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Pacific Island Landbird Monitoring Annual Report, Haleakalā National Park and East Maui Island, 2017

Natural Resource Report NPS/PACN/NRR—2019/1949



ON THE COVER
Kiwikiu (Maui Parrotbill, *Pseudonestor xanthophrys*)
Photo taken in The Nature Conservancy's Waikamoi Preserve by: Zach Pezzillo

Pacific Island Landbird Monitoring Annual Report, Haleakalā National Park and East Maui Island, 2017

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Seth W. Judge[1], Richard J. Camp[2], Christopher C. Warren[3], Laura K. Berthold[3], Hanna L. Mounce[3], Patrick J. Hart[1], and Ryan J. Monello[4]

[1]University of Hawai‘i at Hilo
Department of Biology
200 W. Kawili St.
Hilo, HI 96720

[2]Pacific Island Ecosystems Research Center
U.S. Geological Survey
344 Chain of Craters Road
P.O. Box 44
Hawai‘i National Park, HI 96718

[3]Maui Forest Bird Recovery Project
2465 Olinda Road
Makawao, HI 96768-7138

[4]Pacific Island Network Inventory and Monitoring Program
National Park Service
P.O. Box 52
Hawai‘i National Park, HI 96718

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Abstract

In 2017, the National Park Service Inventory and Monitoring Program, Maui Forest Bird Recovery Project, Pacific Cooperative Studies Unit, State of Hawai‘i Division of Forestry and Wildlife, and the United States Geological Survey, along with several other partners, coordinated and conducted a broad-scale landbird survey on East Maui Island, including portions of Haleakalā National Park (HALE). This survey marks the first interagency effort to collaboratively survey the entire set of East Maui forest bird survey transects since 1980 and provides data for the monitoring of long-term trends in distribution, density, and abundance of landbird species.

The survey area encompassed approximately 146 km^2 of Haleakalā Volcano and was divided into four regions: HALE, Leeward, Kula, and Windward. A total of 32 transects were surveyed using point-transect distance sampling methods, and audio recorders were deployed in HALE to supplement survey efforts. Sufficient detections to allow for density estimation were made for ten species (six native and four non-native). We used a two-sample *z*-test to check for short-term differences in density between our 2017 efforts and the most recent surveys in the HALE (2012) and Windward (2011) Regions. We also determined global population estimates and ranges of the three remaining island-endemic honeycreepers: the endangered Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*), the endangered ‘Ākohekohe (Crested Honeycreeper; *Palmeria dolei*); and the Maui ‘Alauahio (Maui Creeper; *Paroreomyza montana newtoni*).

Surveyors detected a total of 13,502 birds of 27 species. Within the survey area, the most abundant species were the native ‘Apapane (*Himatione sanguinea*; 228,480 ± 19,855 SE) and non-native Japanese White-eye (*Zosterops japonicus*; 127,560 ± 6,544). The two least abundant species were the Kiwikiu (157 ± 67) and ‘Ākohekohe (1,768 ± 315), both species are endemic to Maui Island and only occur within the 2017 survey area. Most tests for differences in density between 2011/12 and 2017 in HALE and Windward Regions were inconclusive due to the relatively small difference and large uncertainty in the density estimates associated with only two sample points in time. However, there were some localized changes in landbird densities within their range on East Maui. Among native species, the threatened ‘I‘iwi (*Drepanis coccinea*) density increased in the Windward Region, Hawai‘i ‘Amakihi (*Chlorodrepanis virens*) density decreased in HALE and Windward Regions, and Kiwikiu density decreased in HALE. Densities of the non-native Japanese Bush-Warbler (*Horornis diphone*) and Red-billed Leiothrix (*Leiothrix lutea*) were found to be increasing in the Windward Region.

All three island-endemic species were found to have declined in abundance by 50% or more over the last 20–35 years. Most concerning is the trend of Kiwikiu; although this species has always had relatively low global population estimates. Our estimate of 157 ± 67 is substantially lower than the prior global estimate of 513 ± 143 made in 1980. Low abundance was accounted by low population density as well as a 27% decline in range. Similarly, range of ‘Ākohekohe declined by 61% and range-wide densities were the lowest ever recorded. In both cases, ranges contracted at lower elevations where both species regularly occurred only 10–15 years ago. Finally, Maui ‘Alauahio

abundance also declined by 50% over the last two decades, but in this case it was primarily due to a decline in density, as the species still occupies much of its previously estimated range.

The simultaneous decline of Kiwikiu, ʻĀkohekohe, and Maui ʻAlauahio over the last several decades suggest landscape-level factors are affecting species endemic to Maui. There are currently three primary threats to native Hawaiian birds in East Maui: disease, depredation, and degradation of habitat. Introduced avian malaria is clearly the most significant long-term threat, as there is broad agreement that malaria will move upward in elevation due to climate change and lead to dramatic declines or the extinction of most native Hawaiian passerine species. The impacts of introduced predators and habitat degradation are known to have large impacts that have been ongoing for decades, and it will be exceedingly difficult to determine which of the factors or interactions are driving the current decline of the remaining endemic species in Maui.

Findings in this report suggest that the implementation of management actions in East Maui take place in an adaptive context. This will enable a greater understanding of what is causing declines, while furthering the conservation knowledge needed to save these species. There are two actions in particular that are likely to have the greatest beneficial impact to native Hawaiian birds in their extant ranges of East Maui: landscape control of avian malaria and of depredation. Preventing habitat degradation is also critical, but habitat restoration efforts have been in place for decades and we assume that they will continue. Ideally, the landscape control of malaria and depredation would occur simultaneously, but either alone would benefit a variety of native bird species and if concurrent monitoring also occurs the results of these conservation activities will help managers better understand and target the cause of declines.

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Introduction

The avifauna of Hawai‘i is characterized by a high level of endemism resulting from adaptive radiation (Fleischer et al. 1998, Pratt 2005, Lerner et al. 2011). Since human colonization of the Hawaiian Islands, the introduction of non-native 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 (Atkinson 1977, Pratt 1994, van Riper and Scott 2001, Pratt et al. 2009). Only 43 of the once 113 species of native landbirds (species that occupy terrestrial habitat) persist in the islands (Pyle and Pyle 2017). Thirty-six of the remaining species are considered threatened or endangered and 11 of them have not been seen in the last 14–45 years (Banko and Banko 2009, Elphick et al. 2010). Many native bird species continue to decline throughout Hawai‘i (Gorresen et al. 2009). For instance, two species of honeycreepers on Kaua‘i Island were recently added to the federal endangered species list (USFWS 2010), and population projections predict extinctions for those species in less than 20 years (Paxton et al. 2016).

Haleakalā Volcano encompasses all of Haleakalā National Park (HALE), several state managed Forest Reserves (FR) and Natural Area Reserves (NAR), and private lands, most of which were included in the 2017 East Maui Island landbird survey area (hereafter: East Maui). The area contains key habitat for a number of honeycreepers, including three species endemic only to East Maui: ‘Ākohekohe (Crested Honeycreeper; *Palmeria dolei*), Kiwikiu (Maui Parrotbill; *Pseudonestor xanthophrys*), and Maui ‘Alauahio (Maui Creeper; *Paroreomyza montana newtoni*) (Scott et al. 1986). Avian disease, habitat conversion, and introduced plants and animals have all had profound negative effects on populations of these birds. The avian community of East Maui experienced the 2004 extinction of the Po‘ouli (*Melamprosops phaeosoma*; Butchart et al. 2018), and likely extinctions of the Maui ‘Ākepa (*Loxops ochraceus*) and Maui Nukupu‘u (*Hemignathus affinis)*; each species has been seen fewer than 10 times in the last 100 years (Banko 1968, Pratt and Pyle 2000, Reynolds and Snetsinger 2001, Bailey 2007). Honeycreeper species that have fared better on East Maui include the ‘Apapane (*Himatione sanguinea*) and Hawai‘i ‘Amakihi (*Chlorodrepanis virens wilsoni*). These species have a broad distribution across the main Hawaiian Islands and have even demonstrated some localized resistance to avian malaria (Atkinson et al. 2000, Foster et al. 2007). The ‘I‘iwi (*Drepanis coccinea*) is still very vulnerable to disease (Atkinson et al. 1995) and appears to be declining in many areas (Camp et al. 2009a, Paxton et al. 2013, Paxton et al. 2016) and for these reasons was listed as threatened in October 2017 (USFWS 2017).

There have also been dynamic shifts in the avian community as native species largely decline and non-native species expand into new habitats. Over 170 species of birds have been introduced to the islands and 54 species have become naturalized (Foster 2009, Pyle and Pyle 2017). Species such as the Japanese Bush-Warbler (*Cettia diphone*), Japanese White-eye (*Zosterops japonicus*), and Red-billed Leiothrix (*Leiothrix lutea*) have expanded into native forests on East Maui (Judge et al. 2013). Along with changes in the bird community, there have been changes in forest bird habitat brought about by ungulates and non-native vegetation. The encroachment of ungulates and weedy shrubs

threatens the unique ecological niches that honeycreepers rely upon. The control of invasive species has been the most challenging and critical management action for preserving habitat that supports honeycreepers (Loope and Medeiros 1995, USFWS 2006). In some areas, habitat management (e.g., predator, ungulate, and weed control) has resulted in stable or increasing populations of native landbirds (Camp et al. 2010).

Repeated landbird surveys are an important tool for identifying temporal changes of populations (Skalski 1990) that may allow resource managers to monitor population trends and determine the efficacy of management actions (Camp et al. 2011). Many endangered species' recovery plans propose target population density values that must be achieved before a population may be considered for downlisting or delisting, such that population monitoring and estimates are integral to endangered species recovery (Tear et al. 1995, Doremus and Pagel 2001).

Methods for long-term landbird population monitoring in Hawai‘i were established by the Hawai‘i Forest Bird Survey of 1976–1983 (Scott et al. 1986). On East Maui, transects were surveyed using point-transect distance sampling methods in 1980. In many cases, the locations were surveyed repeatedly and additional transects were added over time by managers of both state and federal agencies. NPS created the Inventory and Monitoring (I&M) Program following the National Park Omnibus Management Act of 1998. The role of the NPS I&M Pacific Island Network (PACN) in Hawai‘i is to collect, organize, and make available natural resource data and contribute to institutional knowledge by facilitating the transformation of data into information through analysis, synthesis, and modeling (Fancy et al. 2009). PACN first surveyed transects in HALE in 2012 (Judge et al. 2013). The Maui Forest Bird Recovery Project (MFBRP) and the Hawai‘i State Department of Forestry and Wildlife (DOFAW) collaborated to survey transects outside HALE in 2012 (MFBRP unpubl. data). In 2017 DOFAW, MFBRP, and PACN collaboratively surveyed almost all East Maui transects on federal, state, and private lands and provide an updated status of native and non-native landbird species for the entire region and across agency boundaries. This had not occurred since 1980. Here we use these data to provide occurrence, density, and trend data from East Maui to investigate the short- and long-term trajectory of landbird populations over time.

Surveyors also sampled for a number of habitat variables such as canopy height, cover, and predominant understory species. Habitat conditions can influence food availability, which may affect bird population densities in the area (Fretz 2002). If we detect future changes in bird populations, having long-term habitat information may help identify potential reasons behind those changes. Furthermore, the information gathered from the habitat surveys serves as an overview and provides general descriptions of habitat conditions at our study plots. Over time, park managers and researchers may use the information to determine habitat changes in areas critical for native forest birds.

Methods

The landbird vital sign monitoring protocol conducted by the PACN I&M Program surveys three parks on a rotating basis: HALE, Hawai‘i Volcanoes National Park, and National Park of American Samoa. Each park, or units therein, are surveyed at least once every five years to determine landbird status and trends (Camp et al. 2011). The protocol was implemented in 2012 at HALE and we repeated that effort in 2017. DOFAW and MFBRP simultaneously used the same point-transect distance sampling methods on state and private lands on East Maui to enable a comprehensive assessment of landbirds and their most critical habitat in this area (*see* Camp et al. 2011 for details). We provide occurrence and distribution of each landbird species detected during sampling in each region. For species with enough detections to determine density (birds/ha) we provide population estimates in survey inference areas and range-wide estimates of species that only occur in the survey area.

Survey Areas

The East Maui landbird survey was conducted in four regions: Windward, HALE, Leeward, and Kula (Figure 1). The HALE survey region primarily includes the eastern Kīpahulu District. The Windward Region is contiguous with HALE and includes the Hanawī NAR, Hāna FR, Waikamoi Preserve, and Ko‘olau FR. The Kula and Leeward Regions are disjunct units from the other regions and contain various vegetative and climatic conditions that make them unique from the two other regions surveyed. Each region has a unique history of land management and current priorities. The survey area encompasses the most isolated and hard to reach forests of Haleakalā Volcano (maximum elevation 3,056 m). Maps of each survey area and summary of the field effort within each region are provided in the field reports in Appendix A and Appendix B.

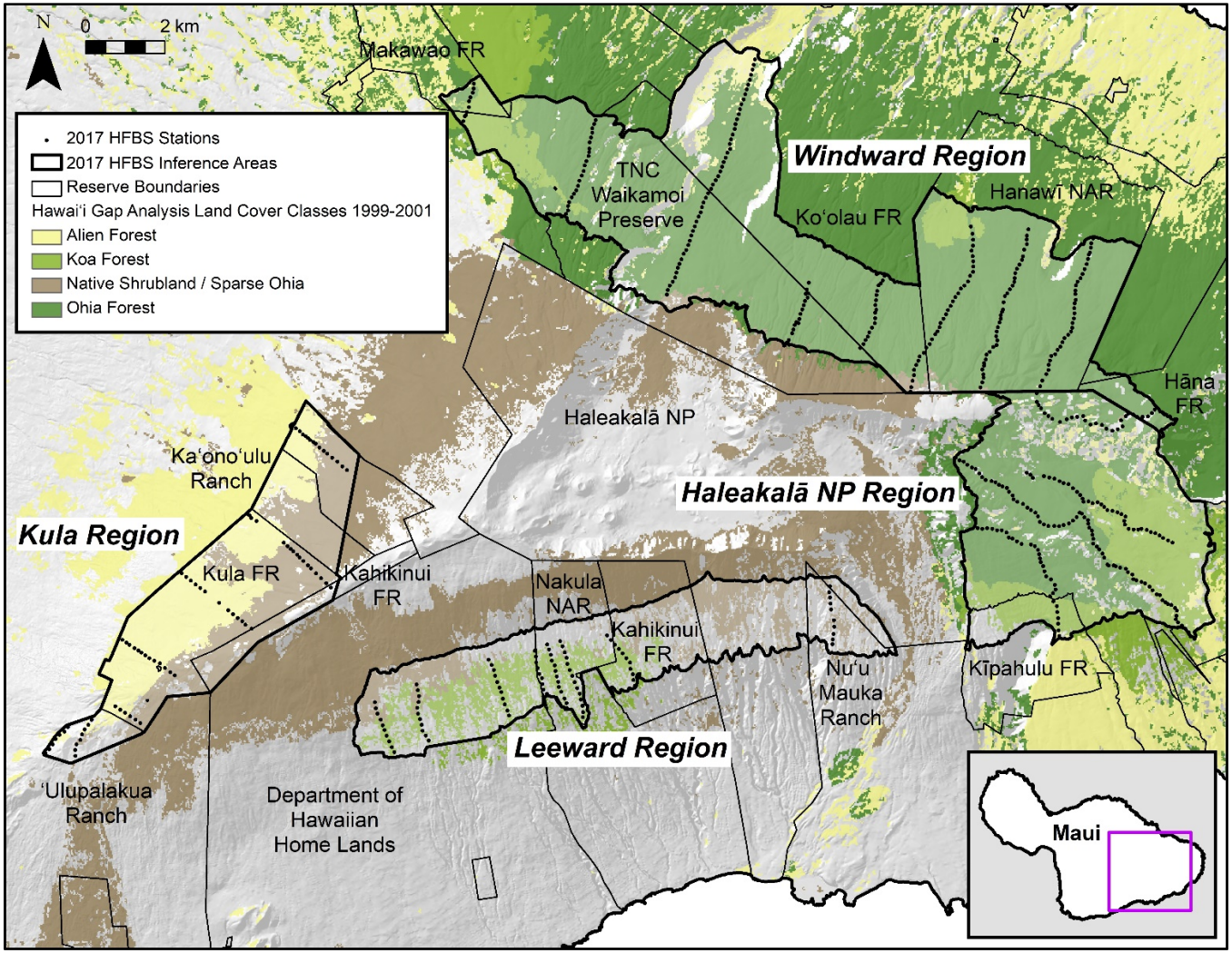


Figure 1. The 2017 East Maui landbird survey area. The area was divided into four regions: Windward, HALE, Leeward, and Kula. These regions include lands managed by the State of Hawai'i, National Park Service, The Nature Conservancy, and private landowners.

Haleakalā National Park Region

Landbird surveys in HALE were conducted in the Kīpahulu District (4,200 ha) which covers the eastern portions of the park. Monitoring transects traversed remote rainforests of Kīpahulu Valley, Manawainui, and the bog ecosystems near the Northeast Rift of Haleakalā Volcano (*see* Appendix A, Figure A-1). Kīpahulu Valley is a dramatic landscape of large headwalls, escarpments, waterfalls, and dense rainforest. The valley is comprised of two large drainages, the Upper and Lower Plateau, which are separated by a steep Central Pali (Warner 1967). The Upper Plateau extends from the valley headwall (2,250 m) and descends almost 12 km to the Pacific Ocean. Kaukau'ai Stream is the major drainage of the Upper Plateau, but many small ephemeral streams flow during wet periods. Landbird monitoring Transect 17 descends 1,200 m in elevation of the Upper Plateau and bisects 8 km of both open 'ōhi'a (*Metrosideros polymorpha*) forest and closed 'ōhi'a–koa (*Acacia koa*) forest. Transect 16 descends 1,100 m of the Lower Plateau; this transect parallels the base of the Central Pali and ends at 840 m elevation. Lower portions of the transect are co-dominated by 'ōhi'a and koa but are also invaded by non-native weedy trees and shrubs.

To the north, the Palikea Stream drains the Lower Plateau and sheer walls of Northeast Rift, rising 500 m in areas. Transect 10 traverses montane bogs, ridges, and promontories of the Northeast Rift, which lies near the northern boundary of HALE and the Hāna FR. Landbird monitoring stations on the Northeast Rift are the highest in the survey (1,640–2,100 m). The area harbors some of HALE's rarest plants, such as *Geranium hanaense, Arnroxiphium gravanum* (greensword), *Viola maviensis* (pāmakani), and *Plantago pachvphylla* (Medeiros et al. 1998). The area ranks among the rainiest places on earth, averaging more than 10,000 mm/year (Giambelluca et al. 2011).

The southern wall of Kīpahulu Valley rises up to the 526 ha Manawainui parcel, often referred to as the "Manawainui Planeze" because the bench is isolated by lava flows older than adjacent Kaupō Gap and Kīpahulu Valley (Peterson 1976). Kuiki is the highest point at approximately 2,300 m, the planeze tapers southward in a pyramid shape, forming steep cliffs on each side (*see* Appendix A, Figure A-1). Landbird monitoring Transect 18 ranges from 1,500–1,800 m, in wet 'ōhi'a forest of this parcel. Manawainui is characterized by high precipitation (>5,000 mm/year; Stein 2007). Precipitation tapers off to the west and transitions to a dry-mesic ecotone (Stein 2007).

Kīpahulu Valley is a closed-entry reserve; access is permitted only to HALE crews, and for select monitoring and research activities. The valley is mostly fenced, and divided into three feral ungulate exclosures with cross-fences near 800 m, 1,200 m, and 2,300 m (HALE unpubl.). Feral ungulate removal and fence maintenance is ongoing and most of the upper elevation areas are ungulate free, with pigs (*Sus scrofa*) and goats (*Capra hircus*) occurring at low and mid-elevation areas, negatively impacting the native understory and spreading seeds of invasive plants. Native floral diversity is high in Kīpahulu Valley, with 89 species of ferns, 209 species of flowering plants, and over 20 species of endemic lobelioids (Herat et al. 1981, Medeiros et al. 1998). Typical northeast tradewinds pervade the valley and precipitation is high, averaging more than 7,000 mm/year (Giambelluca et al. 2011).

Windward Region

The Windward Region covers lands managed by TNC and DOFAW. The region contains Waikamoi Preserve, Hanawī NAR, Ko'olau FR, Makawao FR, and Hāna FR (*see* Appendix B, Figure B-1 and

Figure B-3). The habitat in this region varies from wet ʻōhiʻa-dominated forests in the eastern portion to transitional wet-mesic forests with a mixed koa and ʻōhiʻa canopy along the western edge.

The region has a long history of conservation specifically for native forest birds. Some of the earliest bird collections in the late 19th century were made near the Ukulele Dairy on the western boundary of the Windward Region (Perkins 1903). Concern about the loss of watersheds stimulated the creation of a number of forest reserves in the early part of the 20th century. In 1905, the territorial government created Koʻolau FR in East Maui protecting the vast majority of the area on the windward slopes of Haleakalā. This was shortly followed by the creation of Makawao FR in 1909 and Hāna FR soon after.

Between the 1890s and 1950, the status of many forest bird species was largely unknown and many of the rarest species went unreported until several species, including Kiwikiu, were rediscovered in upper Koʻolau FR, in what is now Hanawī NAR (Richards and Baldwin 1953; Appendix B, Figure B-4). In 1973, a group of students from the University of Hawaiʻi discovered the Poʻouli, a species completely unknown historically, in an area of Hanawī NAR (Casey and Jacobi 1974). This discovery and the dire state of the existing populations of this and other forest bird species sparked numerous conservation actions including fencing and eradicating pigs from the area. The initial fencing and ungulate removal efforts were focused on the upper areas specifically around where Poʻouli were present.

Leeward Region

The Leeward Region encompasses land managed by the State of Hawaiʻi Department of Hawaiian Home Lands (DHHL), DOFAW, and Nuʻu Mauka Ranch (*see* Appendix B, Figure B-5). Leeward Haleakalā Watershed Restoration Partnership (LHWRP) is restoring forest in fenced sections of Nuʻu Mauka Ranch in the eastern portion of this region and are planning new fenced restoration areas on DHHL property in the western portion. Additional restoration is occurring in Nakula NAR and Kahikinui FR by DOFAW and MFBRP. HALE acquired a large unit west of Kahikinui FR, the Nuʻu Unit in 2015. HALE plans to fence a major section of the unit by 2019. The forest quality in this region generally declines from west to east. In the west within DHHL and Nakula NAR, there are large intact patches of koa and ʻōhiʻa woodland and savanna, while in Nuʻu to the east, only scattered ʻōhiʻa and severely eroded, non-native grass covered slopes remain. Thus, the remaining forest bird habitat is mostly in the western portion of the Leeward Region.

This region has a long history of people recognizing the damage being done to the forest by ungulates, but having little success in controlling them (Raymond 1906, Medeiros et al. 1986, Scott et al. 1986). The remnant vegetation suggests that the montane mesic ʻōhiʻa–koa forest of this region was once contained a diverse assemblage of native plant species but no descriptions of the area prior to the introduction of ungulates survive. Control of the ungulates, primarily feral cattle, was attempted as early as 1901 (Raymond 1906) with little lasting effect. In 1928, the Hawaiʻi Territorial Government established Kahikinui FR, which originally was 64.8 km^2 and spanned from Kula FR in the west to Nuʻu in the east (*see* Appendix B, Figure B-5). Large sections of this reserve above 1,200 m were fenced to exclude cattle. In 1983, DOFAW added new fences and conducted additional cattle drives to remove animals. Then in 1984, approximately 80% of the FR was redesignated and placed

under management of DHHL. Only the 2.87 km^2 Papa‘anui Tract and the 15.64 km^2 eastern unit of Kahikinui remained under DOFAW management.

Conservation of the remaining forest along the southern slope ramped up in the late 2000s. In 2007, additional fences were installed around much of the eastern section of Kahikinui above 1,500 m. These were the first fences installed in the reserve capable of excluding goats and pigs in addition to cows. In 2011, DLNR established Nakula NAR, changing 6.12 km^2 of the eastern unit of Kahikinui FR to NAR status. An internal fence within Nakula NAR was installed in 2012 and ungulates were removed from a 1.71 km^2 section, the Wailaulau Unit, by 2013. This was followed by a second internal fence and eradication (West Pahihi Unit) in 2015. The remaining 8.94 km^2 eastern unit of Kahikinui FR, all above 1,500 m, is fenced. Ungulate removal is on-going in this and the adjacent Nakula NAR Mauka Unit. Additional fences are slated for completion in 2018–2019 within DHHL land west of Nakula NAR.

Kula Region

The Kula Region includes land managed by DOFAW, Ka‘ono‘ulu Ranch, and Ulupalakua Ranch/Auwahi Wind (*see* Appendix B, Figure B-6). The largest portion falls within Kula FR, which consists of two units, collectively 19.85 km^2 in size, divided by Ka‘ono‘ulu Ranch. This region includes the smaller of two units of Kahikinui FR (2.87 km^2), bordering Kula FR to the southeast. Finally, the Kula Region also includes the Pu‘u Makua area of Ulupalakua Ranch in an area that is being restored by Auwahi Wind. This area also includes some 15–20 year-old koa forest patches planted by the Auwahi Forest Restoration Project (Medeiros et al. 1998).

Kula FR was established by the Hawai‘i Territorial Government in 1912 to reforest an area that had been converted to pasture and protect the watershed. In 1928, Kahikinui FR was created; bordering Kula FR to the west and extending along the southern slopes to the east (*see* Leeward Region). In 1984, a large section of Kahikinui FR was placed under the management of the DHHL, dividing the reserve into two units. This left a 2.87 km^2 section remaining along the border with Kula FR.

Following its creation, the U.S. Forest Service Hawai‘i Division of Forestry conducted wide-scale plantings of non-native conifers, eucalyptus, and *Acacia* spp. throughout Kula FR (Skolmen 1980). Today the area is dominated by these non-native tree species with a mix of native tree and shrub species. The upper elevation areas are dominated by native shrubland. Although most of Kula and Kahikinui FR are surrounded by fences, these areas are maintained as public hunting units. Kula FR also surrounds Polipoli Spring State Recreation Area and contains many public hiking and bike trails.

East Maui Survey History

The Hawai‘i Forest Bird Survey established survey methodology and transect locations on East Maui in 1980 (Scott et al. 1986). That effort marked the first time East Maui was surveyed using distance sampling methodology, or “variable circular plot” methodology, as it was referred to at the time. Scott et al. (1986) established 1,000 stations on 31 transects (Table 1). In 2017, we delineated the East Maui survey areas into the four regions. Records of East Maui surveys are stored in the Hawai‘i Forest Birds Monitoring Database, which is managed by the USGS Pacific Island Ecosystem Research Center (Camp et al. 2011). We provide a comprehensive account of landbird survey efforts

in each region of East Maui. These data can be referenced to determine when and where each transect was surveyed. Further, we reanalyzed much of the previous survey data to determine long-term trends of Maui endemics. A brief summary of the survey history per region is provided below:

Haleakalā National Park Region

The National Park Service (NPS) began surveying areas of the Kīpahulu District in the early 1990's and continued efforts annually or every 2–3 years (Camp et al. 2009a; Table 1). Surveys were conducted primarily by HALE Resource Management biologists. The PACN landbird monitoring project first surveyed HALE in 2012 (Judge et al. 2013). Five legacy transects were designated for determining population densities and trends of forest birds in the HALE Region (Table 1). PACN landbird monitoring surveys were repeated again in 2017 in coordination with MFBRP. PACN surveys are scheduled to repeat every 5 years (Camp et al. 2011).

Table 1. East Maui landbird survey history (1980–2017) per region. Survey years 1980 and 2017 include all of the regions because of those coordinated efforts.

Region/s	Survey Area	Survey Year	Transects Surveyed	# of Stations Surveyed
HALE, Kula, Leeward, Windward	All East Maui Survey Areas	1980	1–31	1,000
HALE	Kīpahulu District	1992	18, 18A	28
	Kīpahulu District	1993	10, 15–18, 101–103, 105, 106, 18A	203
	Kīpahulu District	1996	16, 17	30
	Kīpahulu District	1997	10, 15–17	83
	Kīpahulu District	1998	10, 15–17	94
	Kīpahulu District	1999	10, 15–18, 18A	96
	Kīpahulu District	2000	10, 15–18, 18A	112
	Kīpahulu District	2001	10, 15–18, 18A	177
	Kīpahulu District	2003	18, 18A	11
	Kīpahulu District	2005	10, 15–18, 18A	149
	Kīpahulu District	2006	18, 18A	16
	Kīpahulu District	2008	15–17	37
	Kīpahulu District	2012	10, 16–18, 1009, 2009, 3009	160

Table 1 (continued). East Maui landbird survey history (1980–2017) per region. Survey years 1980 and 2017 include all of the regions because of those coordinated efforts.

Region/s	Survey Area	Survey Year	Transects Surveyed	# of Stations Surveyed
Leeward	Nakula NAR	1996	25, 26	26
	Kaʻāpuhu District (HALE)	2002	1	11
	Nakula NAR	2017	24, 25, 26.1, 39–42	76
	Nuʻu Mauka Ranch	2017	45	11
Kula	Makawao FR	2003	3, 11, 12, 21, 22, 31, 32	41
	Kula FR	2013	43, 44	22
	Kula FR	2014	43, 44	22
Windward	Hanawī NAR, Waikamoi Preserve	1992	2–9	397
	Hanawī NAR	1995	1–4	40
	Waikamoi Preserve	1994	2–6	102
	Waikamoi Preserve	1996	2–9	182
	Hanawī NAR	1996	1–4	40
	Hanawī NAR	1997	1–4	40
	Hanawī NAR, Waikamoi Preserve	2001	1–9	231
	Hanawī NAR, Waikamoi Preserve	2006	2–9	217
	Hanawī NAR, Waikamoi Preserve	2011	2–9	227
HALE, Kula, Leeward, Windward	All East Maui Survey Areas	2017	2–10, 16–18, 18A, 24–31, 39–47	570

Windward Region

The Nature Conservancy (TNC) conducted surveys in Waikamoi Preserve in 1994 and 1996 (Camp et al. 2009a). MFBRP conducted several research, monitoring, and management activities in habitat critical to the Poʻouli, Kiwikiu, and ʻĀkohekohe in Hanawī NAR and TNC's Waikamoi Preserve from 1997 to 2017 (unpubl. data). Biologists from DOFAW surveyed areas of East Maui in 1992, 1996, 2001, and 2006 (Camp et al. 2009a, Table 1). Monthly surveys were conducted in the Hanawī NAR by USGS biologists from January 1995 through December 1997 (Simon et al. 2002). Transects 2–9 were surveyed in 2006, 2011, and 2017.

Leeward Region

Five transects were originally established in the Leeward Region for the 1980 survey. Two of the five legacy transects established in the Kahikinui FR were surveyed in 1996, but none had been surveyed since (Table 1). Additionally, only the upper elevation (>1800 m) stations of the Leeward Region transects were surveyed in 1996. Transects 24 and 25, surveyed in 1980 and 1996, are the only legacy transects in the Kahikinui FR that still contain significant forest bird habitat. We shifted legacy Transect 26 approximately 1 km to the east to cover an area that falls within good habitat that will also soon be within ungulate-proof fencing; this new (or re-established) transect was dubbed Transect 26A. MFBRP also established a new transect (Transect 42) on DHHL to survey good forest bird habitat between legacy Transects 25 and 26A. Several new transects throughout the region were established to capture the response of the bird community to current and planned forest restoration actions. MFBRP established Transects 39–41 in 2015 as part of a separate effort to survey bird populations in Nakula NAR. Moreover, one transect on Nu‘u Mauka Ranch and two transects on Ulupalakua Ranch were established in areas being restored by LHWRP and Auwahi Wind, respectively. The non-random placement of these new and relocated transects restricts inference to just the transects as they are not representative of the whole region, may induce a bias in population estimates and negate making comparisons to previous surveys in the area and to other areas (Johnson et al. 2006). In 2017, we surveyed eight transects in the Leeward Region (*see* Appendix B, Figure B-5).

Kula Region

The Kula Region is known to support populations of four species of honeycreepers including the only known East Maui populations of Maui ‘Alauahio and ‘I‘iwi outside of the Windward and HALE Regions. Three transects were originally established in Kula FR (Transects 29–31) as part of the HFBS and were last surveyed in 1996 (Table 1). A series of additional temporary transects were established in 2013 by Peter Motyka, a graduate student at Northern Arizona University (Motyka 2016). Motyka (2016) surveyed the legacy and newly established transects in 2013 and 2014. In 2017, we surveyed the three legacy transects and two of Motyka’s Tansects (A and F, now labeled Transect 43 and Transect 44, respectively) within Kula FR. These collectively provided more comprehensive coverage of Kula FR. This was particularly important given that Motyka’s research indicated patchy distributions of many forest bird species within the reserve. In all, seven transects were surveyed in this region in 2017 (*see* Appendix B, Figure B-6).

Landbird Distance Sampling

Surveys commenced March 13, 2017 and concluded June 28, 2017. We sampled for landbirds at 570 stations on 32 transects in the four regions for a total of 73 survey days. Appendix A describes the survey effort and field logistics in HALE. Appendix B summarizes the effort and logistics of the Kula, Leeward, and Windward Regions. All landbird counts began soon after dawn, or when the sunlight struck the treetops. In HALE all counts were concluded by 11:00 HST, while in the Leeward, Kula, and Windward Regions some extended past 11:00, but all concluded before noon. Stations were spaced approximately 150 m apart and surveyed using point-transect distance sampling methods lasting eight minutes. We recorded species, horizontal distance in meters from observer to each bird detected, and detection type (seen, heard or both). Weather conditions were also recorded

at each station. Point-transect distance sampling methods allow for estimating detection probabilities by modeling a species-specific detection function to estimate absolute abundance (Buckland et al. 2001). This method thus accounts for individuals that go undetected, and produces abundance. Robust estimates are reliant upon the critical assumptions that all birds are detected with certainty at the station center point, birds are detected prior to any responsive movement, and distances are measured without error. Details of landbird sampling can be found in Camp et al. (2011).

Landbird habitat data within HALE were also collected at each of the point-transect sampling stations. 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 were described. In addition to habitat characteristics, topographical attributes were collected at each station within HALE. Habitat surveys were collected after completing bird counts (either immediately after completing the station count or after completing the daily counts). Details of habitat sampling can be found in Camp et al. (2011). Sign of feral ungulates (pigs, goats, cattle) was documented opportunistically while hiking transects–either directly or by observing evidence of browsing and footprints.

Data Analysis

Indices

Indices of bird occurrence and abundance were calculated for each species. Percent occurrence was calculated as the number of stations occupied divided by the total number of stations sampled. Similarly, birds per count was calculated as the total number of individuals detected divided by the total number of station counts. Birds per count (BPC) was computed because some stations were sampled more than once, either counted repeatedly by one surveyor or by multiple surveyors. We also computed relative abundance as birds per station (BPS) based on the number of detections made during the first sampling date at each station, regardless of observer.

Density Estimation

Species-specific density estimates (birds/ha) were calculated for ten species–the native Maui ʻAlauahio, ʻApapane, Hawaiʻi ʻAmakihi, ʻĀkohekohe, Kiwikiu, and ʻIʻiwi; and the non-native Japanese Bush-Warbler, Japanese White-eye, House Finch (*Haemorhous mexicanus*), and Red-billed Leiothrix. Each had sufficient detections to adequately characterize detectability (Buckland et al. 2001) using program DISTANCE, version 6.0, release 2 (Thomas et al. 2010). Due to relatively small numbers of detections of the endangered ʻĀkohekohe and Kiwikiu, their detections were pooled with data from all previous surveys to model detectability (2,172 and 261 additional detections, respectively). Preliminary analysis of Maui ʻAlauahio yielded unrealistic uncertainty (%CV > 80); therefore, the 2017 data were pooled with data from all previous surveys (3,559 additional detections). The candidate detection function models were limited to half normal and hazard-rate detection functions with expansion series of order two (Buckland et al. 2001). Following recommendations by Buckland et al. (2001), the half normal was paired with cosine and Hermite polynomial adjustments, and the hazard-rate was paired with cosine and simple polynomial adjustments. Model precision was improved by incorporating sampling covariates in the multiple covariate distance sampling (MCDS) engine of DISTANCE (Thomas et al. 2010). Covariates

included cloud cover, rain, wind, gust, observer, time of detection, and detection type. All covariates were treated as factors, except time of detection, which was treated as a continuous covariate. Assessing time of detection as a continuous covariate helped to determine if the detection rate varied during the morning. Detection type 4, bird first detected aurally but later confirmed visually, was pooled with both detection type 1 and 2, and models of these two datasets fit independently (pooled detection types 1 and 4 versus pooled detection types 2 and 4). Pooling of covariates was used to increase sample size and increase the likelihood of model convergence. Covariates for survey and year were also assessed for the endangered birds and Maui ʻAlauahio because of pooling. Each detectability model in the candidate set was fit, and the model selected was that with the lowest 2nd-order Akaike's Information Criterion corrected for small sample sizes (AICc) (Buckland et al. 2001, Burnham and Anderson 2002; Appendix C). Data were truncated at a distance where the detection probability was approximately 10%. This procedure facilitates modeling by deleting outliers and reducing the number of parameters needed to modify the detection function. Species-specific densities, variances and confidence intervals were derived by bootstrap methods in DISTANCE from 999 iterations (Thomas et al. 2010) from a global detection function using post-stratification procedures stratifying by region. For the endangered birds, species-specific densities by survey and year were estimated from the global detection function using the post-stratification procedure where density and precision were estimated using bootstrap methods. For these range-restricted species only stations sampled within their ranges were used for estimating abundance. Absolute abundance was calculated as mean density of unit estimates weighted by strata area for each species.

Inference Areas

We used transect locations, contour intervals, vegetation, and the current and historical distribution of landbird species to determine the overall inference area and inference for range restricted species for abundance estimates. Inference areas were mapped as a minimum convex polygon (MCP) using ArcMap 10.5.1 (Environmental Systems Research Institute, CA, USA). We first created a MCP around all stations surveyed in 2017. For this MCP, each station was estimated to have a 60-m buffer based on the truncation distance for detections during surveys in 2012 (Judge et al. 2013). We then removed areas from the MCP that were not surveyed or did not contain suitable habitat, primarily at the upper bound edge where wet montane forest transitions to open sub-alpine scrub and barren lava. However, most of the upper elevation limits to the overall inference area followed the highest contour interval surveyed and varied between 1,900 m and 2,170 m. We used the lowest contour interval surveyed in each geographic region as the lower bound edge of the inference area; as well as property boundaries and fences, which are often habitat edges separating reserves from private ranchlands. The lowest elevation surveyed varied between regions and transects and the inference area was adjusted accordingly. The low elevation edge followed contour intervals between 580 m and 1,610 m depending on the region. We used political boundaries or other natural features where the boundary of the inference area changed between contour levels. We estimate that the overall inference area for the 2017 HFBS was 14,600 ha. Methods for determining boundaries are detailed further in Appendix D.

The ranges of ʻIʻiwi and Maui ʻAlauahio extended outside the overall inference area in some places but were smaller than total inference area, and the ranges for the endangered ʻĀkohekohe and

Kiwikiu were restricted to just the Windward and HALE Regions. We describe the methods for delineating ranges here and in further detail in Appendix D. To generate species-specific inference areas for these four range restricted species, we used a similar method as used for creating the overall inference area with additional restrictions. We used observations of the species from 2006–2017 to determine the upper and lower elevation extents occupied by each species. These observations came from the HFBS, banding records, and spot-mapping studies. Using only records since 2006 ensured that the inference areas reflected the current range of each species. The lower edge of the ranges followed the lowest contour interval where each species was observed in each geographic region. The lowest elevational extent reached by each species varied among regions. Transitions between contour intervals were spanned using straight lines, political boundaries, or other physical features (e.g. fence lines). The upper edge for each species' range was created using contour intervals, habitat layers, or political boundaries.

ʻĀkohekohe and Kiwikiu are only found in native forest habitats. For these species, we primarily used habitat layers (Jacobi 1989) for "native forest" excluding all other habitats (namely native shrubland and bare rock) to create the upper edge of their ranges. We estimate that ʻĀkohekohe occupy 2,363 ha (Table 2, Figure 2). We estimate Kiwikiu currently occupy 2,992 ha (Table 2; Figure 3). In addition to native forest, Maui ʻAlauahio are found in native shrubland and some non-native forests, so we used these three layers to define the majority of its range. We primarily used contour intervals as the upper edge of the inference area, which aligned closely to the overall inference area. One notable exception is the upper edge along the boundary between TNC Waikamoi Preserve and HALE, where we used habitat layers delineating the non-native forest habitat within Waikamoi from native shrubland within HALE. In Kula FR, the entire reserve is above the lower elevational extent reached by Maui ʻAlauahio on the windward slopes. In this area, the forest stops abruptly at pasture below approximately 1,430 m. Additionally, the surveyed area of the reserve extends above the extent of native shrubland habitat. As such, we primarily used habitat layers as the lower (which largely follows the FR boundary) and upper edges of the Maui ʻAlauahio inference area in Kula. We then clipped the Maui ʻAlauahio range by the overall inference area to establish the inference area for this species, 9,179 ha (Table 2, Figure 4). While most of the species' range fell within the larger inference area, some areas (e.g., non-native forest in Waikamoi) were not surveyed and were thus excluded from abundance estimation.

