Technical Report HCSU-034

DEVELOPING ACCURATE SURVEY METHODS FOR ESTIMATING POPULATION SIZES AND TRENDS OF THE CRITICALLY ENDANGERED NIHOA MILLERBIRD AND NIHOA FINCH

P. Marcos Gorresen[1], Richard J. Camp[1], Kevin W. Brinck[1], and Chris Farmer[2]

[1]Hawai`i Cooperative Studies Unit, University of Hawai`i at Hilo, P.O. Box 44, Hawai`i National Park, HI 96718
[2]American Bird Conservancy, Kilauea Field Station, P.O.Box 44, Hawai`i National Park, HI 96718

Hawai`i Cooperative Studies Unit
University of Hawai`i at Hilo
200 W. Kawili St.
Hilo, HI 96720
(808) 933-0706

October 2012

This product was prepared under Cooperative Agreement CAG11AC20270 for the Pacific Island Ecosystems Research Center of the U.S. Geological Survey.

Technical Report HCSU-034

Developing Accurate Survey Methods for Estimating Population Sizes and Trends of the Critically Endangered Nihoa Millerbird and Nihoa Finch

P. Marcos Gorresen[1], Richard J. Camp[1], Kevin W. Brinck[1], and Chris Farmer[2]

[1] Hawai`i Cooperative Studies Unit, University of Hawai`i at Hilo,
P.O. Box 44, Hawai`i National Park, HI 96718
[2] American Bird Conservancy, Kīlauea Field Station,
P.O. Box 44, Hawai`i National Park, HI 96718

Hawai`i Cooperative Studies Unit
University of Hawai`i at Hilo
200 W. Kawili St.
Hilo, HI 96720
(808) 933-0706

October 2012

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

This report describes the results of a comparative study of bird survey methods undertaken for the purpose of improving assessments of the conservation status for the two endemic passerines on the Island of Nihoa—Nihoa Millerbird (Sylviidae: *Acrocephalus familiaris kingi*) and Nihoa Finch (Fringilidae: *Telespiza ultima*; also referred herein as millerbird and finch)—both listed as endangered under the Federal Endangered Species Act (ESA) and Hawai`i Revised Statutes 195D. The current survey protocol, implemented since 1967, has produced a highly variable range of counts for both the millerbird and finch, making difficult assessments of population size and trend. This report details the analyses of bird survey data collected in 2010 and 2011 in which three survey methods were compared—strip-transect, line-transect, and point-transect sampling—and provides recommendations for improved survey methods and protocols. Funding for this research was provided through a Science Support Partnership grant sponsored jointly by the U.S. Geological Survey (USGS) and the U.S. Fish and Wildlife Service (USFWS).

Point-transect surveys indicated that millerbirds were more abundant than shown by the strip-transect method, and were estimated at 802 birds in 2010 (95%CI = 652 – 964) and 704 birds in 2011 (95%CI = 579 – 837). Point-transect surveys yielded population estimates with improved precision which will permit trends to be detected in shorter time periods and with greater statistical power than is available from strip-transect survey methods. Mean finch population estimates and associated uncertainty were not markedly different among the three survey methods, but the performance of models used to estimate density and population size are expected to improve as the data from additional surveys are incorporated. Using the point-transect survey, the mean finch population size was estimated at 2,917 birds in 2010 (95%CI = 2,037 – 3,965) and 2,461 birds in 2011 (95%CI = 1,682 – 3,348). Preliminary testing of the line-transect method in 2011 showed that it would not generate sufficient detections to effectively model bird density, and consequently, relatively precise population size estimates. Both species were fairly evenly distributed across Nihoa and appear to occur in all or nearly all available habitat. The time expended and area traversed by observers was similar among survey methods; however, point-transect surveys do not require that observers walk a straight transect line, thereby allowing them to avoid culturally or biologically sensitive areas and minimize the adverse effects of recurrent travel to any particular area. In general, point-transect surveys detect more birds than strip-survey methods, thereby improving precision and resulting population size and trend estimation. The method is also better suited for the steep and uneven terrain of Nihoa.

INTRODUCTION

In biological surveys, the concept *observer effect* refers to changes in the behavior of an organism caused by the act of observation. In 1980, Conant *et al.* (1981) applied several bird survey methods and compared the resulting estimates of millerbird and finch densities on Nihoa. The authors concluded that survey methods conducted while traversing a sample area are prone to attracting inquisitive millerbirds and yielding inflated and imprecise estimates of their densities, whereas stationary methods showed no such bias. Conversely, stationary surveys apparently attracted finches and inflated their density estimate, while mobile surveys were not biased. Moreover, Conant *et al.* (1981) also stated “fixed width strip census yield densities with too large a variance to be useful because of the narrow area (6 m wide) surveyed."

Despite these conclusions, surveys on Nihoa have been conducted for more than 40 years with the fixed-width strip-transect method. Perhaps as a consequence, millerbird population estimates have exhibited relatively high within-year variability and demographically implausible changes from year to year (Figure 1). For example, between 1967 and 2011 annual mean millerbird estimates ranged from 30 to 814, and the 95% confidence interval (CI) for the 2011 population estimate spanned 477 to 1,073 birds. The high variability in these estimates makes determining the actual population size and assessing management needs problematic. It also severely hinders the timely appraisal of population trends. For example, it would take about 55 years to detect a 25% decline and 28 years to detect a 50% decline in the millerbird population given the inter-annual variability exhibited by previous estimates (average coefficient of variation [CV] from 1967 to 2011 ≈ 0.4). As a result, long periods of surveys are required before statistically significant trends can be determined. Reducing extinction risks to the endemic Nihoa Millerbird and Nihoa Finch requires an accurate assessment of these species' population trends so as to project anticipated trajectories and permit prioritization and evaluation of planned or existing management actions (e.g., millerbird translocation, invasive species control, etc.).

This study compares and evaluates survey methods with the objectives of improving the accuracy of density and population estimates for the Nihoa Millerbird and Nihoa Finch. The survey method protocols proposed as a result of this research address model assumption violations and bird behavior that may influence density estimation. Specifically, this USGS/USFWS Science Support Partnership study meets the following objectives:

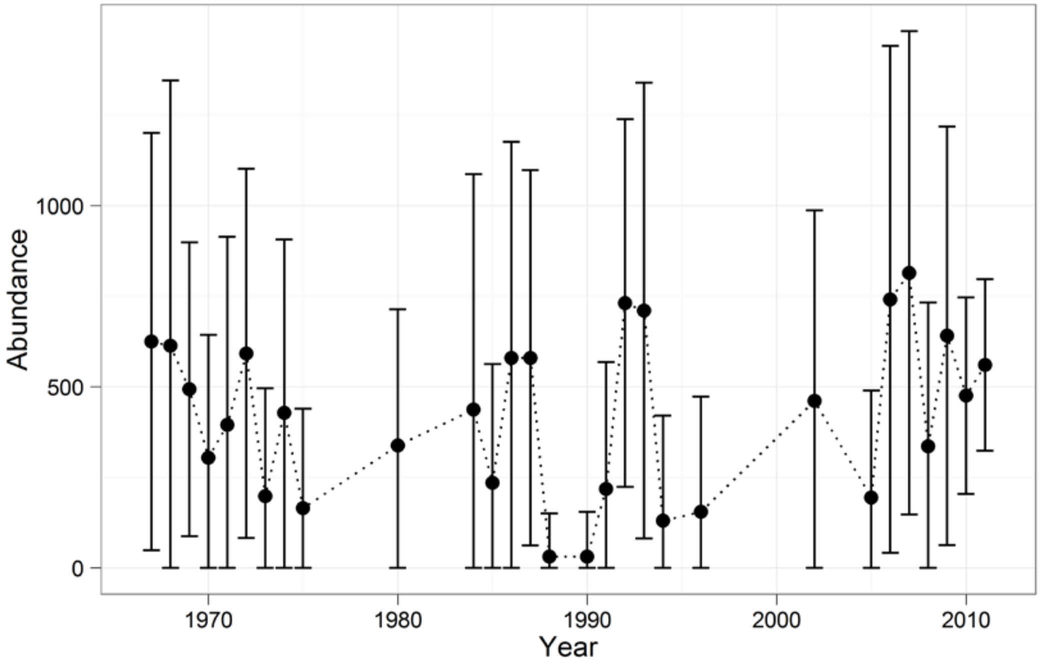
1) Assist with the planning and implementation of current and alternative passerine sampling methods
2) Estimate and compare the precision of current and alternate sampling methods based on specific monitoring objectives
3) Compare logistical, ecological, and cultural advantages and disadvantages of current and alternative survey methods
4) Provide general protocols for survey methods and data analyses

METHODS

Study Area

Nihoa, also known as Moku Manu (or Bird Island), is a volcanic island remnant and the tallest of 10 islands and atolls in the Northwestern Hawaiian Islands (NWHI) that now comprise the Papahānaumokuākea Marine National Monument (PMNM 2008). Located at the southeastern end of the NWHI chain (23° 03′ N, 161° 55′ W), Nihoa is the closest of these islands to the eight main Hawaiian Islands and is situated about 250 km (155 mi) northwest of Kaua`i Island. At only about 72 ha (179 ac) in size, the island's topography is comprised of south-facing drainages sloping down to sea-level and sheer cliffs along the rest of the coastal periphery (Figures 2 and 3). Elevational high points are Miller's Peak (272 m [892 ft]) in the west and Tanager Peak (259 m [850 ft]) in the east. The vegetation on Nihoa consists of low-stature coastal mixed community (*Sida* mixed shrub and grassland) and coastal dry shrubland dominated by 'ilima (*Sida fallax*), `āweoweo (*Chenopodium oahuense*), 'ohai (*Sesbania*

A)



B)

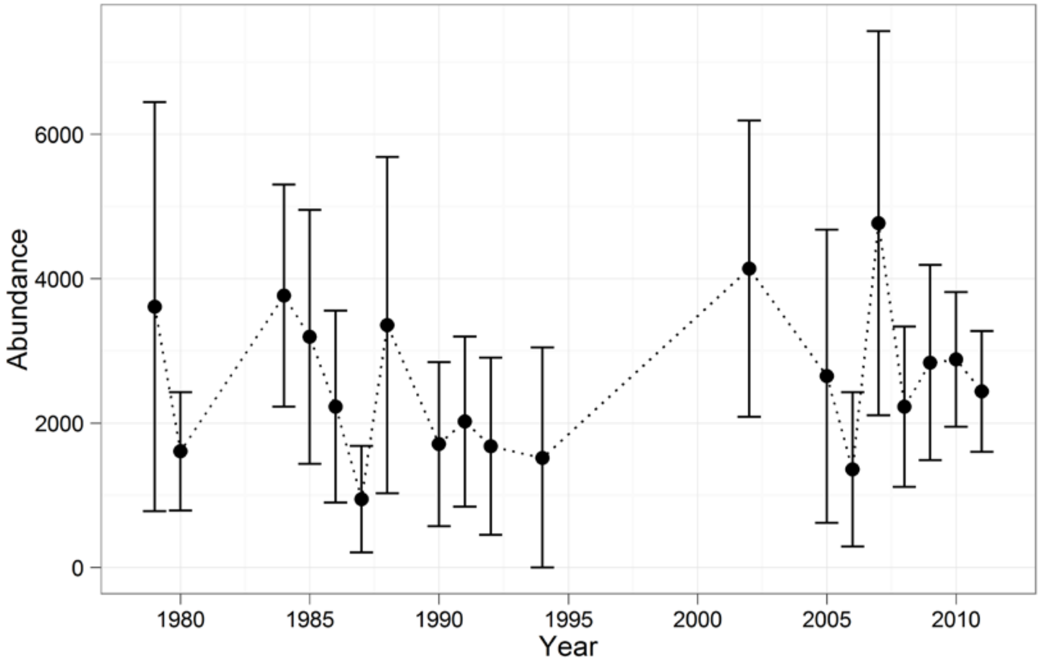


Figure 1. Population estimates for Nihoa Millerbird (panel A) and Nihoa Finch (panel B) derived from strip-transect surveys (USGS, unpub. data).

Figure 2. Aerial view of Nihoa Island, Northwestern Hawaiian Islands. Photo by C. Farmer; September 2011.

Figure 3. View of Nihoa Island from Tanager Peak. Photo by C. Farmer; September 2011.

tomentosa), pōpolo (*Solanum nelsonii*), and kalamālō (*Eragrostis variabilis*; Conant 1985, Wagner *et al.* 1999). In addition to the Nihoa Millerbird and Nihoa Finch, the island supports large populations of many species of seabirds (PMNM 2008). About 61.9 ha (152.9 ac) of the landcover on Nihoa is vegetated and available as millerbird and finch habitat (USGS, unpub. data; Figure 4).

Survey Transect and Station Establishment

This report compares three sampling methods: strip-transects, point-transects, and line-transects. Up to 54 strip-transects have been sampled annually in past surveys (Figure 4). For the strip method, all detections within 8.25 ft (2.5 m) on either side of a 250 foot-long (76.2 m) transect centerline are recorded and more distant detections are ignored (i.e., "bird in/bird out"). In addition to the strip method, the USFWS initiated a preliminary assessment of point-transect sampling in 2009 (Kohley *et al.* 2009). A total of 10 stations were established at the endpoints of five existing transects, and all birds were recorded regardless of the distance to observer (i.e., "variable" distance measures). In 2010, the end points of 52 existing transects were used to establish and sample a total of 91 point-transect stations. In 2011, sampling was extended to a total of 54 transects and 108 stations. Observer-to-bird distances were also recorded simultaneously during 16 strip-transect surveys for use in evaluating line-transect sampling (i.e., by including counts of birds at distances greater than 8.25 ft [2.5 m] strip data can be treated as line-transect data). In addition, 88 point-transect stations were sampled at least twice ("repeat sampling") to improve within-year variance in population estimates. Repeat sampling also was implemented with the longer-term objective of improving trend estimation by providing data on the amount of variance that is attributable to sampling error as distinct from process error (i.e., inter-annual variance). Coordinates for point-transect stations are listed in Appendix 1.

Bird Sampling

The millerbird and finch counts analyzed in this report were conducted between 24 and 27 September 2010 and between 8 and 13 September 2011. Information on the detection type (aural, visual, or both), time of detection, and for point- and line-transect samples, the horizontal distance from the station center or transect centerline to individual birds, were recorded during a six-minute sampling period. Because the presence of an observer may affect bird behavior by causing attraction or avoidance, the orientation of a bird relative to the direction of travel by an observer was also recorded (as "ahead" and "behind"). At each station or transect the cloud cover, rain, wind average, and gust strength conditions were recorded as they can potentially affect an observer's ability to detect birds. In addition, within a 10 m radius of a station the dominant vegetation, canopy cover, canopy height, and vegetation density ("leafiness") were recorded. (See Appendix 2 for descriptions of the detection, sampling, and habitat variables.) Sampling was conducted between dawn and 1100 hours (HST local time) except during periods when rain, wind, or gust exceeded prescribed levels (light rain and wind level 3 on the Beaufort scale). Birds observed after a sampling period or between stations or transects were sometimes noted, but excluded from all subsequent analyses.

Data Handling

Survey data were evaluated for content and completeness in the field and again during data transcription into the Avian Monitoring Entry Form (version 2.1; available upon request). A quality assurance protocol verified data accuracy, all records were line-item proofed and standardized, and an error rate of <1% in data entry was determined through spot-checking

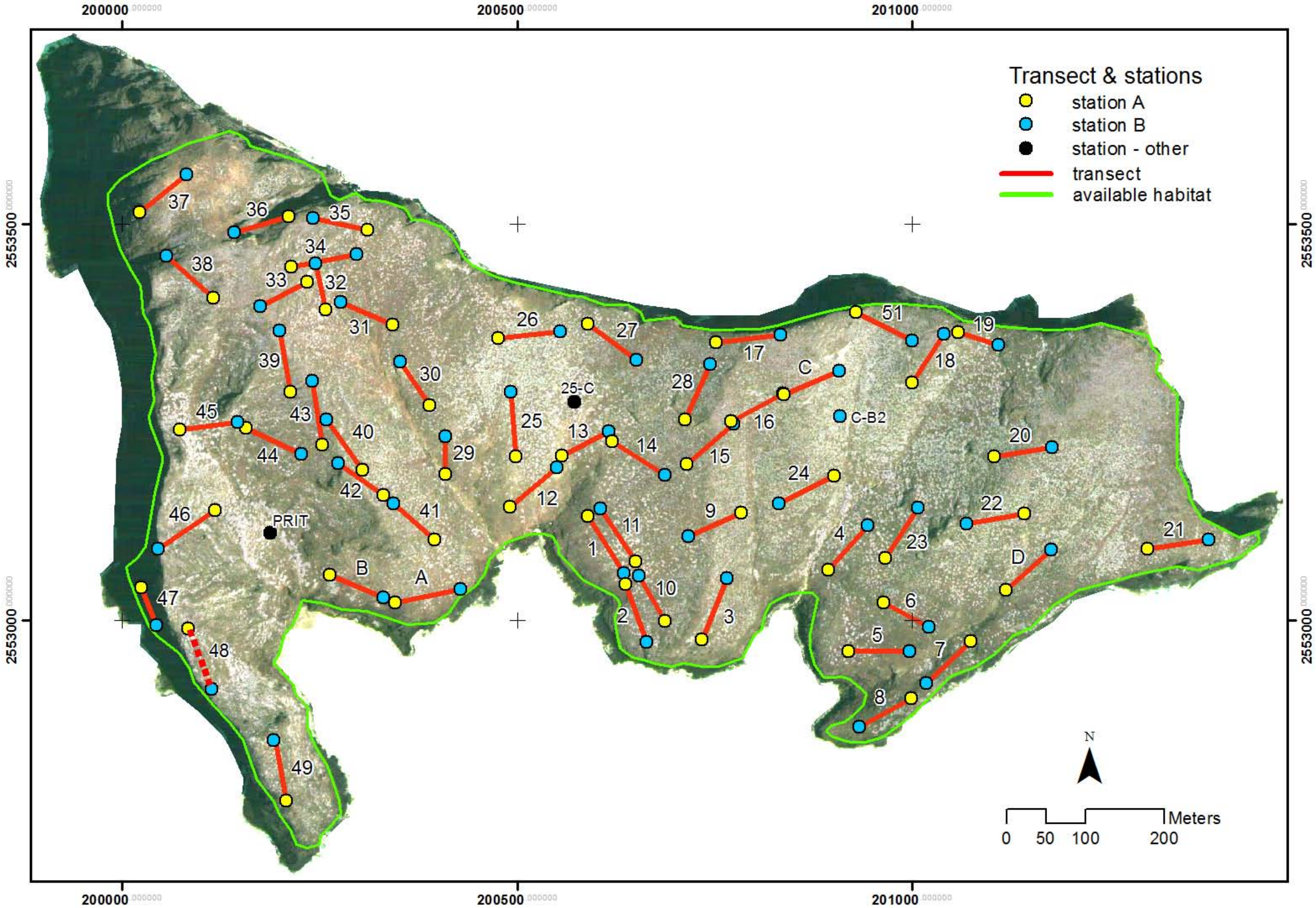


Figure 4. Transects and stations surveyed in 2010 and 2011 on Nihoa Island, Northwestern Hawaiian Islands. Transect identity is shown with numbers, and in a few cases, letters. Yellow and blue points indicate the location of point-transect stations A and B, respectively. Transect 48 was not surveyed in either year but is included to show its location for future survey planning. The extent of available habitat (61.9 ha [152.9 ac]) is shown in green.

before the data were analyzed. Metadata were produced describing the data set and error-checking (Appendix 3).

Analyses

Population estimates and bird abundance

Population sizes from all prior years were estimated by extrapolating the mean density of birds per strip-transect to the total habitat on Nihoa (6,795,360 ft^2). The density of birds per strip-transect was calculated as the count of birds divided by transect area (4,125 ft^2 [= 16.5 x 250 ft]), and the mean calculated depending on how many transects were sampled that year. Estimates of variance in abundance were derived analytically from the aggregate of all strip densities. However, this approach to analyzing bird counts does not incorporate site or sampling factors that affect bird detectability.

