Current distribution and abundance of the O‘ahu ‘Elepaio (*Chasiempis ibidis*)

Author(s): Eric A. Vanderwerf , Michael T. Lohr , Andrew J. Titmus , Philip E. Taylor , and Matthew D. Burt
Source: The Wilson Journal of Ornithology, 125(3):600-608. 2013.
Published By: The Wilson Ornithological Society
DOI: http://dx.doi.org/10.1676/13-018.1
URL: http://www.bioone.org/doi/full/10.1676/13-018.1

The Wilson Journal of Ornithology 125(3):600–608, 2013

CURRENT DISTRIBUTION AND ABUNDANCE OF THE O‘AHU ‘ELEPAIO (*CHASIEMPIS IBIDIS*)

ERIC A. VANDERWERF,[1,5] MICHAEL T. LOHR,[1,3] ANDREW J. TITMUS,[1,4] PHILIP E. TAYLOR,[2] AND MATTHEW D. BURT[2]

ABSTRACT.—The O‘ahu ‘Elepaio (*Chasiempis ibidis*) is an endangered monarch flycatcher endemic to the Hawaiian Island of O‘ahu. Current information on abundance, distribution, and population trend is needed to help assess the species status and identify areas where conservation efforts can be focused. We used spot-mapping methods with song playbacks to conduct surveys in the Ko‘olau Mountains from 2011–2012, and we used occupancy sampling with repeated visits to estimate detection probability. We detected 545 male and 317 female O‘ahu ‘Elepaio. The detection probability of males was 0.92 ± 0.03 and that of females was 0.86 ± 0.05, yielding corrected estimates of 592 males (95% CI = 554–630) and 369 females (95% CI = 327–411). Combined with results of a previous census in the Wai‘anae Mountains that found 192 males and 84 females, the total estimated population of the species is 1,261 birds (95% CI = 1,205–1,317), consisting of about 477 breeding pairs and 307 single males. The O‘ahu ‘Elepaio has declined in abundance by about 50% since the 1990s, when the population was estimated to be about 1,974 birds. The current geographic range of the O‘ahu ‘Elepaio encompassed about 5,187 ha and has declined by 75% since 1975, becoming fragmented into four larger subpopulations with 100 or more birds each and 12 smaller subpopulations. Rat control to reduce nest predation remains the cornerstone of the conservation strategy for the O‘ahu ‘Elepaio, but variation in forest structure, forest dynamics, and continuing evolution of ‘elepaio nesting behavior are likely to play important roles in determining whether this species can persist. *Received 24 January 2013. Accepted 20 March 2013.*

Key words: abundance, detection probability, Hawai’i, O‘ahu ‘Elepaio, range.

The O‘ahu ‘Elepaio (*Chasiempis ibidis*) is a territorial, non-migratory monarch flycatcher (Monarchidae) endemic to the island of O‘ahu in the Hawaiian Archipelago (VanderWerf 1998). ‘Elepaio also occur on Kaua‘i and Hawai’i, and the forms on each island were treated as subspecies for many years, but morphological, behavioral, and genetic evidence indicate ‘elepaio on each island constitute separate species (Conant et al. 1998; VanderWerf 2007, 2012a; VanderWerf et al. 2010). In 2010, the American Ornithologists’ Union changed the taxonomy so that each island form is recognized as a distinct species (Chesser et al. 2010, VanderWerf 2012c). The Kaua‘i ‘Elepaio (*C. sclateri*) and Hawai‘i ‘Elepaio (*C. sandwichensis*) are fairly common and widespread (Scott et al. 1986, Gorresen et al. 2009), but the O‘ahu ‘Elepaio is rare and locally distributed, is listed as endangered under the U.S. Endangered Species Act (USFWS 2000, 2006) and by the State of Hawai‘i, and is considered endangered by the International Union for the Conservation of Nature (IUCN 2012).

The O‘ahu ‘Elepaio was abundant and widespread in forested habitat throughout the island in early 20th century (Seale 1900, Perkins 1903, Bryan 1905), but it has declined steadily and in the 1990s it was estimated to occupy <4% of its presumed prehistoric range and <25% of the range occupied in 1975 (VanderWerf et al. 2001). The island-wide population was estimated to be 1,974 birds based on surveys conducted during the 1990s (VanderWerf et al. 2001). Roughly half of the total population was found in the Wai‘anae Mountains of western O‘ahu and half was found in the Ko‘olau Mountains of eastern O‘ahu. A more recent census in the Wai‘anae Mountains from 2006–2009 found only 300 O‘ahu ‘Elepaio, indicating their numbers have continued to decline (VanderWerf et al. 2011a), but the recent population trend in the Ko‘olau Mountains is unknown.