ʻIʻiwi were found throughout the inference area in the HALE, Kula, and Windward Regions. However, the species was absent from the Leeward Region, which was excluded from density and abundance estimation for this species. Therefore, abundance estimates for this species only apply to the inference area of the survey (1,123 ha) on East Maui (Table 2, Figure 5). ʻIʻiwi occur on West Maui so our inference area does not include the species' entire range on the island. The most recent estimate of ʻIʻiwi from West Maui was 176 ± 74 (SE) in 1980 in a 1,600 ha area (Paxton et al. 2013).

Table 2. Area (ha) on East Maui by region of range restricted landbird species and total inference area for all other landbird species.

Region	Maui ʻAlauahio	ʻĀkohekohe	Kiwikiu	ʻIʻiwi	All Other Species
HALE	2,331.4	824.5	850.2	2,923.5	2,923.6
Kula	2,153.6	0	0	2,153.6	2,391.1
Leeward	0	0	0	0	2,583.1
Windward	4,694.0	1,538.6	2,141.9	6,149.0	6,702.3
Total	**9,179.1**	**2,363.1**	**2,992.1**	**11,226.1**	**14,600.1**

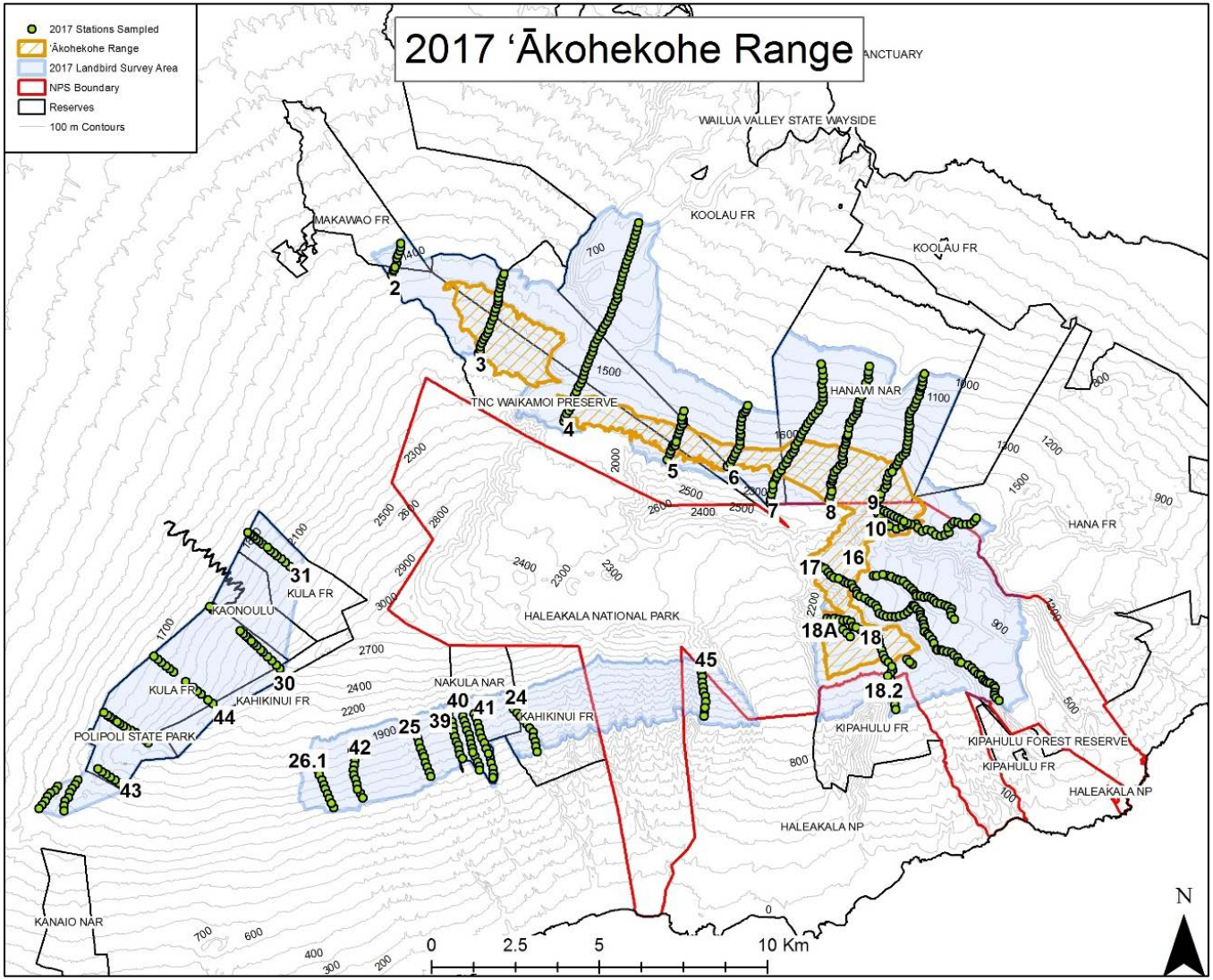


Figure 2. Range of ‘Ākohekohe used for abundance calculations (outlined in orange). Light blue outlined area indicates the 2017 inference area for broadly occurring species.

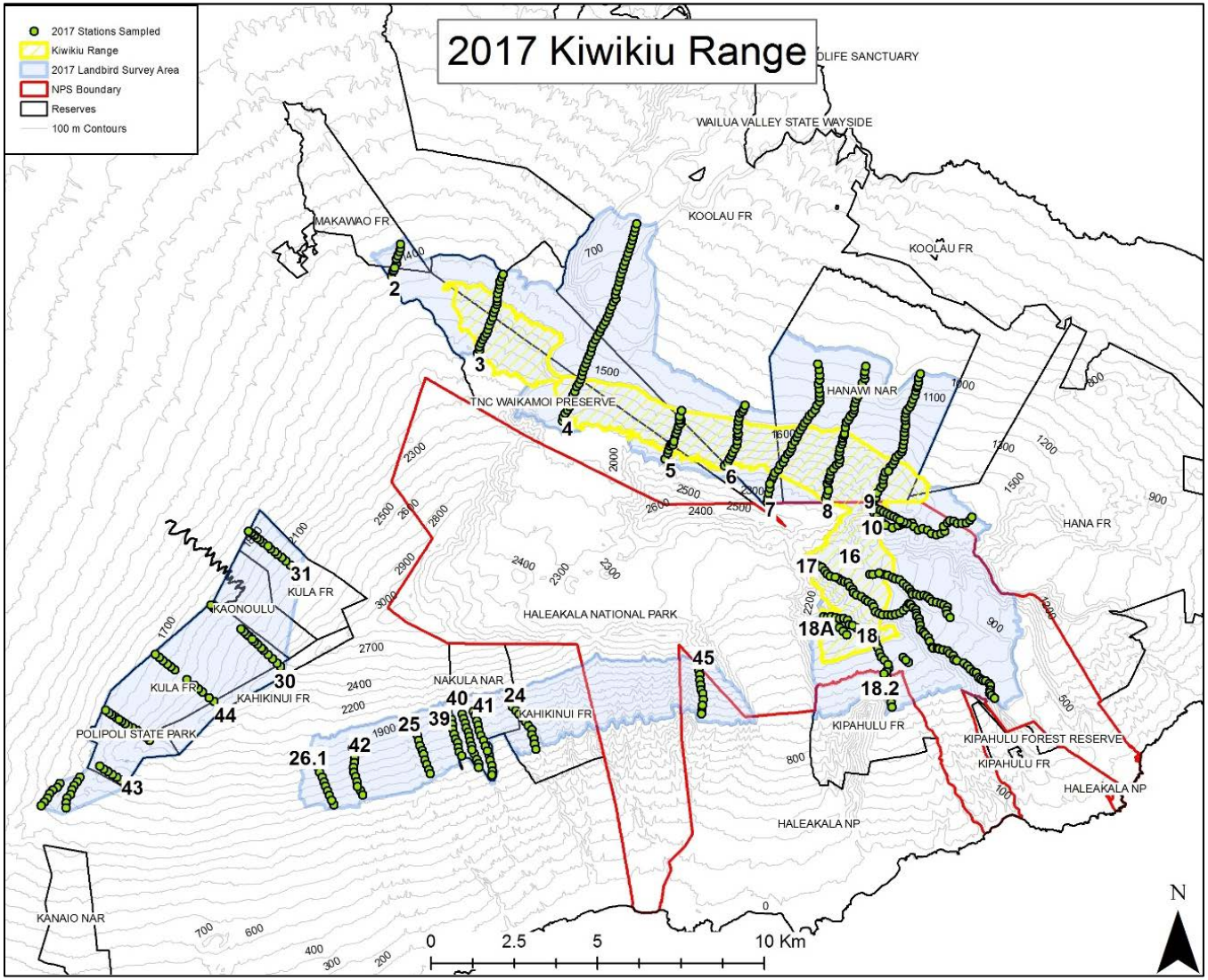


Figure 3. Range of Kiwikiu used for abundance calculations (outlined in yellow). Light blue outlined area indicates the 2017 inference area for broadly occurring species.

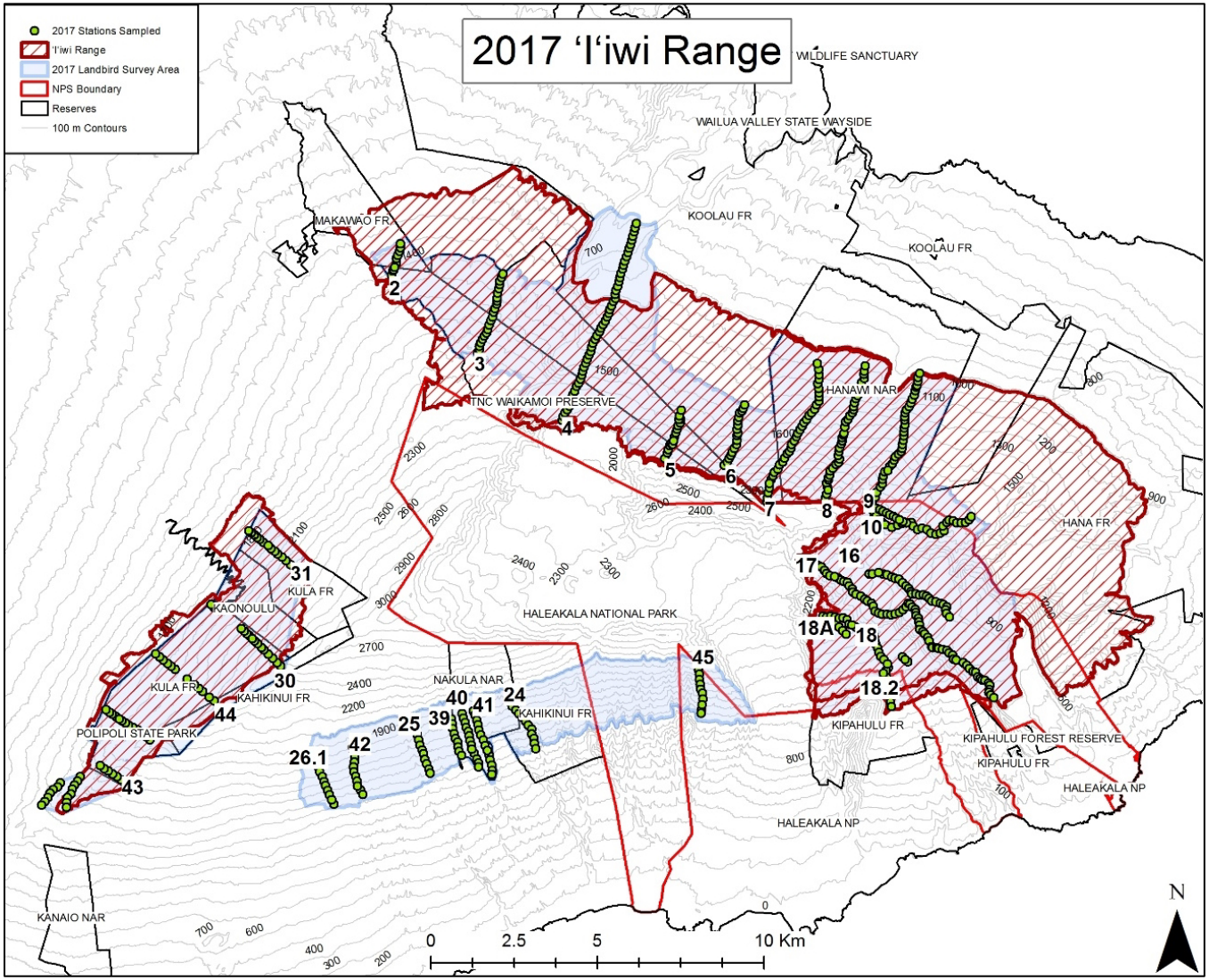


Figure 4. Range of ‘I‘iwi used for abundance calculations (outlined in red). Light blue outlined area indicates the 2017 inference area for broadly occurring species.

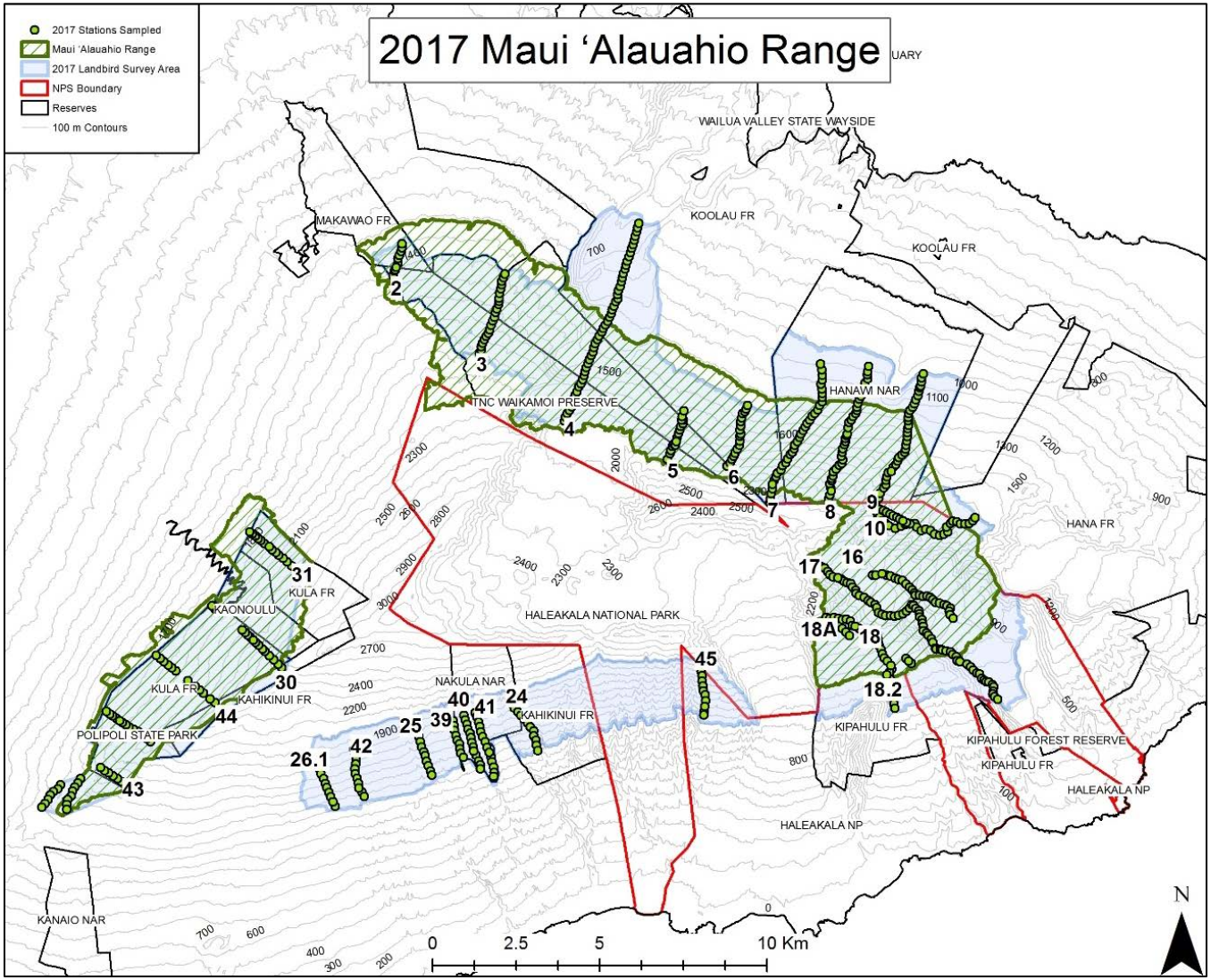


Figure 5. Range of Maui ‘Alauahio used for abundance calculations (outlined in green). Light blue outlined area indicates the 2017 inference area for broadly occurring species.

Trend Model Diagnostics

We assessed the population trends for the ten species for which we estimated densities. Changes in population densities between the 2017 survey and the most recent survey (2011 for HALE or 2012 for the Windward Region) were compared using end-point *z*-test by region. A 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 25% change in the population over 25 years, or a -0.0119 and 0.0093 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).

In addition to using end-point models to assess trends, we investigated using linear regression models to evaluate long-term trends in the endangered Kiwikiu and ʻĀkohekohe; as well as ʻIʻiwi and Maui ʻAlauahio. Preliminary analyses revealed that the trend assessment model could not accurately recover parameters (Appendix E). We therefore compared difference in densities with end-point *z*-tests and used loess smoothers to illustrate the qualitative population patterns of the time series for ʻIʻiwi, Maui ʻAlauahio, ʻĀkohekohe, and Kiwikiu.

Bioacoustics Sampling and Analysis

Detections from rare birds such as Kiwikiu and ʻĀkohekohe were supplemented with audio recording units. These units also allowed the possibility of detecting Maui ʻĀkepa or Maui Nukupuʻu, which have not been detected since 1988 and 1996, respectively (Reynolds et al. 2001). Four recording units were deployed and rotated among survey stations and seldom visited areas within HALE. Audio was recorded at a sample rate of 48,000 Hz in wav format using Wildlife Acoustics SM4 Song Meter recording devices and omnidirectional SMX-II Wildlife Acoustics microphones with a sensitivity of -35 dBV/Pa and frequency response of 20–20,000 Hz (Figure 6). Units were programmed to record in 8-minute bouts every 30 minutes from 06:00 to 21:00. One unit was used to record surveys during point-transect distance sampling to facilitate bird identification calibration. All recordings were sorted and analyzed using Raven 1.5 software (Bioacoustics Research Program2014). Species were identified by experienced biologists and checked with a catalogue of bird songs and calls stored at the University of Hawaiʻi at Hilo Bioacoustic Laboratory. Biologists were trained and calibrated by birdwatching, listening to audio recordings, and studying bird calls as they appear on spectrograms. Calls of unidentified species were shared with experienced primary point counters to confirm identity. Only the presence of identified species was documented, as opposed to calling rate or other variables.

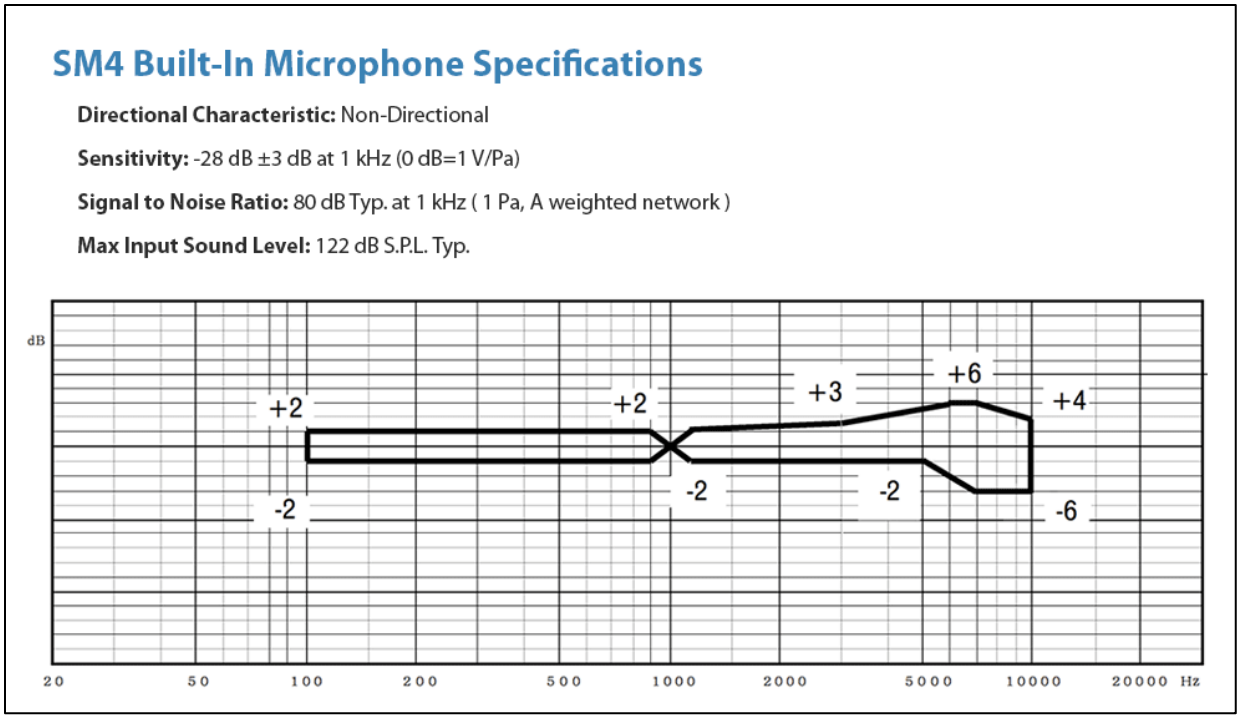


Figure 6. SM4 Song Meter microphone specifications. Image courtesy of wildlifeacoustics.com.

Results

Landbird Results

Indices

A total of 13,502 individuals of 27 landbird species (10 native and 17 non-native) was detected during the 2017 East Maui landbird survey across the four regions (Table 2). Indices of bird occurrence and relative abundance were calculated for all species detected (Table 3). ʻApapane was the most widely distributed and abundant species, occurring at 94% of the stations surveyed and a relative abundance of over five birds per station (BPS). The Hawaiʻi ʻAmakihi and ʻIʻiwi were also broadly distributed, occurring at more than 85% and 57% of the stations sampled, respectively. Hawaiʻi ʻAmakihi had a relative abundance of 2.74 BPS and the threatened ʻIʻiwi had 1.73 BPS. Maui ʻAlauahio occurred at 31% of the stations sampled and at 0.66 BPS. The endangered Kiwikiu and ʻĀkohekohe were the rarest native forest birds detected in the survey, occurring at 1% and 6% of the stations sampled, respectively. The relative abundances for each endangered species was less than 0.12 BPS. Together, the non-native Japanese Bush-Warbler, Japanese White-eye, and Red-billed Leiothrix accounted for a third of all detections. Each species occurred on >70% of the stations sampled (Table 4). The Hwamei, Northern Cardinal, and House Finch were relatively uncommon in the Windward and HALE Regions (Tables 3 and 4). Other non-natives such as the Common Myna, Northern Mockingbird, and Scaly-breasted Munia; as well as some gamebirds and doves were restricted to disturbed areas in the Kula and Leeward Regions. Occurrence maps displaying extent and number of detections of each species are presented in Appendix F.

Table 3. Native and non-native species detected and total number of detections within each region during the 2017 East Maui landbird survey effort. Note that total detections include surveys that were repeated by one or more primary surveyors. Bird names follow the taxonomic authority of the American Ornithological Union (Chesser et al. 2018) with the exception of Kiwikiu, Nēnē, and Pueo which haven't been recognized yet, or are the more commonly used moniker in Hawaiʻi. Scientific names are restricted to species level here while subspecies designations are presented in individual summaries. We use common English names for indigenous seabirds and migratory species.

			Survey Region				
Category	**Species**	**Scientific Name**	**Windward**	**HALE**	**Kula**	**Leeward**	**Total**
Native Species	ʻĀkohekohe	*Palmeria dolei*	33	75	0	0	108
	ʻApapane	*Himatione sanguinea*	1,336	1,479	233	1,000	4,048
	Hawaiʻi ʻAmakihi	*Chlorodrepanis virens*	527	410	379	641	1,957
	ʻIʻiwi	*Drepanis coccinea*	391	652	131	0	1,174
	Kiwikiu	*Pseudonestor xanthophrys*	5	3	0	0	8
	Maui ʻAlauahio	*Paroreomyza montana*	184	216	54	0	454
	Nēnē	*Branta sandvicensis*	0	2	0	12	14

Table 3 (continued). Native and non-native species detected and total number of detections within each region during the 2017 East Maui landbird survey effort. Note that total detections include surveys that were repeated by one or more primary surveyors. Bird names follow the taxonomic authority of the American Ornithological Union (Chesser et al. 2018) with the exception of Kiwikiu, Nēnē, and Pueo which haven't been recognized yet, or are the more commonly used moniker in Hawai'i. Scientific names are restricted to species level here while subspecies designations are presented in individual summaries. We use common English names for indigenous seabirds and migratory species.

			Survey Region				
Category	**Species**	**Scientific Name**	**Windward**	**HALE**	**Kula**	**Leeward**	**Total**
Native Species (continued)	Pacific Golden-Plover	*Pluvialis fulva*	0	0	1	3	4
	Pueo	*Asio flammeus*	0	0	0	11	11
	White-tailed Tropicbird	*Phaethon lepturus*	0	0	0	5	5
Non-native Species	Black Francolin	*Francolinus francolinus*	0	0	5	3	8
	Chukar	*Alectoris chukar*	0	0	6	21	27
	Common Myna	*Acridotheres tristis*	0	0	0	101	101
	Golden Pheasant	*Chrysolophus pictus*	5	3	0	0	8
	Gray Francolin	*Francolinus pondicerianus*	0	0	1	0	1
	House Finch	*Haemorhous mexicanus*	5	0	95	277	377
	Hwamei	*Garrulax canorus*	50	20	1	1	72
	Japanese Bush-Warbler	*Horornis diphone*	903	547	47	303	1,800
	Japanese White-eye	*Zosterops japonicus*	435	423	161	475	1,494
	Mourning Dove	*Zenaida macroura*	0	0	17	4	21
	Northern Cardinal	*Cardinalis cardinalis*	5	0	28	7	40
	Northern Mockingbird	*Mimus polyglottos*	0	0	6	34	40
	Red-billed Leiothrix	*Leiothrix lutea*	411	498	155	152	1,216
	Ring-necked Pheasant	*Phasianus colchicus*	8	1	93	153	255
	Scaly-breasted Munia	*Lonchura punctulata*	0	0	2	95	97
	Sky Lark	*Alauda arvensis*	0	0	12	142	154
	Spotted Dove	*Streptopelia chinensis*	0	0	1	1	2
	Unidentified Bird	N/A	1	1	0	4	6
Total			**4,299**	**4,330**	**1,428**	**3,445**	**13,502**

Table 4. Indices of native and non-native bird detections. Total detections was the number of birds recorded at each of the 570 total stations surveyed, including repeat samples. The “minimum detections” was the number of birds detected during the first sample, regardless of observer. Station occupied was the number of stations where one or more individuals of a species were detected. Percent occurrence was computed as stations occupied divided by 570 total stations surveyed. Birds per station was computed as the minimum detections divided by total stations surveyed.

Category	Species Name	Total Detections	Minimum Detections	Stations Occupied	Percent Occurrence	Birds Per Station
Native Species	ʻĀkohekohe	108	67	35	6	0.12
	ʻApapane	4,048	3,173	534	94	5.57
	Hawaiʻi ʻAmakihi	1,957	1,562	487	85	2.74
	ʻIʻiwi	1,174	984	326	57	1.73
	Kiwikiu	8	6	6	1	0.01
	Maui ʻAlauahio	454	376	175	31	0.66
	Nēnē	14	9	5	1	0.02
	Pacific Golden-Plover	4	4	4	1	<0.01
	Pueo	11	11	9	2	0.02
	White-tailed Tropicbird	5	5	2	<1	<0.01
Non-native Species	Black Francolin	8	8	6	1	0.01
	Chukar	27	22	17	3	0.04
	Common Myna	101	54	40	7	0.09
	Golden Pheasant	8	8	8	1	0.01
	Gray Francolin	1	1	1	<1	<0.01
	House Finch	377	250	116	20	0.44
	Hwamei	72	71	54	9	0.12
	Japanese Bush-Warbler	1,800	1513	450	79	2.65
	Japanese White-eye	1,494	1172	429	75	2.06
	Mourning Dove	21	20	12	2	0.04
	Northern Cardinal	40	39	34	6	0.07
	Northern Mockingbird	40	36	32	6	0.06
	Red-billed Leiothrix	1,216	1,027	418	73	1.8

Table 4 (continued). Indices of native and non-native bird detections. Total detections was the number of birds recorded at each of the 570 total stations surveyed, including repeat samples. The "minimum detections" was the number of birds detected during the first sample, regardless of observer. Station occupied was the number of stations where one or more individuals of a species were detected. Percent occurrence was computed as stations occupied divided by 570 total stations surveyed. Birds per station was computed as the minimum detections divided by total stations surveyed.

Category	Species Name	Total Detections	Minimum Detections	Stations Occupied	Percent Occurrence	Birds Per Station
Non-native Species (continued)	Ring-necked Pheasant	255	193	115	20	0.34
	Scaly-breasted Munia	97	52	32	6	0.09
	Sky Lark	154	77	58	10	0.14
	Spotted Dove	2	2	2	<1	<0.01
	Unidentified Bird	6	6	5	2	0.02

Density and Abundance

There were sufficient detections of ten species to estimate densities (birds/ha). In addition, we combined detections from previous surveys to estimate densities of Kiwikiu, Maui ʻAlauahio, and ʻĀkohekohe (*see* Methods for details). Densities were multiplied by inference area (Table 1) to estimate total absolute abundance (Table 5). These data are presented again in the individual species accounts where we provide density and abundance estimates from previous years for each region and a description of population patterns.

Table 5. Density (birds/ha) and abundance estimates of native and non-native landbirds from the 2017 East Maui landbird survey. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Category	Species	Measurement	Density	Abundance
Native Species	ʻĀkohekohe	point estimate with SE	0.75 ± 0.13	1,768 ± 315
	ʻĀkohekohe	95% confidence interval	0.50–1.02	1,193–2,411
	ʻApapane	point estimate with SE	15.65 ± 1.36	228,480 ± 19,855
	ʻApapane	95% confidence interval	13.21–18.6	192,880–271,500
	Hawaiʻi ʻAmakihi	point estimate with SE	5.33 ± 0.25	77,776 ± 3,694
	Hawaiʻi ʻAmakihi	95% confidence interval	4.86–5.82	71,004–84,995
	ʻIʻiwi	point estimate with SE	4.48 ± 0.31	50,252 ± 3,437
	ʻIʻiwi	95% confidence interval	3.91–5.09	43,908–57,146

Table 5 (continued). Density (birds/ha) and abundance estimates of native and non-native landbirds from the 2017 East Maui landbird survey. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Category	Species	Measurement	Density	Abundance
Native Species (continued)	Kiwikiu	point estimate with SE	0.05 ± 0.02	157 ± 67
	Kiwikiu	95% confidence interval	0.01–0.10	44–312
	Maui ʻAlauahio	point estimate with SE	10.79 ± 1.04	99,060 ± 9,510
	Maui ʻAlauahio	95% confidence interval	9.64–11.65	88,502–106,954
Non-native Species	House Finch	point estimate with SE	0.31 ± 0.06	4,596 ± 878
	House Finch	95% confidence interval	0.21–0.44	3,115–6,451
	Japanese Bush-Warbler	point estimate with SE	2.27 ± 0.09	33,168 ± 1,357
	Japanese Bush-Warbler	95% confidence interval	2.09–2.45	30,562–35,791
	Japanese White-eye	point estimate with SE	8.74 ± 0.45	127,560 ± 6,544
	Japanese White-eye	95% confidence interval	7.84–9.62	114,520–140,460
	Red-billed Leiothrix	point estimate with SE	2.22 ± 0.15	32,374 ± 2,133
	Red-billed Leiothrix	95% confidence interval	1.96–2.52	28,641–36,792

Short-Term Trends (2011, 2012–2017)

We assessed differences between population densities for the ten species using end-point comparisons with a two-sample *z*-test in an equivalency framework. We compared the 2017 densities to those in the Windward Region from 2011, HALE from 2012, and range-wide trends (Table 6). Many comparisons were inconclusive due to relatively small differences and large uncertainties in the density estimates, e.g. ʻĀkohekohe, ʻApapane, and Maui ʻAlauahio. Variances were very large for some species with coefficient of variation about 100% or larger; however, the trend for every native landbird in HALE was decreasing or inconclusive. This was not the case in the Windward Region, where there was at least some evidence of increasing or stable species trends over the last five years. For the native species, notable changes included increases in ʻIʻiwi in the Windward Region, decreases in Hawaiʻi ʻAmakihi in HALE and Windward Regions, decreases in Maui ʻAlauahio in the Windward Region, and the stable trend of Kiwikiu in the Windward Region and declines in HALE. None of the four non-native species were observed to be decreasing (Table 6).

Increases were observed in Red-billed Leiothrix in the Windward Region. House Finch densities were stable in both HALE and Windward Regions.

Long-Term Trajectories (1980–2017)

Long-term population trajectories of the endangered ʻĀkohekohe and Kiwikiu, and the Maui ʻAlauahio fluctuated over the nearly four decades since 1980 (Figures 7, 8, and 9). A general pattern however is common to all three species. Throughout their ranges, species abundances appear to increase in the 1990s and 2000s, but then decrease to current numbers. Abundances for ʻĀkohekohe and Kiwikiu are lower than the initial 1980 abundances. Maui ʻAlauahio are slightly higher than initial abundances but approximately 50% lower than highest estimates in the 1990's. Range-wide patterns demonstrated the most similarities, while trajectories in HALE are much more variable with widely changing abundances occurring over short temporal spans. Again a general pattern is apparent for all three species. Between 1992 and about 2000 abundances increased, and then abundances taper off to the currently reduced numbers of birds.

Table 6. Differences and short-term trends in bird densities in the HALE and Windward study regions. The null hypothesis that density has not changed over time was tested with a *z*-test. Equivalence tests were used to determine if the difference was within the threshold bounds (-0.0199, 0.0093) of a 25% change in density over 25 years. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LELp and UELp = Lower and Upper Equivalence Level p-values. Trends were interpreted as increasing, decreasing, stable, or inconclusive. Inference was limited to the study areas for the wide-spread ʻApapane and Hawaiʻi ʻAmakihi.

Category	Species	Region	Difference	SE	LCL	UCL	z-test p	LEL	UEL	LELp	UELp	Result
Native Species	ʻĀkohekohe	HALE (2012 vs 2017)	-0.23	0.32	-0.75	0.30	0.48	0.53	-0.86	0.70	0.20	Inconclusive
	ʻĀkohekohe	Windward (2011 vs 2017)	-0.24	0.27	-0.69	0.21	0.38	0.62	-1.08	0.73	0.14	Inconclusive
	ʻĀkohekohe	Range-wide (2011/2012 vs 2017)	-0.19	0.20	-0.51	0.14	0.34	0.59	-1.24	0.72	0.11	Inconclusive
	ʻApapane	HALE (2012 vs 2017)	2.46	2.48	-1.62	6.54	0.32	-1.02	0.97	0.15	0.83	Inconclusive
		Windward (2011 vs 2017)	-1.37	2.49	-5.47	2.73	0.58	0.52	-0.57	0.70	0.28	Inconclusive
	Hawaiʻi ʻAmakihi	HALE (2012 vs 2017)	-1.20	0.53	-2.07	-0.33	0.02	2.16	-2.36	0.98	0.01	Decreasing
		Windward (2011 vs 2017)	-1.21	0.52	-2.07	-0.35	0.02	2.19	-2.43	0.99	0.01	Decreasing
	ʻIʻiwi	HALE (2012 vs 2017)	0.10	0.70	-1.04	1.25	0.88	-0.23	0.08	0.41	0.53	Inconclusive
	ʻIʻiwi	Windward (2011 vs 2017)	0.95	0.41	0.28	1.63	0.02	-2.49	2.18	0.01	0.99	Increasing
	ʻIʻiwi	Range-wide (2011/2012 vs 2017)	1.13	0.40	0.47	1.79	0.00	-3.00	2.68	0.00	1.00	Increasing
	Kiwikiu	HALE (2012 vs 2017)	-0.27	0.03	-0.32	-0.22	0.00	6.65	-10.04	1.00	0.00	Decreasing
	Kiwikiu	Windward (2011 vs 2017)	-0.01	0.04	-0.07	0.05	0.77	-1.68	-1.83	0.05	0.03	Stable
	Kiwikiu	Range-wide (2011/2012 vs 2017)	-0.04	0.03	-0.10	0.01	0.17	-0.82	-3.11	0.20	0.00	Inconclusive
	Maui ʻAlauahio	HALE (2012 vs 2017)	-2.03	2.02	-5.35	1.30	0.32	0.97	-1.02	0.83	0.15	Inconclusive
	Maui ʻAlauahio	Windward (2011 vs 2017)	1.39	1.72	-1.44	4.21	0.42	-0.85	0.77	0.20	0.78	Inconclusive
	Maui ʻAlauahio	Range-wide (2011/2012 vs 2017)	0.32	1.50	-2.15	2.80	0.00	-0.26	0.18	0.40	0.57	Inconclusive

Table 6 (continued). Differences and short-term trends in bird densities in the HALE and Windward study regions. The null hypothesis that density has not changed over time was tested with a z-test. Equivalence tests were used to determine if the difference was within the threshold bounds (-0.0199, 0.0093) of a 25% change in density over 25 years. LCI and UCI = Lower and Upper 90% Confidence Intervals; LEL and UEL = Lower and Upper Equivalence Levels (t-values); LELp and UELp = Lower and Upper Equivalence Level p-values. Trends were interpreted as increasing, decreasing, stable, or inconclusive. Inference was limited to the study areas for the wide-spread ‘Apapane and Hawai‘i ‘Amakihi.

Category	Species	Region	Difference	SE	LCL	UCL	z-test p	LEL	UEL	LELp	UELp	Result
Non-native Species	House Finch	HALE (2012 vs 2017)	0.00	0.00	0.00	0.00	0.34	-13.17	-11.98	<0.01	<0.01	Stable
	House Finch	Windward (2011 vs 2017)	<0.01	0.01	-0.02	0.02	0.99	-6.57	-5.12	<0.01	<0.01	Stable
	Japanese Bush-Warbler	HALE (2012 vs 2017)	0.12	0.20	-0.21	0.45	0.57	-0.86	0.34	0.19	0.63	Inconclusive
	Japanese Bush-Warbler	Windward (2011 vs 2017)	0.50	0.21	0.15	0.85	0.02	-2.77	2.16	0.00	0.98	Increasing
	Japanese White-eye	HALE (2012 vs 2017)	-2.04	1.20	-4.01	-0.07	0.09	1.65	-1.74	0.95	0.04	Inconclusive
	Japanese White-eye	Windward (2011 vs 2017)	0.44	0.70	-0.71	1.59	0.53	-0.73	0.55	0.23	0.71	Inconclusive
	Red-billed Leiothrix	HALE (2012 vs 2017)	-0.44	0.35	-1.02	0.14	0.22	1.07	-1.37	0.86	0.09	Inconclusive
	Red-billed Leiothrix	Windward (2011 vs 2017)	0.57	0.24	0.18	0.96	0.02	-2.68	2.15	0.00	0.98	Increasing

Native Species Summaries

ʻĀkohekohe

There was a total of 108 detections of the endangered ʻĀkohekohe during the 2017 survey period. The majority of detections were above 1,600 m elevation in mesic and montane ʻōhiʻa-dominated rainforest in Manawainui within HALE on Transects 18A and 18, and on Windward Transects 8, 9, and 10 (*see* Appendix F, Figure F-1). There were no detections on Windward Transects 4 through 7, nor within Kīpahulu Valley on Transects 16 and 17; both areas include large portions of the species' former and current estimated range.

The overall density of ʻĀkohekohe was 0.75 ± 0.13 birds/ha (SE) and we estimated an abundance of 1,768 ± 315 individuals in the 2,363 ha inference area–the entire species' range (Table 6). Range-wide densities of ʻĀkohekohe increased between 1990 and 2000, but subsequently decreased to current densities of 0.75 birds/ha, which is substantially lower than 1.79 ± 0.26 birds/ha in 1980 (Tables 7 and 8; Figure 7). The almost complete lack of overlap in the 95% CI of density and population estimates of the most recent two surveys versus prior surveys indicate this species has experienced substantial declines over the last two decades (Tables 7 and 8; Figure 7). The individual populations in the Windward and HALE Regions followed similar patterns (Figure 7).

