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2018 KAUA'I FOREST BIRD POPULATION ESTIMATES AND TRENDS

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ABSTRACT

Kaua'i's native forest birds have experienced steep declines since the beginning of systematic surveys in 1981, and declines have accelerated in recent decades. This report details the analysis of the most recent surveys conducted in 2018. Incorporating the new survey results, long-term trends continue to show sharp declines for all native honeycreeper species with the exception of 'apapane (*Himatione sanguinea*), which has stable numbers in core areas of its range. Kaua'i 'elepaio (*Chasiempis sclateri*) continued to decline in the outer portions of its range but increased in the core areas of its range. Abundance estimates of forest birds ranged from slightly higher to slightly lower in most species, indicating a relatively stable period from 2012–2018, and a pause from the rapid declines seen in earlier periods. Many native species now exist in very low numbers, and variation in estimates from survey to survey will increase.

INTRODUCTION

Before the arrival of humans and the many alien species they introduced, Hawaiian forest birds extended from sea level upslope to high elevation subalpine forests and shrubland. However, today Hawaiian forest birds face multiple threats, including habitat loss, introduced predators, invasive plants, and non-native diseases (Pratt *et al.* 2009, Paxton *et al.* 2018), and these threats have led to numerous extinctions since human settlement. Most of Hawai'i's forest birds are restricted to high elevation forests that provide suitable habitat and are largely disease free. On Kaua'i Island, the Alaka'i Plateau provides high elevation (~1,000–1,500 m) forest habitat that is dominated by native species and has been historically disease-free. However, native forest birds on Kaua'i have been experiencing rapid declines in recent years (Paxton *et al.* 2016), which has been associated with increasing disease prevalence (Atkinson *et al.* 2014).

Kaua'i Island was first systematically surveyed for forest birds in 1981 as part of the archipelago-wide Hawai'i Forest Bird Survey effort (Scott *et al.* 1986). In 2000, the number of survey transects was expanded to greatly increase the geographic area being sampled and allow for sampling across the Alaka'i Plateau where Kaua'i's last native forest birds resided (Foster *et al.* 2004). Recent analysis of the historical Kaua'i survey data indicated rapid declines in all native honeycreepers and declines in the Kaua'i 'elepaio (*Chasiempis sclateri*) in the edges of its range (Paxton *et al.* 2016). The analysis concluded that if declines did not level off, a number of species would likely go extinct in the coming decades. This work highlighted the importance of periodic surveys to monitor population trends of forest birds on Kaua'i.

In 2018, Hawaii State Division of Forestry and Wildlife (DOFAW) conducted a survey of historical point count stations, the first since 2012. The survey data were entered into the U.S. Geological Survey Interagency Forest Bird Survey Database and were analyzed using program Distance (Thomas *et al.* 2010) to provide a detection-corrected estimate of each species. This report provides the results of the distance analysis and trends for the Kaua'i forest birds.

METHODS

Field Surveys

Bird surveys were conducted on the Alaka'i Plateau of Kaua'i, an eroded crater of a 5.1 million year old extinct volcano. The plateau slopes gradually downward from the eastern summits (1,598 m) to the west, with bird survey locations occurring between 1,011 and 1,455 m

elevation. Prevailing northeasterly trade winds produce annual rainfall ranging from 11.5 m at the highest elevations in the east to 1.5 m in the southwest (Giambelluca *et al.* 2013). The terrain is extremely rugged with deep canyons eroded into the plateau on all sides. Much of the area is covered in dense montane forest and shrubland, and bogs occupy some depressions. The dominant canopy tree is ʻōhiʻa (*Metrosideros polymorpha*), with koa (*Acacia koa*) co-dominant in drier areas in the west. The higher elevations contain some of the most intact native ecosystems left in Hawaii, but non-native plants and animals occur throughout the native forest and are dominant in some parts of the plateau, especially in lower elevation areas. All eight native forest bird species on Kauaʻi are restricted to the Alakaʻi Plateau. These include six Hawaiian honeycreeper (Carduelinae) species: ʻakikiki (*Oreomystis bairdi*), ʻakekeʻe (*Loxops caeruleirostris*), ʻapapane (*Himatione sanguinea*), ʻiʻiwi (*Drepanis coccinea*), Kauaʻi ʻamakihi (*Chlorodrepanis stejnegeri*), and ʻanianiau (*Magumma parva*). In addition, there are two other native bird species, Kauaʻi ʻelepaio, a monarch flycatcher, and puaiohi (*Myadestes palmeri*), a thrush. The ʻakikiki, ʻakekeʻe, and puaiohi are endangered species, and the ʻiʻiwi is threatened (USFWS 2006). However, the puaiohi, which occurs primarily in steep, narrow stream valleys where few survey stations are located, was not included in this analysis because standard forest bird surveys are an unreliable sampling method for the species (Crampton *et al.* 2017). In addition, several non-native species have become established in numbers sufficient enough to analyze densities and trends. The non-native species included in this report are warbling white-eye, formerly known as Japanese white-eye (*Zosterops japonicus*), hwamei (*Garrulax canorus*), Japanese bush-warbler (*Horornis diphone*), northern cardinal (*Cardinalis cardinalis*), and white-rumped shama (*Copsychus malabaricus*).

Bird surveys were conducted in 1981, 1989, 1994, 2000, 2005, 2007, 2008, 2012, and 2018 using point-transect distance sampling methods (Scott *et al*. 1986, Foster *et al.* 2004, Paxton *et al.* 2016). Six transects, with count stations located at 150-m intervals, were established in 1981 across the southeastern Alakaʻi Plateau (Scott *et al*. 1986), termed Interior (Figure 1). In 2000, an additional 26 transects were established in the northern Alakaʻi, southwestern Alakaʻi, and western (Kōkeʻe) areas, termed Exterior (Figure 1), to improve the spatial coverage of sampling across the forested portion of Kauaʻi above 1,000 m (Foster *et al.* 2004). The Interior area has received nine surveys over 37 years (1981–2018, with an average span between surveys of 4.6 years), whereas the Exterior area has been surveyed six times over 18 years (2000–2018, average span between surveys of 3.6 years). In general, the Interior corresponds to the core range of the native species, whereas the Exterior represents the periphery of native species. However, several species extend beyond the Exterior into lower-elevation forest habitats, which are not surveyed (but where densities are believed to be quite low). Several stations established in 2000 occur within the Interior of the plateau and were included in the survey results for this area. At each station, observers recorded the horizontal distance to each bird detected, the species, and detection type (heard, seen, or both) during an eight-minute count. Cloud cover, rain, wind strength, gust strength, and time of day were also recorded at each station. Sampling started within 30 min of dawn and continued until 12:00 PM and ceased during adverse weather conditions (Camp *et al.* 2009).

Area of Inference

To estimate average density and abundance, we began by defining areas for grouping point count stations. Traditionally, the Alakaʻi Plateau has been partitioned into two sections: Interior, representing the survey stations established in 1981, and Exterior, which includes the area covered by the additional surveys added in 2000 (Figure 1). For each survey year we defined the area of inference for a particular species by taking the intersection of the species range and

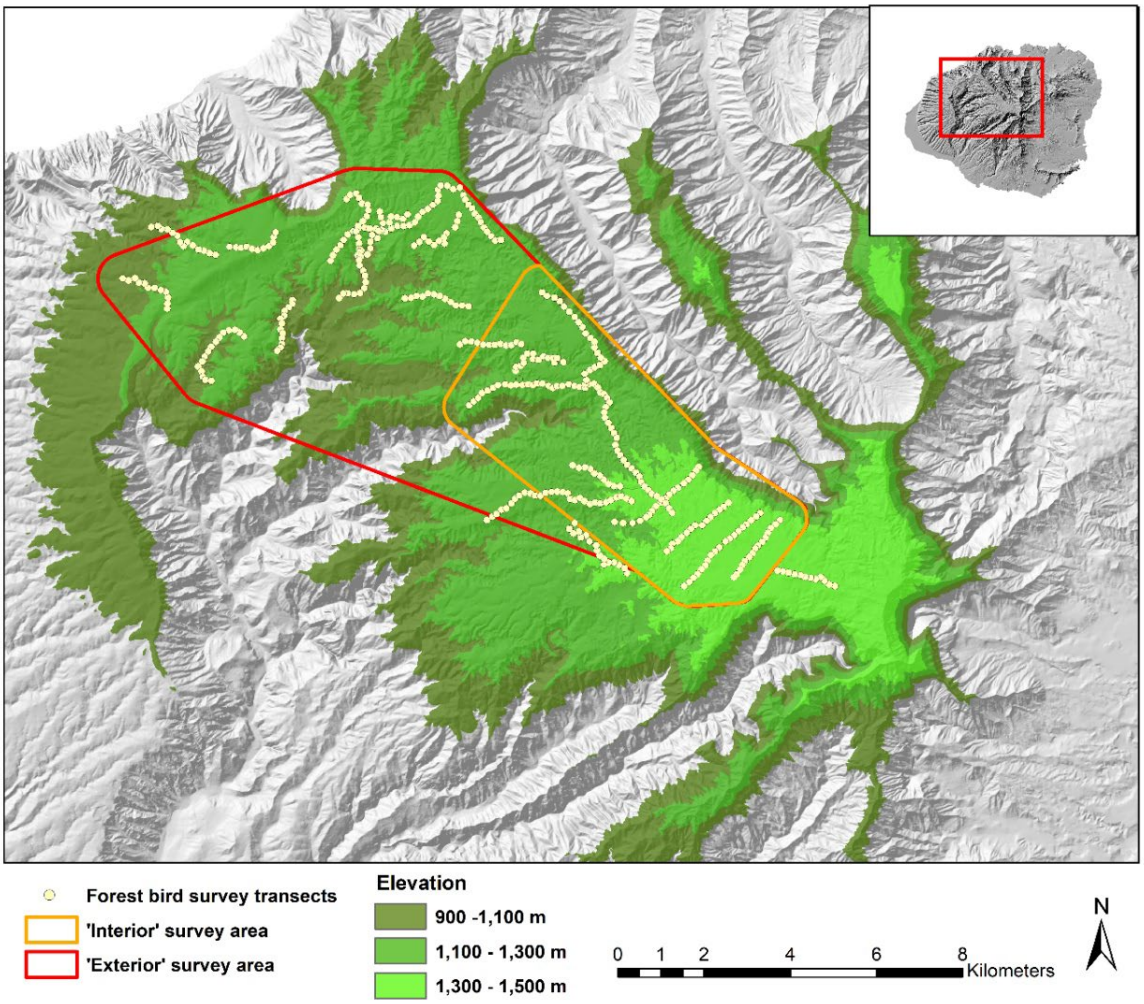


Figure 1. Map of forest bird survey areas on the Alakaʻi Plateau, Kauaʻi. Point count stations (white circles) occurred across the core Interior area (1981–2018) and more recent Exterior (2000–2018) survey areas. Survey locations were grouped by Interior or Exterior and by the three different elevation bands. Maps derived from U.S. Geological Survey 10-m digital elevation models, centered at 159.586041 West, 22.121077 North.

the polygons defining the Interior and Exterior regions. For widespread species, such as ʻapapane, this is clearly not the entire population, and estimates are only for the study area of inference. For more range-restricted species, we also confined the area of inference to the approximate range of the bird species in that year. For example, if a species only occurs in half of the area surveyed, including all areas would have many absences (0s) averaged with detections, greatly biasing the density estimates low. Unique range polygons for survey years were used when appropriate; for example, the range based on the 1981 survey results was used for the 1981, 1989, and 1994 estimates because we did not detect any change in distribution across those periods. For two widespread native species (Kauaʻi ʻamakihi, Kauaʻi ʻelepaio) we used the range determined in 2012, excluding only the highest elevations. For

widespread non-native species we used the union of the Interior and Exterior polygons, representing the area of inference. For ʻakikiki we used a new polygon for 2018 in order to accommodate their reduced range since the 2012 surveys. Even for rare, range-restricted species such as ʻakikiki, similar habitat and anecdotal reports make it likely their range extends beyond the study area of inference, but this habitat is not surveyed and so abundance estimates are only for the population within the study area. The area of the intersection between the species range and the Interior and Exterior polygons was the area of the Interior/Exterior stratum in the particular survey year that a density estimate is being made.

