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# CURRENT DISTRIBUTION AND ABUNDANCE OF THE O`AHU `ELEPAIO

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ABSTRACT.—The O`ahu `Elepaio (*Chasiempis sandwichensis ibidis*) is a monarch flycatcher endemic to the Hawaiian island of O`ahu. This forest bird has declined seriously in the last few decades and was listed as endangered under the federal Endangered Species Act in April 2000. The current distribution and population size of the O`ahu `Elepaio are poorly known, and this information is vital to designing a recovery plan and implementing recovery actions. We surveyed most of O`ahu for `Elepaio from 1992–2000 and compiled published and unpublished observations to estimate the current population size and construct current, recent historical, and prehistoric distribution maps. Based on 411 observations since 1991, we estimate the current population to be 1974 birds in six large subpopulations and several smaller ones. The breeding population consists of about 1768 birds due to a male-biased sex ratio, and the genetically effective population size is even lower because of the fragmented distribution. Total area of the current range is approximately 5486 ha, only 4% of the prehistoric range, and 25% of the range in 1975. Habitat loss to urbanization and agriculture caused large range reductions in the past, but cannot explain more recent declines. `Elepaio disappeared first from areas of higher rainfall, possibly because epizootics of introduced mosquito-borne diseases are more frequent where wetter conditions provide more mosquito breeding habitat. Management is urgently needed to prevent further declines and extirpation of smaller subpopulations. *Received 17 August 2000, accepted 19 January 2001.*

The `Elepaio (*Chasiempis sandwichensis*) is a territorial, nonmigratory monarch flycatcher (Monarchidae) endemic to the Hawaiian Islands (Conant 1977, van Riper 1995, VanderWerf 1998). `Elepaio on the islands of Hawai`i and Kaua`i (*C. s. sandwichensis* and *C. s. sclateri*, respectively) are fairly common and widely distributed at higher elevations (Scott et al. 1986, VanderWerf 1998), but the O`ahu `Elepaio (*C. s. ibidis*) has declined seriously in the last few decades (Fig. 1), disappearing from many areas where it was formerly common (Shallenberger 1977, Shallenberger and Vaughn 1978, Williams 1987, Cowell 1995, VanderWerf et al. 1997). `Elepaio are generalized in habitat selection, flexible in diet and foraging behavior, and are one of the most successful Hawaiian birds in terms of adaptation to disturbed forests composed of alien plants (Conant 1977; Scott et al. 1986; VanderWerf 1993, 1994; VanderWerf et al. 1997). The decline of such an adaptable bird is puzzling, and the causes of the decline are currently under investigation (EAV, unpubl. data). The O`ahu `Elepaio was listed as endangered under the federal Endangered Species Act on 18 April 2000 (U.S. Fish and Wildlife Service 2000). The current distribution and abundance of the O`ahu `Elepaio are poorly known, and this information is vital to designing a recovery plan and implementing recovery actions. The only previous population estimate (200–500 birds; Ellis et al. 1992) was made when little information was available. In 1992 we began conducting surveys to determine where `Elepaio still occurred on O`ahu and to estimate more accurately the current population size. Preliminary results from surveys in southeastern O`ahu were reported by VanderWerf et al. (1997). In this paper, we estimate current population size for the entire island, present range maps depicting the current, recent historical, and presumed prehistoric distributions of `Elepaio on O`ahu, and examine chronological and geographical patterns that help reveal the causes of population decline.

## METHODS

We surveyed most forested areas of O`ahu from 1992–2000. We attempted a complete census in as

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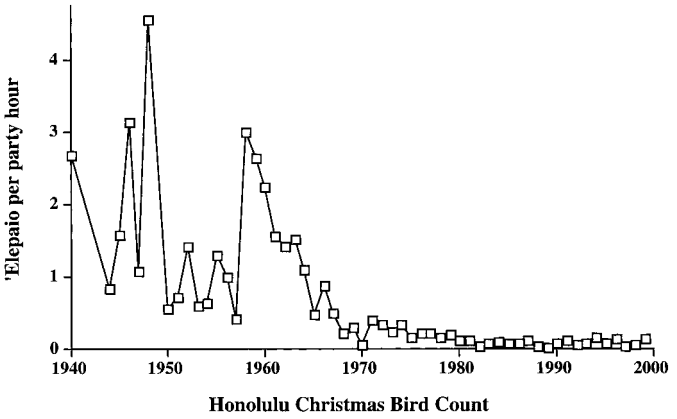


