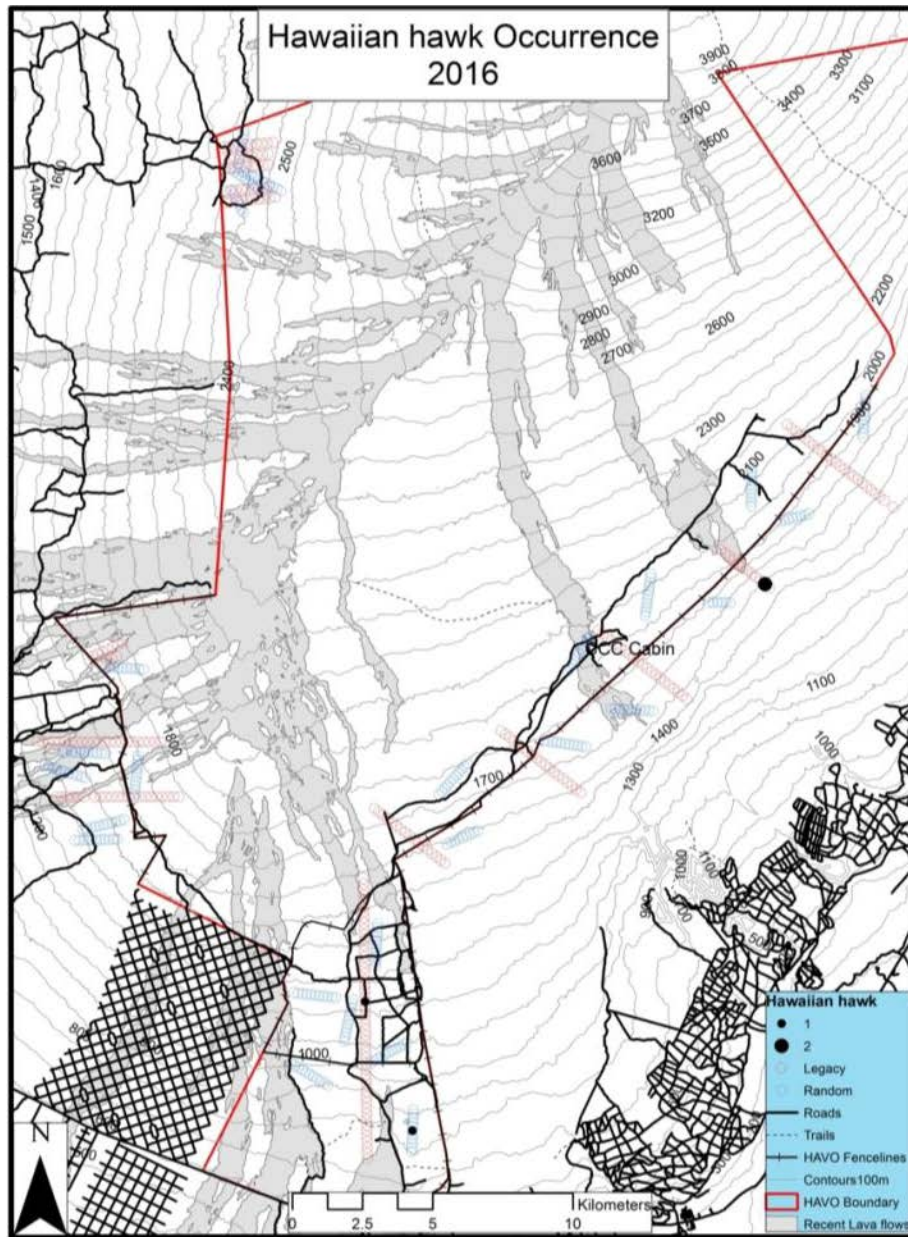


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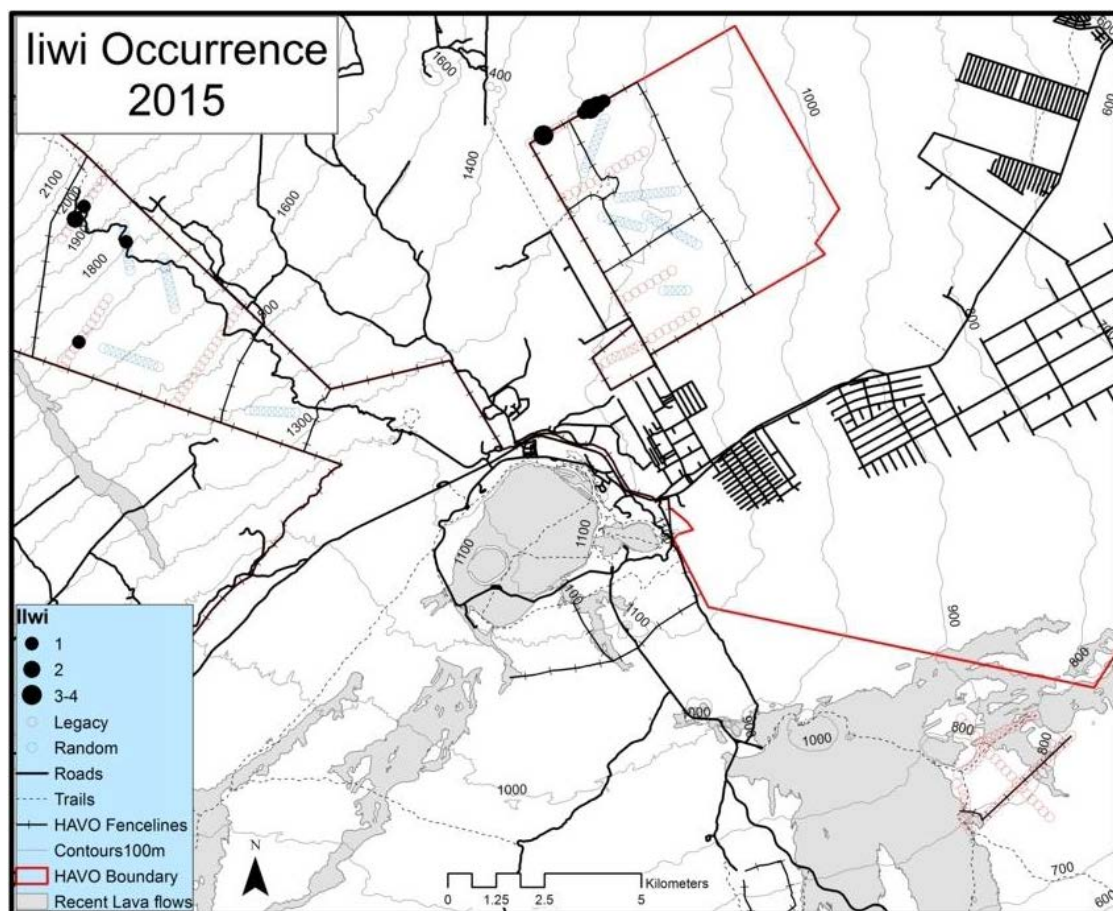


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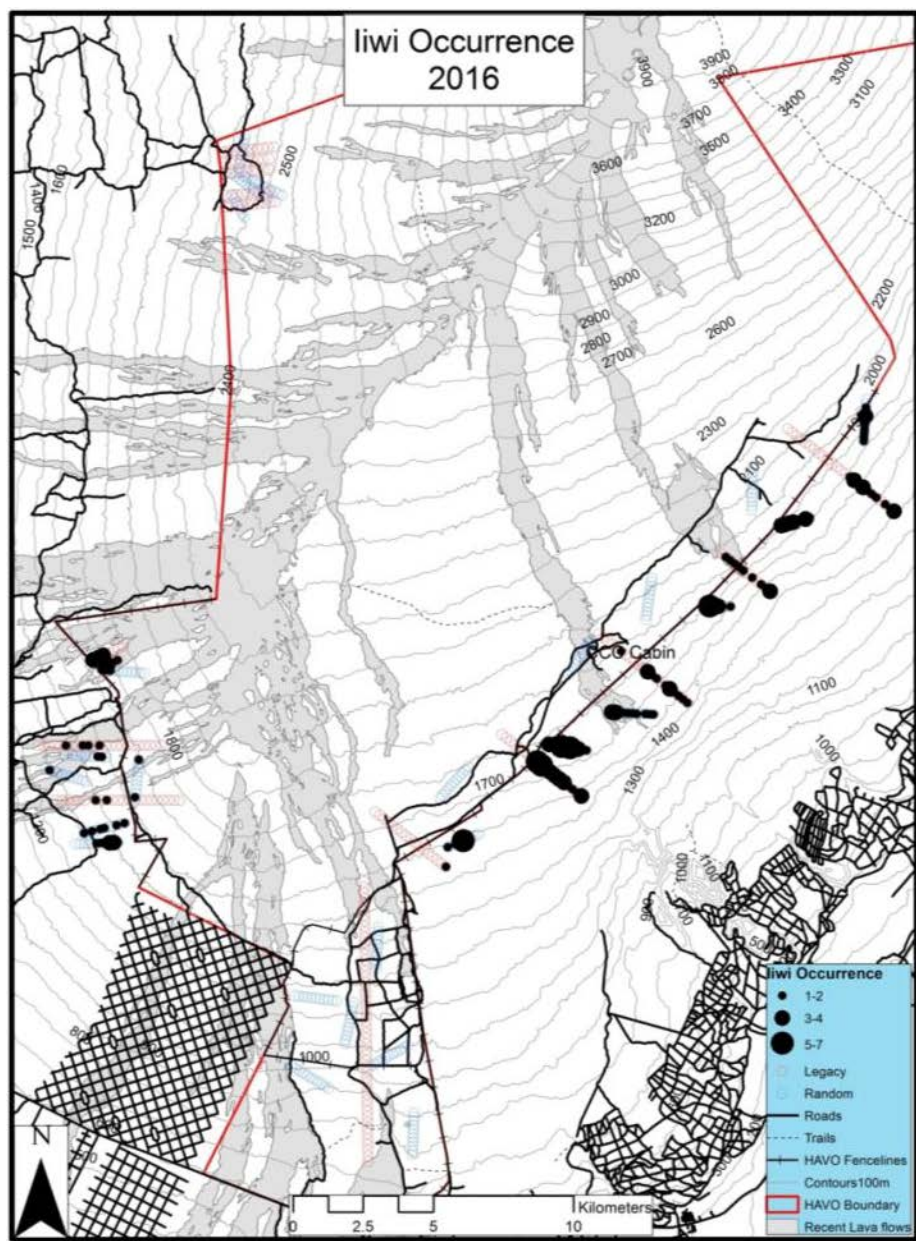


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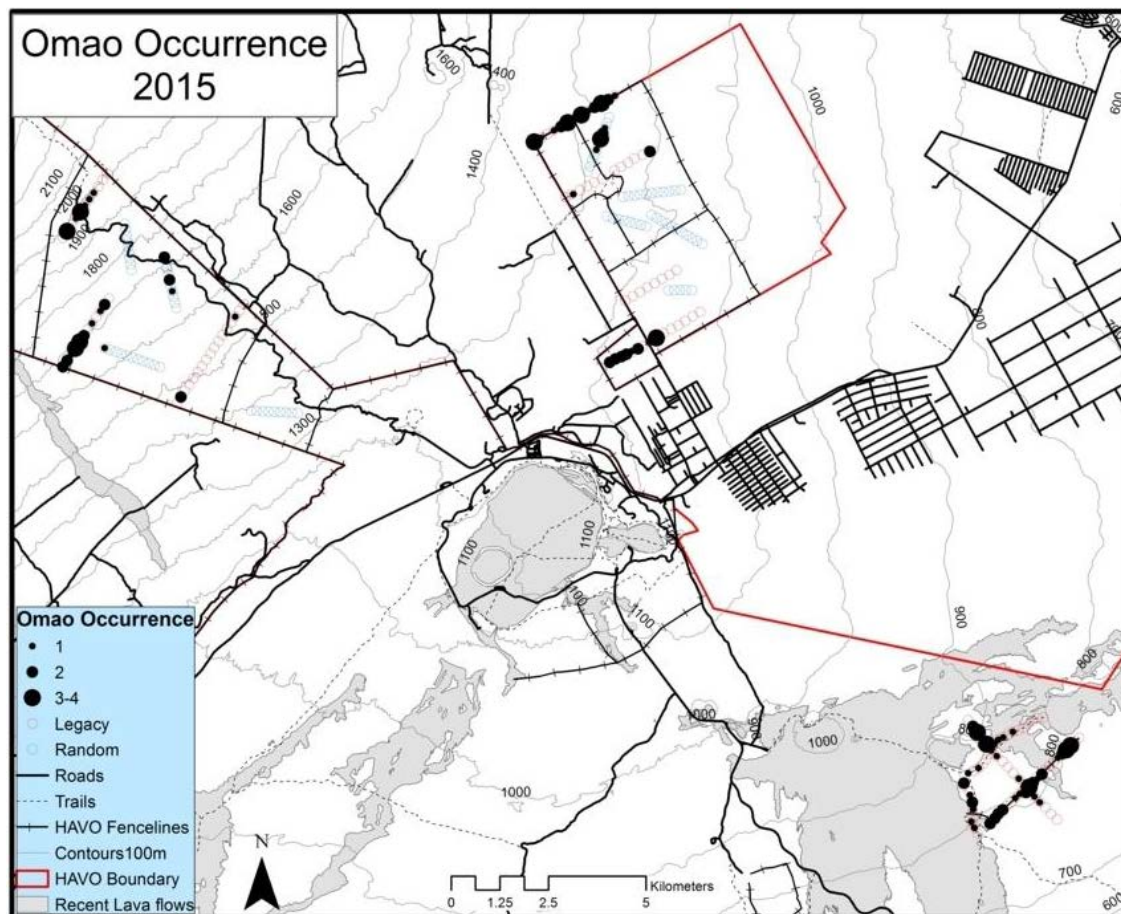


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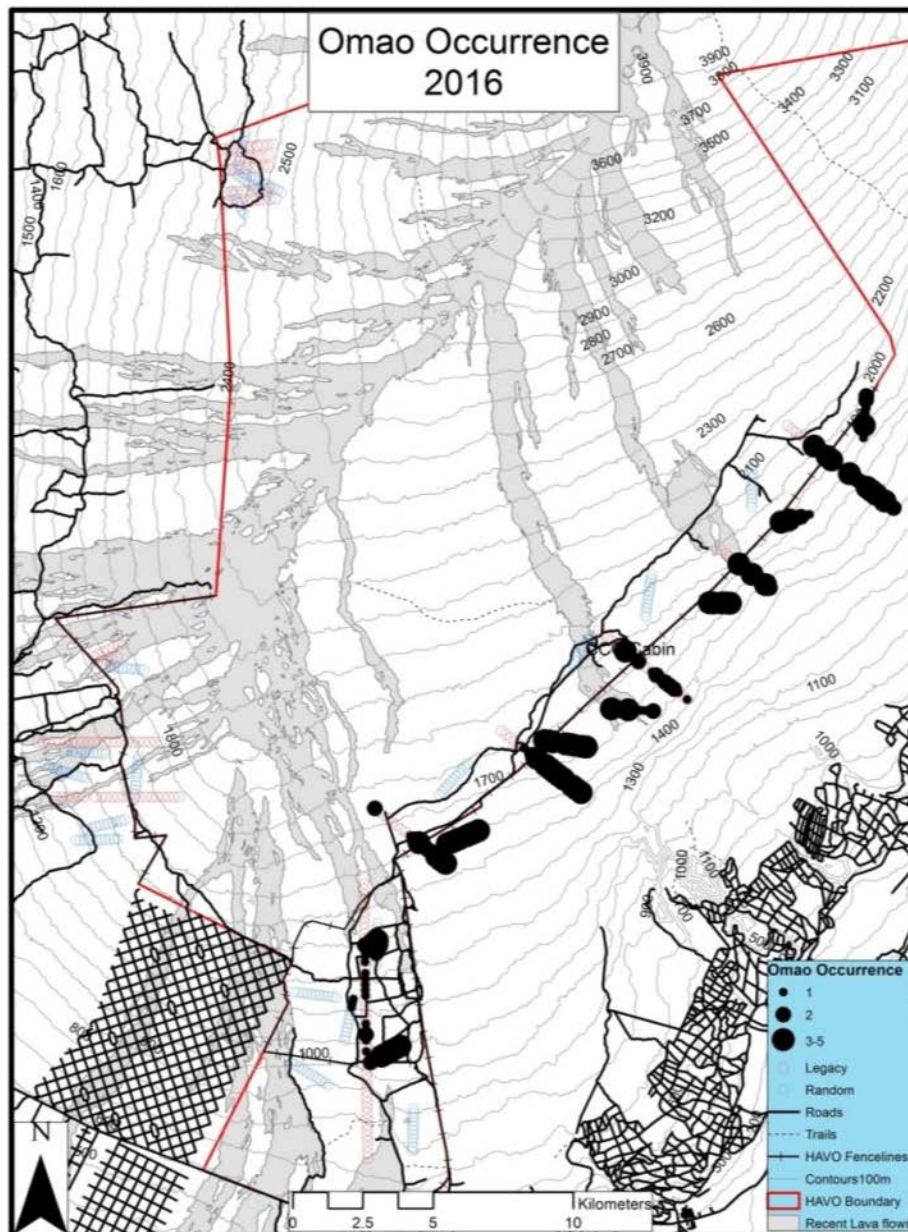


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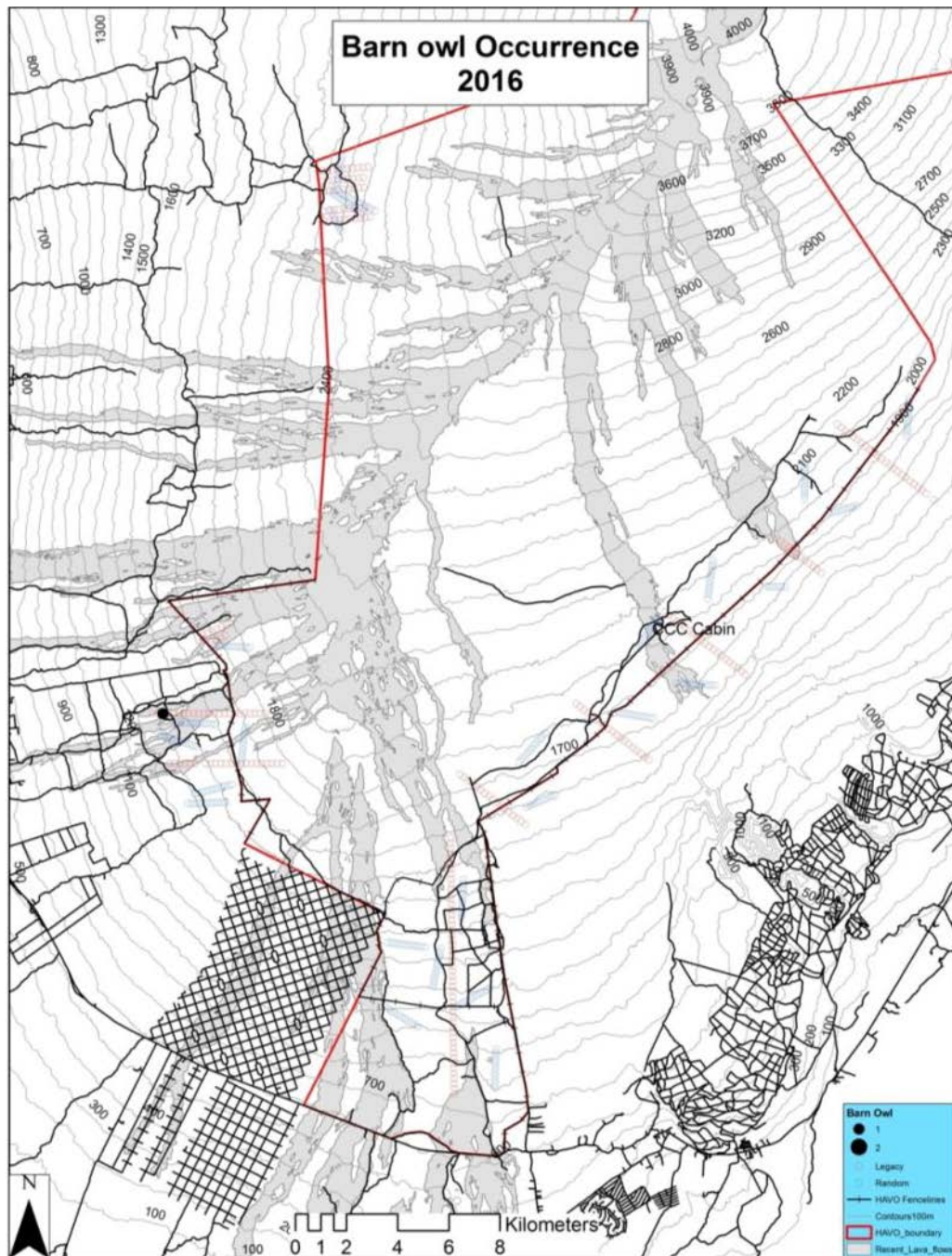


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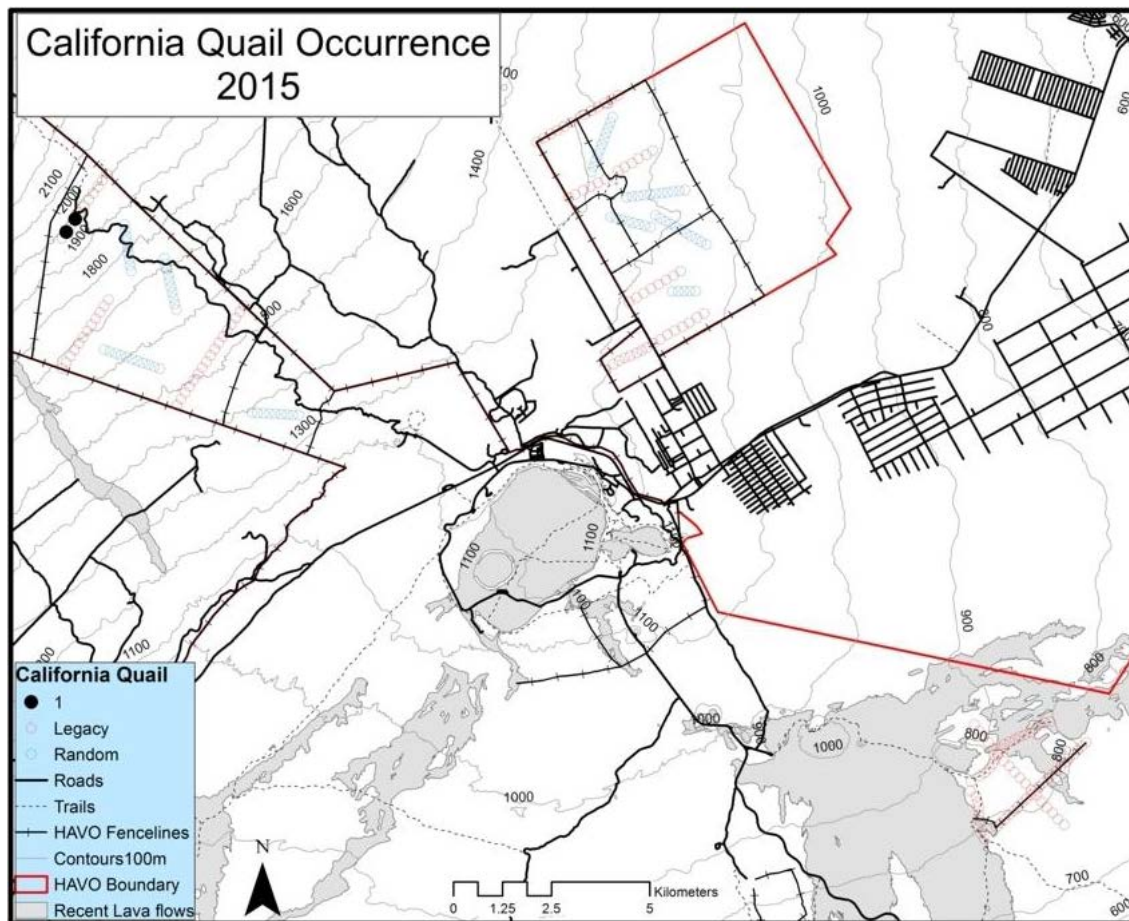