Survey points that fell within the intersection of the species range and Interior and Exterior polygons in a year were assigned to that stratum in that year. Survey points that fell outside of these intersections, in all years, were assigned to a dummy stratum with zero area. In this way program Distance (Thomas *et al.* 2010) can use detections outside of the survey areas to help estimate a detection function, without those detections contributing to estimates of abundance within the stratum.

For elevation strata we began with the intersection of the species range and the union of the Interior and Exterior polygons. Survey stations within this intersection were assigned to strata based on their elevation (as determined by a digital elevation model; DEM) as low (900–1,100 m), medium (1,100–1,300 m), or high (1,300–1,500 m). Survey stations outside this intersection were assigned to a dummy stratum as above. Finally, the intersection polygon was used to extract cell values from a 10-m resolution DEM. The proportion of cell values that fell within each elevation category was multiplied by the area of the intersection polygon to derive the areas of low, medium, and high elevation for each species in each year.

Distance Estimates

We used program Distance (version 7.1) to model species-specific detection functions, determining a best-fitting functional form and assessing each of the potential covariates (Thomas *et al*. 2010). Once we derived species-specific detection functions and truncation distances, we ran separate Distance models stratifying by time (year of survey) and geography (Interior/Exterior or elevation) to produce abundance estimates for each stratum. Uncertainty was estimated by bootstrap simulation, re-sampling within strata 999 times to produce a total of 1,000 estimates for each temporal/geographic stratum. Total abundance (of Interior and Exterior areas) was calculated as the sum of Interior and Exterior estimates for each simulation. Ninety-five percent credible intervals (CI) around each estimate were taken from the 2.5% and 97.5% quantiles of the distribution of bootstrap values.

Trends Assessment

We tested for trends in abundance over time with simple log-linear regression. We used regression on each of the bootstrap simulation estimates to evaluate the distribution of the estimate of slope. We categorized slope estimates as downward, neutral, or upward based on cutoffs of -0.012 and 0.009, which correspond to a decrease or increase of 25% over 25 years. We then used the distribution of bootstrap slopes to evaluate the strength of evidence in favor of each of the three outcomes. We used the 2.5% and 97.5% quantiles of the predicted regression values to generate confidence envelopes around the regression lines.

RESULTS

The analysis of 2018 survey results generally produced slightly higher density estimates than those estimated for the previous survey in 2012. Both of the two most endangered species, ʻakikiki and ʻakekeʻe, had slightly higher mean densities for 2018 compared to 2012, although within the 95% CI of the 2012 estimate. This produced population estimates of 454 (95% CI: 120–886) for ʻakikiki and 1,162 (95% CI: 643–1,698) for ʻakekeʻe (Table 1). Neither of these two species were detected in the Exterior survey area, continuing the trend of contraction to core areas within the Interior survey area. For the ʻanianiau, Kauaʻi ʻamakihi, and Kauaʻi ʻelepaio, density was lower in the Interior in 2018 compared to 2012, but higher in the Exterior (Appendix 1), while ʻiʻiwi had lower densities in both survey areas. Estimates for ʻapapane density were slightly higher in the Interior region in 2018 compared to 2012, but much higher in the Exterior in 2018 (6.9 birds/ha in 2012 versus 10.6 birds/ha in 2018), which led to a large estimated population increase. The pattern in density for native species was lowest in the 900–1,100 m elevation range (ʻakikiki, ʻakekeʻe, ʻanianiau, and ʻiʻiwi were not detected in these areas), and highest in the medium (1,100–1,300 m) to high (1,300–1,500 m) elevations. Non-native species (other than hwamei) were opposite to that of the native species with much higher densities in the lowest elevation strata and lowest density in the upper elevations. Hwamei had low densities in all three elevation strata.

Long-term population trends continued to be steeply downward for most native forest birds (Figure 2). All honeycreepers showed downward trends for the different geographic comparisons (Interior, Exterior, high, medium, and low elevation, and overall), with the one exception being ʻapapane in the Interior, which appeared stable. In contrast, the Kauaʻi ʻelepaio also has declining populations in the Exterior region and at low elevations, but stable populations at medium elevations and upward trends in the Interior and high elevation forests. In most cases the slope of the downward trend for the Interior surveys 2000–2018 is steeper than for trends over the entire period (1981–2018), indicating an acceleration of population declines over the last two decades (Table 2). For non-native species, the trends continue to be mixed. Warbling white-eyes continue to show population declines across the board, as well as northern cardinals. The hwamei and white-rumped shama have mostly stable to slightly increasing populations, while the Japanese bush-warbler shows sustained increases in all strata.

Table 1. Population abundance; density at low (900–1,100 m), medium (1,100–1,300 m), high (1,300–1,500 m) elevations; and density at Interior and Exterior areas for 12 forest birds. Abundance estimates are for the extent within the Interior and Exterior survey areas (Figure 1) and therefore are not global estimates for more widely distributed species. CI are credible intervals.

		Density by elevation (95% CI)			Density by survey area (95% CI)	
Species	2018 abundance (95% CI)	Low	Medium	High	Exterior	Interior
ʻAkekeʻe	1,162 (643–1,698)	0	0.27 (0.122–0.413)	0.295 (0.116–0.496)	0	0.427 (0.236–0.623)
ʻAkikiki	454 (120–886)	0	0.046 (0–0.132)	0.27 (0.032–0.635)	0	0.196 (0.052–0.383)
ʻAnianiau	8,703 (6,467–11,221)	0	1.89 (1.467–2.334)	1.682 (1.165–2.318)	0.512 (0.296–0.764)	2.3142 (1.845–2.827)
ʻIʻiwi	1,855 (1,198–2,531)	0	0.448 (0.29–0.616)	0.436 (0.275–0.596)	0.182 (0.078–0.295)	0.588 (0.407–0.769)
ʻApapane	87,613 (67,915–92,773)	7.376 (5.067–8.195)	13.891 (10.98–14.719)	9.467 (7.165–10.404)	10.608 (8.194–11.304)	12.92 (10.057–13.577)
Kauaʻi ʻamakihi	6,987 (4,672–9,183)	1.573 (0.891–2.302)	0.89 (0.634–1.138)	0.187 (0.077–0.3)	0.998 (0.673–1.313)	0.634 (0.414–0.830)
Kauaʻi ʻelepaio	51,903 (29,203–76,403)	5.098 (2.748–7.654)	7.061 (3.922–10.194)	9.277 (5.233–13.465)	4.413 (2.429–6.606)	9.584 (5.48–13.929)
Warbling white-eye	81,989 (72,478–103,645)	16.81 (14.13–21.442)	9.729 (8.715–12.422)	4.182 (3.533–5.422)	12.045 (10.674–15.191)	6.84 (6.0–8.7)
Hwamei	4,457 (3,643–5,794)	0.471 (0.304–0.681)	0.561 (0.475–0.698)	0.444 (0.3641–0.582)	0.601 (0.491–0.783)	0.459 (0.376–0.594)
Japanese bush-warbler	5,215 (3,863–7,212)	1.194 (0.792–1.652)	0.535 (0.388–0.724)	0.054 (0.022–0.094)	0.934 (0.701–1.284)	0.161 (0.1041–0.235)
Northern cardinal	2,115 (981–3,031)	0.595 (0.24–0.875)	0.18 (0.073–0.26)	0	0.415 (0.194–0.588)	0.007 (0–0.02)
White-rumped shama	1,466 (1,071–2,284)	0.446 (0.271–0.787)	0.162 (0.124–0.243)	0.033 (0.007–0.075)	0.239 (0.179–0.369)	0.083 (0.054–0.135)

