DISTRIBUTION AND ABUNDANCE PATTERNS OF THE PALILA ON MAUNA KEA, HAWAII

CHARLES VAN RIPER, III,[1,4] J. MICHAEL SCOTT,[2] AND DAVID M. WOODSIDE[3]

[1]Department of Zoology, University of Hawaii, Honolulu, Hawaii 96822 USA, [2]Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service, P.O. Box 44, Hawaii Volcanoes National Park, Hawaii 96718 USA, and [3]Hawaii Department of Land and Natural Resources, 1151 Punchbowl Street, Honolulu, Hawaii 96813 USA

ABSTRACT.—Censuses of the known geographical range of the rare and endangered Palila were conducted in January (nonbreeding season) and September (breeding season) 1975. The habitat (mamane and naio forest of Mauna Kea, Hawaii) was divided into five major areas, with each analyzed for vegetational composition, phenology of the predominant tree species, and Palila density. Using a line transect census technique, we determined that: 1) the Palila occupied 5,560 ha, approximately 10% of its former range; 2) Palila populations were more restricted in the nonbreeding season, possibly reflecting their flocking tendency; 3) Palila densities were 38 birds per km^2 in the breeding season and 36 birds per km^2 in the nonbreeding season; 4) Palila population movements were small, and apparently were correlated with patterns of food availability; and 5) all methods of analysis yielded a projected population of approximately 1,600 birds. These low numbers, coupled with its restricted range, make the Palila one of the most vulnerable endangered species. *Received 10 May 1977, accepted 16 November 1977.*

THE Palila (*Psittirostra bailleui*) is a finch-billed member of the endemic Hawaiian honeycreeper family Drepanididae, and is presently considered rare and endangered. We have extrapolated the pre-19th century distribution from analysis of specimens in museums and literature references (Fig. 1). Historically, its range included the mamane (*Sophora chrysophylla*) and mamane-naio (*Myoporum sandwicense*) ecosystems of Mauna Kea, Hualalai, as well as the southwestern slope of Mauna Loa. Mamane fruit is the primary food source of the Palila, although there are no records of the bird occurring in the mamane forest on the eastern slope of Mauna Loa. It was apparently limited to the upper forest regions, as Perkins (1903) found it only from 1,220 to 1,830 m on Hualalai. Wilson and Evans (1890-1899) also reported it as being confined to the upland districts of Hualalai and Mauna Kea.

Palila range has been greatly reduced since the turn of the century. Perkins noted indications of its decline when he reported that in Kona in August 1894 he saw only two males, whereas in 1892 he had observed it "in numbers" (Munro 1960). This was apparently the last recorded sighting of a Palila in this area. The species was found to be locally common in 1943, 1948–49, and 1950 between 2,360 and 2,530 m on the western and northeastern slopes of Mauna Kea (Richards and Baldwin 1953). The last recorded sighting of a bird on the northern slope of Mauna Kea is that of Walker (1968), who observed three individuals above Puu Mali. Berger (1972) found the Palila on Mauna Kea common from 2,135 m to nearly tree line, rarely descending as low as 1,980 m.

Despite a much wider distribution in the past, all information available indicates that today the Palila is found only in parts of the mamane and naio ecosystems of Mauna Kea. In order to document the distribution and abundance of the species, censuses of its entire known geographical range were conducted during January 1975 (nonbreeding season) and again during September 1975 (breeding season).

---

[4] Present address: Cooperative National Park Resources Studies Unit, P.O. Box 54, Hawaii Volcanoes National Park, Hawaii 96718 USA.