The primary threats responsible for the decline of the O‘ahu ‘Elepaio are nest predation by alien black rats (*Rattus rattus*) and mosquito-borne diseases (VanderWerf 2001, VanderWerf and Smith 2002, USFWS 2006, VanderWerf et al.

[1] Pacific Rim Conservation, 3038 O‘ahu Avenue, Honolulu, HI 96822, USA.

[2] U.S. Army Garrison, Environmental Division, Directorate of Public Works, Schofield Barracks, HI 96857, USA.

[3] Current address: 80 Golf Links Drive, Carramar, Western Australia 6031.

[4] Current address: University of Hawai’i at Manoa, Department of Zoology, Honolulu, HI 96822, USA.

[5] Corresponding author;
e-mail: eric@pacificrimconservation.com

2006, VanderWerf 2009). Controlling transmission of mosquito-borne avian diseases in Hawai'i has been very difficult (LaPointe et al. 2009), but rat control has proven to be an effective method of increasing O'ahu 'Elepaio nest success and survival of breeding females, if properly implemented, and has become the cornerstone of the conservation strategy for this species (VanderWerf and Smith 2002, VanderWerf 2009, VanderWerf et al. 2011b). Ground-based rodent control using snap traps and poison bait stations has been conducted in several areas and by several agencies, and has resulted in modest but localized population increases (VanderWerf 2009, VanderWerf et al. 2011b). Restoration of native forest habitat also may be beneficial to the O'ahu 'Elepaio and could reduce the need for rat control by reducing the abundance of non-native, fruit-bearing trees that support large numbers of rats and attract them into the forest canopy (VanderWerf 2009). More diverse and intact native forest also may support higher abundance and diversity of arthropods that are prey for 'elepaio (VanderWerf 1994, Fretz 2002). The O'ahu 'Elepaio is evolving in response to nest predation by rats through increasing nest height (VanderWerf 2012b), and this natural population response in combination with active management may help to decrease the extinction risk of this species.

The purposes of this study were to: (1) provide current information about the distribution and abundance of the O'ahu 'Elepaio; and (2) identify areas where numbers of 'elepaio are declining and where conservation efforts can be focused. This information can be used by agencies and organizations to help assess the conservation status of the species and coordinate management.

METHODS

We used spot-mapping survey methods with song playbacks to determine the distribution and abundance of the O'ahu 'Elepaio in the Ko'olau Mountains. Surveys consisted of walking up or down a valley or ridge or traversing an area of forest and stopping to play recorded O'ahu 'Elepaio songs at approximately 100-meter intervals. 'Elepaio defend territories year-round and playbacks are an efficient method of locating birds and determining the extent of their territory (Falls 1981, VanderWerf 2004). 'Elepaio often respond more strongly to local song dialects (VanderWerf 2007), so recordings used during playbacks were from the area being surveyed or a nearby area. Each playback lasted approximately 3 secs, after which we watched and listened for approximately 20 secs. We repeated this procedure at least three times, unless a bird responded sooner. Most 'elepaio respond to playbacks within 1 min (VanderWerf 2007), but some birds approach quietly and must be searched for visually. We recorded the age and sex of each 'elepaio observed, any behaviors or association with other 'elepaio, and whether each territory contained a pair or a single male. We recorded the location of detections with a Global Positioning System (GPS) device. Consecutive detections were counted as different individuals if the birds could be distinguished by color bands or distinctive plumage, if birds from neighboring territories were observed simultaneously, or if the detections occurred more than 150 m apart, making it unlikely they were from the same territory. 'Elepaio territory size varies with habitat structure and population density (VanderWerf 2004), but the width of a territory is usually 75–150 m. 'Elepaio may move farther and follow an observer for longer distances in areas where their population density is low. If it appeared that a bird might have been following us, we used additional playbacks to ascertain the extent of its territory to avoid counting it twice.

Although playbacks are effective at increasing the detection probability of 'elepaio, some individuals may not respond to playbacks on a given day, resulting in imperfect detection (MacKenzie et al. 2002). To determine the proportion of birds that we may have missed, we repeated surveys three times in four areas and estimated the detection probability using program PRESENCE2 (Hines 2006). We estimated the detection probability for males and females separately, because males are more likely than females to respond to playbacks (VanderWerf and Freed 2003). We used the resulting detection probabilities to correct our estimates of abundance. We calculated 95% confidence intervals around the corrected abundance estimates by using the delta method to calculate the variance, which results in a narrower interval (Oehlert 1992). The equation for the variance around the population estimate for males and females combined is:

$$\mathrm{var}(N) = \left\{ {n_m}^2 * {\sigma_{pm}}^2 * \left(1/{p_m}^2\right)^2 \right\} + \left\{ {n_\mathrm{f}}^2 * {\sigma_{p\mathrm{f}}}^2 * \left(1/{p_\mathrm{f}}^2\right)^2 \right\}$$

Where n_m and n_f are the numbers of birds detected, σ_{pm} and σ_{pf} are the variances of the detection probabilities, and p_m and p_f are the detection probabilities, for males and females respectively.