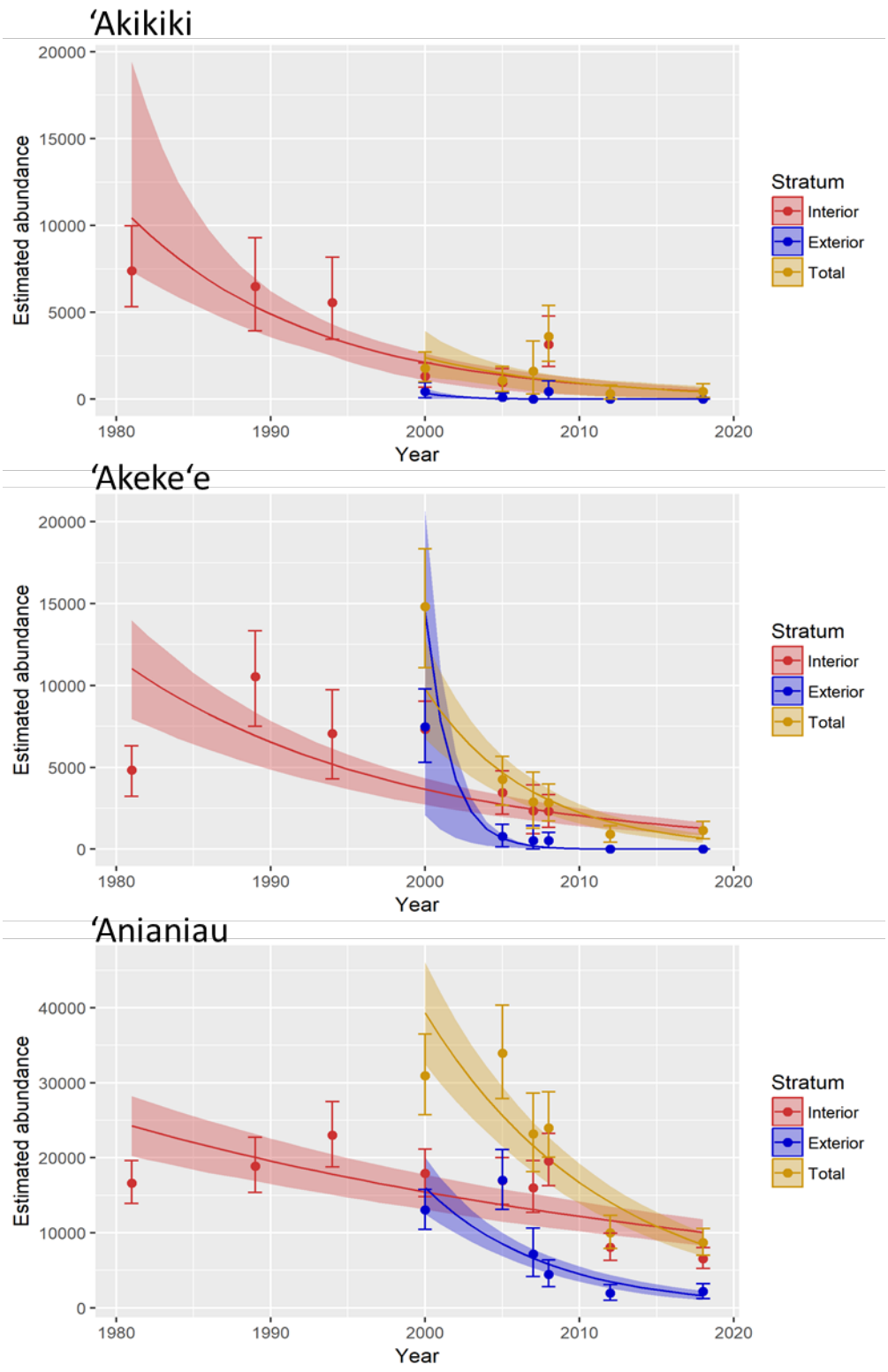
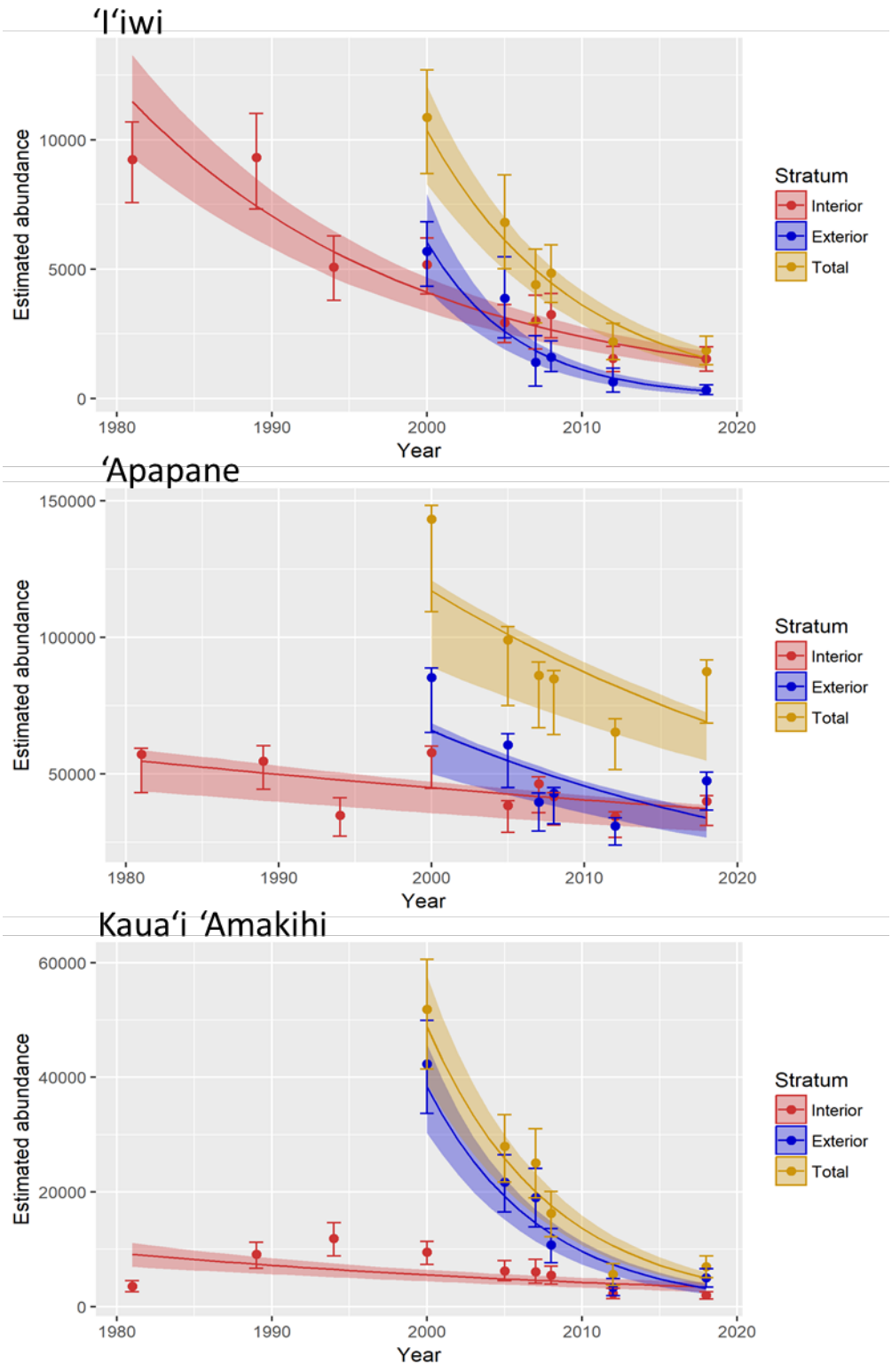


Figure 2. Kauaʻi forest bird abundance trends for Interior (red, 1981–2018), Exterior (blue, 2000–2018), and both areas combined (yellow, 2000–2018). Points give abundance estimates with 95% credible intervals. The line is a best fit for the data points.



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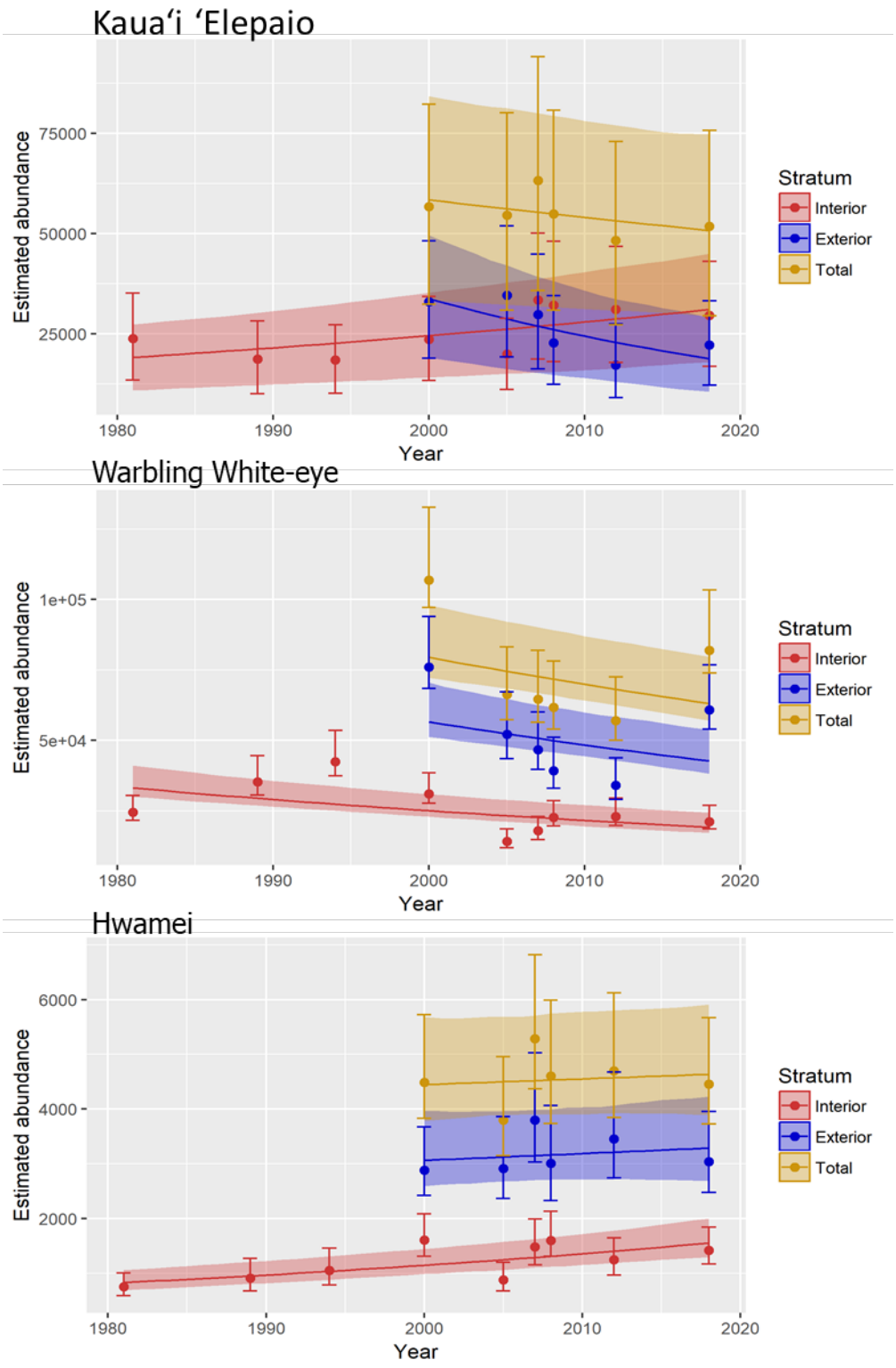

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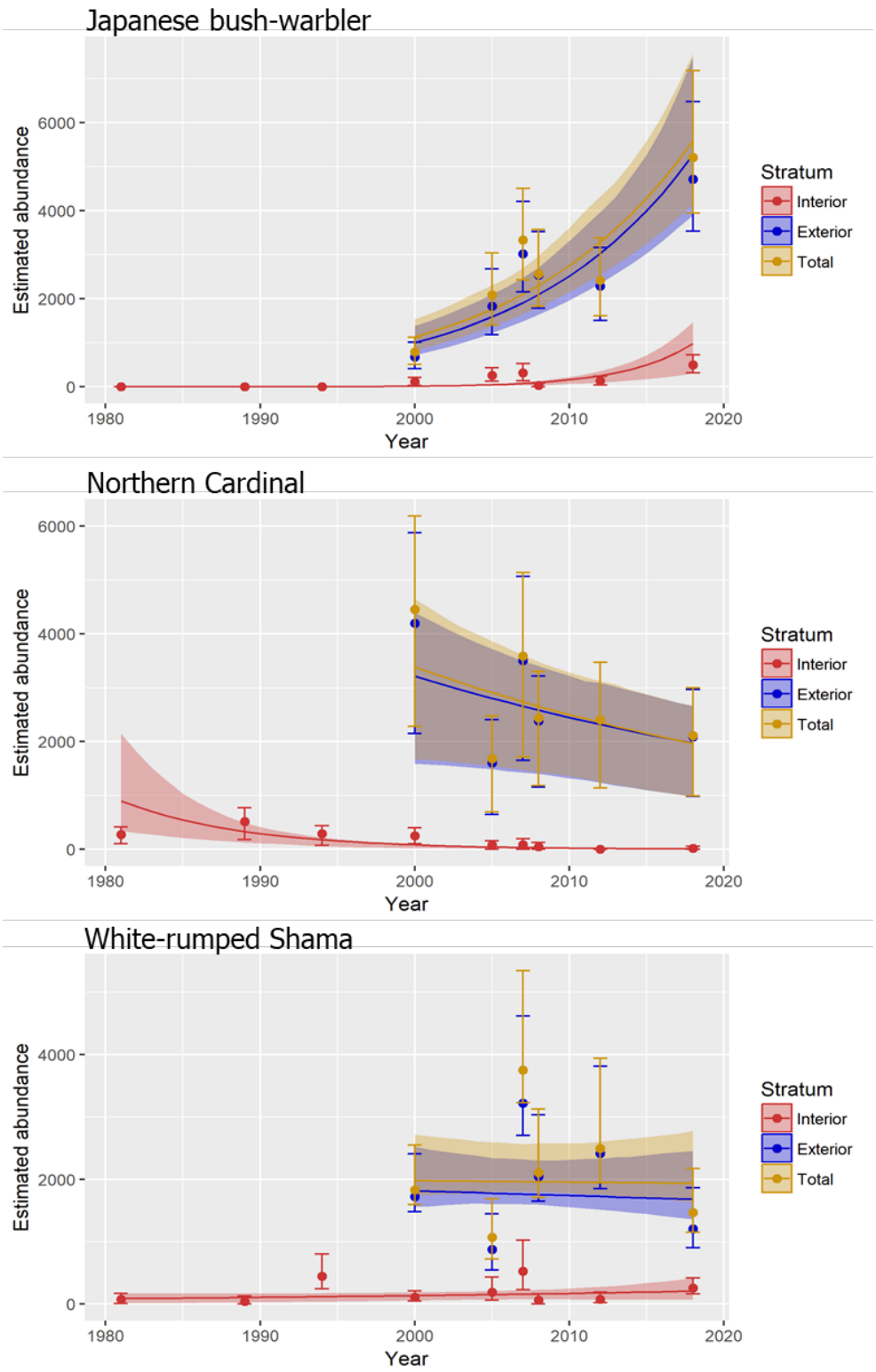