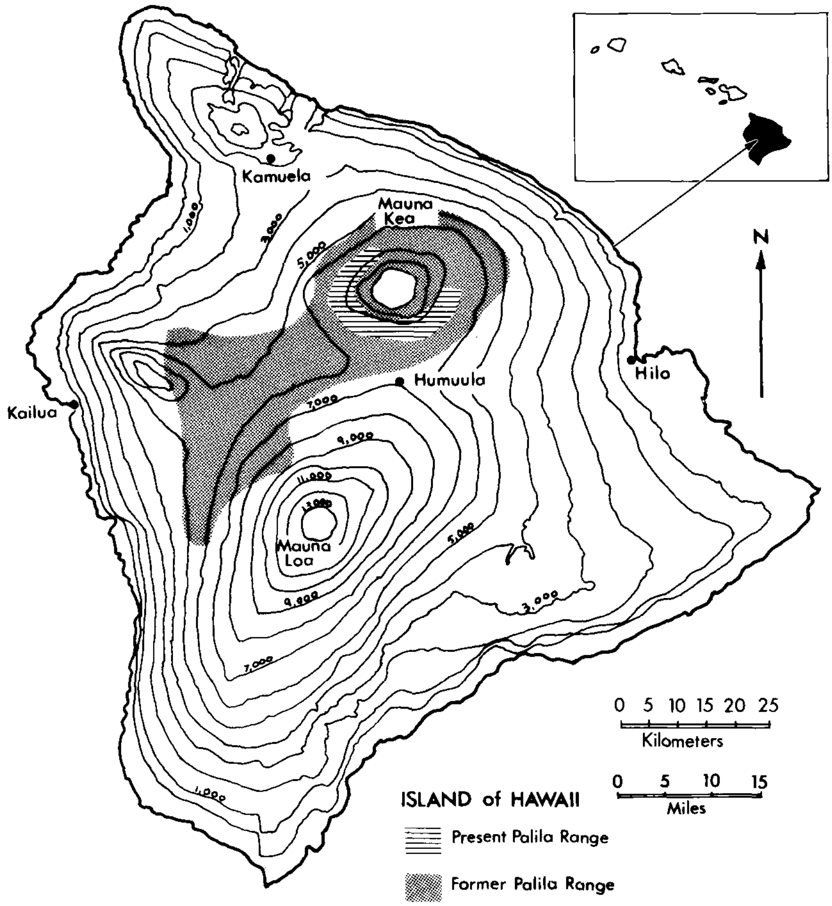


Fig. 1. Map of Hawaii indicating historical range and present distribution of the Palila.

METHODS

Seventeen people representing the Hawaii State Forestry and Fish and Game divisions, U.S. Fish and Wildlife and Forest services, and University of Hawaii participated in two 5-day censuses. The non-breeding season census was conducted from 13–17 January 1975, while the breeding season count was made from 15–19 September 1975. Five repeat censuses involving five observers were conducted from 22–26 September to confirm the reliability of the census technique. Total counts were made in the 80-ha enclosure at Puu Laau utilizing 16 observers on 17 and 23 September 1975. Information was gathered on Palila population numbers and density, geographical range and movements within the range, as well as vegetational phenology (flowering and fruiting densities) of mamane and naio in September.

All the high mamane and naio forest on Mauna Kea was studied, with most of the transects being within the fence-line of the Mauna Kea Game Management District. Natural features such as roads, gulches, and areas lacking trees were used to divide the mountain into five survey sections (Fig. 2). Section One was further divided into two smaller units for the first census and into three on the second (Puu Nanaha to Kemole was covered only on the first count). Within this section the Palila was censused from tree line at 2,815 m to 2,195 m on Parker Ranch. Sections Three, Four, and Five were all covered on a single day in each survey, as each contained only a small relict of mamane forest.

Sections were divided into transects along either 60 or 30 m contours, except for the eight transects from Puu Laau to Puu O Kauha, which were run from high to low elevations during the first census. Elevations were initially measured in feet and the numbers later converted to meters and rounded. Observers used altimeters, topographic maps, and compasses to maintain correct contours. Each section