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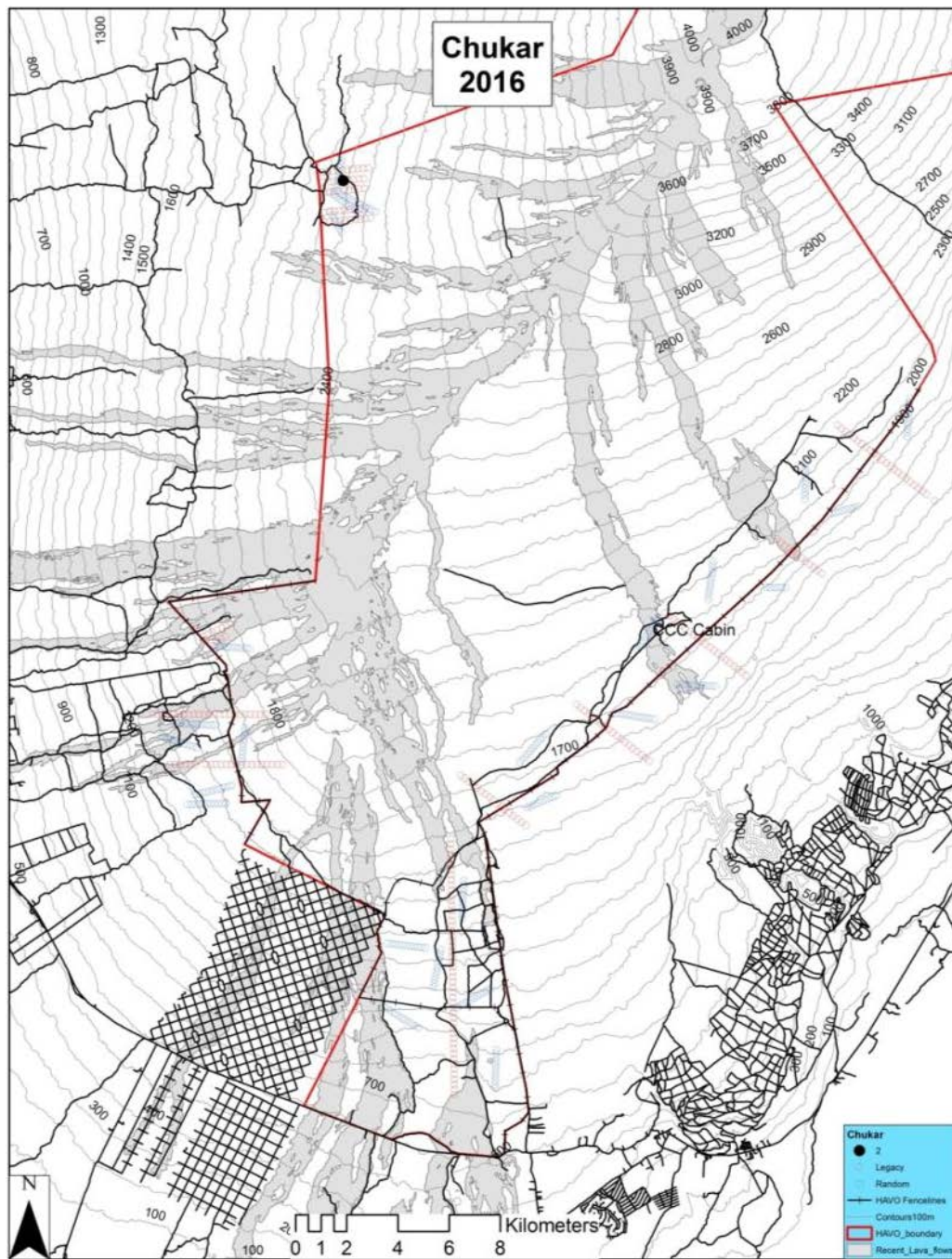


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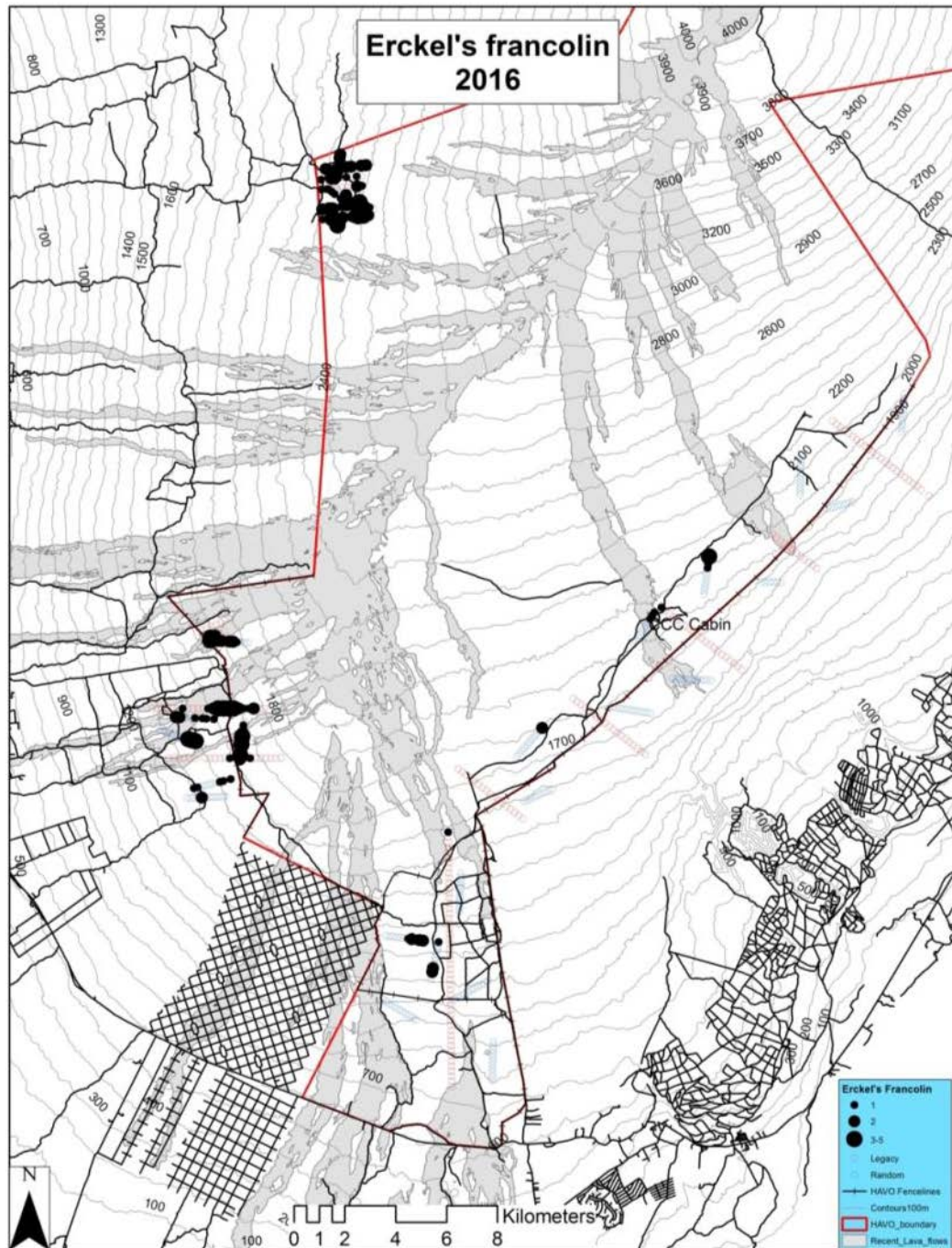


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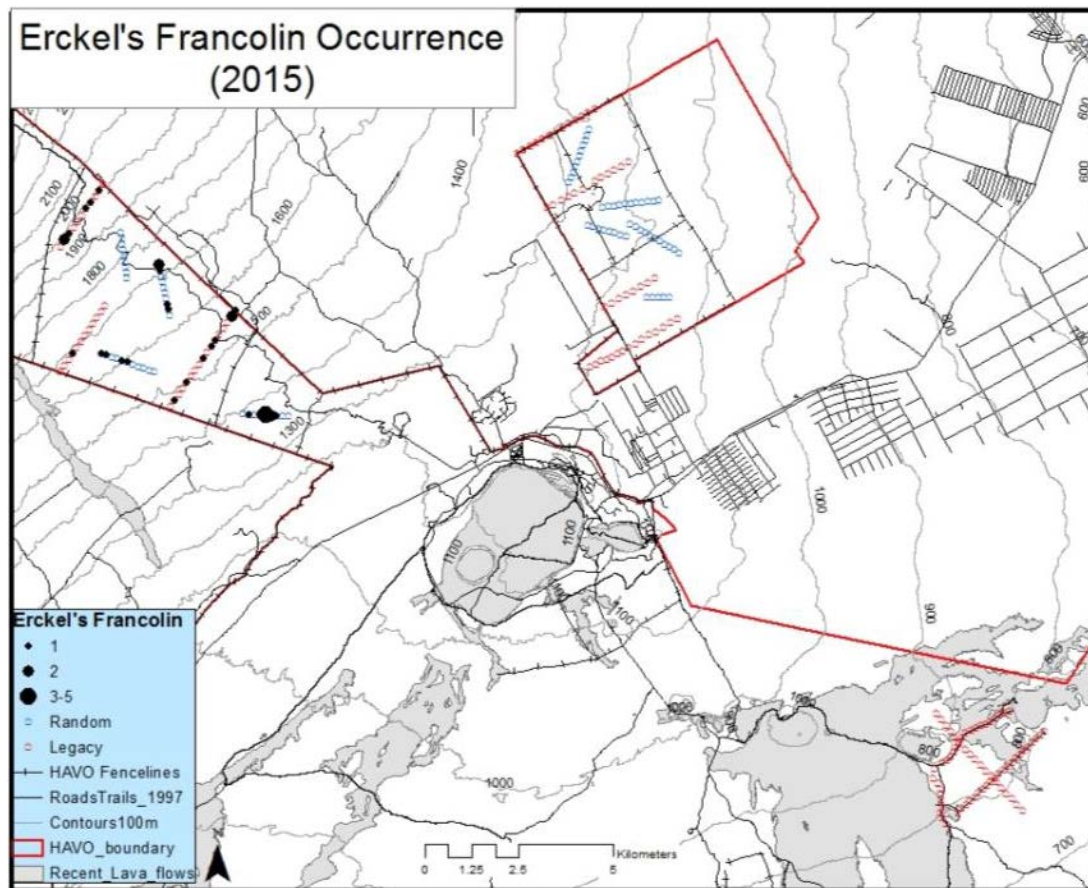


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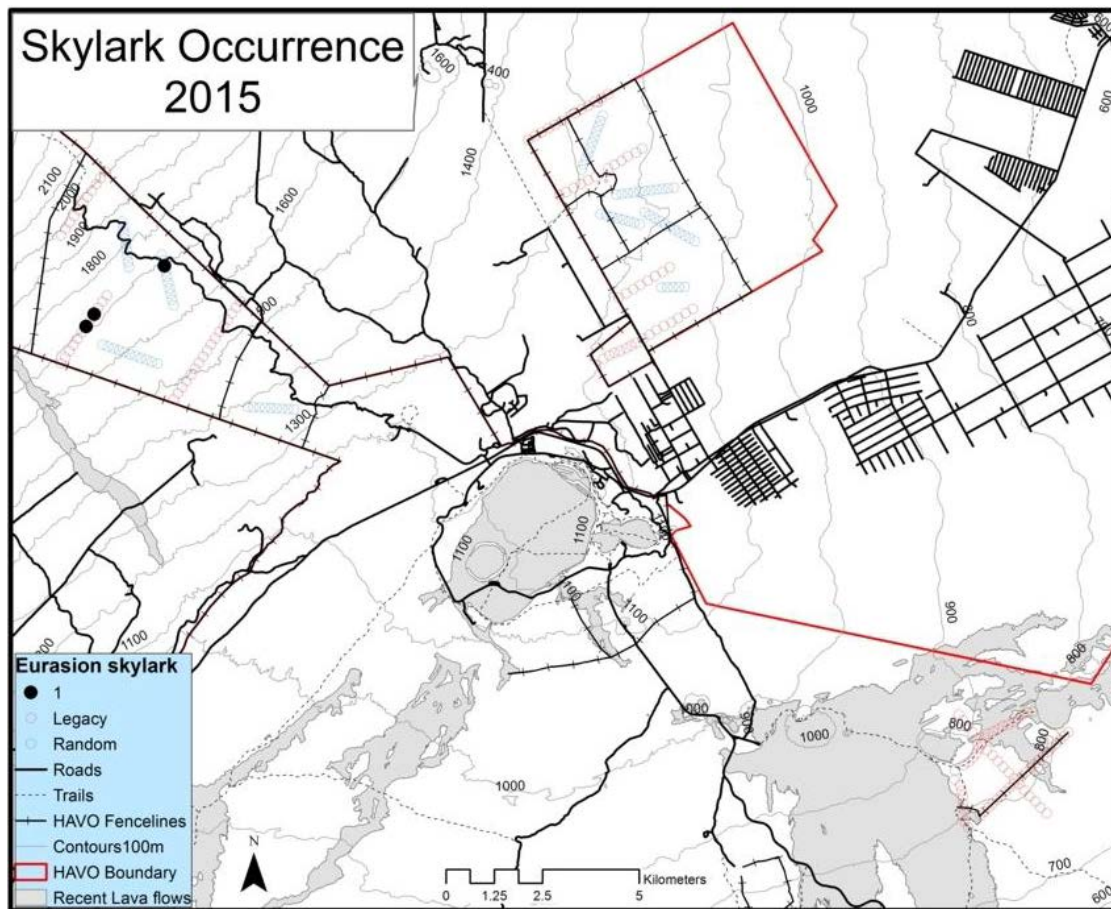


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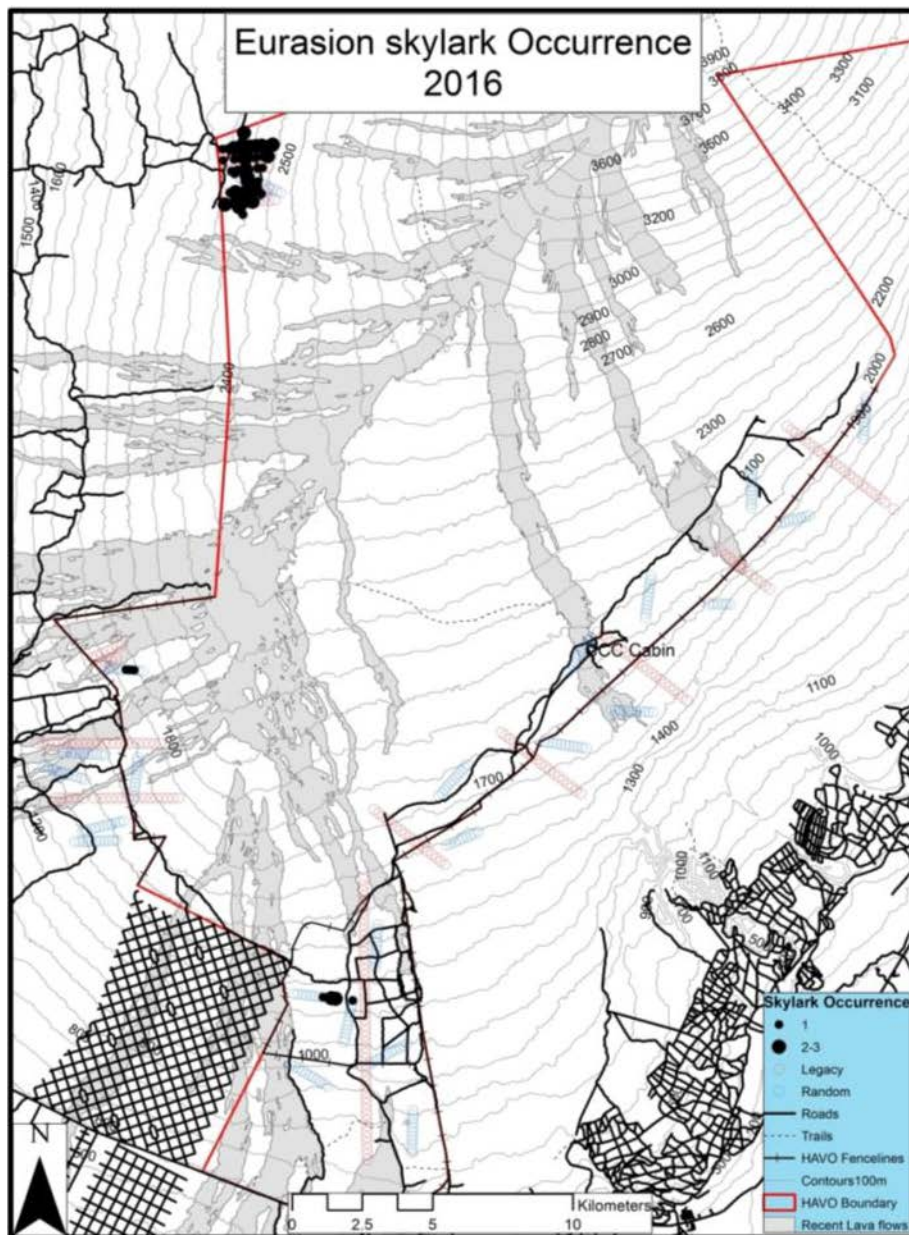


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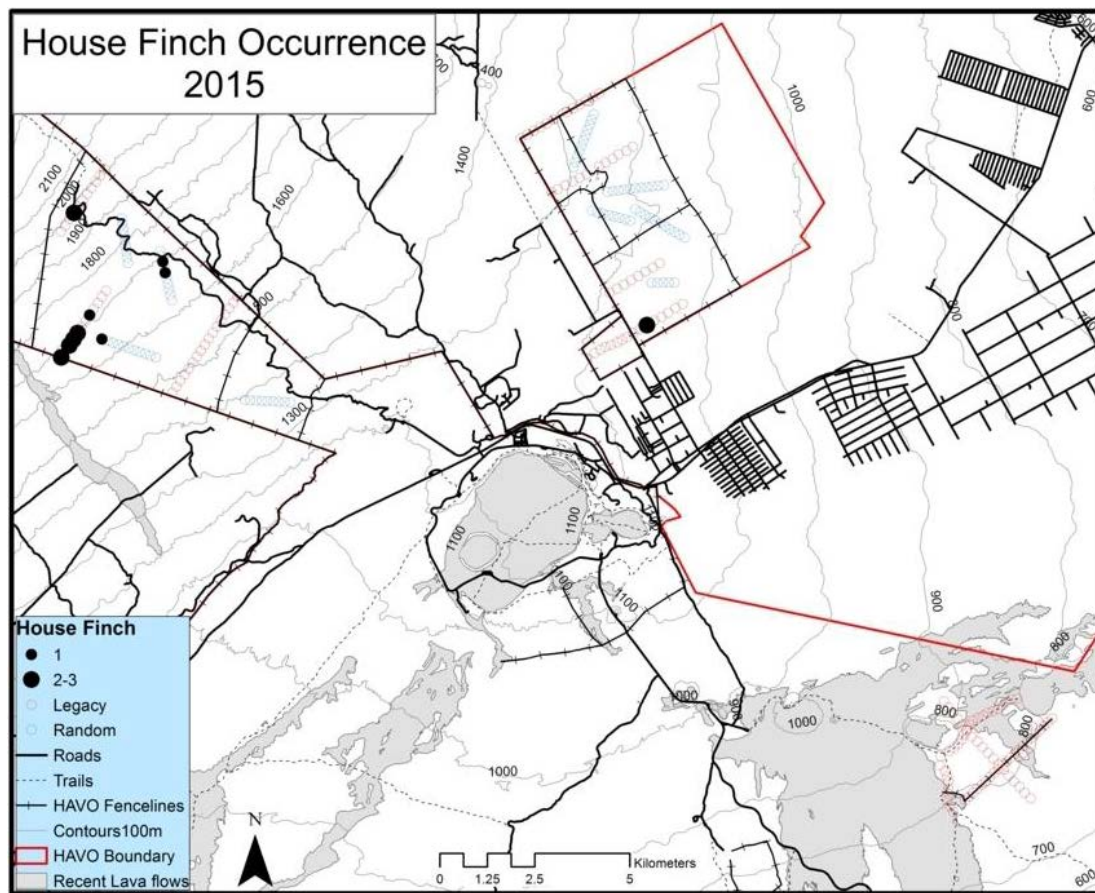


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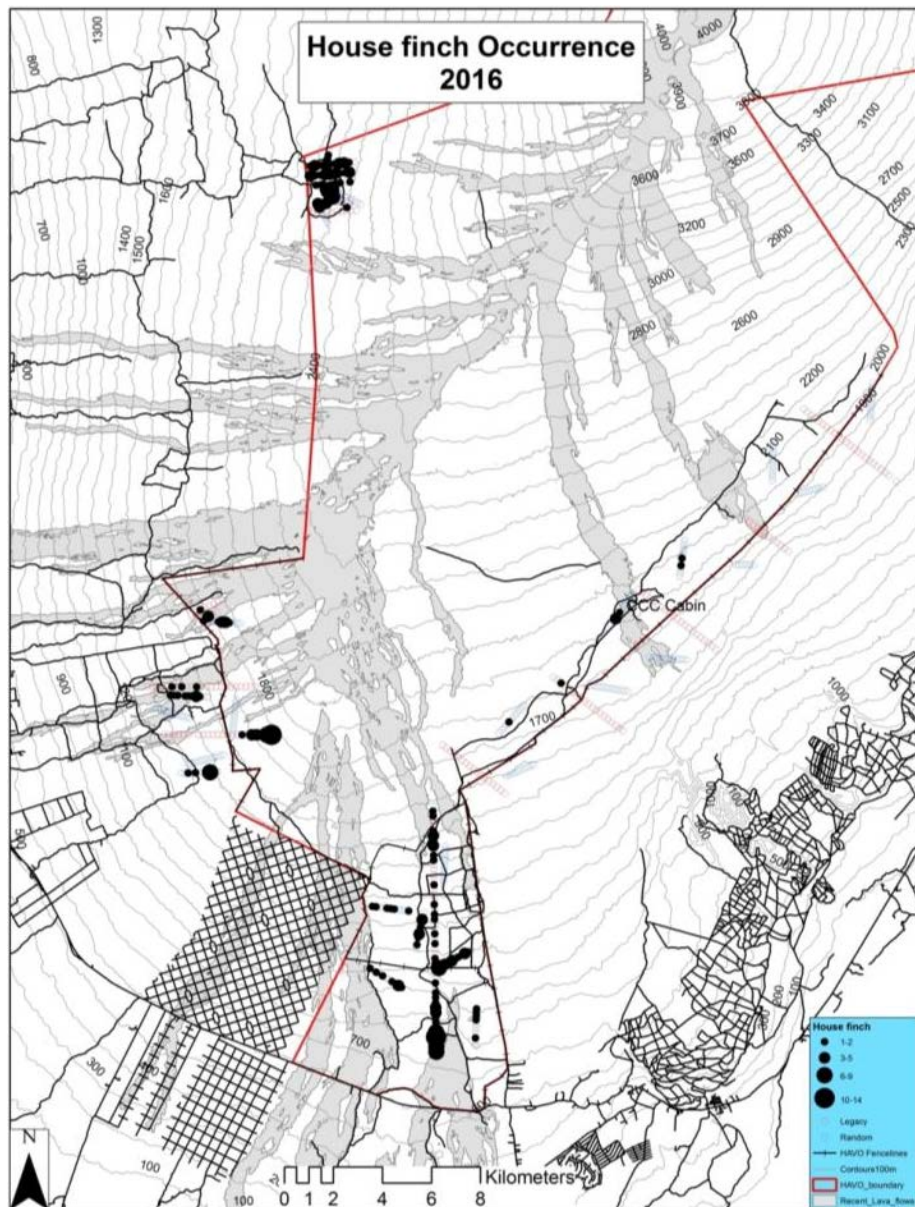