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Table 2. Population trend regression slopes for the 12 Kauaʻi forest birds for multiple forest strata. Negative values indicate downward trends, positive numbers indicate upward trends, and the size of the regression value indicates the steepness of the trend. Strata include the overall study area (Total), which includes the Interior (Int) and Exterior (Ext) regions, and elevational bands from low (900–1,100 m), medium (1,100–1,300 m), and high (1,300–1,500 m). The last category, "Int2000", is the interior from 2000–2018, a period equivalent with the Exterior surveys. Trends are from 2000–2018 for all strata except Interior, which is from 1981–2018. Statistical support for trends based on equivalency tests is indicated by cell shading, with downward trends in red, stable trends in blue, and upward trends in green.

Species	Total	Int	Ext	Low	Med	High	Int2000
ʻAkekeʻe	-0.149	-0.059	-0.601	-0.369	-0.147	-0.125	-0.112
ʻAkikiki	-0.106	-0.091	-0.366	-0.101	-0.178	-0.081	-0.091
ʻAnianiau	-0.086	-0.024	-0.128	-0.489	-0.059	-0.075	-0.065
ʻIʻiwi	-0.106	-0.055	-0.172	-0.368	-0.098	-0.067	-0.071
ʻApapane	-0.028	-0.011	-0.035	-0.049	-0.021	-0.016	-0.019
Kauaʻi ʻamakihi	-0.128	-0.027	-0.139	-0.207	-0.115	-0.134	-0.097
Kauaʻi ʻelepaio	-0.008	0.013	-0.033	-0.021	-0.006	0.021	0.017
Warbling white-eye	-0.013	-0.015	-0.016	-0.018	-0.015	-0.018	-0.007
Hwamei	0.002	0.017	0.003	-0.023	0.002	0.008	-0.001
Japanese bush-warbler	0.089	0.22	0.093	0.107	0.071	0.098	0.063
Northern cardinal	-0.03	-0.144	-0.027	-0.034	-0.041	-0.256	-0.251
White-rumped shama	-0.001	0.029	-0.004	0.013	-0.012	0.252	0.017

DISCUSSION

Kauaʻi forest birds have experienced dramatic declines over the last several decades (Paxton *et al.* 2016). The results from the 2018 surveys support the trends observed in the past. The four native species with the most limited ranges (ʻakikiki, ʻakekeʻe, ʻanianiau, and ʻiʻiwi) have exhibited the steepest declines over the last few decades (average -11% per year) and are no longer detected in low elevation transects (900–1,100 m). In the larger Exterior survey area, ʻakikiki and ʻakekeʻe are no longer detected, and ʻanianiau and ʻiʻiwi exist in low densities. Even in the core Interior area, only ʻanianiau persists at densities greater than 1 bird per hectare (ʻanianiau = 2.3 individuals/ha). The Kauaʻi ʻamakihi, once widespread and common, has also experienced dramatic declines with a current population estimate of 6,987 (95% CI 4,672–9,183), down from a total of 51,817 estimated in 2000 (the earliest period of surveys spanning much of the Alakaʻi Plateau; Appendix I). ʻApapane has also experienced sustained declines over the decades, though at lower rates, and appears stable in the Interior region. Nonetheless,

an estimated 56,000 fewer ʻapapane exist in 2018 compared to 2000. The one native species that showed contrary population trends was the Kauaʻi ʻelepaio. In high elevation forests, and the Interior survey region, Kauaʻi ʻelepaio had positive growth of 1–2% per year from 2000–2018 and was essentially stable in medium elevation habitat (1,100–1,300 m elevation). However, Kauaʻi ʻelepaio were declining in the lowest elevation habitat and overall in the Exterior survey area, which follows the trends of other native species demonstrating contracting ranges toward the core Interior habitats of the Alakaʻi Plateau.

Population estimates for native species in 2018 were generally similar to 2012 estimates. The ʻakikiki and ʻakekeʻe had slightly higher population estimates, though well within the margin of error for each survey period. This may indicate that the rapid decline of ʻakikiki and ʻakekeʻe observed over the last two decades has leveled off, and bird groups have now contracted to core areas where they are able to maintain stable, albeit very small, populations. Furthermore, these species now exist at such low densities that estimating population size is difficult, and numbers will fluctuate from survey to survey. Kauaʻi ʻamakihi, Kauaʻi ʻelepaio, and ʻapapane also had increased population estimates for 2018 compared to 2012, although again (except for ʻapapane) not much higher than the previous survey. Estimates of density vary among surveys for multiple reasons. Each survey is a snapshot of time to estimate a dynamic bird community, and where birds happen to be spatially and temporally during the brief period surveys are conducted can affect survey results. Additionally, birds have less than perfect detectability, and a number of factors can affect bird detection, including the conspicuousness of species, habitat density, terrain, observer skill, and weather. While distance analysis attempts to correct for these factors that affect detectability, the models can only average across factors that will vary for each survey. One implication for these variations across sequential surveys is that any estimate for a given survey is best judged in the context of the entire time series. For example, population estimates for ʻakikiki in 2008 had a ~2.5-fold jump from previous surveys (2000, 2005, 2007) and then dropped by an order of magnitude in the two subsequent surveys (2012 and 2018). Judged within the context of a time series of surveys, the 2008 population estimate for ʻakikiki was clearly an aberration, but at the time it was not clear if the results reflected a population rebound or sampling error. Likewise, results from the 2018 survey analysis will be clearest in the context of additional surveys.

The native Kauaʻi forest bird community has undergone profound changes over the last half century. More than 50 years ago, Kauaʻi was unique among the Hawaiian Islands in still retaining most of its entire forest bird community, but multiple species went extinct in the period between 1969 and 1990, including the greater ʻakialoa (*Hemignathus ellisianus*) last seen in 1969, ʻōʻōʻāʻā (Kauaʻi ʻōʻō; *Moho braccatus*) last seen in 1987, kāmaʻo (*Myadestes myadestinus*) last seen in 1985, ʻōʻū (*Psittirostra psittacea*) last seen in 1989, and the Kauaʻi nukupuʻu (*Hemignathus hanapepe*) last seen in the early 1990s (Banko and Banko 2009). Many of these species had dwindled to very low numbers, and hurricanes Iwa in 1982 and Iniki in 1992 caused considerable damage to the forests of these birds (Harrington *et al.* 1997) and may have been the final tipping point to their extinction. The remaining forest birds appeared fairly stable as recently as 2000 (Foster *et al.* 2004) despite inhabiting lower elevation forests that are expected to be more prone to invasion by mosquitoes and the diseases they transmit. However, bird populations on Kauaʻi have declined rapidly in the last two decades, and multiple species are now at very low numbers and in danger of extinction. A number of conservation actions can be taken to try to stabilize Kauaʻi forest bird populations, including establishing captive populations or translocating to other islands with disease-free habitat, landscape-level mosquito control, predator control, and habitat protection and restoration (Paxton *et al.* 2018).

With periodic surveys of forest birds, managers can assess the response to conservation actions and determine which species are most in need of targeted actions.

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APPENDIX I.

Table. Density and abundance estimates of forest birds by survey region (Interior, Exterior) and elevational strata (high, medium, low) for each survey year, 1981–2018. Abbreviations are as follows: AKEK = ʻakekeʻe; AKIK = ʻakikiki; ANIA = ʻanianiau; APAP = ʻapapane; IIWI = ʻiʻiwi; JABW = Japanese bush-warbler; KAAM = Kauaʻi ʻamakihi; KAEL = Kauaʻi ʻelepaio; MELT = hwamei; NOCA = northern cardinal; WAWE = warbling white-eye; WRSH = white-rumped shama; and CI = credible intervals.

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
AKEK	Interior	1981	3041.3	1.587	1.057	2.073	4,826	3,216	6,304
AKEK	Interior	1989	3041.3	3.469	2.464	4.386	10,549	7,493	13,339
AKEK	Interior	1994	3041.3	2.322	1.414	3.204	7,063	4,299	9,745
AKEK	Interior	2000	3021.6	2.425	1.752	2.992	7,326	5,294	9,040
AKEK	Interior	2005	3021.6	1.148	0.710	1.579	3,470	2,146	4,770
AKEK	Interior	2007	3021.6	0.780	0.309	1.302	2,357	935	3,935
AKEK	Interior	2008	2822.1	0.821	0.472	1.176	2,317	1,331	3,318
AKEK	Interior	2012	2723.6	0.336	0.154	0.531	915	420	1,447
AKEK	Interior	2018	2723.6	0.427	0.236	0.623	1,162	644	1,698
AKEK	Exterior	2000	4027.5	1.859	1.319	2.433	7,487	5,313	9,798
AKEK	Exterior	2005	4027.5	0.195	0.034	0.376	787	137	1,515
AKEK	Exterior	2007	4027.5	0.134	0.000	0.358	539	0	1,440
AKEK	Exterior	2008	1567.7	0.336	0.050	0.653	527	79	1,024
AKEK	Exterior	2012	1531.1	0.000	0.000	0.000	0	0	0
AKEK	Exterior	2018	1531.1	0.000	0.000	0.000	0	0	0
AKEK	Low	2000	1369.7	1.702	0.937	2.477	2,331	1,283	3,393
AKEK	Low	2005	1369.7	0.000	0.000	0.000	0	0	0
AKEK	Low	2007	1369.7	0.000	0.000	0.000	0	0	0
AKEK	Low	2008	307.6	0.000	0.000	0.000	0	0	0
AKEK	Low	2012	188.8	0.000	0.000	0.000	0	0	0
AKEK	Low	2018	188.8	0.000	0.000	0.000	0	0	0
AKEK	Medium	2000	4583.0	1.750	1.281	2.185	8,018	5,870	10,012
AKEK	Medium	2005	4583.0	0.479	0.257	0.727	2,195	1,177	3,331
AKEK	Medium	2007	4583.0	0.349	0.107	0.644	1,598	489	2,952
AKEK	Medium	2008	3044.3	0.383	0.177	0.588	1,165	539	1,791
AKEK	Medium	2012	3041.0	0.098	0.019	0.185	299	58	564
AKEK	Medium	2018	3041.0	0.270	0.122	0.413	822	370	1,255
AKEK	High	2000	1037.7	2.222	1.544	2.904	2,306	1,602	3,013
AKEK	High	2005	1037.7	1.373	0.766	2.039	1,425	795	2,116
AKEK	High	2007	1037.7	1.002	0.279	1.921	1,040	290	1,993
AKEK	High	2008	1033.6	1.094	0.582	1.649	1,131	602	1,704
AKEK	High	2012	1024.8	0.398	0.154	0.706	408	158	723
AKEK	High	2018	1024.8	0.295	0.116	0.496	302	119	508