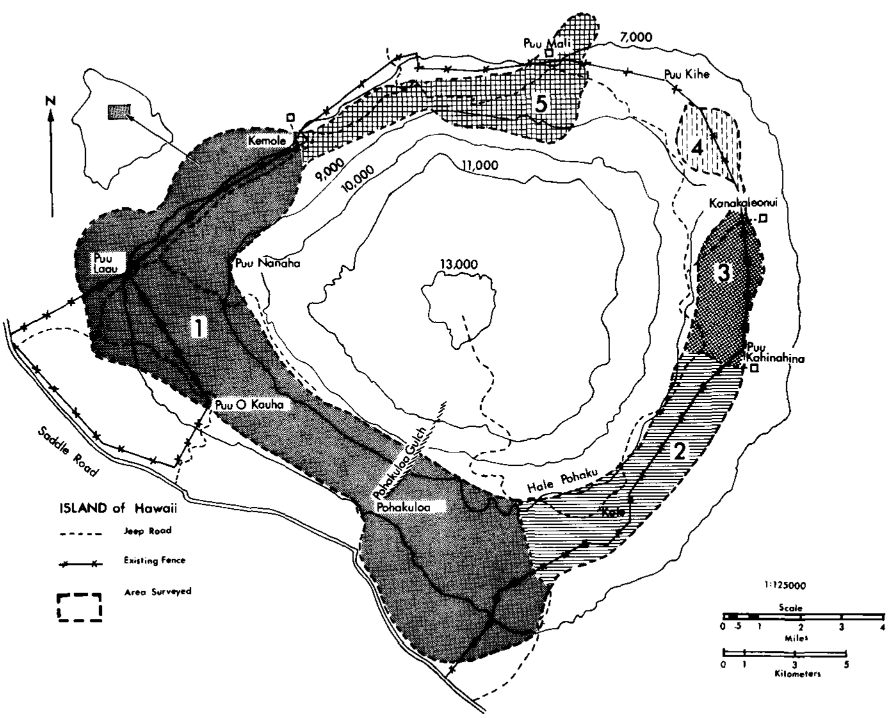


Fig. 2. Map of Mauna Kea, Hawaii indicating sections censused.

was walked from one end to the other, except Section Two during the second census. During this count, observers started simultaneously from a mid-line point on each transect, and walked both directions to respective edges of the forest. The change in technique was to reduce possible bias in the data, as during the first count observations extended well into the afternoon. All other censusing was done during the first 4 h after sunrise, when birds were most conspicuous.

The initial day of each census period was spent refamiliarizing participants with the Palila, and the remainder of the week censusing different forested areas. Each observer walked at slow speeds and recorded age, sex, and social grouping. To minimize double registrations, time of the observation along with direction of flight was recorded. Besides observations of Palila, all endangered species were noted.

Observations made by each observer were recorded as audio when a bird was heard but not seen, audio-visual when it was heard first then seen, or visual if observed first. No "squeaking" or other sounds were used to lure birds. The right angle distance of the sighting from the transect line was determined with a rangefinder or by pacing. Occurrences of the three observational types were plotted against the 276 distance observations for which detection type was noted. This indicated that Palila were detected by audio (or audio-visual) and visual stimuli in approximately equal numbers at distances up to 25 m. However, as the distance from observer increased beyond 25 m there was an increasing reliance on audio stimuli; observations beyond 37 m were almost entirely the result of aural detection. Screening effect of the mamane canopy was probably responsible for the sharp decline in visual detections at greater distances.

The effective area surveyed on each side of the observer was determined by pooling all sightings and finding that distance where the number of sightings first decreased dramatically (Emlen 1971). It was 15 m for the first count and 6 m for the second. This gave a coefficient of detectability (Emlen 1971) for the Palila of 0.21 during the nonbreeding season (January) and 0.11 during the breeding season (September). These detectability values are relatively low, and reflect the quietness of the species and its habit of remaining within the canopy. Palila appeared to vocalize and fly less frequently during the breeding season, and thus we found the difference in distribution of observational distances between the two censuses highly significant ($\chi^2 = 38.7$; df = 10; $P < 0.005$).

Density and total numbers of Palila were determined for each section using the following formulas:

$$D = P/A$$
$$T_j = D \cdot O$$

where D = density of Palila; T_j = total number of Palila; P = number of Palila tallied within effective detection area; A = hectares surveyed within effective detection area; and O = number of hectares bounded by Palila observations (effective habitat).

The effective detection area was calculated for each section using the formula:

$$A = M \cdot L \cdot C$$

where L = total length of all transects bounded by outermost Palila sightings; C = subjectively derived correction factor of either 1.1 or 1.2 for deviation from transect due to roughness of terrain; and M = maximum probable detectability distance from the transect (January = 15 m, September = 6 m) multiplied by 2.

Population and density estimates were developed for each survey using:

$$T = \sum_{j=0}^{n} T_j$$

$$D = T/O$$

where T = total number of Palila; D = density of Palila; O = number of hectares bounded by Palila observations; and j = section number.

In order to measure discontinuity of Palila distribution, a clear acetate sheet marked off into 1 km^2 grids was laid over a topographic map (scale 1:24,000) of Mauna Kea on which the distribution of all sightings had been plotted. The number of grids occupied by birds was recorded for each census period. Although the number of Palila and their conspicuousness were quite different in the two seasons, we believe the intensity of the census effort and the level of resolution used (1-km^2 grids; presence or absence of Palila) permitted analysis of clumped distribution.