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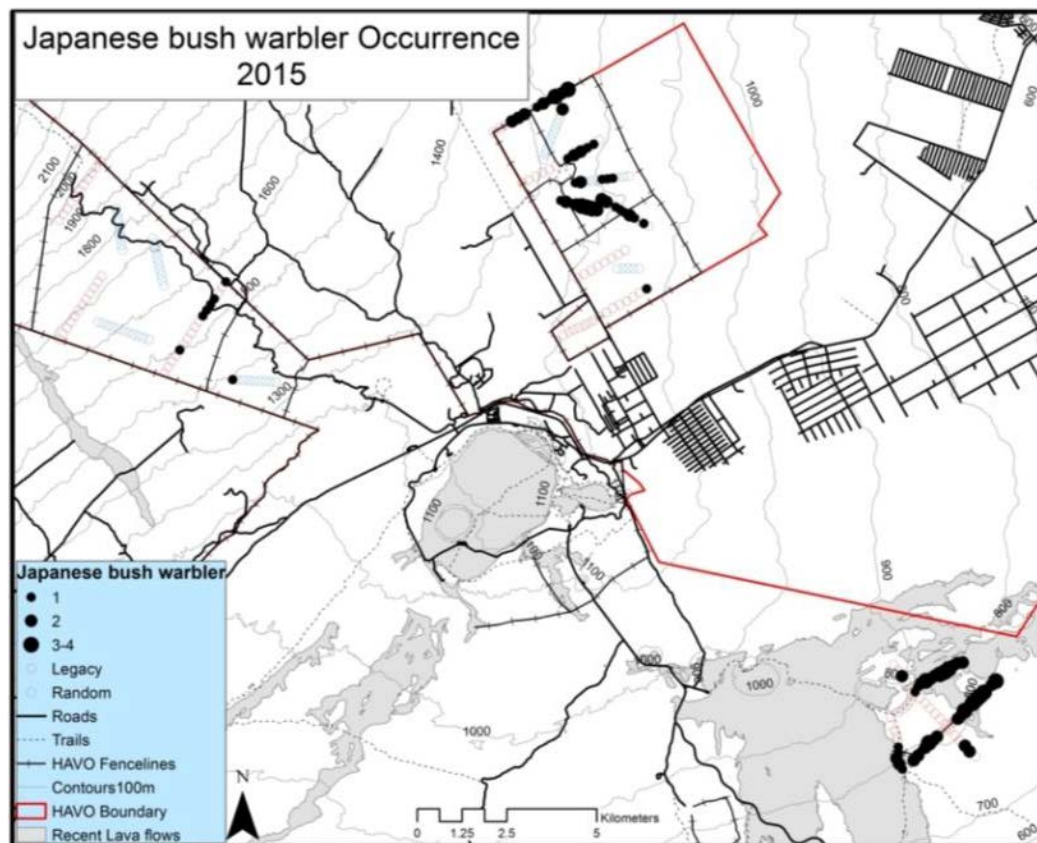


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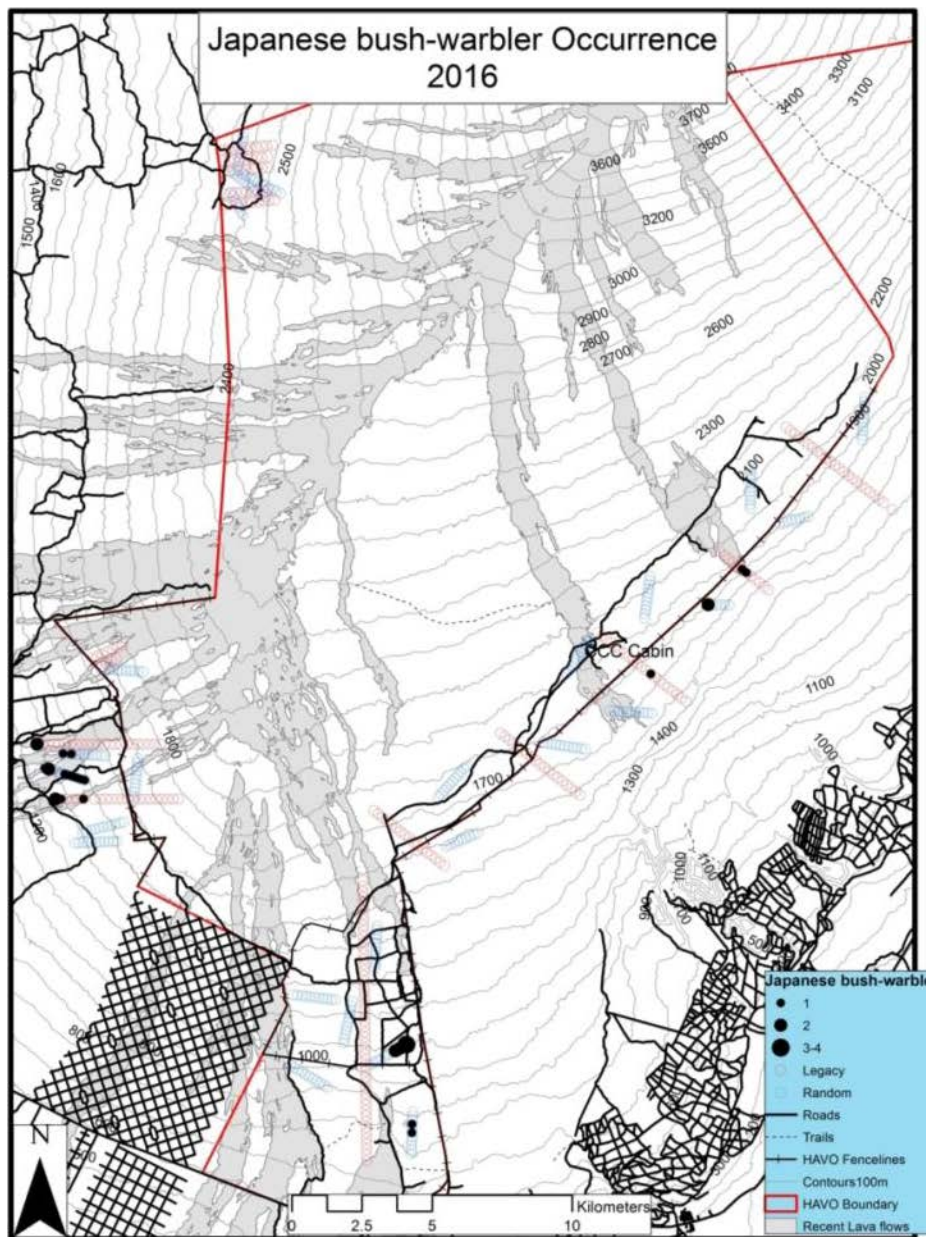


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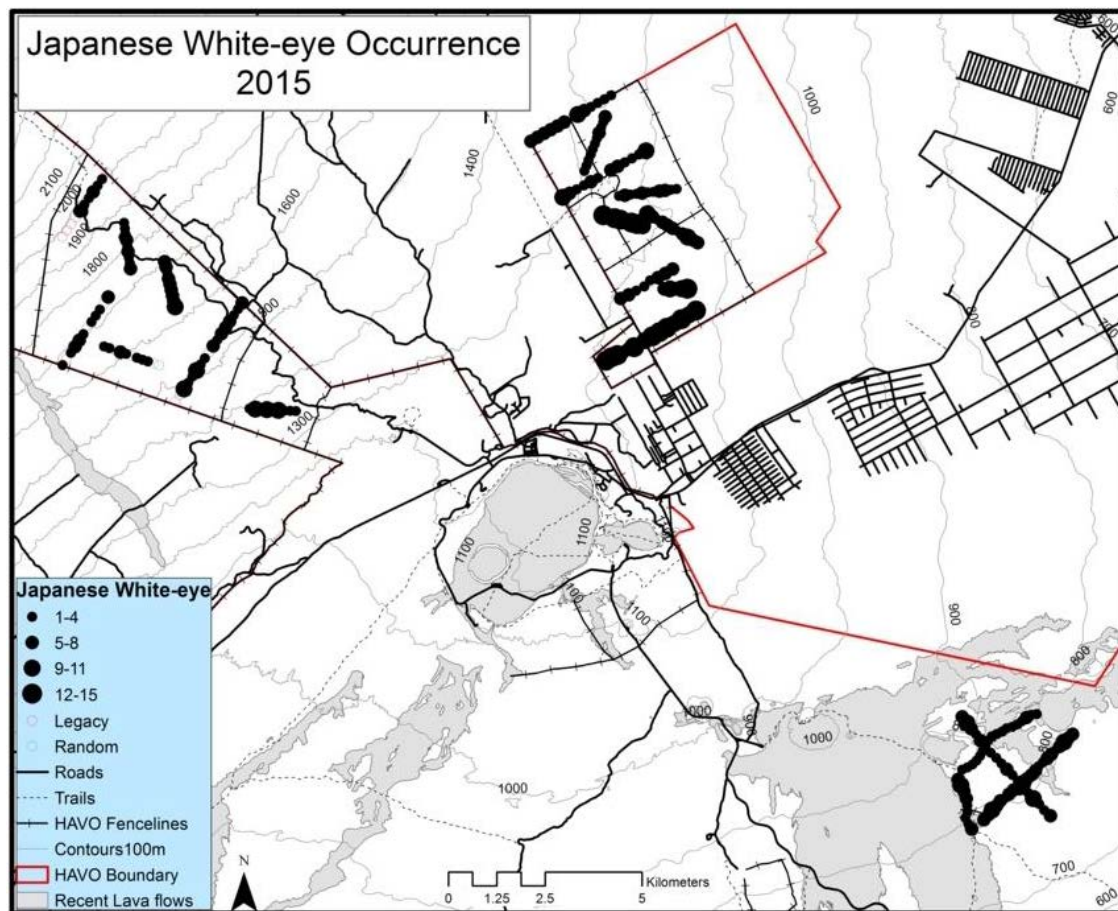


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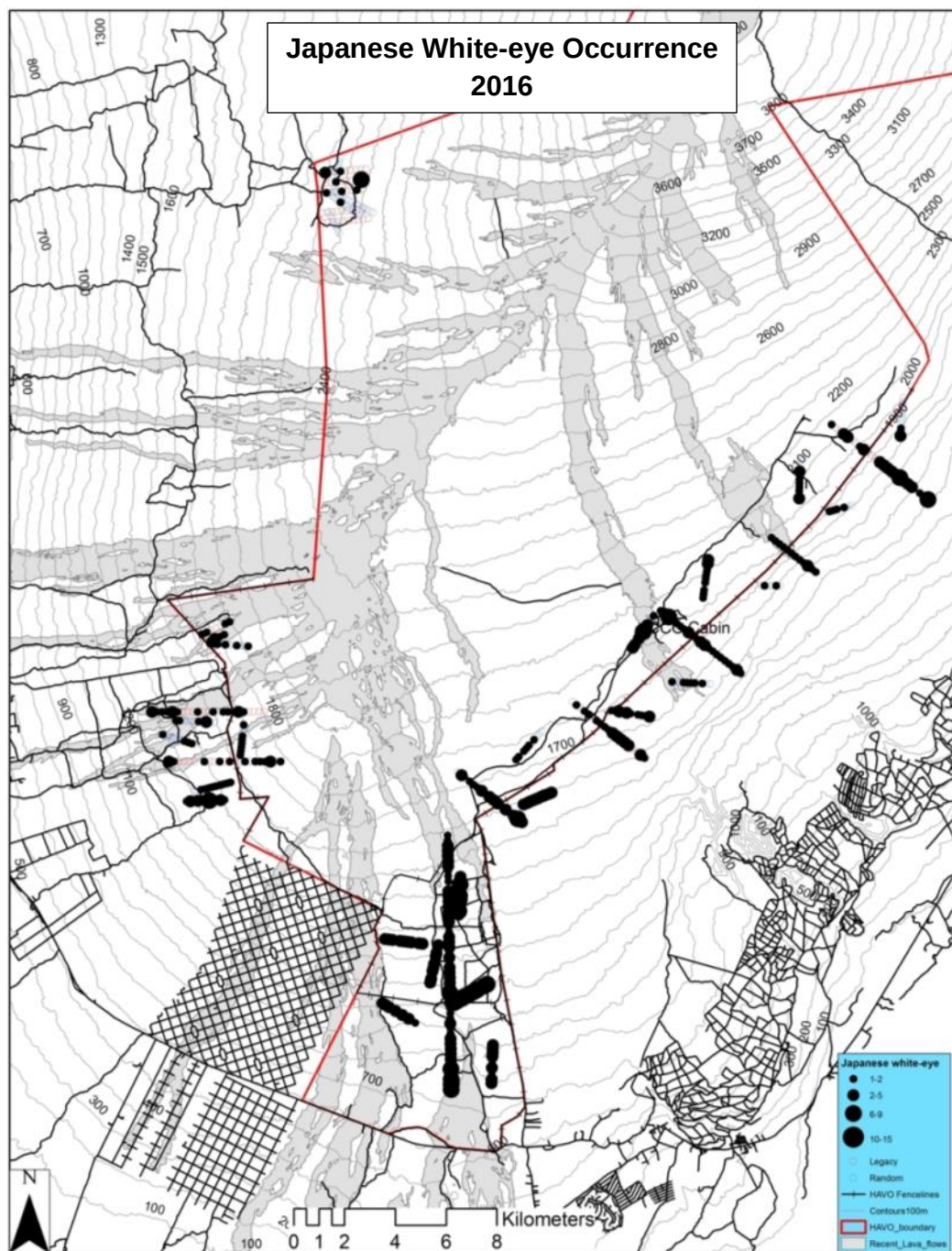


Figure A-27. Japanese White-eye occurrence within Kahuku (2016).

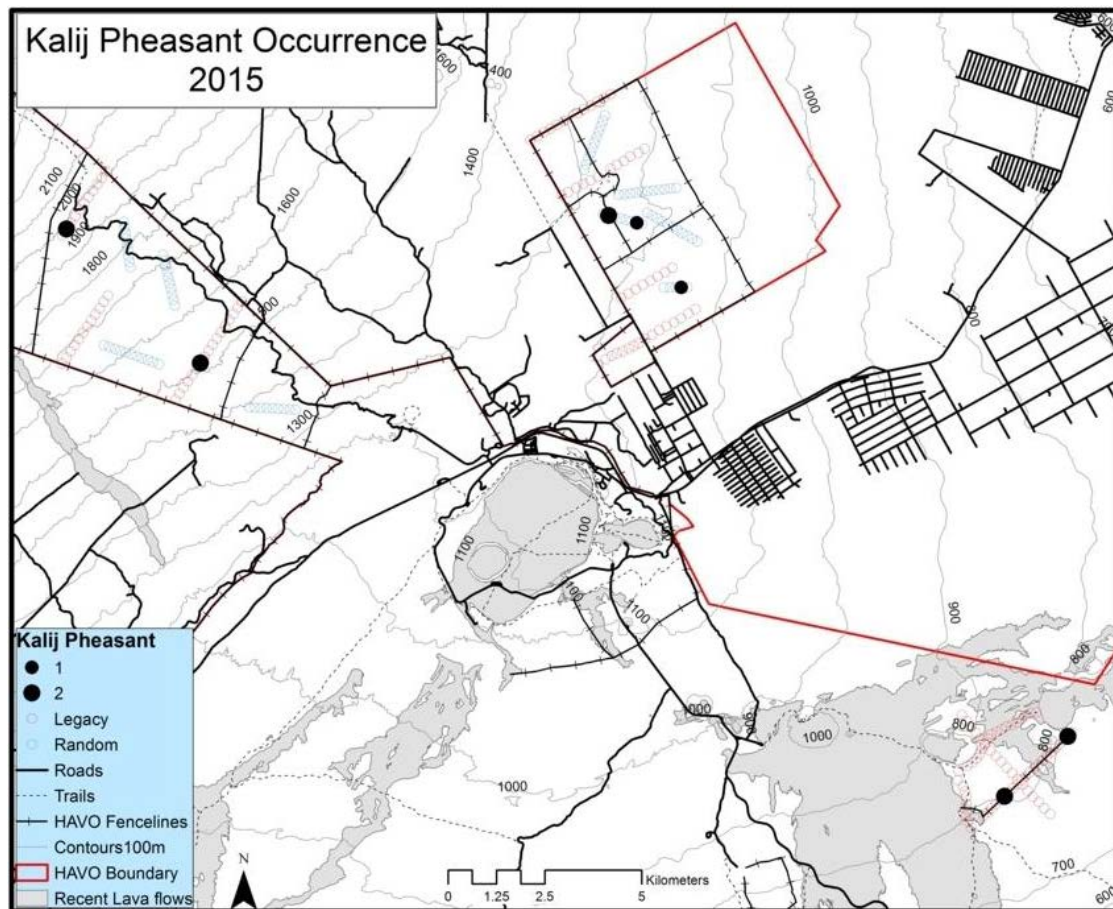


Figure A-28. Kalij Pheasant occurrence within Old HAVO (2015).

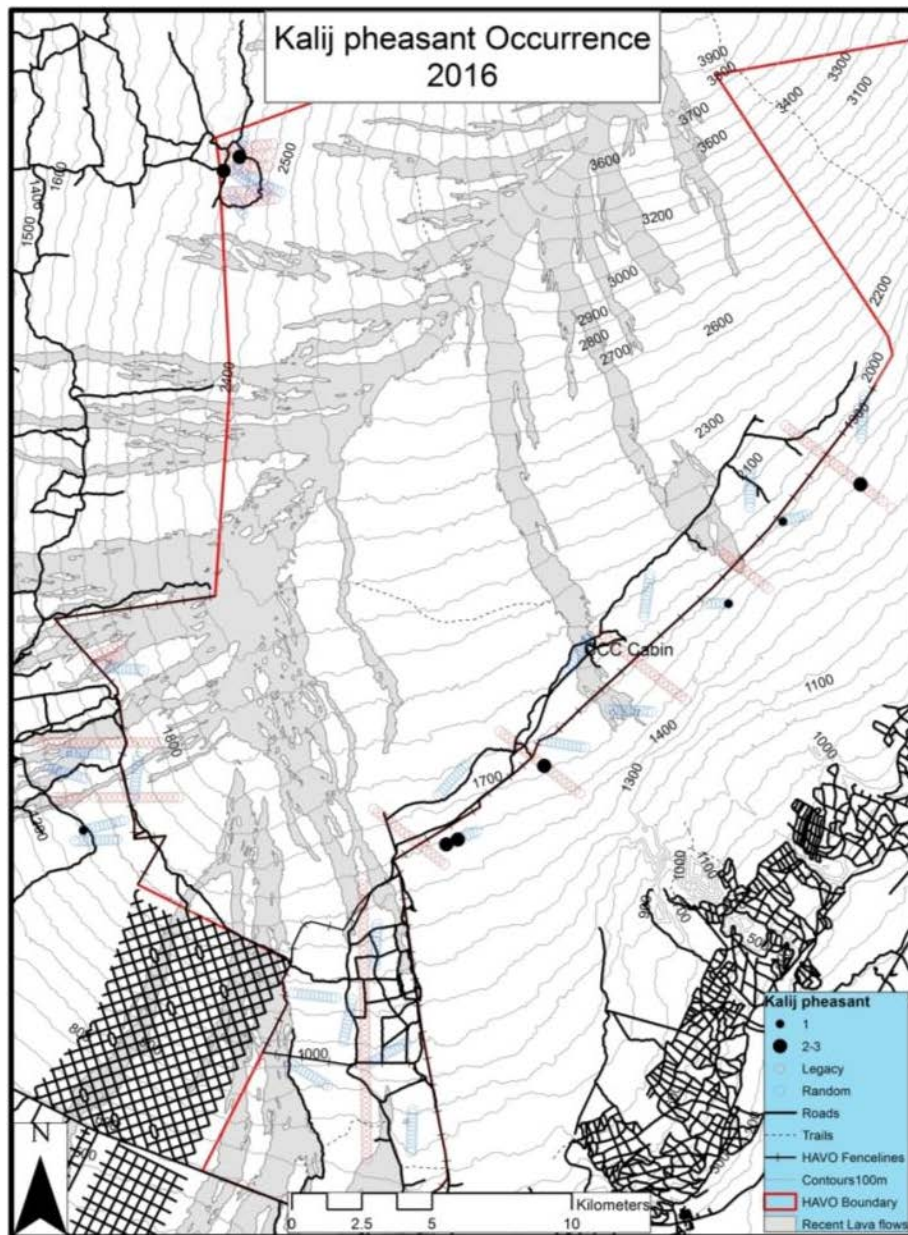


Figure A-29. Kalij Pheasant occurrence within Kahuku (2016).

