

AGE AND SEX IDENTIFICATION OF AKOHEKOHE

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Abstract.—We present methods to determine the age and sex of Akohekohe (*Palmeria dolei*), an endangered Hawaiian honeycreeper, developed on the basis of 45 museum specimens and 91 live birds captured on the island of Maui. Akohekohe retained all juvenal primaries, some juvenal secondaries, and some body feathers after the first prebasic molt; they attained full adult plumage after the second prebasic molt. Retention of brown juvenal body feathers, especially on the head, distinguished most birds in the first basic plumage from adults, which have a full complement of distinctive, black lanceolate body feathers with white, gray, or orange tips. Male Akohekohe were heavier than females and had longer wing, tail, and tarsometatarsus lengths. We present a linear discriminant function to sex both adults and juveniles using lengths of their wing and tarsometatarsus.

IDENTIFICACIÓN DE EDAD Y SEXO EN *PALMERIA DOLEI*

Sinopsis.—Presentamos métodos desarrollados en base de 45 especímenes de museo y 91 aves vivas capturadas en la isla de Maui para determinar la edad y el sexo de *Palmeria dolei*, una especie en peligro de extinción en Hawaii. Estos individuos retuvieron todas las primarias juveniles, algunas secundarias juveniles, y algunas plumas del cuerpo después de la primera muda prebásica; obtuvieron plumaje adulto después de la segunda muda prebásica. La retención de plumas corpóreas juveniles color marrón, especialmente en la cabeza, distinguió a la mayoría de las aves en la primera muda prebásica de los adultos, que tienen un complemento completo de plumas corpóreas negras lanceoladas con las puntas blancas, grises o anaranjadas. Los machos de la especie pesaron más que las hembras y tenían alas, colas y tarsometatarsos más largos. Presentamos una función lineal de discriminación para determinar sexo tanto de adultos como de juveniles utilizando los largos de sus alas y de sus tarsometatarsos.

The Akohekohe (*Palmeria dolei*) is an endangered Hawaiian honeycreeper (Fringillidae: Drepanidinae) endemic to the high elevation wet forests of east Maui Island, Hawaii. Formerly found on the neighboring island of Molokai (Perkins 1903), the current population of approximately 3800 individuals (Scott et al. 1986) is now restricted to a thin band of native ohia (*Metrosideros polymorpha*) forest between 1500 and 2200 m elevation on the north and east slopes of Haleakala volcano. The adult Akohekohe, with its unique forehead crest and distinctive black, white, orange and gray plumage, is easily identified as it moves rapidly over the expansive canopy in search of nectar.

As part of a larger study on Akohekohe ecology, we captured, banded, and described the morphometric and plumage characteristics of 91 live birds. Combining these data with those obtained from 45 museum spec-

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imens, we developed the criteria for aging and sexing necessary for the meaningful interpretation of demographic and behavioral information.

METHODS

We recorded plumage characteristics and external measurements for 45 *Akohekohe* museum specimens collected between 1892 and 1901 from Molokai and Maui; 23 located at the American Museum of Natural History, 11 at the British Museum of Natural History, 9 at the Bernice P. Bishop Museum, Hawaii, and 2 from the Liverpool Museum. We assumed all specimens sexed by examination of their gonads during preparation were correctly sexed and labeled, resulting in a total of 2 juvenile and 5 adult females, and 12 juvenile and 14 adult males having both wing and tarsus measurements necessary for our sexing analyses.

Additional data were gathered from birds captured in mist nets from 1994–1997 in the Waikamoi Preserve (managed by The Nature Conservancy of Hawaii; $n = 2$) or the Hanawi Natural Area Reserve (NAR, State of Hawaii; $n = 89$) on Maui. Banding effort was biased toward the summer months when birds came to understory flowers and were more easily netted, but we did not give preference to individuals of a specific age class. Individuals were given a unique color band combination and sexed by the presence of a brood patch (one juvenile and six adult females) or swollen cloacal protruberance (one adult male), or by subsequent nesting behavior (four juvenile and six adult females; six juvenile and nine adult males). We assumed that only the female incubates eggs and broods nestlings, whereas males feed females on or near the nest—an assumption supported by studies of other Hawaiian honeycreepers (Eddinger 1970, Pletschet and Kelly 1990, Morin 1992, Kepler et al. 1996).