FIG. 1. Decline of the O`ahu `Elepaio illustrated by the number of birds found per party hour each year of the Honolulu Christmas Bird Count.

many areas as possible by surveying entire valleys or ridges. `Elepaio often respond aggressively to tape recordings of their song, and we used playbacks to increase our efficiency at finding birds (Johnson et al. 1981, Marion et al. 1981). Because `Elepaio are nonmigratory and each pair defends an all-purpose territory year round (Conant 1977, van Riper 1995, VanderWerf 1998), we estimated the population size by mapping and counting territories (Falls 1981). Successive observations were considered to represent different territories if neighboring pairs were seen or heard simultaneously, if they could be distinguished by age-related plumage differences (VanderWerf 1998), or if the observations were farther apart (>150 m) than the diameter of the average territory (2 ha; Conant 1977).

In addition to our own surveys, we compiled observations from the literature (e.g., Banko 1981, and field trip reports published in the `Elepaio) and from unpublished sources, including the Natural Heritage Program database of The Nature Conservancy of Hawai`i, the Sightings database from the Occurrence and Status of Birds in Hawai`i project maintained at Bishop Museum in Honolulu, and the O`ahu Forest Bird Survey conducted in 1991 by the Hawai`i State Division of Forestry and Wildlife. A few additional observations were obtained by interviewing land managers and amateur birders.

We constructed the current range map by plotting locations of 411 `Elepaio observations since January 1991 (334 from our surveys and 77 from other sources) on digitized USGS topographic maps, and then drawing polygons around clusters of observations with ArcView GIS software (Environmental Systems Research Institute 1996). We used 1991 as a cutoff for the current range because we were unable to find `Elepaio in several locations where they had been reported until 1989 or 1990. In some areas we were able to determine the complete elevational distribution, but in other areas we did not know the upper or lower range limit. In these cases, we used data from a neighboring area with similar habitat and topography in which we knew the elevational limits, and assumed that `Elepaio occurred at similar elevations in both areas.

We also attempted to reconstruct the recent historical and prehistoric ranges of `Elepaio on O`ahu to provide measures of the degree and rate of decline. The recent historical range map was drawn using the same methods as the current range map, but included an additional 175 observations from 1975–1991. We chose 1975 as the cutoff for the recent historical range because extensive surveys were conducted then (Shallenberger 1977, Shallenberger and Vaughn 1978), and because most previous observations had already been compiled (Banko 1981). The prehistoric range was based on anecdotal accounts by early naturalists of `Elepaio distribution (Seale 1900, Perkins 1903, Bryan 1905, MacCaughey 1919), and the original distribution of forested habitat prior to the arrival of humans (Hawai`i Heritage Program 1991). `Elepaio are generalized in habitat selection, currently found in a variety of forest types, and able to forage and nest in many different plant species (Conant 1977; VanderWerf 1993, 1994, 1998; VanderWerf et al. 1997), so it is likely that they once inhabited most forests on the island.

To estimate the total current population size, we first calculated the size of each subpopulation using one of two methods. In areas with few `Elepaio we attempted to conduct a complete census by surveying the entire area and locating every bird. We made a concerted effort to ascertain whether each bird had a mate, and we used the actual number of birds observed as the size of the subpopulation. In areas with many `Elepaio, where it was not possible to conduct a complete census, we calculated the density of territories in the area that we surveyed, then determined the proportion of the area that we covered, and extrapolated to obtain an estimate of the number of territories in the entire area. Based on long-term monitoring of several large populations, the sex ratio of `Elepaio is usually male-biased on O`ahu, with about 84% of territorial males

TABLE 1. Size and area of O`ahu`Elepaio subpopulations. The location of each subpopulation is shown in Fig. 2 by the corresponding letter. Sizes of subpopulations marked with an asterisk (*) were estimated by extrapolation (see Methods).