In contrast to simple count extrapolations used in past strip-transect surveys, the abundance estimates produced for this report apply a model-based approach to account for individuals that were undetected. Point- and line-transect methods are forms of distance sampling for which the probability of detecting birds is modeled as a function of their distance from an observer and other factors to obtain estimates of the effective area sampled and animal density (Buckland *et al*. 2001, 2004). Robust estimates rely upon the critical assumptions that all birds are detected with certainty at the station center point or transect line, birds are detected before they move in response to the observer, and distances are measured without error. Species density estimates (birds ha^{-1}) were calculated from point- and line-transect data using program DISTANCE, version 6.0, release 2 (Thomas *et al*. 2010). In cases where a station was sampled more than once in a survey period, density estimates were adjusted by effort (i.e., the number of times the station was counted). In addition to estimated densities, birds per station (BPS) values were produced for mapping distributions for both millerbirds and finches. To permit comparisons among annual point-transect surveys in which sampling effort differed, BPS values were calculated from the first of two or more repeat visits to a station.

Detection probability was modeled by functions describing how observations of birds diminished with distance and site and sampling covariates. Candidate detection function models were limited to half normal and hazard-rate detection functions with expansion series of order two (Buckland *et al*. 2001:361, 365); half normal candidates were paired with cosine and Hermite polynomial adjustments, and hazard-rate candidates were paired with cosine and simple polynomial adjustments. The uniform detection function was not considered because covariates cannot be modeled. To improve model precision, we incorporated sampling covariates in the multiple covariate distance sampling (MCDS) engine of DISTANCE (Marques and Buckland 2003, Thomas *et al*. 2010). Sampling covariates included observer, time of detection, detection type, whether a bird was “ahead” or “behind” the observer, cloud cover, and wind strength. Rain and gust strength were not modeled because of too few detections in all but the first categories. Site covariates included dominant vegetation type, vegetation cover, vegetation height, leafiness, and whether a station was the first or second of the pair of stations at the endpoints of a transect. This last variable was included because the speed of an observer’s approach to the first station may be more rapid, thereby potentially affecting bird behavior, than when it is the second station at the end of a slowly traversed transect. If the second station was not preceded by a line-transect survey, it was treated as if it were a rapidly approached station; i.e., a “first” station. All covariates were treated as categorical factors except time of detection, vegetation cover and cloud cover, which were treated as continuous covariates. No covariate interactions were included because of data limitation. Count data were truncated at a distance where the detection probability was <10%. This procedure facilitates modeling by deleting outliers and reducing the number of parameters needed to modify the detection function. We selected the model with the lowest second-order Akaike's Information Criterion value (as corrected for small sample sizes; AIC_c; Buckland *et al*. 2001, Burnham and Anderson 2002). Model fit was assessed by a visual assessment of the quantile plot of the modeled and observed distributions of detection distances. Species densities, variances and confidence intervals were derived from 999 bootstrap iterations in DISTANCE (Thomas *et al*. 2010).

The sampling of rare or uncommon species sometimes yields an insufficient number of detections to effectively fit survey-specific detection function models. To remedy this, pooling count data across survey years to fit a global detection function yields unbiased, or nearly unbiased, estimates and improves estimator certainty (Burnham *et al*. 1980, Buckland *et al*. 2004). This procedure, termed pooling robustness, controls for data collected under variable conditions and effectively reduces heterogeneity in detectability. Model-robustness is further increased by incorporating covariates, thus allowing the shape of detection functions to change according to different subsets of the full set of counts (Buckland *et al*. 2004, Marques *et al*. 2007). The survey year was also included as a covariate to accommodate for differences in detectability between surveys.

Power analysis

For population trends, statistical power is the ability to detect a change in abundance over time when one actually exists (Zar 1996). Power is determined by variability in the data (e.g., normal bird density fluctuations in the absence of a trend, surveying with different observers or at different times of year, etc.), sample size (number of sites surveyed per year), monitoring duration, the frequency of surveys (within and between years), the magnitude of the population change (trend), and the desired or acceptable level of statistical error (i.e., Type I error: the probability of erroneously concluding that there was a trend when none existed; and Type II error: the probability of erroneously missing an existing trend). Typically, the larger the sample size (i.e., number of stations surveyed), the smaller the variability. Power also increases with more frequent sampling, longer periods of monitoring, and higher rates or magnitudes of population change (e.g., 50% versus 25% change). In addition, power is greater for a one-tailed test of trend (e.g., detecting only a population decline) than for a two-tailed test.

Simulations were used to estimate the power to detect modest or large changes in population size (or density) over a range of years given varying levels of within-year variability in abundance estimates. More specifically, we estimated power for two levels of population decline (25% and 50%), three sampling durations (10, 25, and 50 years), and three levels of variance (CV = 0.1 [low], 0.2 [moderate], and 0.3 [high]). This was accomplished by simulating log-linear regressions for each combination of population decline, survey duration, and sampling variance. Trends were specified by using a starting abundance of 750 birds (approximately the average of the point-transect mean millerbird abundance for 2010 and 2011) which then declined at a constant rate to 75% or 50% of the initial value over 10, 25, or 50 survey years. Variance in each year was taken as 10%, 20%, or 30% of the simulated abundance (i.e., CV = 0.1, 0.2, or 0.3). Abundance values were randomly drawn from a normal distribution determined by the mean and variance of each year. Simulated abundances less than zero were avoided by setting the minimum value to one. We then log-transformed the simulated abundances to stabilize the variance and calculated the *p*-value of a linear regression. We repeated this procedure 10,000 times, and took the proportion of simulations with significant *p*-values (≤ 0.05) as the estimated statistical power. Although the power analysis simulated a decline in abundance, the tests were two-tailed and provide estimates equally applicable for detecting increasing abundance.

Sample size

The number of survey points (i.e., sample size) strongly influences the statistical power of a monitoring protocol. The bird count and sampling effort data acquired as part of the 2010–2011 surveys were used to determine the number of sampling units needed to establish reliable abundance estimates given an expected number of individual birds (e.g., an average from past surveys) and expected or desired CV. Using methods described in Buckland *et al.* (2001: 241–246), the number of stations (*K*) needed to produce annual density estimates for a range of CVs ($cv(\hat{D})$) can be calculated with the equation

$$K = \left(\frac{b}{\{cv(\hat{D})\}^2}\right) \times \left(\frac{k_0}{n_0}\right) \qquad \text{(Equation 1)}$$

given the number of point-transect stations sampled (k_0), the number of individual birds detected (n_0), and the variability in the number of birds detected and distance modeling uncertainty (*b*), calculated as

$$b \cong n_0 \times \left\{obs\ cv(\hat{D})\right\}^2 \qquad \text{(Equation 2)}$$

where *b* incorporates the observed CV.

For comparison, sample size requirements were also calculated for line-transect surveys (*L*) with the equation

$$L = \left(\frac{b}{\{cv(\hat{D})\}^2}\right) \times \frac{l_0}{n_0} \qquad \text{(Equation 3)}$$

where l_0 is the number of point-transects sampled. Similarly, sample size requirements were calculated for strip-transect surveys (*S*) with

$$S = \left(s_0 \times \left\{cv(\hat{D})\right\}^2\right) \Big/ obs\ cv(\hat{D})^2 \qquad \text{(Equation 4)}$$

where s_0 is the number of strip-transects sampled.

Equations 1 and 2 were also used to calculate the expected CV from future point-transect surveys given a specified number of stations, and to compare the sampling effort required for point-, line-, and strip-transect surveys. The finch and millerbird abundances observed in 2011 were used as they provided a more conservative (i.e., lower) set of values than the 2010 counts.

Survey efficiency, logistical costs, and resource impacts

Survey methods were compared based on the results of the 2010–2011 bird counts and uncertainty in resulting population size estimates. The effort involved in conducting strip, line, and point surveys was also compared based on the time invested in sampling and travelling between locations.

The utility of the historical strip survey data was examined by comparing the millerbird densities derived from the 2010 and 2011 strip and point-transect surveys. This assessment sought to determine what results might point surveys have yielded if conducted prior to 2010. This was accomplished by fitting a linear regression model of the point estimates as a function of the strip estimates and fixing the intercept at zero (a fixed intercept is required to fit a linear regression model from two points of data). Conservative confidence intervals for predicted point-transect estimates were calculated based on historical (1967–2009) strip-transect estimates by calculating predicted values of the upper and lower limits of the historical strip-transects, plus or minus the additional uncertainty from the regression model prediction. The result is a conservative confidence interval around historical strip-transect surveys adjusted for the observed relationship between strip-transect and point-transect estimates.

RESULTS

Point-transect Surveys

Sampling conditions and site characteristics

In general, the sampling conditions were good during the 2010 and 2011 surveys (Table 1). The weather was only moderately cloudy (averaging 37% and 23% cloud-cover in 2010 and 2011, respectively) and with essentially no rain. Wind was moderate (averaging 1.2 and 1.4, respectively, on the Beaufort scale) with few sustained gusts.

Table 1. Sampling conditions during the 2010 and 2011 point-transect surveys used as distance modeling covariates (mean ± standard deviation; minimum–maximum range).

Survey	Time	Cloud Cover	Rain	Wind
2010	0929 (± 131 min; 0705-1157)	37 (± 26; 0-100)	0.07 (± 0.37; 0-2)	1.5 (± 0.9; 0-3)
2011	0907 (± 124 min; 0659-1150)	23 (± 22; 0-100)	0.02 (± 0.20; 0-2)	1.4 (± 0.7; 0-3)

The site characteristics measured at point-transect stations were relatively unchanged between 2010 and 2011 (Table 2), and indicate both that habitat attributes did not change much during this period and that there was fairly high consistency in the attributes assigned by observers. Vegetation cover was dominated by *Solanum nelsonii*, *Sida fallax*, and *Eragrostis variabilis*. Other species (such as *Chenopodium oahuense*, formerly a common plant but recorded at only two stations in 2011) were not classified as dominant species at any station. The vegetation at about half of the sites consisted of plants less than 0.5 m in height. Plant “leafiness” was subjectively classed as “medium” at about half the stations, with the remaining sites assigned about equally to “low” and “high” classes. The percentage of vegetation cover ranged widely, with a somewhat lower mean value in 2010 (50%) than in 2011 (64%).

Distance models

Up to 23 distance models were evaluated with the Nihoa Millerbird and Nihoa Finch point-transect count data (Appendix 4). For models run separately on 2010 and 2011 millerbird counts, the model accounting for the effects of “detection type” ranked highest to the exclusion

Table 2. Site characteristics at the 2010 and 2011 point-transect survey stations used as distance modeling covariates. Values for the categorical variables vegetation height, leafiness and dominant vegetation type were calculated as the proportion of total counts at stations (number of stations in parentheses). The variable vegetation cover is described by the mean, standard deviation, and minimum to maximum range of values.

		Survey	
		2010	2011[1]
Veg height	Low	48% (43)	50% (99)
	High	52% (47)	50% (101)
Leafiness	Low	32% (29)	34% (68)
	Medium	43% (39)	48% (96)
	High	24% (22)	18% (36)
Dom veg[2]	CHACEL	0.02% (2)	0.02% (4)
	ERAVAR	26% (23)	25% (50)
	PRIREM	0% (0)	0.02% (4)
	SESTOM	0.01% (1)	0.02% (4)
	SIDFAL	33% (30)	29% (57)
	SOLNEL	38% (34)	41% (81)
Veg cover		50% (± 17; 10-90%)	64% (± 18; 20-100%)

[1] Totals to 200, the number of counts at the 108 stations surveyed in 2011

[2] Dominant vegetation: CHACEL = *Chamaesyce celastroides*; ERAVAR = *Eragrostis variabilis*; PRIREM = *Pritchardia remota*; SESTOM = *Sesbania tomentosa*; SIDFAL = *Sida fallax*; and SOLNEL = *Solanum nelsonii*

of all others. This model indicated that there were marked differences in the detection functions of counts obtained by visual compared to auditory observations (Figure 5). Millerbirds generally appear to be more visually detectable at a closer range than birds detected aurally, and the relative absence of auditory counts at short distances (<6 m or so) may indicate that birds close to an observer tend not to vocalize. In contrast, higher than expected visual counts at a distance <10 m appears to demonstrate the attraction of (generally quiet) birds to observers. The final millerbird and finch models selected were based on the data pooled for both 2010 and 2011, and included the covariates “detection type” and “year” to account for differences in bird detections between both years (Table 3). Finch detection functions were comparable to those of millerbirds in that the paucity of auditory counts and the higher than expected number of visual detections at short distances indicated that birds were relatively quiet, but drawn to observers.

Although the covariates in selected models typically accounted for almost all observed variance (as shown by relatively large model weights), lower ranked models include covariates that might exhibit higher model weights if the influence of top-ranked covariates are reduced in future surveys (e.g., survey training that minimizes differences in the abilities of multiple observers to detect birds). For example, the covariate “observer” may reflect disparities in

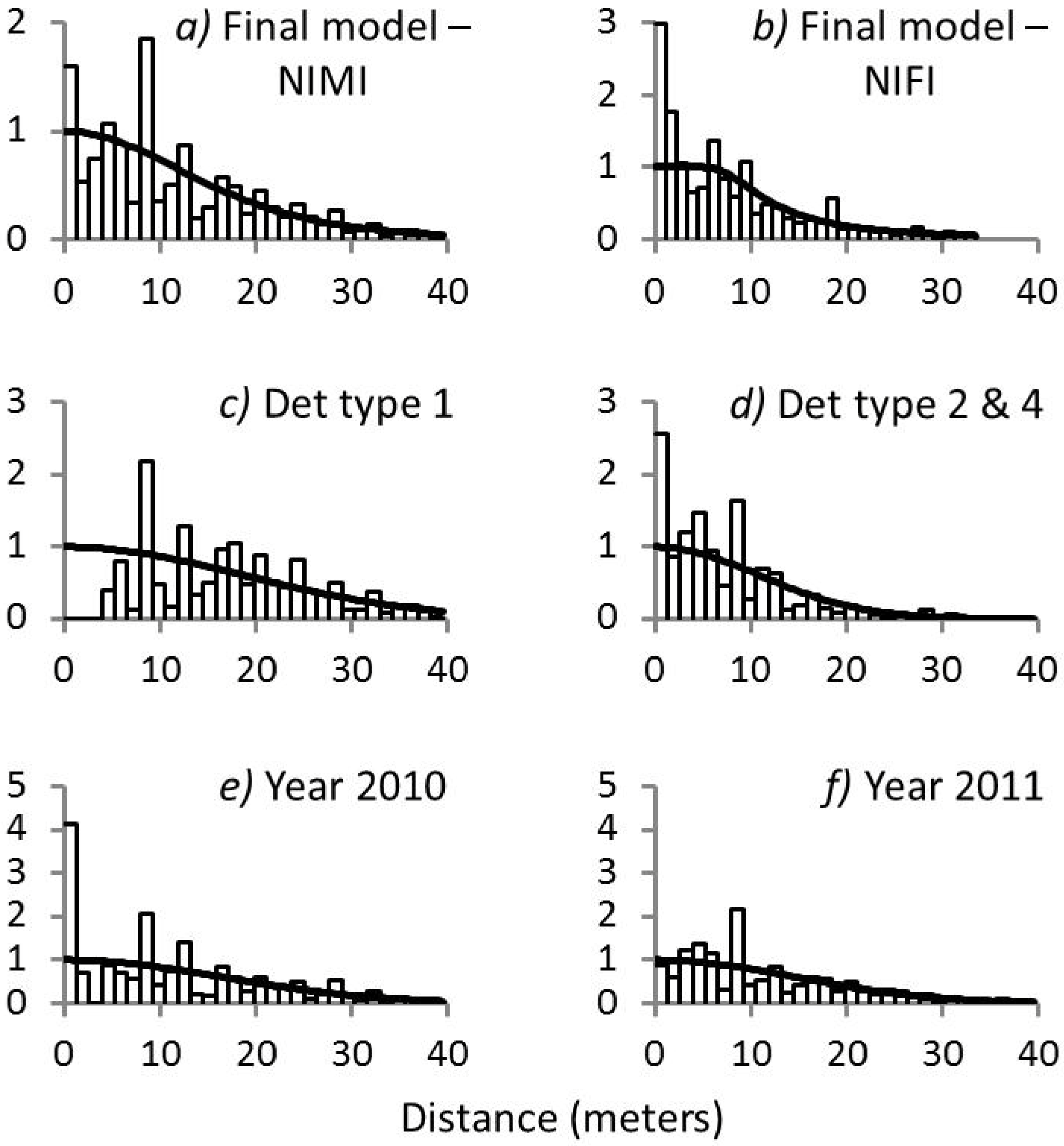


Figure 5. Illustrative set of graphics depicting the modeled detection function (solid line) and relative frequency of observations as a function of distance between observer and bird detection (histogram). The final models selected for Nihoa Millerbird and Nihoa Finch were based on data pooled for both 2010 and 2011 and include the covariates “detection type” and “year” (panels a and b). For brevity, the subsequent graphics show detection function and histogram for the same covariates based on millerbird models only (panels c to f).

recording birds that initially “flushed” at the arrival of an observer at a survey station, and the range of abilities at detecting distant birds. Likewise, “dominant vegetation type” was frequently among the higher ranked covariates and suggests that it may also affect bird detection (Appendix 4).

Table 3. Final models (both for individual and pooled years), used to estimate Nihoa Millerbird and Nihoa Finch abundances. Truncation distance (m) to facilitate model fitting, effective detection radius (EDR; distance at which half of detections were observed), detection probability estimates ($\hat{p}$), and associated standard errors (SE) are presented for each model.

Survey	Model and covariates[1]	Truncation	EDR (SE)	$\hat{p}$ (SE)
Nihoa Millerbird				
2010 & 2011	H-norm Key DT & Year	39.6	19.6 (0.48)	0.24 (0.01)
2010	H-rate Key DT	39.8	21.6 (1.17)	0.30 (0.03)
2011	H-norm Key DT	34.5	18.4 (0.56)	0.28 (0.02)
Nihoa Finch				
2010 & 2011	H-rate Key DT & Year	33.6	16.4 (0.24)	0.24 (0.01)
2010	H-rate Key DT	33.6	16.5 (0.44)	0.24 (0.01)
2011	H-rate Cos Obs	33.6	13.1 (0.26)	0.15 (0.01)

[1] Models included half normal (H-norm) and hazard-rate (H-rate) key detection functions with series expansions cosine (Cos). Covariates included the categorical variables detection type (DT), observer (Obs), and year of survey (Year).

Bird abundance, population size, and distribution

A total of 197 Nihoa Millerbirds was detected in 2010, from which 141 detections were used for modeling (the remainder were omitted because they exceeded the 39.6 m truncation distance; Table 4). In 2011, 284 millerbirds were detected, and 259 were used for distance modeling. In 2010 and 2011 there were 373 and 681 Nihoa Finch detections, respectively, with 327 and 602 detections within the 33.6 m truncation distance and used for modeling.

Table 4. Point-transect survey effort (Stations = number of stations sampled, Effort = number of counts at stations), numbers of Nihoa Millerbird and Nihoa Finch detections, and numbers of detections used to estimate abundances (Modeled).

Survey	Stations	Effort	Detections	Modeled
Nihoa Millerbird				
2010	90	91[a]	197	141
2011	108	200	284	259
Nihoa Finch				
2010	90	91	373	327
2011	108	200	681	602

[a] includes one repeat count at a station

Models based on the combined 2010 and 2011 survey data for the Nihoa Millerbird produced an estimated density of 12.96 birds/ha (95%CI = 10.54–15.58) in 2010 and 11.37 birds/ha (95%CI = 9.35–13.52) in 2011 (Table 5). Estimated Nihoa Finch densities were 35.98 birds/ha (95%CI = 24.24–57.59) in 2010 and 55.95 birds/ha (95%CI = 41.2–74.35) in 2011 (Table 6).

Table 5. Density (birds per ha) and abundance (total population) estimates for the Nihoa Millerbird from point-transect counts in 2010 and 2011. Variance estimates were calculated using bootstrap methods (SE = standard error, %CV = percent coefficient of variation, L 95% CL = lower 95% confidence limit, and U 95% CL = upper 95% confidence limit).