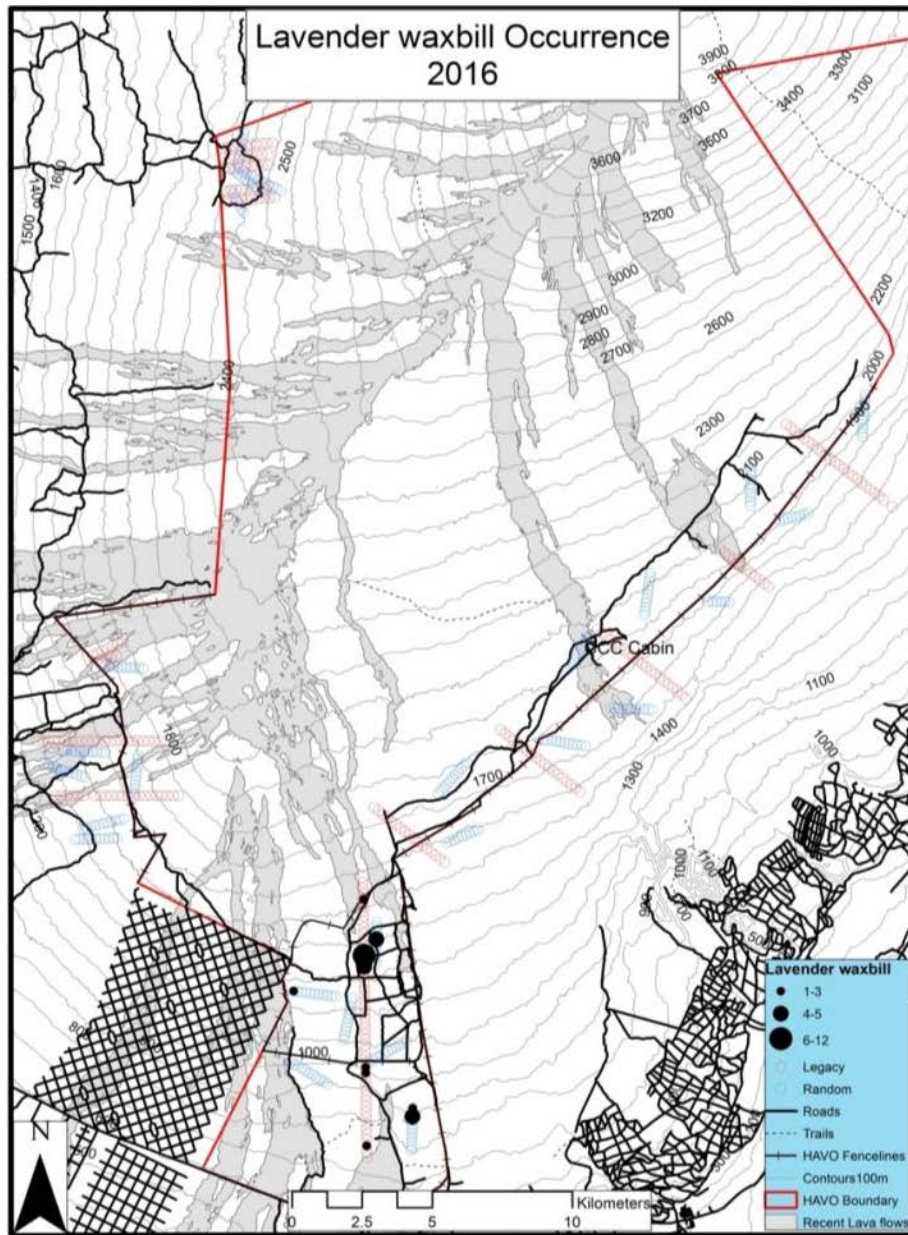


Figure A-30. Lavender Waxbill occurrence within Kahuku (2016).

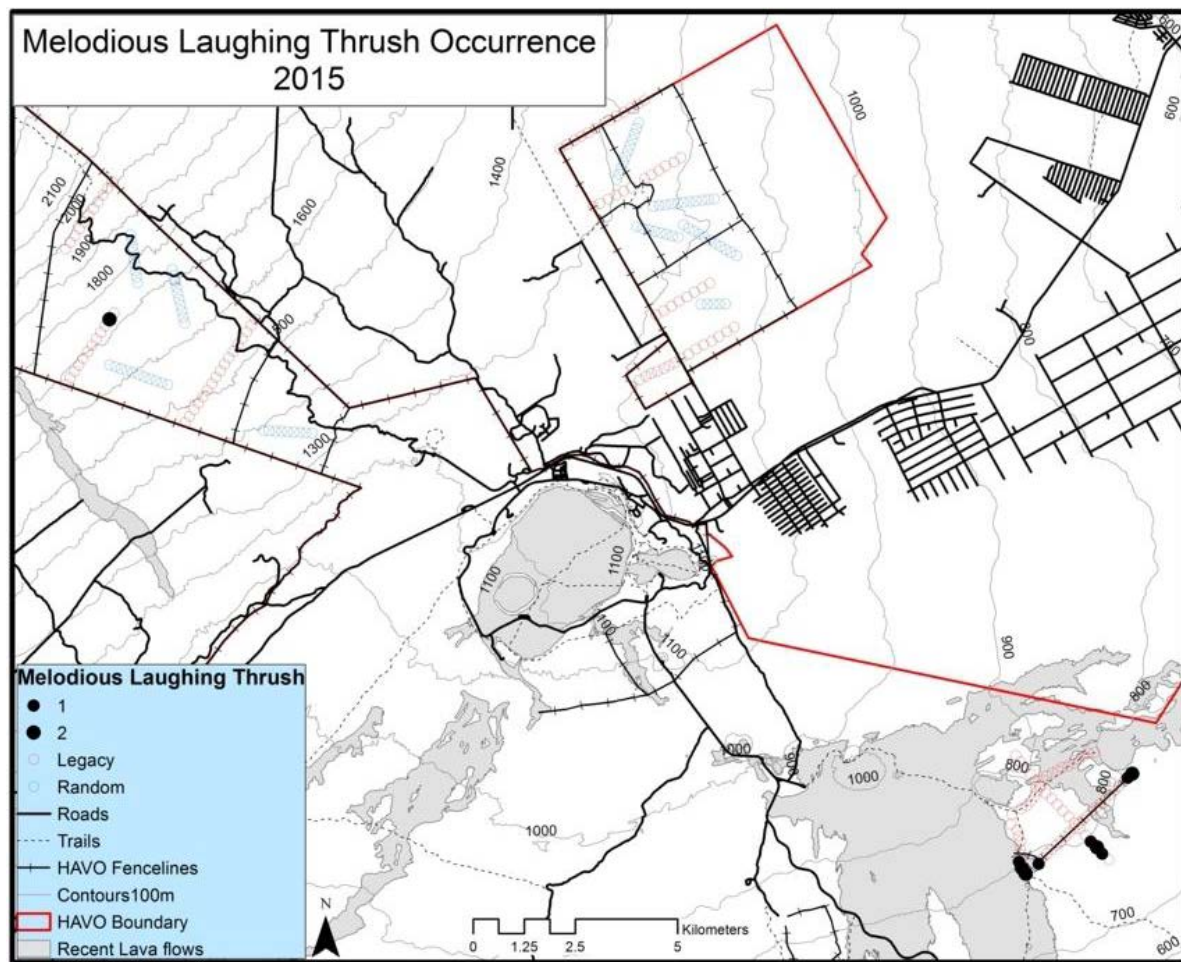


Figure A-31. Hwamei occurrence within Old HAVO (2015).

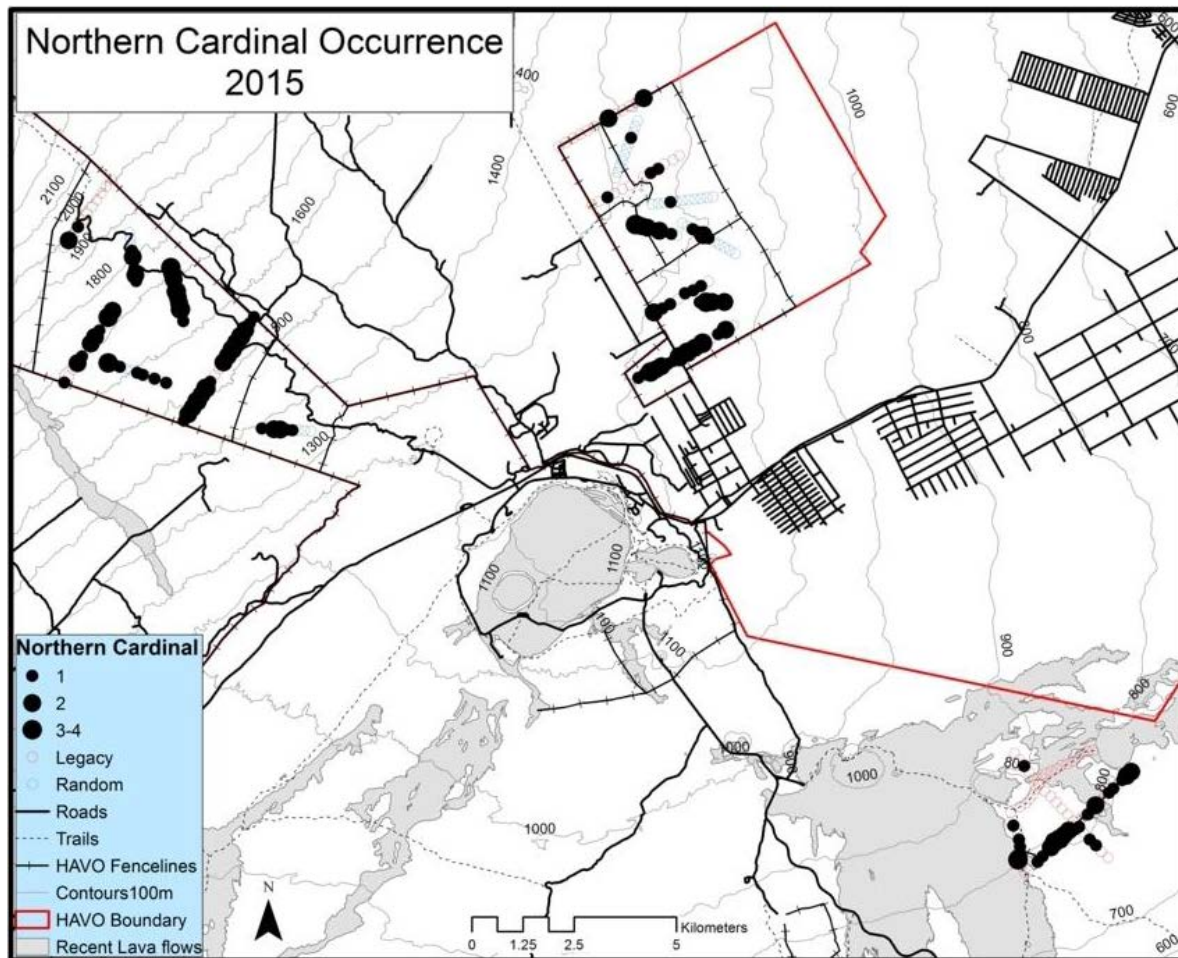


Figure A-32. Northern Cardinal occurrence within Old HAVO (2015).

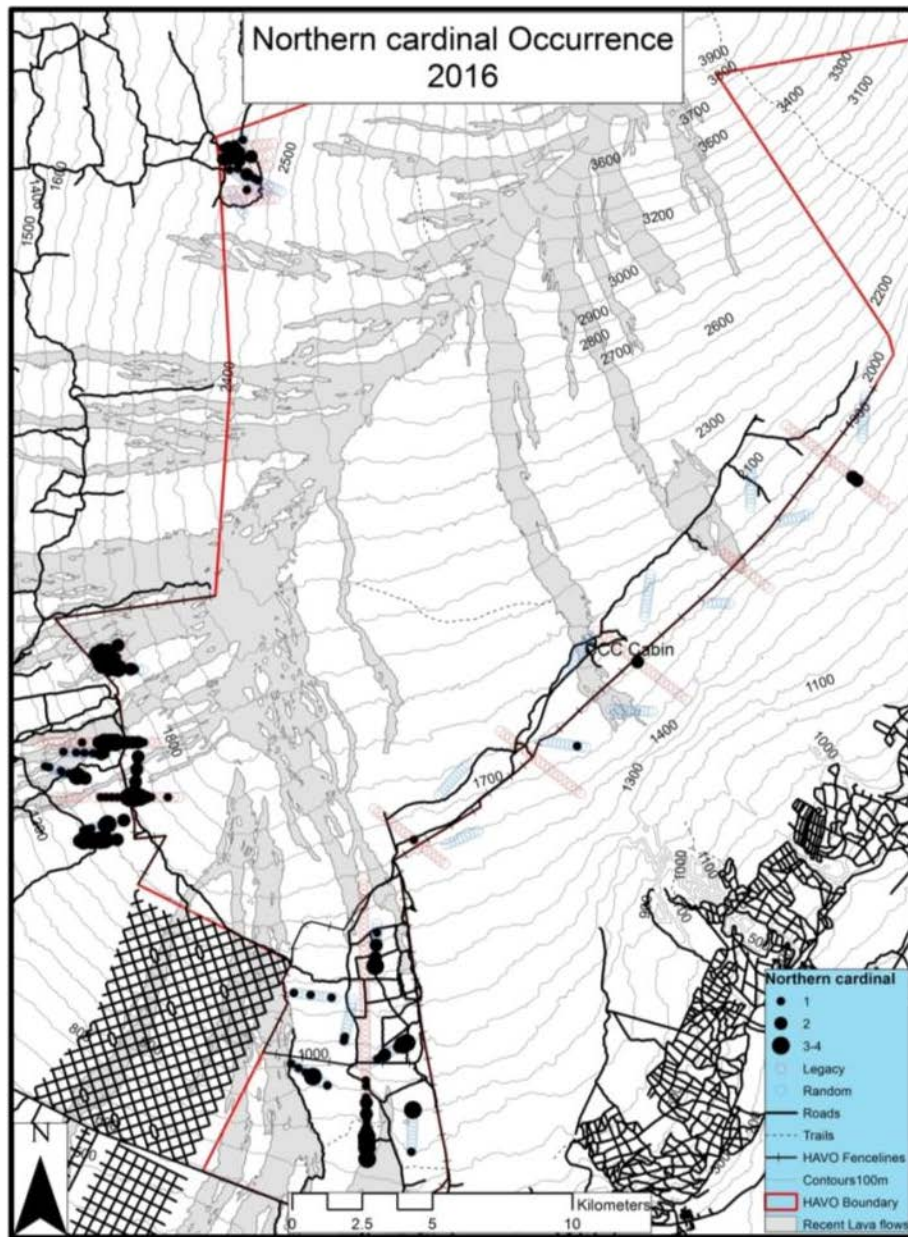


Figure A-33. Northern Cardinal occurrence within Kahuku (2016).

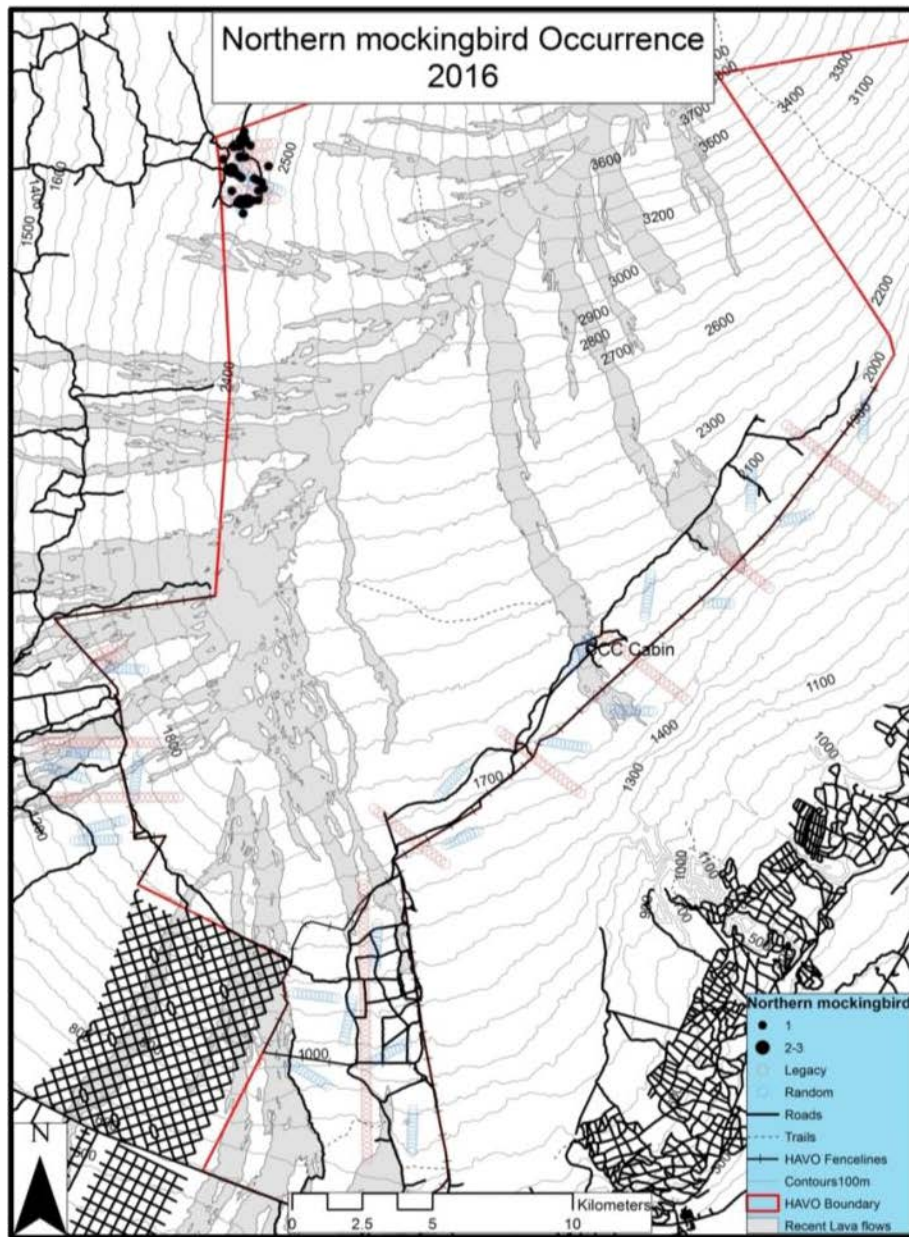


Figure A-34. Northern Mockingbird occurrence within Kahuku (2016).

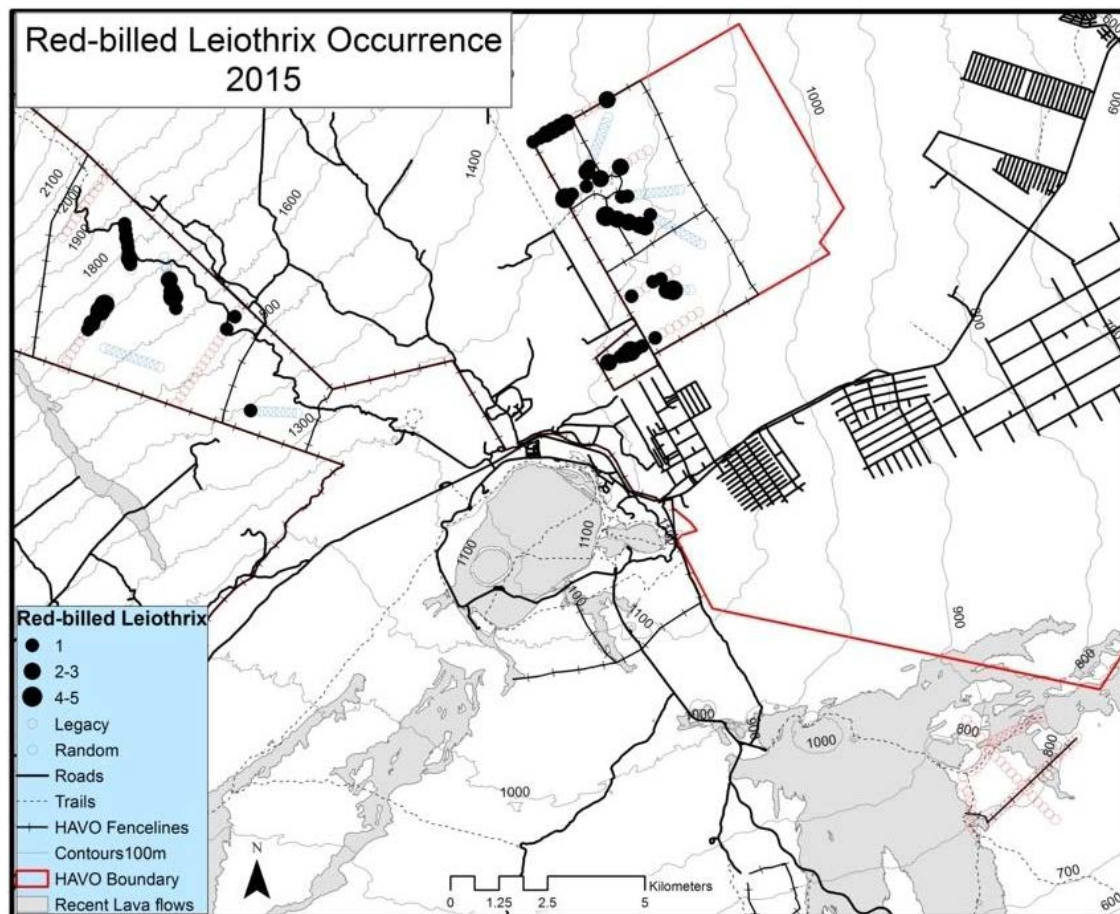


Figure A-35. Red-billed Leiothrix occurrence within Old HAVO (2015).

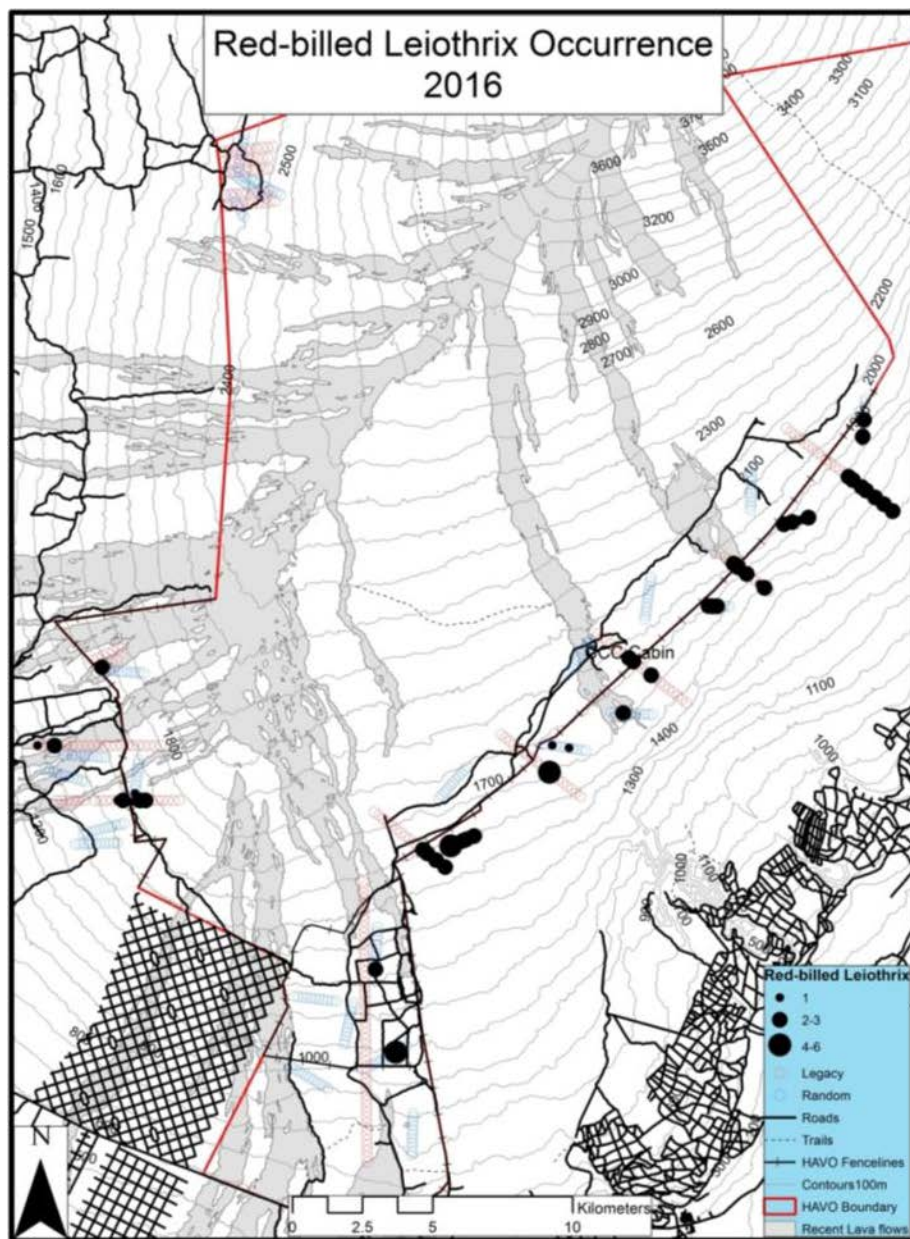


Figure A-36. Red-billed Leiothrix occurrence within HAVO (2016).