Table 7. Range-wide density (birds/ha) and abundance estimates of ʻĀkohekohe from 1980 to 2017. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Total	1980	point estimate with SE	1.79 ± 0.26	4,240 ± 604
	1980	95% confidence interval	1.33–2.32	3,148–5,475
	1992	point estimate with SE	1.80 ± 0.26	4,256 ± 605
	1992	95% confidence interval	1.35–2.33	3,180–5,502
	1993	point estimate with SE	2.69 ± 0.46	6,347 ± 1,087
	1993	95% confidence interval	1.85–3.65	4,373–8,635
	1996	point estimate with SE	2.80 ± 0.33	6,622 ± 787
	1996	95% confidence interval	2.19–3.48	5,176–8,216
	1997	point estimate with SE	2.10 ± 0.45	4,954 ± 1,073
	1997	95% confidence interval	1.23–3.00	2,897–7,084
	1998	point estimate with SE	1.35 ± 0.47	3,182 ± 1,108
	1998	95% confidence interval	0.56–2.44	1,318–5,766
	1999	point estimate with SE	2.71 ± 0.50	6,404 ± 1,173
	1999	95% confidence interval	1.79–3.75	4,232–8,856
	2000	point estimate with SE	5.27 ± 0.63	12,459 ± 1,481

Table 7 (continued). Range-wide density (birds/ha) and abundance estimates of ʻĀkohekohe from 1980 to 2017. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Total (continued)	2000	95% confidence interval	4.15–6.58	9,813–15,540
	2001	point estimate with SE	3.43 ± 0.43	8,098 ± 1,020
	2001	95% confidence interval	2.68–4.28	6,328–10,108
	2005	point estimate with SE	1.86 ± 0.37	4,390 ± 867
	2005	95% confidence interval	1.18–2.59	2,788–6,128
	2006	point estimate with SE	1.89 ± 0.39	4,470 ± 933
	2006	95% confidence interval	1.19–2.70	2,820–6,390
	2011	point estimate with SE	0.94 ± 0.14	2,211 ± 342
	2011	95% confidence interval	0.67–1.22	1,582–2,886
	2017	point estimate with SE	0.75 ± 0.13	1,768 ± 315
	2017	95% confidence interval	0.50–1.02	1,193–2,411

Table 8. Annual (1980–2017) density (birds/ha) and abundance estimates of ʻĀkohekohe within HALE and the Windward Region. The first row is for the point estimate with SE while the second row presents the 95% CI.

Region	Year	Measurement	Density	Abundance
Windward	1980	point estimate with SE	1.61 ± 0.31	2,482 ± 477
	1980	95% confidence interval	1.05–2.26	1,609–3,483
	1992	point estimate with SE	2.29 ± 0.36	3,521 ± 551
	1992	95% confidence interval	1.64–3.03	2,522–4,663
	1996	point estimate with SE	2.81 ± 0.34	4,320 ± 519
	1996	95% confidence interval	2.18–3.50	3,351–5,387
	2001	point estimate with SE	2.41 ± 0.41	3,707 ± 630
	2001	95% confidence interval	1.70–3.21	2,609–4,944
	2006	point estimate with SE	1.95 ± 0.42	2,996 ± 651
	2006	95% confidence interval	1.17–2.82	1,800–4,342
	2011	point estimate with SE	0.93 ± 0.16	1,434 ± 246
	2011	95% confidence interval	0.63–1.27	971–1,952
	2017	point estimate with SE	0.69 ± 0.22	1,064 ± 343

Table 8 (continued). Annual (1980–2017) density (birds/ha) and abundance estimates of ʻĀkohekohe within HALE and the Windward Region. The first row is for the point estimate with SE while the second row presents the 95% CI.

Region	Year	Measurement	Density	Abundance
Windward (continued)	2017	95% confidence interval	0.29–1.17	450—1,806
HALE	1980	point estimate with SE	2.06 ± 0.37	1,698 ± 306
	1980	95% confidence interval	1.38–2.83	1,142–2,333
	1992	point estimate with SE	0.99 ± 0.20	814 ± 166
	1992	95% confidence interval	0.62–1.40	509–1,152
	1993	point estimate with SE	2.69 ± 0.48	2,219 ± 395
	1993	95% confidence interval	1.84–3.68	1,516–3,037
	1997	point estimate with SE	2.10 ± 0.47	1,730 ± 384
	1997	95% confidence interval	1.26–3.04	1,038–2,507
	1998	point estimate with SE	1.33 ± 0.47	1,093 ± 385
	1998	95% confidence interval	0.53–2.35	435–1,940
	1999	point estimate with SE	2.68 ± 0.51	2,210 ± 420
	1999	95% confidence interval	1.76–3.70	1,448–3,051
	2000	point estimate with SE	5.30 ± 0.63	4,368 ± 516
	2000	95% confidence interval	4.13–6.58	3,402–5,429
	2001	point estimate with SE	5.15 ± 0.66	4,250 ± 544
	2001	95% confidence interval	3.94–6.59	3,250–5,430
	2005	point estimate with SE	1.85 ± 0.38	1,523 ± 309
	2005	95% confidence interval	1.15–2.62	946–2,163
	2006	point estimate with SE	1.52 ± 0.45	1,254 ± 374
	2006	95% confidence interval	0.70–2.43	573–2,007
	2012	point estimate with SE	1.02 ± 0.27	837 ± 226
	2012	95% confidence interval	0.51–1.58	417–1,305
	2017	point estimate with SE	0.79 ± 0.16	651 ± 134
	2017	95% confidence interval	0.47–1.12	389–921

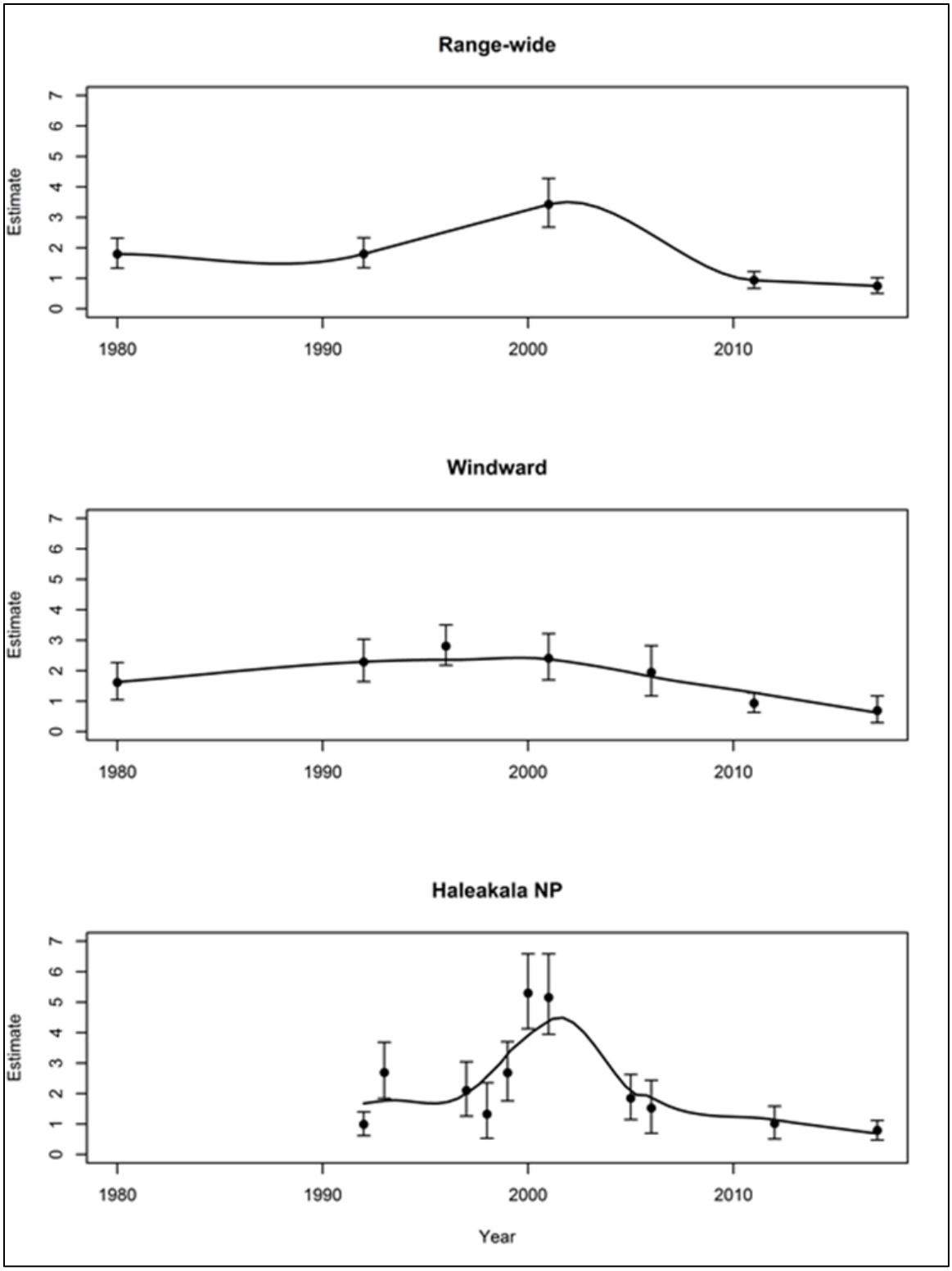


Figure 7. Density estimates for ʻĀkohekohe in the HALE and Windward Regions as well as range-wide since the initial surveys in 1980. Error bars indicate 95% CI and loess smoothers were added to illustrate population patterns.

'Apapane

'Apapane were the most abundant and widely distributed species in the survey (*see* Appendix F, Figure F-2). The species occurred at 94% of the stations surveyed. Overall density was 15.65 ± 1.36 birds/ha and we estimated 228,480 ± 19,855 individuals in the 14,600 ha inference area. Density confidence intervals overlapped between surveys and areas, and there were high abundances compared to all other species (Table 9).

Table 9. Density (birds/ha) and abundance estimates of 'Apapane by region during the 2017 East Maui landbird survey and previous 2011 or 2012 survey. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Windward	2011	point estimate with SE	19.62 ± 1.81	131,510 ± 12,112
	2011	95% confidence interval	16.58–23.96	111,100–160,560
	2017	point estimate with SE	18.25 ± 1.71	122,330 ± 11,438
	2017	95% confidence interval	15.33–22.19	102,740–148,690
HALE	2012	point estimate with SE	17.38 ± 1.68	50,819 ± 4,924
	2012	95% confidence interval	14.57–21.15	42,599–61,849
	2017	point estimate with SE	19.84 ± 1.82	58,011 ± 5,314
	2017	95% confidence interval	16.43–23.94	48,051–70,005
Kula	2017	point estimate with SE	7.27 ± 1.04	17,377 ± 2,478
	2017	95% confidence interval	5.39–9.62	12,889–22,998
Leeward	2017	point estimate with SE	10.83 ± 1.52	27,961 ± 3,917
	2017	95% confidence interval	8.04–14.15	20,777–36,540
Total	2011/2012	point estimate with SE	19.13 ± 1.67	279,270 ± 24,324
	2011/2012	95% confidence interval	16.11–22.74	235,210–332,040
	2017	point estimate with SE	15.65 ± 1.36	228,480 ± 19,855
	2017	95% confidence interval	13.21–18.6	192,880–271,500

Hawai'i 'Amakihi

Hawai'i 'Amakihi occurred at 85% of the stations sampled (*see* Appendix F, Figure F-3). Overall densities were at 5.33 ± 0.25 birds/ha and there were 77,776 ± 3,694 individuals in the 14,600 ha inference area (Table 10). Densities were highest in the non-native forest of the Kula Region where we estimated 8.71 ± 0.70 birds/ha. Densities declined approximately 1.2 birds/ha over the last six years in the Windward, Leeward, and HALE Regions (Table 10).

Table 10. Density (birds/ha) and abundance estimates of Hawai‘i ‘Amakihi by region during the 2017 East Maui landbird survey and previous 2011 or 2012 survey. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Windward	2011	point estimate with SE	6.43 ± 0.39	43,067 ± 2,614
	2011	95% confidence interval	5.72–7.24	38,325–48,511
	2017	point estimate with SE	5.22 ± 0.34	34,951 ± 2,310
	2017	95% confidence interval	4.57–5.89	30,610–39,442
HALE	2012	point estimate with SE	5.37 ± 0.41	15,690 ± 1,197
	2012	95% confidence interval	4.62–6.25	13,523–18,288
	2017	point estimate with SE	4.17 ± 0.33	12,191 ± 969
	2017	95% confidence interval	3.56–4.83	10,399–14,120
Kula	2017	point estimate with SE	8.71 ± 0.70	20,832 ± 1,681
	2017	95% confidence interval	7.36–10.14	17,596–24,250
Leeward	2017	point estimate with SE	5.31 ± 0.59	13,726 ± 1,536
	2017	95% confidence interval	4.25–6.49	10,975–16,770
Total	2011/2012	point estimate with SE	6.26 ± 0.35	91,346 ± 5,115
	2011/2012	95% confidence interval	5.63–6.98	82,129–101,840
	2017	point estimate with SE	5.33 ± 0.25	77,776 ± 3,694
	2017	95% confidence interval	4.86–5.82	71,004–84,995

‘I‘iwi

‘I‘iwi occurred at 57% of the stations sampled, but only within the HALE, Kula, and Windward Regions (*see* Appendix F, Figure F-4). Overall density was 4.48 ± 0.31 birds/ha, and we estimated 50,252 ± 3,437 individuals in the estimated 11,226 ha range for the species on East Maui (Table 11). Density was highest within HALE at 5.66 ± 0.53 birds/ha. There was a range-wide increase in total densities of more than 1.1 birds/ha over the 5-year sample period (Table 10).

Table 11. Density (birds/ha) and abundance estimates of ʻIʻiwi by region during the 2017 East Maui landbird survey and previous 2011 or 2012 survey. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Windward	2011	point estimate with SE	2.84 ± 0.25	17,457 ± 1,508
	2011	95% confidence interval	2.37–3.32	14,555–20,422
	2017	point estimate with SE	3.79 ± 0.33	23,302 ± 2,023
	2017	95% confidence interval	3.16–4.46	19,426–27,402
HALE	2012	point estimate with SE	5.66 ± 0.53	16,559 ± 1,552
	2012	95% confidence interval	4.74–6.74	13,868–19,697
	2017	point estimate with SE	5.77 ± 0.45	16,857 ± 1,322
	2017	95% confidence interval	4.92–6.71	14,385–19,625
KULA	2017	point estimate with SE	3.07 ± 0.51	6,615 ± 1,106
	2017	95% confidence interval	2.13–4.08	4,591–8,797
Total	2011/2012	point estimate with SE	3.35 ± 0.26	37,574 ± 2,893
	2011/2012	95% confidence interval	2.85–3.87	31,980–43,408
	2017	point estimate with SE	4.48 ± 0.31	50,252 ± 3,437
	2017	95% confidence interval	3.91–5.09	43,908–57,146

Kiwikiu

Only eight endangered Kiwikiu individuals were detected. Detections ranged between 1,700 m and 2,400 m elevation (*see* Appendix F, Figure F-9). Detections were within TNC's Waikamoi Preserve on Transects 3 and 4, on Transects 8 and 9 within Hanawī NAR, and within HALE on Transect 10. To estimate the Kiwikiu detection probability we pooled detections across all previous surveys. Overall density was very low (0.05 ± 0.02 birds/ha) and we estimated a total abundance of 157 ± 67 (95% CI 44–312) individuals in their 2,992 ha range. Range-wide densities of Kiwikiu fluctuated between 1980 and 2000, but were always less than 0.2 birds/ha, and the mean population abundance estimates have declined because of low densities and range contraction (Tables 12 and 13). This general pattern was observed in both Windward and HALE Regions (Figure 8). Current densities of 0.03 birds/ha in HALE are about one-half those in Windward at 0.07 birds/ha (Table 13).

Table 12. Kiwikiu density (birds/ha) and abundance estimates (1980–1998). The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
East Maui	1980	point estimate with SE	0.23 ± 0.07	488 ± 141
	1980	95% confidence interval	0.12–0.37	249–798
	1992	point estimate with SE	0.10 ± 0.05	213 ± 110
	1992	95% confidence interval	0.01–0.22	28–468
	1996	point estimate with SE	0.38 ± 0.09	819 ± 193
	1996	95% confidence interval	0.22–0.58	475–1,232
HALE	1980	point estimate with SE	0.08 ± 0.05	64 ± 45
	1980	95% confidence interval	<0.01–0.19	1–163
	1992	point estimate with SE	0.24 ± 0.09	202 ± 80
	1992	95% confidence interval	0.08–0.45	70–380
	1993	point estimate with SE	0.12 ± 0.06	100 ± 53
	1993	95% confidence interval	0.02–0.26	19–223
	1998	point estimate with SE	0.14 ± 0.07	120 ± 58
	1998	95% confidence interval	0.03–0.30	27–258
Total	1980	point estimate with SE	0.17 ± 0.05	513 ± 143
	1980	95% confidence interval	0.09–0.28	261–835
	1992	point estimate with SE	0.15 ± 0.05	447 ± 157
	1992	95% confidence interval	0.06–0.26	186–781
	1993	point estimate with SE	0.12 ± 0.06	362 ± 191
	1993	95% confidence interval	0.02–0.26	66–788
	1996	point estimate with SE	0.38 ± 0.09	1,137 ± 271
	1996	95% confidence interval	0.21–0.57	630–1,695
	1998	point estimate with SE	0.14 ± 0.07	418 ± 199
	1998	95% confidence interval	0.03–0.29	97–854

Table 13. Kiwikiu density (birds/ha) and abundance estimates (2000–2017). The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
East Maui	2001	point estimate with SE	0.11 ± 0.03	227 ± 75
	2001	95% confidence interval	0.04–0.18	94–389
	2006	point estimate with SE	0.16 ± 0.05	336 ± 98
	2006	95% confidence interval	0.08–0.25	165–532
	2011	point estimate with SE	0.08 ± 0.02	169 ± 47
	2011	95% confidence interval	0.04–0.13	91–276
	2017	point estimate with SE	0.07 ± 0.03	146 ± 62
	2017	95% confidence interval	0.01–0.13	30–279
HALE	2000	point estimate with SE	0.27 ± 0.08	229 ± 71
	2000	95% confidence interval	0.12–0.45	102–383
	2001	point estimate with SE	0.35 ± 0.14	295 ± 115
	2001	95% confidence interval	0.13–0.66	111–557
	2005	point estimate with SE	0.02 ± 0.02	20 ± 19
	2005	95% confidence interval	0–0.07	0–62
	2012	point estimate with SE	0.29 ± 0.13	254 ± 113
	2012	95% confidence interval	0.07–0.59	61–504
	2017	point estimate with SE	0.03 ± 0.03	27 ± 27
	2017	95% confidence interval	0–0.11	0–91
Total	2000	point estimate with SE	0.27 ± 0.08	814 ± 252
	2000	95% confidence interval	0.13–0.45	395–1,346
	2001	point estimate with SE	0.18 ± 0.05	544 ± 153
	2001	95% confidence interval	0.09–0.30	280–901
	2005	point estimate with SE	0.02 ± 0.02	67 ± 69
	2005	95% confidence interval	0–0.07	0–216
	2006	point estimate with SE	0.16 ± 0.04	464 ± 129
	2006	95% confidence interval	0.07–0.25	206–737
	2011	point estimate with SE	0.10 ± 0.02	291 ± 69
	2011	95% confidence interval	0.06–0.15	168–442
	2017	point estimate with SE	0.05 ± 0.02	157 ± 67
	2017	95% confidence interval	0.01–0.10	44–312

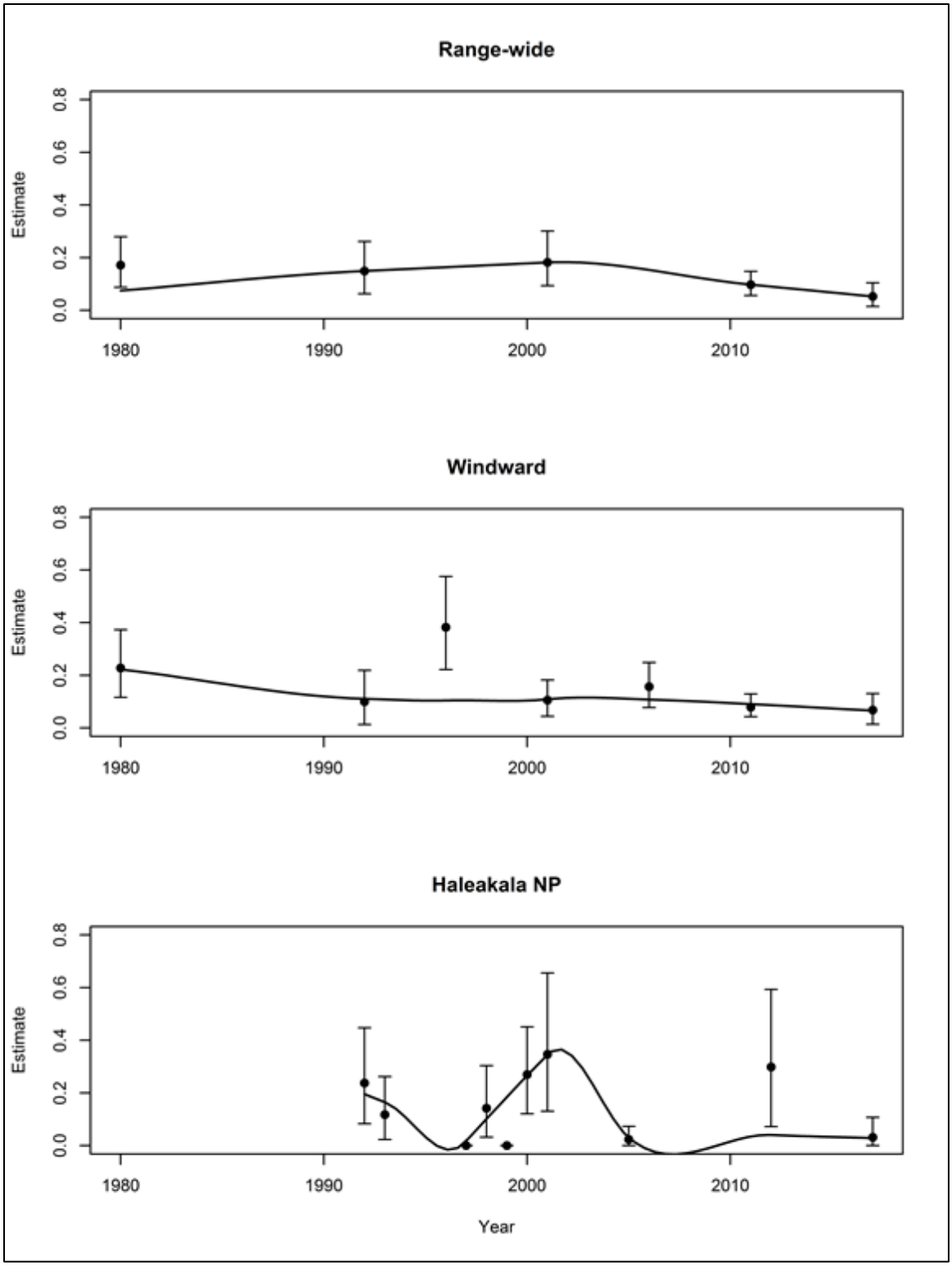


Figure 8. Density estimates for Kiwikiu in the HALE and Windward Regions as well as range-wide since the initials surveys in 1980. Error bars indicate 95% CI and loess smoothers were added to illustrate population patterns.

Maui ʻAlauahio

Maui ʻAlauahio were detected at 31% of surveyed stations; but only in the HALE, Kula, and Windward Regions. The species was not detected in the Leeward Region. Density of Maui ʻAlauahio was 10.79 ± 1.04birds/ha. The species was broadly distributed in native and non-native forest at elevations above 1,200 m in these three regions (*see* Appendix A, Figure A-6). We estimated an abundance of 99,060 ± 9,510 individuals in the 3,121 ha inference area.

The range-wide Maui ʻAlauahio population increased throughout the 1990s, and after peaking in 1999, subsequently decreased through the 2000s, and over the last 5 years densities leveled off at almost 11 birds/ha (Tables 14 and 15; Figure 9). The Windward population matches the range-wide pattern and densities closely, whereas the HALE population appears to have peaked by 2000 and continued to decline to current densities of 10 birds/ha (Tables 14 and 15; Figure 9).

Table 14. Density (birds/ha) and abundance estimates of Maui ʻAlauahio in its entire range for every survey year since 1980. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Total	1980	point estimate with SE	8.17 ± 0.93	74,997 ± 8,520
	1980	95% confidence interval	7.11–8.84	65,271–81,156
	1992	point estimate with SE	18.38 ± 0.63	168,702 ± 5,786
	1992	95% confidence interval	17.83–19.07	163,690–175,045
	1993	point estimate with SE	17.51 ± 1.12	160,762 ± 10,241
	1993	95% confidence interval	16.46–18.69	151,115–171,520
	1996	point estimate with SE	13.38 ± 1.41	122,770 ± 12,952
	1996	95% confidence interval	11.75–14.27	107,845–131,013
	1997	point estimate with SE	23.34 ± 1.82	214,202 ± 16,729
	1997	95% confidence interval	21.24–24.57	195,000–225,557
	1998	point estimate with SE	21.25 ± 2.81	195,055 ± 25,825
	1998	95% confidence interval	19.25–24.47	176,733–224,584
	1999	point estimate with SE	23.45 ± 1.92	215,240 ± 17,585
	1999	95% confidence interval	21.24–24.61	194,945–225,906
	2000	point estimate with SE	22.14 ± 3.43	203,178 ± 31,493
	2000	95% confidence interval	19.19–25.90	176,155–237,774
	2001	point estimate with SE	13.51 ± 1.38	124,027 ± 12,663
	2001	95% confidence interval	12.45–15.07	114,242–138,337
	2005	point estimate with SE	14.16 ± 0.42	130,003 ± 3,874

Table 14 (continued). Density (birds/ha) and abundance estimates of Maui ‘Alauahio in its entire range for every survey year since 1980. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Total (continued)	2005	95% confidence interval	13.73–14.57	126,019–133,766
	2006	point estimate with SE	13.30 ± 1.45	122,063 ± 13,293
	2006	95% confidence interval	12.16–14.93	111,608–137,016
	2011/2012	point estimate with SE	10.47 ± 1.09	96,105 ± 10,014
	2011/2012	95% confidence interval	9.48–11.64	86,983–106,826
	2017	point estimate with SE	10.79 ± 1.04	99,060 ± 9,510
	2017	95% confidence interval	9.64–11.65	88,502–106,954

Table 15. Density (birds/ha) and abundance estimates of Maui ‘Alauahio per region and survey year. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
KULA	1980	point estimate with SE	1.64 ± 0.58	3,531 ± 1,255
	1980	95% confidence interval	0.56–2.79	1,202–5,998
	2017	point estimate with SE	6.27 ± 1.51	13,506 ± 3,251
	2017	95% confidence interval	3.63–9.27	7,810–19,968
Windward	1980	point estimate with SE	9.92 ± 1.23	46,581 ± 5,762
	1980	95% confidence interval	7.48–12.24	35,110–57,473
	1992	point estimate with SE	14.59 ± 1.51	68,485 ± 7,088
	1992	95% confidence interval	11.88–17.51	55,774–82,182
	1996	point estimate with SE	14.55 ± 1.53	68,283 ± 7,204
	1996	95% confidence interval	11.85–17.54	55,605–82,332
	2001	point estimate with SE	11.33 ± 1.39	53,178 ± 6,504
	2001	95% confidence interval	8.65–14.09	40,602–66,157
	2006	point estimate with SE	11.68 ± 1.15	54,835 ± 5,407
	2006	95% confidence interval	9.64–14.26	45,260–66,945
	2011	point estimate with SE	10.25 ± 0.98	48,108 ± 4,594

Table 15 (continued). Density (birds/ha) and abundance estimates of Maui ‘Alauahio per region and survey year. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Windward (continued)	2011	95% confidence interval	8.45–12.08	39,681–56,717
	2017	point estimate with SE	11.64 ± 1.41	54,614 ± 6,630
	2017	95% confidence interval	9.31–14.45	43,706–67,818
HALE	1980	point estimate with SE	7.91 ± 1.00	18,453 ± 2,336
	1980	95% confidence interval	6.01–9.89	14,019–23,052
	1992	point estimate with SE	21.74 ± 1.98	50,676 ± 4,617
	1992	95% confidence interval	18.21–25.89	42,451–60,356
	1993	point estimate with SE	16.14 ± 1.58	37,622 ± 3,676
	1993	95% confidence interval	13.38–19.58	31,202–45,638
	1997	point estimate with SE	24.5 ± 2.43	57,120 ± 5,661
	1997	95% confidence interval	19.98–28.99	46,582–67,579
	1998	point estimate with SE	19.43 ± 2.00	45,302 ± 4,671
	1998	95% confidence interval	15.98–23.38	37,249–54,502
	1999	point estimate with SE	20.82 ± 2.10	48,531 ± 4,907
	1999	95% confidence interval	17.01–25.13	39,667–58,598
	2000	point estimate with SE	21.54 ± 2.13	50,224 ± 4,977
	2000	95% confidence interval	17.42–25.85	40,611–60,261
	2001	point estimate with SE	14.60 ± 1.52	34,039 ± 3,540
	2001	95% confidence interval	11.94–17.41	27,844–40,593
	2005	point estimate with SE	13.87 ± 1.30	32,342 ± 3,021
	2005	95% confidence interval	11.39–16.44	26,548–38,317
	2012	point estimate with SE	12.12 ± 1.63	28,250 ± 3,808
	2012	95% confidence interval	8.97–15.41	20,911–35,937
	2017	point estimate with SE	10.09 ± 1.19	23,529 ± 2,779
	2017	95% confidence interval	7.91–12.44	18,450–29,012

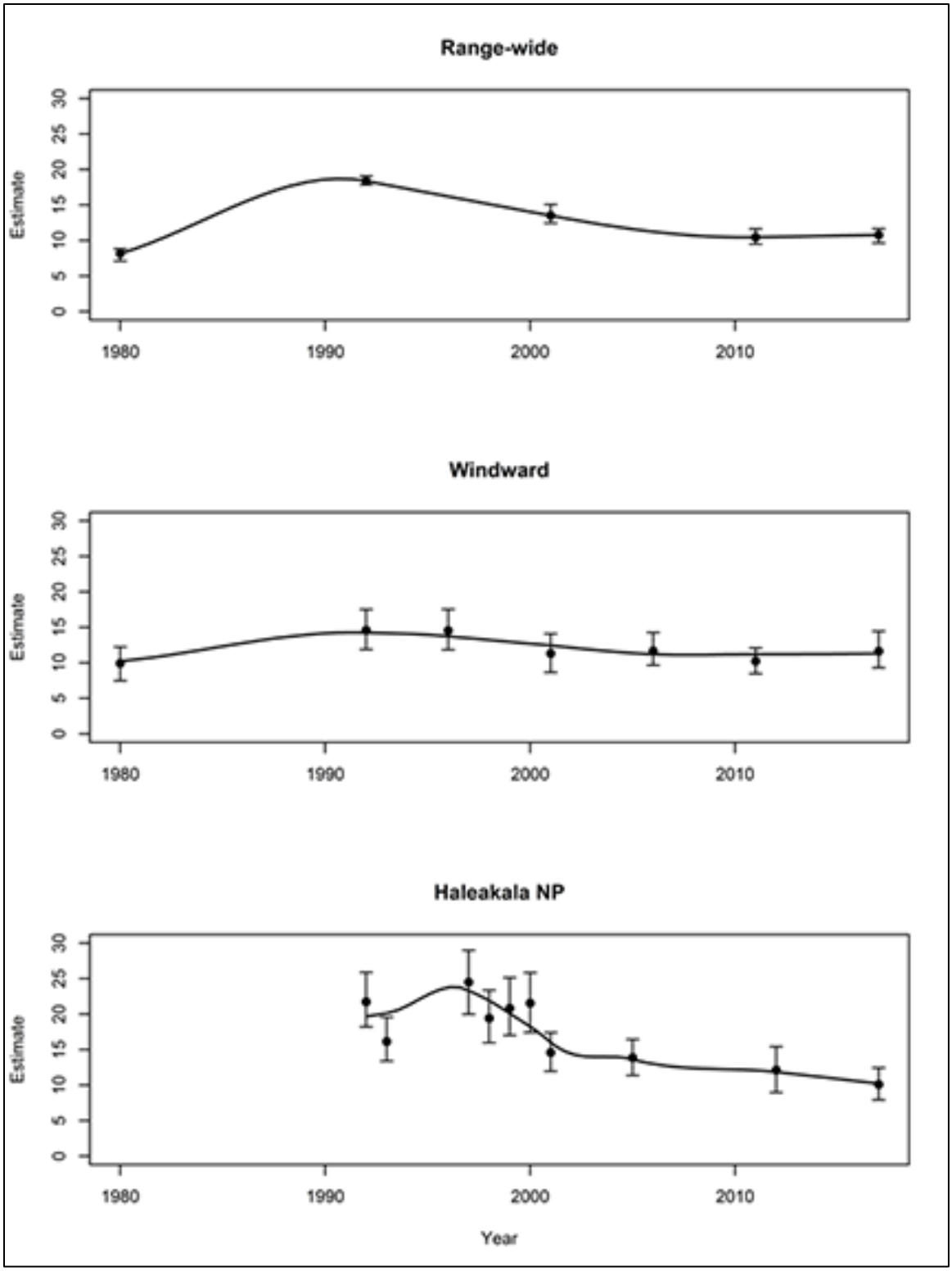


Figure 9. Density estimates for Maui ‘Alauahio in the HALE and Windward Regions as well as range-wide since the initials surveys in 1980. Error bars indicate 95% CI and loess smoothers were added to illustrate population patterns..

Nēnē

There were 14 detections of the endangered Nēnē (Hawaiian Goose; *Branta sandwichensis*). Most detections were on Leeward Transect 41 and near the top of Transect 18A in HALE (*see* Appendix F, Figure F-7).

Pacific Golden-Plover

There were four detections of the migratory Pacific Golden-Plover (Kōlea; *Pluvialis fulva*). All detections were on Leeward transects (*see* Appendix F, Figure F-8).

Pueo

There were 11 detections of the Pueo (Short-eared Owl; *Asio flammeus sandwichensis*). All detections were on Leeward transects (*see* Appendix F, Figure F-7).

White-tailed Tropicbird

There were five detections of the White-tailed Tropicbird (Koa‘e ‘kea; *Phaethon lepturus*). All detections were on Leeward Transect 24 (*see* Appendix F, Figure F-8). This species was noted on other Leeward transects as fly-overs, likely heading to and from nest sites on high-elevation cliff-faces in HALE above these transects.

Non-Native Species Summaries

Black Francolin

There were eight detections of the Black Francolin (*Francolinus francolinus*). All detections were on Kula Transect 47 (*see* Appendix F, Figure F-8).

Chukar

There were 27 total detections of Chukar (*Alectoris chukar*). The detections were near the top of Leeward and Kula transects in talus habitat (*see* Appendix F, Figure F-8).

Common Myna

There were 101 detections of the Common Myna (*Acridotheres tristis*). All detections were on Leeward transects (*see* Appendix F, Figure F-9).

Golden Pheasant

There were eight detections of the Golden Pheasant (*Chrysolophus pictus*). All detections were on Windward and HALE transects (*see* Appendix F, Figure F-8).

Gray Francolin

There was a single detection of the Gray Francolin (*Francolinus pondicerianus*). The detection was in the Kula Region (*see* Appendix F, Figure F-8).

House Finch

There were 377 detections of the House Finch (*Carpodacus mexicanus*), the species occurred at 20% of the stations surveyed. The majority of the detections were on Leeward and Kula transects; with only five in the Windward Region and no detections in HALE (*see* Appendix F, Figure F-10). All density estimates are less than one bird per hectare (Table 16). We estimated an abundance of 4,596 ± 878 birds in the 14,600 ha inference area.

Table 16. Density (birds/ha) and abundance estimates of House Finch by region during the 2017 East Maui landbird survey and previous 2011 or 2012 surveys. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Windward	2011	point estimate with SE	0.01 ± 0.01	39–191
	2011	95% confidence interval	0.01–0.03	96 ± 40
	2017	point estimate with SE	0.01 ± 0.01	31–241
	2017	95% confidence interval	0.01–0.04	97 ± 61
HALE	2012	point estimate with SE	0.004 ± 0.004	12 ± 12
	2012	95% confidence interval	0.001–0.02	2–44
	2017	point estimate with SE	0	0
Kula	2017	95% confidence interval	0.74 ± 0.17	1,762 ± 413
	2017	point estimate with SE	0.46–1.12	1,102–2,677
Leeward	2017	95% confidence interval	0.94 ± 0.18	2,435 ± 472
	2017	point estimate with SE	0.65–1.31	1,689–3,389
Total	2011	95% confidence interval	0.01 ± .004	187 ± 73
	2011	point estimate with SE	0.01–0.02	77–362
	2017	95% confidence interval	0.31 ± 0.06	4,596 ± 878
	2017	point estimate with SE	0.21–0.44	3,115–6,451

Hwamei

There were 72 detections of the Hwamei (Melodious Laughing-Thrush; *Garrulax canorus*). The species was detected in all four regions at 9% of the stations sampled. Occurrence was highest in the Windward and HALE Regions, below 1,300 m elevation, but it was also detected near 2,000 m in the Windward Region (*see* Appendix F, Figure F-13).

Japanese Bush-Warbler

Japanese Bush-Warblers (*Horornis diphone*) were widely distributed and occurred at 79% of the stations sampled (*see* Appendix F, Figure F-11). The species was commonly detected in all four regions. We estimated an overall density of 2.27 ± 0.09 birds/ha and an abundance of 33,168 ± 1,357 individuals in the 14,600 ha inference area. Densities were highest within the Windward Region where we estimated 3.80 ± 0.15 birds/ha (Table 17).

Table 17. Density (birds/ha) and abundance estimates of Japanese Bush-Warblers by region during the 2017 East Maui landbird survey and previous 2011 or 2012 survey. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Windward	2011	point estimate with SE	3.30 ± 0.14	22,105 ± 946
	2011	95% confidence interval	3.03–3.59	20,291–24,032
	2017	point estimate with SE	3.80 ± 0.15	25,472 ± 1,014
	2017	95% confidence interval	3.51–4.09	23,497–27,431
HALE	2012	point estimate with SE	2.33 ± 0.123	6,800 ± 359
	2012	95% confidence interval	2.08–2.56	6,087–7,483
	2017	point estimate with SE	2.44 ± 0.16	7,139 ± 476
	2017	95% confidence interval	2.13–2.77	6,226–8,112
Kula	2017	point estimate with SE	0.31 ± 0.08	738 ± 189
	2017	95% confidence interval	0.17–0.48	407–1,140
Leeward	2017	point estimate with SE	0.82 ± 0.12	2,119 ± 309
	2017	95% confidence interval	0.58–1.06	1,507–2,734
Total	2011	point estimate with SE	3.12 ± 0.12	45,593 ± 1,755
	2011	95% confidence interval	2.89–3.36	42,238–49,076
	2017	point estimate with SE	2.27 ± 0.09	33,168 ± 1,357
	2017	95% confidence interval	2.09–2.45	30,562–35,791

Japanese White-eye

The Japanese White-eye (*Zosterops japonicas*) was widely distributed in all four regions, occurring at 75% of the stations sampled (*see* Appendix F, Figure F-12). Overall density was 8.74 ± 0.45 birds/ha with an abundance of 127,560 ± 6,544 individuals in the 14,600 ha inference area. Density was highest in the Leeward Region with 9.27 ± 0.97 birds/ha (Table 18).

Table 18. Density (birds/ha) and abundance estimates of the Japanese White-eye in each region during the 2017 East Maui landbird survey and previous 2011 or 2012 survey. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Windward	2011	point estimate with SE	7.89 ± 0.42	52,849 ± 2,827
	2011	95% confidence interval	7.09–8.72	47,538–58,437
	2017	point estimate with SE	8.33 ± 0.56	55,823 ± 3,774
	2017	95% confidence interval	7.30–9.46	48,946–63,414
HALE	2012	point estimate with SE	10.87 ± 0.93	31,779 ± 2,714
	2012	95% confidence interval	9.20–12.82	26,899–37,487
	2017	point estimate with SE	8.83 ± 0.77	25,806 ± 2,240
	2017	95% confidence interval	7.33–10.42	21,424–30,470
Kula	2017	point estimate with SE	8.60 ± 1.06	20,556 ± 2,539
	2017	95% confidence interval	6.58–10.78	15,723–25,769
Leeward	2017	point estimate with SE	9.27 ± 0.97	23,957 ± 2,518
	2017	95% confidence interval	7.47–11.31	19,301–29,224
Total	2011	point estimate with SE	8.38 ± 0.46	122,320 ± 6,715
	2011	95% confidence interval	7.55–9.29	110,200–135,660
	2017	point estimate with SE	8.74 ± 0.45	127,560 ± 6,544
	2017	95% confidence interval	7.84–9.62	114,520–140,460

Mourning Dove

There were 21 detections of the Mourning Dove (*Zenaida macroura*) and it occurred at 4% of the stations sampled. All of the detections were on Leeward and Kula transects (*see* Appendix F, Figure F-14). The highest occurrence was on Transects 46 and 47 near Ulupalakua Ranch.

Northern Cardinal

There were 40 detections of the Northern Cardinal (*Cardinalis cardinalis*). The species occurred at 6% of the stations sampled, and was only detected in Leeward, Kula, and lower elevation Windward Region transects (*see* Appendix F, Figure F-14). The species was detected incidentally at approximately 950 m elevation near Transect 17 in HALE.