| Subpopulation | Number of territories observed | Number of territories estimated | Total population size | Breeding population size | Area (ha) |
|---|---|---|---|---|---|
| **Wai`anae Mountains** | | | | | |
| A. Southern Wai`anae (Honouliuli Preserve, Lualualei Naval Magazine)* | 73 | 249 | 458 | 418 | 1165 |
| B. Schofield Barracks West Range* | 92 | 185 | 340 | 310 | 532 |
| C. Makaha, Wai`anae Kai Valleys* | 17 | 67 | 123 | 112 | 459 |
| D. Pahole, Kahanahaiki | 14 | 14 | 16 | 4 | 134 |
| E. Schofield Barracks South Range | 6 | 6 | 6 | 0 | 20 |
| F. Makua Valley | 3 | 3 | 3 | 0 | 19 |
| G. Ka`ala Natural Area Reserve | 3 | 3 | 3 | 0 | 21 |
| H. Makaleha Gulch | 2 | 2 | 2 | 0 | 7 |
| I. Kaluakauila Gulch | 1 | 1 | 1 | 0 | 6 |
| **Ko`olau Mountains** | | | | | |
| J. Southern Ko`olau (Pia, Wailupe, Kapakahi, Kuli`ou`ou, Wai`alae Nui)* | 130 | 258 | 475 | 432 | 1063 |
| K. Waikane, Kahana Valleys* | 25 | 144 | 265 | 242 | 523 |
| L. Central Ko`olau (Moanalua, north and south Halawa, Aiea, Kalauao)* | 32 | 123 | 226 | 206 | 1396 |
| M. Palolo Valley* | 6 | 25 | 46 | 42 | 78 |
| N. Waihe`e Valley | 3 | 3 | 5 | 2 | 32 |
| O. Manoa Valley | 2 | 2 | 2 | 0 | 16 |
| P. Hau`ula | 1 | 1 | 1 | 0 | 4 |
| Q. Waianu Valley | 1 | 1 | 1 | 0 | 8 |
| **Total** | 411 | 1087 | 1974 | 1768 | 5486 |

having a mate ($n$ = 147; EAV, unpubl. data). To estimate the total numbers of birds and breeding pairs in an area, we therefore multiplied the number of territories by 1.84 and 0.84, respectively.

## RESULTS AND DISCUSSION

We estimate that the total current population of the O`ahu `Elepaio is approximately 1974 birds distributed in six relatively large subpopulations and several smaller ones (Table 1, Fig. 2). We could have missed some small subpopulations, but almost certainly found all large subpopulations. The number of birds is divided about equally between the Wai`anae Mountains in the west and the Ko`olau Mountains in the east, with three large subpopulations in each mountain range. Although the central Ko`olau subpopulation covers the largest area (Table 1), `Elepaio are sparsely distributed in this region and the number of birds is lower than in more dense subpopulations. At least eight tiny, remnant subpopulations consisting entirely of males remain in both the Wai`anae and Ko`olau mountains (Table 1), but because there is no chance of reproduction and rescue by immigration is unlikely (see below), these relict subpopulations likely will disappear in a few years as the last adults die. Although the population estimate from this study is higher than the only previous estimate (200–500; Ellis et al. 1992), we emphasize that the number of birds has not increased and that the current estimate is higher because it is based on more thorough surveys.

A more useful measure of the current number of O`ahu `Elepaio is the size of the breeding population, which is about 1768 due to a male-biased sex ratio; only 84% of territorial males have mates in large populations, and many small, declining populations contain only males (Table 1). One of the primary threats to `Elepaio is nocturnal nest predation by introduced black rats (*Rattus rattus*; VanderWerf, in press), and the skewed sex ratio may be the result of greater predation on incubating females. Both sexes incubate, but only the female incubates at night (VanderWerf 1998), making them potentially more vulnerable to nocturnal rats.