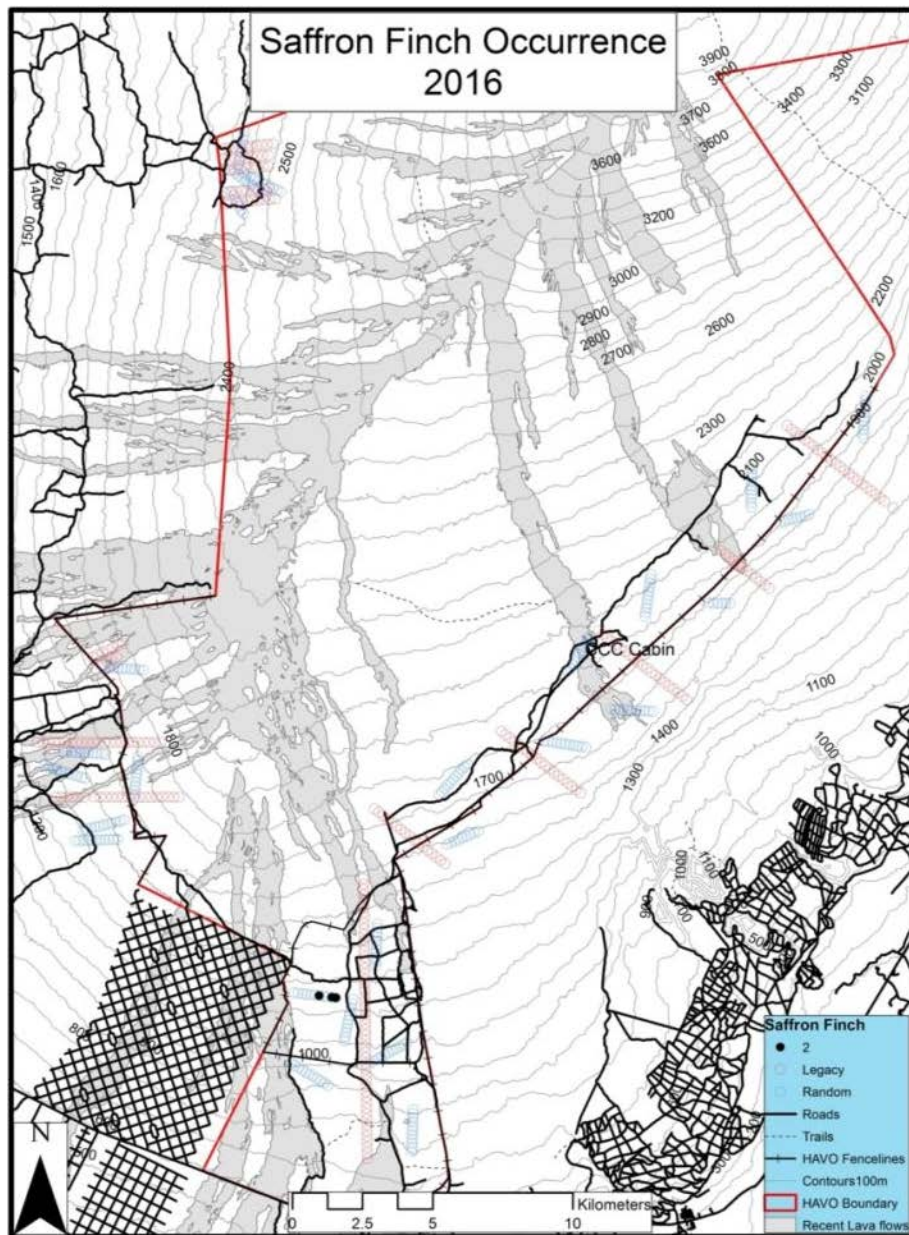


Figure A-37. Saffron Finch occurrence within Kahuku (2016).

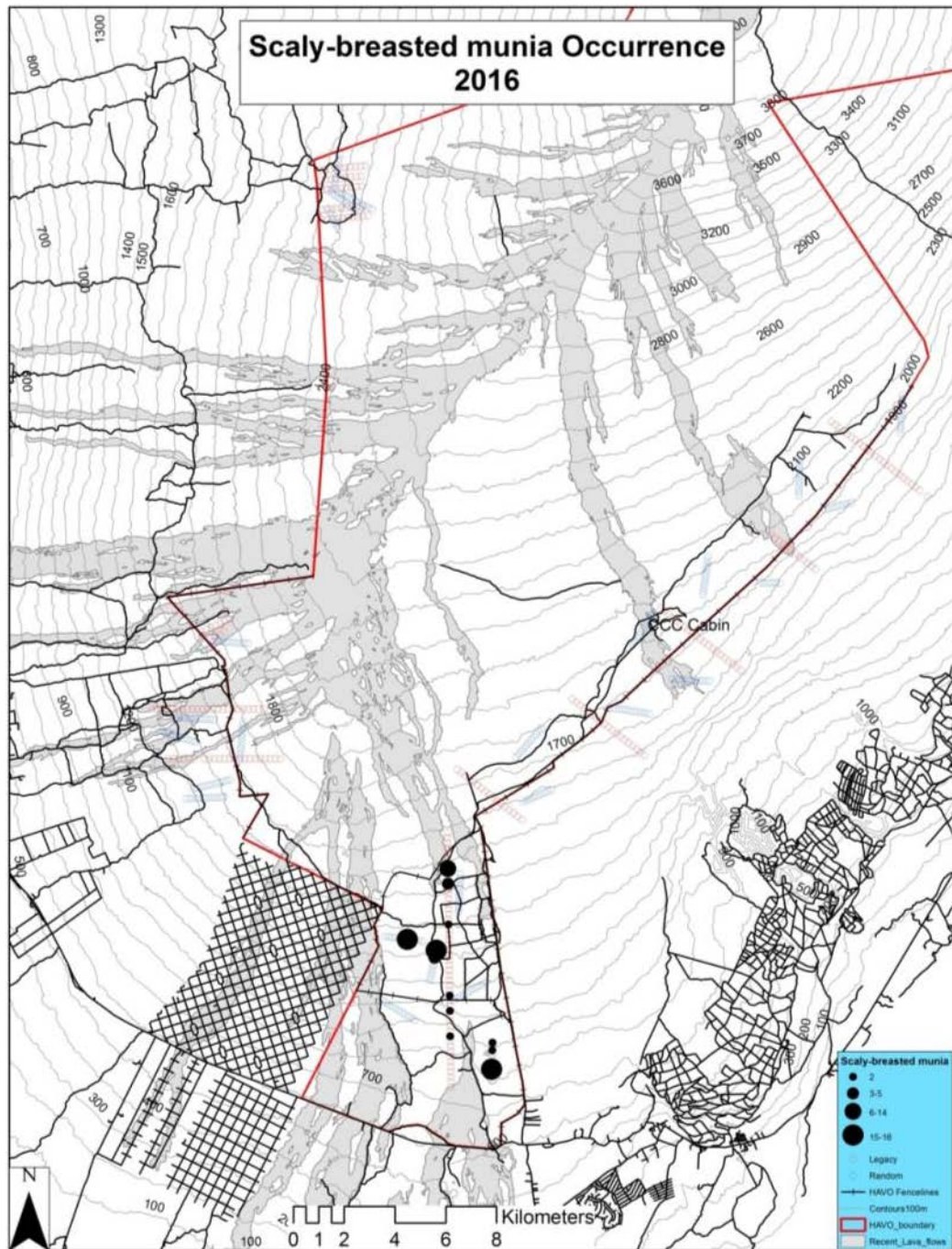


Figure A-38. Scaly-breasted Munia occurrence within Kahuku (2016).

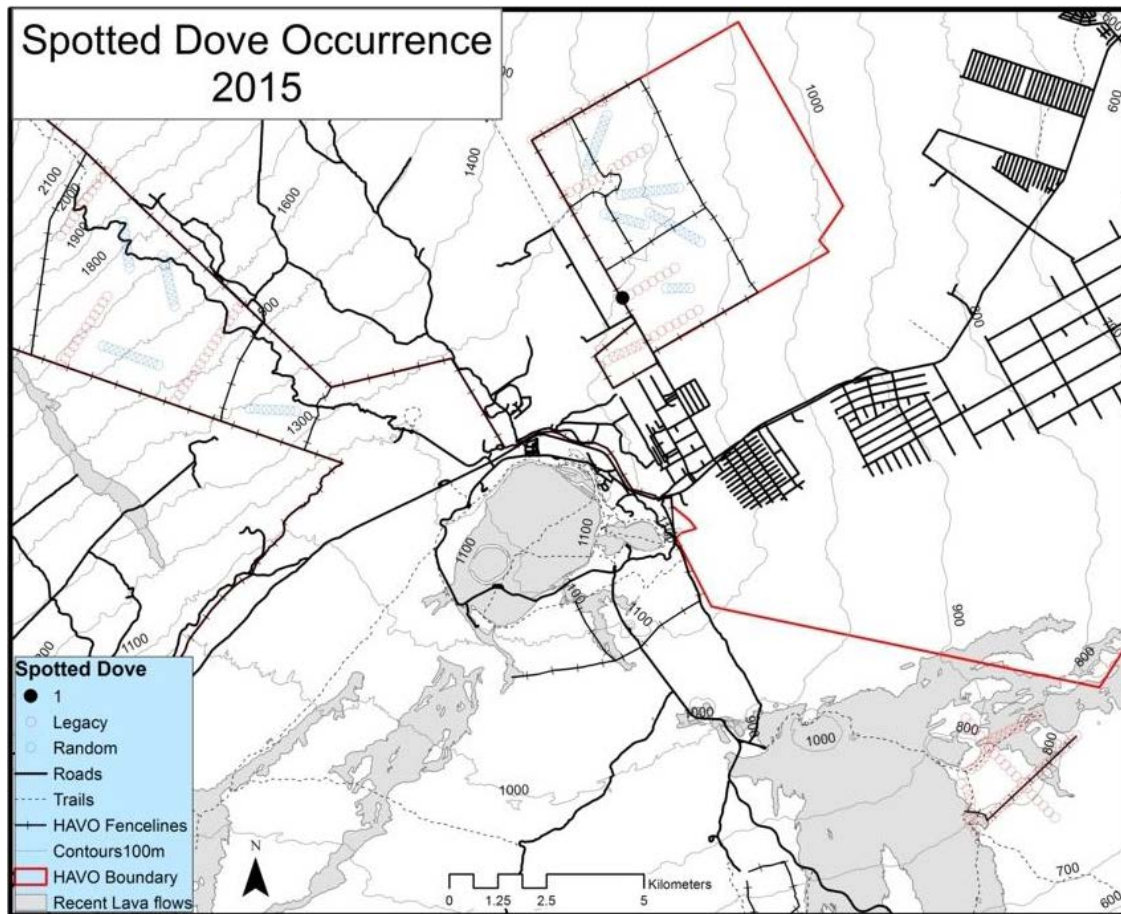


Figure A-39. Spotted Dove occurrence within Old HAVO (2015).

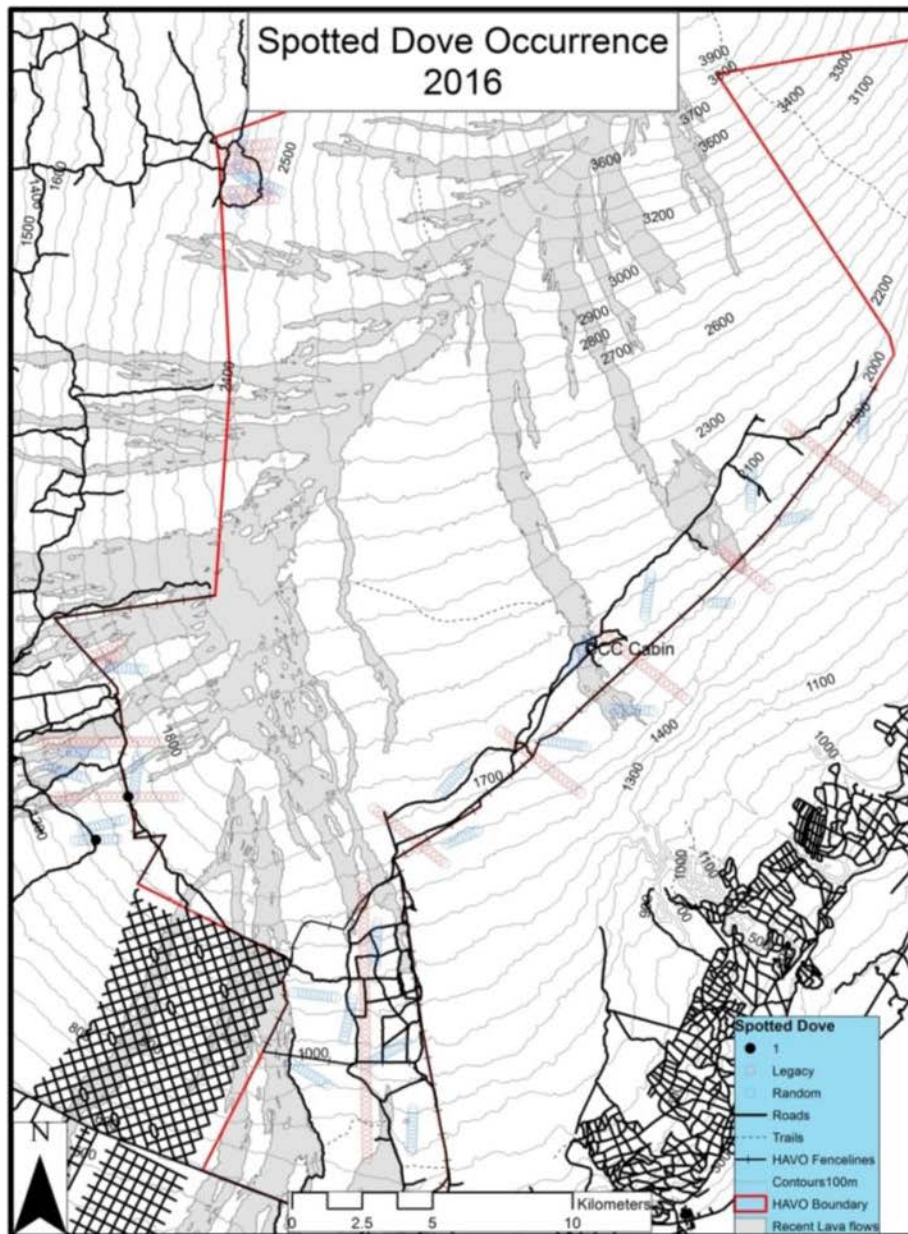


Figure A-40. Spotted Dove occurrence within Kahuku (2016).

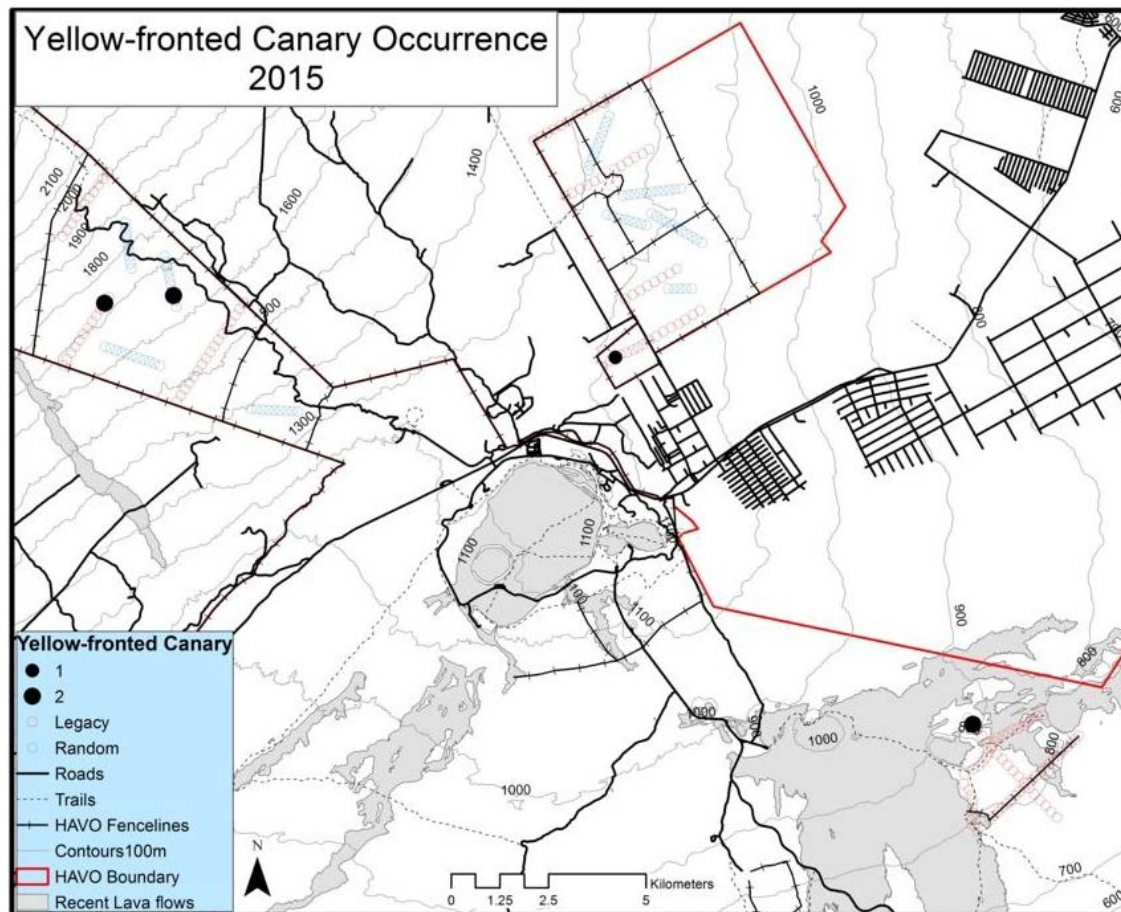


Figure A-41. Yellow-fronted Canary occurrence within Old HAVO (2015).

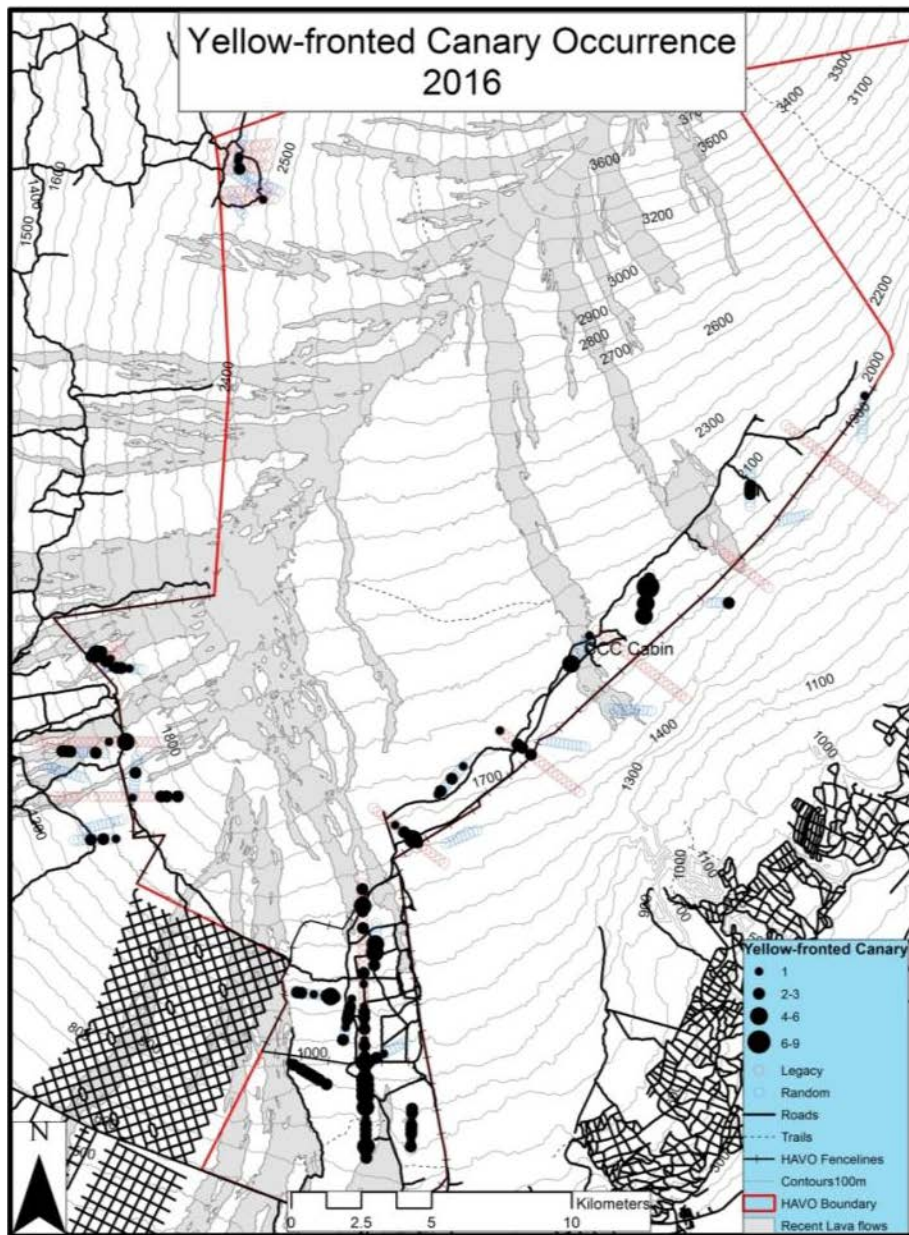


Figure A-42. Yellow-fronted Canary occurrence within Kahuku (2016).