Northern Mockingbird

There were 40 detections of the Northern Mockingbird (*Mimus polyglottos*). The species occurred at 6% of the stations sampled. The species was commonly detected on Leeward transects, was scarce on Kula transects, and was absent from wet Windward and HALE transects (*see* Appendix F, Figure F-14).

Red-billed Leiothrix

The Red-billed Leiothrix (*Leiothrix lutea*) was common and widely distributed, occurring at 73% of the stations sampled and averaging 1.8 BPS. (*see* Appendix F, Figure F-15). Overall density was 2.22 ± 0.15 birds/ha, which equaled an abundance of 32,374 ± 2,133 individuals in the 14,600 ha inference area. Density was highest within HALE, with an estimated density of 2.94 ± 0.23 birds/ha (Table 19). Densities were lowest in the drier Leeward Region (Table 19).

Table 19. Density (birds/ha) and abundance estimates of the Red-billed Leiothrix in each region during the 2017 East Maui landbird survey and previous 2011 or 2012 survey. The first row is for the point estimate with SE while the second row presents the 95% confidence interval.

Region	Year	Measurement	Density	Abundance
Windward	2011	point estimate with SE	2.02 ± 0.14	13,548 ± 917
	2011	95% confidence interval	1.77–2.29	11,869–15,347
	2017	point estimate with SE	2.60 ± 0.20	17,393 ± 1,329
	2017	95% confidence interval	2.24–3.03	15,041–20,290
HALE	2012	point estimate with SE	3.38 ± 0.27	9,871 ± 785
	2012	95% confidence interval	2.87–3.92	8,393–11,460
	2017	point estimate with SE	2.94 ± 0.23	8,592 ± 671
	2017	95% confidence interval	2.54–3.41	7,429–9,985
Kula	2017	point estimate with SE	2.17 ± 0.37	5,195 ± 879
	2017	95% confidence interval	1.53–2.97	3,669–7,092
Leeward	2017	point estimate with SE	0.78 ± 0.14	2,008 ± 371
	2017	95% confidence interval	0.50–1.06	1,294–2,744
Total	2011	point estimate with SE	2.26 ± 0.15	32,980 ± 2,170
	2011	95% confidence interval	1.99–2.58	29,001–37,658
	2017	point estimate with SE	2.22 ± 0.15	32,374 ± 2,133
	2017	95% confidence interval	1.96–2.52	28,641–36,792

Ring-necked Pheasant

There were 255 detections of the Ring-necked Pheasant (*Phasianus colchicus*), occurring at 20% of stations and averaging 0.3 BPS. This gamebird was common on Leeward and Kula transects where it was detected in open shrubland, and scarce in the Windward Region (*see* Appendix F, Figure F-16). The species was absent from the dense wet and mesic forests of HALE.

Scaly-breasted Munia

There were 97 detections of the Scaly-breasted Munia (*Lonchura punctulata*). The species occurred at 6% of stations and was restricted to grass-dominated landscapes of the Leeward and Kula Regions,

with a particularly high occurrence on Transects 39–41 (*see* Appendix F, Figure F-17). The species was not detected in the Windward and HALE Regions.

Sky Lark

There were 154 detections of the Sky Lark (*Alauda arvensis*) and the species occurred at 10% of stations. All of the detections were in open grassland habitats in the Leeward and Kula Regions (*see* Appendix F, Figure F-18).

Spotted Dove

There were two detections of the Spotted Dove (*Spilopelia chinensis*). There was one detection at the top of Transect 25 in the Leeward Region and one detection near the bottom of Kula Transect 31 (*see* Appendix F, Figure F-8).

Unidentified Birds

Surveyors were unable to identify the calls of some species of birds. There were six detections of an unknown species; primarily on Leeward transects (*see* Appendix F, Figure F-8). Notes from the surveyor indicated that the species may have been chips of a Japanese Bush-Warbler.

Incidentally Observed

Newell's Shearwater

The federally threatened Newell's Shearwater (ʻAʻo; *Puffinus newelli*) were heard calling at night during the week of May 22, 2017, from the Delta Shelter near Transect 16 on the lower plateau in HALE. Calls came from the direction of the Northeast Rift, a steep pali (cliff) rising from the Palikea Stream.

Hawaiian Petrel

Observers heard the federally endangered Hawaiian Petrel (ʻUaʻu; *Pterodroma sandwichensis*) calling at several locations within the HALE, Windward, and Leeward Regions where birds were presumably flying to breeding sites within Haleakalā Crater and in Kahikinui FR. Birds were heard during the night hours when observers were camping at field sites, such as West Camp near the top of Transect 17, the sub-alpine area near the top of Transect 18A, and sites in the Leeward Region closer to the alpine rim of Haleakalā Crater. Observers were at these sites periodically in April through May, 2017.

Bioacoustic Sampling

Songmeters were deployed and collected opportunistically during the 2017 survey effort in HALE. A combination of four units were deployed at eight different locations (Table 20; Figure 10). We collected 2,147 eight-minute files over 116 sample days, totaling 17,176 minutes, or approximately 286 hours of audio recordings. Recordings were sorted and data will be presented in supplemental material at a later date.

Table 20. Songmeter locations and metadata from deployments within HALE during the 2017 East Maui landbird survey.

Location	ID	File Prefix	Dates	Files	Sample Days	Total Minutes
Delta Camp	1D	S4A02890	May 24–25, 2017	9	2	72
Palikea	1B	S4A0298	April 7–14, 2017	84	8	672
T10 ST4	2A	HALE-2017	Feb 23–May 17, 2017	1,243	84	9,944
T16 ST8	1A	S4A02890	March 20–27, 2017	64	8	512
T17 ST17	3A	S4A0298	Mar 15–May 23, 2017	507	70	4,056
T17 ST3	3C	S4A0298	May 24–25, 2017	18	2	144
T18a ST10	4A	S4A03005	June 22–July 15, 2017	188	24	1,504
T18a ST4	3B	S4A03005	June 27–29, 2017	34	3	272
Grand Total				**2,147**	**116**	**17,176**

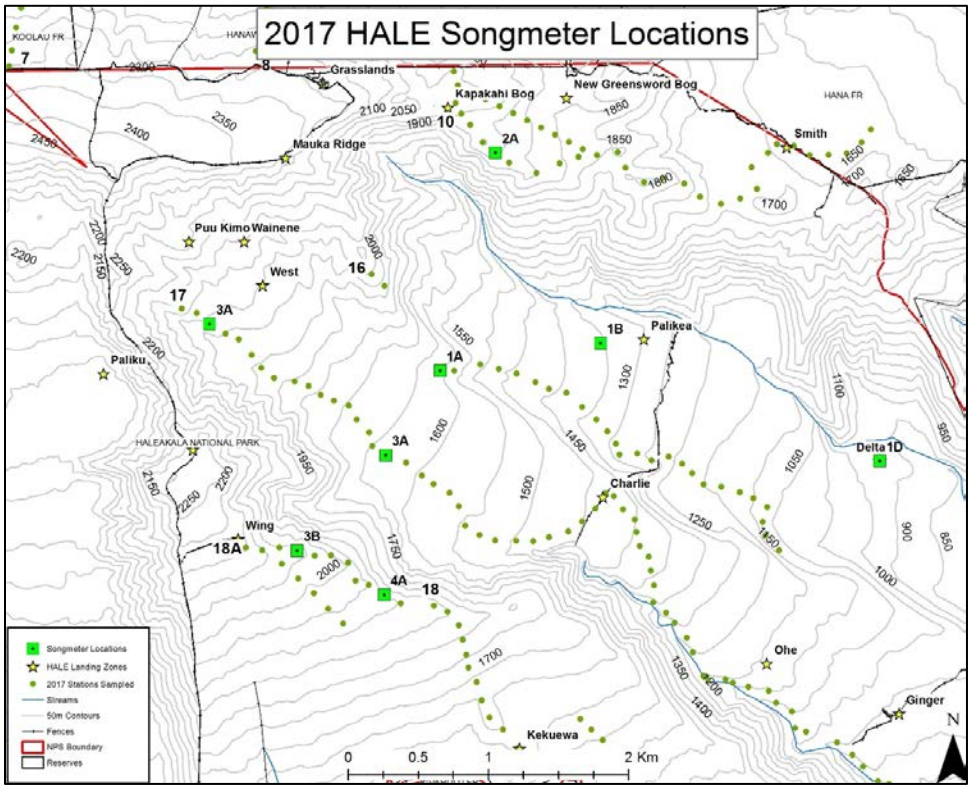


Figure 10. Location of SM4 Song Meter audio recording units deployed during the 2017 East Maui landbird survey.

Habitat

Canopy Composition

We sampled 121 stations for canopy composition in HALE, recording the most common tree species within the 50-m radius plot at each station (Table 21). ʻŌhiʻa occurred at 93% of the stations surveyed, most commonly with mature ʻōlapa (*Cheirodendron trigynum*) which occurred at 64% of the stations surveyed. The native koa occurred at 25% of the stations surveyed, while the remaining native species occurred at less than 5% of the stations surveyed (Table 21). The invasive strawberry guava (*Psidium cattleainum*) was dominant at 13% of the stations surveyed below 1,000 m elevation. The invasive Australian tree fern (*Cyathea australis*) occurred at 3% of the stations sampled, at approximately 800 m elevation. We documented 29 canopy classes of varying levels of dominance, co-dominance, and sub-dominance of tree species (Table 22). Of these stations surveyed, 89% had a closed canopy–with most crowns interlocking (> 60% cover). The remaining 11% of the stations surveyed had an open canopy of some or no interlocking crowns (25–60% cover). We documented tree heights at 119 stations. Trees in the 5–10 m range were the most commonly recorded, occurring at 56% of stations surveyed. We documented trees taller than 10 m at 39.5% of stations surveyed, while trees less than 5 m occurred at 5% of stations surveyed.

Table 21. Canopy tree species recorded at 121 landbird monitoring stations in HALE (50-m radius plot).

Common Name	Scientific Name	% Stations Sampled	Class	Abbreviation
ʻōhiʻa	*Metrosideros polymorpha*	93.4	native tree	Me
ʻōlapa	*Cheirodendron trigynum*	63.6	native tree	Ch
koa	*Acacia koa*	24.8	native tree	Ac
strawberry guava	*Psidium cattleainum*	13.2	exotic tree	Ps
hapuʻu	*Cibotium glaucum*	5.0	native tree fern	Tf
kōlea	*Myrsine* spp.	2.5	native tree/shrub	Myr
ʻolomea	*Perrottetia sandwicensis*	2.5	native tree/shrub	Olo
Australian tree fern	*Cyathea australis*	2.5	exotic tree fern	Atf
pilo	*Coprosma* spp.	1.7	native tree/shrub	Pilo
alani	*Melicope anisata*	0.8	native tree/shrub	Alani
kāwaʻu	*Ilex anomala*	0.8	native tree/shrub	Ilex
native shrubs	Mixed native shrubs >2.5 m	0.8	native shrubs	Ns
native ferns	Mixed native ferns >2.5 m	0.8	native ferns	Nf
exotic trees	Mixed non-native trees	0.8	exotic trees	Xt

Table 22. Canopy composition classes documented at 121 landbird monitoring stations in HALE (50-m radius plot). The species listed first is the most dominant, co-dominant species are separated by a

hyphen, and sub-dominant species are separated by commas (Jacobi 1989). Vegetation codes of dominant canopy species are shown in Table 21, and for understory composition in Table 23.

Canopy composition	Station Count	%
Me, Ch	46	38.02
Me	33	27.27
Me, Ch, Ac	6	4.96
Me, Ac, Ch	5	4.13
Me, Ch, Myr	3	2.48
Ps, Ac	3	2.48
Ac, Ch, Me	2	1.65
Me, Ch, Pilo	2	1.65
Ac, Ch, Olo	1	0.83
Ac-Me, Ch	1	0.83
Ac-Me, Ch, Ps	1	0.83
Me, Alani, Ch	1	0.83
Me, Ch, Ac, Xt	1	0.83
Me, Ch, Ilex	1	0.83
Me, Ch, Tf	1	0.83
Me, Myr	1	0.83
Me, Ns, Nf	1	0.83
Me, Ps, Ch, Me	1	0.83
Ps	1	0.83
Ps, Ac, Ch	1	0.83
Ps, Ac, Me, Ch, Atf	1	0.83
Ps, Ac, Me, Tf	1	0.83
Ps, Ac, Atf	1	0.83
Ps, Ch, Ac, Me	1	0.83
Ps, Ch, Olo, Ac, Me	1	0.83
Ps, Me, Ac, Ch	1	0.83
Ps, Me, Ac, Olo	1	0.83
Ps, Me, Ac, Tf, Atf	1	0.83
Ps, Me, Ac, Tf	1	0.83
Grand Total	**121**	**100.00**

Understory Composition

Understory composition was documented at 120 stations, only within the HALE Region. Species of plants and understory characteristics were lumped into broader categories such as native shrubs, native ferns, introduced ferns, bare ground, etc. (Table 23). A total of 46 combinations of understory classes were documented (Table 24). The combination of native ferns, native shrubs, and native mosses (pooled group including native and non-native mosses and liverworts) was the most common composition class recorded and ranged throughout the entire sampling area (700–2,100 m elevation, occurring at 26% of the stations surveyed (Table 24). The remaining classes each occurred at less than 10% of the stations sampled (Table 24). The most common species in the native shrub class were *Vaccinium calycinum*, *Broussaisia arguta*, and *Leptecophylla tameiameae*. The most common native ferns were *Dicranopterus linearis*, *Diplazium sandwichianum*, and *Sadleria* spp. Bare ground was common in areas disturbed by feral pigs and Transects 16 and 17 in HALE, and in lower elevation areas dominated by strawberry guava. Invasive species *Psidium cattleainum*, *Clidemia hirta*, and *Hedychium gardnerianum* were predominantly recorded at elevations below 1,100 m.

Sign of pigs was documented above the cross-fence near 1,200 m elevation and above the cross-fence near 800 m. The evidence indicated that there were breaches in both fences and ingress had occurred in the higher units of Kīpahulu Valley. Furthermore, pig sign was documented on Transects 18 and 18A in Manawainui. Goats were heard in the Kaukau‘ai Stream gulch near the bottom of Transect 17.

Table 23. Understory classes and species documented at HALE landbird monitoring stations (50-m radius plot).

Common Name	Scientific Name	Class	Abbr.
ative shrubs	–	native shrubs	Ns
native ferns	–	native ferns	Nf
native mosses	–	native mosses	Nm
‘ōhelo	*Vaccinium dentatum*	native shrub	Ns
kanawao	*Broussaisia arguta*	native shrub	Ns
pūkiawe	*Leptecophylla tameiameae*	native shrub	Ns
‘uluhe	*Dicranopterus linearis*	native fern	Nf
‘ākala	*Rubus hawaiensis*	native shrub	Ns
exotic shrubs	–	exotic shrub	Xs
koster's curse	*Clidemia hirta*	exotic shrub	Xs
native grasses	*Deschampsia spp.*	native grasses	Ng
bare ground	–	bare ground	Bg

Table 23 (continued). Understory classes and species documented at HALE landbird monitoring stations (50-m radius plot).

Common Name	Scientific Name	Class	Abbr.
lāukahi nunui	*Elaphoglossum spp.*	native shrub	Ns
ʻalaʻala spp.	*Peperomia* spp.	native shrub	Ns
native sedges	–	native sedges	Nsed
kahili ginger	*Hedychium gardnerianum*	exotic shrub	Xs
poholi	*Diplazium sandwichianum*	native fern	Nf
hāhā	*Cyanea* spp.	native shrub	Ns
exotic grasses	–	exotic grass	Xg
native vines	–	native vines	Nv
alani	*Melicope* spp.	native shrub	Ns
manono	*Hedyotus terminalis*	native vine	Nv
māmaki	*Pipturus albidus*	native shrub	Ns
ʻamaʻu	*Sadleria* spp.	native fern	Nf
āle	*Plantago pachyphylla*	native shrub	Ns
greensword	*Argyroxiphium virescens*	native shrub	Ns
lobelia	*Lobelia gloria-montis*	native shrub	Ns
lobelia	*Clermontia* spp.	native shrub	Ns
maile	*Alyxia oliviformis*	native vine	Nv
paʻiniu	*Astelia menziesiana*	native shrub	Ns
glory-bush	*Tibouchina* spp.	exotic shrub	Xs
thimbleberry	*Rubus rosifolius*	exotic shrub	Xs

Table 24. Frequency of understory composition classes recorded at landbird monitoring stations in HALE in 2017. Abbreviations are shown in Table 23.

Understory Class	Station Count	%	Understory Class	Station Count	%
Nf, Ns	31	25.83	Nf, Nm, Ns, Bg	1	0.83
Ns, Nf	10	8.33	Nf, Ns, Bg, Nm	1	0.83
Ns, Nf, Nm	10	8.33	Nf, Ns, Bg, Xg	1	0.83
Nf, Ns, Nm	7	5.83	Nf, Tf, Ns, Bg, Xs	1	0.83
Nf, Ns, Bg	6	5.00	Nf, Xg, Ns	1	0.83
Nf, Bg, Ns	3	2.50	Ng, Ns, Nf	1	0.83
Bg, Ns	2	1.67	Ns, Bg, Nf	1	0.83
Bg, Xs	2	1.67	Ns, Bg, Nm	1	0.83
Bg, Xs, Nf	2	1.67	Ns, Nf, Xg	1	0.83
Bg, Xs, Nf, Ns	2	1.67	Ns, Ng, Bg, Nf	1	0.83
Nf	2	1.67	Ns, Ng, Nf	1	0.83
Nf, Ns, Nm, Bg	2	1.67	Ns, Nsed, Nf, Bg	1	0.83
Nf, Ns, Xs	2	1.67	Ns, Xs, Nf	1	0.83
Nf, Xs, Ns	2	1.67	Nsed, Ng, Nf	1	0.83
Ng, Ns, Nf, Bg	2	1.67	Nsed, Nf, Ns	1	0.83
Ns	2	1.67	Xs	1	0.83
Ns, Nf, Nm, Bg	2	1.67	Xs, Bg	1	0.83
Ns, Nm, Nf	2	1.67	Xs, Nf, Bg	1	0.83
Xs, Bg, Nf, Ns	2	1.67	Xs, Nf, Bg, Ns	1	0.83
Bg, Nf, Ns	1	0.83	Xs, Nf, Bg, Xg	1	0.83
Bg, Nm, Nf	1	0.83	Xs, Nf, Ns	1	0.83
Bg, Ns, Nf	1	0.83	Xs, Nf, Ns, Bg	1	0.83
Nf, Nm, Ns	1	0.83	Xs, Ns, Nf	1	0.83

Discussion

Landbirds

The 2017 landbird survey marks the first interagency effort to collaboratively survey the East Maui transects since they were initially established during the 1980 Hawai‘i Forest Bird Survey (Scott et al. 1986). This allowed us to estimate the global population estimate and trends of Kiwikiu, ‘Ākohekohe, and Maui ‘Alauahio. Abundance of Kiwikiu was alarmingly low, with an estimated 157 ± 67 (95% CI 44—312) individuals remaining in the wild. Abundance estimates for this species have always been low (the highest was 1,137 ± 271 birds in 1996; this study) and have had wide variance due to low detections rates. Even so, the 2017 density estimate was the lowest from any range-wide survey conducted for the species. We detected a significant decrease in densities within HALE and mean population abundance estimates appear to be markedly lower in the last 10 years than in previous decades. In 1980 and 2001, there were estimated to be fewer than 835 and 901 individuals (upper 95% CI), respectively. In these same years, the lower-bound confidence intervals fell just below 300 (261 in 1980 and 280 in 2001). The current upper-bound value in 2017 was estimated at 312 and is highly concerning for the long-term viability of the species. Under current population trajectories, Mounce et al. (2018) estimated the species is unlikely to persist beyond 25 years.

Kiwikiu’s scarcity is reflective of Hawai‘i’s history of imperiled honeycreepers and bears similarities to the current catastrophic decline of honeycreeper populations on Kaua‘i Island (Paxton et al. 2016). As a result of habitat degradation, non-native competitors, mammalian depredation, and avian malaria, abundances of four endemic honeycreeper species on Kaua‘i have declined approximately 90% over the last 25 years (Paxton et al. 2016). Since 1980, the majority of Kiwikiu detections have been well above 1,500 m elevation, traditionally thought to be fairly safe from disease. Native Hawaiian bird species struggle to persist in a “climatic space” as higher mean global temperatures push the cold-intolerant disease vector, the Southern House Mosquito (*Culex quinquefasciatus*), higher into native forest. Several studies have found mosquito occurrence and disease prevalence to be reduced above 1,500 m in elevation (van Riper et al. 1986, Atkinson and LaPointe 2009, LaPointe et al. 2010, Atkinson et al. 2014) and avian malaria has a relatively strict thermal threshold below which it cannot successfully reproduce (LaPointe et al. 2010). The last population assessment on Maui was over 15 years ago and favorable fluctuations in environmental conditions (e.g., warmer temperatures) may allow vectors to periodically intrude into higher elevations (Atkinson et al. 2014). At lower elevations where mosquitoes and the malaria parasite may persist year-round, avian malaria may prevent juvenile and adult dispersal and movement. We lack a thorough understanding of both how far and often Kiwikiu move between high and low elevations, and information on the use of microhabitats that may expose them to avian malaria. The warming trend at higher elevations may be widening the ecological space available for long-term persistence of vectors and disease that may affect Kiwikiu and other similar species in their core ranges, or movements may be exposing them to malaria (Fortini et al. 2015). Dependent on high adult survivorship and limited by low fecundity, Kiwikiu may have difficulty rebounding from heavy loss of breeding adults (Mounce et al. 2018). Regardless, the declines observed in this study were largely a result of loss of lower elevation habitat throughout the Kiwikiu range and suggests avian malaria is the most likely reason for such losses, despite our inability to understand the specific mechanisms for how or where this is happening.

Additional factors are also likely contributing to low Kiwikiu densities, but these have been relatively consistent over the last several decades. In higher elevations, birds still suffer from rat, cat, and mongoose depredation (Atkinson 1977, Tomich 1986). Two species of rats (*Rattus exulans* and *R. rattus*) are common and widespread in ʻōhiʻa-dominated rainforest within the HALE and the Windward Regions (Stone et al. 1985, Sugihara 1997, Bailey 2007). Stone et al. (1985) captured over 1,000 rats in only three months of trapping in Kīpahulu Valley (HALE), and they observed moderate rates of depredation on quail eggs in artificial nests. In Hawaiʻi Volcanoes National Park, Banko et al. (2019) observed rats raiding nests with eggs, and in some cases rats targeted breeding adults. Rats also consume a considerable amount of invertebrates and plant material and thus have the potential to compete for foraging resources with native landbirds (Sugihara 1997, Shiels and Drake 2011).

Kiwikiu formerly occupied a wide range of habitats, and subfossils have been found in dry forests and lowland habitat– quite different from their current wet or mesic forest habitats (Olson and James 1982). Henshaw (1902) and Perkins (1903) reported that the species showed a preference for koa as a foraging substrate. In our surveys, Kiwikiu were not detected in koa-dominated or co-dominated forests on East Maui. The current range of Kiwikiu is in primarily undisturbed ʻōhiʻa-dominated rainforests in the HALE and Windward Regions. Kiwikiu were detected in transitional habitat between wet ʻōhiʻa-dominated and mesic ʻōhiʻa–koa forest in western TNC's Waikamoi Preserve, but were not observed in similar habitat in Manawainui in HALE. High rainfall may limit koa to elevations below 1,100 m in Kīpahulu Valley (P. J. Hart and S. W. Judge, pers. obs.). Kiwikiu that attempt to disperse into this habitat may be exposed to avian malaria and an understory that is dominated by weedy species such as *Clidemia hirta* and *Psidium cattleainum*. Although native plant species predominate Kiwikiu's range, the current habitat may be suboptimal for this specialized forager. Furthermore, heavy rainfall, common in much of its current range, has been shown to reduce nest success (Becker et al. 2010).

Although not at such perilously low numbers as Kiwikiu, the population trajectory of ʻĀkohekohe should also warrant large concern. We estimated an abundance of 1,768 ± 315 (95% CI 1,193–2,411) individuals. Previous density and abundance estimates have varied throughout the history of these surveys and the highest estimate was 12,459 ± 1,481 individuals in 2000. Abundance estimates have declined precipitously after 2000, and current density is the lowest ever estimated for the species. There are no clear factors that led to this decline, although two threats –disease and stochasticity due to restricted ranges and small population size– may be most likely. First, similar to Kiwikiu, avian malaria may be occurring periodically within the known range of this species, or ʻĀkohekohe movements may be subjecting adults and juveniles to avian malaria in areas that were more recently free of this disease (Wang 2015). The clear loss of lower elevation range from areas that were occupied 15—20 years prior to 2017 for both Kiwikiu and ʻĀkohekohe strongly suggests that avian malaria is affecting these species. Second, ʻĀkohekohe may be subject to more dramatic fluctuations because they have the smallest range of any native landbird on Maui (2,363 ha). This species was not recorded below 1,520 m in 2017 and most observations were above 1,620 m. Camp et al. (2009) reported a range of 5,990 ha. In addition, the ʻōhiʻa forest the ʻĀkohekohe depend on generally stops in sub-alpine habitat above 2,100 m, leaving a narrow strip at just over 500 m in elevation of suitable, relatively disease-free habitat for the species. This narrow range leaves the species more vulnerable

to disease and environmentally stochastic events such as hurricanes. Moreover, low abundance increases the species' risk and susceptibility to demographic stochasticity. We observed a patchiness in ʻĀkohekohe distribution within our estimated range in 2017. The majority of the detections occurred in three distinct areas on East Maui: in Manawainui within HALE, on Transects 8–10 in Hanawī NAR and the Northeast Rift, and in the western portion of TNC's Waikamoi Preserve. Ākohekohe rely on ʻōhiʻa for foraging resources and fruits and flowers in the understory (Scott et al. 1986) and juveniles may travel long distances in search of those resources, including into lower elevations where mosquitoes and avian malaria may exist (Wang 2015).

Estimates of the Maui ʻAlauahio were higher than the other two Maui endemics, but their density and population size have similarly declined. We estimated 99,060 ± 9,510 individuals in their range. The species was widespread in the HALE, Kula, and Windward Regions, but restricted to elevations above 1,200 m. The dramatic difference in densities above and below 1,200 m elevation was also documented by Scott et al. (1986) and is likely due to a susceptibility to avian malaria (Atkinson et al. 2001), and may also be indicative of differences in habitat suitability or increased threats at lower elevation. The species used to be common on Lānaʻi Island and West Maui, but is now extirpated (Perkins 1903, Munro 1944). On East Maui, trends were stable in the 1990s and early 2000s (Camp et al. 2009a). Previous estimates hovered near 200,000 birds, but overall abundance appears to have dropped by approximately 50% in the last 17 years.

The much higher densities of Maui ʻAlauahio compared to Ākohekohe and Kiwikiu might be explained by its generalist diet, higher fecundity, and ability to occupy a variety of habitats including non-native forest and shrubland (e.g., Kula Region), as well as native wet-mesic ʻōhiʻa forests (Perkins 1903, Scott el al. 1986). Additionally, this species occupies much smaller home ranges (less than 10% smaller than Kiwikiu; Warren et al. 2015) that incorporates multiple individuals including more than one generation of offspring, a behavior that is unique among Hawaiian honeycreepers (Baker and Baker 2000). Greater productivity and a generalist diet may allow the species to overcome the short-term impacts of disease through dispersal from malaria-free habitat. The species may offset disease mortality through tolerance or resistance to malaria (Foster et al. 2007); and thus could explain the continued persistence in lower elevations relative to Kiwikiu and ʻĀkohekohe. However, a population decline of 50% over the last two decades suggests the long-term survival of the species is questionable if avian malaria continues to spread upward in elevation.

The relative abundance of ʻApapane may be altering the interspecies dynamics of honeycreepers in wet ʻōhiʻa-dominated forests. The species is flourishing in the HALE and Windward Regions, likely as a result of the abundance of ʻōhiʻa that provides ample foraging and nesting resources. ʻApapane were comparatively less abundant in the more open and disturbed habitats of the Leeward Region and non-native forests of Kula, but were still the most abundant species in those regions. A gregarious species, ʻApapane form small to large flocks as a defense to larger and more aggressive honeycreepers, as well as social coordination for finding roosting and foraging sites (Ward 1964, Pimm and Pimm 1982). A pattern that may be emerging is that the bird community assemblage dependent on ʻōhiʻa, often territorial around blossoming trees, are disappearing leaving only smaller, more gregarious species. The loss of the Bishop's ʻOʻo (*Moho bishopi*; Perkins 1903), Maui ʻĀkepa,

Maui Nukupu‘u (Reynolds and Snetsinger 2001, Judge et al. 2013), and Po‘ouli (Groombridge 2009), and decline of ‘Ākohekohe may all be interacting to affect foraging hierarchy. However, this is speculative, and it is also possible that other factors could be driving such changes. For example, ‘Apapane have not been investigated for avian malaria tolerance, but Gorresen et al. (2017) reported the species occurred at relatively modest densities at lower elevations on Hawai‘i Island (Reynolds et al. 2003, Spiegel et al. 2006, Gorresen et al. 2017) We did not analyze the long-term trends of ‘Apapane on East Maui, but survey data between 1980 and 2001 suggest an increasing population (Camp et al. 2009a).

‘I‘iwi were relatively common throughout the Kula, HALE, and Windward Regions and were detected at elevations as low as 860 m. The species demonstrated increasing trends in the East Maui inference area and within the Windward Region. The large elevational range of ‘I‘iwi was surprising as the species is extremely vulnerable to avian malaria and rarely detected below 1,500 m (Atkinson et al. 2000, Atkinson and LaPointe 2009). PACN landbird surveys in Hawai‘i Volcanoes National Park did not detect ‘I‘iwi below 1,500 m (Judge et al. 2011), and ‘I’iwi on Kaua‘i Island occur only above 1,000 m (Paxton et al. 2013). We suspect that heavy rainfall and cool weather conditions in Kīpahulu Valley and Windward Region may locally limit the cold-intolerant disease vectors (i.e., *Culex quinquefasciatus*; Aruch et al. 2007) and the development of the malaria parasite (*Plasmodium relictum*; Kokkinn et al. 2012). However, if these lower elevation areas have lower disease prevalence allowing the persistence of ‘I‘iwi, this does not explain the absence of other disease-intolerant species unless there are species-specific microhabitats being used and movements being made that create differential population impacts. There is no clinical evidence that suggests ‘I‘iwi have developed resistance to avian malaria and warming climate trends may push the range of mosquitoes to higher elevations and further endanger this iconic honeycreeper (Fortini et al. 2015, Paxton et al. 2016). Our results in the species’ core range are encouraging and are corroborated by Camp et al. (2009), who reported increases over a 21-year period (1980–2001). However, since the initial HFBS survey, the population density on East Maui has declined 34% between 1980 and 2011 (Paxton et al. 2013).

The Hawai‘i ‘Amakihi commonly occurred throughout the survey area. We estimated an abundance of 77,776 ± 3,694 individuals within the inference area. Densities were highest in the non-native forests of the Kula Region. The East Maui population increased in the 1990s and early 2000s (Camp et al. 2009a). However, we detected a recent declining trend in both the Windward and HALE Regions. The species has demonstrated a tolerance to avian malaria on Hawai‘i Island and can reside at low elevations (e.g., < 200 m) where mosquitoes are abundant (Woodworth et al. 2005, Foster et al. 2007). The recent declines may be explained by habitat degradation (Camp et al. in press) and mammalian predators (Wilson Rankin et al. 2018, Banko et al. 2019). Fortunately, Hawai‘i ‘Amakihi are generalist foragers and occur outside our survey area in a wide variety of habitats (Scott et al. 1986, Camp et al. 2009a). This was the only native species that showed higher densities in the drier and predominately non-native forest of Kula, more than double the density recorded in wet, closed-canopy native forest in the HALE Region.

Updating the ranges of ʻĀkohekohe, ʻIʻiwi, Kiwikiu, and Maui ʻAlauahio was a critical step in determining species abundance. Our estimated ranges were smaller than previously reported, ranging from 39% to 94% of most recent estimates in the last 10 years (Table 25). Our data suggest that while some species' densities may remain stable or even increase in the core of their habitat, there appears to be a community-wide reduction in the distribution of rare and uncommon honeycreepers on East Maui.

Table 25. Current and previously estimated ranges of four honeycreepers on East Maui.

Species	Current Range (ha)	Previous Range (ha)	Percent of Range Decline	Source of Previous Range Estimate
ʻĀkohekohe	2,363	5,990	-61	Camp et al. 2009a
ʻIʻiwi	11,226	13,201	-15	Paxton et al. 2013
Kiwikiu	2,992	4,104	-27	Brinck et al. 2012
Maui ʻAlauahio	9,179	9,800	-6	Camp et al. 2009a

There was a strong representation of non-native passerines in each region surveyed, accounting for nearly half of all detections. However, only three species were common and distributed throughout predominantly native habitat: Japanese White-eye, Japanese Bush-Warbler, and Red-billed Leiothrix. Both the Japanese Bush-Warbler and Red-billed Leiothrix demonstrated increasing trends in the Windward Region. The Japanese White-eye was the second most abundant species in the survey area. The species is a generalist forager and may compete with native landbirds (Foster 2009). There is evidence of a negative correlation of Japanese White-eye populations with that of ʻIʻiwi (Mountainspring and Scott 1985). The Red-billed Leiothrix is also omnivorous and with some diet overlap with native forest birds (Foster 2009). These species are also capable of spreading invasive weeds into undisturbed habitats (Foster and Robinson 2007, Chimera and Drake 2010). Japanese Bush-Warblers were sparsely distributed on East Maui in 1980 (Scott et al. 1986). Since then, the species has spread across the island (Foster 2009) and into native forest. The Hwamei and Northern Cardinal were not common in native habitat, but occurred in native to non-native vegetation transition zones. Both species forage for insects and fruits in the understory and are also capable of dispersing seeds of invasive plants (Foster and Robinson 2007). Northern Cardinals appear to avoid intact ʻōhiʻa forest habitat; as they were regularly detected near habitat transitions zones (e.g., top and bottom of transects). However, they may be expanding into native ʻōhiʻa–koa forest in the Leeward Region.

We observed simultaneous declines in density of Kiwikiu, ʻĀkohekohe, and Maui ʻAlauahio. Overall, there was a substantial reduction in these species' abundance in the past 20 years. These declines suggest landscape-level dynamics that are affecting endemic species, despite more habitat protection (i.e., fencing and ungulate removal) on most of the windward slope. Similar trends were observed on Kauaʻi Island, where populations of native birds are collapsing and may face extinction in the near future (Paxton et al 2016). It is unlikely that any single factor can account for the declines

of native forest birds. The combination of disease, mammalian predators, and habitat degradation may have a cumulative negative effect on avian communities. Species' ranges have also contracted in the last 20 years. From 1980 through the early 2000s Kiwikiu were detected as low as 1,200 m in some places. Using these observations, the species range had previously been estimated at ~5,000 ha (Gorresen et al. 2009). Though challenging to detect in the best of circumstances, the species is now either exceptionally rare at these low elevations or is now restricted to above 1,400 m in a current range of 2,992 ha. A similar pattern was seen in ʻĀkohekohe, but with an even greater reduction in current range.

Monitoring Impilications

The current I&M landbird monitoring protocol employing point-transect distance sampling remains the most appropriate survey method for monitoring multi-species forest bird status and trends (Camp et al. 2011). This method is particularly useful for monitoring bird trends across very large areas, in patchy habitats, dense vegetation, and rugged or hazardous terrain. Monitoring long-term trends requires estimating species' status with low (or no) bias and high precision. This requires survey methods that measure the detection probability to account for the number of birds present but missed and provide measures of precision. As such, this eliminates index-based counts such as the Breeding Bird Survey, Christmas Bird Count and area counts (point count, strip transect and spot mapping) (Camp et al. 2011, Marques et al. 2017). As long as critical distance sampling assumptions are met the method allows for estimating unbiased densities (*see* Buckland et al. 2001 for model assumptions). In general, the point-transect distance sampling surveys employed in Hawaiʻi meet the assumptions, and we avoid estimating densities for species, such as gamebirds and seabirds, that violate model assumptions.

Densities are estimated with relatively good precision. Coefficients of variation for the 2017 densities were <10% for all species except ʻĀkohekohe (17%), House Finch (19%) and Kiwikiu (40%). Within specific regions variability was greater but still generally <20%. For the rare species, producing precise estimates was facilitated through pooling detections from previous surveys to estimate detection probabilities. While distance sampling is pooling robust this procedure can induce a bias if the probability of detecting birds' changes over time due to changes in habitat structure or population size. We minimized bias by including the survey year as a covariate when fitting detection functions.

Other survey methods that account for detection probabilities either require multiple visits or inference is limited to small areas requiring establishing many intensely surveyed study sites throughout the study fame. These methods substantially increasing survey cost and time. Mark-resight methods used in MAPS and BBIRD protocols require lengthy field seasons spanning the breeding season and surveys over three to five years to obtain site- or area-specific level estimates of productivity, survival and incidentally abundance. An additional advantage of maintaining the current point-transect distance sampling protocol is that the detections and density estimates can be directly compared to historical surveys including the original Hawaii Forest Bird Survey from the 1970s and 1980s (Camp et al. 2009b).

There is room for improvement in the current protocol. Brinck et al. (2012) identified that power to detection changes in populations could be increased by conducting repeat visits at each station and conducting more frequent surveys. There is a limitation to how much power can be achieved by conducting repeat visits and Brinck et al. (2012) recommend conducting two or three counts. In Appendix E we showed that evaluating long-term trends from the extremely sparse survey data resulted in explosive variance. Thus we restricted trends to end-point comparisons. Conducting surveys more frequently, e.g. annually, has allowed for evaluating population trends of Palila (*Loxioides bailleui*; Genz et al. 2018) and the native birds at Hakalau Forest National Wildlife Refuge (Camp et al. 2016) on Hawai‘i Island. Annual surveys have also allowed for advanced modeling such as density surface mapping and incorporating demographic vital rates with trends analysis (Camp et al. in preparation).

Conservation and Management Implications – A Call to Action

There are currently three primary threats to native Hawaiian birds in East Maui: disease, depredation, and habitat degradation. Based upon our survey data alone, it is not possible to determine which of these factors or interactions are driving the current decline of the remaining endemic forest birds in Maui. Avian malaria is clearly the most significant long-term threat, as there is broad agreement that malaria will move upward in elevation due to climate change and lead to dramatic declines or the extinction of most native Hawaiian bird species (Fortini et al. 2015, Liao et al. 2015). However, the declines observed over the last several decades in East Maui are occurring in elevations above where avian malaria has been observed, and there are species-specific differences when comparing Maui endemics and more common native species (e.g., ‘Apapane and Hawai‘i ‘Amakihi). Several factors could be interacting to obscure a clear relationship between the upmost elevation ranges of malaria and the differences among species, including: 1) episodic transmission of malaria in mid- or high-elevation forests due to seasonal or annual temperature differences (Samuel et al. 2015), which may occur infrequently but result in large population impacts; 2) microhabitat use and behavioral differences by birds in lower or upper elevation forests that limit or increase their exposure to malaria due to differences in microclimate; or 3) unidentified seasonal or exploratory movements of adult birds and dispersal of juvenile birds that facilitate disease exposure in birds that spend the vast majority of their time in largely malaria-free habitat. The sporadic nature of these factors, logistical difficulty of working in endemic bird habitat in East Maui, and virulence of avian malaria in Hawaiian birds suggest that even extensive research efforts could fail to undercover if one or more of these mechanisms is responsible for the decline in endemic bird species.

Depredation and habitat degradation are also important factors that are likely contributing to native bird declines in East Maui, at times possibly even exceeding the current impact of malaria. It is not currently possible to quantify the extent of these impacts, but native forest habitat has remained relatively intact within the current range of endemic species and depredation is unlikely to have been altered dramatically in the last 30 years, as no new predators have been introduced to East Maui over the last 50+ years. This is not to suggest that these two factors are not critical to bird conservation; but it does imply that they are either not solely responsible for the observed declines or it will be exceedingly difficult to disentangle the relative impacts of each, similar to malaria. For example, suboptimal habitat or food availability may be affecting Kiwikiu productivity or survival in HALE,

where the largest, recent declines have been observed. Similarly, depredation impacts could fluctuate among prey resources and with weather, resulting in lower bird populations well after the greatest direct impact has occurred.

In an ecological context, there is clearly little time remaining to conserve Kiwikiu and ʻĀkohekohe populations. Managers face a myriad of choices on where to focus their limited resources, and must make decisions with insufficient or incomplete information. There is a natural inclination to want to definitively identify causes, costs, and benefits better before proceeding with time-intensive and costly management actions. However, because of the difficulty in conclusively identifying the causal factors for the above-stated reasons, we do not think research actions alone are a prudent next step. We strongly suggest that all future work in East Maui take place in an adaptive context via the implementation of management actions. This will increase our understanding of both how to implement the actions and the potential response of birds; a lack-of-response to management actions will still provide important insights and further the conservation knowledge needed to save these species.