Two of the areas we surveyed repeatedly had high densities of ‘elepaio (North Halawa Valley, Pia Valley) and two of the areas had moderate densities (Hawaiiloa Ridge, Wiliwilinui Ridge). For the uncorrected abundance at those sites, we used the highest number of birds detected on any single visit. The proportion of territories in which we detected birds was similar among the three visits for males (mean = 0.92, range 0.91–0.93) and females (mean = 0.60, range 0.55–0.66), indicating there was no systematic pattern or temporal bias in detection probability.

We surveyed almost all areas in the Ko‘olau Mountains where O‘ahu ‘Elepaio have been reported in the last 40 years (Shallenberger 1977, Shallenberger and Vaughn 1978, VanderWerf et al. 2001), with a few exceptions. We were not able to survey some private lands because we could not obtain permission for access, including Punalu‘u, Ka‘a‘awa, and portions of Waiahole Valley. Several areas we covered had never been surveyed but contained suitable habitat, such as upper Waimalu and Waimano valleys.

To determine the current range of the O‘ahu ‘Elepaio, we used a Geographic Information System (GIS) to create a 200-m radius buffer around all points where we detected birds, and then drew a polygon around the buffered points. In cases where we suspected the range did not extend 200 m from the observation point, such as steep cliffs at the head of a valley or a narrow ridge that supported only low vegetation not suitable for ‘elepaio, we drew the polygon to coincide with the limiting geographic or vegetative feature. We used this procedure to measure the geographic range of the O‘ahu ‘Elepaio in the Ko‘olau Mountains using detections reported in this study, and also using detections reported in the Wai‘anae Mountains of western O‘ahu by VanderWerf et al. (2011a), where the size of the current range has not been measured.

RESULTS

We detected 545 male and 317 female O‘ahu ‘Elepaio during surveys in the Ko‘olau Mountains from January 2011–June 2012 (Fig. 1). The detection probability of males was 0.92 ± 0.03 and that of females was 0.86 ± 0.05, based on areas that we surveyed on three occasions. Applying the detection probabilities to the numbers of actual detections, and using the delta method to calculate confidence intervals, yielded corrected estimates of 592 males (95% CI = 554–630) and 369 females (95% CI = 327–411), and a total population estimate of 961 (95% CI = 905–1,017). The proportion of paired males was 0.58 overall (Table 1), and was generally higher in and near areas where rats have been controlled, including Wailupe Valley west fork (0.78), Pia Valley (0.82), and Kupaua Valley (0.88).

The geographic range of the O‘ahu ‘Elepaio encompassed a total of 5,187 ha (12,811 ac) in 2011–2012, including 3,948 ha (9,749 ac) in the Ko‘olau Mountains and 1,239 ha (3,060 ac) in the Wai‘anae Mountains (Table 2, Fig. 2). In the Ko‘olau Mountains, the range was fragmented into six subpopulations, including two relatively large subpopulations in the central and southeastern Ko‘olau Mountains that contained over 400 birds each, a smaller subpopulation of about 25 birds in Waikane and Kahana valleys on the windward (eastern) side of the island, and three tiny remnants consisting of 1–4 birds in Nu‘uanu, Waihe‘e, and Waiahole valleys. Moanalua Valley had the most ‘elepaio territories (n = 79), but Wailupe Valley had the most breeding pairs (n = 51).

DISCUSSION

The current total population size of the O‘ahu ‘Elepaio, obtained by combining the results of this study for the Ko‘olau Mountains and those reported by VanderWerf et al. (2011a) for the Wai’anae Mountains, is 1,261 birds (95% CI = 1,205–1,317), which consists of about 477 breeding pairs and 307 single males. This estimate is roughly 50% lower than the previous estimate of 1,974 birds that was based on surveys conducted in the 1990s (VanderWerf et al. 2001). Most of the decline has occurred in the Wai‘anae Mountains, where ‘elepaio numbers dropped from about 950 in the 1990s to only 300 in 2006–2009, though some of the decline was caused by overestimation in the 1990s (VanderWerf et al. 2011a). In contrast, the status of the O‘ahu ‘Elepaio in the Ko‘olau Mountains has remained more stable, with 1,020 birds estimated to occur in the 1990s and about 961 today.