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
AKIK	Interior	1981	2914.4	2.535	1.829	3.427	7,389	5,331	9,988
AKIK	Interior	1989	2914.4	2.227	1.347	3.192	6,490	3,926	9,303
AKIK	Interior	1994	2914.4	1.912	1.180	2.808	5,573	3,438	8,185
AKIK	Interior	2000	2443.6	0.544	0.286	0.850	1,329	698	2,076
AKIK	Interior	2005	2443.6	0.395	0.149	0.727	965	364	1,775
AKIK	Interior	2007	2443.6	0.662	0.126	1.369	1,618	309	3,344
AKIK	Interior	2008	2314.7	1.359	0.815	2.069	3,146	1,887	4,788
AKIK	Interior	2012	2314.0	0.145	0.000	0.354	336	0	818
AKIK	Interior	2018	2314.0	0.196	0.052	0.383	454	120	886
AKIK	Exterior	2000	1443.5	0.315	0.053	0.670	455	77	968
AKIK	Exterior	2005	1443.5	0.075	0.000	0.250	108	0	361
AKIK	Exterior	2007	1443.5	0.000	0.000	0.000	0	0	0
AKIK	Exterior	2008	976.6	0.471	0.000	1.075	460	0	1,050
AKIK	Exterior	2012	1137.7	0.000	0.000	0.000	0	0	0
AKIK	Exterior	2018	320.6	0.000	0.000	0.000	0	0	0
AKIK	Low	2000	233.8	0.056	0.000	0.192	13	0	45
AKIK	Low	2005	233.8	0.000	0.000	0.000	0	0	0
AKIK	Low	2007	233.8	0.000	0.000	0.000	0	0	0
AKIK	Low	2008	112.3	0.000	0.000	0.000	0	0	0
AKIK	Low	2012	148.7	0.000	0.000	0.000	0	0	0
AKIK	Low	2018	24.6	0.000	0.000	0.000	0	0	0
AKIK	Medium	2000	2620.5	0.308	0.149	0.513	806	390	1,343
AKIK	Medium	2005	2620.5	0.062	0.000	0.163	163	0	427
AKIK	Medium	2007	2620.5	0.348	0.000	0.843	911	0	2,208
AKIK	Medium	2008	2214.6	0.696	0.361	1.184	1,542	799	2,622
AKIK	Medium	2012	2314.1	0.056	0.000	0.194	130	0	450
AKIK	Medium	2018	1621.0	0.046	0.000	0.132	75	0	214
AKIK	High	2000	1031.2	0.448	0.175	0.812	462	181	837
AKIK	High	2005	1031.2	0.628	0.221	1.228	648	228	1,266
AKIK	High	2007	1031.2	0.389	0.000	0.905	401	0	933
AKIK	High	2008	962.8	0.935	0.403	1.570	900	388	1,512
AKIK	High	2012	988.8	0.125	0.000	0.344	124	0	340
AKIK	High	2018	988.9	0.270	0.032	0.635	267	32	628
ANIA	Interior	1981	2993.1	5.545	4.641	6.560	16,598	13,890	19,636
ANIA	Interior	1989	2993.1	6.307	5.143	7.592	18,877	15,393	22,722
ANIA	Interior	1994	2993.1	7.692	6.270	9.189	23,024	18,766	27,504
ANIA	Interior	2000	2993.1	5.982	4.952	7.063	17,905	14,823	21,140
ANIA	Interior	2005	2993.1	5.662	4.615	6.696	16,946	13,812	20,042
ANIA	Interior	2007	2993.1	5.341	4.247	6.547	15,985	12,712	19,596
ANIA	Interior	2008	2993.1	6.538	5.433	7.771	19,570	16,263	23,260

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
ANIA	Interior	2012	2827.2	2.848	2.228	3.514	8,051	6,301	9,935
ANIA	Interior	2018	2827.2	2.314	1.845	2.827	6,541	5,216	7,994
ANIA	Exterior	2000	4392.7	2.969	2.385	3.596	13,044	10,475	15,797
ANIA	Exterior	2005	4392.7	3.874	2.986	4.802	17,017	13,115	21,095
ANIA	Exterior	2007	4392.7	1.635	0.948	2.421	7,180	4,165	10,637
ANIA	Exterior	2008	4392.7	1.011	0.634	1.446	4,441	2,785	6,352
ANIA	Exterior	2012	4225.8	0.462	0.230	0.738	1,952	972	3,119
ANIA	Exterior	2018	4225.8	0.512	0.296	0.764	2,162	1,251	3,227
ANIA	Low	2000	1546.1	1.790	1.250	2.504	2,768	1,933	3,872
ANIA	Low	2005	1546.1	1.173	0.429	2.149	1,814	663	3,323
ANIA	Low	2007	1546.1	0.122	0.000	0.406	189	0	628
ANIA	Low	2008	1546.1	0.357	0.000	0.941	552	0	1,455
ANIA	Low	2012	1342.7	0.119	0.000	0.384	160	0	515
ANIA	Low	2018	1342.7	0.000	0.000	0.000	0	0	0
ANIA	Medium	2000	4697.2	3.719	3.034	4.447	17,471	14,252	20,890
ANIA	Medium	2005	4697.2	5.109	4.185	6.154	23,999	19,659	28,907
ANIA	Medium	2007	4697.2	3.163	2.332	4.135	14,858	10,952	19,421
ANIA	Medium	2008	4697.2	3.542	2.834	4.417	16,636	13,314	20,748
ANIA	Medium	2012	4667.5	1.396	1.045	1.825	6,515	4,880	8,516
ANIA	Medium	2018	4667.5	1.886	1.466	2.334	8,803	6,844	10,893
ANIA	High	2000	1037.7	5.606	4.579	6.844	5,817	4,752	7,103
ANIA	High	2005	1037.7	5.369	4.143	6.595	5,571	4,299	6,843
ANIA	High	2007	1037.7	6.376	4.819	8.182	6,617	5,001	8,491
ANIA	High	2008	1037.7	5.997	4.890	7.322	6,223	5,075	7,599
ANIA	High	2012	1037.7	2.875	2.164	3.737	2,984	2,246	3,878
ANIA	High	2018	1037.7	1.682	1.165	2.318	1,745	1,209	2,405
IIWI	Interior	1981	2999.1	3.081	2.524	3.564	9,239	7,570	10,689
IIWI	Interior	1989	2999.1	3.107	2.444	3.674	9,318	7,328	11,018
IIWI	Interior	1994	2999.1	1.695	1.264	2.096	5,082	3,790	6,286
IIWI	Interior	2000	2884.1	1.796	1.399	2.149	5,179	4,036	6,199
IIWI	Interior	2005	2884.1	1.018	0.750	1.260	2,936	2,163	3,634
IIWI	Interior	2007	2884.1	1.043	0.663	1.384	3,008	1,911	3,990
IIWI	Interior	2008	2793.8	1.162	0.840	1.452	3,246	2,348	4,057
IIWI	Interior	2012	2602.4	0.596	0.399	0.772	1,550	1,038	2,009
IIWI	Interior	2018	2602.4	0.588	0.407	0.769	1,529	1,059	2,002
IIWI	Exterior	2000	3463.4	1.643	1.255	1.970	5,689	4,345	6,823
IIWI	Exterior	2005	3463.4	1.117	0.678	1.581	3,870	2,348	5,477
IIWI	Exterior	2007	3463.4	0.403	0.140	0.702	1,395	484	2,431
IIWI	Exterior	2008	1793.5	0.890	0.582	1.240	1,596	1,044	2,223
IIWI	Exterior	2012	1794.2	0.361	0.136	0.650	648	245	1,166

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
IIWI	Exterior	2018	1794.2	0.182	0.078	0.295	326	140	529
IIWI	Low	2000	1077.3	0.601	0.348	0.844	647	375	909
IIWI	Low	2005	1077.3	0.214	0.000	0.558	231	0	601
IIWI	Low	2007	1077.3	0.000	0.000	0.000	0	0	0
IIWI	Low	2008	364.9	0.000	0.000	0.118	0	0	43
IIWI	Low	2012	249.2	0.056	0.000	0.177	14	0	44
IIWI	Low	2018	249.2	0.000	0.000	0.000	0	0	0
IIWI	Medium	2000	4224.7	1.580	1.262	1.898	6,677	5,331	8,018
IIWI	Medium	2005	4224.7	1.226	0.903	1.536	5,181	3,816	6,491
IIWI	Medium	2007	4224.7	0.806	0.496	1.137	3,404	2,097	4,804
IIWI	Medium	2008	3187.8	1.003	0.736	1.286	3,197	2,347	4,100
IIWI	Medium	2012	3114.3	0.511	0.332	0.672	1,592	1,035	2,093
IIWI	Medium	2018	3114.3	0.448	0.290	0.616	1,394	905	1,918
IIWI	High	2000	1037.7	1.338	0.995	1.640	1,388	1,033	1,702
IIWI	High	2005	1037.7	0.614	0.363	0.895	637	377	929
IIWI	High	2007	1037.7	0.746	0.401	1.111	774	416	1,153
IIWI	High	2008	1030.8	0.779	0.505	1.096	803	521	1,130
IIWI	High	2012	1032.9	0.319	0.149	0.502	330	154	518
IIWI	High	2018	1032.9	0.436	0.275	0.596	450	284	615
APAP	Interior	1981	3097.1	18.476	13.946	19.193	57,221	43,192	59,442
APAP	Interior	1989	3097.1	17.690	14.337	19.513	54,788	44,403	60,432
APAP	Interior	1994	3097.1	11.290	8.807	13.360	34,966	27,276	41,376
APAP	Interior	2000	3097.1	18.692	14.436	19.464	57,889	44,710	60,280
APAP	Interior	2005	3097.1	12.429	9.278	12.991	38,492	28,735	40,235
APAP	Interior	2007	3097.1	14.991	11.556	15.833	46,429	35,788	49,036
APAP	Interior	2008	3097.1	13.515	10.120	13.959	41,857	31,342	43,230
APAP	Interior	2012	3097.1	11.130	8.626	11.691	34,471	26,714	36,208
APAP	Interior	2018	3097.1	12.920	10.057	13.577	40,015	31,148	42,049
APAP	Exterior	2000	4584.3	18.632	14.235	19.357	85,414	65,257	88,738
APAP	Exterior	2005	4584.3	13.230	9.827	14.132	60,649	45,050	64,784
APAP	Exterior	2007	4584.3	8.656	6.362	9.375	39,682	29,167	42,980
APAP	Exterior	2008	4584.3	9.383	6.921	9.833	43,015	31,728	45,079
APAP	Exterior	2012	4487.1	6.904	5.327	7.566	30,977	23,901	33,951
APAP	Exterior	2018	4487.1	10.608	8.194	11.304	47,598	36,767	50,724
APAP	Low	2000	1698.6	17.180	13.042	17.847	29,182	22,153	30,315
APAP	Low	2005	1698.6	9.122	5.964	10.364	15,495	10,129	17,605
APAP	Low	2007	1698.6	5.913	3.760	7.145	10,043	6,387	12,135
APAP	Low	2008	1698.6	6.666	3.974	8.059	11,323	6,751	13,688
APAP	Low	2012	1659.8	4.657	3.025	5.651	7,730	5,021	9,380
APAP	Low	2018	1659.8	7.376	5.067	8.195	12,243	8,410	13,603