Given this, there are two actions that are most likely to have the greatest beneficial impact to native Hawaiian bird communities in East Maui: landscape control of avian malaria and depredation. Preventing habitat degradation is also critical, but habitat restoration efforts have been in place for decades and we assume that they will continue to occur. Ideally, the landscape control of malaria and depredation would occur simultaneously, but either alone would benefit a variety of native bird species and help managers better understand and target the causes of declines. The most likely route to control malaria is via reducing or eliminating the only vector of this disease in Hawaiʻi, the non-native mosquito *Culex quinquefasciatus*, via sterile male techniques (Liao et al. 2017). Predator control has been tried in various forms in Hawaiʻi, but landscape controls have yet to be implemented in native bird habitats on the main Hawaiian Islands due to their controversial nature. The most likely method to achieve landscape-scale control of rodents and mongooses (*Herpestus javanicus*) is the repeated aerial delivery of diphacinone in core habitat areas of the endemic species (Barun et al. 2011), while feral cats (*Felis catus*) could be controlled through trapping (Nogales et al. 2004, Campbell et al. 2011). Management of feral cat colonies would reduce cat recruitment in forest bird habitat, but could be met with strong public opposition (Wald and Jacobson 2014, Wald et al. 2016). Landscape control of malaria or depredation is controversial, uncertain, and will be expensive; but a growing body of evidence suggests they are also the only two methods that will halt or reverse the long-term decline of native Hawaiian bird communities (Paxton et al. 2018). Other scientists have also concluded that now is the time to act, even in the absence of perfect knowledge (Samuel et al. 2011, Fortini et al. 2015).

Finally, Kiwikiu are of particular concern due to the observation that only 44–312 Kiwikiu still exist in the wild as of 2017, and that they have declined precipitously over the last several decades. Adding to the urgency of this situation is the finding that efforts to propagate Kiwikiu in captivity have had limited and inconsistent success, in part due to the small number of birds in the flock (B. Masuda, pers. comm.). This underscores the urgent need to develop strategies that will immediately increase the viability of this species *in situ*. The Maui Forest Bird Working Group (which includes

MFBRP as well as all land managers and stakeholders across these species' ranges) is currently planning to reintroduce Kiwikiu to the Leeward Region of Maui, starting with Nakula Natural Area Reserve in 2019. The reintroduction will include some Kiwikiu from conservation breeding centers managed by San Diego Zoo Global and translocated wild individuals from the windward slope (Mounce et al. 2018). Since 2013, DOFAW, MFBRP, and the DLNR Plant Extinction Prevention Program have planted more than 200,000 native plants in the Nakula FR and Kahikinui FR (MFBRP unpublished data), in preparation for the reintroduction (Mounce et al. 2018). As the leeward forest regenerates and is restored, the newly reintroduced population of Kiwikiu will hopefully persist and expand in the Leeward Region, thereby increasing both the range and abundance of the species. This effort is a critical need and an excellent example of moving forward with on-the-ground conservation actions in the face of imperfect knowledge, and it is an effort that should be emulated with landscape-scale control techniques for predators and disease.

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Appendix A. 2017 Haleakalā National Park Landbird Monitoring Field Effort Report

Executive Summary

This report summarizes the field methods and survey effort for the 2017 landbird survey within Haleakalā National Park (HALE). This study was conducted under a cooperative agreement between the National Park Service and the University of Hawai‘i at Hilo (UHH), joint agreement H8080090008. Fieldwork preparation and data collection methods were followed as prescribed in the Landbird Vital Sign Monitoring Protocol (Camp et al. 2011) except where noted.

A total of 169 stations on 8 transects (5 legacy and 3 random) were surveyed for landbirds and landbird habitat in Kīpahulu Valley and Manawainui. Surveys began on March 14, 2017 and concluded June 28, 2017. Four primary counters surveyed the stations over 29 calendar days. A total of 4,330 bird detections of 14 different species were recorded within HALE. Each station was surveyed for landbird habitat characteristics.

Introduction

The PACN landbird vital sign monitoring protocol (hereafter Protocol) field season of 2017 was conducted in Haleakalā National Park (HALE). The park was surveyed to estimate species-specific bird abundance, density and distribution, as well as to describe landbird habitat. Training and sampling procedures followed the Protocol (Camp et al. 2011). This report documents the field effort and describes the logistical needs and considerations for future sampling of each unit.

Four primary point counters (Table A-1) conducted the field work, including field preparation, training, data collection, and data management. Joy Tamayose, of HALE Endangered Species Management, provided much expertise in landbird identification and habitat characteristics. Christopher Warren and Laura Berthold from the Maui Forest Bird Recovery Project served as primary counters. Seth Judge, the Project Field Lead, conducted the majority of the data collection and coordinated the field effort. Patrick Hart (Department of Biology, University of Hawai‘i at Hilo) served as the project Principal Investigator and assisted with planning, preparations, and reporting. Richard Camp (USGS-PIERC) assisted with data analysis and reporting, and issues pertaining to the Protocol. HALE Resource Management Chief Stephen Robertson provided logistical assistance. HALE Aviation Manager Timothy Bailey and Woody Mallinson from Vegetation Management assisted with helicopter operations. PACN Inventory and Monitoring Program Director Ryan Monello offered further support with project and permitting needs. Invaluable field assistance was provided by HALE vegetation management personnel, each of whom provided significant effort in establishing transects through dense forests and identifying rare plant species.

Table A-1. List of primary observers for HALE landbird monitoring data collection.

Observer	Observer Code
Seth W. Judge	SWJ
Joy A. Tamayose	JAT
Christopher C. Warren	CCW
Laura K. Berthold	LKB

Methods

Training

Bird Identification

Field ornithologists knowledgeable in the identification of Hawaiian forest birds participated in 20 days of training to learn species- and region-specific bird vocalizations. Identification skills were improved through rigorous training in the field and by practice with Hawaiian bird recordings (Pratt 1996). The field crew studied historical references and bird guides (Perkins 1903, Berger 1981, Pratt et al. 1987).

Distance Measurement Training

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

Habitat Identification

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

Establishing Transects and Stations

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

Transects were marked with blue flagging for ease of navigation by future surveyors. Flag spacing depended on the density of the forest and understory, but typically was placed 5–20 m apart so that the next or previous flag was always visible. Orange flagging was placed approximately 5 and 10 m away from the station to prevent surveyors from accidentally missing the station. Stations were marked with pink and white flagging, and a metal tag with the transect and station number. The method deviated from the Protocol as HALE Resource Management preferred to tie flagging to trees on the transect, rather than stake each station with a pole.

Data Collection

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

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

2017 Field Effort Summary

HALE was surveyed for birds and habitat during the 2017 field season. Five legacy transects and three random transects were surveyed in areas of Kīpahulu Valley, Manawainui, and Northeast Rift (Table A-2). Surveys began on March 23, 2017 and concluded June 28, 2017. In total, four primary point counters required 29 survey days to conduct sampling. Travel to field sites was occasionally hampered by weather, helicopter availability, and logistical concerns. Teams were able to survey over a total of six weeks of field work. In total, 169 stations (Table A-2) were surveyed for landbirds and habitat characteristics. A total of 4,330 birds of 14 species were detected in the survey.

HALE vegetation management personnel had flagged and "brushed" each transect prior to the arrival of the landbird monitoring team. Field efforts were scheduled according to helicopter readiness, weather considerations, and observer availability. Field operations were based out of NPS built

shelters in the restricted access Scientific Reserve. Work load was quantified by "survey days," or the number of primary point counters available per day.

Table A-2. Transects and number of stations surveyed during the 2017 landbird survey within HALE.

Transect #	*# of Stations Surveyed*
10	28
11R	5
16	28
17	70
18	12
18A	13
7R	3
8R	10
Total	**169**

Helicopter Operations

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

Transect Descriptions and Field Logistics

Transect Preparation

In 2012, the HALE vegetation management crew flagged and brushed all of the landbird monitoring legacy transects. As a result, less preparation was needed in 2017. Transects 10 and the upper portion of 16 were accessed by crew in February 2017 to flag and brush. HALE-Resources Management

(HALE-RM) also brushed the lowest portion of Transect 17. During surveys, flagging was added or replaced while surveyors hiked along transects.

Transect 10

Legacy Transect 10 traverses the Northeast Rift and the montane bogs near the Northeastern boundary of HALE. The transect is 28 stations long, station zero is the highest point (2,100 m) and the transect ends at station 27 (1,640 m; Figure A-1). The transect crosses the HALE boundary near station 23 and stations 24–27 fall inside the Hāna Forest Reserve. The transect can be accessed from the Smith Camp or Grasslands shelter. On May 15, surveyors Judge and Berthold hiked to the Grasslands shelter because Windward helicopters were being repaired. The hike involved crossing Haleakalā Crater and hiking up to the northeast crater rim via an old MFBRP and HALE RM trail (Crystal Caves trail). Permission and exact locations of the access trail should be requested from staff in the future. The Grasslands shelter was seldom used and in poor condition so future surveyors may prefer to tent camp. Judge and Berthold based field operations from the shelter for two nights and then they surveyed down the transect and continued to the Smith shelter. On May 16, they surveyed the upper portion of Transect 10 (stations 0–7) and returned to Grasslands. On May 17, they surveyed random Transect 8 (Figure A-1). On May 18, they resurveyed stations 0–7 and then split the effort of surveying stations 8–19. They then continued to the Smith shelter. The next morning, they surveyed stations 19–27 and then were picked up by helicopter at 2pm. Stations 20–27 are on State land and DOFAW managers should be notified before surveys.

Transect 16

Legacy Transect 16 traverses the Lower Plateau of Kīpahulu Valley. The transect is 43 stations long, it begins at Station zero (1,980 m) and ends at Station 42 (860 m; Figure A-1). Field operations were based from Mauka Ridge and out of the Palikea and Delta Camps. On April 4, surveyors Tamayose and secondary Nick Agorastos (Hawai‘i Island - NARS) were shuttled via helicopter from the Windward Heli-base to Mauka Ridge, an open area approximately 500 m from Station zero. They had a difficult time navigating to the transect and thus were only able to survey Stations zero and one. They continued all the way to Palikea Camp, where gear was left for them via a sling load drop. Surveyors can access the highest stations via the “MAPA trail”, a challenging uphill hike from Palikea Camp. On April 5, Tamayose and Agarostos hiked along the fence from Palikea to access Station 14, they surveyed uphill from there to station 8. On April 6, they hiked along the fence again to Station 15 and surveyed down to Station 21 where they saw weeds on the transect. Instead of hiking further they opted to turn around and return to Palikea Camp so they would not track weeds uphill. The surveyors were extracted via helicopter on the morning of April 8.

Tamayose and secondary point counter Carl Scharwz (HALE-RM) returned to survey Transect 16 during the week of May 22. On May 22, they were shuttled from the ‘Ohe‘o LZ to Delta Camp. Delta Camp is one of the lower shelters in Kīpahulu. Travel to and from the shelter to Transect 16 is very difficult because of dense understory. There was no prior preparation of the transect or access trails and the surveyors had a trouble accessing the transect. On May 23, they surveyed stations 22–32. On May 24, they were unable to access lower stations because of the predominately weedy understory. Tamayose and crew spent a total of four calendar days surveying the transect.

Transect 16 has specific logistical challenges. Stations 0–6 lie on a very steep ridge. If surveyors cannot be shuttled to Mauka Ridge to access those stations, they would have to depart Palikea Camp during the predawn hours to survey all the way up to Station zero. If surveyors cannot be shuttled to Mauka Ridge at first light, they may need to be "bumped" up to Mauka Ridge from Palikea Camp. Another possibility is camping at Mauka Ridge and surveying to and from the transect over 2–3 days. The lower portions of the transect are almost impossible to hike through without a prior team brushing the transect with machetes and/or chainsaws.

Transect 17

Legacy Transect 17 is the longest transect in HALE. The transect traverses nearly the entire length of the Upper Plateau, starting at Station one (2,020 m; Figure A-1) and ending at Station 75 (700 m). Field operations were based out of the West, Charlie, Ohē, and Ginger Camps. Surveys on Transect 17 began on March 14, 2017. Surveyor Judge joined the I&M vegetation crew on helicopter operations and flew to the Charlie LZ on the morning of March 14. After arrival, Judge had enough time to survey Stations 30–32, which are the closest to Charlie Camp. On March 15, Judge hiked uphill from camp to Station 18 and surveyed down from there to Station 29. On March 16, Judge surveyed Stations 33–43 and returned back to Charlie Camp. The entire crew was flown out to the ʻOheʻo LZ on the morning of March 17.

Primary point counter Judge and secondary counter Ryan Monello returned to transect the week of April 3, 2017. The team coordinated helicopter operations with the I&M vegetation crew. The crews attempted to fly into the valley on April 3 but the weather prevented any access. The crews made it in on April 4, when both teams flew to the Ohe LZ. Judge and Monello had enough time to survey Stations 44–46. On April 5, Judge and Monello surveyed Stations 47–57 and hiked over to the Ginger Camp. From Ginger Camp surveyors cannot hike uphill towards Ohē Camp because of the risk of spreading weeds uphill. On April 6, Judge and Monello surveyed Stations 58–71. The lower sections of the transect are completely invaded by strawberry guava and traveling through the area is very difficult. HALE resource management flew into Ginger Camp the previous week and flagged and cut the lowest section of the transect. The transect continues to Station 75 but the surveyors did not have enough time to finish them. Judge and Monello hiked back up to Ginger camp and all of the field crews were flown out to the ʻOheʻo LZ on April 7.

Primary point counter Judge, Jenna Fish of HALE RM, and Jeremy Miller (journalist) flew to the Wainēnē LZ on May 22. The West Camp and LZ are closest to the top of Transect 17, but the camp hadn't been visited in several months and was overgrown, so landing there was impossible. The Wainēnē LZ is an open area next to the small lake and approximately a 10-minute hike from the West camp (*see* Appendix B, Figure B-1). The transect can be reached by a 30-minute hike to Station 1. A blue flagged trail leads south towards the Koʻukoʻuai Stream. On May 23, the crew of three hiked to Station 1 and surveyed down to Station 11. The transect is overgrown and slow to hike through. On May 24, the crew started early and hiked to Station 12 and surveyed down to Station 17. The transect crosses the stream at several locations. It was a hazardous to hike and should not be crossed during periods of high rain. The crew opened up the West LZ by cutting down vegetation so the helicopter could land. On May 25, the entire crew was picked up and flown to the ʻOheʻo LZ.

The effort concluded surveys on Transect 17. Transect 17 required eight days to survey 71 stations, an average of approximately 10 stations per day. However, access to field sites was limited because of inclement weather and surveys are often hampered by rain. Furthermore, surveys were limited to Tuesday through Thursday, because helicopter shuttles were scheduled on Mondays and Fridays and there wasn't time for field work on those days. Consequently, the transect may require well over 4 weeks of field work to completely survey. Crews were fortunate with mostly good weather in 2017.

Transects 18, 18A, and 18.2

Legacy Transects 18 and 18A can be accessed from the lower ʻŌhiʻa Camp or Wing Camp in Manawainui (Figure A-1). The transects were not designated in the Protocol, but were surveyed upon agreement with HALE resource managers and the monitoring team (Judge et al. 2013). The transects lies in habitat ideal for several species of rare honeycreepers. Surveyors Judge, Tamayose, and Warren flew to the Wing LZ on March 20. The Wing LZ is near the top of Transect 18A. There is not an established camp in the area so the crew camped in the relatively open sub-alpine area. The next morning, with all of their gear, the crew surveyed Transect 18 (Stations 1–11). The crew continued down Transect 18A to Transect 18. They hiked all the way to ʻŌhiʻa Camp. The hike was very long and grueling and should only be attempted by fit and experienced personnel. On March 22, surveyor Tamayose surveyed the bottom half of Transect 18 (Stations 6–12). Judge and Warren hiked up to Station 6, and surveyed the rest of the transect through station one. There was enough time to survey Stations 11–13 on Transect 18A. On March 23, Judge and Tamayose surveyed three stations on random Transect 7. The transect was very overgrown and difficult to travel through. Warren surveyed transect 18.2 on state land (*see* Appendix B for a description). Transect 18.2 (a.k.a. 18B) is invaded by many noxious weeds and it is recommended that surveyors not return up to HALE so as to avoid spreading weeds to higher areas. The crew was extracted by helicopter on the same afternoon. It took the team three days to survey all three transects. Surveyors Judge and Tracen Oania (NARS) returned to survey Transect 18A again to retrieve audio recorders and to collect more survey data in this isolated area known for endangered species detections. On June 26, the two crewmembers were shuttled to the Wing LZ and camped there. On June 27, they surveyed all of transect 18A. On June 28 they surveyed random Transect 11 (Figure A-1) On June 28, the two returned to the area to look specifically for Kiwikiu and did not detect any of the species. The crew was flown out of the Wing Camp area the afternoon of June 28.

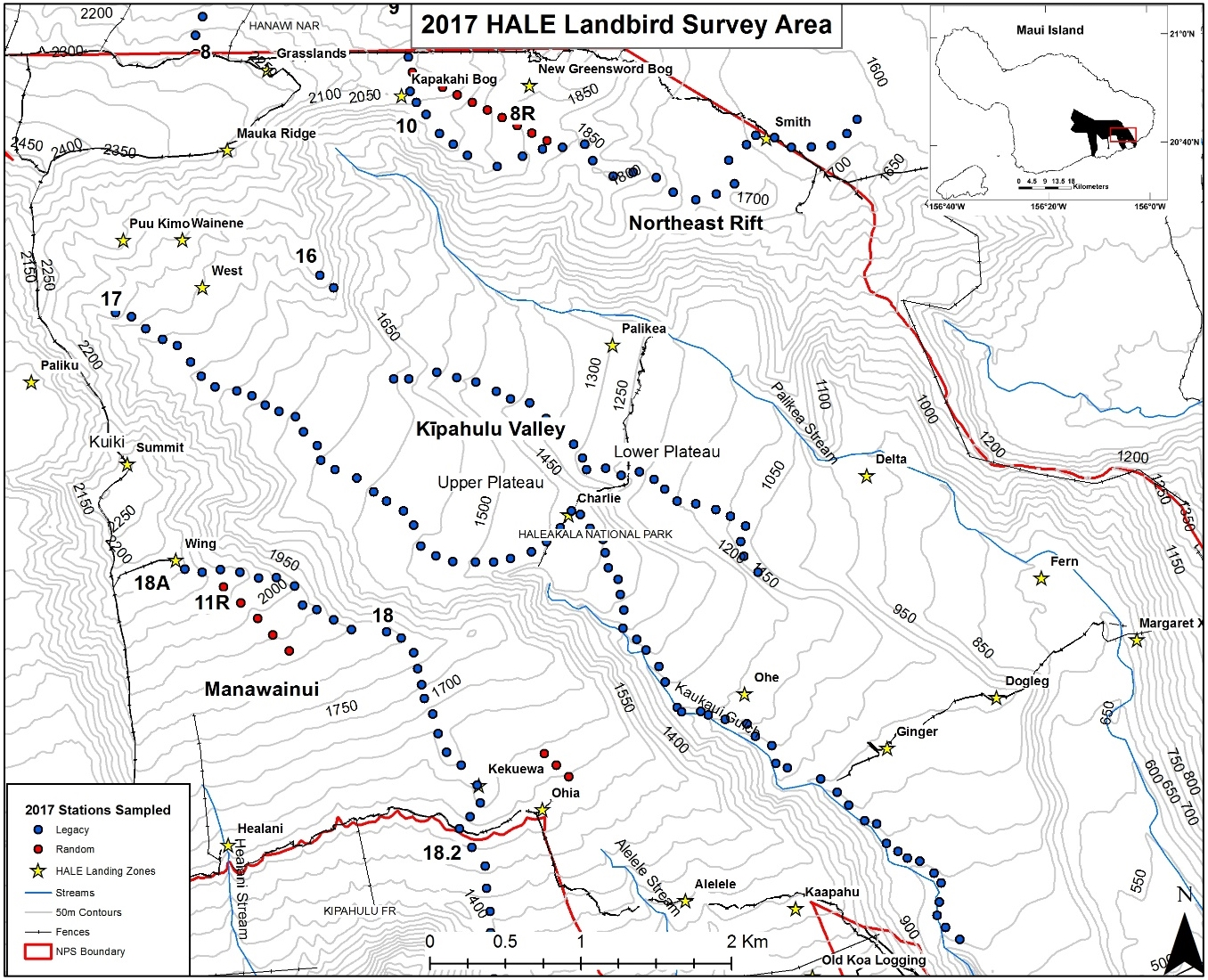


Figure A-1. HALE landbird monitoring transects (2017). Legacy Transects 10, 16, 17, 18, and 18A are to be surveyed every five years, and random Transects (11R and 8R) are one time only sites.

Discussion

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

The 2017 field effort was a collaborative process and the project would not have been completed without the cooperation from HALE Resource Management personnel. The Vegetation Management division cleared and flagged most of the transects in fragile areas of the Kīpahulu Valley Scientific Reserve. Their effort saved the landbird monitoring team months of field work. Flagging and maintaining foot paths and transects in Kīpahulu Valley is an enormous challenge and only experienced field biologists knowledgeable in HALE plant communities and weed protocols should enter the reserve.

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

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Appendix B. 2017 East Maui Forest Bird Field Survey Report

Executive Summary

In spring 2017, numerous agencies conducted the Hawai‘i Forest Bird Surveys in East Maui under the guidance of the State of Hawai‘i Department of Land and Natural Resources (DLNR). Maui Forest Bird Recovery Project (MFBRP) led the coordination of the surveys and staff acted as primary counters for the majority of the transects. A number of organizations supported the surveys by clearing and flagging transects and providing staff support as counters. These organizations included Auwahi Wind (AW), the Division of Forestry and Wildlife (DOFAW), East Maui Watershed Partnership (EMWP), National Park Service (NPS), Natural Resource Data Solutions, Leeward Haleakalā Watershed Restoration Partnership (LHWRP), Maui Invasive Species Committee (MISC), The Nature Conservancy (TNC), U.S. Geological Survey (USGS), and U.S. Fish and Wildlife Service (USFWS).

Additionally, several unaffiliated people volunteered their time as primary and secondary counters. In total 27 transects were surveyed including 18 legacy transects and nine newly installed transects (Figure B-1). Six of the 18 legacy transects had not been conducted in at least twenty years. The remaining legacy transects were all conducted most recently in 2011/2012 on the regular state five-year cycle. In a few cases, legacy transects were expanded to include stations that had not been surveyed for more than a decade. The newly created transects were mostly placed in areas that are the focus of forest recovery efforts. As a whole, the surveys conducted in 2017 were the most comprehensive forest bird surveys conducted in East Maui since 1980.

Windward Transects

The windward Haleakalā transects have historically been the most consistently surveyed transects on Maui. Between DLNR and the National Park Service, all or part of Transects 2–10 and 16–18 (Figure B-1) have mostly been surveyed on a five-year cycle. The four transects in Haleakalā National Park (Transect 10 and Transects 16–18) were previously surveyed in 2012 as part of the NPS Pacific Island Landbird Monitoring Program (Judge et al. 2013). The remaining eight transects (2–9) are primarily on either state managed conservation lands or TNC’s Waikamoi Preserve. This group of transects was last surveyed in 2011 as part of the HFBS. It was great to have the opportunity to collaborate with the NPS Inventory and Monitoring Program to ensure that all the windward transects were done in the same year in 2017. All the windward transects, state and national park, have not been surveyed in the same year since 2001 (Camp et al. 2009a).

The majority of windward transects outside of Haleakalā National Park (HALE) were cleared and flagged prior to the surveys. Transects 5 and 6 were surveyed without prior clearing and reflagging. Similarly, some of the National Park transects were cleared prior to counts and some were cleared on the same trip as the counts. With few exceptions, at least some flagging remained on all of the windward transects.

The windward transects were conducted using the same stations as were planned for the 2011/2012 surveys. The one exception was that Transect 18 was expanded from the 2012 extent, which stopped at the fence marking the approximate southern boundary of HALE. The expansion followed the

original Transect 18 route down to 1,200 m elevation into what is now Kīpahulu Forest Reserve (FR). Even though this section was part of the original Transect 18, this lower section will be known as Transect 18B to avoid confusion with naming changes to other sections of the transect.

Leeward Transects

Nine transects were originally established on the leeward slopes of Haleakalā for the 1980 surveys. These are on lands now managed by DOFAW (Kahikinui FR and Kula FR), NEPM (Nakula NAR), Department of Hawaiian Home Lands (DHHL), HALE, and Ulupalakua Ranch.

The primarily non-native forests of Kula FR are home to four species of honeycreepers including the only known East Maui populations of Maui ʻAlauahio and ʻIʻiwi outside of those found on the windward slopes. Three transects were originally established in Kula FR (Transects 29–30). These were last surveyed as part of the HFBS in 1996. A series of additional temporary transects were established in 2013 by Peter Motyka, a graduate student at the University of Northern Arizona (Motyka 2016). Motyka surveyed the legacy transects and his newly established transects in 2013 and 2014. In 2017, we surveyed the three legacy transects and two of Motyka's transects (A and F, now dubbed Transects 43 and 44) within Kula FR. These collectively provided more comprehensive coverage of Kula FR. This was particularly important given that Motyka's research indicated patchy distributions of many forest bird species within the reserve.

Three of the five legacy transects established in the Kahikinui region were surveyed in 1996, but none have been surveyed since. Only the upper elevation (above ~1,800 m) stations of the leeward transects were surveyed in 1996. Today, a remnant stand of montane mesic forest exists from ~1,100 m to ~2,000 m in elevation and extends from DHHL in the west to the western edge of the Kaupō Gap (Nuʻu) in the east. Forest quality (species diversity, canopy cover, and density of forest "patches") generally declines from west to east. As such, the majority of the existing forest bird habitat exists in DHHL, Nakula NAR, and Kahikinui FR, in the western section of the forest band. Transects 24 and 25, surveyed in 1980 and 1996 (upper Transect 25 only), are the only legacy transects in the Kahikinui region that still contain significant forest bird habitat. Legacy Transect 26 now falls outside any significant forest bird habitat. By shifting Transect 26 ~1 km to the east, we re-established this transect in good habitat that will also soon be within ungulate-proof fencing. This newly established (or re-established) transect was dubbed Transect 26A. We also established a new transect (Transect 42) on DHHL to survey good forest bird habitat between Transects 25 and 26A.

Restoration efforts are also taking place in a number of places that would not be covered by the legacy transects. To capture the response of the bird community to these efforts we established several new transects throughout the region. MFBRP established Transects 39–41 in 2015 as part of a separate effort to survey bird populations in Nakula NAR. We also established one transect on Nuʻu Mauka Ranch and two transects on Ulupalakua Ranch in areas being restored by LHWRP and Auwahi Wind, respectively.

In 2017, we surveyed legacy Transects 24, 25, 29, 30, and 31; as well as nine newly established transects on the leeward slopes of Haleakalā. Nearly all of the leeward transects were flagged in 2017 prior to the count as little to no sign of the original flagging persisted on the legacy transects and the

remainder were newly established. The three Nakula transects were the only leeward transects that did not require flagging prior to the count as these were last surveyed in 2016.

Newly created and resurrected legacy transects consisted of survey stations placed approximately 150 m apart. Legacy stations were intended to be placed 134 m apart, following methods of Scott et al. (1986). However, in reality many legacy stations were spaced too close from one another to maintain independence (e.g., < 70 m). This is likely because the original stations were established using hip-chain measurements. Using modern GPS and GIS technology we were able to maintain a more consistent distance between stations. This also allowed us to use a direct distance, i.e., "as the ʻAlalā flies", more relevant to auditory detections rather than an along-the-ground distance. Little physical evidence of the original legacy stations were found along the resurrected transects. To recreate these transects we established new stations along the same routes as the original transects. If a newly created point fell near the GPS location of the original station, it was given the same name as the original station. However, new stations that fell between two stations or elsewhere were given new names with a letter added, e.g. "Transect 18B" and "Station 13A". This will allow per-point comparison with historic data from stations with the same name and full transect comparisons including all sampled stations.

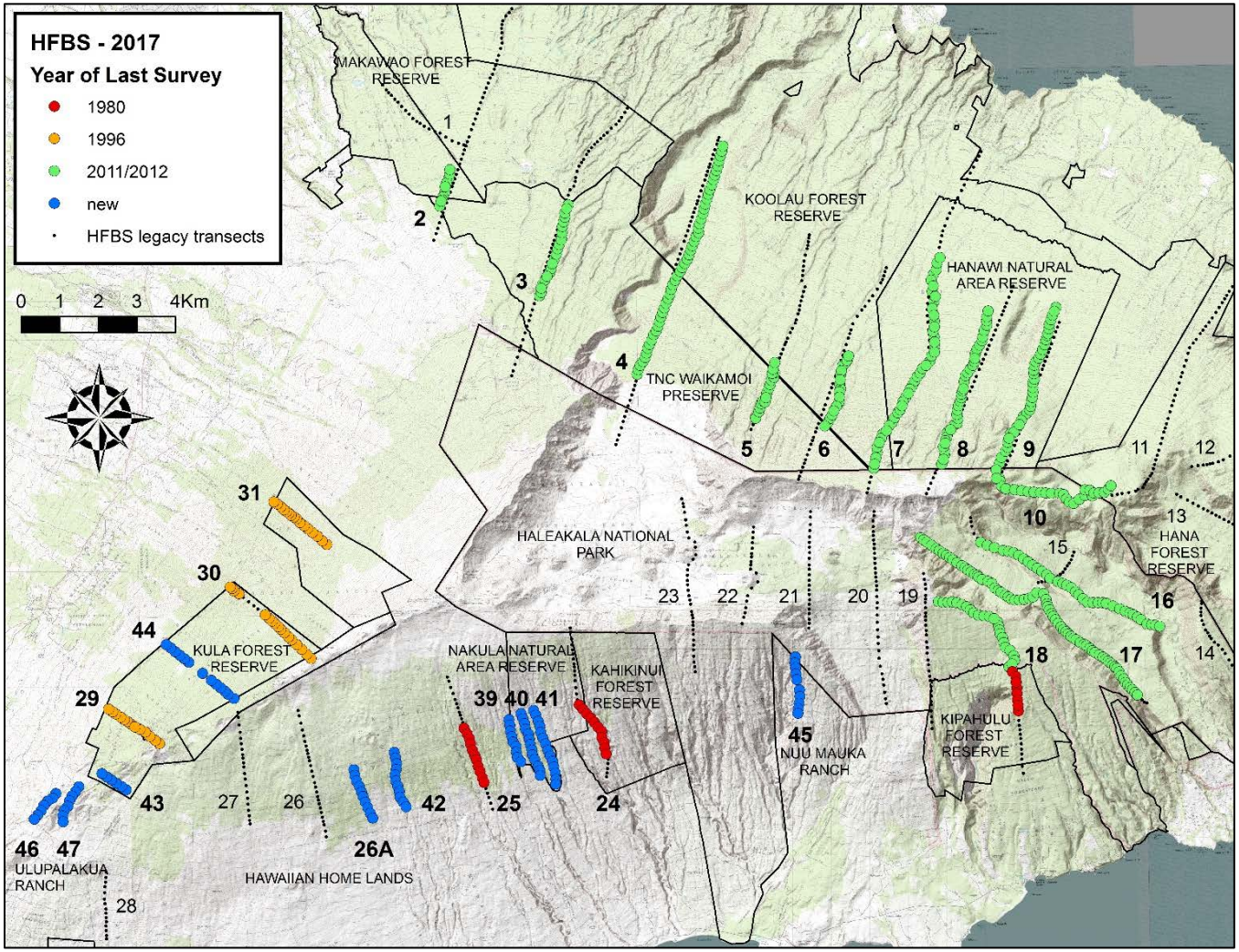


Figure B-1. Hawai‘i Forest Bird Survey (HFBS) transects sampled in 2017. All colored transects were surveyed in 2017. The different colors indicate the previous year each transect was sampled. Blue transects were first sampled as part of the HFBS in 2017. Stations in black are legacy HFBS stations sampled in 1980, showing the location and extent of the original survey.

Person Effort

Conducting these surveys generally requires a fair amount of effort to first clear and flag transects and then conduct the surveys themselves. Many transects are in difficult to access areas, each with their own set of challenges like dense vegetation, loose footing, or feral animals. As such, these surveys would not have been possible without the support of the conservation community and landowners and managers. More than ten different agencies provided support in the form of information and/or personnel. Each transect held its own inherent difficulties and required a varying amount of effort to complete. Most of the leeward transects required little clearing but still needed flagging and most stations were marked with PVC poles due to a lack of trees onto which flagging could be tied. These transects were short enough to be surveyed in a single morning. In contrast, the windward transects often required multiple days to complete, with separate trips of clearing or surveying. Nine transects were accessed by vehicle and on foot exclusively, while the remainder required the use of helicopters. In total, the **2017 HFBS required 159 person days** to complete, clearing and counting (Table B-1).

Table B-1. Person days required for clearing/flagging and surveying each HFBS transect in 2017. Agency abbreviations can be found in the text.

Transect	Agency Clearing	Days	Person Days	Agency Counting	Days	Person Days
2	MFBRP	1	3	TNC	1	2
3	MFBRP/MISC	2	10	MFBRP/NPS	2	4
4	MFBRP/EMWP/MISC	1	10	MFBRP/TNC	2	4
5	N/A	0	0	MFBRP/TNC	2	4
6	N/A	0	0	MFBRP	2	4
7	NEPM/MFBRP	2	7	MFBRP/USFWS	3	6
8	NEPM/NAH	1	5	MFBRP/USFWS	3	5
9	NEPM/NAH	1	3	MFBRP/USGS	3	6
10	N/A	0	0	NPS/MFBRP	4	6
16	N/A	0	0	NPS	6	6
17	N/A	0	0	NPS	8	8
18	DOFAW*	1	3	NPS/MFBRP	3	9
24	DOFAW	1	3	MFBRP	1	2
25	LHWRP	1	2	MFBRP/LHWRP	1	2
26A	LHWRP	1	3	MFBRP/LHWRP	1	2

* DOFAW cleared the lower section (18B) only; the rest of Transect 18 was not cleared prior to the survey.

Table B-1 (continued). Person days required for clearing/flagging and surveying each HFBS transect in 2017. Agency abbreviations can be found in the text.

Transect	Agency Clearing	Days	Person Days	Agency Counting	Days	Person Days
29	MFBRP	2	6	MFBRP	1	2
30	MFBRP	1	1	MFBRP	1	2
31	MFBRP	1	2	MFBRP	1	2
39	N/A	0	0	MFBRP	1	1
40	N/A	0	0	MFBRP	1	1
41	N/A	0	0	MFBRP	1	1
42	LHWRP	1	2	MFBRP/LHWRP	1	2
43	MFBRP	1	1	MFBRP	1	2
44	MFBRP	1	2	MFBRP	1	2
45	LHWRP	1	1	MFBRP/LHWRP	1	2
46	AW	1	2	MFBRP/AW	1	2
47	AW	1	2	MFBRP/AW	1	2
Total		**22**	**68**	**–**	**54**	**91**

* DOFAW cleared the lower section (18B) only; the rest of Transect 18 was not cleared prior to the survey.

Future Surveys

Many participants of the 2017 HFBS made a number of helpful suggestions for future surveys.

In general, the leeward transects were comparatively easy to conduct and have the potential to capture very interesting patterns in the bird community of this side of Haleakalā. We feel strongly that these transects should be included in future surveys.

In general, clearing the windward transects is very time consuming. In 2017, we focused on flagging and clearing the longest transects; some were not cleared in time for the survey. This was the case for Transects 5 and 6, which were surveyed without prior clearing. Although these two transects are shorter, they were also not cleared in 2011. As such, by the next survey they will not have been adequately cleared for over ten years. Without prior clearing, observers also have less of a chance to make observations between points as they push and cut their way to each successive station.

Transect 5 could easily be extended down to the LZ. Currently TR5 ends at station 18 and then observers follow the legacy transect downhill to an LZ below 1,500 m. There is no reason why observers cannot count while on their way to the LZ unless there are time restrictions that the 2017 survey did not encounter. The 2017 surveyors noted ‘I‘iwi in the area of the LZ and this is possibly still in the range of the two endangered bird species.

Transect 18 (now Transect 18B) was re-extended into Kīpahulu FR in 2017. This resurrected section goes through near-pristine native forest for several stations before entering a forest dominated by invasive plant and animal species. Future surveys should count Stations 13A–16A and no further, especially if hiking back up to more pristine areas. This will reduce the threat of unintentionally moving invasive plant seeds uphill.

The Hanawī Transects 7–9 are among the most rugged; this is especially true of the top sections of the transects. The terrain has proven too difficult for many surveyors in the past and again in 2017, leading to minor injuries and early pullouts. It is highly suggested that only experienced personnel in peak condition be allowed on these transects so this pattern is not repeated. Transect 2 and 3 are comparatively easy for less field savvy surveyors and provide a good alternative.

Following suggestions by Brinck et al. (2012) repeat visits will improve the power to detect changes in ʻĀkohekohe and Kiwikiu status. To increase the survey period within the ranges of ʻĀkohekohe and Kiwikiu it would not be difficult to repeat the first day of counts on all of the windward transects. This would likely increase a survey trip by one day. For example, surveyors on the Hanawī NAR transects are typically dropped at the top of their transects and survey 10–15 stations on the first morning. These stations account for the majority of the stations in the ranges of the two endangered bird species. If surveyors left their backpacking gear at the top, they could take daypacks and survey downhill in the morning of the first day and then return to the top in the afternoon. Then, the following morning, surveyors could take all their gear and survey the top section again before camping lower down on the transect the following night. A similar plan could be followed for Transects 4–6. Transect 3 is one of the most accessible transects and could easily be accessed on several successive days.

General Bird Observations

Given the extensive coverage achieved during the 2017 counts, a more complete picture of the bird community in East Maui is provided in the main body of this report. Here we provide a general summary for grant and State of Hawaii reporting purposes. We were able to cover most areas containing extensive forest bird habitat, including several different forest types. As such, the 2017 count will provide information about variation in bird densities in many areas that have not been available for decades. Surveyors also recorded anecdotal notes that provide valuable additional information to what may come out of the analyses.

Kiwikiu (Maui Parrotbill; Pseudonestor xanthophrys)

The Kiwikiu is undoubtedly the most difficult species on Maui to detect using the variable circular plot design. We expected few observations of the species based on the detection history of this species from past surveys despite good coverage of the species' range. Eleven transects were conducted within the Kiwikiu range, Transects 3–10, and Transects 16–18. We recorded Kiwikiu seven times on five out of the 11 transects surveyed, including Transects 3 (twice), 4, 8, 9 and 10 (twice). Foraging signs were evident along Transect 5 as well, although the species was not recorded on the counts. Missing the species on Transects 5 and 6 was not unexpected as the species range is narrow in this area. The species is undoubtedly present along the upper portions of Transects 16 and 17, but it was not recorded on the counts. We did not detect Kiwikiu, on or off the counts, along

Transect 18 and we found no clear foraging signs. This was somewhat unexpected although previous research in Manawainui found comparatively low densities of Kiwikiu in the region. The weather during 2017 survey of Transect 18 was also not ideal, i.e., windy, reducing the opportunity for distant detections. The habitat in this area, however, remains in excellent condition.

ʻĀkohekohe (Palmeria dolei)

Eleven transects were conducted within the ʻĀkohekohe range, Transects 3–10 and Transects 16–18. The distribution of this species may be the most limited of all of Maui's native forest birds. The primary elevation range for ʻĀkohekohe appears to be between 1,500–2,100 m but the highest densities seem to be in an even narrower range, 1,700–2,000 m. This reduces the number of point count stations that fall within the ʻĀkohekohe range. Their low-pitched songs can easily be missed particularly in less than ideal weather conditions. The species was recorded on all transects within its range except Transects 4–6. These transects are in the middle of the species' range. If the species is no longer present or is present at very low densities in these areas, the population in the Waikamoi Preserve may be effectively isolated from the remaining population(s).

The variation in vocalizations for this species was apparent to surveyors. The most common whistles heard in the different parts of the species' range were extremely variable and future surveyors should keep this in mind. ʻĀkohekohe in Waikamoi and Hanawī often give a single, clear upslurred whistle as a primary contact note. This whistle was heard only rarely along Transect 18 in Manawainui and had a raspier quality, more similar to ʻIʻiwi. The Manawainui birds also used a three-note whistle and a downslurred whistle very similar to Kiwikiu calls. These calls were the most frequently heard vocalization from ʻĀkohekohe in the area and are unlike anything typically heard from the species elsewhere. This is a potential source of identification confusion.

Maui ʻAlauahio (Parareomyza montana)

The 2017 HFBS surveys were the first to incorporate the entire Maui ʻAlauahio range since the original counts in 1996. This includes the windward transects, Kula, and possibly Kahikinui. Nineteen transects within the currently recognized Maui ʻAlauahio range (not including Kahikinui) were surveyed in 2017. This will provide a much more comprehensive estimate of total abundance and variation in density as any time since 1996. Two newly created, Transects 46 and 47, cover a section of Ulupalakua Ranch being restored by Auwahi Wind. We detected Maui ʻAlauahio on Transect 47, which is outside of the current range map for the species. This is an exciting find, although not unexpected given contiguous habitat from occupied habitat in Kula FR. Nonetheless, this shows that the restoration being conducted in this area will have an immediate positive impact on this and other species.