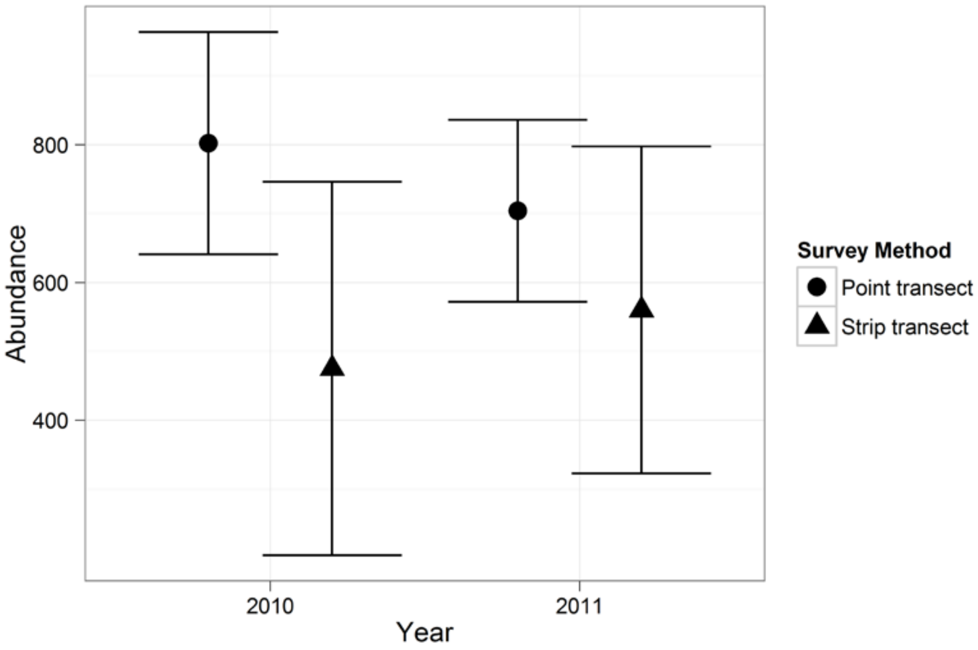
Survey		Estimate	SE	%CV	L 95% CL	U 95% CL
Combined surveys						
2010	Density	12.96	1.33	10.26	10.54	15.58
	Abundance	802	82.28	10.26	652	964
2011	Density	11.37	1.09	9.57	9.35	13.52
	Abundance	704	67.35	9.57	579	837
Individual surveys						
2010	Density	10.22	3.67	35.87	5.44	18.52
	Abundance	633	266.98	35.87	336	1,147
2011	Density	12.29	1.36	11.05	9.82	15.02
	Abundance	761	84.06	11.05	608	930

Table 6. Density (birds per ha) and abundance (total population) estimates for the Nihoa Finch from point-transect counts in 2010 and 2011. Variance estimates were calculated using bootstrap methods (SE = standard error, %CV = percent coefficient of variation, L 95% CL = lower 95% confidence limit, and U 95% CL = upper 95% confidence limit).

Survey		Estimate	SE	%CV	L 95% CL	U 95% CL
Combined surveys						
2010	Density	47.12	7.77	16.49	32.90	64.05
	Abundance	2,917	480.93	16.49	2,037	3,965
2011	Density	39.75	6.61	16.62	27.17	54.09
	Abundance	2,461	408.95	16.62	1,682	3,348
Individual surveys						
2010	Density	35.98	8.80	24.45	24.24	57.59
	Abundance	2,227	544.48	24.45	1,500	3,565
2011	Density	55.95	8.32	14.88	41.23	74.35
	Abundance	3,463	515.29	14.88	2,552	4,602

These densities were extrapolated to the 61.9 ha (152.9 ac) of available habitat to yield mean Nihoa Millerbird population size estimates of 802 birds (95%CI = 652–964) in 2010 and 704 birds (95%CI = 579–837) in 2011 (Figure 6). The mean Nihoa Finch population size was estimated at 2,917 birds (95%CI = 2,037–3,965) in 2010 and 2,461 birds (95%CI = 1,682–3,348) in 2011. Note that the measurement of 61.9 ha (152.9 ac) of available habitat was obtained by delineating vegetated land cover and excluding steep cliffs (USGS, unpub. data) and differs slightly from the 63.1 ha (6,795,360 sq ft) used in previous field reports (e.g., Kropidlowski *et al*. 2008, VanderWerf *et al.* 2011).

A)



B)

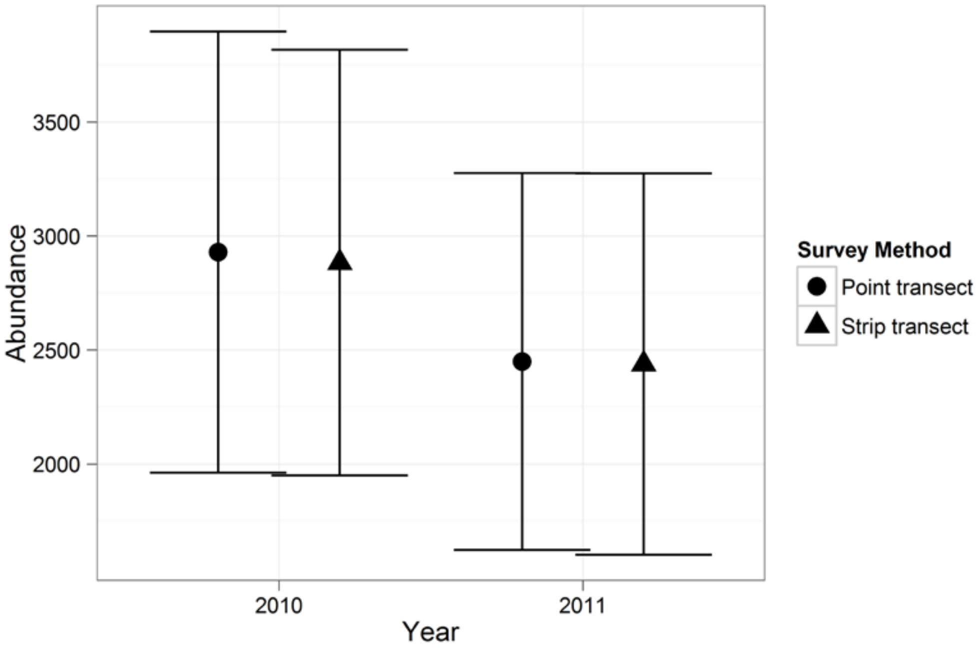


Figure 6. Comparison of the population estimates (mean and 95%CI) for point- and strip-transect methods for the Nihoa Millerbird (panel A) and Nihoa Finch (panel B) in 2010 and 2011.

Model performance is often improved with the incorporation of more observations. In the case of the millerbird density models, the combined 2010 and 2011 count data had considerably lower within-year variance than models based on the separate datasets for each year (Table 5). For instance, CV was 36% in 2010 but only 11% for that year from models that pooled millerbird count data for both years. Similarly, for the finch the CV was 24% in 2010 but only 16% for the models that combined the 2010 and 2011 counts (Table 6).

Both millerbirds and finches were fairly evenly distributed across Nihoa in 2010 and 2011 (Figures 7, 8, 9, and 10). No notable gaps in occurrence were evident, although millerbirds were not detected at a few stations in the west part of the island in 2010 and in the east part in 2011. The high proportion of stations with bird detections also indicates near complete use of available habitat for both species in both years. Millerbirds and finches were recorded at 80–81% and 96–97% of stations, respectively (Table 7). However, these measures of occupancy do not account for imperfect detection and as such underestimate true occupancy.

Power analysis

The ability of a series of surveys to detect trends depends to a large extent on the amount of within-year variability in estimated bird abundance. Prospective power analysis of our data showed that for a species undergoing a 25% decline from its initial abundance, adequate power was only attained in situations when CV was no more 10% and survey monitoring efforts were sustained for about 25 years or more (Table 8; Figure 11). Higher levels of CV (e.g., ≥ 20%) were shown to be incapable of detecting trends even for efforts lasting as long as 50 years. High within-year variability only permitted identification of a significant trend when the magnitude of the population decline was on the order of a 50% change over a period of at least 22 years.

The sample size (i.e., number of counts) needed to yield a desired within-year CV in point-transect surveys depends on bird abundance and observed CV, and consequently, differed for the millerbird and finch (Table 9). For example, about 244 samples are needed to attain a 10% CV for the millerbird (a level that provides sufficient statistical power to detect a 25% decline in abundance in about 25 years, or a 50% decline in less than 10 years). However, because of the relatively higher CV observed for the finch (about 17%), as many as 443 samples would be required to achieve a 10% CV. Note that a similar sampling effort may be obtained from a set of stations sampled once or a smaller set sampled multiple times. That is, a sample size of 200 counts may be derived from 200 stations sampled once or 100 stations sampled twice (although repeated sampling of too few stations will diminish the capacity of bird detection models to distinguish spatially varying covariate effects). Alternatively, 100 point-transect stations may be expected to yield a CV of 16% and 22% for each species.

Comparison of Survey Methods

Bird abundance and uncertainty in estimates

The results of strip- and line-transects differed from those of point-transect survey methods. Although the confidence intervals overlap, estimated mean millerbird abundance for the point-transect surveys appeared markedly higher than those from strip sampling method in both years (e.g., strip mean equaled 507 birds, whereas point mean equaled 802 birds in 2010; Tables 5, 6, 10, Figure 6). Potential sources of bias in population estimates derived from strip-transects can arise because birds may initially be secretive (and unobserved) as an observer moves rapidly along a strip, and observer (and other) effects are not modeled with this survey method. In contrast, the estimated mean finch population size and variance were very similar

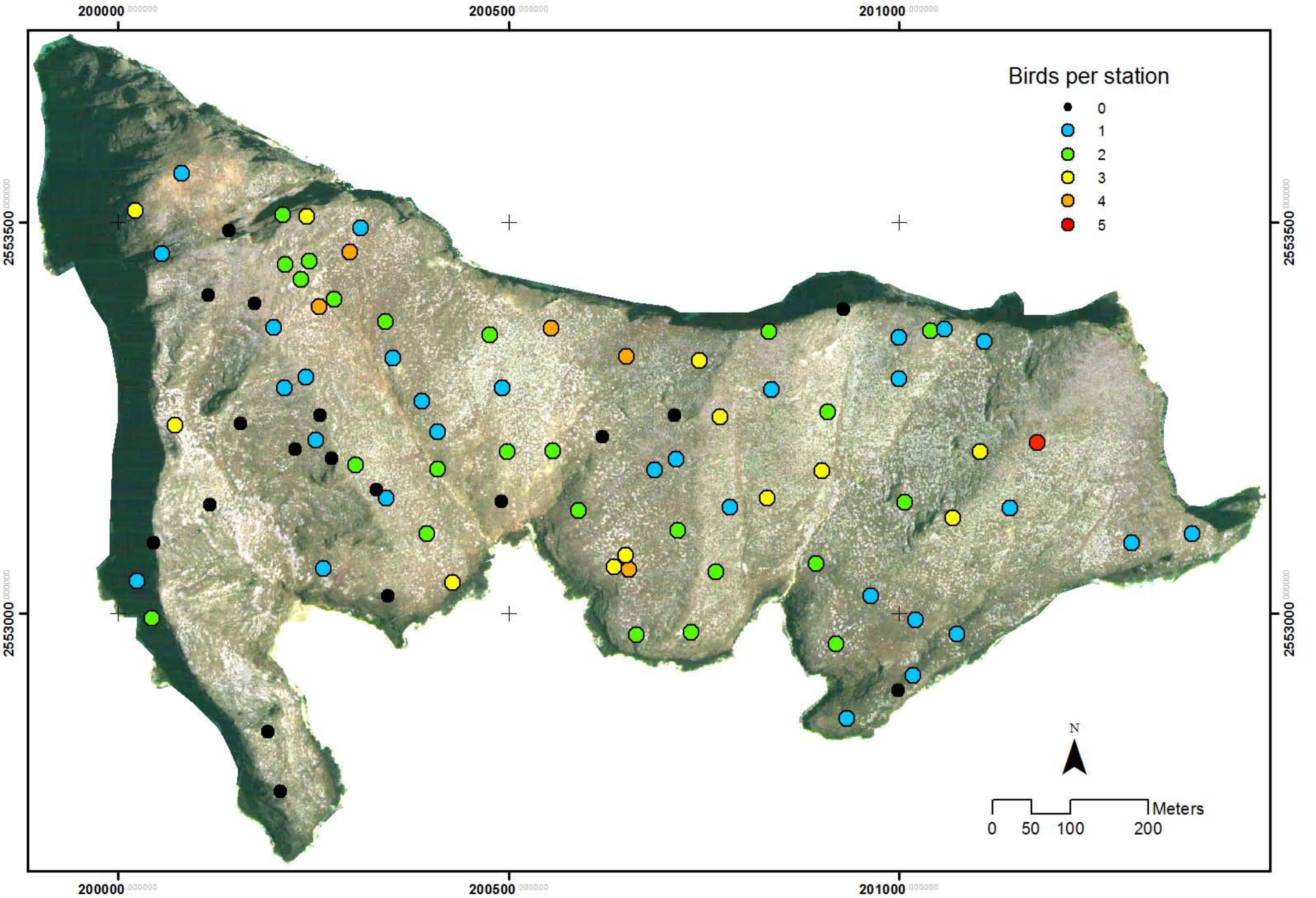


Figure 7. Nihoa Millerbird abundance (birds per station) and distribution in 2010 on Nihoa Island, Northwestern Hawaiian Islands.

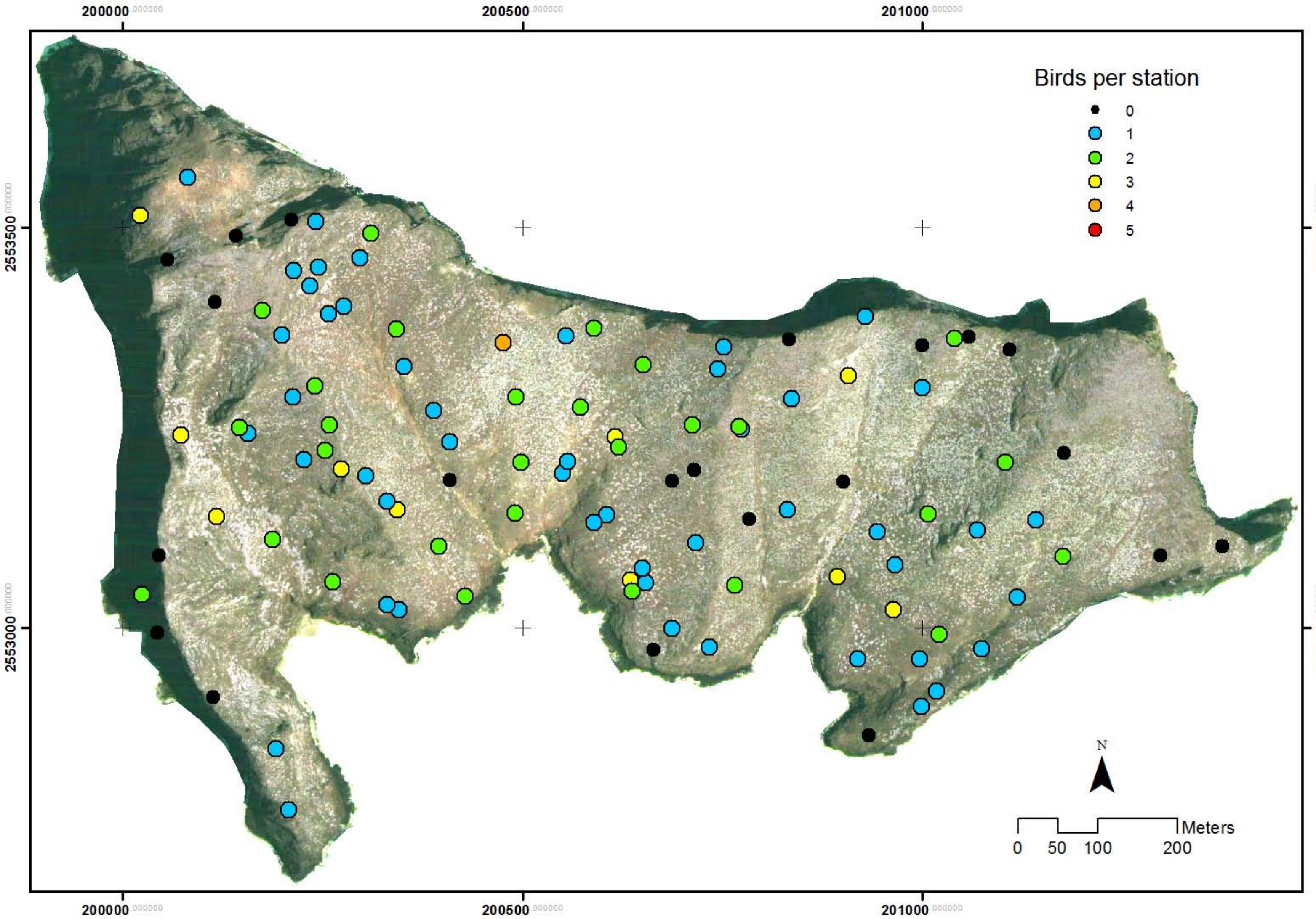


Figure 8. Nihoa Millerbird abundance (birds per station) and distribution in 2011 on Nihoa Island, Northwestern Hawaiian Islands. For comparability to 2010 results, only the counts for the first of two or more repeat surveys are shown.

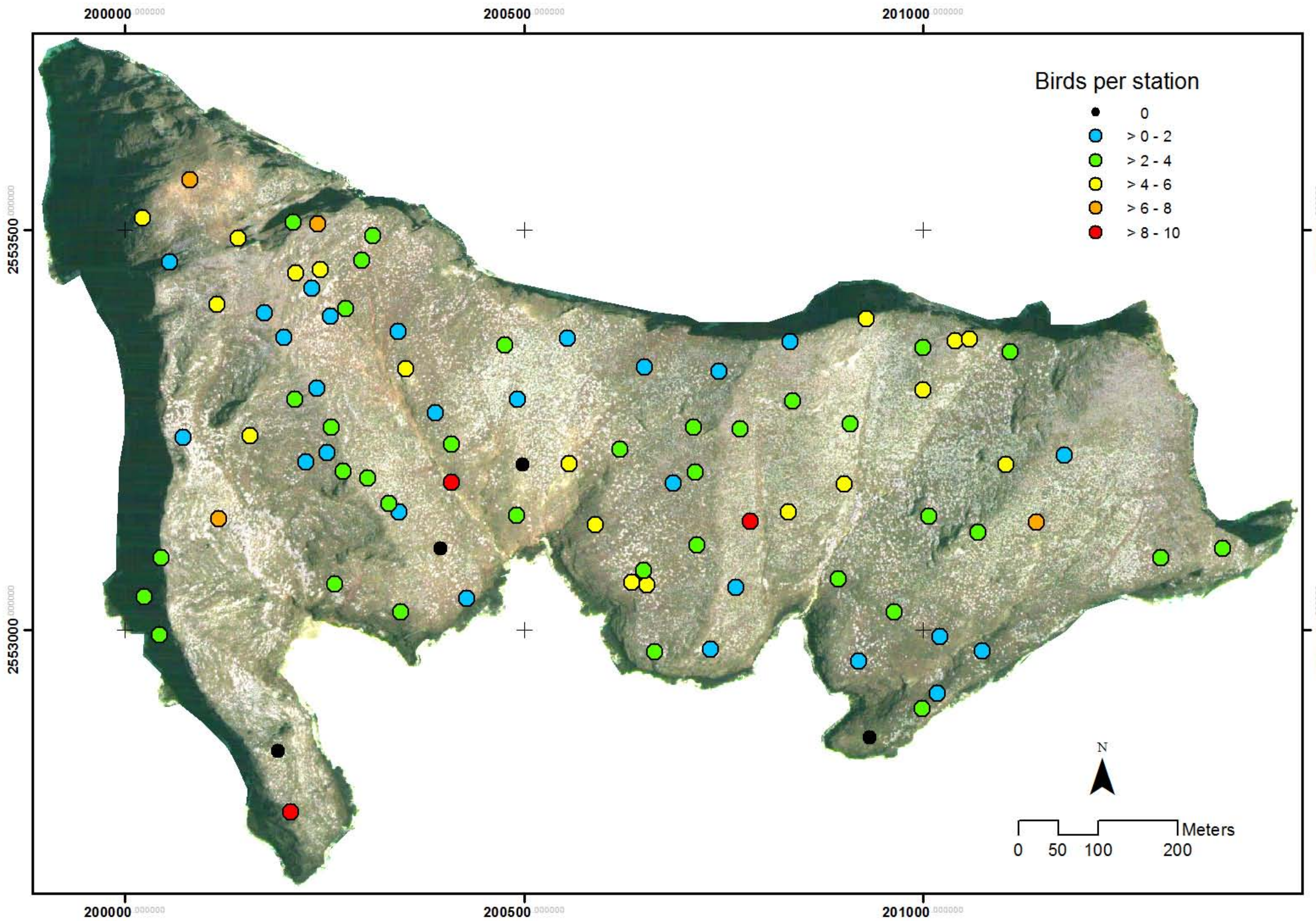


Figure 9. Nihoa Finch abundance (birds per station) and distribution in 2010 on Nihoa Island, Northwestern Hawaiian Islands.