For each bird, we measured the wing chord (WING) to the nearest millimeter using a metal rule with stop, from the bend to the tip of the longest primary of the unflattened, folded wing. CULMEN length (from the anterior edge of the external nasal opening to bill tip) was measured with digital calipers to the nearest 0.1 mm, as the forehead crest prevented exposed culmen measurements. Tarsometatarsus length (TARSUS) was measured from the intertarsal joint to the distal end of the last leg scale with digital calipers to the nearest 0.1 mm, and tail length (TAIL) was measured to the nearest millimeter by inserting a plastic rule between the central rectrices and pressing it firmly against the point of insertion of the feathers. For live birds, MASS was recorded to the nearest gram using a 50-g spring balance scale. Our numbering system for primaries and secondaries followed that in Pyle et al. (1987).

We used plumage characteristics to assign an age class of juvenile or adult to 44 of 45 museum specimens and 84 of 91 live birds. For the purposes of this paper, juveniles were defined as those with at least some yellowish brown, unmodified juvenal feathering. Timing of molt was determined from the 44 museum specimens and 90 live individuals (including 12 recaptures) having both capture month and molt information. All measurements (except MASS) and plumage descriptions were recorded

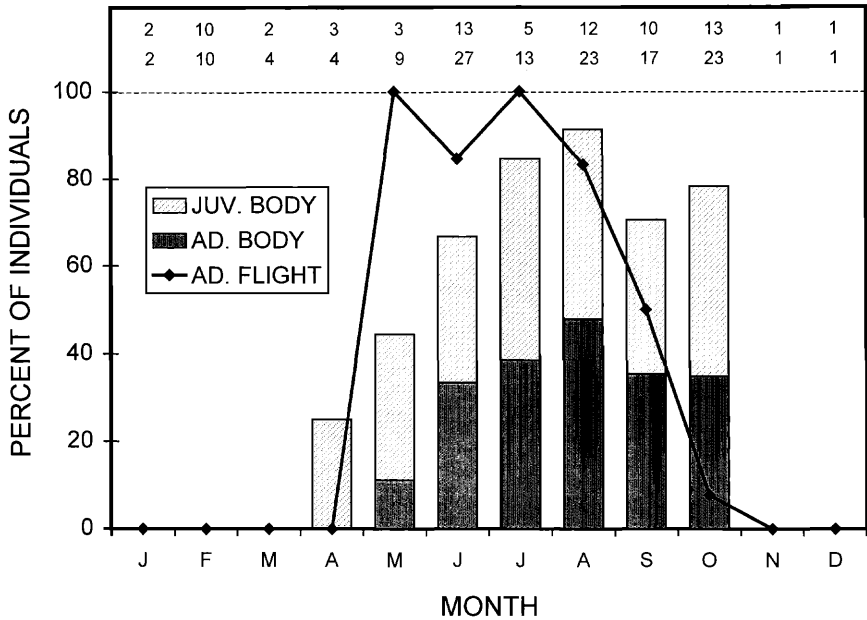


FIGURE 1. Timing of molt in Akohekohe determined from museum specimens and live birds caught in mist nets on Maui. Top row of numbers shows sample sizes for adults (flight molt), bottom row shows sample sizes for both age classes (body molt).

for museum specimens by TKP or by P. Baker, an experienced bird bander, as instructed by TKP.

We used SAS statistical software to perform *t*-tests on body measurements to compare museum specimens and live birds, males and females, and juvenile and adult age classes. For both age classes, we used stepwise discriminant analyses to determine the best set of variables for sexing Akohekohe, and classed each individual by sex using linear discriminant functions (SAS 1987). To produce unbiased error rates, we classified individuals by a jackknife procedure (i.e., each discriminant function was computed from the other observations in the data set, excluding the observation being classified; SAS 1987).

RESULTS

Age determination.—Based on the examination of our study birds, we were able to make several generalizations concerning molt and plumage characteristics.

Akohekohe undergo a single annual molt during the months of April through (at least) October (Fig. 1), following or partially overlapping a breeding season that extends from November–June (Biological Resources Division, unpubl. data). During the first prebasic molt, juveniles retain most flight feathers. In addition, some juvenal body feathers are usually

retained, especially on the head, which allows juvenal and first basic plumage to be distinguished from definitive (adult) plumage. Birds in the later stages of their second prebasic molt retaining no juvenal body plumage cannot be distinguished from birds in adult prebasic plumage or adult prebasic molt and should, therefore, be classified as adults.