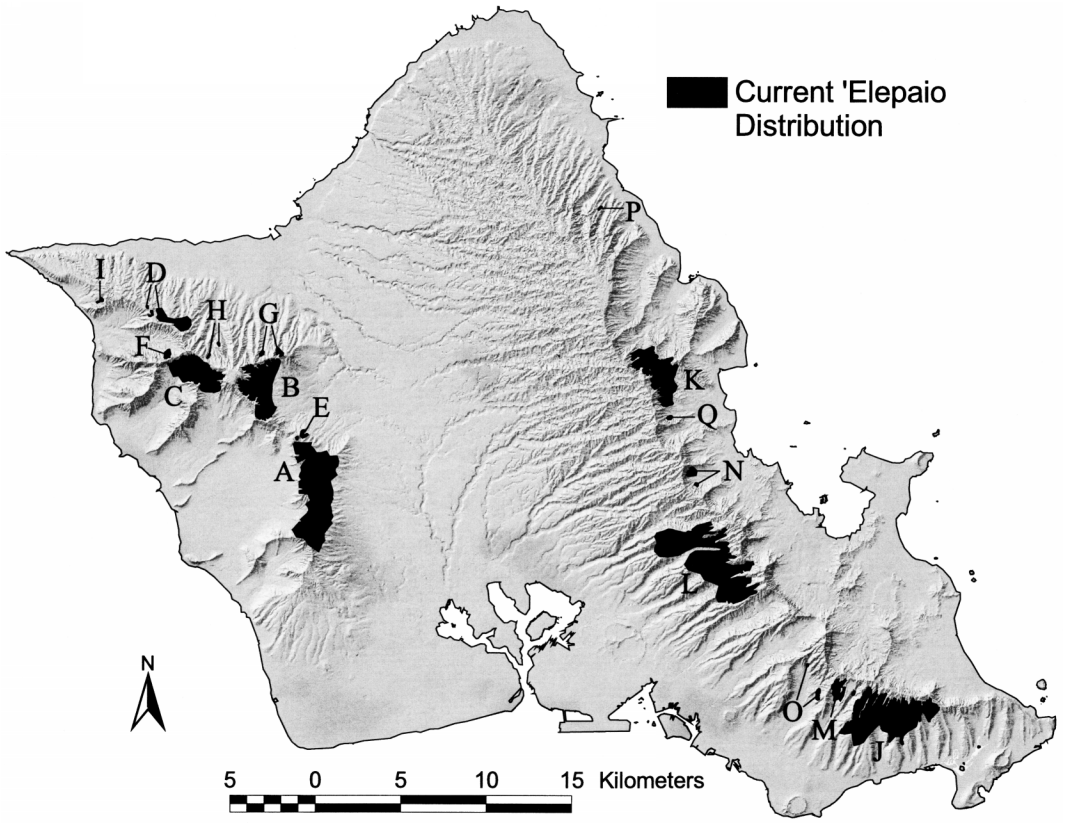


FIG. 2. Current distribution of the O`ahu `Elepaio. Subpopulations are identified by letters corresponding to those in Table 1.

The genetically effective population size, though unknown, probably is reduced by the geographically fragmented distribution (Grant and Grant 1992). Natal dispersal distances in `Elepaio are usually <1 km and adults are highly philopatric (VanderWerf 1998). Most subpopulations are separated by many km of unsuitable urban and agricultural habitat, so extensive exchange among subpopulations is unlikely. The current distribution superficially appears to constitute a metapopulation (Gilpin and Hanski 1991), but whether any exchange occurs among subpopulations is unknown. Habitat in most currently occupied areas is not saturated and there is space available, so young birds may not have to disperse far in search of breeding opportunities. The genetic population structure is unknown, but the degree of differentiation is likely to increase because most subpopulations are isolated.

The aggregate geographic area of the current range is approximately 5486 ha (Table 1), of which 55% is dominated by introduced plants and 45% by native plants (Hawai`i Heritage Program 1991). This does not imply that `Elepaio prefer introduced plant species, but probably reflects a preference by `Elepaio for riparian vegetation in valleys, and the high degree of habitat disturbance and abundance of introduced plants in riparian areas (VanderWerf et al. 1997). Of the 45% of the current range that is dominated by native plants, 51% is categorized as wet forest, 38% as mesic forest, and 11% as dry forest, shrubland, and cliffs (Hawai`i Heritage Program 1991).