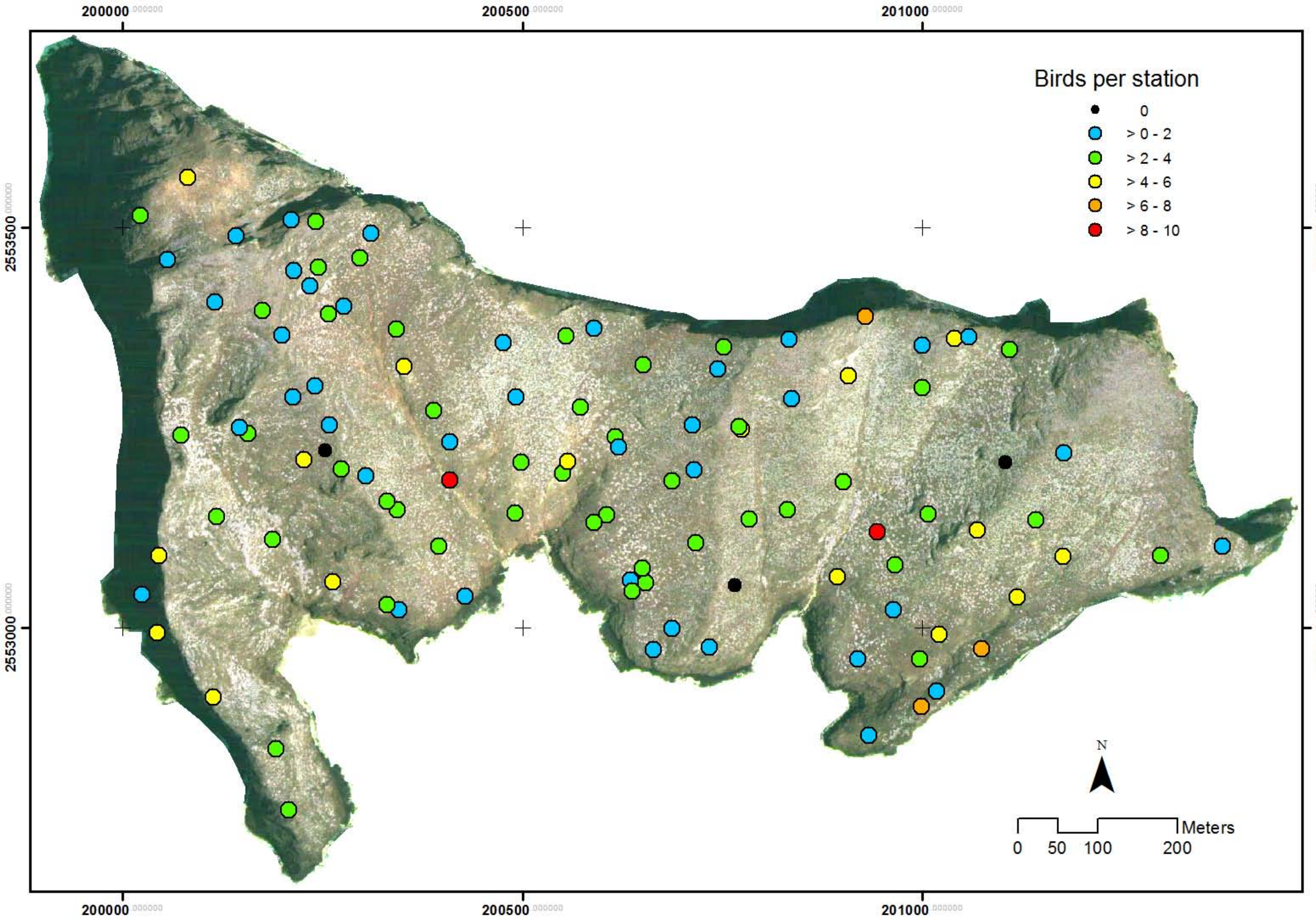


Figure 10. Nihoa Finch abundance (birds per station) and distribution in 2011 on Nihoa Island, Northwestern Hawaiian Islands. For comparability to 2010 results, only the counts for the first of two or more repeat surveys are shown.

Table 7. Numbers of point-transect sampling stations occupied (Stns) and total birds detected (Det) within the truncation distance by species and survey year. Percent occupancy (Occ) and mean number of birds per station (BPS) is based on the number of stations sampled (90 stations in 2010 and 108 stations in 2011). For comparability, the values are adjusted for sampling effort and include only the detections made during the first visit to stations.

	2010				2011			
Species	Stns	Det	Occ	BPS	Stns	Det	Occ	BPS
Nihoa Millerbird	72	139	80.0	1.5	87	138	80.6	1.3
Nihoa Finch	86	318	95.6	3.5	105	344	97.2	3.2

Table 8. Prospective power to detect a one-sided test for both small, moderate, and large declines in density given a range of percent coefficient of variation (%CV) levels and sampling duration. Adequate power (i.e., ≥ 0.80) is indicated with shading. Figure 11 depicts the power estimates graphically.

		Duration of study (years)		
Decline	%CV	10	25	50
25%	10	0.400	0.836	0.983
	20	0.098	0.270	0.502
	30	0.046	0.117	0.214
50%	10	0.964	1.000	1.000
	20	0.505	0.889	0.982
	30	0.234	0.524	0.748

between strip and point survey methods for both 2010 and 2011. This indicates that unmodeled heterogeneity in the point survey counts (e.g., amount and composition of vegetation cover, etc.) may still contribute to low precision in estimated finch abundance.

Sampling using line-transect methods were not fully implemented in either 2010 or 2011 because of the effort devoted to conducting the standard strip surveys and the concurrent effort to acquire count data with point-transect methods. Nevertheless, the data that are available indicates that this method would not have generated a sufficient number of detections for use in distance-based models. In 2011, only 10 millerbirds were detected along the 16 line-transects surveyed. Extrapolating from these numbers yields an expected count of only about 31 millerbirds if all 50 transects had been sampled with the line-transect method. Distance analyses generally require between 80 and 100 detections to adequately model, particularly when incorporating covariates (Buckland *et al*. 2001).

In general, the levels of within-year variance exhibited in counts derived from strip surveys were insufficiently precise to permit detection of an acute downward trend even over relatively long periods of monitoring. For example, a 50% reduction in the millerbird population size would likely require more than 20 years of surveys to detect given a CV of 21%, and over 50 years given a CV of 29%. In contrast, the 10% CV obtained from the point surveys of

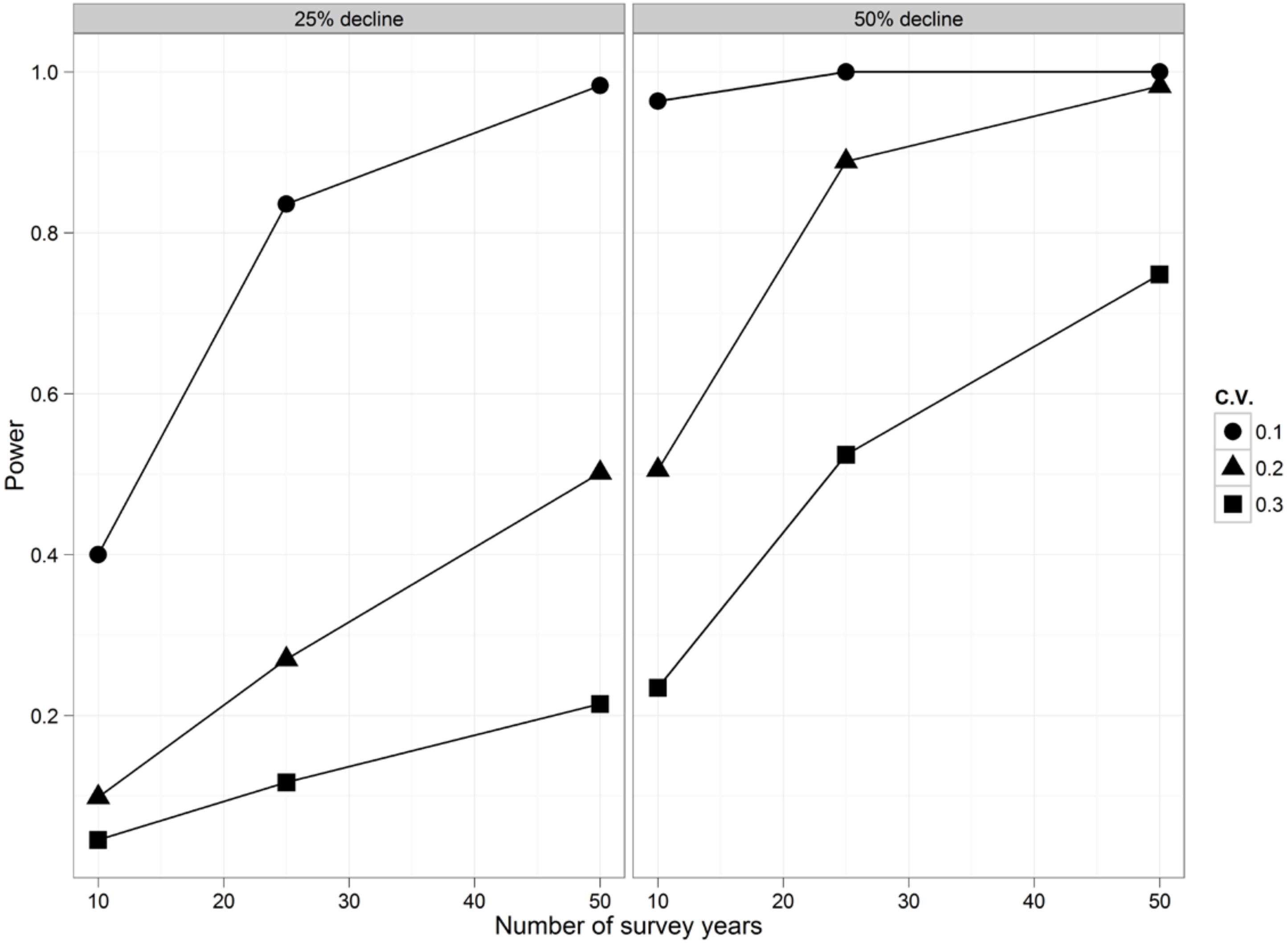


Figure 11. Prospective power for a two-tailed test to detect moderate and large changes in population size given a range of coefficient of variation (C.V.) levels and sampling duration. Results are shown for simulated declines in population size and values are tabulated in Table 8.

Table 9. Approximate number of point-transect counts needed to yield desired CV (coefficient of variation; panel A), and expected CV given a range of sampling effort levels (panel B). Abundances used for sampling effort estimation were based on the 2011 survey and include repeat counts at stations.

A)

	Sampling effort for given CV			
Species	10%	20%	30%	40%
Nihoa Millerbird	244	61	27	15
Nihoa Finch	443	111	49	28

B)

	CV by sampling effort				
Species	25	50	100	150	200
Nihoa Millerbird	32%	23%	16%	13%	12%
Nihoa Finch	43%	30%	22%	18%	15%

Table 10. Strip-transect survey results for 2010 and 2011, including effort (number of transects), Nihoa Millerbird and Nihoa Finch detections, estimated population size and standard deviation (SD), percent coefficient of variation (%CV), and lower (L) and upper (U) 95% confidence limits (95% CL). Values were recalculated from survey data and discrepancies with trip report values reflect data analysis error (e.g., inclusion of birds recorded outside the strip-transect width).

	Transects	Detections	Population	SD	%CV	L 95% CL	U 95% CL
Nihoa Millerbird							
2010	52	16	507	146.86	29.0	178	835
2011	51	18	581	120.51	20.7	312	851
Nihoa Finch							
2010	52	93	2,946	473.04	16.1	1,888	4,004
2011	51	76	2,455	418.72	17.1	1,517	3,393

millerbirds in 2010 and 2011 would allow determination of a 50% decline in less than 10 years. Ranging from 16 to 17% in 2010 and 2011, the CVs observed for finch counts were similar to those of the strip survey results, and both methods would entail at least 15 years of annual surveys to statistically determine a halving of the population size.

The sampling effort required to attain low levels of CV from line- and strip-transect surveys make using these methods relatively impractical (Table 11). For example, about 555 counts would be required to attain a 10% CV from line-transect surveys of the millerbird, and over 3,000 line-transect counts are needed to achieve a similar level of certainty for the finch (based

Table 11. Approximate number of samples (i.e., counts) needed to yield a desired coefficient of variation for line- and strip-transect surveys. Abundances used for sampling effort estimation were based on 2011 survey data.

	Sampling effort for given CV					
	Line-transect			Strip-transect		
Species	10%	20%	30%	10%	20%	30%
Nihoa Millerbird	555	139	62	214	54	24
Nihoa Finch	3,468	867	385	146	37	16

on the abundance and observed variance counts in 2011). Although counts may be conducted repeatedly on the same set of line-transects to obtain a sample size objective, this approach is likely unachievable for finch surveys. The sampling effort required to conduct strip-transect surveys is somewhat more modest, in part because this method does not incorporate the variance associated with modeling bird detectability. Nevertheless, a 10% CV may only be achieved provided a sampling effort of 146 strip-transect counts (which may be obtained by sampling 50 transects three times within a short period).

Survey efficiency, logistical costs, and resource impacts

Observers during the 2010 and 2011 surveys used a global positioning system (GPS) receiver to create a track log of the paths taken between survey stations and along transects. Mapping and review of the tracks in a geographical information system (GIS) revealed the difficulty experienced by observers in maintaining a straight path during the strip- and line-transect surveys (Figure 12). A cursory assessment showed that the paths were not linear, and some were up to 25% longer than the prescribed length of 250 ft (76.2 m). This resulted in an underestimation of actual transect length, and consequently, an overestimation of bird density using the strip-transect method. The line-transect method also relies on maintaining a relatively straight path, but only insofar as an observer needs it to estimate the distance of birds from the centerline. Modest deviations can be accommodated if an observer mentally adjusts distance estimations accordingly (however, this may be difficult to accomplish in practice on steep and uneven terrain).

The amount of time devoted to each of the three methods—strip, line, and point—can be compared based on the time spent at, and travelling between, transects in 2010 (Table 12). A total of 929 minutes (15.5 hours) was needed to travel among transects. Given the 303 minutes spent slowly walking while sampling the strip-transects, this method required a total of 1,232 minutes (or 4.1 person days assuming a five-hour survey per person per day) to complete 52 transects. The time required for line-transect sampling would be similar to that of strip-transects. Point-transect sampling of 91 stations required 546 minutes, and approximately the same amount of travel time (1,475 minutes or 4.9 person days) to complete. A comparable sampling effort of 52 point-transect stations would take about 1,229 minutes (4.1 person days); i.e., the same time needed to complete a strip-transect.

Another assessment of survey efficiency may be gained by comparing the number of bird detections relative to sampling effort. Adjusting for survey effort reveals considerable differences among method results. For example, strip-transect surveys generated 16 and 24

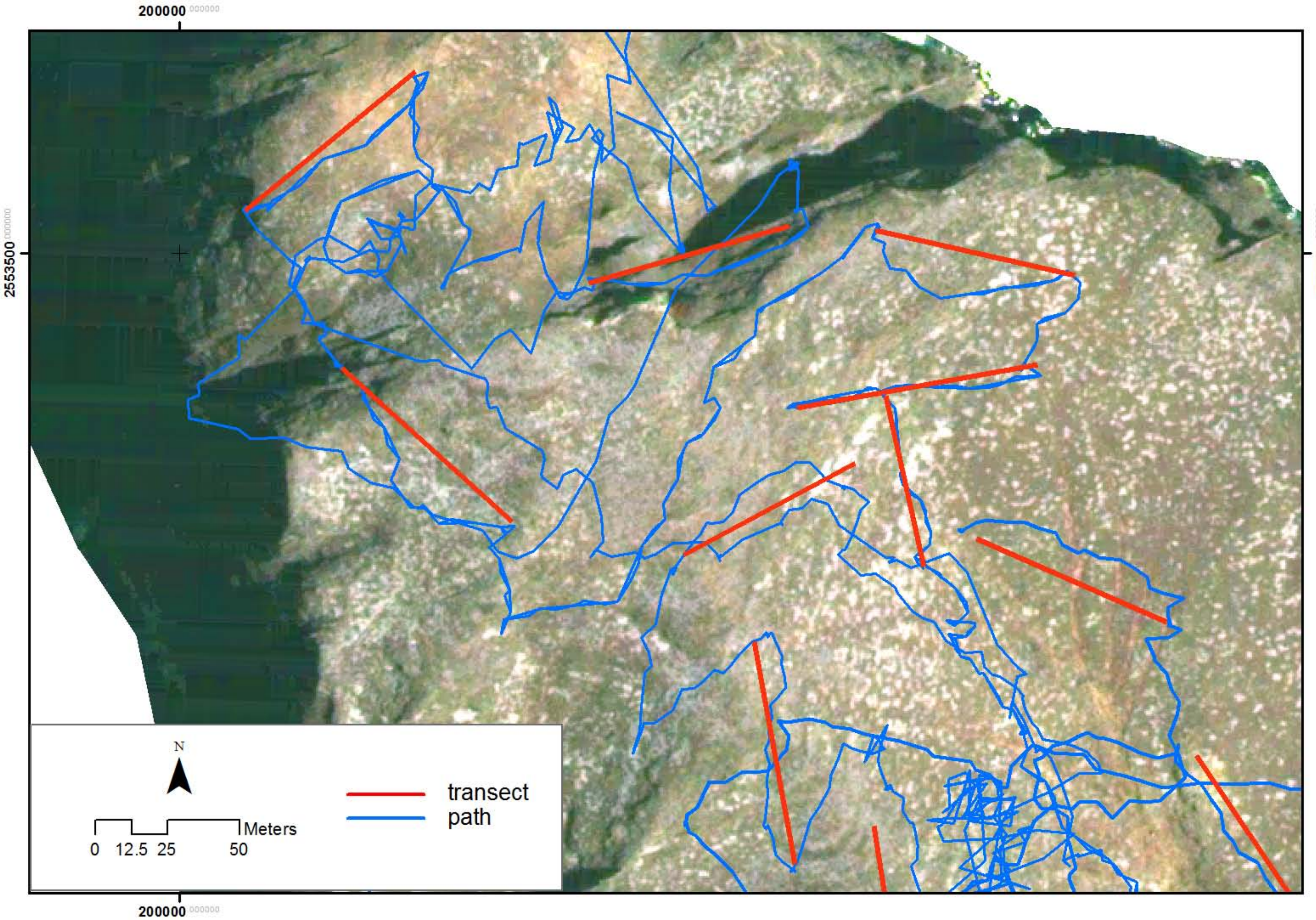


Figure 12. The difficulty experienced by observers in maintaining a straight path on steep and rocky terrain during strip-transect surveys is shown with a GPS track log of the actual routes taken relative to transect location on Nihoa Island, Northwestern Hawaiian Islands.