In order to determine the reliability of the census techniques, five transects in an area within Section One were replicated during each of 5 days from 22–26 September 1975. These transects were chosen because they were located where Palila were observed during both count periods. They were censused by the same observer (with one exception), at the same time of day, and under uniform weather conditions. All species of birds were recorded. The variation around our first day estimated mean was reduced 38.4% on the second day, and 51.5% on the fifth. Therefore, very little would have geen gained in terms of accuracy of our estimate by increasing the sample size five-fold.

Two total counts of the Palila were done as an additional check on the census technique. On 17 and 23 September 1975, 16 observers spaced 6 m apart made two complete sweeps of the 80-ha enclosure at Puu Laau. Two-way radios and direct vocal communication were used to keep the line straight and to avoid double registrations. To further avoid counting the same bird twice, Palila that flew in front of an observer were not counted unless they were seen to fly out of the enclosure. During the two counts 90 and 74 Palila were observed, giving a projected density of 113 and 93 birds per km^2. The transect censuses yielded an estimate of 93 birds in the enclosure. This was only 12% more than the average of 82 birds from both total counts. Given that Palila move freely in and out of the enclosure, the relatively close agreement of the two estimates suggests that the strip census technique does provide a reliable estimate of Palila numbers.

Phenological data on mamane trees were gathered during the second major census, and during repeated counts in Section One. Each observer measured the amount of flowering and percentage of green pods present for the first 20 mamane trees along his route, and then 20 more every subsequent 90 min until the transect ended. Similar information was gathered on the first 20 naio trees of each transect. A value of 5 was assigned when 1–5% of the total tree was flowering or fruiting, a value of 10 when 5–25%, or a 15 when >25% of the tree was blooming or had fruit (van Riper 1975). Data taken on repeated counts showed that the original information from Section One was repeatable. Values established by repeated counts were 0.17% for mamane green pod frequency and 0.24% for bloom; during the earlier census the values were 0.41% for pods and 0.25% for mamane bloom.

Results and Discussion

Population estimate.—During the January census (Table 1), 597 km of transect were walked and 2,185 ha surveyed. The outermost transects recording Palila

TABLE 1. Summary data of sections censused for Palila during January and September

	Sections (j)					
	1	2	3	4	5	Total
Hectares in section	9,596	3,292	394	354	2,424	16,060
Hectares surveyed						
January	937	768	38	55	387	2,185
September	464	153	23	20	55	715
Number of observers						
January	17	17	4	4	5	17
September	17	16	5	4	6	17
Birds observed						
January	212	76	19	0	0	307
September	128	47	1	1	0	177
Birds visually confirmed						
January	183	56	13	0	0	252
September	98	41	1	1	0	141
Birds within detection distance (P)						
January	119	47	2	0	0	168
September	55	24	0	1	0	80
Hectares surveyed in detection area (A)						
January	286	234	12	0	0	532
September	148	49	0	7	0	204
Hectares in effective habitat (O)						
January	3,323	736	394	0	0	4,453
September	4,275	691	0	85	0	5,051
Mean density of birds per km^2 (D)						
January	42	20	17	0	0	36
September	37	49	0	14	0	38
Estimated population (T)						
January	1,382	146	67	0	0	1,595
September	1,590	338	0	12	0	1,940

bounded approximately 4,453 ha, which was 20.4% of all forest on the mountain. Palila were not found on the north slope of Mauna Kea in the area extending from above Puu Laau past Kemole and Puu Mali to Kanakaleonui; they were found in three disjunct areas on the south and southeast slopes. A total of 307 Palila was observed during the census, 252 of these being visually confirmed. The Palila population during this period was estimated at about 1,595 (95% Confidence Interval = 1,146–2,049) birds using a mean density of 36 birds per km^2.

During the September census 586 km of transect were walked and 715 ha surveyed (Table 1). One hundred seventy-seven Palila were observed, of which 141 were visually confirmed. Again Palila were not found on the north slope of Mauna Kea; they were, however, present in four disjunct areas on the south and southeast slopes. The population during this period was estimated to be 1,940 (95% CI = 1,643–2,237) birds using a mean density of 38 Palila per km^2.

A second method of projecting population numbers was done by considering each daily census as an estimation of Palila density. This technique estimated a Palila population during the breeding season of 1,251 (95% CI = 789–1,713), and during the nonbreeding season 1,614 (95% CI = 1,057–2,171). The two population estimates from both seasons indicated that there were approximately 1,600 birds on the mountain.