Before humans arrived, forest covered about 127,000 ha on O`ahu (Hawai`i Heritage Program 1991), and `Elepaio probably once inhabited much of that area. Reports by early naturalists indicate that `Elepaio were widespread and abundant on O`ahu. Bryan (1905)

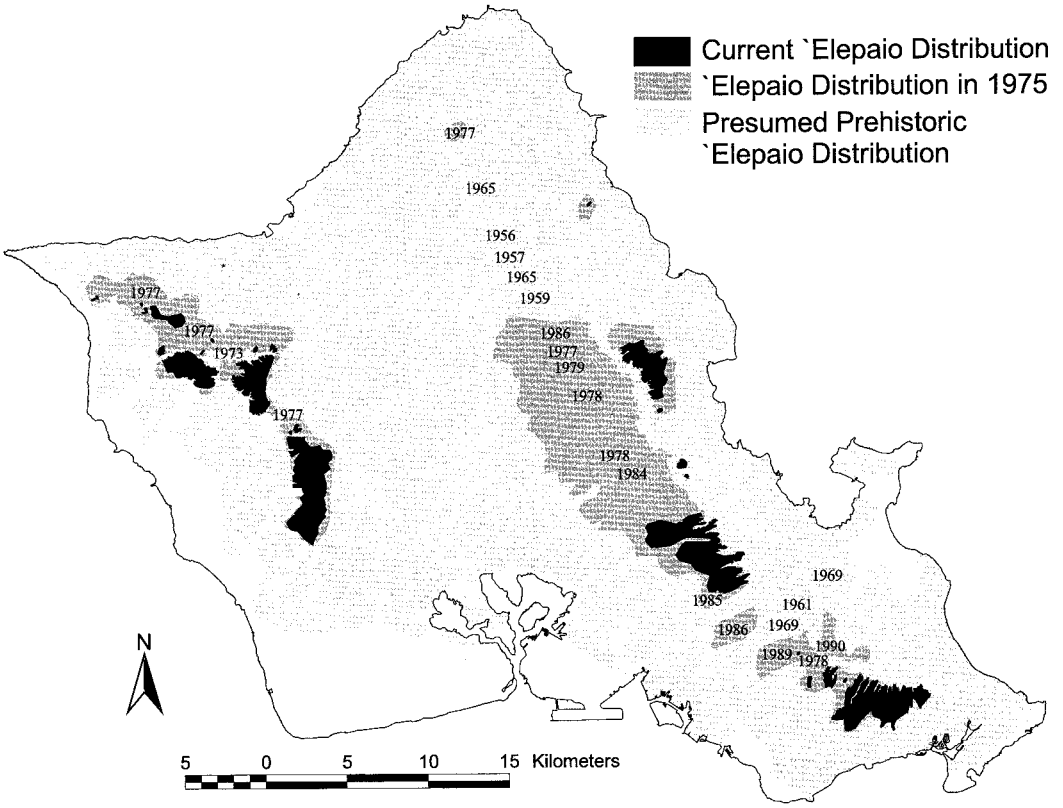


FIG. 3. Current, recent historical (1975), and presumed prehistoric distributions of `Elepaio on O`ahu. Years indicate when `Elepaio were last observed in that area. Prehistoric distribution based on prehuman distribution of forest habitat (Hawai`i Heritage Program 1991).

called the O`ahu `Elepaio ''the most abundant Hawaiian species on the mountainside all the way from the sea to well up into the higher elevations.'' Perkins (1903) remarked on its ''universal distribution . . . , from the lowest bounds to the uppermost edge of continuous forest.'' Seale (1900) stated the `Elepaio was ''the commonest native land bird to be found on the island,'' while MacCaughey (1919) described it as ''the most abundant representative of the native woodland avifauna'' and ''abundant in all parts of its range.'' Based on these reports and on the original distribution of forest, we estimate that the O`ahu `Elepaio currently occupies only about 4% of its original prehistoric range (Fig. 3), and that its range has declined by as much as 96% since humans arrived in Hawai`i 1600 years ago (Kirch 1982). Much of this decline can be attributed to habitat loss, particularly at low elevations. Fifty-six percent of the original prehistoric range is currently zoned for urban or agricultural development, and practically no `Elepaio remain in urban or agricultural areas. Habitat loss through development has thus had an important negative impact on the distribution and abundance of the `Elepaio, but habitat alteration in the form of gradual replacement of native forest with introduced forest appears not to have limited its distribution.