Table 12. Time required to complete point- and strip-transect counts in 2010. Point count time is based on a single visit to each station (90 stations). Strip count time is based on a survey of 50 transects. Time in person days assumes a start time at about 0700 hours and completion of sampling by 1200 hours (5 hours per day).

Activity	Time (minutes)	Time (hours)	Time (person days)
travel between stations/transects	929	15.5	-
point-transect count	546	9.1	-
strip-transect count	303	5.1	-
travel + point-transect count	1,475	24.6	4.9
travel + strip-transect count	1,232	20.5	4.1

millerbird detections in 2010 and 2011, which yielded an average of only 0.31 and 0.44 birds per sample, respectively (Table 10). Surveys recorded 10 millerbird detections along 16 line-transects in 2011, yielding a comparably low “return” of 0.63 birds per sample (USGS, unpub. data). In contrast, a total of 139 and 138 millerbirds were detected with point-transect sampling during the first visits to stations in 2010 and 2011, producing an average of 1.5 and 1.3 birds per sample, respectively (Table 7). The disparity in these results accounts for much of the improved accuracy in estimates derived from point-transect surveys compared to line and strip methods.

The relationship between the 2010 and 2011 strip- and point-transect counts was evaluated for the purpose of retrospectively generating population estimates for a set of simulated point surveys spanning the 1968–2009 period. However, the correlation of survey data demonstrated that this approach does not yield useful results. The resulting annual population size estimates for millerbird combined uncertainty from three sources: the variance intrinsic to each of the two methods and variance from the regression of the strip and point surveys. The confidence intervals generated are almost twice that of the original strip intervals, making a reasonable estimate of population size infeasible (Figure 13). For example, the 95% CIs of most simulated estimates of population size bracketed zero (as frequently did the corresponding intervals for historical strip surveys), and extended to improbably high abundances. If simultaneous strip- and point-transect surveys are conducted in the future, moderately improved confidence intervals could be estimated from the increased sample size and by fitting the intercept in the regression model (which was set to zero in this exercise because only two years of data were available).

DISCUSSION

This report describes the results of a comparative study of methods for estimating the population sizes of the Nihoa Millerbird and Nihoa Finch. Unequivocal improvements to the accuracy of millerbird estimates were obtained from the point-transect compared to the strip-transect survey method. The two- to three-fold increase in precision for the annual population size estimates will permit trends to be quantitatively assessed within reasonably short periods and allow for more effective management responses. Moreover, the estimated numbers of

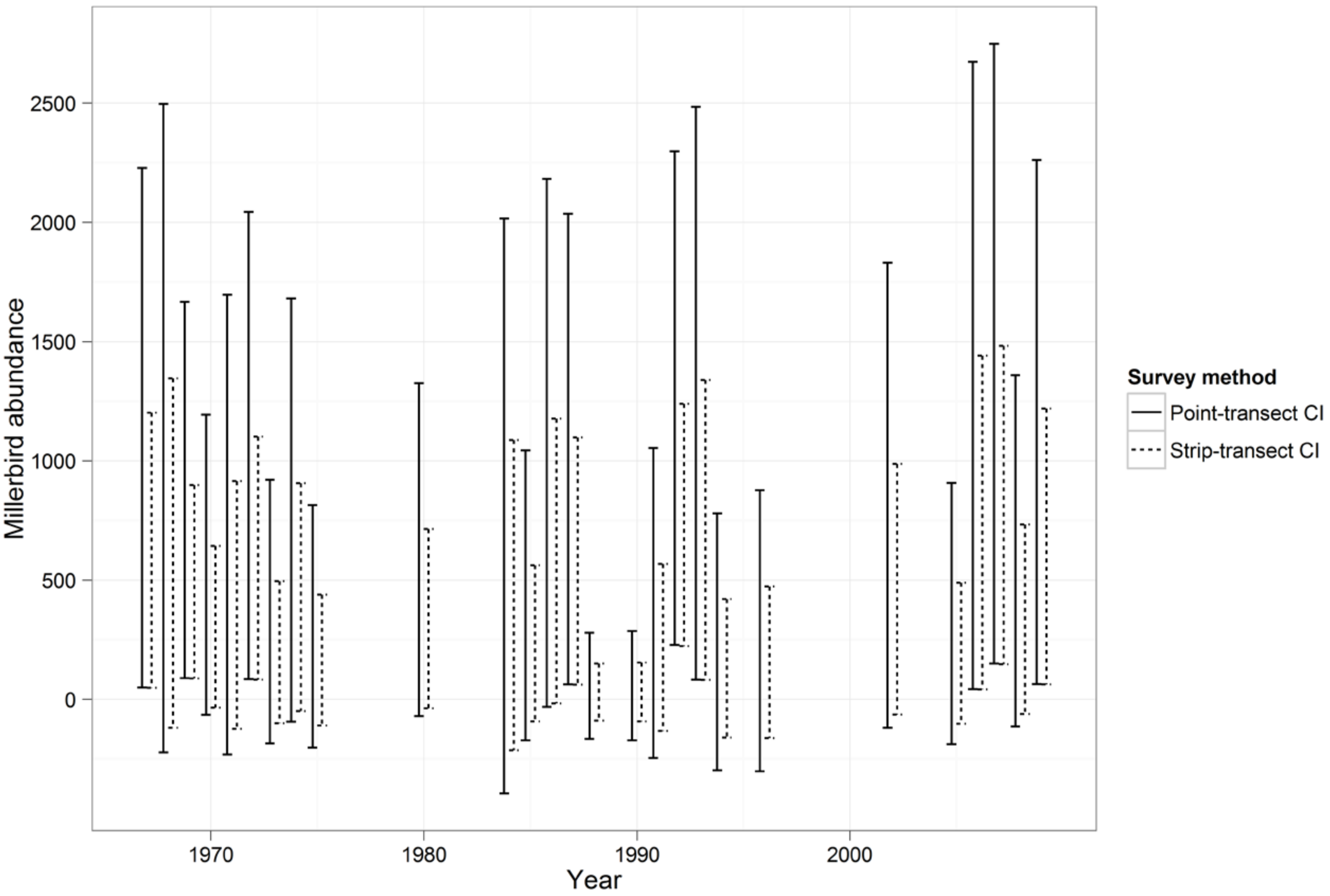


Figure 13. Predicted point-transect 95% confidence intervals (CI) based on the observed 2010 and 2011 Nihoa Millerbird counts and 95% confidence intervals derived from strip-transect surveys.

millerbirds in 2010 and 2011 appear to be higher than previously thought, a felicitous outcome for a critically endangered species. Finch population estimates were not markedly different between methods, but the performance of distance models based on point-transect counts and the precision of the resulting estimates may be expected to improve as additional surveys are incorporated. It is also important to note that the inclusion of subsequent survey data will improve the detection models but result in revisions to previous population size estimates (because each new dataset affects the detection function of the distance model). Therefore, while precision may improve, the estimated means will differ somewhat among re-analyses.

Strip-transect surveys are undesirable for a variety of reasons that contribute to low accuracy and statistical power. The method does not incorporate the effects of site-specific and time-varying variables on bird detectability (e.g., habitat and weather conditions). The method also does not account for the behavioral responses of birds to observers walking through territories. That is, birds may initially be secretive (and unobserved) as an observer moves rapidly along a strip; however, the strip-transect method does not adjust density estimates for this and other effects. In addition, the paucity of strip-transect detections means that small, random differences in counts can lead to highly variable annual density and population estimates. The difficulties observers have in maintaining a straight line also results in the underestimation of transect lengths and the overestimation of bird abundance. The problems associated with the low number of bird counts and difficulties walking transects also apply to line-transect sampling. Finally, line- and strip-transect methods do not provide sufficient flexibility for managers to minimize the unintended effects of monitoring bird status on Nihoa.

The unintended effects of monitoring bird status on Nihoa primarily arise from the amount of travel necessary to reach and traverse sampling locations (Figure 14). Adverse effects on vegetation are noticeable in areas receiving high amounts of foot traffic (C. Farmer, pers. obs.). Although bird surveyors are instructed to avoid archeological sites, impacts to the vegetation may also contribute to soil compaction, increased runoff, and erosion. In addition, the inadvertent trampling and collapse of seabird burrows may occur as observers negotiate steep and uneven terrain. Although the extent of area traversed by observers is similar among survey methods, point-transect surveys do not require that observers maintain a straight transect line. This allows observers to better avoid sensitive areas and select different routes to the same location, thereby minimizing the effects of recurrent travel to any particular area (or conversely, to use established trails). Moreover, flexibility in traversing the survey will allow observers to select less dangerous routes and reduce the chance of accidents.

Modifications to sampling designs to minimize natural resources impacts can entail reduction of the number of locations sampled. However, such reductions should be offset by use of repeat counts at each station. Repeat counts will also provide a means of distinguishing within-year from between-year variability. Partitioning out within-year variability will allow for more sophisticated state-space models offering improved precision in annual population estimates and increased statistical power to detect trends. The inference of population size and distribution from bird counts requires that Nihoa be sampled as broadly as is logistically practical. This means that any reduction in the number of sites sampled should be done within a probabilistic design that retains a spatially-balanced distribution of sample locations (i.e., the non-random exclusion sites or areas will restrict inference to the sampled habitat). This may be accomplished by randomly selecting stations to exclude from the current pool of survey stations. Stations in close proximity (e.g., less than twice the effective detection radius) may be

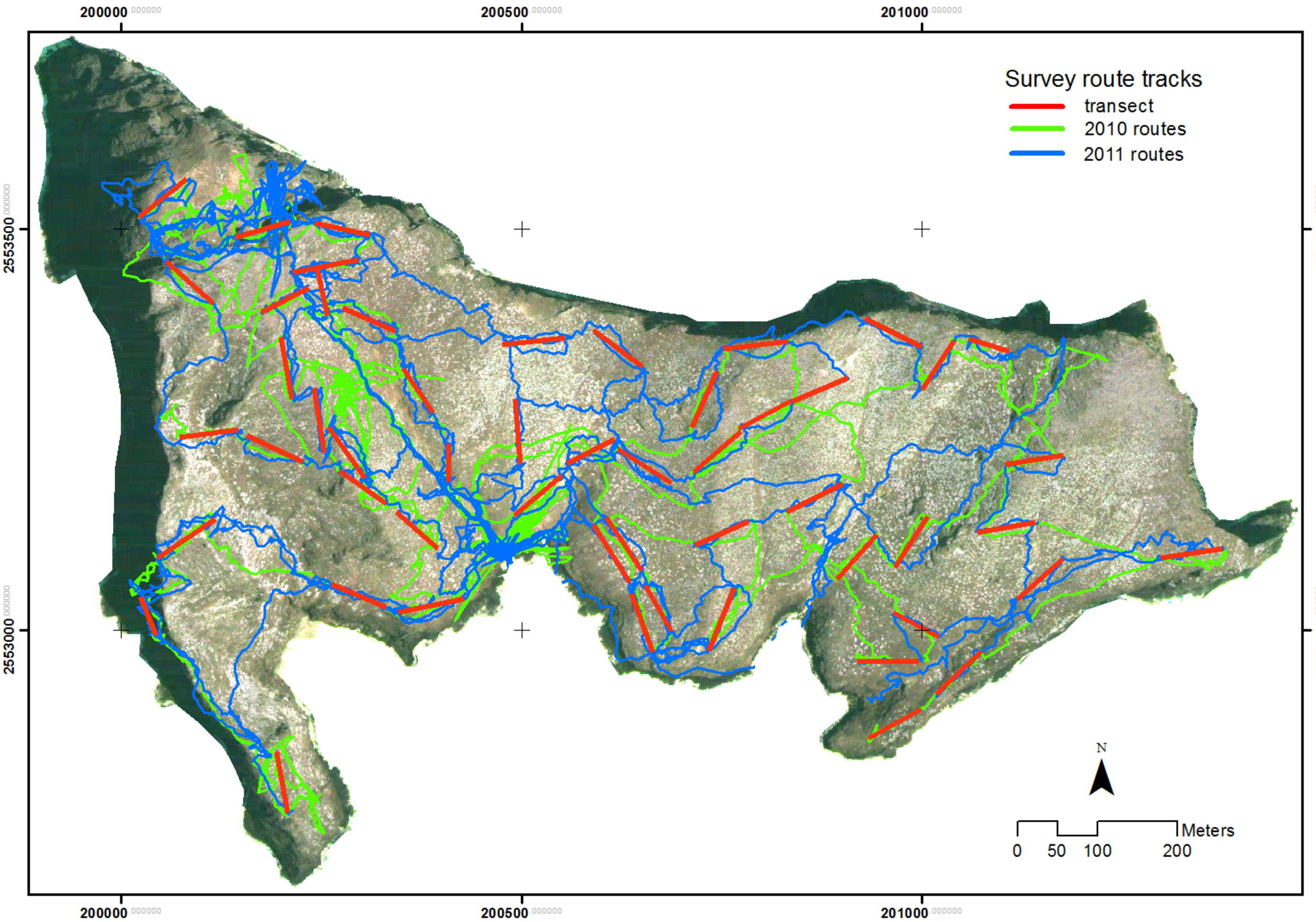


Figure 14. Routes taken to survey transects in 2010 and 2011 on Nihoa Island, Northwestern Hawaiian Islands.

weighted more heavily in selecting them for exclusion. Although the distribution of sample station was based on the end-points of existing transects, it is not clear whether the original transects were randomly distributed when first established. While a wholesale revision to the sampling design may be desirable, reducing the number or range of sampling stations would cause a loss of inference compared to the 2010 and 2011 surveys. Appendix 5 provides further recommendations for the design of a bird survey program to effectively monitor the species status of the Nihoa Millerbird and Nihoa Finch.

ACKNOWLEDGEMENTS

The study was funded jointly by the U.S. Geological Survey and the U.S. Fish and Wildlife Service through project (11-R1-01) of the Science Support Partnership (SSP) with additional support provided by the USGS Pacific Island Ecosystems Research Center. Thane K. Pratt furnished the necessary spark of interest to initiate the study and Michelle Reynolds provided helpful guidance at its completion. This report was improved by reviews from Thane K. Pratt and Sheila Conant.

LITERATURE CITED

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 2001. Distance sampling: estimating abundance of biological populations. Chapman and Hall, London.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas (editors). 2004. Advanced distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, NY.

Burnham, K. P., D. R. Anderson, and J. L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monograph 72. 202 pp.

Conant, S. 1985. Recent observations on the plants of Nihoa Island, Northwest Hawaiian Islands. Pacific Science 39:135–149.

Conant, S., M. S. Collins, and C. J. Ralph. 1981. Effects of observers using different methods upon the total population estimates of two resident island birds. Studies in Avian Biology 6:377–381.

Kohley R., P. Luscomb, M. MacDonald, and D. Tsukayama. 2009. Nihoa Millerbird pre-translocation and Nihoa biological monitoring expedition, September 6–18, 2009. Nihoa Island, Northwest Hawaiian Islands, Papahānaumokuākea Marine National Monument, USFWS, Honolulu, HI.

Kropidlowski, S., D. Tsukayama, and H. Freifeld. 2008. Nihoa biological and cultural monitoring expedition, October 21–26, 2008. Nihoa Island, Northwest Hawaiian Islands, Hawaiian Islands National Wildlife Refuge, USFWS, Honolulu, HI.

Marques, F. F. C., and S. T. Buckland. 2003. Incorporating covariates into standard line transect analyses. Biometrics 59:924–935.

Marques, T. A., L. Thomas, S. G. Fancy, and S. T. Buckland. 2007. Improving estimates of bird density using multiple-covariate distance sampling. The Auk 124:1229–1243.

Papahānaumokuākea Marine National Monument (PMNM). 2008. Papahānaumokuākea Marine National Monument management plan: Volume I. National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, and Hawai`i Department of Land and Natural Resources, Honolulu, HI. Available at: www.papahanaumokuakea.gov/management/mp/vol1_mmp08.pdf Accessed 17 October 2012.

Thomas, L., S. T. Buckland, E. A. Rextad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5–14.

Wagner, W. L., D. Herbst, and S. H. Sohmer. 1999. Manual of the flowering plants of Hawai‘i. University of Hawai`i Press, Honolulu, HI.

VanderWerf, E. A., D. H. Tsukayama, F. A. Amidon, and W. Aldeguer. 2011. Nihoa Island biological monitoring and management, 2–16 September 2011. Unpublished report to the U.S. Fish and Wildlife Service.

Zar, J. H. 1996. Biostatistical analysis. Third edition. Prentice Hall, Inc., Englewood Cliffs, NJ.

APPENDIX 1: COORDINATES OF SURVEY LOCATIONS

Coordinates for point-transect stations surveyed on Nihoa in 2010 and 2011 (Figure 4). List includes several additional stations not sampled in either year which may be included in subsequent surveys. Easting and northing coordinates are in a UTM – Zone 4 North projection and WGS 84 datum.

Station	Latitude (North)	Longitude (West)	Easting	Northing	Alt. (m)	2010 survey	2011 survey	Established
1A	23.05979077	161.92200713	200590	2553131	47	y	y	OCT 2008
1B	23.05915190	161.92155350	200635	2553059	32	y	y	OCT 2008
2A	23.05902366	161.92152735	200637	2553045	43		y	OCT 2008
2B	23.05836886	161.92125410	200664	2552972	46	y	y	OCT 2008
3A	23.05841010	161.92057676	200733	2552975	48	y	y	OCT 2008
3B	23.05911577	161.92027509	200766	2553053	62	y	y	OCT 2008
4A	23.05923765	161.91903415	200893	2553063	58	y	y	OCT 2008
4B	23.05974676	161.91854917	200944	2553119	92		y	SEP 2010
5A	23.05831103	161.91876375	200919	2552960	53	y	y	OCT 2008
5B	23.05832670	161.91800402	200997	2552960	66		y	OCT 2008
6A	23.05887613	161.91833586	200964	2553022	90	y	y	OCT 2008
6B	23.05860984	161.91777586	201021	2552991	93	y	y	OCT 2008
7A	23.05845821	161.91725777	201074	2552973	108	y	y	OCT 2008
7B	23.05796511	161.91778718	201018	2552920	79	y	y	OCT 2008
8A	23.05779009	161.91797501	200999	2552901	72	y	y	OCT 2008
8B	23.05745029	161.91860475	200933	2552865	46	y	y	OCT 2008
9A	23.05986134	161.92012128	200783	2553135	97	y	y	OCT 2008
9B	23.05958860	161.92075873	200717	2553106	93	y	y	OCT 2008
10A	23.05861831	161.92103114	200687	2552999	75		y	OCT 2008
10B	23.05912893	161.92136440	200654	2553056	80	y	y	OCT 2008
11A	23.05928324	161.92140807	200650	2553073	72	y	y	OCT 2008
11B	23.05988138	161.92186137	200605	2553141	68		y	OCT 2008