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
APAP	Medium	2000	4713.7	18.502	14.266	19.237	87,211	67,247	90,678
APAP	Medium	2005	4713.7	14.356	10.918	14.923	67,669	51,465	70,344
APAP	Medium	2007	4713.7	12.723	9.681	13.396	59,974	45,631	63,146
APAP	Medium	2008	4713.7	12.839	9.685	13.302	60,521	45,654	62,702
APAP	Medium	2012	4713.7	8.201	6.478	8.968	38,659	30,536	42,270
APAP	Medium	2018	4713.7	13.891	10.980	14.719	65,480	51,757	69,379
APAP	High	2000	1037.7	14.510	11.093	15.238	15,057	11,511	15,812
APAP	High	2005	1037.7	9.617	7.038	9.987	9,979	7,303	10,363
APAP	High	2007	1037.7	12.826	9.825	13.741	13,309	10,195	14,259
APAP	High	2008	1037.7	10.136	7.494	10.590	10,518	7,776	10,989
APAP	High	2012	1037.7	11.909	8.680	12.731	12,358	9,007	13,211
APAP	High	2018	1037.7	9.467	7.165	10.404	9,824	7,435	10,797
KAAM	Interior	1981	3097.1	1.145	0.826	1.467	3,547	2,559	4,543
KAAM	Interior	1989	3097.1	2.937	2.164	3.612	9,096	6,702	11,188
KAAM	Interior	1994	3097.1	3.837	2.847	4.726	11,882	8,816	14,636
KAAM	Interior	2000	3097.1	3.060	2.376	3.672	9,478	7,358	11,373
KAAM	Interior	2005	3097.1	2.022	1.451	2.596	6,263	4,495	8,040
KAAM	Interior	2007	3097.1	1.959	1.320	2.650	6,066	4,090	8,206
KAAM	Interior	2008	3097.1	1.770	1.263	2.265	5,483	3,913	7,013
KAAM	Interior	2012	3097.1	0.732	0.443	1.035	2,267	1,373	3,207
KAAM	Interior	2018	3097.1	0.634	0.414	0.830	1,964	1,283	2,571
KAAM	Exterior	2000	5035.5	8.408	6.685	9.913	42,339	33,661	49,917
KAAM	Exterior	2005	5035.5	4.313	3.280	5.259	21,716	16,518	26,480
KAAM	Exterior	2007	5035.5	3.774	2.755	4.782	19,003	13,873	24,077
KAAM	Exterior	2008	5035.5	2.142	1.516	2.705	10,786	7,634	13,622
KAAM	Exterior	2012	5035.5	0.667	0.378	0.978	3,359	1,903	4,924
KAAM	Exterior	2018	5035.5	0.998	0.673	1.313	5,023	3,390	6,611
KAAM	Low	2000	1797.1	11.356	8.769	13.605	20,409	15,760	24,451
KAAM	Low	2005	1797.1	8.165	5.778	10.380	14,674	10,384	18,654
KAAM	Low	2007	1797.1	2.502	1.433	3.630	4,496	2,575	6,523
KAAM	Low	2008	1797.1	0.974	0.376	1.614	1,750	677	2,901
KAAM	Low	2012	1797.1	0.097	0.000	0.362	175	0	650
KAAM	Low	2018	1797.1	1.573	0.891	2.302	2,827	1,601	4,137
KAAM	Medium	2000	4714.2	5.775	4.463	6.816	27,226	21,039	32,131
KAAM	Medium	2005	4714.2	3.286	2.442	3.985	15,491	11,511	18,787
KAAM	Medium	2007	4714.2	3.490	2.566	4.371	16,451	12,095	20,604
KAAM	Medium	2008	4714.2	2.333	1.759	2.875	10,998	8,295	13,556
KAAM	Medium	2012	4714.2	0.952	0.645	1.283	4,489	3,039	6,048
KAAM	Medium	2018	4714.2	0.890	0.634	1.138	4,194	2,987	5,364
KAAM	High	2000	1037.7	1.793	1.217	2.330	1,861	1,263	2,418

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
KAAM	High	2005	1037.7	0.673	0.291	1.077	698	302	1,117
KAAM	High	2007	1037.7	1.250	0.639	1.901	1,297	664	1,973
KAAM	High	2008	1037.7	0.989	0.563	1.372	1,026	584	1,424
KAAM	High	2012	1037.7	0.285	0.083	0.507	296	86	526
KAAM	High	2018	1037.7	0.187	0.077	0.300	194	80	311
KAEL	Interior	1981	3097.1	7.717	4.342	11.346	23,901	13,449	35,139
KAEL	Interior	1989	3097.1	6.046	3.265	9.120	18,725	10,112	28,247
KAEL	Interior	1994	3097.1	5.996	3.277	8.805	18,571	10,149	27,271
KAEL	Interior	2000	3097.1	7.647	4.319	11.088	23,684	13,376	34,340
KAEL	Interior	2005	3097.1	6.470	3.616	9.343	20,037	11,199	28,935
KAEL	Interior	2007	3097.1	10.807	6.050	16.180	33,471	18,736	50,109
KAEL	Interior	2008	3097.1	10.380	5.856	15.537	32,148	18,137	48,119
KAEL	Interior	2012	3097.1	10.043	5.766	15.105	31,103	17,858	46,781
KAEL	Interior	2018	3097.1	9.584	5.480	13.929	29,683	16,972	43,140
KAEL	Exterior	2000	5035.5	6.574	3.770	9.576	33,103	18,985	48,221
KAEL	Exterior	2005	5035.5	6.877	3.832	10.320	34,630	19,297	51,968
KAEL	Exterior	2007	5035.5	5.919	3.224	8.915	29,803	16,236	44,891
KAEL	Exterior	2008	5035.5	4.522	2.461	6.865	22,770	12,394	34,569
KAEL	Exterior	2012	5035.5	3.415	1.802	5.461	17,194	9,075	27,500
KAEL	Exterior	2018	5035.5	4.413	2.429	6.606	22,220	12,231	33,263
KAEL	Low	2000	1797.1	5.961	3.332	8.805	10,713	5,988	15,823
KAEL	Low	2005	1797.1	7.739	3.814	12.087	13,909	6,854	21,723
KAEL	Low	2007	1797.1	5.691	2.871	8.571	10,227	5,159	15,404
KAEL	Low	2008	1797.1	4.983	2.670	8.029	8,956	4,799	14,429
KAEL	Low	2012	1797.1	3.691	1.517	6.504	6,634	2,726	11,689
KAEL	Low	2018	1797.1	5.098	2.748	7.654	9,162	4,938	13,756
KAEL	Medium	2000	4714.2	6.774	3.786	9.771	31,935	17,847	46,062
KAEL	Medium	2005	4714.2	6.296	3.542	9.149	29,681	16,699	43,130
KAEL	Medium	2007	4714.2	7.149	4.028	10.532	33,703	18,987	49,652
KAEL	Medium	2008	4714.2	6.211	3.475	9.036	29,281	16,381	42,596
KAEL	Medium	2012	4714.2	4.242	2.336	6.231	19,997	11,014	29,374
KAEL	Medium	2018	4714.2	7.061	3.922	10.194	33,286	18,490	48,056
KAEL	High	2000	1037.7	6.942	3.956	9.940	7,204	4,106	10,315
KAEL	High	2005	1037.7	7.955	4.398	11.759	8,255	4,563	12,203
KAEL	High	2007	1037.7	13.101	7.392	19.427	13,595	7,671	20,160
KAEL	High	2008	1037.7	11.851	6.627	17.537	12,298	6,877	18,199
KAEL	High	2012	1037.7	14.267	8.073	21.101	14,805	8,377	21,897
KAEL	High	2018	1037.7	9.277	5.233	13.465	9,627	5,431	13,973
WAWE	Interior	1981	3096.8	7.901	6.973	9.842	24,468	21,595	30,478
WAWE	Interior	1989	3096.8	11.367	9.876	14.383	35,201	30,582	44,540

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
WAWE	Interior	1994	3096.8	13.677	12.057	17.263	42,356	37,339	53,460
WAWE	Interior	2000	3096.8	10.006	8.928	12.443	30,985	27,649	38,535
WAWE	Interior	2005	3096.8	4.587	3.807	5.980	14,204	11,790	18,517
WAWE	Interior	2007	3096.8	5.794	4.782	7.433	17,942	14,809	23,018
WAWE	Interior	2008	3096.8	7.307	6.347	9.226	22,629	19,655	28,572
WAWE	Interior	2012	3096.8	7.416	6.371	9.546	22,966	19,729	29,561
WAWE	Interior	2018	3096.8	6.837	6.000	8.700	21,172	18,581	26,943
WAWE	Exterior	2000	5049.3	15.039	13.550	18.615	75,939	68,420	93,991
WAWE	Exterior	2005	5049.3	10.326	8.625	13.296	52,141	43,550	67,134
WAWE	Exterior	2007	5049.3	9.256	7.872	11.881	46,737	39,746	59,991
WAWE	Exterior	2008	5049.3	7.757	6.522	10.114	39,169	32,932	51,069
WAWE	Exterior	2012	5049.3	6.736	5.748	8.660	34,012	29,023	43,726
WAWE	Exterior	2018	5049.3	12.045	10.674	15.191	60,817	53,897	76,702
WAWE	Low	2000	1797.1	18.640	16.364	23.231	33,498	29,409	41,749
WAWE	Low	2005	1797.1	21.597	16.086	29.667	38,813	28,908	53,315
WAWE	Low	2007	1797.1	8.999	6.932	12.044	16,172	12,458	21,644
WAWE	Low	2008	1797.1	12.749	9.158	18.219	22,912	16,458	32,742
WAWE	Low	2012	1797.1	8.141	6.294	11.154	14,631	11,311	20,044
WAWE	Low	2018	1797.1	16.810	14.130	21.442	30,210	25,393	38,534
WAWE	Medium	2000	4714.2	13.769	12.562	17.337	64,908	59,218	81,731
WAWE	Medium	2005	4714.2	6.515	5.479	8.326	30,714	25,828	39,251
WAWE	Medium	2007	4714.2	8.437	7.229	10.750	39,771	34,078	50,677
WAWE	Medium	2008	4714.2	6.928	5.985	8.787	32,662	28,216	41,423
WAWE	Medium	2012	4714.2	6.460	5.638	8.289	30,452	26,577	39,074
WAWE	Medium	2018	4714.2	9.729	8.715	12.422	45,866	41,086	58,560
WAWE	High	2000	1037.7	8.632	7.491	10.980	8,957	7,774	11,394
WAWE	High	2005	1037.7	3.497	2.714	4.868	3,629	2,817	5,052
WAWE	High	2007	1037.7	4.176	2.866	6.138	4,333	2,974	6,369
WAWE	High	2008	1037.7	7.132	6.128	9.032	7,401	6,359	9,372
WAWE	High	2012	1037.7	7.541	6.152	9.969	7,825	6,384	10,345
WAWE	High	2018	1037.7	4.182	3.533	5.422	4,340	3,666	5,627
MELT	Interior	1981	3096.8	0.243	0.189	0.324	754	586	1,003
MELT	Interior	1989	3096.8	0.295	0.218	0.411	913	676	1,273
MELT	Interior	1994	3096.8	0.339	0.254	0.470	1,051	786	1,455
MELT	Interior	2000	3096.8	0.518	0.424	0.674	1,604	1,312	2,086
MELT	Interior	2005	3096.8	0.284	0.217	0.387	880	673	1,199
MELT	Interior	2007	3096.8	0.479	0.373	0.643	1,484	1,155	1,992
MELT	Interior	2008	3096.8	0.516	0.422	0.687	1,599	1,308	2,128
MELT	Interior	2012	3096.8	0.402	0.311	0.532	1,245	964	1,647
MELT	Interior	2018	3096.8	0.459	0.376	0.594	1,420	1,166	1,840