TABLE 2. Abundance of all bird species on transect at 2,380 meters elevation between Puu O Kauha and approximately 1.6 kilometers north of Puu Laau cabin[a]

Species	Birds per km²
Amakihi (*Loxops virens*)	180
Elepaio (*Chasiempis sandwichensis*)	76
Palila (*Psittirostra bailleui*)	27
Japanese White-eye (*Zosterops japonica*)	26
European Skylark (*Alauda arvensis*)	23
Red-billed Leiothrix (*Leiothrix lutea*)	17
House Finch (*Carpodacus mexicanus*)	14
Golden Plover (*Pluvialis dominica*)	8
Apapane (*Himatione sanguinea*)	3
Akiapolaau(*Hemignathus wilsoni*)	2
Creeper (*Loxops maculata*)[b]	1.2
Melodious Laughing-thrush (*Garrulax canorus*)	0.8
Turkey (*Meleagris gallopavo*)[c]	
California Quail (*Lophortyx californicus*)[c]	
Cardinal (*Cardinalis cardinalis*)[d]	
Short-eared Owl (*Asio flammeus*)[d]	

[a] Birds were censused on 17, 23, 25, and 26 September; Akiapolaau was censused also on 24 September
[b] Estimates based on total counts of 80-ha enclosure
[c] Observed in flocks therefore no estimate was made
[d] Observed in low numbers in vicinity of Puu Laau cabin

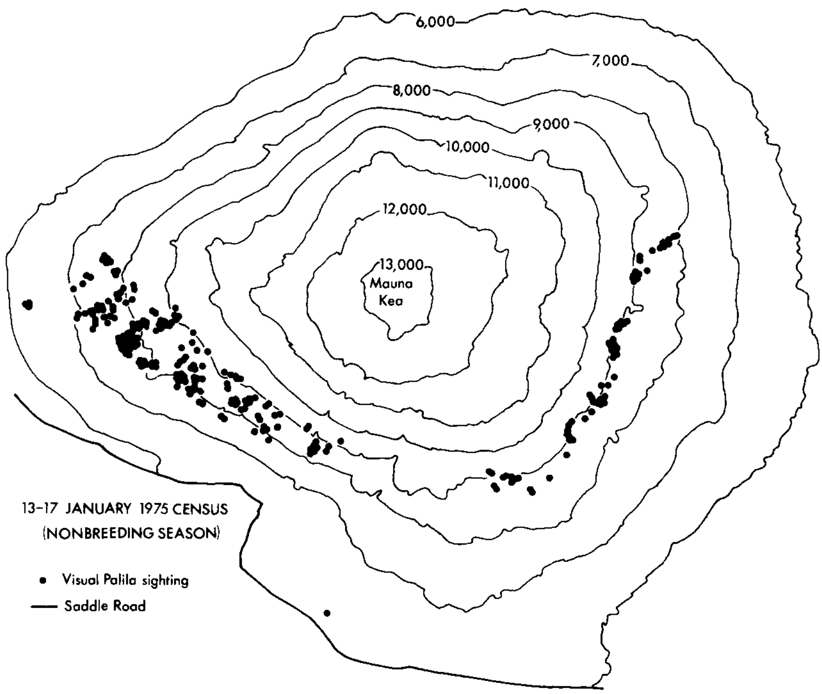
It is possible that the larger mean estimate during the September census may have actually reflected greater numbers during that period, rather than simple variation around the mean. We sampled in the latter part of the breeding season when young were present in greatest numbers. Highest mortality is to young of the year, and this might account for the reduced number of birds recorded in January. However, the variances of our estimates are too large to draw any conclusions.

Population density.—Estimated Palila densities varied seasonally and between sections (Table 1). Densities doubled in Section Two from January to September, due in part perhaps to an influx of birds from Section Three. The higher population estimate in September resulted from slightly greater densities and a larger distributional area.

All density estimates for Palila were less than has been recorded for most native passerine species in other suitable habitat on Hawaii. Recent studies have shown that Apapane (*Himatione sanguinea*) densities frequently exceed 1,000 birds per km² in its best habitat (Conant 1975, pers. observ.). Densities of the rarer species (e.g. Akiapolaau *Hemignathus wilsoni*, Creeper *Loxops maculata*, and Akepa *Loxops coccinea*) are usually less than 50 birds per km². Akiapolaau densities determined by Conant were 35 birds per km². Palila densities of 36–38 birds per km² are generally less than other native birds. However, Palila had the fourth highest density of 16 species found in the Puu Laau area of Mauna Kea (Table 2). Historically, Palila probably had much higher densities, but it is unknown what these densities may have been.