Station	Latitude (North)	Longitude (West)	Easting	Northing	Alt. (m)	2010 survey	2011 survey	Established
12A	23.05988389	161.92297666	200491	2553143	43	y	y	OCT 2008
12B	23.06033660	161.92240627	200550	2553192	67		y	OCT 2008
13A	23.06047096	161.92234383	200557	2553207	73	y	y	OCT 2008
13B	23.06076600	161.92176749	200616	2553238	109		y	OCT 2008
14A	23.06064882	161.92172483	200621	2553225	105	y	y	OCT 2008
14B	23.06027776	161.92107062	200687	2553183	121	y	y	OCT 2008
15A	23.06040633	161.92080609	200714	2553197	131	y	y	OCT 2008
15B	23.06087824	161.92023620	200774	2553248	142		y	OCT 2008
16A	23.06090925	161.92026788	200771	2553251	141	y	y	OCT 2008
16B	23.06123530	161.91963488	200836	2553286	161	y	y	OCT 2008
17A	23.06180544	161.92046838	200752	2553351	204		y	OCT 2008
17B	23.06190209	161.91967101	200834	2553360	204	y	y	OCT 2008
18A	23.06138325	161.91803855	201000	2553299	161	y	y	OCT 2008
18B	23.06194953	161.91766195	201040	2553361	190	y	y	OCT 2008
19A	23.06197534	161.91748685	201058	2553364	189	y	y	OCT 2008
19B	23.06183880	161.91699048	201109	2553347	231	y	y	OCT 2008
20A	23.06055947	161.91701068	201104	2553206	187	y	y	OCT 2008
20B	23.06068503	161.91630115	201177	2553218	200	y	y	OCT 2008
21A	23.05954752	161.91509474	201298	2553090	176	y	y	OCT 2008
21B	23.05966537	161.91434607	201375	2553101	129	y	y	OCT 2008
22A	23.05992505	161.91662041	201142	2553135	164	y	y	OCT 2008
22B	23.05979622	161.91733950	201068	2553122	155	y	y	OCT 2008
23A	23.05938282	161.91832513	200966	2553078	109		y	OCT 2008
23B	23.05995950	161.91794115	201007	2553141	137	y	y	SEP 2010
24A	23.06031212	161.91898143	200901	2553182	97	y	y	OCT 2008
24B	23.05998355	161.91965525	200831	2553147	100	y	y	SEP 2010

Station	Latitude (North)	Longitude (West)	Easting	Northing	Alt. (m)	2010 survey	2011 survey	Established
25A	23.06045093	161.92291640	200498	2553206	81	y	y	OCT 2008
25B	23.06118652	161.92299259	200492	2553288	104	y	y	OCT 2008
25C	23.06109474	161.92220343	200572	2553276	97		y	SEP 2011
26A	23.06180418	161.92316006	200476	2553356	119	y	y	OCT 2008
26B	23.06188742	161.92239999	200554	2553364	123	y	y	OCT 2008
27A	23.06198272	161.92205415	200590	2553374	135		y	OCT 2008
27B	23.06158676	161.92145141	200651	2553329	146	y	y	OCT 2008
28A	23.06091688	161.92083408	200712	2553253	158	y	y	OCT 2008
28B	23.06154879	161.92054122	200744	2553323	188	y	y	SEP 2010
29A	23.06023501	161.92377227	200410	2553184	63	y	y	OCT 2008
29B	23.06067070	161.92378535	200409	2553232	90	y	y	OCT 2008
30A	23.06102266	161.92398886	200389	2553271	107	y	y	OCT 2008
30B	23.06150990	161.92435917	200352	2553326	127	y	y	OCT 2008
31A	23.06192472	161.92446797	200342	2553372	142	y	y	OCT 2008
31B	23.06217181	161.92511623	200276	2553401	160	y	y	OCT 2008
32A	23.06208171	161.92529183	200258	2553391	175	y	y	OCT 2008
32B	23.06261279	161.92543415	200245	2553451	202	y	y	OCT 2008
33A	23.06239989	161.92553138	200234	2553427	216	y	y	OCT 2008
33B	23.06210409	161.92610605	200175	2553396	210	y	y	OCT 2008
34A	23.06256937	161.92573464	200214	2553446	207	y	y	OCT 2008
34B	23.06272049	161.92492277	200297	2553461	197	y	y	OCT 2008
35A	23.06300087	161.92480023	200310	2553492	229	y	y	OCT 2008
35B	23.06312970	161.92547858	200241	2553508	225	y	y	OCT 2008
36A	23.06313733	161.92577153	200211	2553509	239	y	y	OCT 2008
36B	23.06294538	161.92644308	200142	2553489	254	y	y	OCT 2008
37A	23.06315107	161.92761236	200022	2553515	269	y	y	OCT 2008

Station	Latitude (North)	Longitude (West)	Easting	Northing	Alt. (m)	2010 survey	2011 survey	Established
37B	23.06359707	161.92704524	200082	2553563	262	y	y	OCT 2008
38A	23.06219629	161.92668758	200115	2553407	234	y	y	OCT 2008
38B	23.06266501	161.92727323	200056	2553460	269	y	y	OCT 2008
39A	23.06114445	161.92570833	200213	2553288	159	y	y	OCT 2008
39B	23.06183780	161.92586004	200199	2553366	183	y	y	OCT 2008
40A	23.06026854	161.92479872	200305	2553190	91	y	y	OCT 2008
40B	23.06083197	161.92525939	200259	2553253	138	y	y	OCT 2008
41A	23.05948491	161.92389423	200396	2553101	72	y	y	OCT 2008
41B	23.05988867	161.92440930	200344	2553147	98	y	y	OCT 2008
42A	23.05997978	161.92454115	200330	2553157	102	y	y	OCT 2008
42B	23.06033936	161.92510307	200274	2553198	126	y	y	OCT 2008
43A	23.06054841	161.92530440	200253	2553222	147	y	y	OCT 2008
43B	23.06126732	161.92544346	200241	2553302	177	y	y	OCT 2008
44A	23.06071437	161.92625248	200156	2553242	152	y	y	OCT 2008
44B	23.06043827	161.92556273	200227	2553210	145	y	y	OCT 2008
45A	23.06068101	161.92706184	200073	2553240	141	y	y	OCT 2008
45B	23.06078821	161.92635390	200146	2553250	150		y	OCT 2008
46A	23.05977744	161.92661500	200117	2553139		y	y	OCT 2008
46B	23.05932415	161.92730323	200046	2553090	169	y	y	OCT 2008
47A	23.05887203	161.92750297	200024	2553040	153	y	y	OCT 2008
47B	23.05844648	161.92730583	200043	2552993	121	y	y	OCT 2008
48A	23.05841700	161.92691700	200083	2552989				
48B	23.05773586	161.92660997	200113	2552913	97		y	SEP 2011
49A	23.05648117	161.92567329	200208	2552771	77	y	y	SEP 2011
49B	23.05716958	161.92582785	200192	2552848	60	y	y	OCT 2008
51A	23.06217383	161.91874875	200929	2553388	198	y	y	OCT 2008

Station	Latitude (North)	Longitude (West)	Easting	Northing	Alt. (m)	2010 survey	2011 survey	Established
51B	23.06186822	161.91805607	200999	2553353	196	y	y	OCT 2008
AA	23.05876080	161.92436236	200346	2553022	46	y	y	OCT 2008
AB	23.05893498	161.92356507	200428	2553039	35	y	y	OCT 2008
BA	23.05906624	161.92518337	200262	2553057	60	y	y	OCT 2008
BB	23.05882014	161.92451592	200330	2553028	52		y	OCT 2008
CA	23.06122400	161.91963000	200838	2553284	157			OCT 2008
CB	23.06150679	161.91895653	200908	2553314	153		y	SEP 2011
CB2	23.06098586	161.91892083	200909	2553257	135	y		SEP 2010
DA	23.05905241	161.91684681	201119	2553038	127		y	SEP 2011
DB	23.05952271	161.91629637	201176	2553089	154		y	SEP 2011
PRIT	23.05952908	161.92592517	200187	2553110	67		y	SEP 2011

APPENDIX 2: DATABOOKS

Example of data book content and layout adapted from the 2011 survey (following pages).

Time: record using a 24-hour clock format

Clouds: record to the nearest 10%

Rain: (stop count if persists above a 3)

0 = no rain
1 = mist or fog
2 = light drizzle
3 = light rain
4 = heavy rain; birds are swimming

Wind speed: (sustained; stop count if wind persists above 3)

0 = calm; smoke rises vertically; ≤ 1 mph
1 = smoke drifts; 1-3 mph
2 = wind felt on face; leaves rustle; 4-7 mph
3 = leaves, small twigs in constant motion
4 = branches strongly in motion
5 = birds blow away; forget about it

Gust: The maximum wind speed during the count. Gust should never be less than wind. If wind speed is constant through the count then Gust = Wind

Detection Types (dt):

Nihoa Bird Survey 2011

Observer:________________ Initials:________

Date(s): ______________________________

GPS unit: ______________________________

Transects surveyed: ______________________________

____

____

Time: record using a 24-hour clock format

Clouds: record to the nearest 10%

Rain: (stop count if persists above a 3)

0 = no rain
1 = mist or fog
2 = light drizzle
3 = light rain
4 = heavy rain; birds are swimming

Wind speed: (sustained; stop count if wind persists above 3)

0 = calm; smoke rises vertically; ≤ 1 mph
1 = smoke drifts; 1-3 mph
2 = wind felt on face; leaves rustle; 4-7 mph
3 = leaves, small twigs in constant motion
4 = branches strongly in motion
5 = birds blow away; forget about it

Gust: The maximum wind speed during the count. Gust should never be less than wind. If wind speed is constant through the count then Gust = Wind

Nihoa Bird Survey 2011

Observer:________________ Initials:________

Date(s): ______________________________

GPS unit: ______________________________

Transects surveyed: ______________________________

____

____

Notes:

Point transect survey Time

Date	Line Transect	Start	End
Clouds (0-10)	Rain (0-6)	Wind (0-5)	Gust (≥ wind)
Dom Veg	Cover	Height	Leafiness

species	time	dist	dt	dir

Notes:

Point transect survey Time

Date	Line Transect	Start	End
Clouds (0-10)	Rain (0-6)	Wind (0-5)	Gust (≥ wind)
Dom Veg	Cover	Height	Leafiness

species	time	dist	dt	dir

Line transect survey Time

Date	Line Transect	Start	End

Clouds (0-10)	Rain (0-6)	Wind (0-5)	Gust (≥ wind)

species	time	dist	dt	time	dist	dt

Point transect survey Time

Date	Line Transect	Start	End

Clouds (0-10)	Rain (0-6)	Wind (0-5)	Gust (≥ wind)

Dom Veg	Cover	Height	Leafiness

species	time	dist	dt	dir

Line transect survey Time

Date	Line Transect	Start	End

Clouds (0-10)	Rain (0-6)	Wind (0-5)	Gust (≥ wind)

species	time	dist	dt	time	dist	dt

Point transect survey Time

Date	Line Transect	Start	End

Clouds (0-10)	Rain (0-6)	Wind (0-5)	Gust (≥ wind)

Dom Veg	Cover	Height	Leafiness

species	time	dist	dt	dir

APPENDIX 3: METADATA

Metadata describing the 2010 Nihoa bird survey:

Hawaii Forest Bird Interagency Database Project

Identification_Information
User_Defined_Information
Data_Quality_Information
Distribution_Information
Metadata_Reference_Information

Identification Information

Section Index

Citation:

Citation Information:

Originator: Richard J. Camp, USGS PIERC
Publication Date: 03 July 2011
Publication Time: Unknown
Title: Hawaii Forest Bird Interagency Database Project
Publication Information:

Publication Place: Kilauea Field Station
Publisher: HFBIDP

Online Linkage:
http://biology.usgs.gov/pierc/HFBIDPSite/HFBIDPHome.htm

Description:

Abstract: Island of Nihoa, Northwest Hawaiian Islands, Nihoa Passerine Survey, 2010.

Purpose: To establish base line information on bird species composition, distribution and density on Nihoa.
Supplemental Information: Point-Transect Sampling method lasting 8 minutes. Distance to each bird was estimated to the nearest meter and recorded as exact. There were no methodology anomalies. Transect 29 had station A sampled 2 times. All other stations were sampled 1 time. All passerines were surveyed resulting in 709 records.

Time Period of Content:

Time Period Information:

Range of Dates/Times:

Beginning Date: 24 September 2010

Beginning Time: 08:17:00
Ending Date: 27 September 2010
Ending Time: 11:01:00

Currentness Reference: publication date

Status:

Progress: Complete
Maintenance and Update Frequency: As needed

Spatial Domain:

Bounding Coordinates:

West Bounding Coordinate: 14.8463
East Bounding Coordinate: 14.8664
North Bounding Coordinate: 145.5450
South Bounding Coordinate: 145.5732

Keywords:

Theme:

Theme Keyword Thesaurus: Hawaii Forest Bird Interagency Database Project
Theme Keyword: Point-Transect Sampling
Theme Keyword: Hawaii
Theme Keyword: Nihoa
Theme Keyword: Monitoring

Theme Keyword: Nihoa Millerbird
Theme Keyword: Nihoa Finch

Place:

Place Keyword Thesaurus: Hawaii Forest Bird Interagency Database Project
Place Keyword: Hawaii

Access Constraints:

Some Hawaii Forest Birds Interagency Database Project data sets may contain data with Access constraints. Such areas include sensitive information on the locations of endangered species or cultural artifacts and data which contain private or confidential information. In addition some data sets are collaborative efforts with outside researchers and represent unpublished work for which we request respect for intellectual property rights. Some data sets are not complete and if access is given the use may be restricted until completion. Please contact the Hawaii Forest Birds Interagency Database Project Coordinator at the Pacific Islands Ecosystem Research Center for details on any Access constraints.

Use Constraints:

Some Hawaii Forest Birds Interagency Database Project data sets may contain data with use constraints. Such areas include sensitive information on the locations of endangered species or cultural artifacts and data which contain private or confidential information. In addition some data sets are collaborative efforts with outside researchers and represent unpublished work for which we request respect for intellectual property rights. Some data sets are not complete and if access is given the use may be restricted until completion. Please contact the Hawaii Forest Birds Interagency Database Project Coordinator at the Pacific Islands Ecosystem Research Center for details on any use constraints.

Point of Contact:

Contact Information:

Contact Person Primary:

Contact Person: Richard J. Camp
Contact Organization: USGS PIERC

Contact Position: Project Coordinator
Contact Address:

Address Type: mailing address
Address: USGS PIERC, PO Box 44
City: Hawaii National Park
State or Province: Hawaii
Postal Code: 96718
Country: USA

Contact Voice Telephone: 808-985-6405
Contact Electronic Mail Address: rick_camp@usgs.gov

Data Set Credit:

Acknowledgement of the National Park Service, U.S. Fish and Wildlife Service, Hawaii GAP, The Nature Conservancy - Hawaii, State of Hawaii Department of Forestry and Wildlife, Kamehameha Schools, Hawaii Natural Heritage Program, Pacific Cooperative Studies Unit - University of Hawaii, U.S. Forest Service, Pacific Basin Information Node - U.S. Geological Survey and Pacific Island Ecosystems Research Center of Biological Resources Division - U.S. Geological Survey would be appreciated in products derived from these data.

Native Data Set Environment: Data books.

User Defined Information

Section Index

User Defined Memo:

Label: Transects and Stations Sampled
Value:

1	A-B, LINE	Station at start, end and along line-transect;
2	B, LINE	Station at end and along line-transect;
3	A-B, LINE	Station at start, end and along line-transect;
4	A, LINE	Station at start and along line-transect;
5	A, LINE	Station at start and along line-transect;
6	A-B, LINE	Station at start, end and along line-transect;
7	A-B, LINE	Station at start, end and along line-transect;
8	A-B, LINE	Station at start, end and along line-transect;
9	A-B, LINE	Station at start, end and along line-transect;
10	B, LINE	Station at end and along line-transect;
11	A, LINE	Station at start and along line-transect;
12	A, LINE	Station at start and along line-transect;
13	A, LINE	Station at start and along line-transect;
14	A-B, LINE	Station at start, end and along line-transect;
15	A, LINE	Station at start and along line-transect;
16	A-B, LINE	Station at start, end and along line-transect;
17	B, LINE	Station at end and along line-transect;
18	A-B, LINE	Station at start, end and along line-transect;
19	A-B, LINE	Station at start, end and along line-transect;
20	A-B, LINE	Station at start, end and along line-transect;
21	A-B, LINE	Station at start, end and along line-transect;
22	A-B, LINE	Station at start, end and along line-transect;
23	B, LINE	Station at end and along line-transect;
24	A-B, LINE	Station at start, end and along line-transect;
25	LINE	Surveyed using line-transect sampling;
26	A-B, LINE	Station at start, end and along line-transect;
27	B, LINE	Station at end and along line-transect;
28	A-B, LINE	Station at start, end and along line-transect;

29	A-B, LINE	Station at start, end and along line-transect;
30	A-B, LINE	Station at start, end and along line-transect;
31	A-B, LINE	Station at start, end and along line-transect;
32	A-B, LINE	Station at start, end and along line-transect;
33	A-B, LINE	Station at start, end and along line-transect;
34	A-B, LINE	Station at start, end and along line-transect;
35	A-B, LINE	Station at start, end and along line-transect;
36	A-B, LINE	Station at start, end and along line-transect;
37	A-B, LINE	Station at start, end and along line-transect;
38	A-B, LINE	Station at start, end and along line-transect;
39	A-B, LINE	Station at start, end and along line-transect;
40	A-B, LINE	Station at start, end and along line-transect;
41	A-B, LINE	Station at start, end and along line-transect;
42	A-B, LINE	Station at start, end and along line-transect;
43	A-B, LINE	Station at start, end and along line-transect;
45H	A, LINE	Station at start and along line-transect;
46G	A-B, LINE	Station at start, end and along line-transect;
47F	A-B, LINE	Station at start, end and along line-transect;
49C	A-B, LINE	Station at start, end and along line-transect;
51	A-B, LINE	Station at start, end and along line-transect;
441	A-B, LINE	Station at start, end and along line-transect;
EXTRA	B, LINE	Station at end and along line-transect;
AEXTRA	A-B, LINE	Station at start, end and along line-transect;
BEXTRA	A-B, LINE	Station at start, end and along line-transect;

User Defined Memo:

Label: References
Value:

American Ornithologists' Union (A.O.U.). 1998. Check-list of North American birds, 7th ed. American Ornithologists' Union, Washington, D.C.

Scott, J. M., S. Mountainspring, F. L. Ramsey, and C. B. Kepler. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Studies in Avian Biology No. 9. Cooper Ornithological Society. Allen Press, Lawrence, KS, U.S.A.

User Defined Memo:

Label: Variables Recorded
Value:
Time was always recorded
Cloud Cover was always recorded
Rain was always recorded
Wind was recorded sometimes
Gust was recorded sometimes

User Defined Text:

Label: Observers
Value:

Chris A. Farmer, Ruby L. Hammond, Daniel H. Tsukoyama

User Defined Memo:

Label: Original metadata written

Value: July 2011

Value: Alex White

User Defined Memo:

Label: Original metadata updated

Value: November 2011

Value: Alex White

Data Quality Information

Section Index

Logical Consistency Report: Data were line item proofed and spot-checked by. Less than 1% of spot-checked records contained errors, therefore no further actions taken.
Completeness Report: Survey and metadata complete.
Lineage:

Source Information:

Source Citation:

Citation Information:

Originator: Richard J. Camp, USGS PIERC
Publication Date: 03 July 2011
Publication Time: Unknown
Title: Hawaii Forest Bird Interagency Database Project
Publication Information:

Publication Place: Kilauea Field Station
Publisher: HFBIDP

Online Linkage: http://biology.usgs.gov/pierc/HFBIDPSite/HFBIDPHome.htm

Type of Source Media: paper and disc
Source Time Period of Content:

Time Period Information:

Range of Dates/Times:

Beginning Date: 24 September 2010

Beginning Time: 08:17:00
Ending Date: 27 September 2010
Ending Time: 11:01:00

Source Currentness Reference: publication date

Source Citation Abbreviation: HFBIDP
Source Contribution: Holly Freifeld, Fish and Wildlife Service, provided field books via Intraoffice transfer. Readable and complete (data book version).

Process Step:

Process Description: Field book data were received from Holly Freifeld.
Process Date: June 2011 by Alex White to line-item proof and spot-check data. July 2011 by Alex White to write and standardize metadata.

Distribution Information

Section Index

Distributor:

Contact Information:

Contact Person Primary:

Contact Person: Richard J. Camp
Contact Organization: USGS PIERC

Contact Position: Project Coordinator
Contact Address:

Address Type: mailing address
Address: USGS PIERC, PO Box 44
City: Hawaii National Park
State or Province: Hawaii
Postal Code: 96718
Country: USA

Contact Voice Telephone: 808-985-6405
Contact Electronic Mail Address: rick_camp@usgs.gov

Resource Description: Survey Identification Information based on Hawaii Forest Bird Survey (Scott et al. 1986). Electronic copy located at PIERC-KFS. Backup copy on external hard drive at PIERC-KFS. Hard copy located at PIERC-KFS.
Distribution Liability: Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.
Technical Prerequisites: Access 2000.