It has long been a mystery as to whether any ʻAlauahio remain in Kahikinui. In their report, Scott et al. (1986) refer to three populations of ʻAlauahio, windward, Kula, and Kahikinui. However, no Maui ʻAlauahio were recorded in Kahikinui on the official counts in 1980 or after. The precise location(s) of the supposed Kahikinui sighting(s) seems to have been lost and may have been anecdotal in 1980. The range map for the species presented by Scott et al. (1986) suggest that the species may have been present somewhere along Transects 26 or 27 (*see* Appendix C, Figure C-2). Sadly, very little forest now exists between Transect 26A and Kula FR, the area covered by Transects

26 and 27. If the species still exists in Kahikinui, it is likely to be in the area between Transect 26A to Nakula NAR. However, the species was not recorded during the 2017 survey anywhere in Kahikinui. Only a few unconfirmed sightings of the species have been reported and observers could not eliminate Hawai‘i ‘Amakihi, an abundant species in the area, as a possibility. The forest at the far western edge of the Kahikinui forest band (Transects 26A and 42) have some of the best forest and remains the best possibility of the persistence of ‘Alauahio in the region.

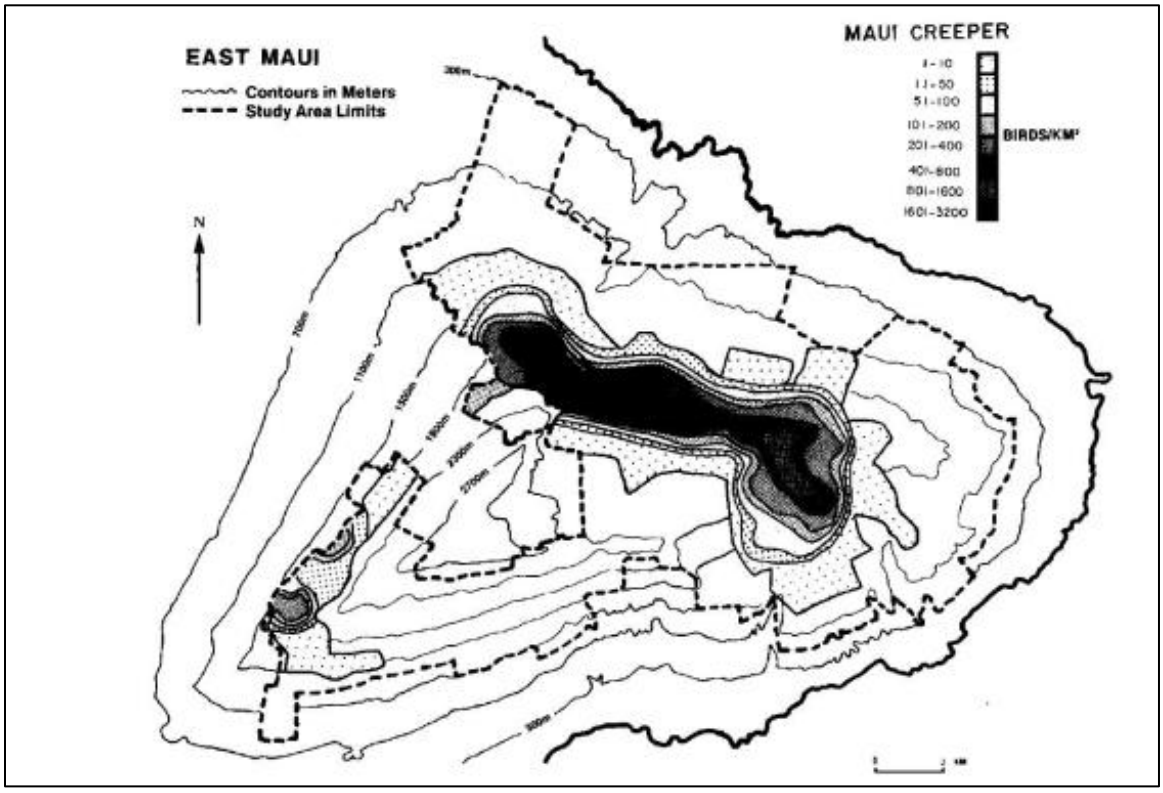


Figure B-2. Figure 125 from Scott et al. (1986) showing range of Maui ‘Alauahio (Creeper) in 1980. The map shows the species ranging into the Kahikinui region in the area of legacy Transects 26 and 27.

‘I‘iwi (Drepanis coccinea)

The recent listing of ‘I‘iwi as a threatened species on the U. S. Endangered Species List has brought much deserved attention to the plight of this species as a whole. Fortunately, the population(s) on windward East Maui is among the most robust and the species appears to be stable or increasing in many of the areas covered by the 2017 surveys. As with ‘Alauahio, the 2017 surveys provided the best coverage of the species’ range in East Maui since 1980. Also, like ‘Alauahio, these surveys provided the opportunity to search for the species in areas that they have not been recorded in quite some time. Despite the close proximity to known populations and the species’ ability to disperse long distances, ‘I‘iwi have not been recorded from Kahikinui. During the 2017 counts we did not record ‘I‘iwi outside of the areas where the species has been known to exist. Although the surveys in Kahikinui covered a lot of habitat, the potential still exists for the species to be present in low numbers given the short survey period.

Three hypotheses may explain the absence of ʻIʻiwi and ʻAlauahio from Kahikinui that are not mutually exclusive. 1) The remaining habitat is not yet suitable for these species. This seems unlikely, especially for ʻIʻiwi given that the species occupies some marginal habitat, including non-native forests. If this hypothesis is correct, we should see the species recolonize the area in the future in response to restoration efforts and natural regeneration. 2) Disease may not allow the species to persist. MFBRP is currently conducting disease sampling in Nakula NAR. They found elevated mosquito (*Culex quinquefasciatus*) capture rates compared to other areas but comparable (or possibly lower) rates of *Plasmodium* infection in the local bird populations. 3) Past populations in the region died out for some unknown reason and the region simply has not yet been re-colonized. Under this scenario, there may be nothing preventing these species from occupying the region and it will simply take a few pioneering individuals to re-colonize the area.

Preliminary results suggest some endemic avian malaria above 1,500 m This elevation is considered relatively safe for native forest birds on the windward slopes, as few mosquitoes are present at this elevation. Both ʻIʻiwi and ʻAlauahio persist below 1,200 m on the windward slopes, albeit in reduced densities. However, birds down below 1,200 m undoubtedly encounter infected mosquitoes. As such, if disease is limiting in forests above 51,500 m on the leeward slopes, infection rates must be higher than those seen below 1,200 m in the windward habitat. At this point, this seems unlikely.

Hawaiʻi ʻAmakihi (Chlorodrepanis virens wilsoni)

This species continues to be among the most widely distributed native forest bird on East Maui. Hawaiʻi ʻAmakihi and ʻApapane were recorded on all transects surveyed in 2017. Although not captured in the surveys (that stop around 900 m at the lowest), ʻAmakihi are now present at some sites below 300 m on East Maui. Following the previously reported trend, surveyors observed a trend of increasing density of ʻAmakihi at lower elevations.

ʻApapane (Himotione sanguinea)

As the most abundant Hawaiian honeycreeper, ʻApapane were common throughout the survey area. The species became noticeably less common or absent below 1,200 m in some areas. However, ʻApapane were recorded all the way to the bottom of several windward transects. This includes Transect 4 that extends below 600 m. Along the leeward transects, ʻApapane often were not detected at the lowest points around 1,200 m. This may also be related to habitat as most ʻohiʻa are present above 1,400 m in this habitat. Despite this however, ʻApapane seemed to be very abundant along the leeward transects.

Transect Descriptions and Logistics

Transect 2 (Makawao FR)

Legacy Transect 2 cuts through the far western edge of the Waikamoi Preserve and into Makawao FR (Figure B-3). Access to this transect is restricted and was granted by TNC and Haleakalā Ranch; TNC staff conducted the counts. This is a fairly easy and short transect and is accessed off roads and well-worn trails. This is a single day transect and can be coupled with the second day of transect 3, which ends farther up Haleakalā Ranch/Olinda Road, for driving out of the site. The original transect started higher in what is now mostly non-native habitat and continued below Haleakalā Ranch/Olinda Road where it now ends. The transect now starts on an accessible trail at the edge of a gulch and it is

likely not worth including upper historic stations. Similarly, below Haleakalā Ranch/Olinda Road is largely non-native ginger dominated forest and not likely to hold substantial populations of native birds.

Transect 3 (TNC Waikamoi Preserve)

Legacy Transect 3 cuts through Waikamoi Preserve and is a well-worn trail particularly on the upper portion (Figure B-3). The original transect started higher in what is now exclusively conifer forest. The current transect starts at Station 6, right at the boundary between the non-native and native forests. Access to Waikamoi Preserve is restricted and granted through TNC. The transect ends at the Flume and access must also be granted by East Maui Irrigation who also holds the key to the gate at the end of the flume. This is a two-day transect and can be accessed through hiking alone and surveyors can be picked up at the 4WD Haleakalā Ranch/Olinda Road at the end of the Flume. Access to and keys for Haleakalā Ranch Road were granted by Haleakalā Ranch. In 2011 and 2017, surveyors hiked back out after the first day of surveying. On the second day the surveyors were dropped off at Hosmer Grove in Haleakalā NP and hiked in early to where the first day surveyors ended. They then continued down the flume to the road and hiked to the bottom of Transect 2 and were driven out from there. The road is drivable, however, to the gate at the Flume.

Transect 4 (Koʻolau Gap)

Legacy Transect 4 follows the center of the Koʻolau Gap starting in TNC Waikamoi Preserve and ends in Koʻolau FR (Figure B-3). Access is restricted and must be requested from TNC and DOFAW. Access to this transect is via helicopter only. Transect 4 is one of the longest transects and is still surveyed along essentially it's entire original extent. Given the length this is a four-day transect and is best split up between two teams. Lorax Camp maintained by East Maui Watershed Partnership is situated directly on the transect and is at the half-way point. This provides a perfect place to drop the team that will survey the lower half and pick up the team that surveyed the top section at the end of the survey. The top team was dropped near the NP fence line above the top station; there are very few landmarks except a few TNC veg monitoring plots (PVC). Both teams camped where they ended their surveys after the first day (Stations 26 and 50). Camping hammocks are highly recommended. The egress at the bottom was confusing given the number of hunter trails (also flagged) in the area. Helicopter pick up for the lower section is on the road near the Piʻinau Gaging station. It may be possible to access the gaging station via 4WD vehicle if access and keys are given by East Maui Irrigation.

Transects 5 and 6 (eastern Waikamoi Preserve)

Legacy Transects 5 and 6 both start in Waikamoi Preserve and end in Koʻolau FR (*see* Appendix C, Figure C-3). Access must be granted from TNC and DOFAW. Access to these transects is via helicopter only, ingress and egress. Both transects take two days to survey and camping is required (Transect 5: Station 12 was used in 2017, tents or hammocks; Transect 6: above Station 21, hammocks recommended). Neither transect have been cleared in a very long time and surveyors cleared and counted on the same trips in both 2011 and 2017. For Transect 5 surveyors can be dropped in the shrubland just above Station 3. Transect 5 ends at Station 18 and then surveyors must hike downhill to a flagged LZ. Given the timing in 2017, future surveys should re-expand the transect down to the LZ, likely re-adding stations 19–21. For Transect 6, surveyors can be dropped

off at Camp 1 LZ above an A-frame structure in the shrubland. Surveyors can be picked up at Station 27 (may need additional clearing).

Transects 7, 8, and 9 (Hanawī NAR)

Legacy Transects 7, 8, and 9 are all within Hanawī NAR and are accessed via helicopter (*see* Appendix C, Figure C-4). These three transects take three days each; two nights of camping. On the first day surveyors were flown to the top of each transect (near the first station for Transects 7 and 8; at Geologist Camp for Transect 9). On Transect 7, surveyors can camp at Moonlight Hotel Camp on the first night and I'm Cold LZ (east across a stream from Station 31) on the second night. Transect 7 was surveyed down to Station 39 in 2017 and then the surveyors returned to I'm Cold Camp for the flight out. In the past the transect has continued down and the egress was at Loulu Camp. For transect 8, surveyors can camp at Poʻouli Camp the first night (they may have to backtrack on the second day to where they ended the survey on the first day) and then at Station 35 (hammock recommended). Pick up is at a boggy clearing between Station 43 and 44. There are no full camps along Transect 9 and camping hammocks are recommended for camping along the transect. Pick up is at Pono LZ southeast of Station 33 (leave time to locate).

Transect 18.2 (a.k.a 18B; Manawainui)

Legacy transect 18 begins in the Manawainui section of HALE and ends at the southern boundary fence (Figure B-1). In 2017, we resurveyed the lower section of historic Transect 18 that continues below the fence into Kīpahulu FR. This was surveyed after the upper sections of the transect (*see* Appendix A) and accessed from ʻŌhiʻa Camp, which is to the east along the fence. From the fence the transect is within intact native forest with lots of extremely thick ʻuluhe (cleared prior to the survey by DOFAW; the survey would have been nearly impossible without). Below Station 16A, the habitat abruptly changes to fully invaded forest of strawberry guava and Australian tree fern. It is recommended that the survey end at Station 16A, particularly if the surveyor(s) are hiking back uphill as in 2017. Egress is via helicopter at ʻŌhiʻa Camp.

Transects 24, 39, 40, and 41 (Nakula)

Legacy transect 24 and newly created (2015) Transects 39–41 are all within Nakula NAR and/or Kahikinui FR (*see* Appendix C, Figure C-5). These transects start at essentially tree line (~1,800 m), traverse remnant mesic forest, and end at the lower edge of the remaining forest. All of these transects are single-day surveys. Transect 24 is accessed via helicopter, dropped off near the top station and being picked up near the last station. Transects 39–41 can be accessed via helicopter and surveyors can be dropped off at the first station. However, these transects can also be accessed from Camp Release (30–45 min hike to the top of each). Surveyors for Transects 39–41 have always hiked back to Camp Release and flown out from there.

Transects 25, 26A, and 42 (Kahikinui)

Legacy Transect 25 and newly created Transects 26A and 42 are on Department of Hawaiian Home Lands (access must be facilitated through Leeward Haleakalā Watershed Restoration Partnership [LHWRP]) (Figure B-5). These transects are single-day surveys and are best accessed using helicopters. All three transects start above tree line and traverse a band of remnant mesic forest and end at a fence (or will in the future). Surveyors can be dropped at or near the first station and picked

up at or below the last station. In 2017, most survey teams had to hike down below 900 m to get below thick clouds. But, the area below the last station on all transects is open rangeland and easy to hike. In 2017, teams were comprised of a surveyor and a LHWRP staff member to address the safety concerns surrounding the feral cattle in the area. The cattle are in process of being removed from all of the surveyed area and future surveys may not have this concern.

Transects 29, 30, 31, 43 and 44 (Kula FR)

Legacy Transects 29–31 and newly created Transects 43 and 44 cover much of Kula FR (Figure B-6). All of these are drive-in/hike-in single-day transects. Transects 29, 44, and 30 are all accessed via Skyline Road above Poli Poli Springs State Recreation Area. Surveyors for these transects can be picked up along the road where the transects cross Waipoli Road. The beginning of Transect 30 is past a gate and surveyors have to hike up the road for a few minutes to reach the transect. Transect 30 is divided into two sections because a heavy blackberry infestation and downfall make traversing the entire transect very difficult. The upper section ends at Station 13 and then the surveyor must hike down to Waipoli Road via a service road. The lower section is accessed off the Boundary Trail. Transect 31 is accessed by hiking the Waiakoa Loop Trail and then up the Waiakoa Trail to the top of the transect. The start of Transect 43 is accessed off the Haleakalā Ridge Trail and an old forestry road. This transect ends near the Plum Trail; egress is via the trail system back to the trailhead.

Transect 45 (Nuʻu)

Newly created Transect 43 is on Nuʻu Mauka Ranch property being restored by LHWRP (Figure B-5). This is near the western edge of the Kaupō Gap in mostly rocky, open land with remnant forest patches. Access is via helicopter facilitated by LHWRP. This is a single-day transect.

Transects 46 and 47 (Puʻu Makua)

Newly created Transects 46 and 47 are on Puʻu Makua, part of Ulupalakua Ranch property being restored by Auwahi Wind (Figure B-6). These transects can be accessed via UTV facilitated by Auwahi Wind. These transects largely parallel each other, one traversing a restoration area and the other going through remnant forest.

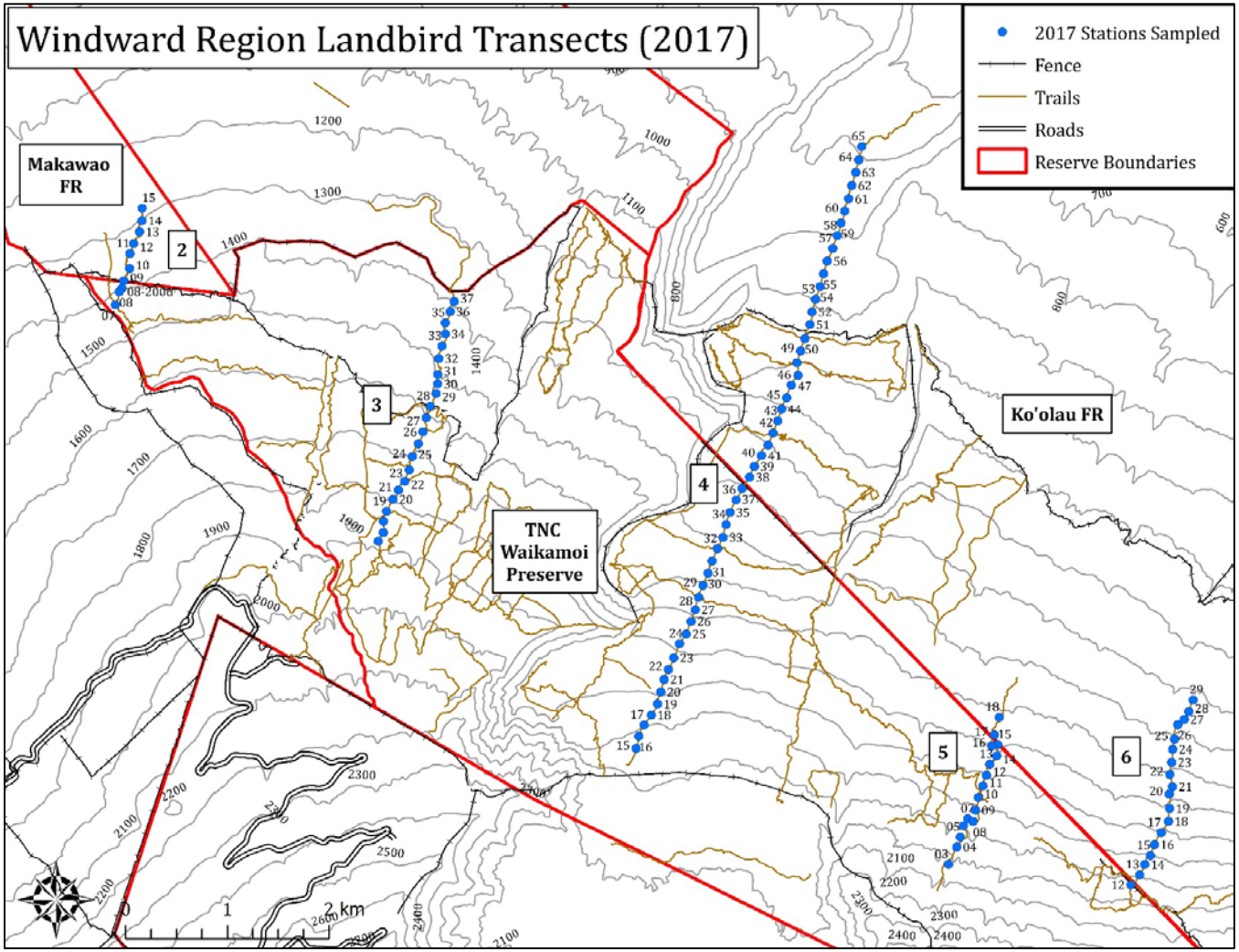


Figure B-3. Legacy Transects 2 through 6 in the Windward Region.

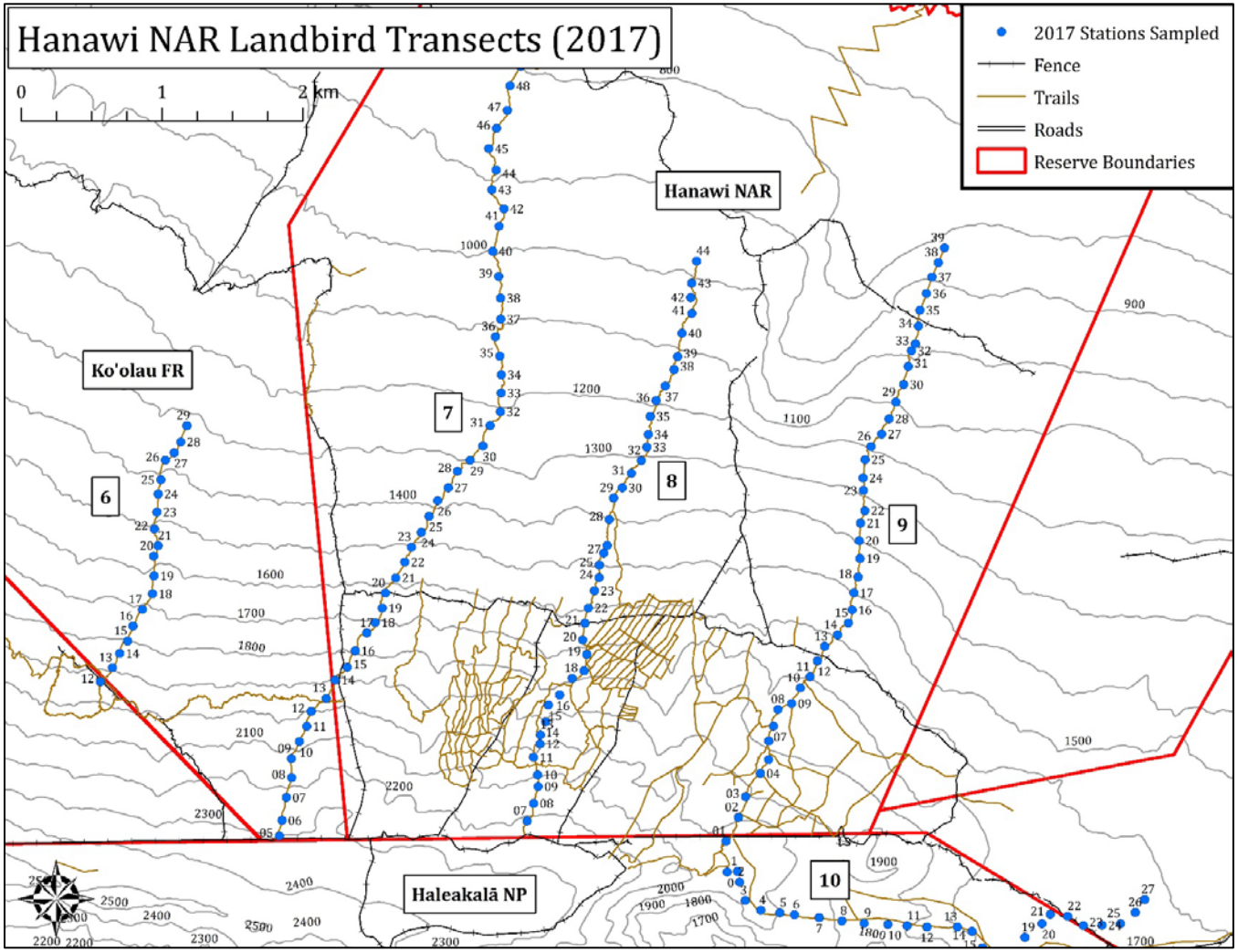


Figure B-4. Transects in the Hanawī NAR in the Windward region.

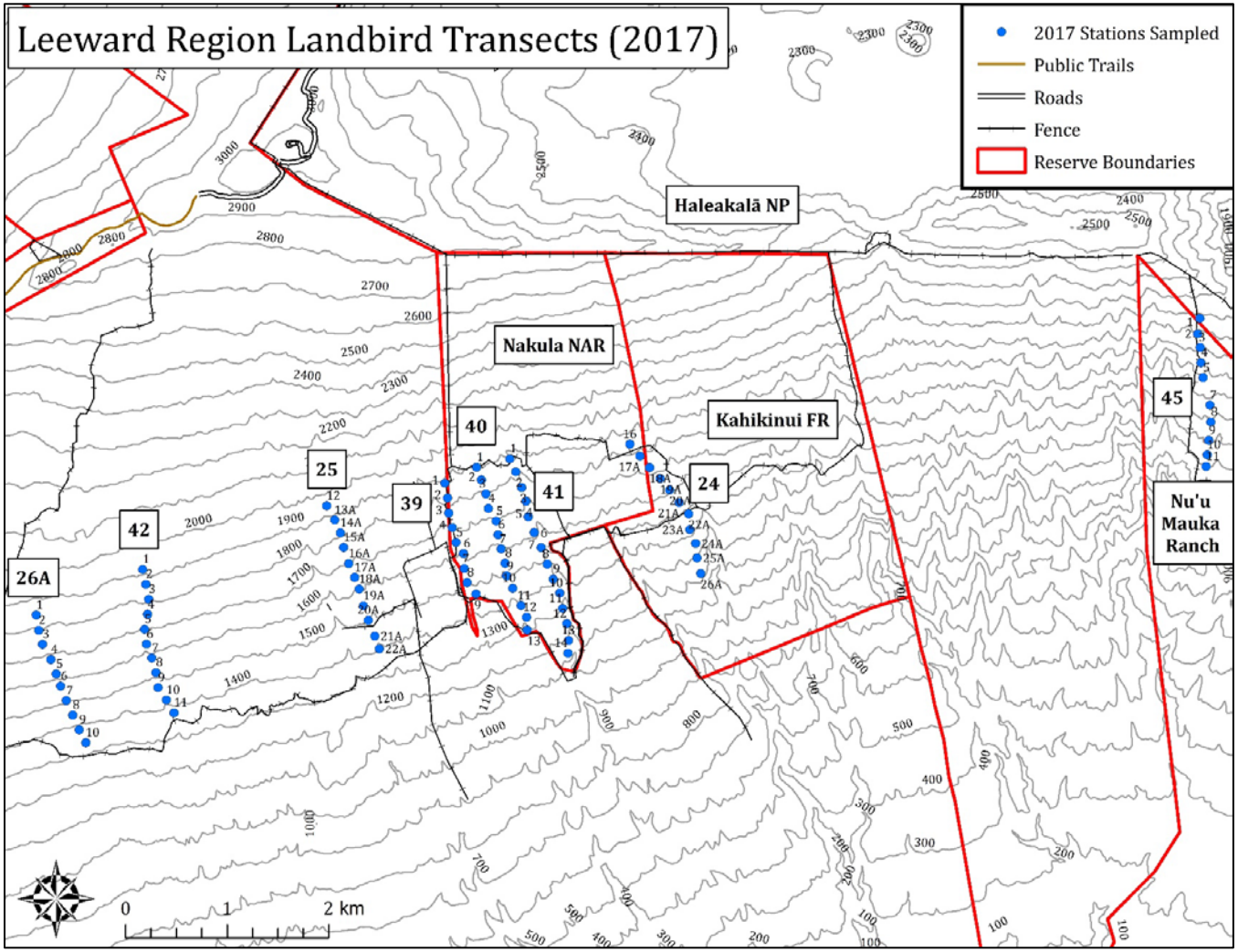


Figure B-5. Transects in the Leeward Region.

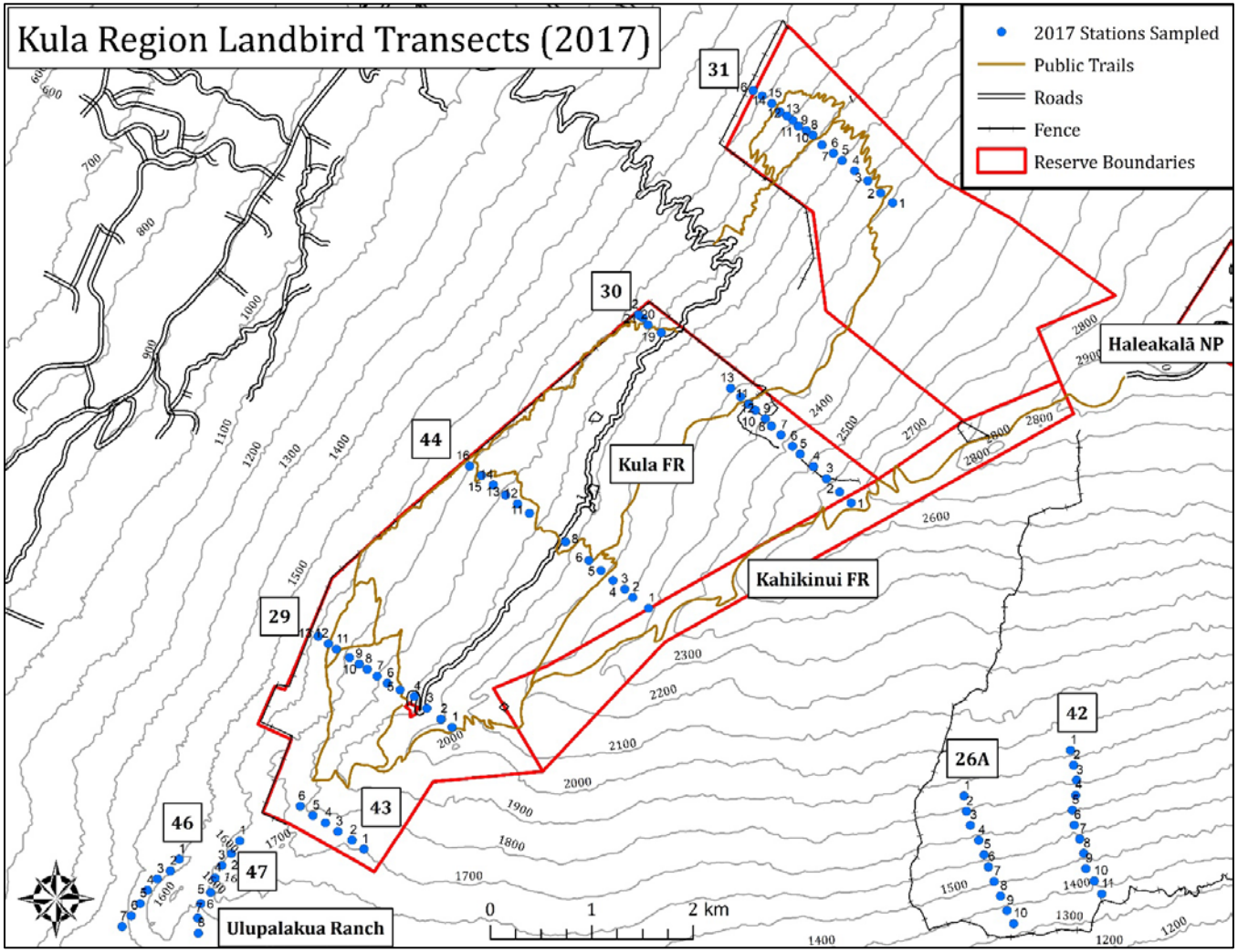


Figure B-6. Transects in the Kula Region.

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Appendix C. Model Selection

Model Selection

Model parameters and model-selection results for forest birds of the Maui 2017 survey. Within each species analysis, models were sorted by differences in second-order Akaike's information criterion corrected for small sample size (ΔAICc) between each candidate model and the model with the lowest AICc value. Models examined included half-normal (HN) and hazard-rate (HR) key detection functions and with cosine (COS), Hermite polynomial (Hpoly), and simple polynomial (Spoly) series expansions. Covariates were incorporated with the most parsimonious model to improve model precision. Covariates included the categorical variables cloud cover (Cloud), amount of rain (Rain), Beaufort wind scale (Wind), Beaufort gust scale (Gust), observer (Obs), time of day (Time), survey month (Month), and survey year (Year). Time of day (CountTime) was also evaluated as a continuous variable. The number of estimated parameters (Num params), and negative log-likelihood (-LogL) are presented. The Akaike model weight (AICc weights) is the likelihood that each model is the best of the converged models evaluated for each species.

Table C-1. Model parameters and model-selection results for forest birds of the Maui 2017 survey (ʻĀkohekohea). Truncation: 70 m, 9 bins.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HN	Cos(2,3)	Year	16	9053.03	18138.19	0	1.00000	–
HN	Cos(2,3)	Rain	6	9187.73	18387.47	249.28	0.00000	–
HN	Cos(2,3)	Cloud	13	9183.05	18392.19	254.00	0.00000	–
HN	Cos	None	3	9196.34	18398.68	260.49	0.00000	–
HN	Hpoly	None	2	9197.78	18399.57	261.38	0.00000	–
HN	Cos(2,3)	CountTime	4	9195.86	18399.73	261.54	0.00000	–
HN	Key	None	1	9208.97	18419.94	281.75	0.00000	–
HR	Key	None	2	9219.95	18443.90	305.71	0.00000	–
HR	Cos	None	–	–	–	–	–	Model failed to converge
HR	Spoly	None	–	–	–	–	–	Model failed to converge
HN	Cos(2,3)	Gust	–	–	–	–	–	Model failed to converge
HN	Cos(2,3)	Obs	–	–	–	–	–	Model failed to converge
HN	Cos(2,3)	Time	–	–	–	–	–	Model failed to converge
HN	Cos(2,3)	Wind	–	–	–	–	–	Model failed to converge

[a] Data were grouped into 9 bins for analysis.

Table C-2. Model parameters and model-selection results for forest birds of the Maui 2017 survey (‘Apapane). Truncation: 55.1 m.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HN	Key	Obs	23	32322.03	64690.19	0	1.00000	–
HN	Cos	None	2	32446.85	64897.70	207.51	0.00000	–
HN	Key	None	1	32448.88	64899.77	209.58	0.00000	–
HR	Cos	None	3	32452.55	64911.10	220.91	0.00000	–
HR	Key	None	2	32499.21	65002.41	312.22	0.00000	–
HN	Key	CountTime	3	32520.28	65046.57	356.38	0.00000	–
HN	Key	Rain	3	32520.28	65046.57	356.38	0.00000	–
HN	Key	Year	4	32520.28	65048.57	358.38	0.00000	–
HN	Key	Cloud	5	32520.28	65050.57	360.38	0.00000	–
HN	Key	Wind	5	32520.28	65050.57	360.38	0.00000	–
HN	Key	Gust	6	32520.28	65052.57	362.38	0.00000	–
HN	Key	Time	17	32520.28	65074.64	384.45	0.00000	–
HN	Hpoly	None	–	–	–	–	–	Key model selected
HR	Spoly	None	–	–	–	–	–	Model failed to converge

Table C-3. Model parameters and model-selection results for forest birds of the Maui 2017 survey (Hawai‘i ‘Amakihi). Truncation: 54.0 m.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HR	Key	Obs	14	14373.69	28775.50	0	1.00000	–
HR	Key	Year	4	14463.71	28935.43	159.93	0.00000	–
HR	Key	Gust	6	14511.78	29035.58	260.08	0.00000	–
HR	Key	Cloud	5	14513.22	29036.46	260.96	0.00000	–
HR	Key	Wind	4	14515.52	29037.04	261.54	0.00000	–
HR	Key	CountTime	3	14515.89	29037.79	262.29	0.00000	–
HR	Spoly	None	3	14516.60	29039.20	263.70	0.00000	–
HR	Key	None	2	14518.09	29040.19	264.69	0.00000	–
HR	Key	Time	17	14503.02	29040.20	264.70	0.00000	–
HR	Key	Rain	3	14522.09	29050.18	274.68	0.00000	–
HN	Key	None	1	14527.50	29057.00	281.50	0.00000	–
HN	Cos	None	–	–	–	–	–	Model failed to converge
HN	Hpoly	None	–	–	–	–	–	Model failed to converge
HR	Cos	None	–	–	–	–	–	Key model selected
HR	Key	Survey	–	–	–	–	–	Model failed to converge

Table C-4. Model parameters and model-selection results for forest birds of the Maui 2017 survey (House Finch). Truncation: 114.0 m.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HN	Key	Month	4	1546.00	3100.11	0	0.96663	–
HN	Key	Gust	7	1546.54	3107.41	7.30	0.02512	–
HN	Key	Rain	5	1550.67	3111.51	11.40	0.00323	–
HN	Key	Wind	5	1550.76	3111.71	11.60	0.00293	–
HR	Spoly	None	3	1554.06	3114.20	14.09	0.00084	–
HN	Key	None	1	1556.57	3115.15	15.04	0.00052	–
HR	Key	None	2	1555.79	3115.61	15.50	0.00042	–
HN	Key	Obs	4	1554.40	3116.92	16.81	0.00022	–
HN	Key	Time	11	1548.46	3119.73	19.62	0.00005	–
HN	Key	Cloud	3	1557.88	3121.84	21.73	0.00002	–
HN	Key	CountTime	3	1557.93	3121.94	21.83	0.00002	–
HN	Cos	None	–	–	–	–	–	Model failed to converge
HN	Hpoly	None	–	–	–	–	–	Model failed to converge
HR	Cos	None	–	–	–	–	–	Model failed to converge
HN	Key	Year	–	–	–	–	–	Model failed to converge

Table C-5. Model parameters and model-selection results for forest birds of the Maui 2017 survey (ʻIʻiwi). Truncation: 48.0 m.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HR	Key	Obs	8	8115.88	16247.82	0	0.99983	–
HR	Key	Year	3	8135.74	16265.44	17.62	0.00015	–
HR	Key	Cloud	5	8130.32	16270.68	22.86	0.00001	–
HR	Key	Gust	6	8130.63	16273.29	25.47	0.00000	–
HR	Cos	None	4	8133.09	16274.20	26.38	0.00000	–
HR	Key	Wind	5	8132.47	16274.97	27.15	0.00000	–
HR	Key	None	2	8135.74	16275.50	27.68	0.00000	–
HR	Key	Rain	3	8135.28	16276.57	28.75	0.00000	–
HR	Key	CountTime	3	8135.33	16276.68	28.86	0.00000	–
HN	Cos	None	3	8135.62	16277.25	29.43	0.00000	–
HN	Key	None	1	8142.31	16286.63	38.81	0.00000	–
HR	Key	Time	17	8130.54	16295.37	47.55	0.00000	–
HN	Hpoly	None	–	–	–	–	–	Model failed to converge
HR	Spoly	None	–	–	–	–	–	Key model selected

Table C-6. Model parameters and model-selection results for forest birds of the Maui 2017 survey (Japanese Bush-Warbler). Truncation: 72.0 m.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HR	Key	Obs	17	16866.97	33768.09	0	1.00000	–
HR	Key	Survey	7	16909.09	33832.21	64.12	0.00000	–
HR	Key	Year	4	16928.18	33864.36	96.27	0.00000	–
HR	Key	Gust	6	16955.57	33923.16	155.07	0.00000	–
HR	Key	Cloud	5	16959.20	33928.41	160.32	0.00000	–
HR	Key	Wind	4	16962.24	33932.49	164.40	0.00000	–
HR	Key	None	2	16965.62	33935.25	167.16	0.00000	–
HR	Key	Month	4	16963.90	33935.81	167.72	0.00000	–
HR	Key	CountTime	3	16965.36	33936.72	168.63	0.00000	–
HR	Key	Rain	3	16966.21	33938.42	170.33	0.00000	–
HN	Key	None	1	17080.96	34163.91	395.82	0.00000	–
HN	Cos	None	–	–	–	–	–	Model failed to converge
HN	Hpoly	None	–	–	–	–	–	Model failed to converge
HR	Cos	None	–	–	–	–	–	Model failed to converge
HR	Spoly	None	–	–	–	–	–	Model failed to converge
HR	Key	Time	–	–	–	–	–	Model failed to converge

Table C-7. Model parameters and model-selection results for forest birds of the Maui 2017 survey (Japanese White-eye). Truncation: 43.9 m.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HN	Key	Obs	11	9914.27	19850.63	0	1.00000	–
HN	Key	Survey	2	9936.42	19876.85	26.22	0.00000	–
HN	Key	Year	3	9935.58	19877.17	26.54	0.00000	–
HN	Key	Rain	2	9944.94	19893.88	43.25	0.00000	–
HN	Key	Wind	3	9946.40	19898.81	48.18	0.00000	–
HN	Cos	None	2	9947.48	19898.96	48.33	0.00000	–
HN	Key	Gust	5	9939.88	19899.07	48.44	0.00000	–
HN	Key	Cloud	4	9945.88	19899.78	49.15	0.00000	–
HR	Cos	None	4	9945.99	19900.00	49.37	0.00000	–
HN	Key	None	1	9949.47	19900.94	50.31	0.00000	–
HN	Key	CountTime	2	9948.86	19901.72	51.09	0.00000	–
HR	Spoly	None	3	9948.91	19903.82	53.19	0.00000	–
HR	Key	None	2	9954.16	19912.32	61.69	0.00000	–
HN	Hpoly	None	–	–	–	–	–	Model failed to converge
HN	Key	Month	–	–	–	–	–	Model failed to converge
HN	Key	Time	–	–	–	–	–	Model failed to converge

Table C-8. Model parameters and model-selection results for forest birds of the Maui 2017 survey (Kiwikiua[a]). Truncation: 76.0 m.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HR	Key	None	2	1129.36	2262.75	0	0.74648	–
HN	Cos	None	2	1130.87	2265.75	3.00	0.16656	–
HN	Key	None	1	1132.52	2267.05	4.30	0.08695	–
HN	Hpoly	None	–	–	–	–	–	Key model selected
HR	Cos	None	–	–	–	–	–	Model failed to converge
HR	Spoly	None	–	–	–	–	–	Model failed to converge
HR	Key	Cloud	–	–	–	–	–	Covariate not evaluated
HR	Key	CountTime	–	–	–	–	–	Covariate not evaluated
HR	Key	Gust	–	–	–	–	–	Covariate not evaluated
HR	Key	Obs	–	–	–	–	–	Covariate not evaluated
HR	Key	Rain	–	–	–	–	–	Covariate not evaluated
HR	Key	Time	–	–	–	–	–	Covariate not evaluated
HR	Key	Wind	–	–	–	–	–	Covariate not evaluated
HR	Key	Year	–	–	–	–	–	Covariate not evaluated

Table C-9. Model parameters and model-selection results for forest birds of the Maui 2017 survey (Maui ‘Alauahioa[a]). Truncation: 37.0 m.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HN	Cos(2,3)	Obs	23	12315.11	24676.40	0	1.00000	–
HN	Cos(2,3)	Year	17	12504.28	25042.66	366.26	0.00000	–
HN	Cos(2,3)	CountTime	4	12557.44	25122.90	446.50	0.00000	–
HN	Cos(2,3)	Wind	5	12556.64	25123.29	446.89	0.00000	–
HN	Cos	None	3	12563.63	25133.26	456.86	0.00000	–
HN	Cos(2,3)	Cloud	4	12563.58	25135.17	458.77	0.00000	–
HR	Key	None	2	12591.25	25186.50	510.10	0.00000	–
HN	Key	None	1	12658.44	25318.88	642.48	0.00000	–
HN	Hpoly	None	–	–	–	–	–	Model failed to converge
HR	Cos	None	–	–	–	–	–	Model failed to converge
HR	Spoly	None	–	–	–	–	–	Model failed to converge
HN	Cos(2,3)	Gust	–	–	–	–	–	Model failed to converge
HN	Cos(2,3)	Rain	–	–	–	–	–	Model failed to converge
HN	Cos(2,3)	Time	–	–	–	–	–	Model failed to converge

[a] Data were grouped into 9 bins for analysis.