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
MELT	Exterior	2000	5049.3	0.571	0.479	0.728	2,881	2,419	3,675
MELT	Exterior	2005	5049.3	0.578	0.469	0.764	2,916	2,367	3,860
MELT	Exterior	2007	5049.3	0.752	0.601	0.995	3,797	3,034	5,024
MELT	Exterior	2008	5049.3	0.595	0.461	0.804	3,005	2,327	4,061
MELT	Exterior	2012	5049.3	0.684	0.542	0.926	3,455	2,737	4,675
MELT	Exterior	2018	5049.3	0.601	0.491	0.783	3,037	2,477	3,954
MELT	Low	2000	1797.1	0.643	0.487	0.863	1,156	876	1,551
MELT	Low	2005	1797.1	0.633	0.404	0.931	1,137	726	1,673
MELT	Low	2007	1797.1	0.780	0.542	1.113	1,402	974	2,001
MELT	Low	2008	1797.1	0.738	0.498	1.027	1,327	896	1,846
MELT	Low	2012	1797.1	0.513	0.307	0.817	922	552	1,469
MELT	Low	2018	1797.1	0.471	0.304	0.681	846	547	1,224
MELT	Medium	2000	4714.2	0.573	0.491	0.709	2,702	2,317	3,343
MELT	Medium	2005	4714.2	0.467	0.381	0.597	2,200	1,796	2,813
MELT	Medium	2007	4714.2	0.653	0.541	0.834	3,076	2,550	3,933
MELT	Medium	2008	4714.2	0.510	0.402	0.665	2,403	1,896	3,135
MELT	Medium	2012	4714.2	0.579	0.469	0.747	2,728	2,211	3,522
MELT	Medium	2018	4714.2	0.561	0.475	0.698	2,643	2,241	3,289
MELT	High	2000	1037.7	0.491	0.387	0.640	510	402	664
MELT	High	2005	1037.7	0.208	0.135	0.312	216	140	324
MELT	High	2007	1037.7	0.372	0.235	0.543	386	244	563
MELT	High	2008	1037.7	0.506	0.393	0.665	525	408	690
MELT	High	2012	1037.7	0.384	0.288	0.524	398	299	544
MELT	High	2018	1037.7	0.444	0.364	0.582	461	378	604
JABW	Interior	1981	3096.8	0.000	0.000	0.000	0	0	0
JABW	Interior	1989	3096.8	0.000	0.000	0.000	0	0	0
JABW	Interior	1994	3096.8	0.000	0.000	0.000	0	0	0
JABW	Interior	2000	3096.8	0.037	0.011	0.069	115	34	215
JABW	Interior	2005	3096.8	0.084	0.041	0.139	259	127	431
JABW	Interior	2007	3096.8	0.102	0.046	0.169	315	141	524
JABW	Interior	2008	3096.8	0.011	0.000	0.027	34	0	85
JABW	Interior	2012	3096.8	0.046	0.014	0.079	142	44	244
JABW	Interior	2018	3096.8	0.161	0.104	0.235	498	323	727
JABW	Exterior	2000	5049.3	0.134	0.083	0.201	677	418	1,013
JABW	Exterior	2005	5049.3	0.362	0.236	0.530	1,829	1,190	2,678
JABW	Exterior	2007	5049.3	0.599	0.427	0.834	3,023	2,156	4,213
JABW	Exterior	2008	5049.3	0.502	0.354	0.698	2,535	1,790	3,527
JABW	Exterior	2012	5049.3	0.453	0.298	0.627	2,286	1,507	3,167
JABW	Exterior	2018	5049.3	0.934	0.701	1.284	4,717	3,540	6,484
JABW	Low	2000	1797.1	0.113	0.037	0.210	203	67	378

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
JABW	Low	2005	1797.1	0.921	0.519	1.397	1,655	933	2,510
JABW	Low	2007	1797.1	0.609	0.315	0.979	1,094	567	1,760
JABW	Low	2008	1797.1	0.772	0.477	1.134	1,388	857	2,038
JABW	Low	2012	1797.1	0.721	0.428	1.105	1,295	770	1,986
JABW	Low	2018	1797.1	1.194	0.792	1.652	2,146	1,424	2,970
JABW	Medium	2000	4714.2	0.126	0.082	0.184	594	387	869
JABW	Medium	2005	4714.2	0.176	0.112	0.262	832	526	1,237
JABW	Medium	2007	4714.2	0.409	0.275	0.542	1,929	1,295	2,553
JABW	Medium	2008	4714.2	0.222	0.140	0.327	1,048	662	1,540
JABW	Medium	2012	4714.2	0.239	0.149	0.352	1,128	704	1,659
JABW	Medium	2018	4714.2	0.535	0.388	0.724	2,522	1,829	3,413
JABW	High	2000	1037.7	0.008	0.000	0.020	8	0	21
JABW	High	2005	1037.7	0.032	0.000	0.070	33	0	73
JABW	High	2007	1037.7	0.000	0.000	0.000	0	0	0
JABW	High	2008	1037.7	0.010	0.000	0.032	10	0	33
JABW	High	2012	1037.7	0.010	0.000	0.030	10	0	31
JABW	High	2018	1037.7	0.054	0.022	0.094	56	23	98
NOCA	Interior	1981	3096.8	0.088	0.033	0.136	274	103	420
NOCA	Interior	1989	3096.8	0.167	0.059	0.251	517	184	777
NOCA	Interior	1994	3096.8	0.095	0.025	0.142	293	77	440
NOCA	Interior	2000	3096.8	0.081	0.033	0.128	251	102	397
NOCA	Interior	2005	3096.8	0.026	0.000	0.050	79	0	156
NOCA	Interior	2007	3096.8	0.028	0.000	0.064	88	0	197
NOCA	Interior	2008	3096.8	0.017	0.000	0.042	52	0	131
NOCA	Interior	2012	3096.8	0.000	0.000	0.000	0	0	0
NOCA	Interior	2018	3096.8	0.007	0.000	0.020	22	0	62
NOCA	Exterior	2000	5049.3	0.832	0.426	1.164	4,202	2,149	5,878
NOCA	Exterior	2005	5049.3	0.318	0.129	0.476	1,606	650	2,405
NOCA	Exterior	2007	5049.3	0.694	0.328	1.004	3,502	1,657	5,068
NOCA	Exterior	2008	5049.3	0.472	0.229	0.637	2,385	1,157	3,216
NOCA	Exterior	2012	5049.3	0.476	0.225	0.688	2,406	1,138	3,473
NOCA	Exterior	2018	5049.3	0.415	0.194	0.588	2,093	981	2,969
NOCA	Low	2000	1797.1	1.185	0.574	1.621	2,130	1,031	2,913
NOCA	Low	2005	1797.1	0.728	0.279	1.077	1,309	502	1,935
NOCA	Low	2007	1797.1	1.052	0.464	1.538	1,890	834	2,763
NOCA	Low	2008	1797.1	0.787	0.354	1.142	1,415	637	2,052
NOCA	Low	2012	1797.1	0.748	0.302	1.134	1,344	543	2,038
NOCA	Low	2018	1797.1	0.595	0.240	0.875	1,069	431	1,572
NOCA	Medium	2000	4714.2	0.550	0.275	0.792	2,591	1,295	3,735
NOCA	Medium	2005	4714.2	0.128	0.037	0.206	603	176	969

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
NOCA	Medium	2007	4714.2	0.307	0.131	0.447	1,448	620	2,105
NOCA	Medium	2008	4714.2	0.208	0.092	0.301	981	435	1,418
NOCA	Medium	2012	4714.2	0.237	0.098	0.340	1,119	461	1,605
NOCA	Medium	2018	4714.2	0.180	0.073	0.260	848	346	1,224
NOCA	High	2000	1037.7	0.085	0.032	0.139	88	33	144
NOCA	High	2005	1037.7	0.016	0.000	0.048	17	0	50
NOCA	High	2007	1037.7	0.000	0.000	0.000	0	0	0
NOCA	High	2008	1037.7	0.000	0.000	0.000	0	0	0
NOCA	High	2012	1037.7	0.000	0.000	0.000	0	0	0
NOCA	High	2018	1037.7	0.000	0.000	0.000	0	0	0
WRSH	Interior	1981	3096.8	0.024	0.004	0.055	74	13	171
WRSH	Interior	1989	3096.8	0.015	0.000	0.041	46	0	128
WRSH	Interior	1994	3096.8	0.143	0.079	0.258	443	246	800
WRSH	Interior	2000	3096.8	0.036	0.017	0.068	111	53	210
WRSH	Interior	2005	3096.8	0.062	0.021	0.139	191	66	432
WRSH	Interior	2007	3096.8	0.171	0.075	0.330	529	231	1,022
WRSH	Interior	2008	3096.8	0.020	0.000	0.053	62	0	164
WRSH	Interior	2012	3096.8	0.025	0.007	0.062	78	21	193
WRSH	Interior	2018	3096.8	0.083	0.054	0.135	258	166	419
WRSH	Exterior	2000	5049.3	0.341	0.293	0.477	1,720	1,481	2,407
WRSH	Exterior	2005	5049.3	0.174	0.109	0.286	877	548	1,446
WRSH	Exterior	2007	5049.3	0.637	0.536	0.914	3,218	2,704	4,613
WRSH	Exterior	2008	5049.3	0.405	0.327	0.601	2,043	1,651	3,033
WRSH	Exterior	2012	5049.3	0.478	0.367	0.754	2,415	1,851	3,809
WRSH	Exterior	2018	5049.3	0.239	0.179	0.369	1,208	905	1,865
WRSH	Low	2000	1797.1	0.497	0.359	0.756	894	645	1,359
WRSH	Low	2005	1797.1	0.274	0.091	0.552	492	164	992
WRSH	Low	2007	1797.1	0.913	0.658	1.430	1,641	1,182	2,570
WRSH	Low	2008	1797.1	0.634	0.409	1.018	1,140	736	1,830
WRSH	Low	2012	1797.1	0.857	0.610	1.360	1,540	1,096	2,444
WRSH	Low	2018	1797.1	0.446	0.271	0.787	802	487	1,415
WRSH	Medium	2000	4714.2	0.229	0.192	0.322	1,080	905	1,520
WRSH	Medium	2005	4714.2	0.132	0.077	0.216	621	362	1,018
WRSH	Medium	2007	4714.2	0.440	0.345	0.648	2,075	1,627	3,056
WRSH	Medium	2008	4714.2	0.201	0.152	0.316	949	715	1,492
WRSH	Medium	2012	4714.2	0.238	0.159	0.389	1,122	750	1,835
WRSH	Medium	2018	4714.2	0.162	0.124	0.243	764	584	1,144
WRSH	High	2000	1037.7	0.000	0.000	0.000	0	0	0
WRSH	High	2005	1037.7	0.000	0.000	0.000	0	0	0
WRSH	High	2007	1037.7	0.000	0.000	0.000	0	0	0