Metadata Reference Information

Section Index

Metadata Date: 03 July 2011
Metadata Review Date:
Metadata Future Review Date:
Metadata Contact:

Contact Information:

Contact Person Primary:

Contact Person: Richard J. Camp
Contact Organization: USGS PIERC

Contact Position: Project Coordinator
Contact Address:

Address Type: mailing address
Address: USGS PIERC, PO Box 44
City: Hawaii National Park
State or Province: Hawaii
Postal Code: 96718
Country: USA

Contact Voice Telephone: 808-985-6405
Contact Electronic Mail Address: rick_camp@usgs.gov

Metadata Standard Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata Standard Version: FGDC-STD-001-1998

SMMS Metadata report generated 03 July 2011

Metadata describing the 2011 Nihoa bird survey:

Hawaii Forest Bird Interagency Database Project

Identification_Information
User_Defined_Information

Data_Quality_Information
Distribution_Information
Metadata_Reference_Information

Identification Information

Section Index

Citation:

Citation Information:

Originator: Richard J. Camp, USGS PIERC
Publication Date: 03 November 2011
Publication Time: Unknown
Title: Hawaii Forest Bird Interagency Database Project
Publication Information:

Publication Place: Kilauea Field Station
Publisher: HFBIDP

Online Linkage:
http://biology.usgs.gov/pierc/HFBIDPSite/HFBIDPHome.htm

Description:

Abstract: Island of Nihoa, Northwest Hawaiian Islands, Nihoa Passerine Survey, 2011.

Purpose: To establish base line information on bird species composition, distribution and density on Nihoa.
Supplemental Information: Point-Transect Sampling method lasting 8 minutes. Distance to each bird was estimated to the nearest meter and recorded as exact. There were no methodology anomalies. Transect 1-7, 10-13, 15-18, 20-27, 29-32, 34, 36, 37, 39-43, AEXTRA, BEXTRA and DEXTRA had stations A-B sampled 2 times; transect 33 had station A sampled 2 times; transect 38 had station B sampled 2 times; transects 14 and 35 had stations A-B sampled 3 times. All other transects were sampled 1 time. All passerines were surveyed resulting in 1,094 records.

Time Period of Content:

Time Period Information:

Range of Dates/Times:

Beginning Date: 08 September 2011

Beginning Time: 07:50:00
Ending Date: 13 September 2011
Ending Time: 08:55:00

Currentness Reference: publication date

Status:

Progress: Complete
Maintenance and Update Frequency: As needed

Spatial Domain:

Bounding Coordinates:

West Bounding Coordinate: 14.8463
East Bounding Coordinate: 14.8664
North Bounding Coordinate: 145.5450
South Bounding Coordinate: 145.5732

Keywords:

Theme:

Theme Keyword Thesaurus: Hawaii Forest Bird Interagency Database Project
Theme Keyword: Point-Transect Sampling
Theme Keyword: Hawaii
Theme Keyword: Nihoa
Theme Keyword: Monitoring

Theme Keyword: Nihoa Millerbird
Theme Keyword: Nihoa Finch

Place:

Place Keyword Thesaurus: Hawaii Forest Bird Interagency Database Project
Place Keyword: Hawaii

Access Constraints:

Some Hawaii Forest Birds Interagency Database Project data sets may contain data with Access constraints. Such areas include sensitive information on the locations of endangered species or cultural artifacts and data which contain private or confidential information. In addition some data sets are collaborative efforts with outside researchers and represent unpublished work for which we request respect for intellectual property rights. Some data sets are not complete and if access is given the use may be restricted until completion. Please contact the Hawaii Forest Birds Interagency Database Project Coordinator at the Pacific Islands Ecosystem Research Center for details on any Access constraints.

Use Constraints:

Some Hawaii Forest Birds Interagency Database Project data sets may contain data with use constraints. Such areas include sensitive information on the locations of endangered species or cultural artifacts and data which contain private or confidential information. In addition some data sets are collaborative efforts with outside researchers and represent unpublished work for which we request respect for intellectual property rights. Some data sets are not complete and if access is given the use may be restricted until completion. Please contact the Hawaii Forest Birds Interagency Database Project Coordinator at the Pacific Islands Ecosystem Research Center for details on any use constraints.

Point of Contact:

Contact Information:

Contact Person Primary:

Contact Person: Richard J. Camp
Contact Organization: USGS PIERC

Contact Position: Project Coordinator
Contact Address:

Address Type: mailing address
Address: USGS PIERC, PO Box 44
City: Hawaii National Park
State or Province: Hawaii
Postal Code: 96718
Country: USA

Contact Voice Telephone: 808-985-6405
Contact Electronic Mail Address: rick_camp@usgs.gov

Data Set Credit:

Acknowledgement of the National Park Service, U.S. Fish and Wildlife Service, Hawaii GAP, The Nature Conservancy - Hawaii, State of Hawaii Department of Forestry and Wildlife, Kamehameha Schools, Hawaii Natural Heritage Program, Pacific Cooperative Studies Unit - University of Hawaii, U.S. Forest Service, Pacific Basin Information Node - U.S. Geological Survey and Pacific Island Ecosystems Research Center of Biological Resources Division - U.S. Geological Survey would be appreciated in products derived from these data.

Native Data Set Environment: Data books.

User Defined Information

Section Index

User Defined Memo:

Label: Transects and Stations Sampled
Value:

1	A-B, LINE	Station at start, end and along line-transect;
2	A-B, LINE	Station at start, end and along line-transect;
3	A-B, LINE	Station at start, end and along line-transect;
4	A-B, LINE	Station at start, end and along line-transect;
5	A-B, LINE	Station at start, end and along line-transect;
6	A-B, LINE	Station at start, end and along line-transect;
7	A-B, LINE	Station at start, end and along line-transect;
8	A-B, LINE	Station at start, end and along line-transect;
9	A-B, LINE	Station at start, end and along line-transect;
10	A-B, LINE	Station at start, end and along line-transect;
11	A-B, LINE	Station at start, end and along line-transect;
12	A-B, LINE	Station at start, end and along line-transect;
13	A-B, LINE	Station at start, end and along line-transect;
14	A-B, LINE	Station at start, end and along line-transect;
15	A-B	Station at start and end of transect;
16	A-B	Station at start and end of transect;
17	A-B, LINE	Station at start, end and along line-transect;
18	A-B, LINE	Station at start, end and along line-transect;
19	A-B, LINE	Station at start, end and along line-transect;
20	A-B, LINE	Station at start, end and along line-transect;
21	A-B, LINE	Station at start, end and along line-transect;
22	A-B, LINE	Station at start, end and along line-transect;
23	A-B, LINE	Station at start, end and along line-transect;
24	A-B, LINE	Station at start, end and along line-transect;

25	A-C, LINE	Surveyed using line-transect sampling;
26	A-B, LINE	Station at start, end and along line-transect;
27	A-B, LINE	Station at start, end and along line-transect;
28	A-B, LINE	Station at start, end and along line-transect;
29	A-B, LINE	Station at start, end and along line-transect;
30	A-B, LINE	Station at start, end and along line-transect;
31	A-B, LINE	Station at start, end and along line-transect;
32	A-B, LINE	Station at start, end and along line-transect;
33	A-B, LINE	Station at start, end and along line-transect;
34	A-B, LINE	Station at start, end and along line-transect;
35	A-B, LINE	Station at start, end and along line-transect;
36	A-B, LINE	Station at start, end and along line-transect;
37	A-B, LINE	Station at start, end and along line-transect;
38	A-B, LINE	Station at start, end and along line-transect;
39	A-B, LINE	Station at start, end and along line-transect;
40	A-B, LINE	Station at start, end and along line-transect;
41	A-B, LINE	Station at start, end and along line-transect;
42	A-B, LINE	Station at start, end and along line-transect;
43	A-B, LINE	Station at start, end and along line-transect;
44	A-B, LINE	Station at start, end and along line-transect;
45	A-B, LINE	Station at start, end and along line-transect;
46G	A-B, LINE	Station at start, end and along line-transect;

47	A-B, LINE	Station at start, end and along line-transect;
47F	A-C	Station at start and end of transect;
49	A-B, LINE	Station at start, end and along line-transect;
49C	B	Station at end of transect;
51	A-B, LINE	Station at start, end and along line-transect;
441	A-B, LINE	Station at start, end and along line-transect;
466	A-B	Station at start and end of transect;
AEXTRA	A-B, LINE	Station at start, end and along line-transect;
BEXTRA	A-B, LINE	Station at start, end and along line-transect;
CEXTRA	B, LINE	Station at end and along line-transect;
DEXTRA	A-B, LINE	Station at start, end and along line-transect;
PRIT_FAA		No station recorded;

User Defined Memo:

Label: References
Value:

American Ornithologists' Union (A.O.U.). 1998. Check-list of North American birds, 7th ed. American Ornithologists' Union, Washington, D.C.

Scott, J. M., S. Mountainspring, F. L. Ramsey, and C. B. Kepler. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Studies in Avian Biology No. 9. Cooper Ornithological Society. Allen Press, Lawrence, KS, U.S.A.

User Defined Memo:

Label: Variables Recorded
Value:

Time was always recorded

Cloud Cover was recorded sometimes

Rain was recorded sometimes

Wind was recorded sometimes

Gust was recorded sometimes

User Defined Text:

Label: Observers
Value:

Fred A. Amidon, Daniel H. Tsukoyama, Eric A. Vanderwerf

User Defined Memo:

Label: Original metadata written

Value: November 2011

Value: Alex White

User Defined Memo:

Label: Original metadata updated

Value: November 2011

Value: Alex White

Data Quality Information

Section Index

Logical Consistency Report: Data were line item proofed and spot-checked by. Less than 1% of spot-checked records contained errors, therefore no further actions taken.
Completeness Report: Survey and metadata complete.
Lineage:

Source Information:

Source Citation:

Citation Information:

Originator: Richard J. Camp, USGS PIERC
Publication Date: 03 November 2011
Publication Time: Unknown
Title: Hawaii Forest Bird Interagency Database Project
Publication Information:

Publication Place: Kilauea Field Station
Publisher: HFBIDP

Online Linkage:
http://biology.usgs.gov/pierc/HFBIDPSite/HFBIDPHome.htm

Type of Source Media: paper and disc
Source Time Period of Content:

Time Period Information:

Range of Dates/Times:

Beginning Date: 08 September 2011

Beginning Time: 07:50:00
Ending Date: 13 September 2011
Ending Time: 08:55:00

Source Currentness Reference: publication date

Source Citation Abbreviation: HFBIDP
Source Contribution: Holly Freifeld, Fish and Wildlife Service, provided field books via Intraoffice transfer. Readable and complete (data book version).

Process Step:

Process Description: Field book data were received from Holly Freifeld.
Process Date: June 2011 by Alex White to line-item proof and spot-check data. July 2011 by Alex White to write and standardize metadata.

Distribution Information

Section Index

Distributor:

Contact Information:

Contact Person Primary:

Contact Person: Richard J. Camp
Contact Organization: USGS PIERC

Contact Position: Project Coordinator
Contact Address:

Address Type: mailing address
Address: USGS PIERC, PO Box 44
City: Hawaii National Park
State or Province: Hawaii
Postal Code: 96718
Country: USA

Contact Voice Telephone: 808-985-6405
Contact Electronic Mail Address: rick_camp@usgs.gov

Resource Description: Survey Identification Information based on Hawaii Forest Bird Survey (Scott et al. 1986). Electronic copy located at PIERC-KFS. Backup copy on external hard drive at PIERC-KFS. Hard copy located at PIERC-KFS.
Distribution Liability: Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.
Technical Prerequisites: Access 2000.

Metadata Reference Information

Section Index

Metadata Date: 03 November 2011
Metadata Review Date:
Metadata Future Review Date:
Metadata Contact:

Contact Information:

Contact Person Primary:

Contact Person: Richard J. Camp
Contact Organization: USGS PIERC

Contact Position: Project Coordinator
Contact Address:

Address Type: mailing address
Address: USGS PIERC, PO Box 44
City: Hawaii National Park
State or Province: Hawaii
Postal Code: 96718
Country: USA

Contact Voice Telephone: 808-985-6405
Contact Electronic Mail Address: rick_camp@usgs.gov

Metadata Standard Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata Standard Version: FGDC-STD-001-1998

SMMS Metadata report generated 03 November 2011

APPENDIX 4: MODEL SELECTION

Model parameters and ranking results are described here for the Nihoa Millerbird and Nihoa Finch from the 2010 and 2011 surveys. Models were ranked by differences between each candidate model and the model with the lowest 2nd-order Akaike's Information Criterion value (ΔAIC_c) after correcting for small sample size. Base models included half normal (H-norm) and hazard-rate (H-rate) key detection functions with series expansions cosine (Cos), hermite polynomial (H-poly), and simple polynomial (S-poly). Covariates were incorporated with the highest AIC ranked base model. Categorical variables included detection type (DectType), dominant vegetation type (DomVeg), detection ahead or behind an observer relative to direction of travel (A or B), height of the vegetation (VegHeight), amount of foliage (Leafiness), observer (Obs), station at the beginning or end of the strip transect (StrtEnd), repeat count at a station (Repeat), wind speed (Wind), and year of survey (Year). Continuous variables included the covariates vegetation cover (VegCover), cloud cover (Cloud), and time of detection (TimeDet). For each model, the number of estimated parameters (Num Param), estimate of the log-likelihood (LogL), and AIC model weight (w_i) are provided. The selected model is indicated in bold.

Appendix 4 — Table A. Model parameters and model selection results for the Nihoa Millerbird from the 2010 survey.

Model	Num Param	LogL	AICc	ΔAICc	w_i
H-rate Key DectType[1]	4	-487.74	983.78	0.00	0.999993
H-norm Key	1	-503.28	1008.59	24.81	0.000004
H-rate S-poly	3	-502.58	1011.34	27.56	0.000001
H-rate Cos	3	-502.89	1011.96	28.18	0.000001
H-rate Key	2	-504.96	1014.01	30.23	0.000000
H-rate Key TimeDet	3	-505.05	1016.27	32.49	0.000000
H-rate Key VegHeight	3	-505.05	1016.27	32.49	0.000000
H-rate Key StrtEnd	3	-505.05	1016.27	32.49	0.000000
H-rate Key AB	3	-505.05	1016.27	32.49	0.000000
H-rate Key VegCover	3	-505.05	1016.27	32.49	0.000000
H-rate Key Obs	4	-505.05	1018.39	34.61	0.000000
H-rate Key Leafiness	4	-505.05	1018.39	34.61	0.000000
H-rate Key DomVeg[2]	4	-505.05	1018.39	34.61	0.000000
H-rate Key Wind	5	-505.05	1020.54	36.76	0.000000

H-rate Key Cloud	12	-505.05	1036.53	52.75	0.000000
H-norm Cos[3]					
H-norm H-poly[3]					

[1] Detection types pooled
[2] Dominant vegetation types pooled
[3] Key model selected

Appendix 4 — Table B. Model parameters and model selection results for the Nihoa Millerbird from the 2011 survey.

Model	Num Param	LogL	AICc	ΔAICc	w_i
H-norm Key DectType[1]	2	-873.71	1751.47	0.00	1.000000
H-norm Key Obs	3	-890.46	1787.01	35.54	0.000000
H-norm Key Leafiness	3	-892.00	1790.10	38.63	0.000000
H-norm Key AB	2	-893.61	1791.28	39.81	0.000000
H-norm Key	1	-894.65	1791.32	39.85	0.000000
H-norm Key VegHeight	2	-894.06	1792.16	40.69	0.000000
H-norm Key VegCover	2	-894.07	1792.19	40.72	0.000000
H-rate S-poly	3	-893.30	1792.70	41.23	0.000000
H-norm Key TimeDet	2	-894.44	1792.93	41.46	0.000000
H-rate Cos	4	-892.49	1793.13	41.66	0.000000
H-norm Key StrtEnd	2	-894.60	1793.24	41.77	0.000000
H-norm Key Repeat	3	-893.65	1793.40	41.93	0.000000
H-norm Key Wind	4	-892.91	1793.97	42.50	0.000000
H-norm Key DomVeg	6	-891.39	1795.11	43.64	0.000000
H-rate Key	2	-896.17	1796.39	44.92	0.000000
H-norm Key Cloud	11	-890.74	1804.55	53.08	0.000000
H-norm Cos[2]					
H-norm H-poly[2]					

[1] Detection types pooled
[2] Key model selected

Appendix 4 — Table C. Model parameters and model selection results for the Nihoa Millerbird from the combined 2010 and 2011 surveys.

Model	Num Param	LogL	AICc	ΔAICc	w_i
H-norm Key DectType[1]	2	-1436.56	2877.14	0.00	0.525992
H-norm Key DectType[1] & Year	3	-1436.22	2878.50	1.36	0.266476
H-norm Key DectType	3	-1436.47	2879.00	1.86	0.207532
H-norm Key Obs	5	-1463.17	2936.49	59.35	0.000000
H-norm Key VegCover	2	-1468.50	2941.03	63.89	0.000000
H-norm Key Obs[2]	2	-1469.11	2942.25	65.11	0.000000
H-norm Key Year	2	-1469.68	2943.39	66.25	0.000000
H-rate S-poly	3	-1468.85	2943.75	66.61	0.000000
H-norm Key Repeat	3	-1468.85	2943.76	66.62	0.000000
H-norm Key	1	-1471.20	2944.41	67.27	0.000000
H-norm Key DomVeg	6	-1466.94	2946.08	68.94	0.000000
H-norm Key StrtEnd	2	-1471.04	2946.11	68.97	0.000000
H-norm Key TimeDet	2	-1471.06	2946.14	69.00	0.000000
H-norm Key VegHeight	2	-1471.09	2946.21	69.07	0.000000
H-norm Key AB	2	-1471.09	2946.22	69.08	0.000000
H-rate Cos	4	-1469.39	2946.88	69.74	0.000000
H-norm Key Wind	4	-1469.41	2946.91	69.77	0.000000
H-norm Key Leafiness	3	-1470.77	2947.59	70.45	0.000000
H-norm Key DomVeg[3]	5	-1470.81	2951.76	74.62	0.000000
H-rate Key	2	-1476.81	2957.64	80.50	0.000000
H-norm Key Cloud	11	-1468.95	2960.57	83.43	0.000000
H-norm Cos[4]					
H-norm H-poly[4]					

[1] Detection types pooled
[2] Observers pooled
[3] Dominant vegetation types pooled
[4] Key model selected

Appendix 4 — Table D. Model parameters and model selection results for the Nihoa Finch from the 2010 survey.

Model	Num Param	LogL	AICc	ΔAICc	w_i
H-rate Key DectType[1]	3	-1104.03	2215.14	0.00	0.876148
H-rate Key Cloud	12	-1097.05	2219.09	3.95	0.121575
H-rate Key DomVeg[2]	4	-1110.20	2228.52	13.38	0.001089
H-rate Key Obs	4	-1110.87	2229.86	14.72	0.000557
H-rate Key Wind	5	-1109.99	2230.16	15.02	0.000480
H-rate Key StrtEnd	3	-1114.16	2234.38	19.24	0.000058
H-rate Key	2	-1115.43	2234.89	19.75	0.000045
H-rate Key VegHeight	3	-1115.04	2236.16	21.02	0.000024
H-norm Cos	3	-1116.19	2238.46	23.32	0.000008
H-rate Key AB	3	-1116.79	2239.65	24.51	0.000004
H-rate Key TimeDet	3	-1116.82	2239.72	24.58	0.000004
H-rate Key Cover	3	-1116.86	2239.79	24.65	0.000004
H-rate Key Leafiness	4	-1116.46	2241.05	25.91	0.000002
H-norm Key	1	-1120.41	2242.82	27.68	0.000001
H-norm H-poly[3]					
H-rate Cos[3]					
H-rate S-poly[3]					

[1] Detection types pooled
[2] Dominant vegetation types pooled
[3] Key model selected

Appendix 4 — Table E. Model parameters and model selection results for the Nihoa Finch from the 2011 survey.