Table C-10. Model parameters and model-selection results for forest birds of the Maui 2017 survey (Red-billed Leiothrix). Truncation: 57.2 m.

Model	Series adjustment	Covariate	Num params	-LogL	AICc	ΔAICc	AICc weights	Notes
HR	Key	Obs	12	8135.37	16294.88	0	1.00000	–
HR	Key	Wind	4	8157.33	16322.69	27.81	0.00000	–
HR	Key	Survey	7	8157.13	16328.32	33.44	0.00000	–
HR	Key	Year	4	8161.56	16331.14	36.26	0.00000	–
HR	Key	None	2	8165.30	16334.61	39.73	0.00000	–
HR	Key	CountTime	3	8158.74	16338.30	43.42	0.00000	–
HR	Key	Rain	3	8166.45	16338.92	44.04	0.00000	–
HR	Key	Cloud	3	8166.67	16339.35	44.47	0.00000	–
HR	Key	Gust	6	8164.01	16340.05	45.17	0.00000	–
HR	Key	Month	4	8166.58	16341.18	46.30	0.00000	–
HN	Key	None	1	8183.59	16369.19	74.31	0.00000	–
HN	Cos	None	–	–	–	–	–	Model failed to converge
HN	Hpoly	None	–	–	–	–	–	Model failed to converge
HR	Cos	None	–	–	–	–	–	Key model selected
HR	Spoly	None	–	–	–	–	–	Convergence failed in bootstrap iterations
HR	Key	Time	–	–	–	–	–	Model failed to converge

Appendix D. Inference Area Justifications

The 2017 East Maui landbird survey area naturally fell into four Regions (polygons): Windward, Leeward, HALE, and Kula FR. The Windward Region is subdivided into sections based on habitat and elevations surveyed. These sections included Makawao FR, upper Waikamoi (between the Koʻolau Gap and Makawao FR), Koʻolau Gap, TR5 and TR6 (western Waikamoi and Koʻolau FR), Hanawī NAR, and Hāna FR (including a small area of Koʻolau FR). The HALE Region was subdivided into Kīpahulu Valley and Manawainui. The Kula and Leeward Regions were not subdivided.

To determine the lower edge of the inference area in each section of the Windward and HALE Regions, we first determined the nearest 10 m contour interval that encapsulated a 60 m buffer around the lowest point count station. This generally served as the lower bound edge for all sections. However, this contour varied by section. In a few cases, political boundaries were used particularly when transitioning between sections.

Lower edge

- Makawao FR/TR2 – 1,280 m contour
- Upper Waikamoi/TR3 – Waikamoi Preserve boundary between TR2 and TR3, then 1310m contour
- Koʻolau Gap/TR4 – upper rim on west and east sides of the gap, 580 m contour across the gap
- Western Waikamoi/TR5 and TR6 – 1,310 m contour
- Hanawī NAR/TR7, 8, and 9 – NAR boundary on east and west sides, 910 m contour across bottom
- Hāna FR/TR10 – 1,610 m contour
- Kīpahulu Valley/TR16, 17 – NP boundary (which follows the north rim of the Kīpahulu Valley), then 720m contour (except an unsurveyed portion)
- Manawainui/TR18 – 1,220 m contour across bottom, FR and NP boundaries on western edge (that follow the eastern rim of Kaupō Gap).

Upper edge

- Manawainui – 2,170 m contour
- Kīpahulu Valley – Habitat layer delineating “forest habitat” (This extended farther than the 2,020 m contour.)
- Hanawī NAR – NAR/NP boundary until the intersection with the Waikamoi boundary
- TR5 and TR6 – 2,070 m contour
- Koʻolau Gap – 1,900 m contour

- Upper Waikamoi – Trail layer that follows the line of the conifer and native forest boundary (roughly along the 1,900 m contour) until preserve boundary, boundary back to TR2 area.

Kiwikiu Inference Area

Lower edge

- Upper Waikamoi/TR3 – 1,520 m contour
- Koʻolau Gap/TR4 – 1,520 m contour
- Western Waikamoi/TR5 and TR6 – 1,520 m contour until TR5. 1,430 m contour from TR6 east
- Hanawī NAR/TR7, 8, and 9 – 1,430 m contour until TR8. Fenceline (roughly the 1,610 m contour) by TR9 to NP boundary.
- Hāna FR/TR10 – Fenceline to NP boundary. Transition to 2,020 m contour.
- Kīpahulu Valley/TR16, 17 – 1430 m contour past TR16. 1,520 m contour past TR17 to edge of valley.
- Manawainui/TR18 – 1,740 m contour to central Manawainui. Habitat layer connects to top edge.

Upper edge

- Manawainui - "Forest" or "Scattered Forest" habitat type layer from the State of Hawaiʻi Office of Planning (http://planning.Hawaiʻi.gov/gis/download-gis-data/)
- Kīpahulu Valley – Habitat layer
- Hanawī NAR – Habitat layer (except one additional section to incorporate the top of TR9 and TR10.
- TR5 and TR6 – Habitat layer
- Koʻolau Gap – Habitat layer
- Upper Waikamoi – Trail layer that follows the line of the conifer and native forest boundary (roughly along the 1,900 m contour) until intersection with habitat layer delineating native forest past TR3.

ʻĀkohekohe Inference Area

Lower edge

- Upper Waikamoi/TR3 – 1,520 m contour
- Koolau Gap/TR4 – 1,670 m contour
- Western Waikamoi/TR5 and TR6 – 1670m contour to Hanawī NAR boundary.
- Hanawī NAR/TR7, 8, and 9 – 1,570 m contour from TR7 to TR8. Transition to 1670m between TR8 and TR9. Straight line transition from TR9 to 1,820 m contour.
- Hāna FR/TR10 – 1,820 m contour
- Kīpahulu Valley/TR16, 17 – 1,820 m contour past TR10. 1,690 m contour across valley.

- Manawainui/TR18 – 1,620 m contour to NP boundary. Habitat layer connects to top edge.

Upper edge

- Manawainui - "Forest" or "Scattered Forest" habitat type layer from the State of Hawai'i Office of Planning.
- Kīpahulu Valley – Habitat layer
- Hanawī NAR – Habitat layer (except one additional section to incorporate the top of TR9 and TR10.
- TR5 and TR6 – Habitat layer
- Ko'olau Gap – Habitat layer
- Upper Waikamoi – Trail layer that follows the line of the conifer and native forest boundary (roughly along the 1,900 m contour) until intersection with habitat layer delineating native forest past TR3.

Maui 'Alauahio Inference Area

Lower edge

- Upper Waikamoi/TR3 – 1,220 m contour
- Ko'olau Gap/TR4 – 1,100 m contour
- Western Waikamoi/TR5 and TR6 – 1200 m contour
- Hanawī NAR/TR7, 8, and 9 – 1,220 m contour until TR9. Straight transition to NP boundary where TR10 crosses boundary.
- Hāna FR/TR10 –NP boundary.
- Kīpahulu Valley/TR16, 17 – NP boundary to 850 m contour (except one section in the east where the species status is unknown). 850 m contour across TR16 (lower shelf). Transition to 1040m contour across TR17 (upper shelf).
- Manawainui/TR18 – 1,520 m contour to NP boundary. NP boundary up to habitat layer.

Upper edge

- Manawainui - "Forest" or "Scattered Forest" habitat type layer from the State of Hawai'i Office of Planning.
- Kīpahulu Valley – Habitat layer
- Hanawī NAR – 2,230 m contour to Waikamoi boundary.
- TR5 and TR6 – 2,070 m contour from Waikamoi boundary to rim of Koolau Gap.
- Ko'olau Gap – Habitat layer for "native shrubland".
- Upper Waikamoi – Habitat layer for "non-native forest" from Gap to 1,220 m contour.

Appendix E. Population Trend Assessment

In addition to using end-point models to assess trends, we investigated using linear regression models to evaluate long-term trends in the two endangered species and Maui ‘Alauahio. We used a log-link regression model to calculate the distribution of the posterior probabilities of the slope using the interface to OpenBUGS MCMC Software package BRugs (version 0.9-0; 2017-06-26; Thomas et al. 2006) in program R (version 3.4.1; 2017-06-30; R Core Team 2017). The intercept parameter describes the density at time $t = 0$, the slope is the rate of change with each unit increase in time t, and precision equals 1/variance. The intercept and slope parameters were given diffuse normal priors, and a diffuse gamma prior was given for precision. A diffuse prior distribution was chosen to restrict the posterior distribution to the likelihood, which was dominated by the observed data. The trends were centered, and the model parameters were estimated from 50,000 iterations for each of three chains (i.e., model runs) after discarding the first 2,000 iterations (a “burn-in” period). The three chains were pooled (150,000 total samples) to calculate the posterior distribution.

We used a 25% change of a population in 25 years as the threshold for defining the ecological relevance of a trend. Trends were defined as an ecologically meaningful decrease when the slope exceeded the lower threshold (< -0.0119), an ecologically meaningful increase when the slope surpassed the upper threshold (> 0.0093), and an ecologically negligible trend when the slope fell within the threshold levels (-0.0119 < slope < 0.0093) (Camp et al. 2008).

Model diagnostics were conducted to assess the validity of using linear models to assess trends. The distance-derived density estimates for each species-region strata were fitted with a traditional least-squares model using simple linear regression in R. The R language ‘LearnBayes’ library (Albert 2012) was used to sample from the joint posterior distribution of the slope and variance following model diagnostics procedures in Maindonald and Braun (2006). Histograms of the simulated posterior draws of the regression coefficients beta and error standard deviation sigma were plotted and inspected visually to ascertain for deviations from a normal distribution. Because of the small sample size in the time series, < 10 surveys, we also conducted a Shapiro-Wilk test to quantitatively test if the errors came from normal distribution (Adler 2010).

Diagnostic plots indicate little to no evidence of non-normality in the residuals from the log-linear model of annual density time series for any species-region strata. The posterior medians of the regression parameters slope were similar in value to the ordinary regression estimates, and the histograms of simulated draws from the marginal posterior distributions appeared approximately normally distributed. Evidence that the data were normally distributed was supported by the Shapiro-Wilk test (p-value > 0.05). There was evidence that the error distributions were non-normal and skewed indicating unequal variances. The standard procedure of log-transforming the density data was used to stabilize the error variances (Dixon and Pechmann 2005).

Outliers were also identified using Bayesian residuals and visually inspected following methods detailed in Maindonald and Braun (2006). No densities were identified as outliers for any species-region strata; < 0.4 probability for all strata.

Temporal autocorrelation in annual abundances was assessed with the 'acf' function in R and AIC procedures were used to identify the lag autocorrelation that removed serial correlation. AIC statistics indicate that an independence model was appropriate for all species-region strata; therefore, all trend assessments were conducted using log-linear regression models.

Inspection of the model diagnostics do not show serious violation of the model assumptions. However, preliminary analyses revealed that the trend assessment model could not accurately recover parameters in our time series although the models appeared to mix well and convergence was achieved. We assessed identifiability of the intercept and slope parameters under a simulated data set with 25% change in density over 25 years of a fully annualized time series compared to a sparse time series similar to our data set. Although the fully annualized time series performed as expected, we were unable to recover unbiased or precise estimates for either the intercept or slope parameters from the sparse time series. Estimator bias exceeded 100 magnitude and the interquartile ranges of the sparse time series estimates bracketed the true values estimated from the fully annualized time series only because the former possessed extreme levels of uncertainty (e.g., coefficient of variation >> 1000%). Therefore, a regression model was not robust when confronted with the extremely sparse survey data restricting trends assessment to end-point comparisons and employing qualitative loess smoothers to illustrate population pattern and could not be used to evaluate the long-term population trends for the two endangered species and Maui 'Alauahio.

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Thomas, A., B. O'Hara, U. Ligges, and S. Sturtz. 2006. Making BUGS Open. R News 6:12–17. https://cran.r-project.org/doc/Rnews/

Appendix F. East Maui Bird Occurrence Maps

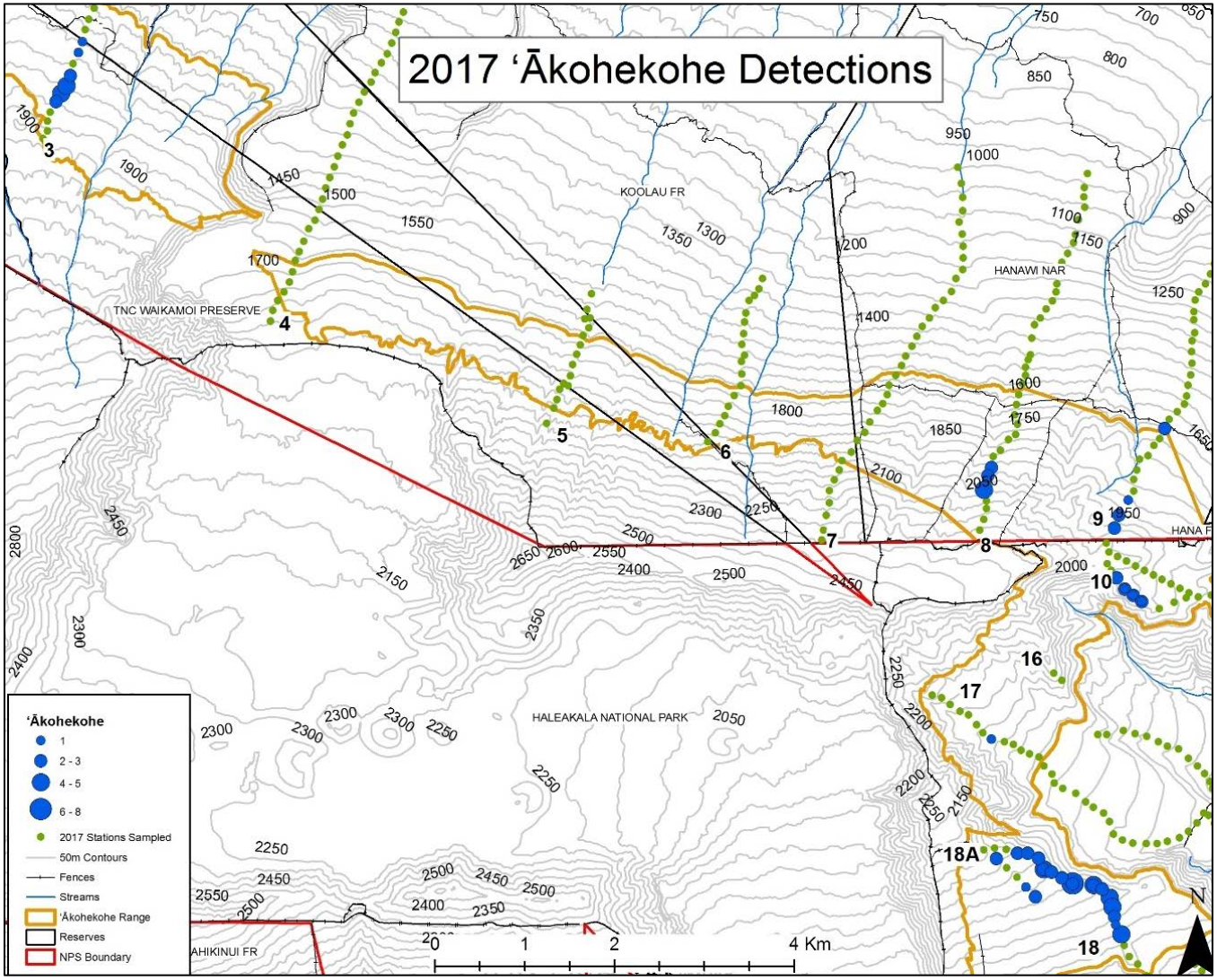


Figure F-1. ‘Ākohekohe detections during the 2017 East Maui landbird survey.

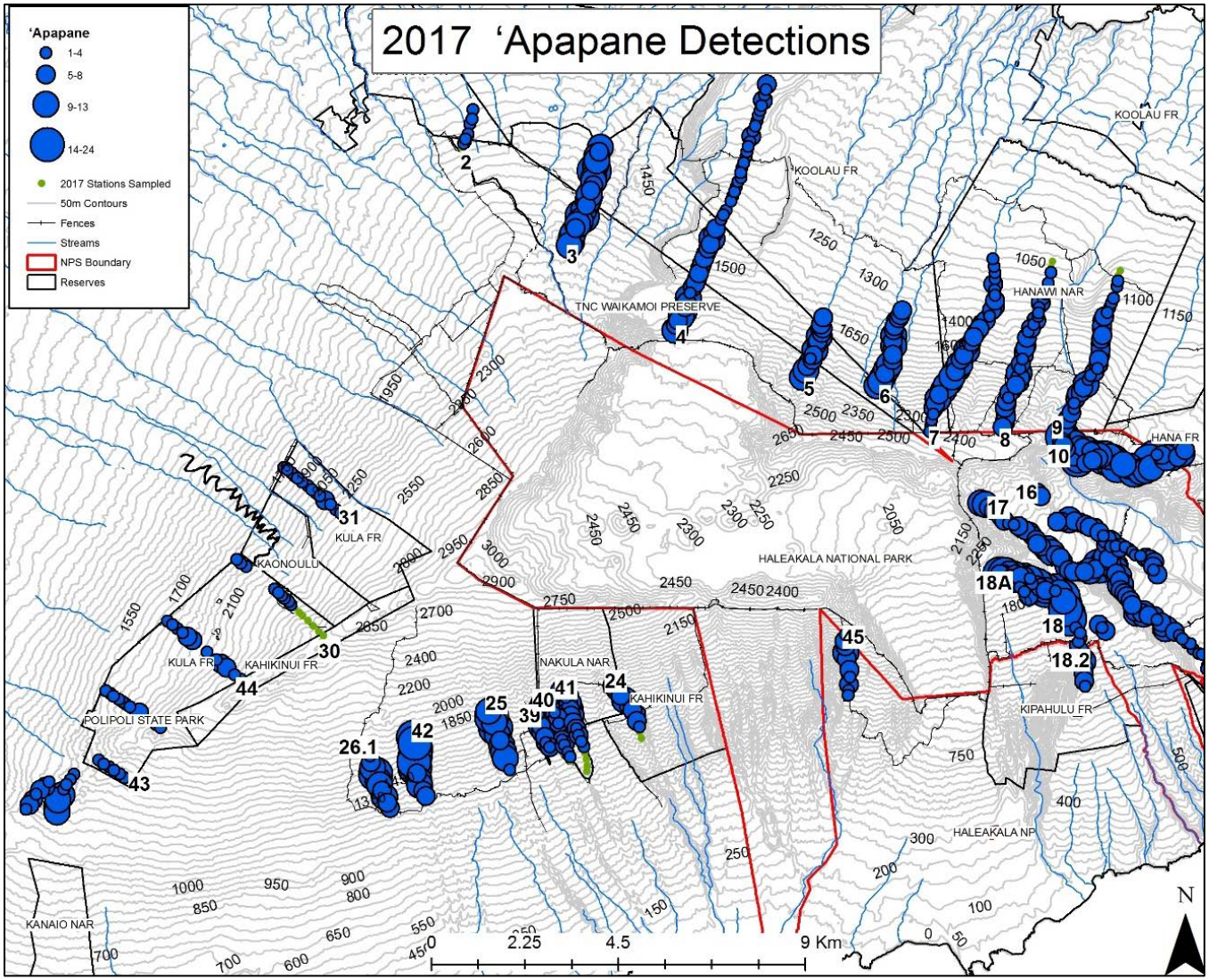


Figure F-2. ‘Apapane detections during the 2017 East Maui landbird survey.

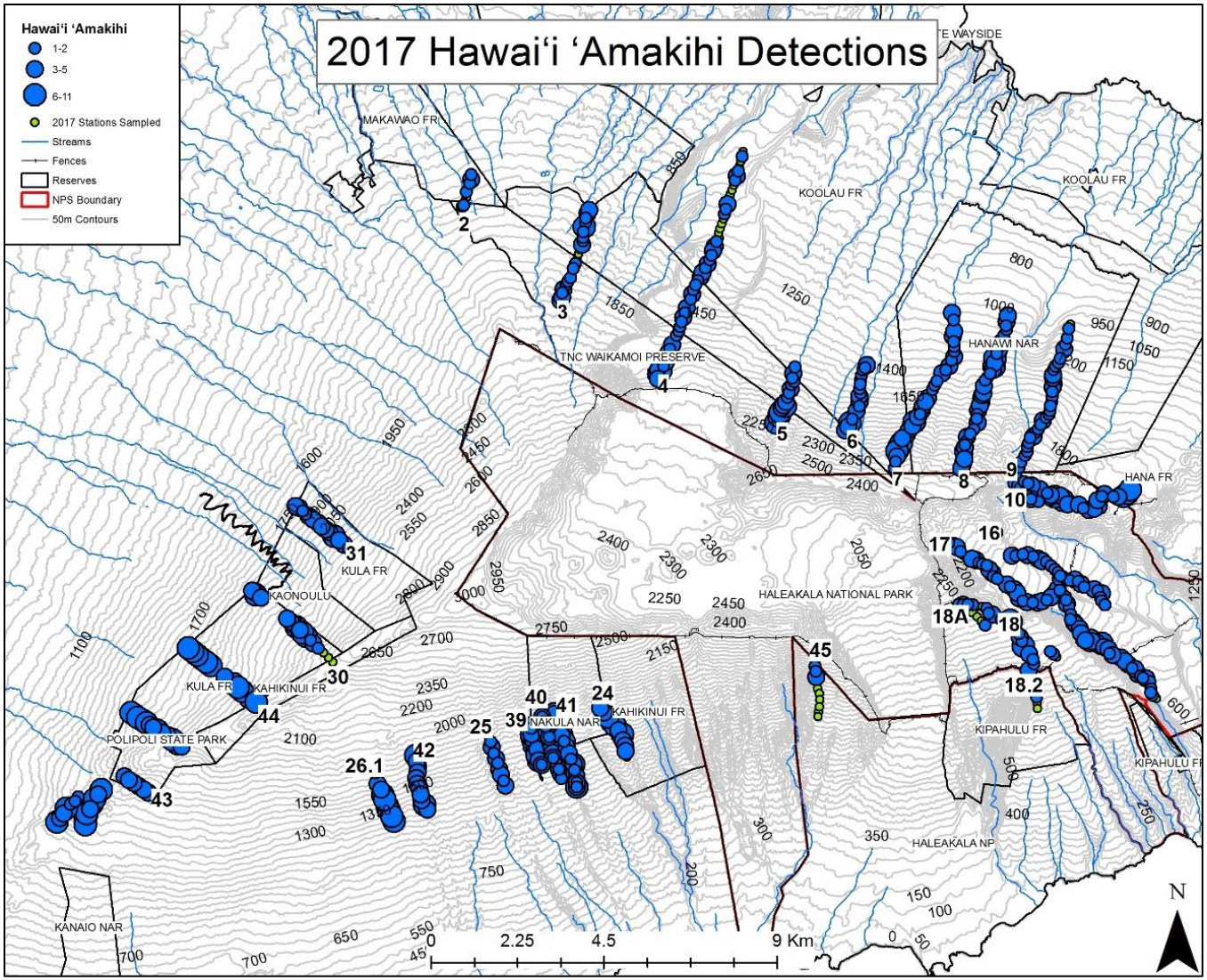


Figure F-3. Hawai‘i ‘Amakihi detections during the 2017 East Maui landbird survey.

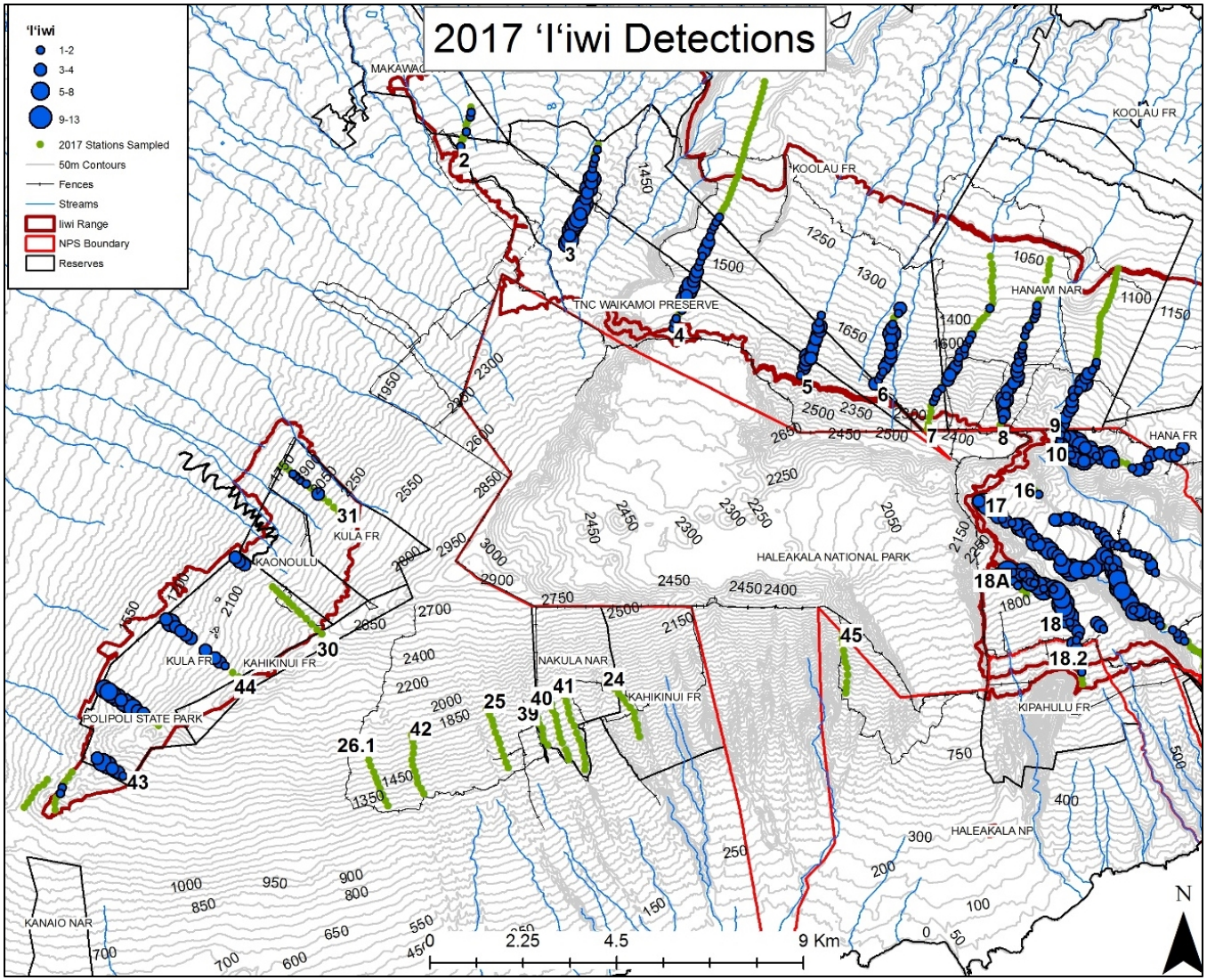


Figure F-4. ‘I‘iwi detections during the 2017 East Maui landbird survey.

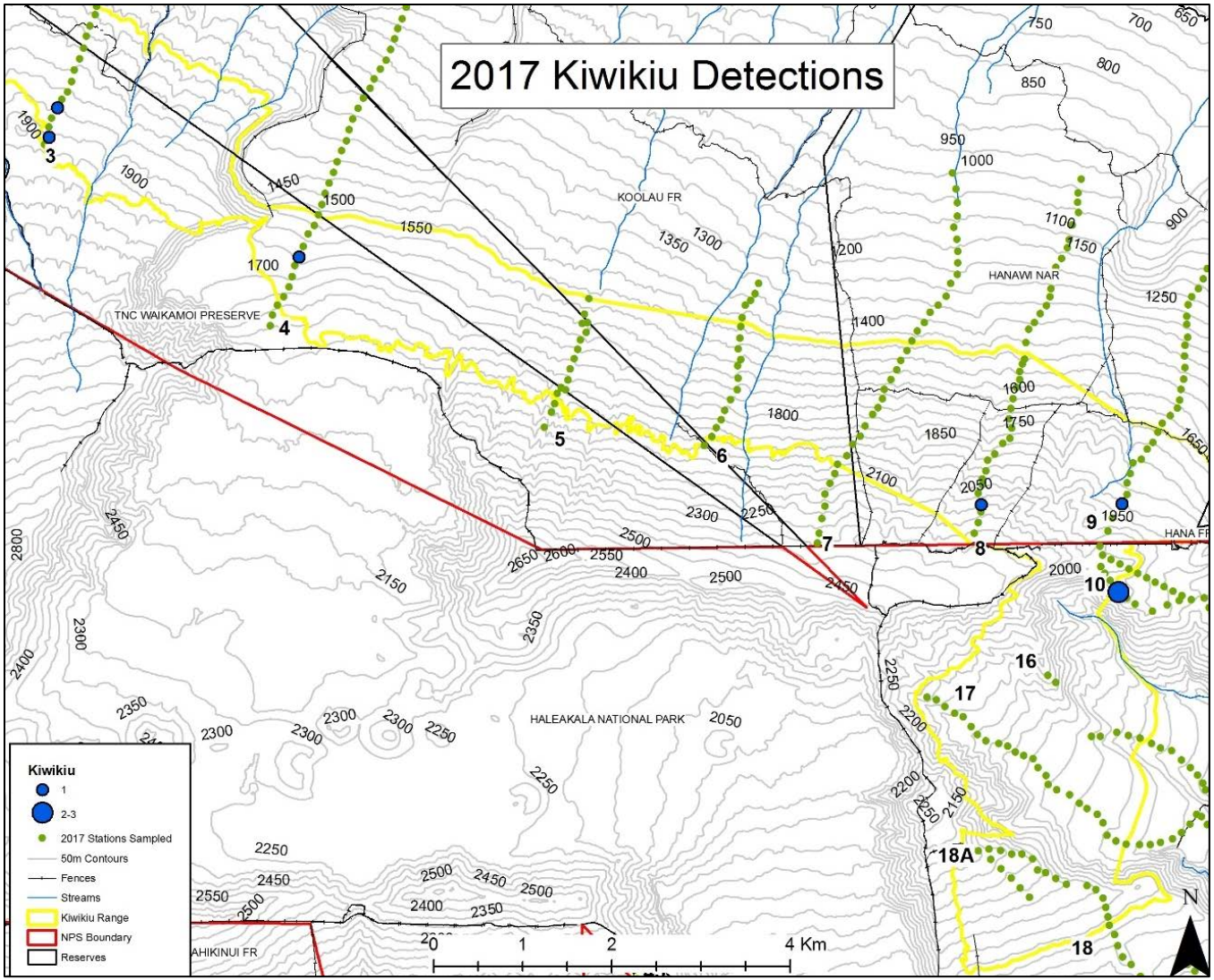


Figure F-5. Kiwikiu detections during the 2017 East Maui landbird survey.

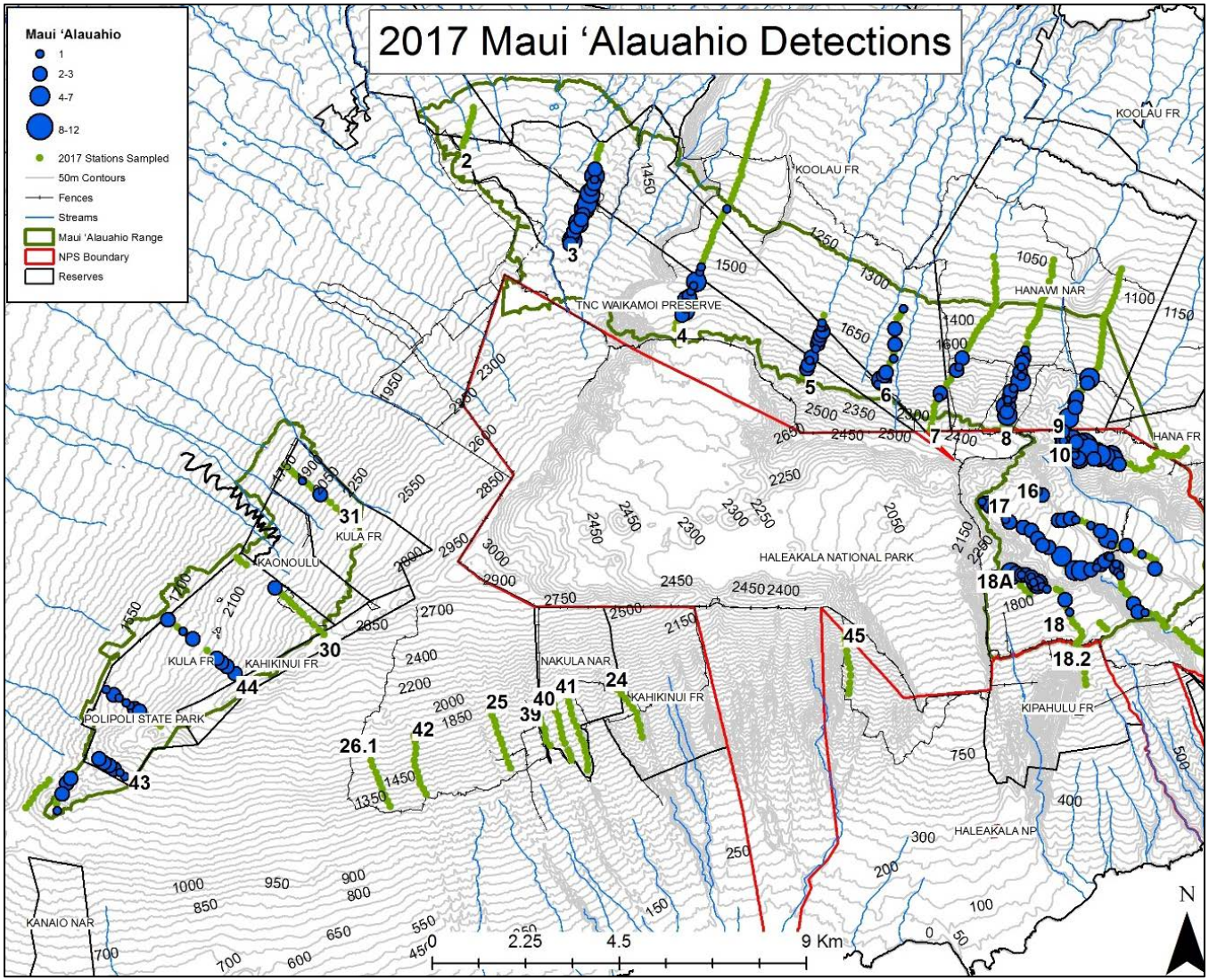


Figure F-6. Maui ‘Alauahio detections during the 2017 East Maui landbird survey.

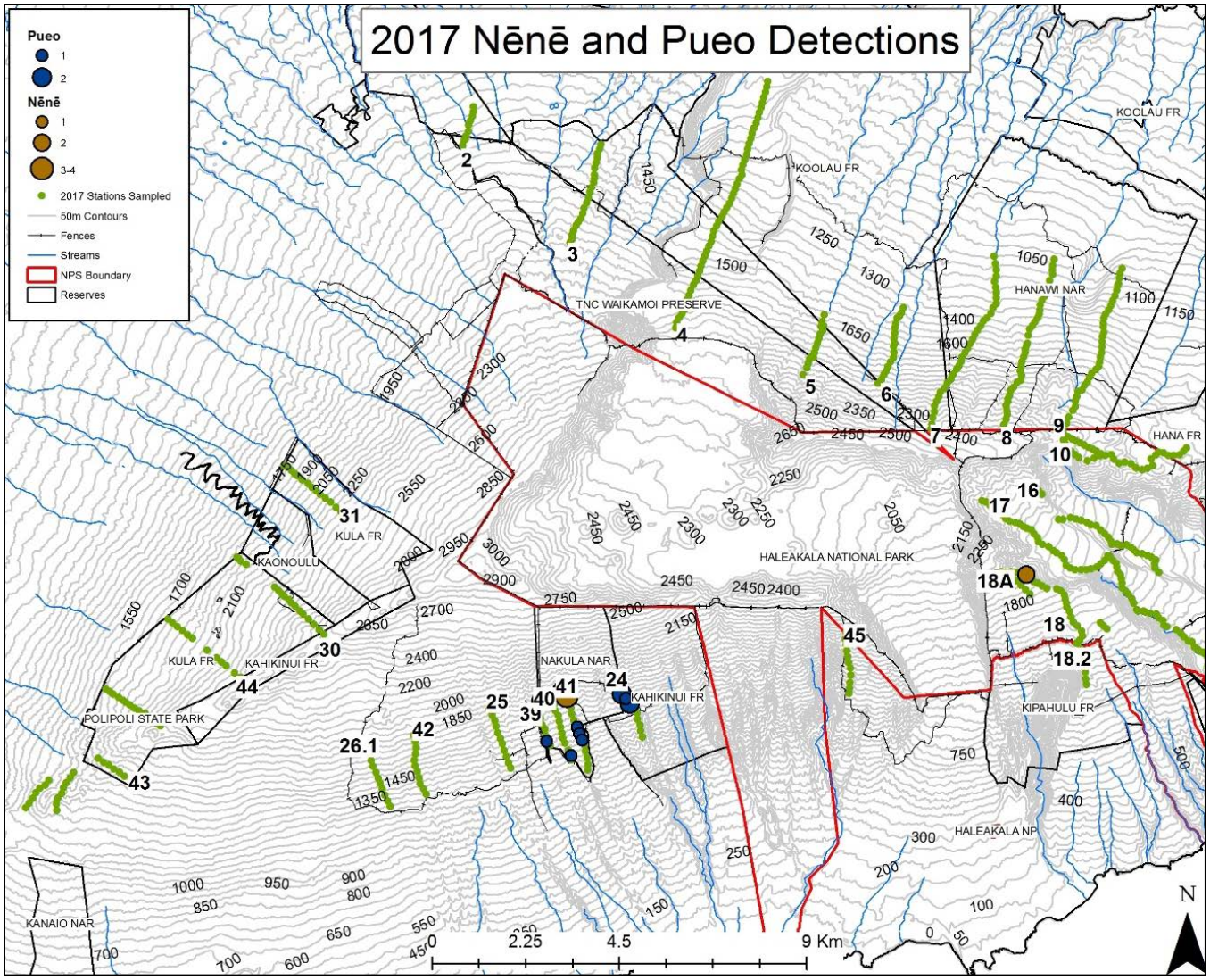


Figure F-7. Nēnē and Pueo detections during the 2017 East Maui landbird survey

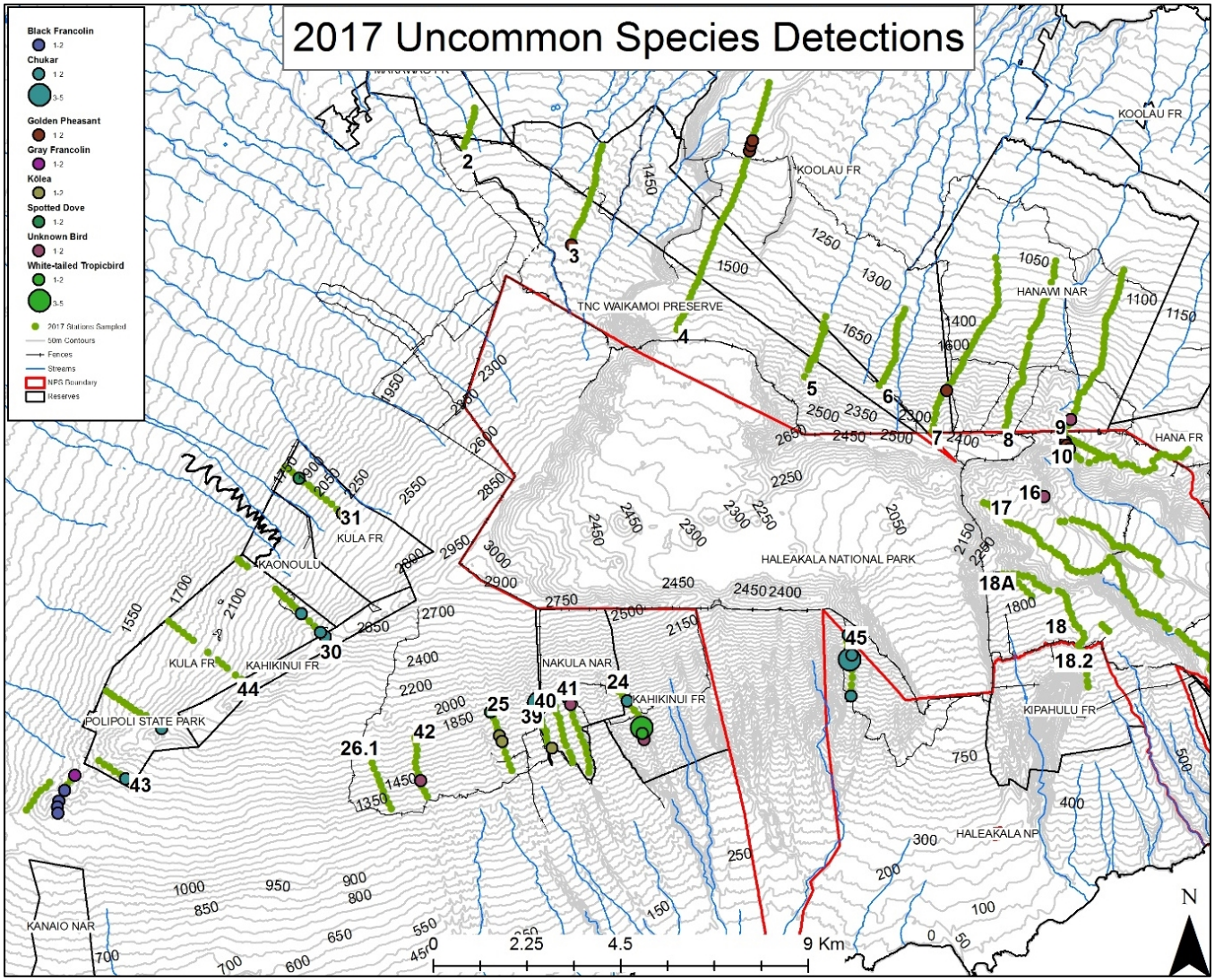


Figure F-8. Uncommon species detected during the 2017 East Maui landbird survey.