The geographic range of the O‘ahu ‘Elepaio has declined by about 75% over the past 40 years, from to 21,563 ha in 1975, to 5,483 ha in the

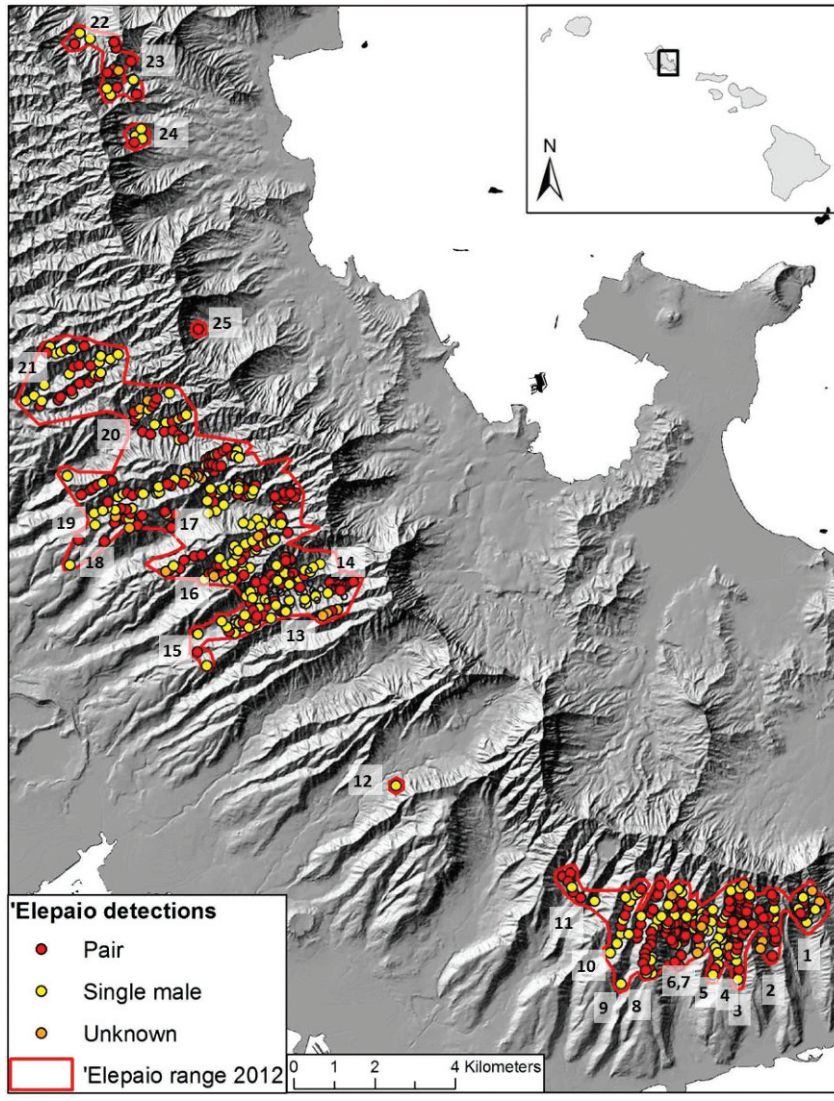

FIG. 1. Locations of detections of O‘ahu ‘Elepaio in the Ko‘olau Mountains in 2011–2012. Numbers correspond to the Location Codes listed in Table 1.

1990s, and 5,187 ha in 2011–2012 (Table 2). The range is now highly fragmented, and most subpopulations are isolated from each other by unsuitable habitat and the limited dispersal behavior of ‘elepaio (VanderWerf 2008). The pattern of decline in geographic range has varied among regions and among time periods. In the Ko‘olau Mountains of eastern O‘ahu, the range declined by 80% from 1975 to the 1990s, but since the 1990s rate of decline has slowed or even stopped in some areas. The range in the central Ko‘olau Mountains appears to have increased since the 1990s (Table 2), but this was caused by more thorough survey coverage in 2011–2012 and the rediscovery of ‘elepaio in two valleys where they were thought to have disappeared (Waimano, Waimalu). ‘Elepaio have continued to decline on the windward side of the Ko‘olau Mountains, in Waikane, Kahana, and Waiahole Valleys. In contrast, in the Wai’anae Mountains of western O‘ahu, the range of ‘elepaio declined by 50% from 1975 to the 1990s, and has continued to decline at the same rate. The only large subpopulations left in the Wai’anae range occur in areas

TABLE 1. Abundance of O‘ahu ‘Elepaio in the Ko‘olau Mountains. Locations are listed from southeast to northwest in each region. Location codes correspond to numbers shown in Fig. 1.