Model	Num Param	LogL	AICc	ΔAICc	w_i
H-rate Cos Obs	6	-2051.81	4115.76	0.00	0.982255
H-rate Cos DectType	6	-2055.84	4123.81	8.05	0.017546
H-rate Cos DomVeg	9	-2057.34	4132.99	17.23	0.000178
H-rate Cos	4	-2065.82	4139.71	23.95	0.000006
H-rate S-poly	3	-2068.04	4142.11	26.35	0.000002
H-rate Cos StrtEnd	5	-2066.04	4142.17	26.41	0.000002
H-rate Cos Time	5	-2066.04	4142.17	26.41	0.000002
H-rate Cos Cover	5	-2066.04	4142.18	26.42	0.000002
H-rate Cos AB	5	-2066.04	4142.18	26.42	0.000002
H-rate Cos VegHeight	5	-2066.04	4142.18	26.42	0.000002
H-norm Cos	3	-2068.42	4142.88	27.12	0.000001
H-rate Cos Cloud	14	-2057.43	4143.58	27.82	0.000001
H-rate Cos Leafiness	6	-2065.95	4144.05	28.29	0.000001
H-rate Cos Repeat	6	-2066.03	4144.21	28.45	0.000001
H-rate Key	2	-2070.47	4144.97	29.21	0.000000
H-rate Cos Wind	7	-2065.96	4146.12	30.36	0.000000
H-norm Key	1	-2090.92	4183.84	68.08	0.000000
H-norm H-poly[1]					

[1] Key model selected

Appendix 4 — Table F. Model parameters and model selection results for the Nihoa Finch from the combined 2010 and 2011 surveys.

Model	Num Param	LogL	AICc	ΔAICc	w_i
H-rate Key DectType[1]	3	-3168.39	6342.81	0.00	0.843437
H-rate Key DectType[1] & Year	4	-3169.07	6346.18	3.37	0.156411
H-rate Key Obs	6	-3173.99	6360.08	17.27	0.000150
H-rate Key DomVeg	7	-3177.46	6369.04	26.23	0.000002
H-rate Key Cloud	12	-3173.97	6372.28	29.47	0.000000
H-rate S-poly	4	-3188.33	6384.71	41.90	0.000000
H-rate Key	2	-3190.70	6385.40	42.59	0.000000
H-norm Cos	2	-3192.55	6389.11	46.30	0.000000
H-rate Key Year	3	-3197.68	6401.39	58.58	0.000000
H-rate Key Height	3	-3197.73	6401.49	58.68	0.000000
H-rate Key StrtEnd	3	-3197.80	6401.63	58.82	0.000000
H-rate Key Cover	3	-3197.82	6401.66	58.85	0.000000
H-rate Key AB	3	-3197.82	6401.66	58.85	0.000000
H-rate Key Time	3	-3197.46	6401.77	58.96	0.000000
H-rate Key Leafiness	4	-3197.60	6403.25	60.44	0.000000
H-rate Key Repeat	4	-3197.74	6403.52	60.71	0.000000
H-rate Key Wind	5	-3197.46	6404.99	62.18	0.000000
H-norm Key	1	-3213.03	6428.07	85.26	0.000000
H-norm H-poly[2]					
H-rate Cos[2]					

[1] Detection types pooled

[2] Key model selected

APPENDIX 5: MONITORING PROTOCOL - SURVEY METHOD AND DATA ANALYSES

Objectives

This monitoring protocol outlines a general approach for the sampling and estimation of population size and trends for the Nihoa Millerbird and Nihoa Finch. Trend detection involves evaluating changes over time, and the protocol provides the technical underpinnings and methods for conducting surveys that are reliable and comparable.

Key monitoring and survey elements

1. Establish quantitative monitoring objectives and alert limits for triggering management response.
2. Conduct surveys using standard point-transect sampling methods. Record environmental conditions, habitat characteristics, and bird detection attributes to be used as sampling and site covariates in distance modeling.
3. Apply distance modeling to estimate densities and annual population size.
4. Conduct sampling of a sufficient number of stations to attain a within-year CV of 10% or less. Conduct sampling on a sufficiently frequent basis to maintain adequate power to detect trends.
5. For comparability among years, conduct surveys consistently during the same time of year.
6. Apply trend assessment methods that conclusively identify negligible (stable) trends and short-term changes in trajectory.
7. Critically assess survey results and make necessary changes to plans for subsequent surveys.

Monitoring objectives and alert limits

The results from monitoring may be used to trigger actions to arrest population declines. Alert limits can provide objective criteria to judge when a population requires increased monitoring, management, or additional research to determine likely causes of the problem (Dunn 2002). Current plans, specifically the Papahānaumokuākea Marine National Monument management plan (PMNM 2008), the Northwestern Hawaiian Islands Passerines Recovery Plan (USFWS 1984) and Hawaii's Comprehensive Wildlife Conservation Strategy for the Northwestern Hawaiian Islands (Mitchell *et al.* 2005), do stipulate that the current program of bird monitoring be continued, and that among other priorities, a program for monitoring habitat conditions and invasive species also be developed. However, the existing plans do not provide specific limits or thresholds that would trigger bird recovery actions. Therefore, for this revised and improved monitoring protocol, we provide examples adapted from the Red List Criteria developed by the International Union for Conservation of Nature (BirdLife International 2000). These criteria are based on several biological factors related to extinction risk that include population size, rate of decline, area of geographic distribution, and degree of population and distribution fragmentation.

For a criterion specifying a population size threshold to be meaningful, a monitoring program should seek to produce annual estimates with a within-year coefficient of variation (CV) of 10% or less. Moreover, an appropriately conservative interpretation of a population size estimate (relative to an alert limit threshold) should be obtained from the lower 95% confidence limit rather than the point estimate of the mean. A monitoring program must also be able to effectively detect a quantified population change over a specified period of time. An example monitoring objective would be to detect at least a 50% reduction in population size within a 10-

year period (or three generations, whichever is longer). Comparable or alternative thresholds should be clearly specified in the development of alert limits for a monitoring program. The Red List Criteria guidelines also consider a population which exhibits “extreme fluctuation” over time as an indicator of an imperiled status, but do not define this quantitatively. One approach is to assess a time series retrospectively, and to designate a population as highly variable when between-year variance is in excess of a pre-defined value (e.g., CV > 50%; or alternatively, variance as a normalized estimate of the realized rate of population change; see Houlahan *et al.* 2000, Green 2003). However, this “reactive” approach runs the risk of not identifying an emerging problem and may have limited use for planning purposes. More informative methods to assess population fluctuation should incorporate prognostic and risk-based analyses that make it possible to predict time to extinction or an abundance threshold (e.g., population viability analysis [Morris and Doak 2002], viable population monitoring [Staples *et al.* 2005]). Note that because of the high amount of uncertainty in the population size estimates, an assessment of population variability from the strip-transects surveys is not likely to be informative.

Finally, although the millerbird and finch appear to occur in all or nearly all available habitat and each persists as a single population on Nihoa, survey data can be used to assess whether the area of occupancy has changed. For example, the introduction of an invasive species may degrade habitat in parts of the island, and bird occurrence maps may exhibit diminished abundance or range contraction in these areas. The Red List Criteria do not define thresholds for assessing changes to the area of occupancy, but declines in this metric in excess of 50% over a 10-year period may serve as an appropriate alert limit. Occupancy analysis (MacKenzie *et al.* 2006) may also be used to estimate the proportion of area occupied for surveys in which repeat within-year samples are available. Generally, temporally repeated sampling (i.e., at least twice) within each season is necessary for estimation of detection probability and occupancy metrics. Spatially replicated sampling can also be used in certain study designs (e.g., Pavlacky *et al.* 2012).

Point-transect sampling

The estimation of bird abundance as described in this protocol is based on distance-based survey techniques. Bird-to-observer distance measurements permit estimated densities to be adjusted by species detection probabilities to account for the effects of distance (and other variables) on bird detection (Buckland *et al.* 2001). A major advantage of being able to include covariates in detection probabilities is that it allows (with enough samples) a comparison of the results of surveys conducted in different seasons and with differing probabilities of detecting birds. For most situations, this technique is the best method for determining abundance and monitoring trends for landbirds and has been used for over 30 years in Hawai`i (Camp *et al.* 2009). Relative index counts (e.g., area count, point count, strip-transect, and spot mapping) are generally unsuitable sampling methods because they do not account for differential detection probabilities between surveys (Anderson 2001). Point-transect sampling is suitable for multi-species studies and applicable where birds occur in patchy habitats, dense vegetation, and rugged or hazardous terrain.

Buckland (2006) recommends point-transect counts obtain an “instantaneous count” of birds present. This means that when approaching a station, it is important to record all birds that flush as if they had been detected during the survey at their initial distances from the survey station. A full six-minute count is started without delay as soon as the counter arrives at the sampling station center. Observers are to record each species detected (using a four-character abbreviation code), method of detection (heard or seen), and the exact time of detection (to the nearest minute). Radial (horizontal) distance from the station center-point to the location at which a bird is first detected should take into account the effects of steep slopes on the distance measures. For example, a detection up a steep slope will appear to be more distant than if it were measured on a horizontal plane. Therefore a bird's location relative to an observer should be estimated as if from a "bird's eye view." In addition, because birds located downslope are easier to detect than those upslope, its position on a slope relative to an observer should be recorded (upslope, downslope or level), and this information can be incorporated into distance modeling. Ideally, distances should be measured to the nearest meter with laser range finders. To account for the behavioral effects of observer presence and movement, the location of a bird relative to the direction of travel by an observer should also be recorded ("ahead" or "behind"). A copy of the 2011 Nihoa bird survey booklets for recording field observations is included in Appendix 2. The booklets should be revised to omit the line/strip-transect pages if this method is not used in future surveys.

Sampling conditions are to be recorded and should generally characterize the entire six-minute count. Cloud cover is estimated to the nearest 10%. Rain is assigned into five classes ranging from no rain to heavy rain. Wind and wind gust speed are recorded using the Beaufort scale. Surveys will only be conducted during appropriate weather: rain less than a light rain, wind not exceeding 3 on the Beaufort scale, and wind gust not exceeding 4 on the Beaufort scale. Brief periods of gusts exceeding a scale of 3 can be offset by extending the survey period by an equivalent amount of time.

A global positioning system (GPS) receiver should be used to collect a track log delineating the path taken by an observer during a survey. This information is often important in resolving discrepancies in survey locations and can be used to assess the relative amount of traffic by observers across Nihoa. GPS units should be set to record waypoints and track log positions in the appropriate time zone (i.e., Hawaii-Aleutian time zone) and coordinate system (e.g., latitude-longitude or Universal Projection Mercator coordinate system Zone 4N NAD83). Data reporting should include information on the projection and datum of all locations.

The Hawai`i Forest Bird Interagency Database Project (HFBIDP) has designed and maintains a customized Microsoft Access database for entering and managing forest bird survey data. The database accommodates only data collected using point-transect sampling methods. Data from field books are entered into the Avian Monitoring Entry Form (AMEF Version 2.1; available upon request). The AMEF database represents the user interface for the data and consists of forms, queries, and Visual Basic for Applications (VBA) code for the application itself. After a series of quality control checks, these database records are then uploaded into the central Hawai`i Forest Bird Monitoring Database, a repository for all point-transect sampling conducted in Hawai`i.

Density and population size estimation

Buckland *et al*. (2001, 2004) and Thomas *et al*. (2010) provide detailed descriptions of analytical methods and procedures to estimate bird densities. Here we provide a brief description of the procedures. Analysis is conducted using the latest version of the free software DISTANCE. In general, a detection function for each species is fitted to truncated distance data through a model-fitting procedure where the best-fit model has the lowest Akaike's Information Criterion (AIC) value. From this model, encounter rates, detection probabilities, density estimates and associated variance and 95% confidence intervals are generated for each species. Inclusion of covariates is assessed using AIC methods. Although it is best to estimate detection probabilities independently for each survey when there are ample observations, survey data can also be pooled across years to increase the sample size. If data are pooled, post-stratification procedures are used for calculating annual density estimates. Variance and 95% confidence intervals are calculated using bootstrap methods.

Sample size

The bird count and sampling effort data acquired from on-going surveys can provide the information needed for reassessment of the study design used for population monitoring. Survey results should be periodically evaluated (e.g., decadally) for evidence of improved accuracy of within-year population estimates that may permit decreased sampling effort in future surveys.

Sample size requirements may be reassessed using methods described in Buckland *et al.* (2001: 241–246), where the number of stations (K) needed to produce annual density estimates for a range of CVs ($cv(\hat{D})$) can be calculated with the equation

$$K = \left(\frac{b}{\{cv(\hat{D})\}^2}\right) \times \left(\frac{k_0}{n_0}\right) \qquad \text{(Equation 1)}$$

given the number of point-transect stations sampled (k_0), the number of individual birds detected (n_0), and the variability in the number of birds detected and distance modeling uncertainty (b), calculated as

$$b \cong n_0 \times \left\{obs\ cv(\hat{D})\right\}^2 \qquad \text{(Equation 2)}$$

where b incorporates the observed CV (e.g., current annual CV or average CV over a recent survey period).

Sampling effort may also be reassessed in terms of the frequency of surveys. Annual surveys will provide the greatest power to detect increasing or decreasing trends in population size. However, if within-year precision is high, an alternative monitoring approach for reducing costs would be to perform annual surveys during the early stages of the program and then reduce the frequency of monitoring (e.g., after 10 years) to a biennial sampling scheme. This determination should be done only after development of objectives specifying the magnitude of change and the time period within which change will be evaluated (e.g., 50% decline within a 10-year period).

Sampling period

Hawaiian passerines are generally more vocal, and therefore more detectable, during their courtship and breeding season (generally December–May for most species; Ralph and Fancy 1994, Simon *et al.* 2002). Although it is preferable to survey when birds are most detectable, little or no information on this topic is available for the Nihoa Millerbird and Nihoa Finch. Moreover, survey logistics may preclude surveys in certain times of year. In light of this, population monitoring should apply as consistent a survey schedule as possible. If the timing of surveys varies substantially from year to year, the variance in population density estimates will likely increase, thus reducing the reliability of results and the ability to detect trends. Distance-based count methods such as point-transect surveys can accommodate sampling at various times of years by incorporating season (or month) as a covariate. However, accurate density estimation will depend on acquiring a minimum of three observations (i.e., surveys) at the same time of year to adequately model and distinguish year effects from season effects.

Trend assessment

A variety of methods exist for the estimation of trends in bird counts and population size (e.g., see Thomas 1996). Although a review and comparison of such methods is beyond the scope of this protocol, several general guidelines are proffered. Trend estimation can be accomplished with such methods as a linear regression of log-transformed counts or Poisson regression, and can incorporate covariates to accommodate variables of interest. Besides the conventional frequentist approach, trend estimation can also be performed in a Bayesian framework in which inference is based on parameter distributions as conditioned on the data (Link and Barker 2010). This approach can also facilitate the distinction of statistically inconclusive results due to high variability in the count data from negligible trends arising from near-zero regression slopes (Camp *et al*. 2008). Model-based methods are also available that entail the use of temporally replicated samples for use in partitioning of the observed variation in counts into effects from the observation process (i.e., bird detectability) and the unobserved biological process (e.g., changes in bird abundance over time and the spatial or habitat-based structure of bird distribution; Kery and Royle 2010). Change-point analyses can also be used to identify break-points and time series segments whose trajectory differs from the overall long-term trend (e.g., Fujisaki *et al*. 2008).

Adaptive monitoring

Protocols for assessing population status require realistic and measurable objectives to provide an effective link between monitoring and management (Camp *et al*. 2009). Monitoring objectives are central to informing management decisions by discriminating among competing hypotheses about how populations respond to environmental change or management actions. Clearly articulated objectives guide and control how data are sampled and interpreted, and they provide a measure of accountability in tracking progress toward achieving management goals. Regularly reviewing (e.g., after every 5 or 10 surveys) the monitoring design and sampling methods also allows improved techniques to be incorporated into the overall scheme (e.g., reallocation of survey effort, use of new sampling or analytical methods; Johnson *et al*. 2006).

Literature cited in Appendix 5

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29:1294–1297.

BirdLife International. 2000. Threatened birds of the world. Lynx Edicions and BirdLife International, Barcelona and Cambridge, UK.

Buckland, S. T. 2006. Point transect surveys for songbirds: robust methodologies. Auk 123:345–357.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 2001. Distance sampling: estimating abundance of biological populations. Chapman and Hall, London, UK.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas (editors). 2004. Advanced distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, UK.

Camp, R. J., M. H. Reynolds, B. L. Woodworth, P. M. Gorresen, and T. K. Pratt. 2009. Monitoring Hawaiian forest birds. Pages 83–107 *in* T. K. Pratt, C. T. Atkinson, P. C. Banko, J. D. Jacobi, B. L. Woodworth (editors). Conservation biology of Hawaiian forest birds: implications for island avifauna. Yale University Press, New Haven, CT.

Camp, R. J., N. E. Seavy, P. M. Gorresen, and M. H. Reynolds. 2008. A statistical test to show negligible trend: comment. Ecology 89:1469–1472.

Dunn, E. H. 2002. Using decline in bird populations to identify needs for conservation action. Conservation Biology 16:1632–1637.

Fujisaki, I., E. V. Pearlstine, and M. Miller. 2008. Detecting population decline of birds using long-term monitoring data. Population Ecology 50:275–284.

Green, D. M. 2003. The ecology of extinction: population fluctuation and decline in amphibians. Biological Conservation 111:331–343.

Houlahan, J. E., C. S. Findlay, B. R. Schmidt, A. H. Meyer, and S. L. Kuzmin. 2000. Quantitative evidence for global amphibian decline. Nature 404:752–755.

Johnson, L. M., R. J. Camp, K. W. Brinck, and P. C. Banko. 2006. Long–term population monitoring: lessons learned from an endangered passerine in Hawai`i. Wildlife Society Bulletin 34:1055–1063.

Kery, M., and J. A. Royle. 2010. Hierarchical modelling and the estimation of abundance and population trends in metapopulation designs. Journal of Animal Ecology 79:453–461.

Link, W. A., and R. J. Barker. 2010. Bayesian inference with ecological applications. Academic Press, New York, NY.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier Academic Press, New York, NY.

Mitchell, C., C. Ogura, D. W. Meadows, A. Kane, L. Strommer, S. Fretz, D. Leonard, and A. McClung. 2005. Hawaii's Comprehensive Wildlife Conservation Strategy. Department of Land and Natural Resources, Honolulu, HI.

Morris, W. F., and D. F. Doak. 2002. Quantitative conservation biology: theory and practice of population viability analysis. Sinauer Associates, Sunderland, MA.

Papahānaumokuākea Marine National Monument (PMNM). 2008. Papahānaumokuākea Marine National Monument management plan: Volume I. National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service, and Hawai`i Department of Land and Natural Resources, Honolulu, HI. Available at: www.papahanaumokuakea.gov/management/mp/vol1_mmp08.pdf Accessed 17 October 2012.

Pavlacky, D. C., J. A. Blakesley, G. C. White, D. J. Hanni, and P. M. Lukacs. 2012. Hierarchical multi-scale occupancy estimation for monitoring wildlife populations. Journal of Wildlife Management 76:154–162.

Ralph, C. J., and S. G. Fancy. 1994. Timing of breeding and molting in six species of Hawaiian honeycreepers. Condor 96:151–161.

Simon, J. C., T. K. Pratt, K. E. Berlin, J. R. Kowalsky, S. G. Fancy, and J. S. Hatfield. 2002. Temporal variation in bird counts within a Hawaiian rainforest. Condor 104:469–481.

Staples, D. F., M. L. Taper, and B. B. Shepard. 2005. Risk-based viable population monitoring. Conservation Biology 19:1908–1916.

Thomas, L. 1996. Monitoring long-term population change: why are there so many analysis methods? Ecology 77:49–58.

Thomas, L., S. T. Buckland, E. A. Rextad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5–14.

U.S. Fish and Wildlife Service (USFWS). 1984. Recovery plan for the Northwestern Hawaiian Islands passerines. U.S. Fish and Wildlife Service, Portland, OR. 66 pp.