In 1975, `Elepaio inhabited approximately 21,467 ha on O`ahu, almost four times the area of the current range (Fig. 3). Land use has not changed substantially over this period, so the recent decline cannot be attributed to habitat loss. Several areas of O`ahu that once supported `Elepaio and still contain seemingly suitable forest habitat are currently unoccupied. `Elepaio were observed regularly into the 1970s or early 1980s at Poamoho, Schofield-Waikane, Kipapa, Manana, and

Waimano (Shallenberger 1977, Shallenberger and Vaughn 1978), but `Elepaio have disappeared from all these areas, even though the forest is apparently little changed.

Based on the years when `Elepaio were last observed in different parts of the island, a geographic pattern of decline is evident (Fig. 3). `Elepaio first disappeared from the northern end of the Ko`olau Mountains in the 1950s and 1960s. By the 1970s the decline was more widespread, and `Elepaio disappeared from much of the northern and central Ko`olau Mountains and parts of the northern Wai`anae Mountains, including Mt. Ka`ala and its northern slopes. In the 1980s, the last `Elepaio in the northern Ko`olau Mountains were lost at Poamoho and Waimano, and `Elepaio began to disappear from portions of the southern Ko`olau Range, including Tantalus and Kalihi. Populations in Manoa, Waianu, Pahole, and Makua shrank drastically over the same period, and probably will be gone soon.

Perhaps not coincidentally, declines in both the Ko`olau and Wai`anae Mountains occurred first in areas with higher rainfall. Peaks in mean annual rainfall on O`ahu occur in three regions, each associated with high mountains: (1) over a large portion of the northern Ko`olau Mountains, (2) in a small area of the southern Ko`olau Mountains centered on Manoa and Nu`uanu Valleys, and (3) at the northern end of the Wai`anae Mountains centered on the northeast slope of Mt. Ka`ala (Giambelluca et al. 1986). These are the same three centers in which `Elepaio were first documented to have disappeared. `Elepaio may have declined in wetter areas because such places provide more breeding habitat for the introduced mosquito *Culex quinquefasciatus.* This mosquito is the primary vector for two introduced diseases, avian malaria (*Plasmodium relictum*) and avian poxvirus (*Avipoxvirus* sp.), which are known to cause mortality of many species of Hawaiian forest birds, including `Elepaio (Warner 1968, van Riper et al. 1986, Atkinson et al. 1995, VanderWerf 1998). Goff and van Riper (1980) found that on the island of Hawai`i the abundance of *Culex* mosquito larvae varied seasonally with rainfall, and that in some areas larvae were present only after heavy rains. Likewise, the abundance of mosquitoes on O`ahu may be higher or may peak more often in areas with higher rainfall, possibly leading to more frequent outbreaks of disease and more rapid declines in native bird populations. Most remaining O`ahu `Elepaio occur in mesic areas of the Wai`anae Mountains and on the drier leeward side of the Ko`olau Mountains.

In summary, the range of the Oahu `Elepaio has declined by 96% since humans arrived in Hawai`i, by 75% in the last 25 yr, and continues to decline. The total population is small, the breeding population is even smaller, the distribution is highly fragmented, and most subpopulations are isolated. Management is urgently needed to prevent further declines and to begin recovery. The three primary threats to the O`ahu `Elepaio are habitat loss, nest predation by introduced black rats, and diseases carried by introduced mosquitoes (VanderWerf 1998). Protection of forest habitat on O`ahu is essential for the continued survival of `Elepaio. Rodent control programs have been started in several areas and have been successful at increasing nest success of `Elepaio (VanderWerf, in press), but should be expanded to protect more birds. Investigation of the genetic basis for possible disease resistance and identification of resistant individuals would be extremely valuable, and would greatly enhance the value of captive breeding as a recovery strategy.

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