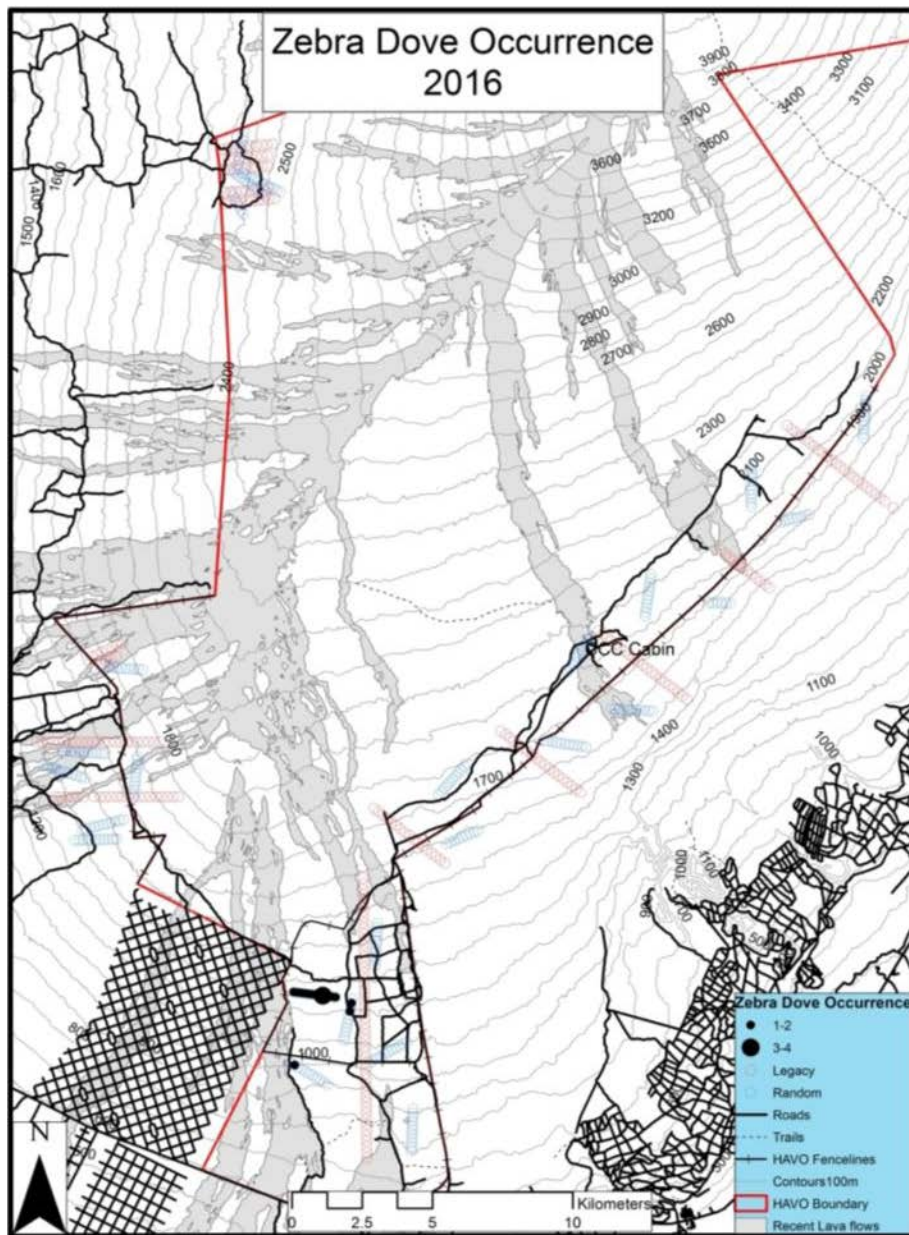


Figure A-43. Zebra Dove occurrence within Kahuku (2016).

Appendix B. Habitat Results

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Table B-1. Canopy height classes sampled at landbird monitoring stations within each tract.

Tract	# Stations Sampled	Percent of Canopy Height Class Sampled		
		1 (2-5 m tall)	2 (5-10 m tall)	3 (> 10 m tall)
East Rift Zone	64	15.63	26.56	57.81
Honomalino	97	27.84	27.84	44.33
Kahuku	190	18.95	22.63	58.42
Mauna Loa South Flank	117	0.85	18.80	80.34
Mauna Loa Strip	57	21.05	43.86	35.09
Northwest Kahuku	70	42.86	54.29	2.86
‘Ōla’a	86	0.00	24.42	75.58
Pāpā	17	17.65	58.82	23.53

Table B-2. Canopy cover classes sampled at landbird monitoring stations within each tract.

Tract	# Stations Sampled	% Not sampled	% Closed (>60% cover)	% Open (25-60% cover)	% Very scattered (<5% cover)	% No canopy (0% cover)
East Rift Zone	64	0.00	53.13	39.06	4.00	1.00
Honomalino	98	1.02	10.20	42.86	15.31	30.61
Kahuku	193	1.55	38.86	29.02	16.58	13.99
Mauna Loa South Flank	117	0.00	3.42	35.90	48.72	11.97
Mauna Loa Strip	73	6.85	24.66	13.70	16.44	38.36
Northwest Kahuku	84	3.57	0.00	7.14	42.86	46.43
‘Ōla’a	87	0.00	83.91	14.94	1.15	0.00
Pāpā	20	15	0	15	40	30

Table B-3. Distribution of downhill aspect (North, South, East, West) recorded at landbird monitoring stations.

Tract	Aspect Bearing	# of Stations
East Rift Zone	E	11
East Rift Zone	N	9
East Rift Zone	S	17
East Rift Zone	W	18
Honomalino	E	1
Honomalino	N	2
Honomalino	S	23
Honomalino	W	58
Kahuku	E	76
Kahuku	N	1
Kahuku	S	47
Kahuku	W	41
Mauna Loa South Flank	N	1
Mauna Loa South Flank	S	73
Mauna Loa South Flank	W	43
Mauna Loa Strip	E	28
Mauna Loa Strip	N	11
Mauna Loa Strip	S	29
Mauna Loa Strip	W	3
Northwest Kahuku	W	84
‘Ōla’a	E	25
‘Ōla’a	N	15
‘Ōla’a	S	15
‘Ōla’a	W	29
Pāpā	E	1
Pāpā	N	1
Pāpā	S	6
Pāpā	W	12

Table B-4. Slope variability recorded in each landbird monitoring tract.

Tract	Slope Variability	# of Stations
East Rift Zone	Not sampled	40
East Rift Zone	Low	13
East Rift Zone	Medium	2
Honomalino	Not sampled	18
Honomalino	Low	58
Honomalino	Medium	8
Kahuku	Not sampled	48
Kahuku	Low	104
Kahuku	Medium	13
Mauna Loa South Flank	Not sampled	41
Mauna Loa South Flank	Low	59
Mauna Loa South Flank	Medium	17
Mauna Loa Strip	Not sampled	10
Mauna Loa Strip	High	1
Mauna Loa Strip	Low	38
Mauna Loa Strip	Medium	22
Northwest Kahuku	Not sampled	49
Northwest Kahuku	High	2
Northwest Kahuku	Low	27
Northwest Kahuku	Medium	6
‘Ōla’a	Not sampled	8
‘Ōla’a	Low	63
‘Ōla’a	Medium	13
Pāpā	Not sampled	1
Pāpā	Low	18
Pāpā	Medium	1

Table B-5. Occurrence of understory and canopy classes recorded in the East Rift Zone.

Height Class	Class Name	% Occurrence
Understory Class*	Native Fern, Native Shrubs	23.44
	Native Fern, Native Grasses, Native Shrubs	7.81
	Native Fern, Native Shrubs, Exotic Grasses	6.25
	Native Fern, Native Grasses	4.69
	Native Shrubs, Native Fern	4.69
	Native Fern, Exotic Grasses, Exotic Shrubs	3.13
	Native Fern, Native Shrubs, Exotic Shrubs	3.13
	Native Fern, Native Shrubs, Native Grasses	3.13
	Native Shrubs, Matted Fern	3.13
	Native Shrubs, Native Fern, Exotic Grasses	3.13
	Native Shrubs, Tree Ferns	3.13
	Native Shrubs-Tree Ferns	3.13
	Classes occurring Less than 2%	31.25
Canopy Class**	'ōhi'a	43.75
	'ōhi'a, Tree Ferns	10.94
	'ōhi'a, Tree Ferns, 'ōlapa	9.38
	'ōhi'a, 'ōlapa	7.81
	'ōhi'a, faya Tree	4.69
	Tree Fern, 'ōhi'a, Native Trees	4.69
	'ōhi'a, 'ōlapa, Tree Ferns	3.13
	'ōhi'a, <i>Psidium cattleianum</i>	3.13
	Classes Occurring Less Than 2%	12.50

* 64 stations sampled

**64 stations sampled

Table B-6. Occurrence of understory and canopy classes recorded in Honomalino.

Height Class	Class Name	% Occurrence
Understory Class*	Exotic Grasses	33.67
	Bare Ground	23.47
	Exotic Grasses, Native Shrubs	8.16
	Exotic Grasses, Matted Fern	5.10
	Bare Ground, Native Shrubs	4.08
	Bare Ground, Native Shrubs, Native Grasses	3.06
	Bare Ground, Exotic Grasses	2.04
	Bare Ground, Exotic Grasses, Native Shrubs	2.04
	Bare Ground-Native Shrubs	2.04
	Exotic Grasses, Native Shrubs-Bare Ground	2.04
	Native Shrubs, Bare Ground, Native Grasses	2.04
	Native Shrubs, Exotic Grasses	2.04
	Native Shrubs-Bare Ground	2.04
	Classes occurring Less than 2%	8.16
	<i># Stations sampled</i>	98
Canopy Class**	‘ōhi‘a, koa	45.92
	‘ōhi‘a	34.69
	‘ōhi‘a-koa	15.31
	‘ōhi‘a, Native trees	2.04
	Not sampled	1.02
	koa	1.02

*98 stations sampled

**98 stations sampled

Table B-7. Occurrence of understory and canopy classes recorded in Kahuku.

Height Class	Understory Classes	% Occurrence
Understory Class*	Native Shrubs, Native Grasses, Bare Ground	12.50
	Native Shrubs, Bare Ground	7.81
	Native Shrubs, Matted Fern, Bare Ground	7.81
	Bare Ground, Native Shrubs	7.29
	Matted Fern, Native Shrubs, Bare Ground	7.29
	Tree Ferns, Bare Ground	4.17
	Tree Ferns, Native Shrubs	4.17
	Matted Fern, Native Shrubs	3.65
	Tree Ferns-Native Shrubs	3.65
	Bare Ground-Native Shrubs	3.13
	Native Shrubs, Matted Fern	3.13
	Bare Ground	2.60
	Bare Ground, Native Shrubs, Native Grasses	2.08
	Bare Ground, Tree Ferns	2.08
	Native Shrubs, Native Grasses	2.08
	Native Shrubs, Tree Ferns	2.08
	Classes Occurring Less Than 2%	24.48
Canopy Class**	‘ōhi’a	50.78
	‘ōhi’a, Native Trees	12.44
	‘ōhi’a, ‘ōlapa	8.81
	‘ōhi’a, Tree Fern, ‘ōlapa	7.25
	‘ōhi’a, ‘ōlapa, Tree Fern	4.66
	‘ōhi’a, koa-Native Trees	2.59
	Tree Fern, ‘ōhi’a, Native Trees	2.07
	Classes Occurring Less Than 2%	9.84
	Not Sampled	1.55

*192 stations sampled

**193 stations sampled

Table B-8 (continued). Occurrence of understory and canopy classes recorded in Mauna Loa South Flank.

Height Class	Understory Classes	% Occurrence
Understory Class*	Exotic Grasses	50.00
	Exotic Grasses, Bare Ground	12.93
	Exotic Grasses, Matted Fern	12.93
	Exotic Grasses, Native Shrubs	3.45
	Exotic Grasses, Exotic Shrubs	3.45
	Classes Occurring Less Than 2%	17.24
Canopy Class**	‘ōhi’a	48.72
	‘ōhi’a, koa	20.51
	‘ōhi’a-koa	11.97
	‘ōhi’a, Exotic trees	5.98
	‘ōhi’a, ‘ōlapa, Tree fern	5.13
	Classes Occurring Less Than 2%	7.69

*116 stations sampled

**117 stations sampled

Table B-9. Occurrence of understory and canopy classes recorded in Mauna Loa Strip.

Height Class	Understory Classes	% Occurrence
Understory Class*	Bare Ground, Native Shrubs	23.61
	Native Grasses, Native Shrubs	19.44
	Native Shrubs	16.67
	Native Grasses	12.50
	Native Shrubs, Native Grasses	11.11
	Native Shrubs, Bare Ground	5.56
	Native Shrubs, Exotic Grasses	2.78
	Native Shrubs, Native Grasses, Bare Ground	2.78
	Classes Occurring Less Than 2%	5.56
Canopy Class**	‘ōhi’a	24.66
	koa	16.44
	koa, a‘ali‘i	10.96

*72 stations sampled

**73 stations sampled

Table B-9 (continued). Occurrence of understory and canopy classes recorded in Mauna Loa Strip.

Height Class	Understory Classes	% Occurrence
Canopy Class** (continued)	Not sampled	9.59
	‘ōhi’a, māmane	6.85
	‘ōhi’a, Koa	5.48
	māmane, a’ali’i	5.48
	koa, māmane	4.11
	māmane	4.11
	‘ōhi’a-māmane	2.74
	Classes Occurring Less Than 2%	9.59

*72 stations sampled

**73 stations sampled

Table B-10. Occurrence of understory and canopy classes recorded in Northwest Kahuku.

Height Class	Understory Classes	% Occurrence
Understory Class*	Bare Ground, Exotic Grasses	30.95
	Bare Ground	22.62
	Bare Ground, Exotic Grasses, Exotic Shrubs	9.52
	Bare Ground, Exotic Shrubs	5.95
	Bare Ground, Native Shrubs	4.76
	Bare Ground, Exotic Grasses, Exotic Shrubs, Native Shrubs	2.38
	Bare Ground, Exotic Shrubs, Native Shrubs	2.38
	Bare Ground, Native Shrubs, Exotic Grasses	2.38
	Bare Ground, Native Shrubs, Exotic Shrubs, Exotic Grasses	2.38
	Exotic Grasses, Bare Ground	2.38
	Exotic Grasses, Exotic Shrubs, Bare Ground	2.38
	Classes Occurring Less Than 2%	11.90
Canopy Class**	māmane	22.62

*84 stations sampled

**84 stations sampled

Table B-10. Occurrence of understory and canopy classes recorded in Northwest Kahuku.

Height Class	Understory Classes	% Occurrence
Canopy Class** (continued)	māmane, naio	17.86
	‘ōhi’a	14.29
	‘ōhi’a, māmane	10.71
	māmane, ‘ōhi’a	7.14
	māmane, ‘ōhi’a-naio	4.76
	māmane-naio	2.38
	Classes Occurring Less Than 2%	14.29
	Not sampled	5.95

*84 stations sampled

**84 stations sampled

Table B-11. Occurrence of understory and canopy classes recorded in ‘Ōla’a.

Height Class	Understory Classes	% Occurrence
Understory Class*	Exotic Shrubs, Native Fern, Native Shrubs	56.98
	Exotic Shrubs, Native Shrubs, Native Fern	24.42
	Native Fern, Exotic Shrubs, Native Shrubs	4.65
	Native Fern, Native Shrubs	4.65
	Native Fern, Native Shrubs, Exotic Shrubs	2.33
	Native Fern, Native Shrubs, Exotic Vines	1.16
	Native Shrubs, Native Fern	1.16
	Native Shrubs, Native Fern, Exotic Grasses	1.16
	Native Shrubs-Native Fern	1.16
	Tree Ferns	1.16
	Tree Ferns-Native Shrubs	1.16
Canopy Class**	‘ōhi’a, ‘ōlapa	24.14
	‘ōhi’a, Tree fern, ‘ōlapa	19.54
	‘ōhi’a-‘ōlapa	6.90
	‘ōhi’a, ‘ōlapa, Native trees	5.75
	‘ōhi’a, Tree fern	4.60

*86 stations sampled

**87 stations sampled

Table B-11 (continued). Occurrence of understory and canopy classes recorded in 'Ōla'a.

Height Class	Understory Classes	% Occurrence
Canopy Class** (continued)	'ōhi'a, 'ōlapa, kawau	4.60
	'ōhi'a, 'ōlapa	3.45
	'ōlapa, Native trees	2.30
	'ōlapa, 'ōhi'a	2.30
	'ōhi'a, 'ōlapa, olomea	2.30
	Classes Occurring Less Than 2%	24.14

*86 stations sampled

**87 stations sampled

Table B-12. Occurrence of understory and canopy classes recorded in Pāpā.

Height Class	Understory Classes	% Occurrence
Understory Class*	Bare Ground	15
	Bare Ground-Native Shrubs, Exotic Shrubs	15
	Exotic Grasses, Native Shrubs	15
	Bare Ground, Native Shrubs, Native Grasses	10
	Bare Ground, Exotic Grasses	5
	Bare Ground, Native Shrubs-Exotic Shrubs	5
	Exotic Grasses-Bare Ground, Native Shrubs	5
	Exotic Grasses-Native Shrubs	5
	Exotic Grasses-Native Shrubs, Bare Ground	5
	Exotic Shrubs, Native Shrubs	5
	Native Shrubs, Bare Ground, Native Grasses	5
	Native Shrubs, Exotic Grasses, Native Grasses, Bare Ground	5
	Native Shrubs, Native Grasses, Bare Ground	5
Canopy Class**	'ōhi'a	40
	'ōhi'a, koa	30

*20 stations sampled

**20 stations sampled

Table B-12 (continued). Occurrence of understory and canopy classes recorded in Pāpā.

Height Class	Understory Classes	% Occurrence
Canopy Class** (continued)	‘ōhi’a-koa	15
	koa- naio	5
	‘ōhi’a, koa, kōlea, Native trees	5
	Not sampled	5

*20 stations sampled

**20 stations sampled

Appendix C. AIC Statistics

Model selection based on AIC* for 'Apapane.

C-1

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	Δ AICc	w	Justification
Hazard Rate	Cos(2,3)	Cover	7	35036.93	70087.88	0.00	0.99388	–
Hazard Rate	Cos(2,3)	Tract	11	35038.02	70098.06	10.18	0.00612	–
Hazard Rate	Cos(2,3)	24Detect	5	35108.93	70227.88	140.00	0.00000	–
Hazard Rate	Cos(2,3)	Detect	6	35108.05	70228.12	140.24	0.00000	–
Hazard Rate	Cos(2,3)	Obs	9	35145.14	70308.31	220.43	0.00000	–
Hazard Rate	Cos(2,3)	Year	5	35197.90	70405.80	317.92	0.00000	–
Hazard Rate	Cos(2,3)	TranType	5	35234.41	70478.83	390.95	0.00000	–
Hazard Rate	Cos(2,3)	14Detect	5	35249.46	70508.93	421.05	0.00000	–
Hazard Rate	Cos(2,3)	Wind	6	35263.70	70539.40	451.52	0.00000	–
Hazard Rate	Cos(2,3)	Gust	7	35265.71	70545.43	457.55	0.00000	–
Hazard Rate	Cos(2,3)	Cloud	6	35270.11	70552.23	464.35	0.00000	–
Hazard Rate	Cos(2,3)	Rain	6	35271.19	70554.39	466.51	0.00000	–
Hazard Rate	Cos(2,3)	Time	5	35273.30	70556.61	468.73	0.00000	–
Hazard Rate	Cos	–	4	35274.50	70557.01	469.13	0.00000	–
Hazard Normal	Cos	–	3	35285.36	70576.71	488.83	0.00000	–
Hazard Normal	Key	–	1	35323.64	70649.28	561.40	0.00000	–
Hazard Rate	Key	–	2	35352.91	70709.81	621.93	0.00000	–
Hazard Normal	H-poly	–	–	–	–	–	–	Parameters highly correlated
Hazard Rate	S-poly	–	–	–	–	–	–	Parameters at lower bound
Hazard Rate	Cos(2,3)	Height	–	–	–	–	–	Maximum probability of detection > 1

* 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 selection based on AIC* for Hawai'i 'Amakihi.

C-2

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	ΔAICc	w	Justification
Hazard Normal	Cos(2)	24Detect	3	15444.60	30895.21	0.00	0.62011	–
Hazard Normal	Cos(2)	Detect	4	15444.09	30896.19	0.98	0.37989	–
Hazard Normal	Cos(2)	Obs	7	15528.96	31071.96	176.75	0.00000	–
Hazard Normal	Cos(2)	14Detect	3	15561.38	31128.77	233.56	0.00000	–
Hazard Normal	Cos(2)	Cover	5	15573.19	31156.40	261.19	0.00000	–
Hazard Normal	Cos(2)	Year	3	15577.75	31161.50	266.29	0.00000	–
Hazard Normal	Cos(2)	Gust	5	15595.91	31201.84	306.63	0.00000	–
Hazard Normal	Cos(2)	Tract	9	15592.37	31202.78	307.57	0.00000	–
Hazard Normal	Cos(2)	Wind	4	15604.63	31217.27	322.06	0.00000	–
Hazard Normal	Cos(2)	TranType	3	15610.62	31227.25	332.04	0.00000	–
Hazard Normal	Cos(2)	Height	4	15612.27	31232.54	337.33	0.00000	–
Hazard Normal	Cos(2)	Rain	4	15614.58	31237.17	341.96	0.00000	–
Hazard Normal	Cos(2)	Cloud	4	15616.44	31240.88	345.67	0.00000	–
Hazard Normal	Cos(2)	Time	3	15617.63	31241.26	346.05	0.00000	–
Hazard Normal	Cos	–	2	15619.67	31243.35	348.14	0.00000	–
Hazard Normal	Key	–	1	15622.77	31247.55	352.34	0.00000	–
Hazard Rate	Cos	–	4	15621.18	31250.38	355.17	0.00000	–
Hazard Rate	Key	–	2	15631.10	31266.21	371.00	0.00000	–
Hazard Normal	H-poly	–	–	–	–	–	–	Parameters highly correlated
Hazard Rate	S-poly	–	–	–	–	–	–	Parameters highly correlated

* 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 selection based on AIC* for Hawai'i Elepaio.

C-3

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	$\Delta AICc$	w	Justification
Hazard Rate	Key	24Detect	3	657.70	1321.55	0.00	0.69181	–
Hazard Rate	Key	14Detect	3	658.56	1323.26	1.71	0.29421	–
Hazard Rate	Key	Cover	4	660.63	1329.49	7.94	0.01306	–
Hazard Rate	Key	Tract	6	661.18	1334.88	13.33	0.00088	–
Hazard Rate	Key	Height	3	668.74	1343.57	22.02	0.00001	–
Hazard Rate	Key	Cloud	3	669.14	1344.43	22.88	0.00001	–
Hazard Rate	Key	Wind	3	669.29	1344.72	23.17	0.00001	–
Hazard Normal	Key	–	1	672.08	1346.18	24.63	0.00000	–
Hazard Rate	Key	–	2	641.15	1346.38	24.83	0.00000	–
Hazard Rate	Key	Time	3	670.23	1346.60	25.05	0.00000	–
Hazard Rate	Key	Rain	3	670.64	1347.42	25.87	0.00000	–
Hazard Rate	Key	Gust	4	669.74	1347.72	26.17	0.00000	–
Hazard Rate	Key	TranType	3	670.85	1347.85	26.30	0.00000	–
Hazard Rate	Key	Year	3	671.10	1348.35	26.80	0.00000	–
Hazard Rate	Key	Obs	4	670.62	1349.49	27.94	0.00000	–
Hazard Normal	Cos	–	–	–	–	–	–	Key model selected
Hazard Normal	H-poly	–	–	–	–	–	–	Key model selected
Hazard Rate	Cos	–	–	–	–	–	–	Key model selected
Hazard Rate	Key	Detect	–	–	–	–	–	Parameters highly correlated
Hazard Rate	S-poly	–	–	–	–	–	–	Key model selected

* 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 selection based on AIC* for Hawai'i Creeper.

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	Δ AICc	w	Justification
Hazard Normal	Key	–	1	101.16	204.5	0.00	1.00000	–
Hazard Rate	Key	–	–	–	–	–	–	Parameters at lower bound

* 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 selection based on AIC* for Hawai'i 'Akepa.

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	Δ AICc	w	Justification
Hazard Normal	Key	–	1	216.14	434.36	0.00	0.61775	–
Hazard Rate	Key	–	2	215.54	435.32	0.96	0.38225	Hazard Rate Key model chosen because of spike at near distances and lack of data in intervening distances.

* 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).

G-1

Model selection based on AIC* for House Finch. Truncation = 89.