Geographical range.—Range, defined as that area bounded by a line connecting the outermost sightings, encompassed 4,453 ha in January and 5,051 ha in September. There was a large overlap between counts, and a combined total range of about 5,560 ha. Interseasonal range differences appeared to be the result of the population dispersing for breeding, as the total elevational range was 915 m in the breeding season compared to 365 m in the nonbreeding season (Fig. 3).

A breeding season dispersal was supported by data on the number of 1-km² grids occupied by birds in Sections One and Two during each census. In the breeding



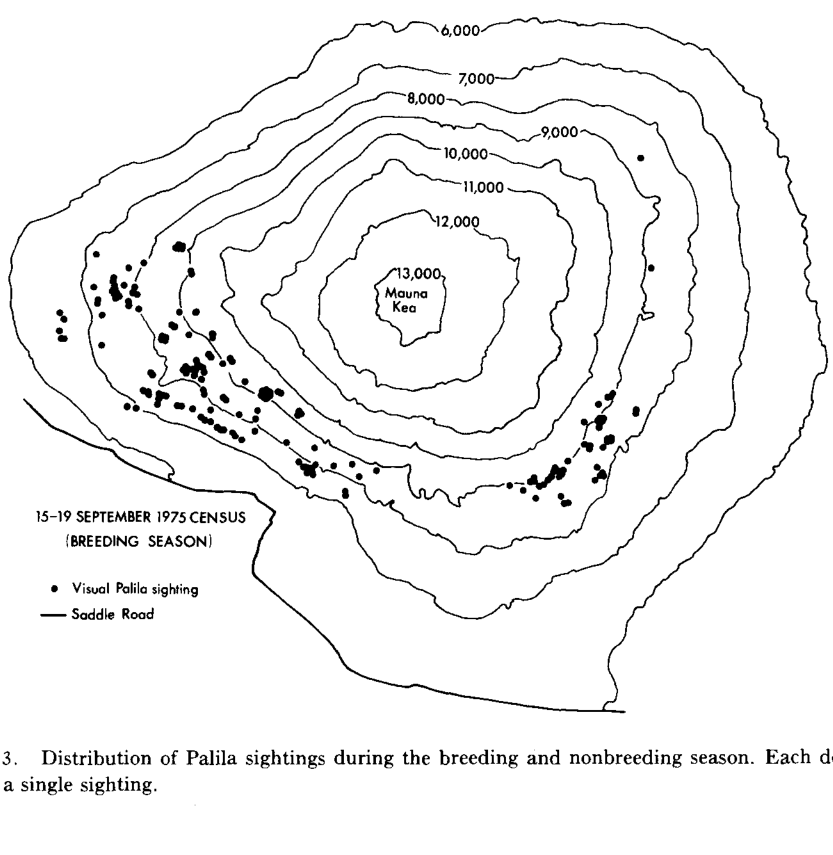


Fig. 3. Distribution of Palila sightings during the breeding and nonbreeding season. Each dot represents a single sighting.