Code	Location	# pairs	# single males	Proportion pairs
1	Kuli’ou’ou+Ka’alakei Valleys	8	5	0.62
2	Kupaua Valley	15	2	0.88
3	Pia Valley	32	7	0.82
4	Hawai’iloa Ridge	6	2	0.75
5	Kulu’i Valley	7	12	0.37
6	Wailupe Valley east fork	8	9	0.47
7	Wailupe Valley west fork	43	12	0.78
8	Wiliwilinui Ridge+Waialae Iki	10	7	0.59
9	Kapakahi Gulch	9	2	0.82
10	Waialae Nui Valley	4	9	0.31
11	Palolo Valley	5	2	0.71
	Southeastern Ko‘olau Total	145	71	0.67
12	Nu’uanu Valley	0	1	0.00
13	Manaiki Valley+Tripler Ridge	2	3	0.40
14	Moanalua Valley upper	20	14	0.59
15	Moanalua Valley lower	18	27	0.40
16	South Halawa Valley	24	26	0.48
17	North Halawa Valley	26	25	0.51
18	Aiea Loop Trail	7	3	0.70
19	Kalauao Valley	30	22	0.58
20	Waimalu Valley	20	11	0.65
21	Waimano Valley	14	16	0.47
	Central Ko‘olau Total	162	146	0.53
22	Kahana Valley	3	2	0.60
23	Waikane Valley	6	4	0.60
24	Waiahole Valley	1	3	0.25
25	Waihe’e Valley	1	0	1.00
	Windward total	11	9	0.55
	Grand Total	317	228	0.58

where the primary threat, nest predation by rats, has been managed (VanderWerf et al. 2011a, b).

The current surveys were more thorough than those in the 1990s and the population estimates were obtained by somewhat different methods, so care is needed in comparing the results and interpreting the apparent trends. During surveys in the 1990s, some areas were surveyed only partially and the density of territories was extrapolated to produce an estimate for a larger area. For example, in the 1990s only the lower section of Kalaua‘o Valley was surveyed, which produced only a few ‘elepaio, but the current surveys revealed that many more ‘elepaio were present higher in the valley. Similarly, zero ‘elepaio were detected in Waimano Valley in the 1990s when only the lower section was surveyed, but in the current surveys we detected 14 pairs and 16 single male elepaio in the higher portions of the valleys that were not surveyed previously. The number of ‘elepaio estimated to occur in the central leeward Ko‘olau Mountains thus appears to have increased from about 226 in the 1990s to over 500 today, but this difference is primarily because of greater survey effort.

Although we attempted to survey as much of the Ko‘olau Mountains as possible, some areas were simply too steep to access on foot. A few ‘elepaio probably occur in areas we did not survey, including the upper reaches and tributaries of some larger valleys, such as South Halawa and Waimalu, that were blocked by waterfalls and would have required rappelling from adjacent ridges in order to survey. Some areas that we did not survey in 2011–2012 have been surveyed repeatedly in the past and have yielded zero ‘elepaio for many years, including the Kahuku Training Area, Schofield Barracks East Range, and other areas in the northern Ko‘olau Mountains managed by the U.S. Army (VanderWerf et al. 2001, OANRP 2012).

The primary management tool for the O‘ahu ‘Elepaio has been rat control to reduce nest

TABLE 2. Geographic range size (ha) of O‘ahu ‘Elepaio subpopulations in the Ko‘olau and Wai’anae Mountains in 1975, the 1990s, and 2011–2012. Merged cells indicate subpopulations that formerly were continuous.

Mountain range	Subpopulation	1975	1990s	2011–2012
Ko‘olau	Southeastern Ko‘olau		1,063	1,019
	Palolo	2,391	78	
	Manoa		16	0
	Nu’uanu		Unknown	10
	Kapalama	414	0	0
	Central Ko‘olau	11,059	1,396	2,724
	Maunawili	344	0	0
	Waihe’e		32	10
	Waiahole	1,255	523	30
	Waikane-Kahana			155
	Hau’ula	120	0	0
	Kahuku	121	0	0
	Ko‘olau Total	15,705	3,120	3,948
Wai’anae	Palehua			121
	Palikea-Palawai	1,732	1,165	118
	Puali’i			9
	‘Ekahanui-Kalua’a			308
	Lualualei			0
	Schofield West Range	783	532	364
	Makaha-Wai’anae Kai		459	230
	Makua	3,343	19	77
	Pahole-Kahanahaiki		0	134
	Ka’ala		21	12
	Wai’anae Total	5,857	2,363	1,239
Both	Grand Total	21,563	5,483	5,187

predation (VanderWerf 2009, VanderWerf et al. 2011a), and the beneficial effects of this technique on ‘elepaio demography were evident during surveys. In areas where rats have been controlled, ‘elepaio numbers have remained stable or increased and the proportion of pairs was higher. This pattern was most striking in Wailupe Valley, where rats have been controlled in the west fork but not in the east fork, and in Moanalua Valley, where rats are controlled only in the upper portion of the valley (Table 1). Areas where rats are controlled likely serve as sources of emigrants that help to support ‘elepaio numbers in nearby areas, but predation by rats on nesting females causes the adjacent areas to act as sinks (VanderWerf 2009).