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	ΔAICc	w	Justification	Weights**
Hazard Rate	Key	Tract	8	2325.78	4667.83	0.00	0.99303	Bootstrap model failed to converge; used next best-fit model to estimate abundance and variance	1.00000
Hazard Rate	Key	Year	3	2335.91	4677.86	10.03	0.00659	–	0.00664
Hazard Rate	Key	Obs	4	2337.95	4683.97	16.14	0.00031	–	0.00031
Hazard Rate	Key	Height	4	2339.48	4687.03	19.20	0.00007	–	0.00007
Hazard Rate	Key	Cloud	3	2357.46	4720.96	53.13	0.00000	–	0.00000
Hazard Rate	Key	Gust	4	2362.34	4732.76	64.93	0.00000	–	0.00000
Hazard Rate	Key	–	2	2364.61	4733.24	65.41	0.00000	–	0.00000
Hazard Rate	Key	Wind	4	2363.22	4734.51	66.68	0.00000	–	0.00000
Hazard Rate	Key	24Detect	3	2364.76	4735.56	67.73	0.00000	–	0.00000
Hazard Rate	Key	Rain	3	2364.86	4735.76	67.93	0.00000	–	0.00000
Hazard Rate	Key	TranType	3	2364.89	4735.83	68.00	0.00000	–	0.00000
Hazard Rate	Key	14Detect	3	2364.89	4735.83	68.00	0.00000	–	0.00000
Hazard Rate	Key	Time	3	2364.89	4735.83	68.00	0.00000	–	0.00000
Hazard Rate	Key	Cover	4	2364.76	4737.60	69.77	0.00000	–	0.00000
Hazard Rate	Key	Detect	4	2364.76	4737.60	69.77	0.00000	–	0.00000
Hazard Normal	Key	–	1	2371.21	4744.43	76.60	0.00000	–	0.00000
Hazard Normal	Cos	–	–	–	–	–	–	Maximum probability of detection > 1	–
Hazard Normal	H-poly	–	–	–	–	–	–	Key model selected	–
Hazard Rate	Cos	–	–	–	–	–	–	Parameters at lower bound	–
Hazard Rate	S-poly	–	–	–	–	–	–	Maximum probability of detection > 1	–

* 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).

**Sum of weights = 1.007018

Model selection based on AIC* for 'I'iwi.

C-1

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	Δ AICc	w	Justification
Hazard Rate	Key	24Detect	3	1560.33	3126.73	0.00	0.99846	–
Hazard Rate	Key	Obs	4	1565.79	3139.68	12.95	0.00154	–
Hazard Rate	Key	Year	3	1577.83	3161.72	34.99	0.00000	–
Hazard Normal	Key	–	1	1590.19	3182.39	55.66	0.00000	–
Hazard Rate	S-poly	–	3	1588.27	3182.61	55.88	0.00000	–
Hazard Rate	Key	–	2	1589.76	3183.55	56.82	0.00000	–
Hazard Rate	Key	TranType	3	1589.58	3185.22	58.49	0.00000	–
Hazard Rate	Key	Gust	3	1589.59	3185.24	58.51	0.00000	–
Hazard Rate	Key	Wind	3	1589.68	3185.41	58.68	0.00000	–
Hazard Rate	Key	Cloud	3	1589.81	3185.68	58.95	0.00000	–
Hazard Rate	Key	Rain	3	1589.87	3185.79	59.06	0.00000	–
Hazard Rate	Key	Height	3	1589.90	3185.86	59.13	0.00000	–
Hazard Rate	Key	14Detect	3	1589.97	3186.01	59.28	0.00000	–
Hazard Rate	Key	Time	3	1589.99	3186.04	59.31	0.00000	–
Hazard Rate	Key	Cover	4	1589.58	3187.26	60.53	0.00000	–
Hazard Normal	Cos	–	–	–	–	–	–	Maximum probability of detection > 1
Hazard Normal	H-poly	–	–	–	–	–	–	Parameters highly correlated
Hazard Rate	Cos	–	–	–	–	–	–	Key model selected
Hazard Rate	Key	Tract	–	–	–	–	–	Failed to converge
Hazard Rate	Key	Detect	–	–	–	–	–	Failed to converge

* 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 selection based on AIC* for Japanese Bush Warbler.

C-2

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	$\Delta AICc$	w	Justification
Hazard Rate	Key	Cover	3	710.85	1427.85	0.00	0.98424	–
Hazard Rate	Key	Tract	7	711.32	1437.35	9.50	0.00852	–
Hazard Rate	Key	Gust	3	716.97	1440.09	12.24	0.00216	–
Hazard Rate	Key	Time	3	717.72	1441.58	13.73	0.00103	–
Hazard Rate	Key	–	2	719.20	1442.48	14.63	0.00065	–
Hazard Rate	Key	14Detect	2	719.20	1442.48	14.63	0.00065	–
Hazard Rate	Key	Year	2	719.20	1442.48	14.63	0.00065	–
Hazard Rate	Key	Cloud	3	718.36	1442.86	15.01	0.00054	–
Hazard Rate	Key	24Detect	3	718.99	1444.13	16.28	0.00029	–
Hazard Rate	Key	Detect	3	718.99	1444.13	16.28	0.00029	–
Hazard Rate	Key	Wind	3	719.07	1444.28	16.43	0.00027	–
Hazard Rate	Key	Rain	3	719.16	1444.47	16.62	0.00024	–
Hazard Rate	Key	TranType	3	719.24	1444.63	16.78	0.00022	–
Hazard Rate	Key	Height	3	719.51	1445.17	17.32	0.00017	–
Hazard Rate	Key	Obs	3	720.37	1446.88	19.03	0.00007	–
Hazard Normal	Key	–	1	727.25	1456.53	28.68	0.00000	–
Hazard Normal	Cos	–	–	–	–	–	–	Maximum probability of detection > 1
Hazard Normal	H-poly	–	–	–	–	–	–	Parameters highly correlated
Hazard Rate	Cos	–	–	–	–	–	–	Maximum probability of detection > 1
Hazard Rate	S-poly	–	–	–	–	–	–	Maximum probability of detection > 1

* 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 selection based on AIC* for Japanese White-eye.

C-3

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	$\Delta AICc$	w	Justification
Hazard Normal	Key	Obs	5	12183.92	24377.85	0.00	1.00000	–
Hazard Normal	Key	Cover	4	12206.24	24420.49	42.64	0.00000	–
Hazard Normal	Key	Detect	3	12226.34	24458.70	80.85	0.00000	–
Hazard Normal	Key	24Detect	2	12235.28	24474.55	96.70	0.00000	–
Hazard Normal	Key	Year	2	12263.91	24531.82	153.97	0.00000	–
Hazard Normal	Key	14Detect	2	12268.47	24540.95	163.10	0.00000	–
Hazard Normal	Key	TranType	2	12295.33	24594.67	216.82	0.00000	–
Hazard Normal	Key	Height	3	12295.42	24596.85	219.00	0.00000	–
Hazard Normal	Key	Time	2	12299.54	24603.09	225.24	0.00000	–
Hazard Normal	Key	Wind	3	12301.50	24609.00	231.15	0.00000	–
Hazard Normal	Key	Cloud	3	12302.75	24611.51	233.66	0.00000	–
Hazard Normal	Key	Gust	4	12303.31	24614.63	236.78	0.00000	–
Hazard Normal	Key	–	1	12307.07	24616.15	238.30	0.00000	–
Hazard Normal	Key	Rain	3	12305.33	24616.68	238.83	0.00000	–
Hazard Rate	Cos	–	3	12309.18	24624.36	246.51	0.00000	–
Hazard Rate	Key	–	2	12312.47	24628.94	251.09	0.00000	–
Hazard Normal	Cos	–	–	–	–	–	–	Key model selected
Hazard Normal	H-poly	–	–	–	–	–	–	Parameters highly correlated
Hazard Rate	S-poly	–	–	–	–	–	–	Parameters highly correlated
Hazard Normal	Key	Tract	–	–	–	–	–	Failed to converge

* 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 selection based on AIC* for Northern Cardinal.

	Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	$\Delta AICc$	w	Justification
C-4	Hazard Rate	Key	Tract	17	3035.34	6105.63	0.00	0.78160	–
	Hazard Rate	Key	Cover	5	3049.05	6108.18	2.55	0.21840	–
	Hazard Rate	Key	Detect	4	3081.81	6171.69	66.06	0.00000	–
	Hazard Rate	Key	24Detect	3	3084.84	6175.72	70.09	0.00000	–
	Hazard Rate	Key	Year	3	3086.62	6179.28	73.65	0.00000	–
	Hazard Rate	Key	Height	4	3088.00	6184.07	78.44	0.00000	–
	Hazard Rate	Key	Obs	5	3092.59	6195.27	89.64	0.00000	–
	Hazard Rate	Key	Wind	4	3099.85	6207.76	102.13	0.00000	–
	Hazard Rate	Key	–	2	3104.60	6213.31	107.68	0.00000	–
	Hazard Rate	Key	TranType	3	3105.22	6216.47	110.84	0.00000	–
	Hazard Rate	Key	Cloud	3	3105.80	6217.64	112.01	0.00000	–
	Hazard Rate	Key	Rain	3	3106.28	6218.60	112.97	0.00000	–
	Hazard Rate	Key	Time	3	3106.36	6218.75	113.12	0.00000	–
	Hazard Rate	Key	14Detect	3	3106.38	6218.80	113.17	0.00000	–
	Hazard Normal	Key	–	1	3108.65	6219.31	113.68	0.00000	–
	Hazard Rate	Key	Gust	5	3105.60	6221.29	115.66	0.00000	–
	Hazard Normal	Cos	–	–	–	–	–	–	Maximum probability of detection > 1
	Hazard Normal	H-poly	–	–	–	–	–	–	Key model selected
	Hazard Rate	Cos	–	–	–	–	–	–	Maximum probability of detection > 1
	Hazard Rate	S-poly	–	–	–	–	–	–	Maximum probability of detection > 1

* 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 selection based on AIC* for 'Ōma'o.

C₁₅

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	ΔAICc	w	Justification
Hazard Rate	Key	Year	3	2613.32	5232.67	0.00	0.98825	–
Hazard Rate	Key	Tract	8	2613.34	5242.91	10.24	0.00591	–
Hazard Rate	Key	Obs	5	2616.63	5243.35	10.68	0.00474	–
Hazard Rate	Key	TranType	3	2620.54	5247.12	14.45	0.00072	–
Hazard Rate	Key	Cover	5	2619.23	5248.56	15.89	0.00035	–
Hazard Rate	Key	24Detect	3	2623.92	5253.89	21.22	0.00002	–
Hazard Rate	Key	Detect	4	2623.93	5255.93	23.26	0.00001	–
Hazard Rate	Key	Cloud	3	2628.74	5263.52	30.85	0.00000	–
Hazard Rate	Key	Gust	5	2627.77	5265.64	32.97	0.00000	–
Hazard Rate	Key	Rain	3	2630.02	5266.08	33.41	0.00000	–
Hazard Rate	Key	–	2	2631.58	5267.17	34.50	0.00000	–
Hazard Rate	Key	Height	3	2631.02	5268.08	35.41	0.00000	–
Hazard Rate	Key	14Detect	3	2631.44	5268.92	36.25	0.00000	–
Hazard Rate	Key	Time	3	2631.64	5269.31	36.64	0.00000	–
Hazard Rate	Key	Wind	4	2631.12	5270.31	37.64	0.00000	–
Hazard Normal	Key	–	1	2652.53	5307.07	74.40	0.00000	–
Hazard Normal	Cos	–	–	–	–	–	–	Maximum probability of detection > 1
Hazard Normal	H-poly	–	–	–	–	–	–	Parameters highly correlated
Hazard Rate	Cos	–	–	–	–	–	–	Maximum probability of detection > 1
Hazard Rate	S-poly	–	–	–	–	–	–	Maximum probability of detection > 1

* 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 selection based on AIC* for Red-billed Leiothrix.

C-6

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	ΔAICc	w	Justification
Hazard Rate	Key	Year	3	1504.71	3015.49	0.00	0.75019	–
Hazard Rate	Key	24Detect	3	1506.51	3019.09	3.60	0.12401	–
Hazard Rate	Key	Detect	3	1506.51	3019.09	3.60	0.12401	–
Hazard Rate	Key	Height	3	1512.06	3030.19	14.70	0.00048	–
Hazard Rate	Key	TranType	3	1512.45	3030.98	15.49	0.00032	–
Hazard Rate	Key	Time	3	1512.71	3031.48	15.99	0.00025	–
Hazard Rate	Key	–	2	1514.10	3032.24	16.75	0.00017	–
Hazard Rate	Key	Rain	3	1513.53	3033.12	17.63	0.00011	–
Hazard Rate	Key	Obs	3	1513.56	3033.19	17.70	0.00011	–
Hazard Rate	Key	Wind	4	1512.65	3033.41	17.92	0.00010	–
Hazard Rate	Key	Cloud	3	1513.71	3033.49	18.00	0.00009	–
Hazard Rate	Key	Gust	4	1512.76	3033.64	18.15	0.00009	–
Hazard Rate	Key	Cover	3	1514.04	3034.14	18.65	0.00007	–
Hazard Normal	Key	–	1	1520.16	3042.32	26.83	0.00000	–
Hazard Normal	Cos	–	–	–	–	–	–	Maximum probability of detection > 1
Hazard Normal	H-poly	–	–	–	–	–	–	Parameters highly correlated
Hazard Rate	Cos	–	–	–	–	–	–	Maximum probability of detection > 1
Hazard Rate	S-poly	–	–	–	–	–	–	Key model selected
Hazard Rate	Key	Tract	–	–	–	–	–	Failed to converge
Hazard Rate	Key	14Detect	–	–	–	–	–	Failed to converge

* 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 selection based on AIC* for Yellow-fronted Canary.

Model/Species	Series expansion	Covariate	# Params	-LogL	AICc	ΔAICc	w	Justification
Hazard Rate	Key	Cover	3	1100.13	2206.34	0.00	0.89648	Bootstrap model failed to converge; used next best-fit model to estimate abundance and variance
Hazard Rate	Key	Obs	3	1102.28	2210.66	4.32	0.10339	–
Hazard Rate	Key	Detect	4	1108.21	2224.58	18.24	0.00010	–
Hazard Rate	Key	24Detect	3	1111.33	2228.74	22.40	0.00001	–
Hazard Rate	Key	TranType	3	1112.17	2230.44	24.10	0.00001	–
Hazard Normal	Key	–	1	1114.35	2230.71	24.37	0.00000	–
Hazard Rate	Key	–	2	1114.14	2232.33	25.99	0.00000	–
Hazard Rate	Key	Cloud	3	1113.27	2232.62	26.28	0.00000	–
Hazard Rate	Key	14Detect	3	1113.36	2232.82	26.48	0.00000	–
Hazard Rate	Key	Time	3	1113.77	2233.64	27.30	0.00000	–
Hazard Rate	Key	Height	3	1113.98	2234.06	27.72	0.00000	–
Hazard Rate	Key	Gust	4	1113.98	2236.11	29.77	0.00000	–
Hazard Rate	Key	Wind	4	1114.13	2236.41	30.07	0.00000	–
Hazard Normal	Cos	–	–	–	–	–	–	Key model selected
Hazard Normal	H-poly	–	–	–	–	–	–	Key model selected
Hazard Rate	Cos	–	–	–	–	–	–	Key model selected
Hazard Rate	S-poly	–	–	–	–	–	–	Key model selected
Hazard Rate	Key	Tract	–	–	–	–	–	Failed to converge
Hazard Rate	Key	Rain	–	–	–	–	–	Failed to converge
Hazard Rate	Key	Year	–	–	–	–	–	Failed to converge

* 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).

Appendix D. Hawai‘i Volcanoes National Park Landbird Monitoring Field Report (2015-2016)

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Abstract

This abstract summarizes the field methods and survey effort for the 2015-2016 Pacific Island Network Landbird Monitoring Project on Hawai‘i Island. Bird and habitat surveys were conducted within the boundaries of Hawai‘i Volcanoes National Park, The Nature Conservancy’s Kona Hema Unit, and the Ka‘ū Forest Reserve. This study was conducted under a cooperative agreement between the National Park Service and the Hawai‘i-Pacific Islands Cooperative Ecosystems Studies Unit (HPI CESU), joint agreement H8080090008. Fieldwork preparation and data collection methods were followed as prescribed in the Pacific Island Network Landbird Monitoring Protocol (Camp et al. 2011) except where noted.

The landbird project was conducted over two separate years in tract groups one (Old HAVO) and two (Kahuku Unit). Surveys in the Old HAVO tracts: Mauna Loa Strip Road, ‘Ōla’a, and East Rift Zone, were conducted from 3 March 2015 through 23 April 2015. The Kahuku Unit surveys, which occurred in 5 separate tracts: Honomalino, Kahuku, Mauna Loa South Flank, Northwest Kahaku and Pāpā, were conducted from 8 February 2016 through 13 April 2016. A total of 757 stations on 62 transects were sampled for landbird occurrence and abundance; as well as several habitat variables. In Old HAVO two observers surveyed 239 stations on 21 transects total. The Old HAVO survey effort took place over 20 calendar days totaling 34 survey days (product of calendar days and surveyors in field). A total of 518 stations were sampled in the Kahuku Unit on 41 transects. The Kahuku Unit effort was completed over 29 calendar days totaling 51 survey days. All legacy transects are permanently marked for future surveys and new unmarked random transects will be generated and surveyed in subsequent years according to procedures in the Protocol (Camp et al. 2011).

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Introduction

The Landbird Monitoring field season of 2015-2016 was conducted on Hawai‘i Island within Hawai‘i Volcanoes National Park (HAVO), Ka‘ū 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. Training and sampling procedures followed the Pacific Island Network Inventory and Monitoring Program (PACN) Landbird Monitoring Protocol (hereafter 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 five (Table D-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. In 2015, during the survey of Old HAVO, Seth Judge and Dean Sedgwick conducted all of the survey work. In 2016, Seth Judge and field technician Carine Squibb conducted the majority of the survey work. Patrick Hart (Professor and Chair, Department of Biology-University of Hawai‘i at Hilo) and Nicole Fernandez (University of Hawai‘i at Hilo graduate student) participated as primary point counters on a small portion of survey work within the Honomalino tract. There were no secondary counters during survey work for either 2015 or 2016.

Table D-1. 2015-2016 landbird survey primary point count surveyors.

Observer	Observer Code	Contact information
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Patrick Hart served as the project Principal Investigator and assisted with planning and preparations. Richard Camp (Hawai‘i Cooperative Studies Unit, University of Hawai‘i 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. Keola Awong (HAVO Kahuku Unit Area Manager), Ryan Monello (PACN Program Manager) and Kelly Kozar (PACN Data Manager) offered further assistance with project needs.

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—Seth Judge, Dean Sedgwick, and Patrick J. Hart—had multiple years of experience counting birds and conducting avian research on Hawai‘i

Island. Carine Squibb had three years of field experience working on research projects investigating populations of Hawaiian landbirds (both native and non-native) in addition to two years of mainland point count experience. Nicole Fernandez, a graduate student, had prior primary count experience on Hawai‘i Island but was a relative novice surveying in HAVO. Nevertheless, the entire crew participated in the training and calibration to standardize bird identification and distance measurements. Training and calibration were conducted in HAVO. Additionally, surveyors participated in annual point counts in the USFWS Hakalau National Wildlife Refuge, Keauhou managed by the Three Mountain Alliance, and the Palila (*Loxioides bailleui*) counts on Mauna Kea. Inexperienced point counters were paired with the primary counters and both discussed what was heard and seen after each count. Additionally, surveyors explored areas of HAVO where forest birds could be readily seen and heard. Common birds such as ‘Apapane (*Himatione sanguinea*), Hawai‘i ‘Amakihi (*Chlorodrepanis 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. Surveys did not commence until each primary counter was confident of identifying birds visually and aurally.

Distance Measurement Training

In addition to bird detections, the crew practiced estimating distances. 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. Surveyors also carried range finders in the field and spent a minute or two before each survey to familiarize themselves with the surroundings and gain accurate distances of trees or other features within the survey area.

Habitat Identification

Training for habitat data collection focused on field methods outlined in the Protocol (Camp et al. 2011). Each primary point counter had several years of field experience on Hawai‘i Island and already knew many of the dominant plants encountered in HAVO. Unknown plants or habitat encountered in the field were not assigned a vegetation class. Class descriptions were often lumped into broad native or non-native categories.

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, white gas, propane 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. Surveyors also needed a measuring tape and range finders for distance estimates. The project purchased two new GPS units in 2015, which may be available for future surveys. The project also used two densiometers and two clinometers for habitat measurements. Thermometers were not purchased; thus, temperatures were not recorded during bird surveys.

Transect and Station Maintenance

All legacy transects and stations were established during the field season of 2010 (Judge et al. 2011). Transects were navigated using GPS units and magnetic compasses as prescribed in the Protocol (Camp et al. 2011). Although the GPS units have a compass function, the crew found it more accurate in closed canopy forests to navigate to stations by reading the bearing in degrees from the GPS and then following that bearing using a magnetic compass. The Garmin 60CSX units typically had an accuracy of three to six meters, and random stations were surveyed as close as possible to the waypoint in GPS.

Transects were maintained and flagging was replaced or refreshed during the 2015-2016 field seasons. No flagging was placed on randomly prescribed landbird transects. Blue flagging marked the length and path of legacy transects. Orange flagging was placed approximately five and 10 m away from the station to prevent surveyors from accidentally missing the station. In 2010, 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). PVC poles were still in good condition in 2015-2016 and only pink flagging was added to pole and nearest tree.

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). Surveyors reviewed plant guides to accurately identify species or families in the field. Each primary point counter also had several years of field experience on Hawaii Island and already knew many of the dominant plants encountered in the landbird monitoring tracts.

Results

Summary of Tracts

A total of eight tracts were surveyed for birds and habitat variables during the 2015-2016 field season (Table D-2). 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 D-1). 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, counter availability and habitat characteristics. Workload was quantified by “survey days”, or the number of primary point counter times calendar days surveyed. 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. Access to the Northwest Kahuku tract required helicopter assistance for transporting gear and crewmembers. The Pacific Area Communications Center (HAVO 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 D-2. Summary of landbird monitoring survey effort in 2015-2016.

Tract	Total Transects	Total Stations	Survey Dates (2015-2016)	Calendar Days	Survey Days
East Rift Zone	4 Legacy	67	3/31/15, 4/1/15, 4/22/15, 4/23/15	4	8
Honomalino	2 Legacy/ 5 Random	100	3/25/16, 4/6/16, 4/7/16, 4/12/16, 4/13/16	5	9
Kahuku	5 Legacy/ 8 Random	193	2/16/16, 2/17/16, 2/18/16, 2/23/16, 2/24/16, 2/25/16, 3/9/16, 3/10/16, 3/29/16, 3/30/16	10	20
Mauna Loa South Flank	1 Legacy/6 Random	117	2/8/16, 2/9/16, 2/10/16, 2/11/16, 2/19/16, 2/26/16, 3/8/16, 3/11/16, 3/23/16	9	12
Mauna Loa Strip	3 Legacy/4 Random	79	3/9/15, 3/12/15, 3/13/15, 3/18/15, 3/19/15	5	9
Northwest Kahuku	5 Legacy/ 4 Random	86	3/14/16-3/17/16	4	8
‘Ōla’a	5 Legacy/4 Random	93	3/3/15, 3/5/15, 3/6/15, 3/10/15, 3/16/16, 3/17/15, 3/20/15, 3/23/15, 3/24/15, 3/25/15	11	15
Pāpā	2 Legacy/ 1 Random	22	4/5/2016	1	2
Total	27 Legacy/ 32 Random	757	–	49	83

East Rift Zone

The East Rift Zone is a remote tract on the eastern flank of Kīlauea Volcano (Figure D-1). The survey was reserved for two weeks in April 2015 and took eight survey days to complete. It was the lowest in elevation of all of the sites designated for the survey and the only tract on Kīlauea Volcano. Some of the transects were near the Pu‘u ‘Ō‘ō vent, which has been volcanically active since 1983. The vent has spewed lava and volcanic gases almost constantly for the last 30 years. The tract was littered with earth cracks, steam vents, and large pit craters as well as dense matted fern, which made 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.