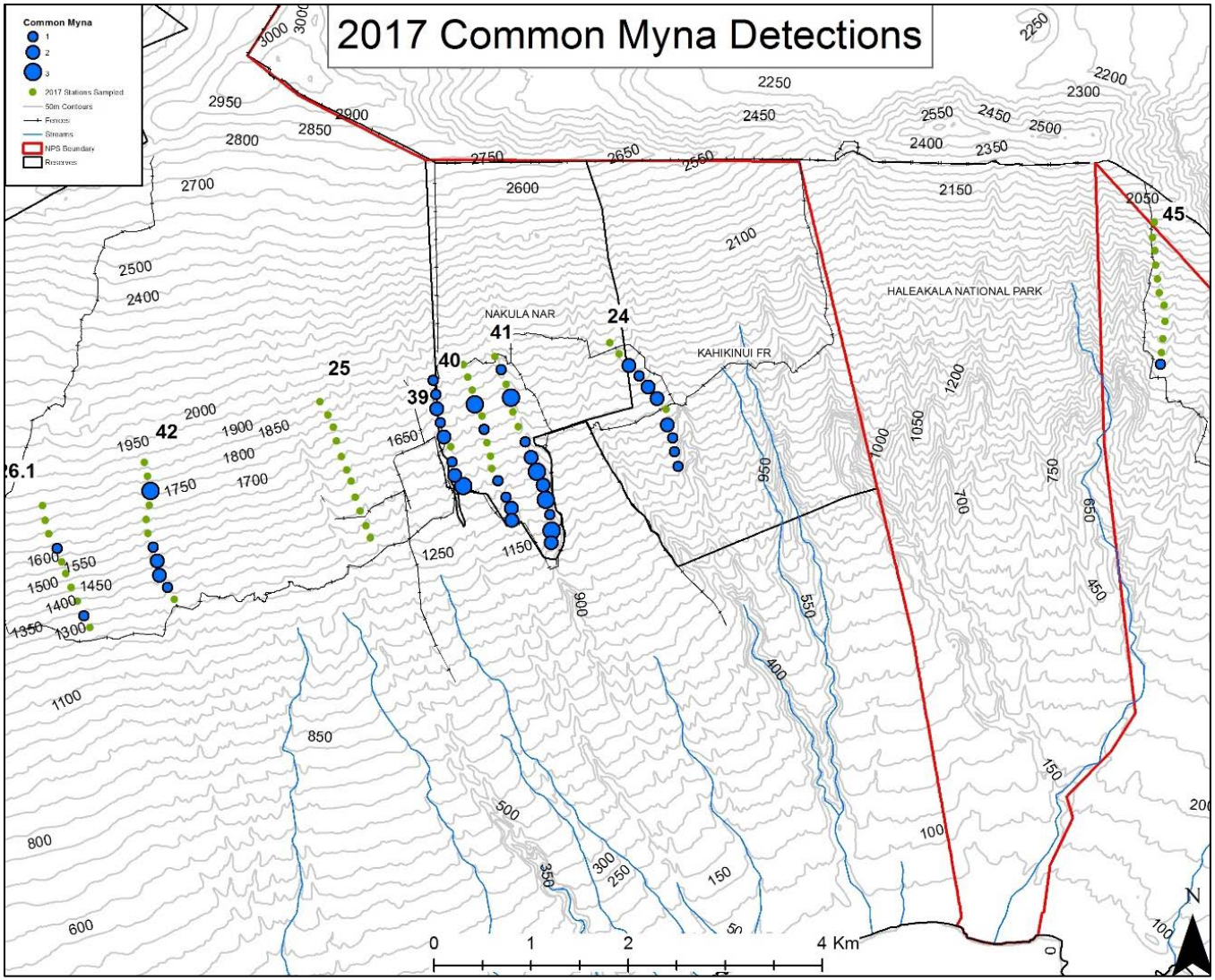


Figure F-9. Common Myna detections during the 2017 East Maui landbird survey.

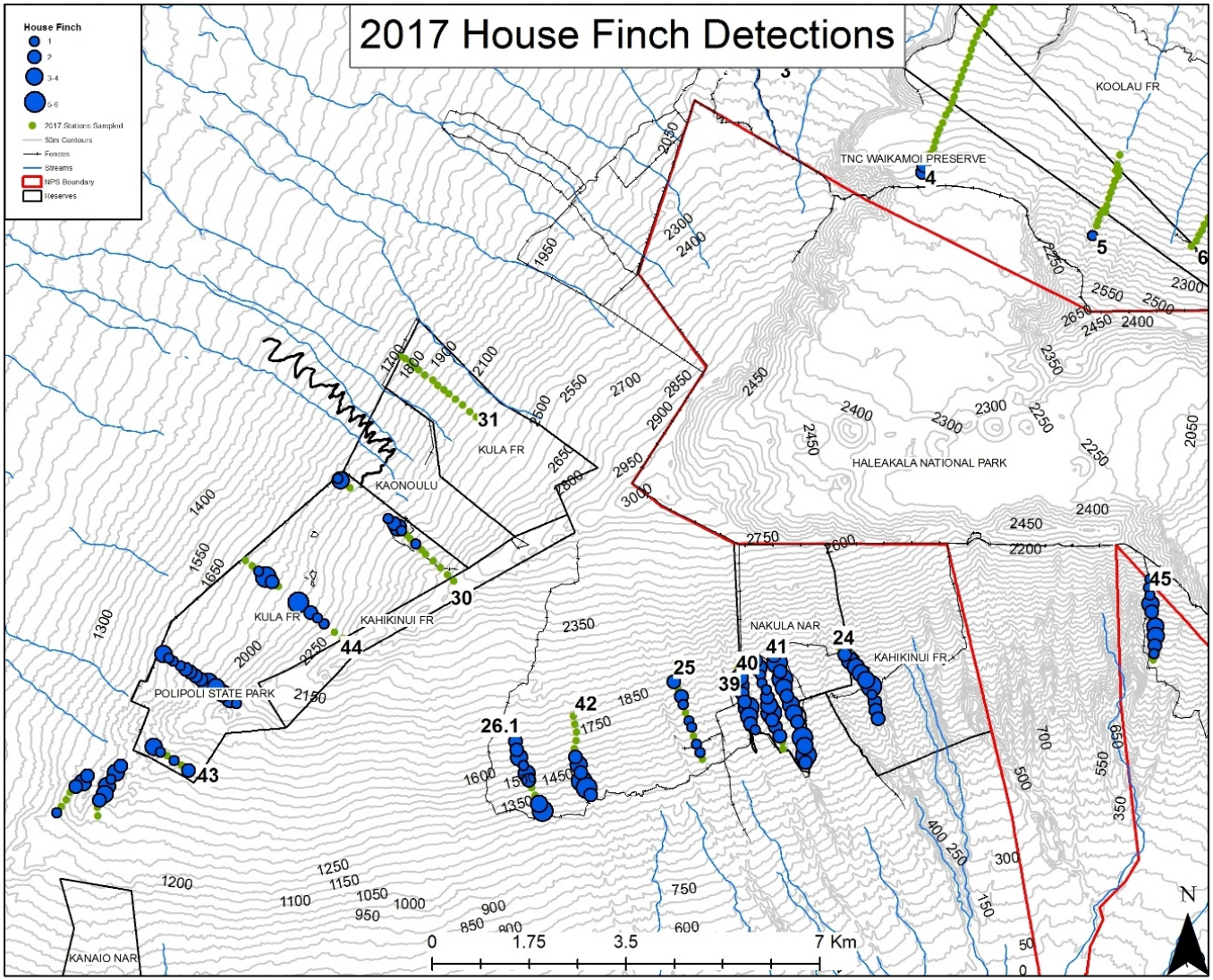


Figure F-10. House Finch detections during the 2017 East Maui landbird survey.

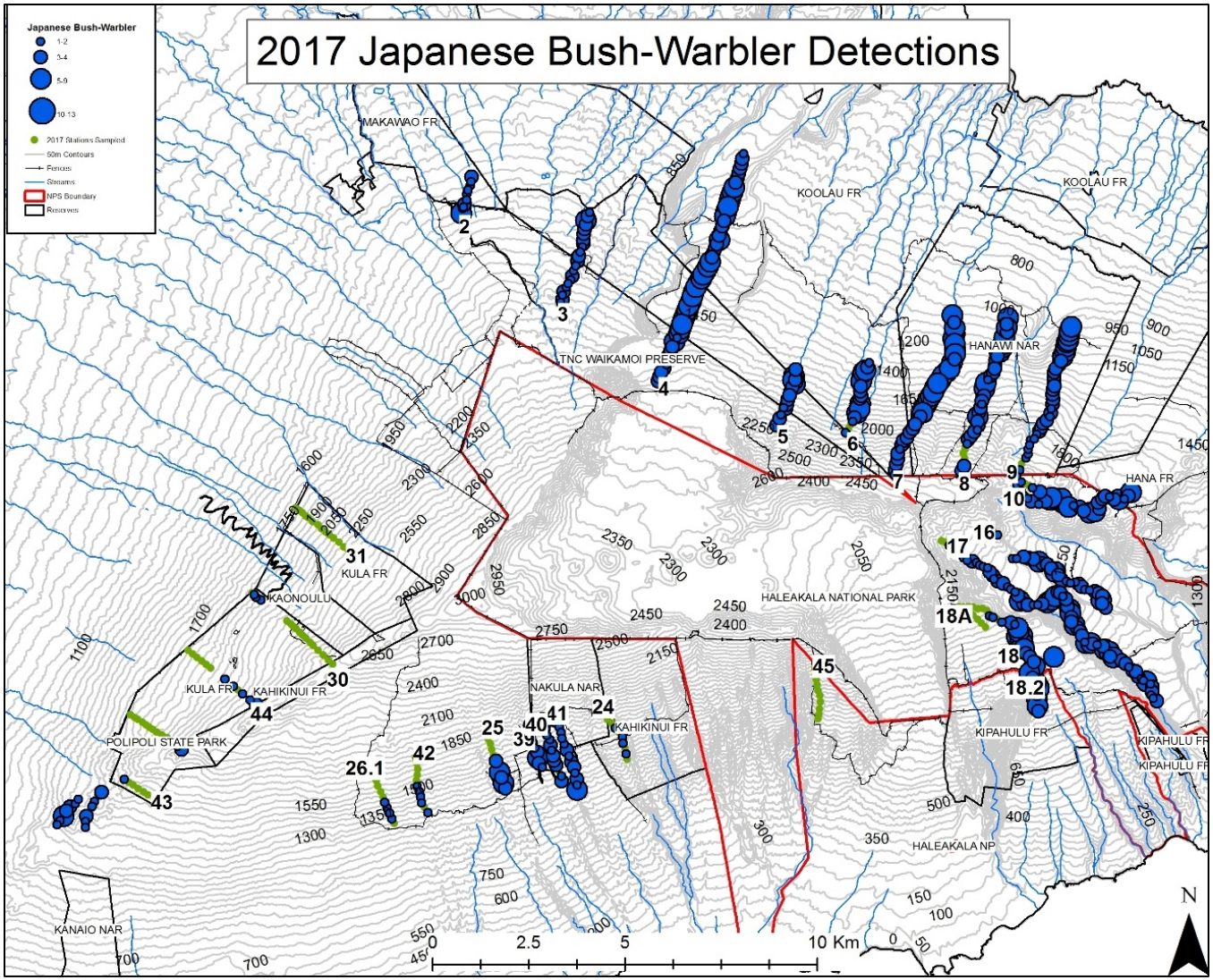


Figure F-11. Japanese Bush-Warbler detections during the 2017 East Maui landbird survey.

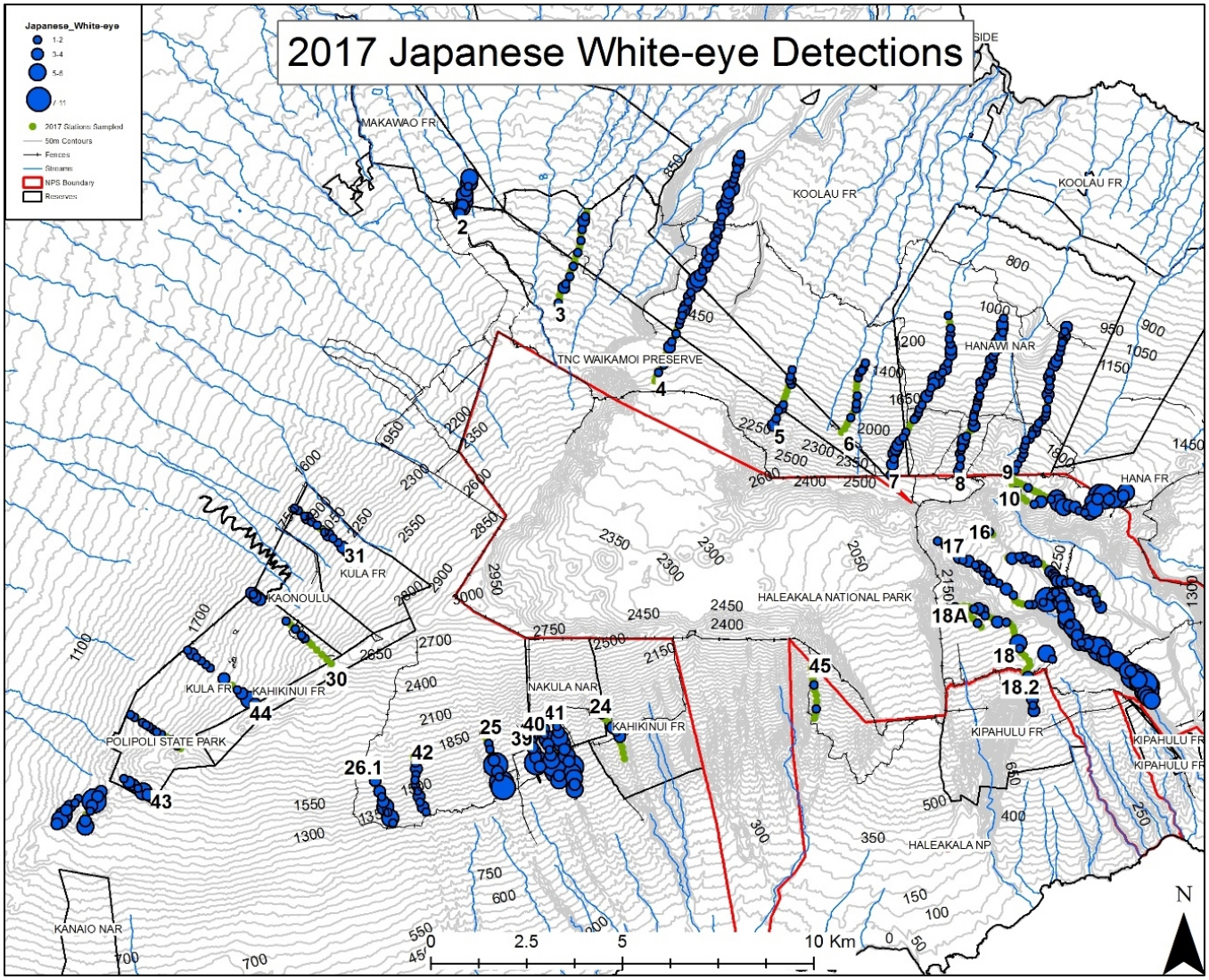


Figure F-12. Japanese White-eye detections during the 2017 East Maui landbird survey.

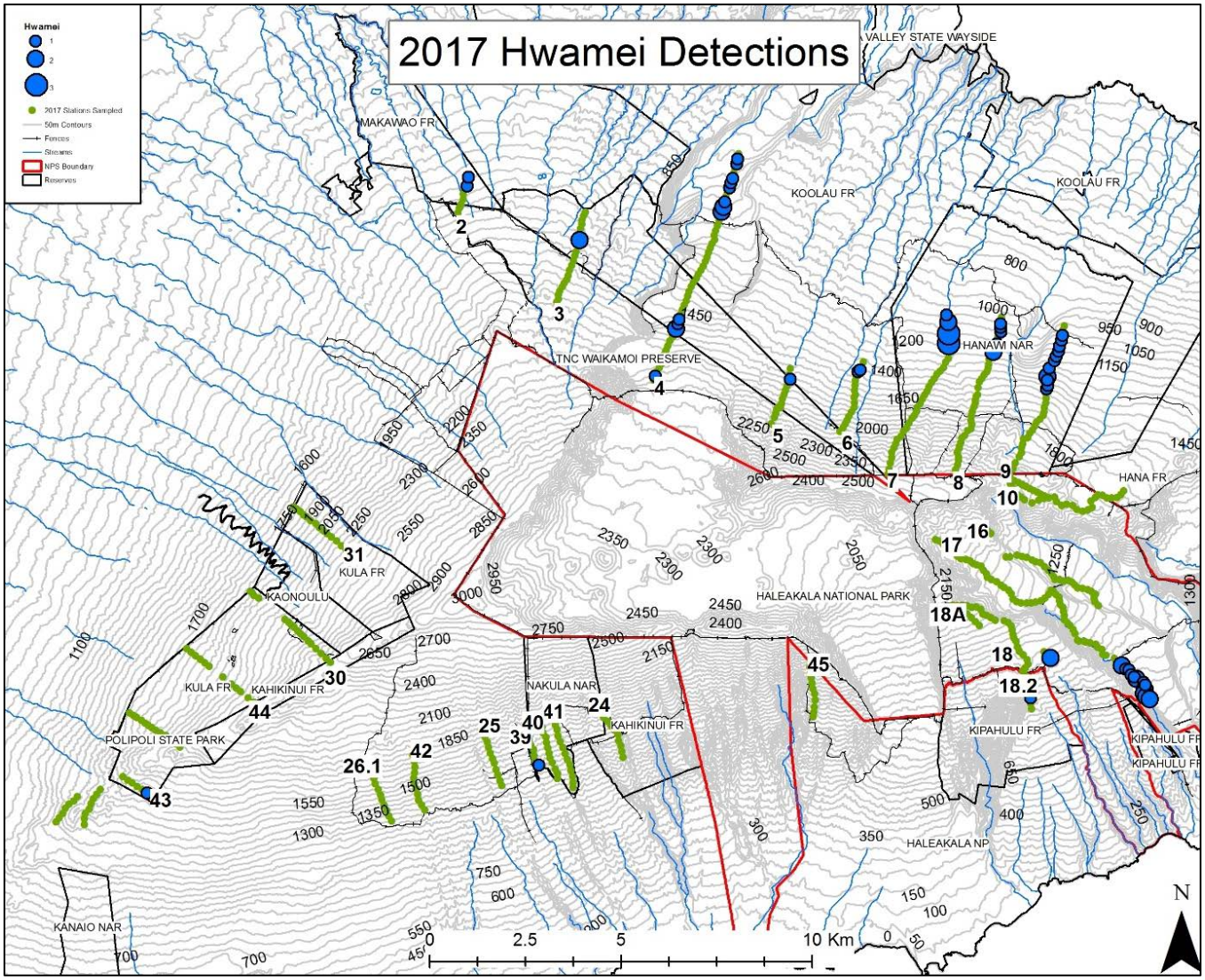


Figure F-13. Hwamei (Melodious Laughing Thrush) detections during the 2017 East Maui landbird survey.

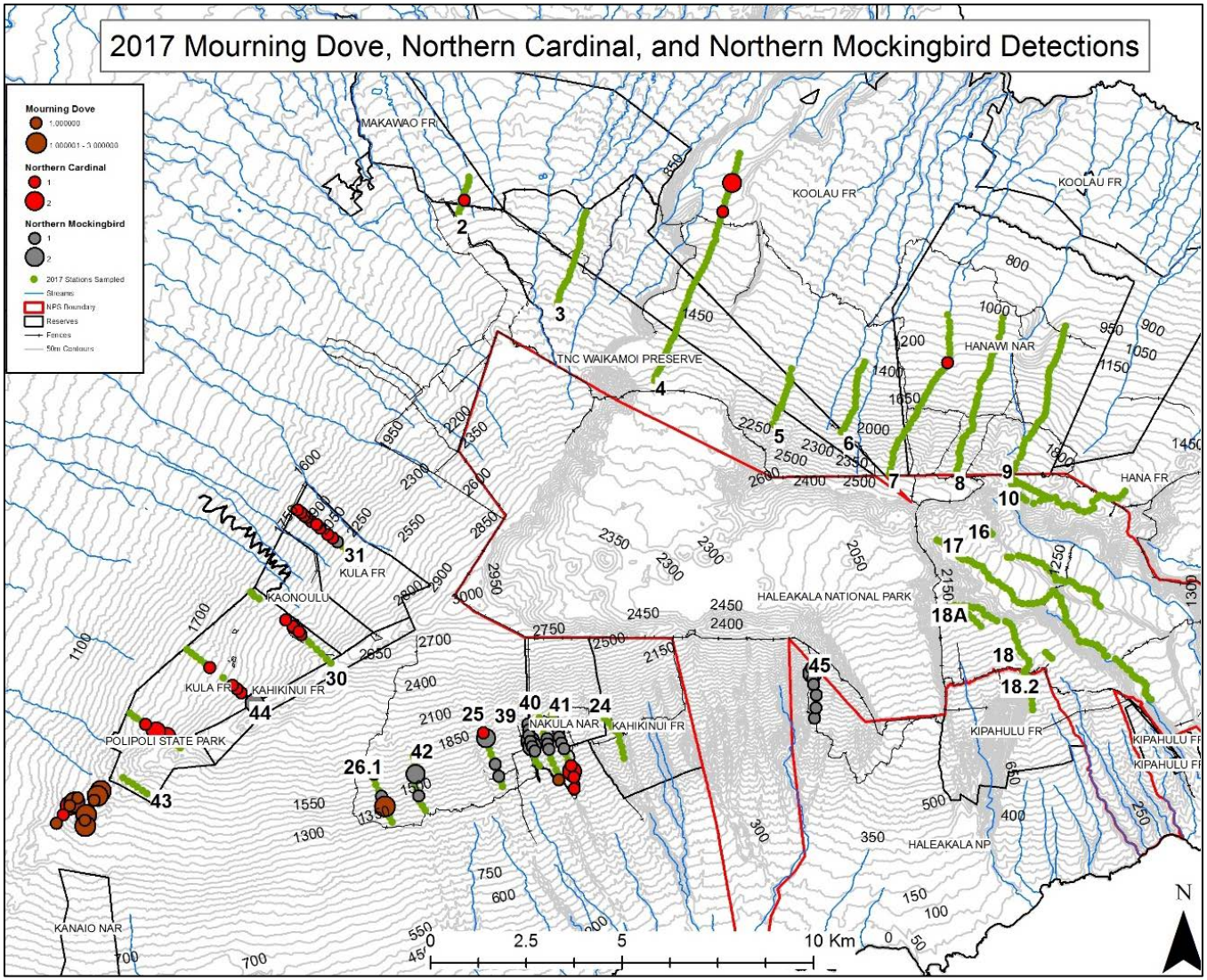


Figure F-14. Mourning Dove, Northern Cardinal, and Northern Mockingbird detections during the 2017 East Maui landbird survey.

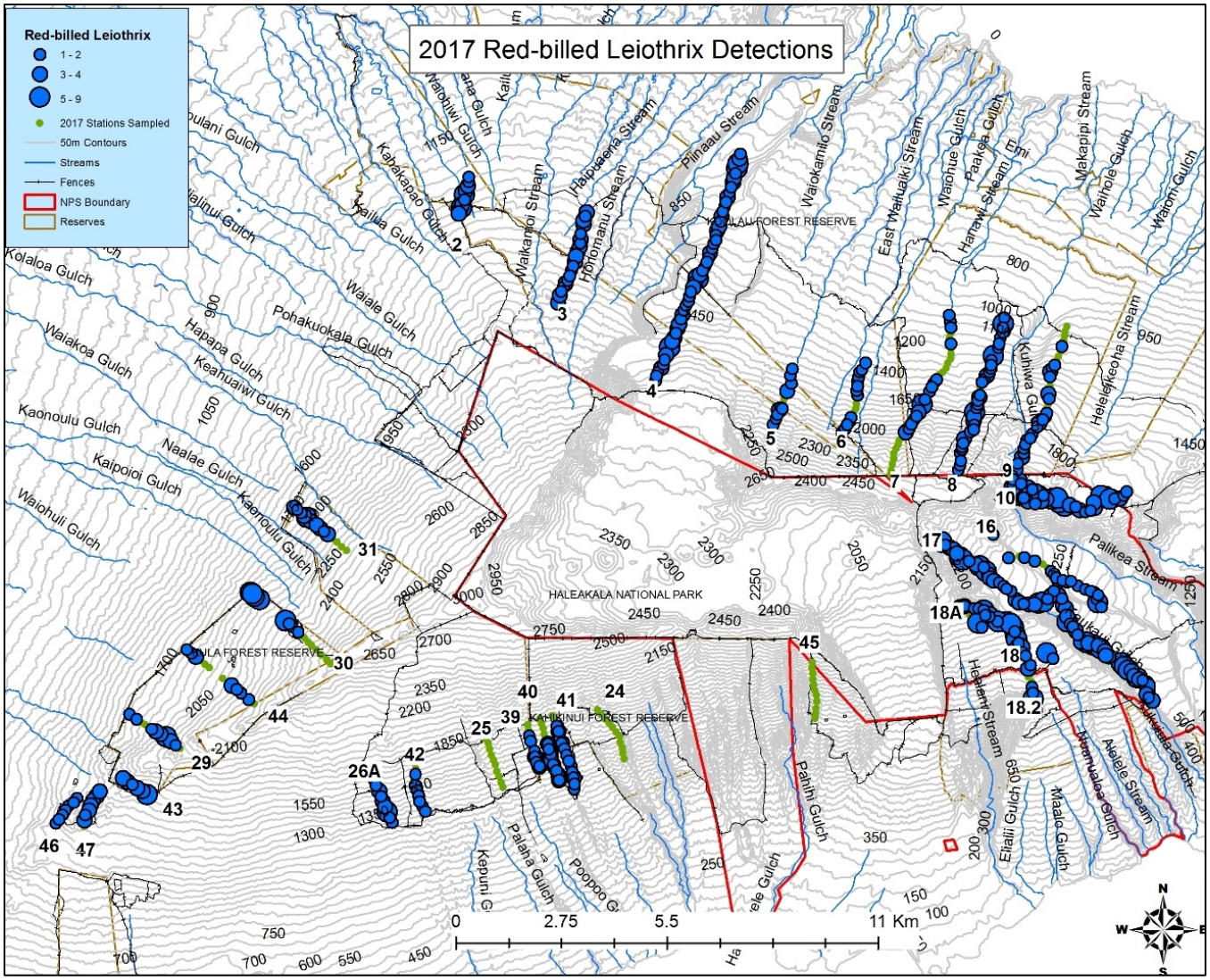


Figure F-15. Red-billed Leiothrix detections during the 2017 East Maui landbird survey.

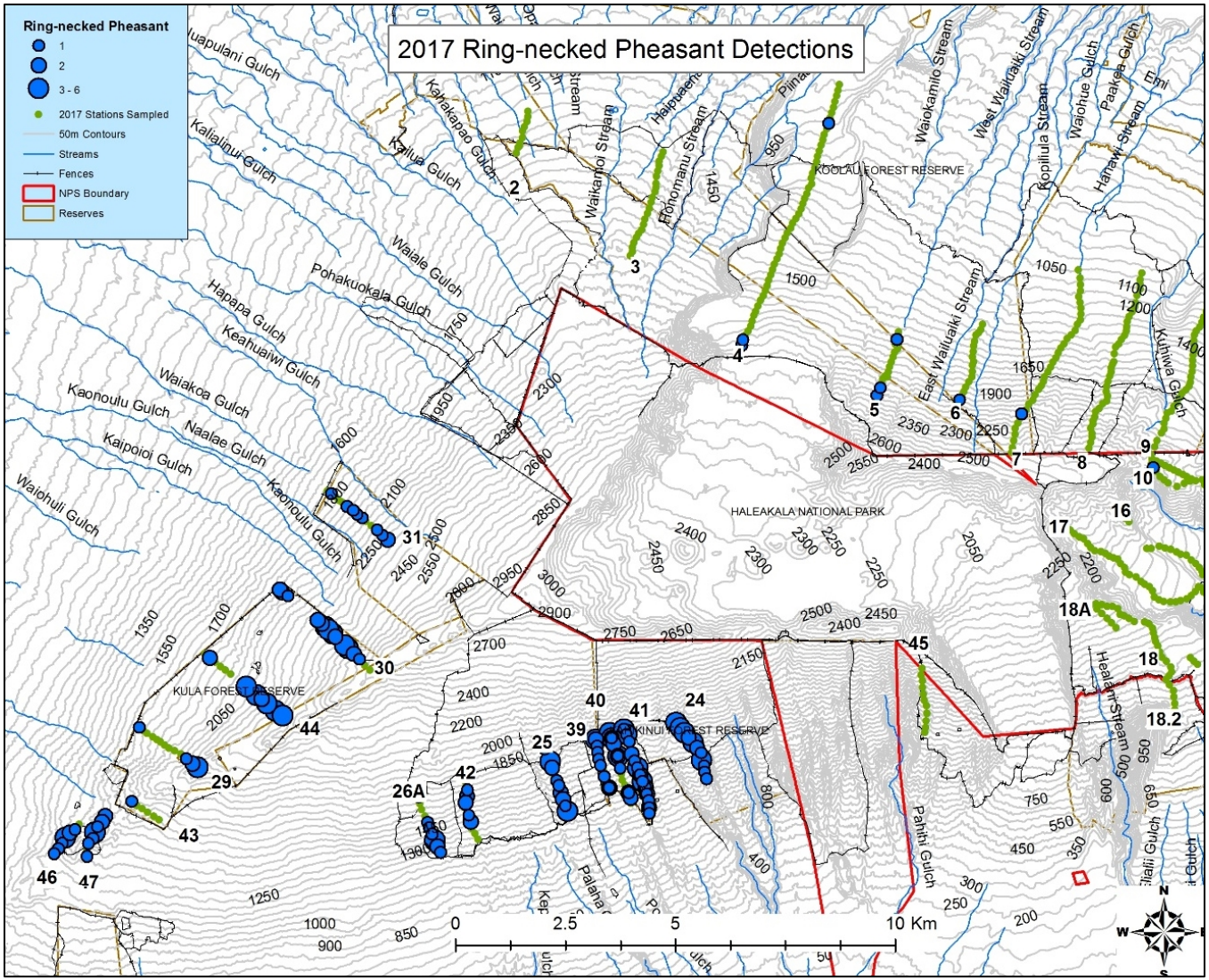


Figure F-16. Ring-necked Pheasant detections during the 2017 East Maui landbird survey.

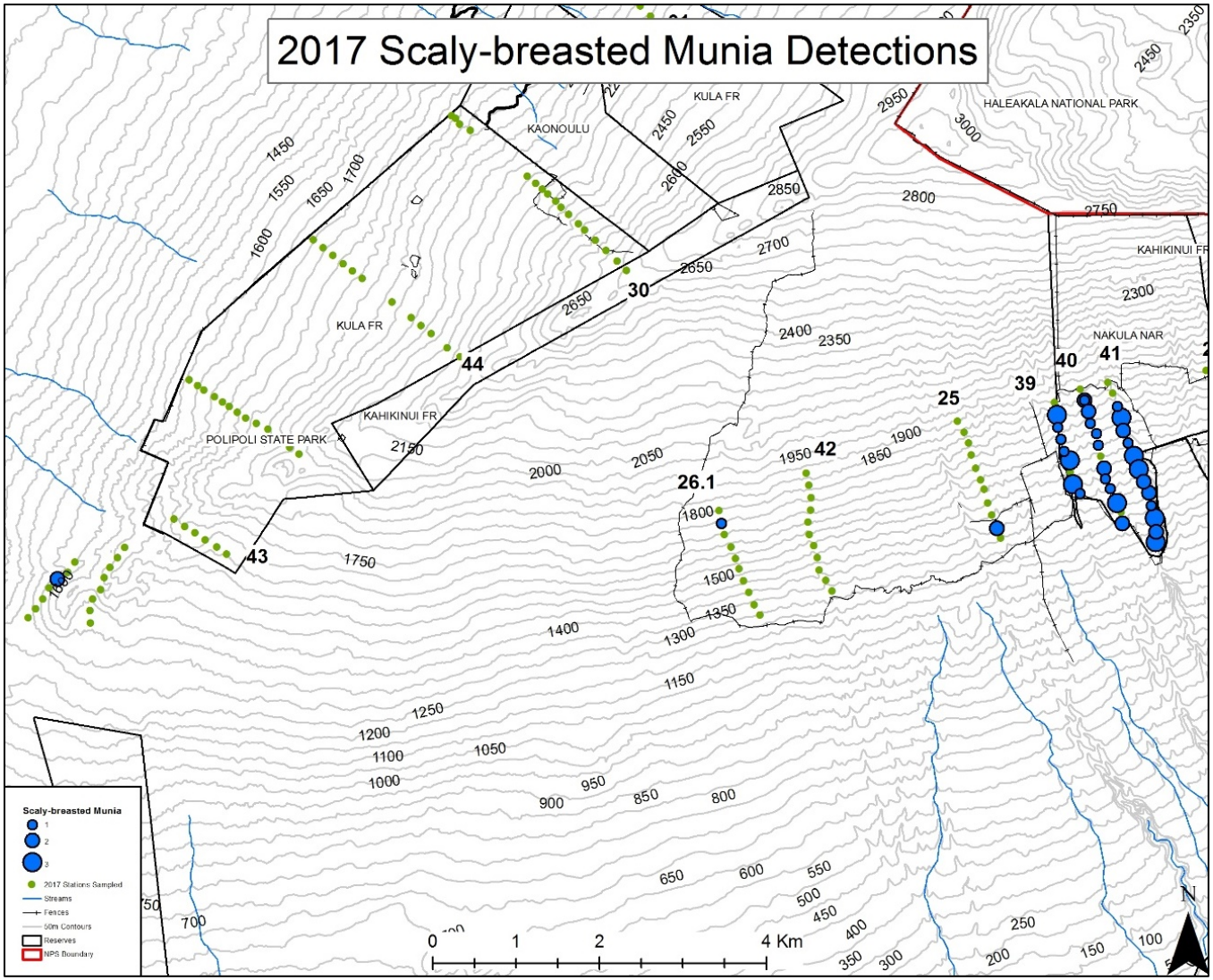


Figure F-17. Scaly-breasted Munia detections during the 2017 East Maui landbird survey.

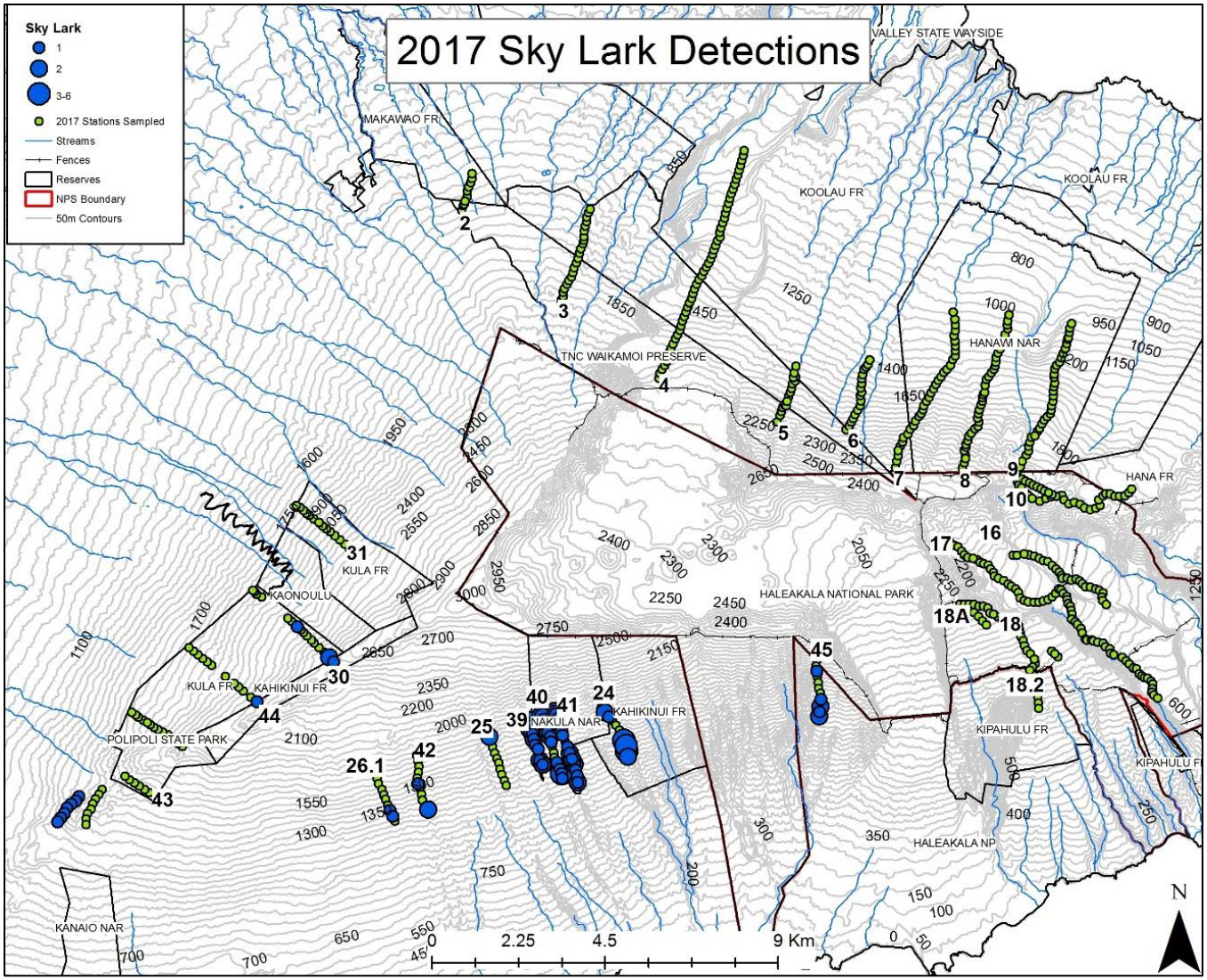


Figure F-18. Sky Lark detections during the 2017 East Maui landbird survey.

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

NPS 162/154902, July 2019

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525