				Density			Abundance		
Species	Stratum	Year	Area (ha)	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
WRSH	High	2008	1037.7	0.023	0.000	0.066	24	0	68
WRSH	High	2012	1037.7	0.012	0.000	0.043	12	0	45
WRSH	High	2018	1037.7	0.033	0.007	0.075	34	7	78

APPENDIX II.

Table. Population trends for forest birds by survey region (Interior, Exterior) and elevational strata (high, medium, low) for each survey period. Abbreviations are as follows: AKEK = ʻakekeʻe; AKIK = ʻakikiki; ANIA = ʻanianiau; APAP = ʻapapane; IIWI = ʻiʻiwi; JABW = Japanese bush-warbler; KAAM = Kauaʻi ʻamakihi; KAEL = Kauaʻi ʻelepaio; MELT = hwamei; NOCA = northern cardinal; WAWE = warbling white-eye; WRSH = white-rumped shama; and CI = credible intervals.

			Regression slope			Intercept		
Species	Stratum	Time period	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
AKEK	Interior	1981–2018	-0.059	-0.071	-0.047	7.620	7.331	7.881
AKEK	Interior2000	2000–2018	-0.112	-0.140	-0.086	7.600	7.312	7.867
AKEK	Exterior	2000–2018	-0.601	-0.633	-0.545	3.822	2.730	4.285
AKEK	Low	2000–2018	-0.369	-0.388	-0.346	0.459	0.385	0.518
AKEK	Medium	2000–2018	-0.147	-0.191	-0.112	7.059	6.657	7.408
AKEK	High	2000–2018	-0.125	-0.174	-0.085	6.617	6.256	6.922
AKEK	Total	2000–2018	-0.149	-0.176	-0.123	7.798	7.516	8.064
AKIK	Interior	1981–2018	-0.091	-0.152	-0.070	6.747	5.650	7.174
AKIK	Interior2000	2000–2018	-0.091	-0.215	-0.027	6.699	5.628	7.112
AKIK	Exterior	2000–2018	-0.366	-0.445	-0.261	1.804	0.387	2.458
AKIK	Low	2000–2018	-0.101	-0.199	0.000	-0.377	-0.693	-0.074
AKIK	Medium	2000–2018	-0.178	-0.467	0.001	5.125	3.521	6.155
AKIK	High	2000–2018	-0.081	-0.219	0.007	5.638	4.527	6.244
AKIK	Total	2000–2018	-0.106	-0.231	-0.044	6.781	5.704	7.199
ANIA	Interior	1981–2018	-0.024	-0.028	-0.020	9.431	9.254	9.584
ANIA	Interior2000	2000–2018	-0.065	-0.076	-0.056	9.433	9.254	9.587
ANIA	Exterior	2000–2018	-0.128	-0.157	-0.104	8.522	8.295	8.731
ANIA	Low	2000–2018	-0.489	-0.594	-0.400	4.119	2.656	5.281
ANIA	Medium	2000–2018	-0.059	-0.070	-0.048	9.468	9.287	9.616
ANIA	High	2000–2018	-0.075	-0.094	-0.058	8.334	8.143	8.493
ANIA	Total	2000–2018	-0.086	-0.096	-0.076	9.807	9.622	9.949
IIWI	Interior	1981–2018	-0.054	-0.061	-0.049	7.794	7.597	7.983
IIWI	Interior2000	2000–2018	-0.071	-0.089	-0.055	7.801	7.602	7.985
IIWI	Exterior	2000–2018	-0.172	-0.215	-0.135	7.117	6.821	7.367
IIWI	Low	2000–2018	-0.368	-0.441	-0.245	1.620	0.301	2.617
IIWI	Medium	2000–2018	-0.098	-0.119	-0.080	7.926	7.724	8.120
IIWI	High	2000–2018	-0.067	-0.092	-0.042	6.400	6.144	6.617
IIWI	Total	2000–2018	-0.106	-0.121	-0.091	8.264	8.078	8.434
APAP	Interior	1981–2018	-0.011	-0.013	-0.009	10.499	10.381	10.662
APAP	Interior2000	2000–2018	-0.019	-0.024	-0.015	10.520	10.393	10.680
APAP	Exterior	2000–2018	-0.035	-0.041	-0.029	10.642	10.518	10.803
APAP	Low	2000–2018	-0.049	-0.064	-0.037	9.308	9.149	9.513
APAP	Medium	2000–2018	-0.021	-0.026	-0.017	10.886	10.770	11.056

			Regression slope			Intercept		
Species	Stratum	Time period	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
APAP	High	2000–2018	-0.016	-0.025	-0.009	9.226	9.108	9.411
APAP	Total	2000–2018	-0.028	-0.032	-0.024	11.283	11.159	11.446
KAAM	Interior	1981–2018	-0.027	-0.035	-0.019	8.343	8.140	8.554
KAAM	Interior2000	2000–2018	-0.097	-0.117	-0.080	8.319	8.118	8.529
KAAM	Exterior	2000–2018	-0.139	-0.157	-0.123	9.271	9.051	9.472
KAAM	Low	2000–2018	-0.207	-0.304	-0.141	7.604	6.703	8.261
KAAM	Medium	2000–2018	-0.115	-0.129	-0.103	9.158	8.956	9.352
KAAM	High	2000–2018	-0.134	-0.181	-0.097	6.352	5.992	6.657
KAAM	Total	2000–2018	-0.128	-0.140	-0.115	9.615	9.414	9.800
KAEL	Interior	1981–2018	0.013	0.009	0.017	10.206	9.664	10.593
KAEL	Interior2000	2000–2018	0.017	0.010	0.024	10.227	9.684	10.615
KAEL	Exterior	2000–2018	-0.033	-0.044	-0.022	10.113	9.574	10.520
KAEL	Low	2000–2018	-0.021	-0.041	-0.001	9.112	8.568	9.535
KAEL	Medium	2000–2018	-0.006	-0.014	0.002	10.235	9.711	10.628
KAEL	High	2000–2018	0.021	0.012	0.030	9.240	8.719	9.651
KAEL	Total	2000–2018	-0.008	-0.014	-0.002	10.885	10.357	11.275
WAWE	Interior	1981–2018	-0.015	-0.018	-0.011	10.027	9.896	10.217
WAWE	Interior2000	2000–2018	-0.007	-0.014	0.001	9.979	9.846	10.171
WAWE	Exterior	2000–2018	-0.016	-0.023	-0.009	10.833	10.714	11.017
WAWE	Low	2000–2018	-0.018	-0.029	-0.006	10.116	9.978	10.314
WAWE	Medium	2000–2018	-0.015	-0.021	-0.008	10.597	10.469	10.785
WAWE	High	2000–2018	-0.018	-0.029	-0.006	8.668	8.519	8.875
WAWE	Total	2000–2018	-0.013	-0.019	-0.007	11.198	11.082	11.387
MELT	Interior	1981–2018	0.017	0.010	0.023	7.217	7.033	7.430
MELT	Interior2000	2000–2018	0.000	-0.010	0.010	7.227	7.042	7.443
MELT	Exterior	2000–2018	0.003	-0.007	0.014	8.084	7.903	8.300
MELT	Low	2000–2018	-0.023	-0.047	0.001	7.007	6.791	7.218
MELT	Medium	2000–2018	0.002	-0.006	0.011	7.889	7.731	8.063
MELT	High	2000–2018	0.008	-0.007	0.024	6.012	5.834	6.212
MELT	Total	2000–2018	0.002	-0.006	0.010	8.444	8.270	8.659
JABW	Interior	1981–2018	0.220	0.193	0.238	4.713	4.011	5.151
JABW	Interior2000	2000–2018	0.063	0.017	0.113	5.006	4.256	5.460
JABW	Exterior	2000–2018	0.093	0.075	0.114	7.707	7.493	8.008
JABW	Low	2000–2018	0.107	0.070	0.154	6.981	6.728	7.323
JABW	Medium	2000–2018	0.071	0.052	0.091	7.083	6.876	7.387
JABW	High	2000–2018	0.098	-0.006	0.241	1.897	1.020	2.659
JABW	Total	2000–2018	0.089	0.073	0.109	7.799	7.588	8.098
NOCA	Interior	1981–2018	-0.144	-0.204	-0.095	2.655	1.448	3.653
NOCA	Interior2000	2000–2018	-0.251	-0.421	-0.100	2.643	1.404	3.622
NOCA	Exterior	2000–2018	-0.027	-0.049	-0.005	7.579	7.219	8.105

			Regression slope			Intercept		
Species	Stratum	Time period	Mean	95% CI lower	95% CI upper	Mean	95% CI lower	95% CI upper
NOCA	Low	2000–2018	-0.034	-0.067	-0.008	7.028	6.619	7.542
NOCA	Medium	2000–2018	-0.041	-0.072	-0.013	6.749	6.326	7.277
NOCA	High	2000–2018	-0.256	-0.317	-0.191	0.337	-0.097	0.737
NOCA	Total	2000–2018	-0.030	-0.052	-0.008	7.605	7.245	8.126
WRSH	Interior	1981–2018	0.029	-0.012	0.085	5.091	4.323	5.475
WRSH	Interior2000	2000–2018	0.017	-0.032	0.066	5.037	4.225	5.425
WRSH	Exterior	2000–2018	-0.004	-0.026	0.016	7.558	7.362	7.740
WRSH	Low	2000–2018	0.013	-0.023	0.046	6.988	6.719	7.225
WRSH	Medium	2000–2018	-0.012	-0.034	0.011	7.007	6.793	7.209
WRSH	High	2000–2018	0.252	0.161	0.320	1.117	0.138	1.731
WRSH	Total	2000–2018	-0.001	-0.020	0.016	7.675	7.490	7.853