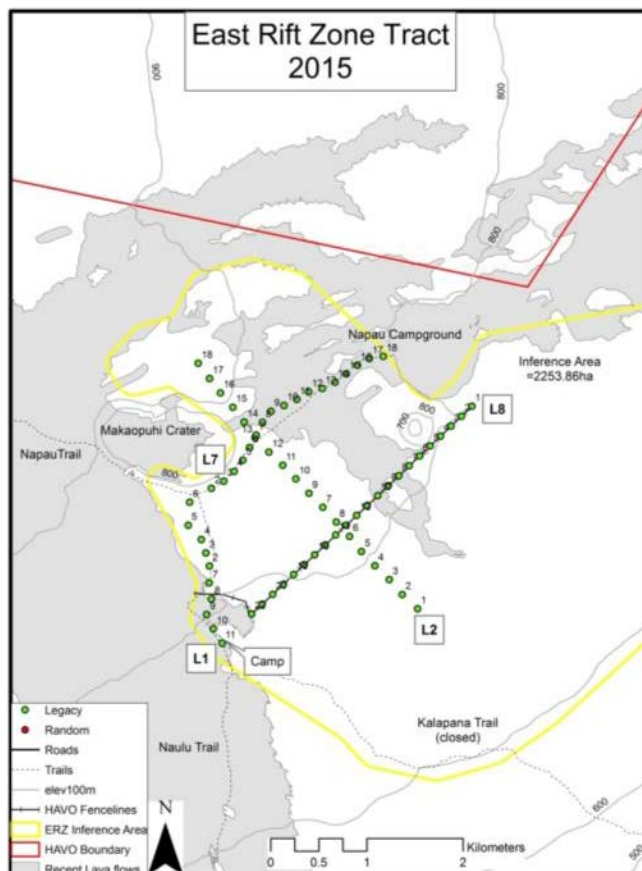


Figure D-1. East Rift Zone tract landbird monitoring stations surveyed in 2015.

A crew of two (Judge and Sedgwick) camped for four nights at a spike camp, situated near the intersection of the Naulu trail and the closed Kalapana trail approximately three km from the Kealakomo trailhead (Figure D-1). Potable water was not available anywhere within the East Rift Zone tract. Approximately 1.5 gallons per person per day were needed in the field. Judge and Sedgwick hiked in all of the water needed for the field effort.

A substantial portion of the prescribed legacy and random transects were too hazardous to survey in 2010. Additionally, the random transects prescribed in 2015 were also too hazardous to survey; thus, stations were assigned to fencelines and trails where surveyors would be safe from hazardous

conditions (earth cracks, tree molds and lava tubes). Legacy transects one and two were surveyed in both 2010 and 2015. More stations were added to legacy transect 1 in 2015 and two new legacy transects were added (7 and 8) in 2015 and will be surveyed in future survey years. Legacy transect 2 lies in a dense and difficult area and future surveyors may need to cut the path with machetes, which may take several days and considerable effort.

Honomalino

The Honomalino tract lies within HAVO and The Nature Conservancy's (TNC) Kona Hema unit on the southwest flank of Mauna Loa (Figure D-2). The tract was comprised of two legacy transects totaling 45 stations and 5 random transects of 55 stations. Sampling was conducted in March and April (Table D-2) and 9 survey days were dedicated to the tract.

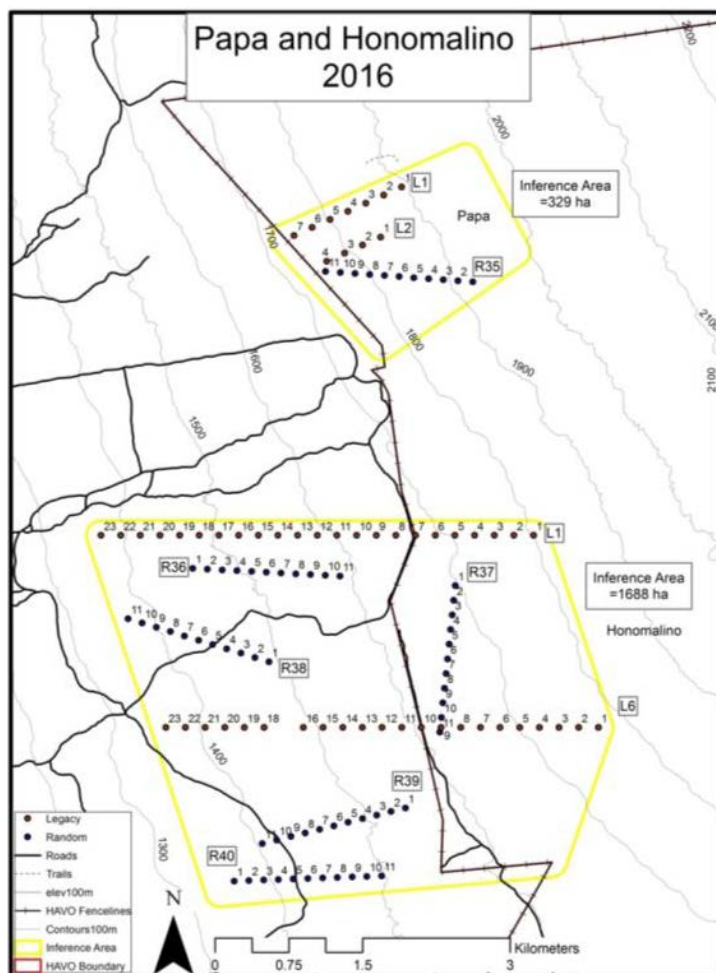


Figure D-2. Honomalino tract and Pāpā tract landbird monitoring stations surveyed in 2016.

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 approximately a 30-minute drive from Highway 11 and central to most of the landbird transects. The majority of the transects lie in the TNC tract. A TNC research permit was arranged with Natural Resource Manager Linda Schubert 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. The crew surveyed the TNC stations without placing any flagging according to TNC requirements. HAVO stations were established following protocol procedures in 2010 and flagging was refreshed in 2016.

Kahuku

The Kahuku study area was the largest of the tracts and required the most time to survey, 20 survey days. Five legacy transects totaling 93 stations and 10 random transects of 100 stations were designated for the landbird survey (Table D-2). The majority of the legacy stations were within the Ka‘ū Forest Reserve. Transects were approached at higher elevations inside HAVO by the upper Kahuku Road (Figure D-3). The tract required 20 survey days to survey.

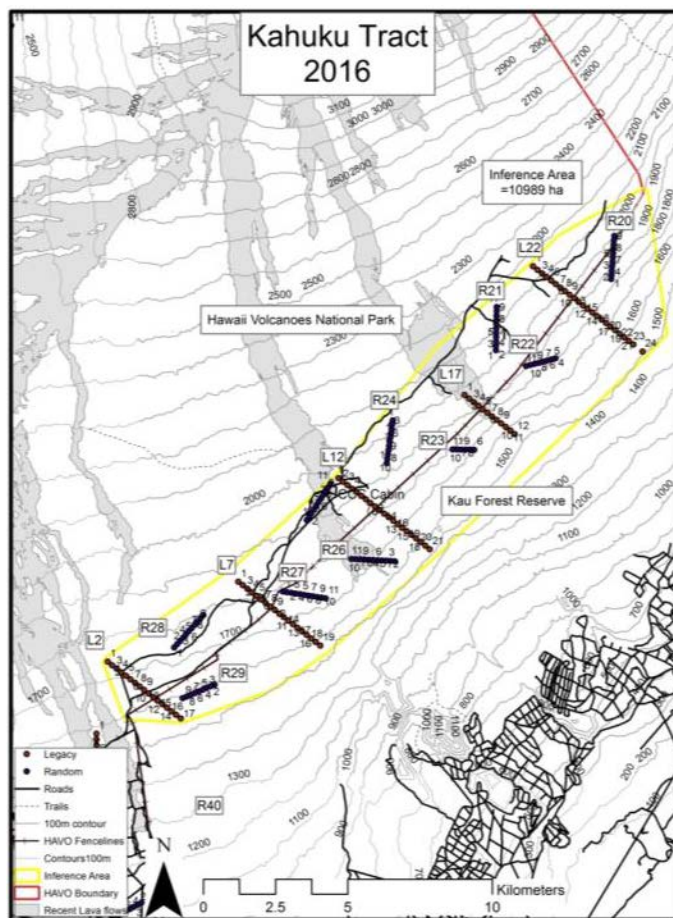


Figure D-3. Kahuku tract landbird monitoring stations surveyed in 2016.

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 Keola Awong (HAVO Kahuku Unit Manager). It was important to coordinate with Awong to avoid interfering with NPS Resource Management hunters during the control effort of invasive ungulates. Fieldwork was prohibited during hunting activities for safety concerns.

The transects in this tract were long and difficult to walk, especially the lower halves of the transect where vegetation was thick and impeded navigation. *Broussaisia arguta* (kanawao) in particular was especially dense in areas of the Ka'ū Forest Reserve. Surveyors must double back on the transect to return to the road for pickup which added a lot of time in the field. The crew rarely finished their daily duties in under eight hours and occasionally were unable to finish the transect before 11 am. Station 20 of legacy transect 7 and station 25 of legacy transect 22 were not surveyed due to time constraints. The road up to and past the Nene cabin required a 4x4 truck and 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 L22; Figure D-3).

Feral dogs were a concern in Kahuku. Random transect 22 was only partially completed due to the presence of feral dogs in the lower elevation stations. Such dogs can be dangerous as they often have been wild for several generations and subsist by killing and scavenging large ungulates. Consequently, the crew carried cans of pepper spray during the survey effort and stayed in close communication via radio.

Mauna Loa South Flank

The Mauna Loa South Flank tract (Figure D-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 D-2). Transect 3 was the only legacy transect at the tract, but it was long at 51 stations. There were 6 random transects of 66 stations. The tract required 12 survey days to complete.

Transect 3 was fairly easy to navigate because it runs through former pasture lands. However, the flagging was often placed very far apart because of the lack of trees, so it was necessary to navigate with a GPS. 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.

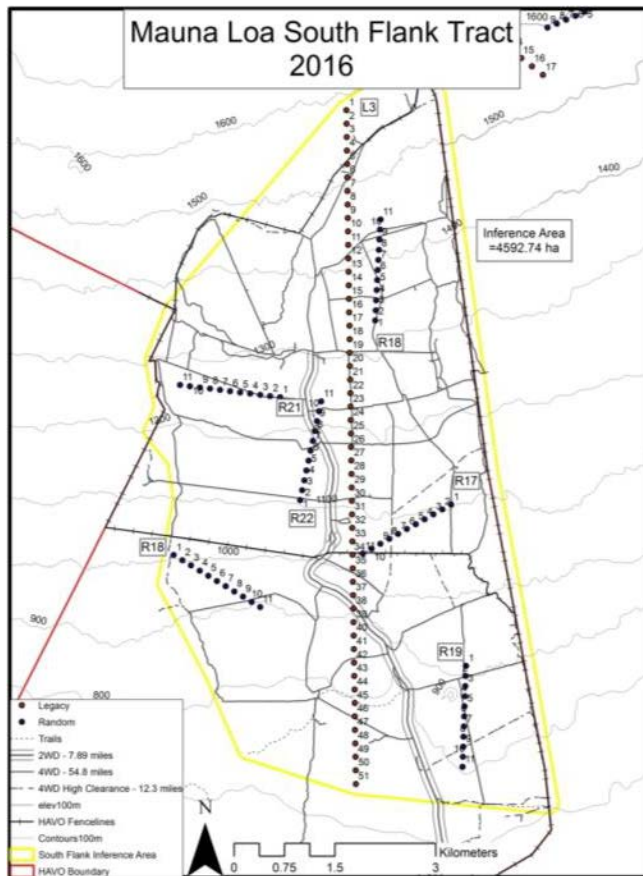


Figure D-4. Mauna Loa South Flank tract landbird monitoring tract stations surveyed in 2016.

‘Ōla’a Unit

The ‘Ōla’a Unit Tract was the easiest tract to access because of its close proximity to field station (Figure D-5). There were five legacy transects totaling 47 stations and six random transects of 46 stations. The crew required fifteen survey days to complete the bird surveys.

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 in 2015 (Table D-2). The tract’s dense, predominately native wet forest was difficult to navigate through. Legacy transect 1 was located directly on the northwest fence line of the tract, a permanent and well maintained boundary fence. There were three separate units in the ‘Ōla’a survey area—‘Ōla’a Puu Unit, ‘Ōla’a Small Tract Unit, and the ‘Ōla’a 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 ‘Ōla’a Puu Unit where feral pig damage was evident.

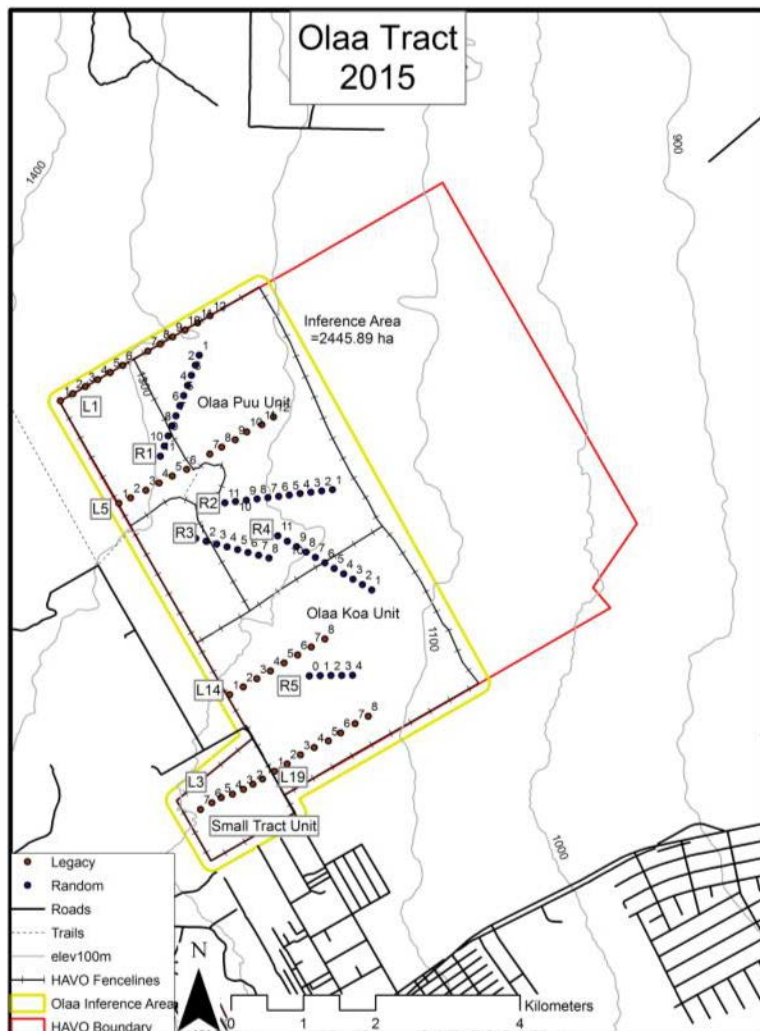


Figure D-5. ‘Ōla’a tract landbird monitoring stations surveyed in 2015.

Mauna Loa Strip

The Mauna Loa Strip tract was surveyed opportunistically throughout the sampling period in 2015 (Table D-1). The majority of the transects were accessed by the Mauna Loa Road which connects to Highway 11 between the 30 and 31-mile markers and continues upslope to the Mauna Loa Trail (Figure D-6). There were three legacy transects totaling 40 stations and four random transects of 39 stations. The tract required 9 survey days to complete.

The tract was difficult to survey and maintain 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. All transects were accessed from the Mauna Loa Road except transect 14, which was accessed through the Kapapala Ranch. Permission from both Kapapala Ranch and HAVO resource management is required to access this portion of the tract. This transect can be reached by taking the power line road that connects to the Mauna Loa Road near the second cattle guard, an approximate 10 minute drive on a dirt road to the HAVO and Kapapala Ranch boundary

fence and gate. At the time of these surveys, the gate key was the same for the majority of the HAVO gates. Access to the transect continues upslope on a rough 4x4 road that parallels the HAVO boundary fence, 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 Mauna Loa Road because of 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.

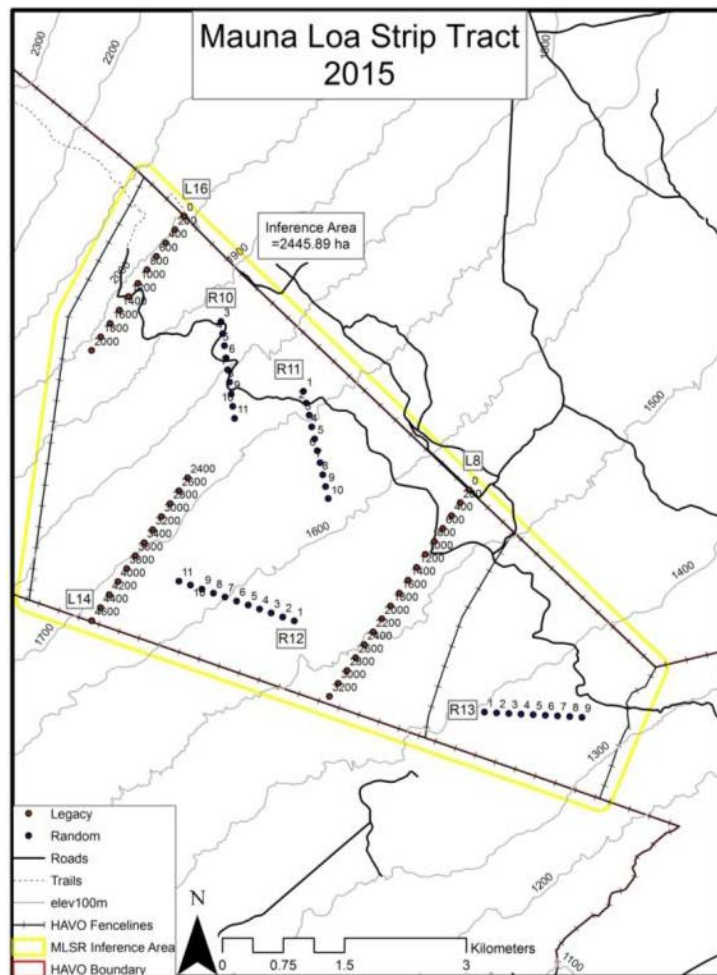


Figure D-6. Mauna Loa Strip tract landbird monitoring stations surveyed in 2015.

Northwest Kahuku

Surveys in this tract were conducted from 14 March 2016 through 17 March 2016 (Table D-2). There were five legacy transects totaling 47 stations and four random transects of 39 stations. The tract was accessed by helicopter because of its isolation and adjacent private land (Figure D-7). A crew of two primary point counters surveyed the tract over a four-day period (8 survey days). A random transect was dropped because surveyors had to be shuttled out of the field early on the 18 March 2016 because of deteriorating weather conditions. It's important to arrive to the tract as early as possible on the first day in order to survey that day. Additionally, helicopter scheduling for the last day out,

typically Friday, is problematic because the clouds move in mid-day. Therefore, it's difficult for two primary counters to survey all of the prescribed stations in 8 survey days. Each surveyor can survey two separate transects in a single day because transects are fairly quick to negotiate and spaced approximately 400 m apart.

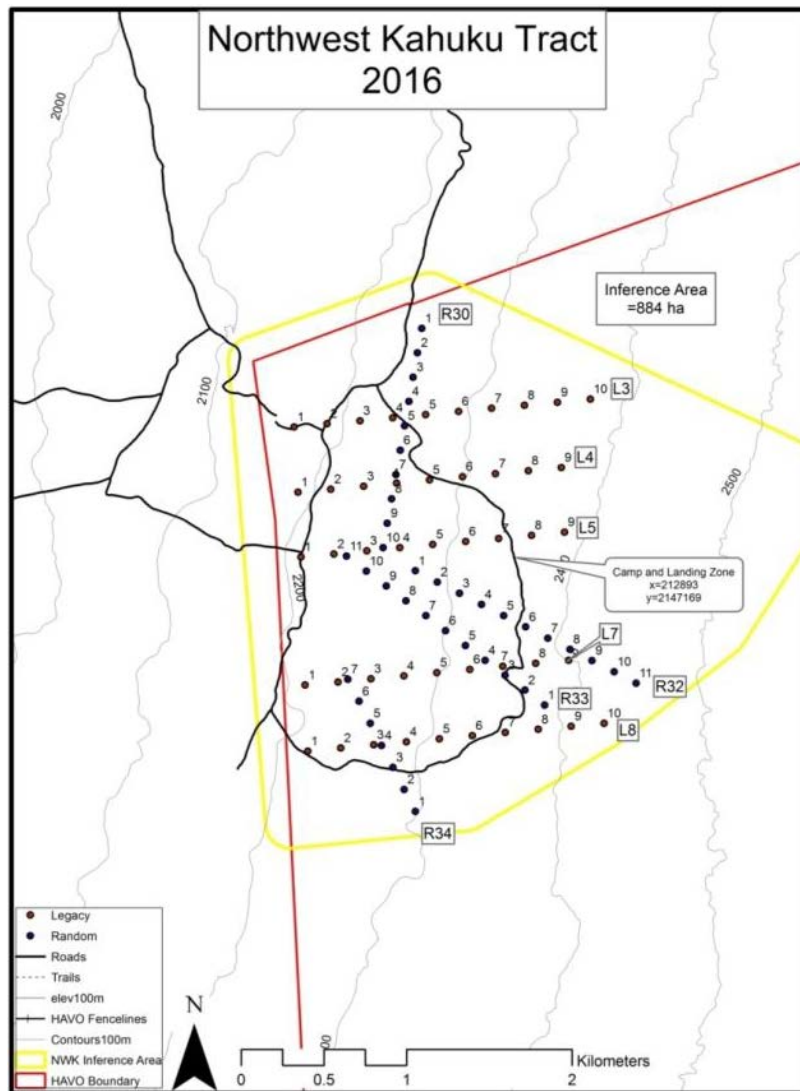


Figure D-7. Northwest Kahuku tract landbird monitoring stations surveyed in 2016.

The survey crew staged helicopter operations on the Hilo-Kona Road within the Mauna Loa Forest Reserve. The road is off of the Mauna Loa Observatory road and approximately 20 minutes from the saddle road turn off. The transport of the two member crew, water, camping gear, and field gear required one personnel shuttle and one shuttle of the sling load of gear with the pilot only. 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. Flight arrangements were made six weeks in advance and each crew member was required to take the online A-100, A-116, and A-200 Combination Helicopter and Airplane Safety modules offered by the U.S. Government Interagency Aviation Training website: (<https://www.iat.gov/Training/pages/online.asp>). Landbird field coordinator Judge completed the S-271 Interagency Helicopter Air Crewmember Training and thus was able to safely perform sling hook-ups and coordinate with the pilot and Heli-Managers.

Pāpā

The Pāpā tract was entirely in HAVO and an approximate 30-minute drive from the TNC cabin (Figure D-2). 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 11 stations. The survey was conducted and finished on April 5, 2016 (Table D-2).

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 Pāpā 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.

Discussion

The 2015-2016 Landbird Monitoring field season was conducted safely and efficiently. The weather was good for the majority of the sampling period and did not hamper data collection. The transects and permanent stations were marked clearly with flagging following protocol procedures. It should be noted that flagging often degrades in windy and sunny conditions. The next HAVO surveys are tentatively scheduled to occur in 2020 for Old HAVO and 2021 for the Kahuku 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 and replace or add to existing 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. Thus, 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.

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