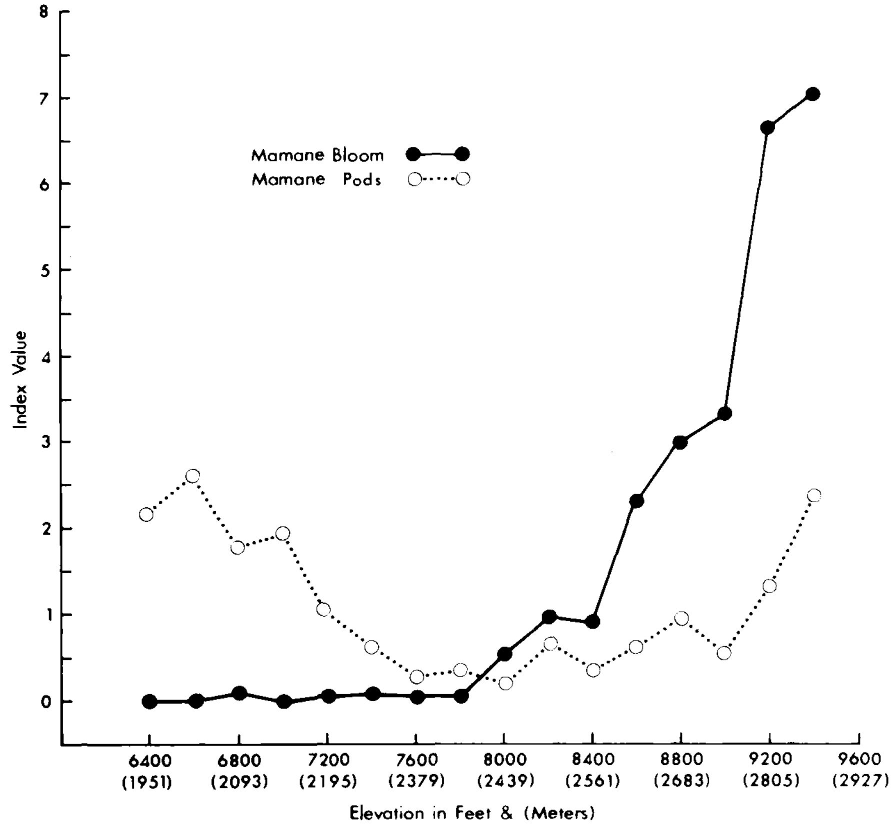


Fig. 4. Phenological data of mamane flowering and fruiting taken 17 and 19 September 1975 in Section One from Puu Laau to Pohakuloa Gulch, Hawaii.

season 50% (61 of 121) of the 1-km^2 grids censused contained Palila, while 30% (44 of 148) contained birds in the nonbreeding season. This may reflect larger home ranges during the breeding season, but data are not available to substantiate this. Information on the sizes of social groups also supported the idea that Palila distribution was clumped during the nonbreeding season (Table 3). Group size was significantly larger in the nonbreeding season ($\chi^2 = 14.9$; df $= 5$; $P < 0.025$).

Influence of vegetation on Palila distribution.—During the January census we noticed a similarity between Palila densities and mamane phenology patterns. We thus compiled data on flowering and fruiting of mamane and naio during the September count (Fig. 4). Mamane bloom was limited to higher elevations, and while Palila were found at tree line, flowering did not appear to have as much of an

TABLE 3. Palila social groups (visually confirmed) in the breeding and nonbreeding censuses

	Size of social group										
Season	1	2	3	4	5	6	7	8	Total	$\bar{X}$	SD
Breeding	139	34	8	3	1	0	0	0	185	1.34	0.69
Nonbreeding	64	18	12	7	2	0	0	1	104	1.75	1.21

influence on the distribution of birds as did pod abundance. Mid-elevational ranges on Mauna Kea (2,255–2,440 m) had low mamane pod numbers during September, and this was where we recorded lowest Palila densities. Trees in the lower forest were in peak production, and this may be why birds were found at lower elevations during this census. Also, a large population shift occurred between February and June in Section One, apparently in response to the shifting of green mamane pod concentrations (pers. observ.).

The influence of naio on Palila distribution is still not very clear. Perch trees (25 naio, 67 mamane) were recorded in Section One, and birds showed no preference between species ($\chi^2 = 1.24$; df = 1; $P = 0.26$). Palila did show a tendency to perch in naio with berries when only naio were considered as possible perch sites ($\chi^2 = 7.29$; df = 1; $P < 0.01$). The preference for naio trees with berries may indicate that Palila were foraging on these fruits or associated insects.

Palila were apparently also influenced by forest composition in that birds were usually found in stands of large mamane. For example, in Sections Three and Four birds were only at the highest elevations, where the greatest number of large trees were found. In Pohakuloa Flats (Section One) only one bird was recorded, and there were many young but few large trees. No birds were recorded in Section Five (Puu Mali) which had large but widely scattered trees that possibly were not abundant enough for permanent Palila habitation.

During both censuses Palila were recorded at tree line. In Section Three and Four birds were found only above 2,500 m. In Section Two (January), we found the greatest numbers and highest densities at elevations near tree line. No birds were recorded below 2,620 m, and density increased with increasing elevation until 2,775 m. The reason may be that there are a proportionately greater number of large trees at higher elevations (van Riper 1975), and larger trees produce more pods.

During both censuses Palila range was within the mamane forest of Mauna Kea, and birds were usually found only in areas with large mamane trees. Palila occupied about 25% of the 21,860 ha of forest, which gives it the most restricted geographical range of any native passerine on Hawaii. Low population numbers, restricted range, and in particular a dependency upon a single vegetation type make the Palila one of the most vulnerable endangered species today.