O‘ahu ‘Elepaio have declined severely on the windward (eastern) side of the Ko‘olau Mountains, where estimated numbers dropped from 272 birds in the 1990s to only 35 today. Some of this decline may have been caused by an overestimate of the number of birds in Kahana Valley, which was only partially surveyed in the 1990s, but ‘elepaio have disappeared from much of Waikane and Waiahole Valleys where they were known to occur previously. Rats were controlled in Waikane Valley for several years by the U.S. Army but the control effort was not sufficient and ‘elepaio numbers continued to decline (VanderWerf et al. 2011a). Management of the remaining ‘elepaio in Waikane should be resumed using new techniques, including native forest restoration, to prevent extirpation of ‘elepaio from the windward side of the island. If active management is resumed in Waikane, translocating the few remaining ‘elepaio from other valleys on the windward side to Waikane could be considered in order to consolidate the last remnants and provide a greater overall chance of persistence.

‘Elepaio numbers have increased or remained stable in some areas where no rat control or other active management has been conducted, possibly because of changes in ‘elepaio behavior and geographic variation in forest structure. VanderWerf (2012b) showed that ‘elepaio in southeastern O‘ahu are evolving to nest higher off the ground in response to predation by rats, and it is possible that the continued presence of ‘elepaio in areas that receive no management is caused by similar changes in nesting behavior or by changes in habitat use. For example, ‘elepaio numbers in

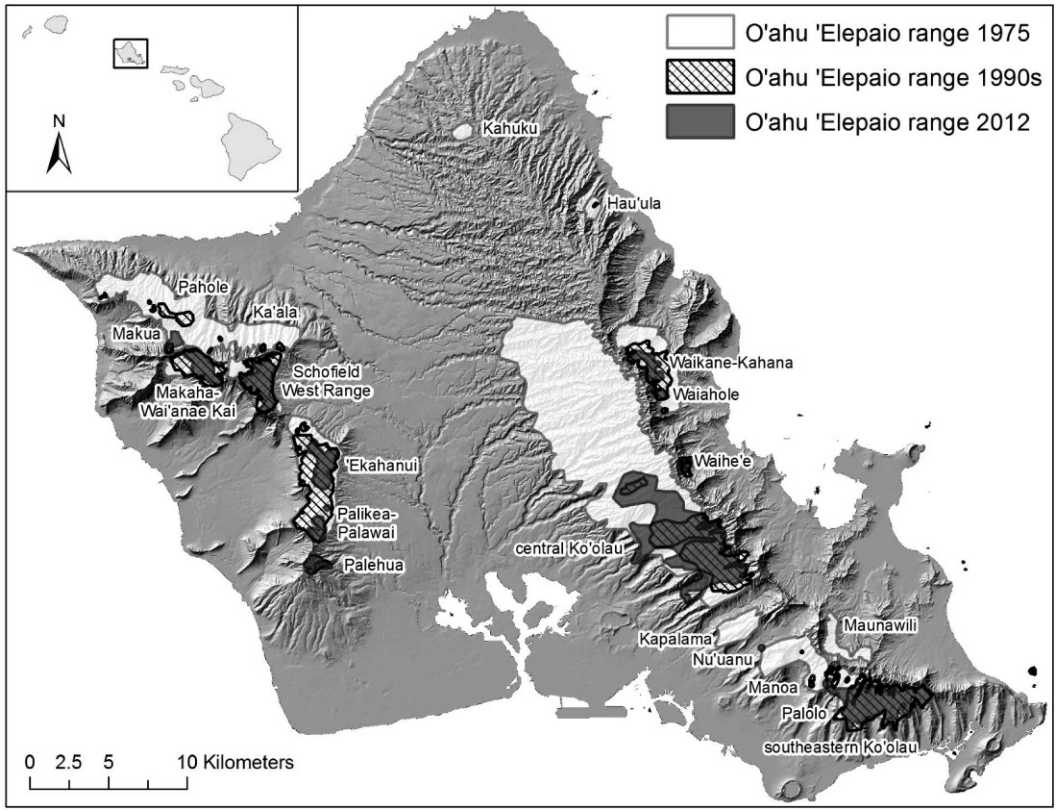

FIG. 2. Geographic range of the O‘ahu ‘Elepaio in 1975, the 1990s, and 2012.