ACKNOWLEDGMENTS

This study could not have been completed without the help and cooperation of various observers who spent long and arduous hours in the field. In addition to ourselves the individuals who participated in the Palila count are listed below, with those who participated in both censuses indicated by an asterisk: Ronald Bachman, David Fellows, Harry Fergestrom*, Jon Giffin*, Samuel Kamelamela, Ernest Kosaka, Eugene Kridler*, Kiyoshi Kubo, Howard Horiuchi, Steven Montgomery, Miles Nakahara, Lawrence Pank, Joseph Olival, Howard Sakai*, Nelson Santos*, Paul Scowcroft*, John Sincock, Thomas Telfer, Charles Wakida*, Ralph Saito, and Ronald Walker. The following agencies provided manpower and other assistence during the counts: U.S. Fish and Wildlife Service, Hawaii Division of Fish and Game, Hawaii Division of Forestry, and U.S. Forest Service. We thank P. H. Baldwin, J. T. Emlen, O. Järvinen, P. Scowcroft, and J. Sincock for their comments on the manuscript. We are also indebted to Sandra van Riper for her care in editing and comments upon the paper, and to Susan Monden for preparing illustrations. The first author was supported by the Frank M. Chapman Memorial Fund of the American Museum of Natural History, U.S. Fish and Wildlife Service, and World Wildlife Fund Grant US-35 during field phases of this study, and by a National Park Service Contract No. 8000 7 0009 during preparation of the manuscript.

Literature Cited

Berger, A. J. 1972. Hawaiian birdlife. Honolulu, Univ. Press Hawaii.

Conant, S. 1975. Spatial distribution of bird species on the east flank of Mauna Loa. IBP Island Ecosystems IRP Tech. Rep. No. 74.

Emlen, J. T. 1971. Population densities of birds derived from transect counts. Auk 88: 323–342.

Munro, G. C. 1960. Birds of Hawaii. Rutland, Vermont, Chas. E. Tuttle Co., Inc.

Perkins, R. C. L. 1903. Vertebrata (Aves). Pp. 368–465 *in* Fauna Hawaiiensis, vol. 1, part 4. (David Sharp, Ed.). Cambridge, England, The Univ. Press.

Richards, L. P., & P. H. Baldwin. 1953. Recent records of some Hawaiian honeycreepers. Condor 55: 221–222.

van Riper, C., III. 1975. Composition and phenology of the dry forest on Mauna Kea, Hawaii, as related to the annual cycle of the Amakihi (*Loxops virens*) and Palila (*Psittirostra bailleui*). IBP Island Ecosystems IRP Tech. Rep. No. 51.

Walker, R. L. 1968. Field notes from Ronald L. Walker, February 12, 1968: Mauna Kea, Hawaii. Elepaio 28: 98–99.

Wilson, S. B., & A. H. Evans. 1890–1899. Aves Hawaiienses: The birds of the Sandwich Islands. London, R. H. Porter.

A Checklist of the Birds of Afghanistan, containing a comprehensive review of the status, distribution and ecology of the birds of Afghanistan is currently being prepared by M. Beaman, S. C. Madge, and C. Waller. The authors would appreciate receiving any unpublished records or other suitable material for inclusion in the work. These should be sent to **Mr. S. C. Madge, Springholme, 2, Caudle Hill, Fairburn, nr. Knottingley, W. Yorkshire, England.** Contributions will of course be fully acknowledged.

The winner of the first annual **Hawk Mountain Research Award** was James C. Bednarz of Iowa State University, for his study "Status and habitat utilization of the Red-shouldered Hawk in Iowa."

The Board of Directors of Hawk Mountain Sanctuary Association announces its second annual award of $250 for support of raptor research. The Hawk Mountain Research Award is granted annually to a student engaged in research on raptors (Falconiformes). To apply, students should submit a description of their research program, a curriculum vitae, and two letters of recommendation by 31 October 1978 to: **Mr. Alex Nagy, Hawk Mountain Sanctuary Association, Route 2, Kempton, Pennsylvania 19529.** A final decision will be made by the Board of Directors in February 1979.

Only undergraduate and graduate students enrolled in a degree granting institution are eligible. Projects will be judged competitively on the basis of their potential contribution to improved understanding of raptor biology and their ultimate relevance to conservation of North American hawk populations.