‘Aiea have increased from only one pair and one single male in the 1990s to seven pairs and three single males today. In 2011, we observed an ‘elepaio pair in ‘Aiea nesting in a *Eucalyptus robusta* tree over 30 m tall, where they likely were safe from rats. ‘Elepaio have not been observed using this alien tree species previously, though it is common on O‘ahu. If this behavior becomes widespread and more ‘elepaio begin using tall alien trees that lack fruit they may suffer lower rates of nest predation. In Waialae Iki Valley, we found that ‘elepaio were common in forest consisting almost entirely of 20-m tall strawberry guava trees with virtually no understory. In such habitat, ‘elepaio have no choice but to nest high off the ground, where nest predation by rats is less likely. Forest structure, dynamics, and tree species composition all may play a role in determining whether ‘elepaio can persist in an area. Kalaua‘o Valley, which supports one of the densest concentrations of O‘ahu ‘Elepaio and contains relatively intact native forest in the upper reaches, has been proposed as a natural area reserve by the Hawai’i Division of Forestry and Wildlife. Such designation may result in more funding for management to prevent the spread of non-native trees and support the persistence of ‘elepaio.

ACKNOWLEDGMENTS

Funding for O‘ahu ‘Elepaio surveys in the Ko‘olau Mountains was provided by the U.S. Fish and Wildlife Service. Monitoring of O‘ahu ‘Elepaio in Moanalua Valley was funded by the U.S. Army. For granting access to conduct surveys, we thank the Hawai‘i Division of Forestry and Wildlife, the Hawaii Division of State Parks, the U.S. Fish and Wildlife Service, the U.S. Army, the Honolulu Board of Water Supply, Ohulehule Forest Conservancy, Laura Thompson, and the Oahu Country Club. For assistance with surveys we thank Amy Tsuneyoshi and Paul Zweng. The manuscript was improved by comments from Rick Camp and an anonymous reviewer.

LITERATURE CITED

BRYAN, W. A. 1905. Notes on the birds of the Waianae Mountains. Bishop Museum Occasional Papers 2:37–49.

CHESSER, R. T., R. C. BANKS, F. K. BARKER, C. CICERO, J. L. DUNN, A. W. KRATTER, I. J. LOVETTE, P. C. RASMUSSEN, J. V. REMSEN JR., J. D. RISING, D. F. STOTZ, AND K. WINKER. 2010. Fifty-first supplement to the American Ornithologists’ Union check-list of North American birds. Auk 127:726–744.

CONANT, S., H. D. PRATT, AND R. J. SHALLENBERGER. 1998. Reflections on a 1975 expedition to the lost world of the Alaka’i and other notes on the natural history, systematics, and conservation of Kaua’i birds. Wilson Bulletin 110:1–22.

FALLS, J. B. 1981. Mapping territories with playback: an accurate census method for songbirds. Studies in Avian Biology 6:86–91.

FRETZ, J. S. 2002. Scales of food availability for an endangered insectivore, the Hawaii Akepa. Auk 119:166–174.

GORRESEN, P. M., R. J. CAMP, M. H. REYNOLDS, B. L. WOODWORTH, AND T. K. PRATT. 2009. Status and trends of native Hawaiian songbirds. Pages 108–136 *in* Conservation biology of Hawaiian forest birds: implications for island avifauna (T. K. Pratt, C. T. Atkinson, P. C. Banko, J. D. Jacobi, and B. L. Woodworth, Editors). Yale University Press, New Haven, Connecticut, USA.

HINES, J. E. 2006. PRESENCE2. Version 4.9. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA. www.mbr-pwrc.usgs.gov/software/presence.html (accessed 26 Aug 2012).

INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE (IUCN). 2012. IUCN Red List of threatened species. Version 2012.2. *Chasiempis ibidis*. International Union for the Conservation of Nature, Gland, Switzerland. www.iucnredlist.org

LAPOINTE, D. A., C. T. ATKINSON, AND S. I. JARVI. 2009. Managing disease. Pages 405–424 *in* Conservation biology of Hawaiian forest birds: implications for island avifauna (T. K. Pratt, C. T. Atkinson, P. C. Banko, J. D. Jacobi, and B. L. Woodworth, Editors). Yale University Press, New Haven, Connecticut, USA.

MACKENZIE, D. I., J. D. NICHOLS, G. B. LACHMAN, S. DROEGE, J. A. ROYLE, AND C. A. LANGTIMM. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.

OAHU ARMY NATURAL RESOURCE PROGRAM (OANRP). 2012. Status report for the Makua and Oahu implementation plans. Pacific Cooperative Studies Unit and U.S. Army Garrison, Honolulu, Hawaii, USA. manoa.hawaii.edu/hpicesu/DPW/2012_YER/default.htm

OEHLERT, G. W. 1992. A note on the delta method. American Statistician 46:27–29.

PERKINS, R. C. L. 1903. Aves. Pages 368–465 *in* Fauna Hawaiiensis (D. Sharp, Editor). Cambridge University Press, Cambridge, United Kingdom.

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 9:1–431.

SEALE, A. 1900. Field notes on the birds of Oahu, H. I. Bishop Museum Occasional Papers 1:33–46.

SHALLENBERGER, R. J. 1977. Bird and mammal survey of Army lands in Hawaii. Ahuimanu Productions, Kailua, Hawaii, USA.

SHALLENBERGER, R. J. AND G. K. VAUGHN. 1978. Avifaunal survey in the central Koolau Range, Oahu. Ahuimanu Productions, Honolulu, Hawaii, USA.

U.S. FISH AND WILDLIFE SERVICE (USFWS). 2000. Final rule to list as endangered the O‘ahu ‘Elepaio from the Hawaiian Islands and determination of whether designation of critical habitat is prudent. Federal Register 65:20760–20769.

U.S. FISH AND WILDLIFE SERVICE (USFWS). 2006. Revised recovery plan for Hawaiian forest birds. U.S. Fish and Wildlife Service, Portland, Oregon, USA.

VANDERWERF, E. A. 1994. Intraspecific variation in elepaio foraging behavior in Hawaiian forests of different structure. Auk 111:917–932.

VANDERWERF, E. A. 1998. ‘Elepaio (*Chasiempis sandwichensis*). The birds of North America. Number 344.

VANDERWERF, E. A. 2001. Rodent control decreases predation on artificial nests in O‘ahu ‘Elepaio habitat. Journal of Field Ornithology 72:448–457.

VANDERWERF, E. A. 2004. Demography of Hawai‘i ‘Elepaio: variation with habitat disturbance and population density. Ecology 85:770–783.

VANDERWERF, E. A. 2007. Biogeography of ‘Elepaio: evidence from inter-island song playbacks. Wilson Journal of Ornithology 119:325–333.

VANDERWERF, E. A. 2008. Sources of variation in survival, recruitment, and natal dispersal of the Hawai‘i ‘Elepaio. Condor 110:241–250.

VANDERWERF, E. A. 2009. Importance of nest predation by alien rodents and avian poxvirus in conservation of Oahu Elepaio. Journal of Wildlife Management 73:737–746.

VANDERWERF, E. A. 2012a. Ecogeographic patterns of morphological variation in elepaios (*Chasiempis* spp.): Bergmann’s, Allen’s, and Gloger’s rules in a microcosm. Ornithological Monographs 73:1–34.

VANDERWERF, E. A. 2012b. Evolution of nesting height in an endangered Hawaiian forest bird in response to a non-native predator. Conservation Biology 26:905–911.

VANDERWERF, E. A. 2012c. Meet the ‘Elepaios: Hawaii’s ‘‘new’’ endemic flycatchers. Birding 44:34–45.

VANDERWERF, E. A., M. D. BURT, J. L. ROHRER, and S. M. MOSHER. 2006. Distribution and prevalence of mosquito-borne diseases in O‘ahu ’Elepaio. Condor 108:770–777.

VANDERWERF, E. A. AND L. A. FREED. 2003. ’Elepaio subadult plumages reduce aggression through graded status-signaling, not mimicry. Journal Field Ornithology 74:406–415.

VANDERWERF, E. A., S. M. MOSHER, M. D. BURT, AND P. E. TAYLOR. 2011a. Current distribution and abundance of O‘ahu ‘Elepaio (Aves: Monarchidae) in the Wai‘anae Mountains. Pacific Science 65:311–319.

VANDERWERF, E. A., S. M. MOSHER, M. D. BURT, P. E. TAYLOR, AND D. SAILER. 2011b. Variable efficacy of rat control in conserving O‘ahu ‘Elepaio populations. Pages 124–130 *in* Island invasives: eradication and management (C. R. Veitch, M. N. Clout, and D. R.

Towns, Editors). International Union for the Conservation of Nature, Gland, Switzerland.

VANDERWERF, E. A., J. L. ROHRER, D. G. SMITH, AND M. D. BURT. 2001. Current distribution and abundance of the O'ahu 'Elepaio. Wilson Bulletin 113:10–16.

VANDERWERF, E. A. AND D. G. SMITH. 2002. Effects of alien rodent control on demography of the O'ahu 'Elepaio, an endangered Hawaiian forest bird. Pacific Conservation Biology 8:73–81.

VANDERWERF, E. A., L. C. YOUNG, N. W. YEUNG, AND D. B. CARLON. 2010. Stepping stone speciation in Hawaii's flycatchers: molecular divergence supports new island endemics within the Elepaio. Conservation Genetics 11:1283–1298.