The juvenal plumage of Akohekohe is characterized by solid dark gray flight feathers, dusky gray plumage on the back and breast, lighter gray and buff belly, vent, and face, light or pale brown crown, nape, and eye ring, uniform gray or off-white epaulets, and a relatively short, light buff crest. The mostly dark gray or black bill may contain some dull orange coloration. During their first prebasic molt, Akohekohe attain most of the black or spangled lanceolate body feathers of the adult, but maintain some juvenal body feathers, and most dark-tipped flight feathers. Where replaced, terminal ends of new tertials (secondaries 7–9), secondaries, and rectrices are usually white-tipped from 1–5 mm. Primaries are probably not replaced during this molt. After the complete second prebasic molt, body plumage, except for lower belly and vent area, is lanceolate with white, gray or orange tips, epaulets have a distinct white-over-orange pattern, eye ring and thighs are dull orange, and the feathers of the nape are mostly bright orange. All secondaries and rectrices, and often some primaries, are typically white-tipped, and all lesser and greater coverts have tips of white, dull orange, or a combination of both. The crest is mostly white or off-white, but may have a dull yellow cast (possibly from an accumulation of pollen), and the bill is completely black.

Based on evidence from live birds undergoing molt and from several recaptured individuals, it appears that some birds may replace a dark-tipped primary with a new, dark-tipped primary. In addition, heavily worn primaries and rectrices may lose their white tips and appear dark-tipped.

Sex determination.—We found no reliable means to sex Akohekohe from plumage or soft parts. Although male museum specimens had smaller TARSUS measurements than live males ($t = 2.84$, $P = 0.007$), combining these data sets did not meaningfully alter the discriminant function used for sexing. All body measurements of adult males were significantly larger than those of adult females (Table 1), and most individuals were accurately sexed using WING and TARSUS values.

The following discriminant function correctly sexed 24 of 24 (100%) adult males and 12 of 13 (92%) adult females:

$$D = 1.03 (\text{WING}) + 2.59 (\text{TARSUS}) - 171.00 \quad (1)$$

where D is the discriminant score for an individual (Fig. 2a). Akohekohe with negative values should be classified as females, and those with positive values should be classified as males.

Juvenile female measurements did not differ significantly from those of adult females (WING, $t = 0.75$, $P = 0.459$; TARSUS, $t = 0.52$, $P = 0.608$). Juvenile males, however, were significantly smaller than adult males (WING, $t = 4.79$, $P < 0.001$; TARSUS, $t = 2.82$, $P = 0.007$). While juvenile males were also significantly larger than juvenile females (Table

TABLE 1. Comparative linear measurements (mm) and mass (g) of Akohekohe. Mass values are for live birds only.

	Males			Females			t-test	
	n	Mean	SE	n	Mean	SE	t	P
Juveniles								
Wing	18	88.00	0.52	7	83.14	0.85	4.88	<0.000
Tail	18	63.78	0.82	7	59.42	0.84	3.84	0.006
Tarsus	18	31.43	0.26	7	29.34	0.57	3.83	0.001
Bill	18	15.46	0.27	7	15.77	0.15	0.70	0.493
Mass	7	29.00	1.30	5	22.70	1.04	3.55	0.005
Adults								
Wing	24	92.54	0.63	13	84.23	0.94	7.52	<0.000
Tail	23	67.56	0.60	12	63.08	0.98	4.12	0.002
Tarsus	24	32.29	0.18	13	29.72	0.44	6.40	<0.000
Bill	23	16.34	0.10	13	15.83	0.17	2.73	0.010
Mass	9	28.83	0.58	8	23.64	0.98	4.99	<0.000

1) and adult females (WING, $t = 3.74$, $P = 0.008$; TARSUS, $t = 3.56$, $P = 0.007$), a substantial measurement overlap was not overcome by a separate discriminant function for juveniles. Thus, with both age classes combined, we used the same discriminant function above to correctly sex 19 of 20 (95%) females and 36 of 42 (86%) males (Fig. 2b).

In both age classes, males had greater MASS than females (Table 1). While excluded from discriminant functions because of small sample sizes and variability, MASS may be useful in confirming or rejecting the sex classification of "borderline" individuals, especially juvenile males.

DISCUSSION

Molt patterns for Akohekohe were similar to at least two other sympatric and closely related species, the Apapane (*Himatione sanguinea*) and Iwi (*Vestiaria coccinea*) (Amadon 1950, Baldwin 1953, Fancy et al. 1993). Juvenal primaries and most secondaries were retained until the second prebasic molt. Typically, at least some brown or gray-brown juvenal body feathers were also retained, particularly on the head and nape, and provided the best distinguishing characteristic separating juveniles from adults.

Reliable methods to differentiate birds undergoing the later stages of first prebasic molt from those in the early stages of second prebasic molt were not found. The presence of white tips on wing feathers, for example, was generally associated with other indicators of later plumage stages, but was highly variable. Similarly, birds in the later stages of the second prebasic molt, having lost all juvenal body feathers, were indistinguishable from those in their adult prebasic molt. Because our data set contained very few recaptures of known age individuals, determining techniques to more accurately assign relative age scores to subadult birds should be a focus of future field studies.

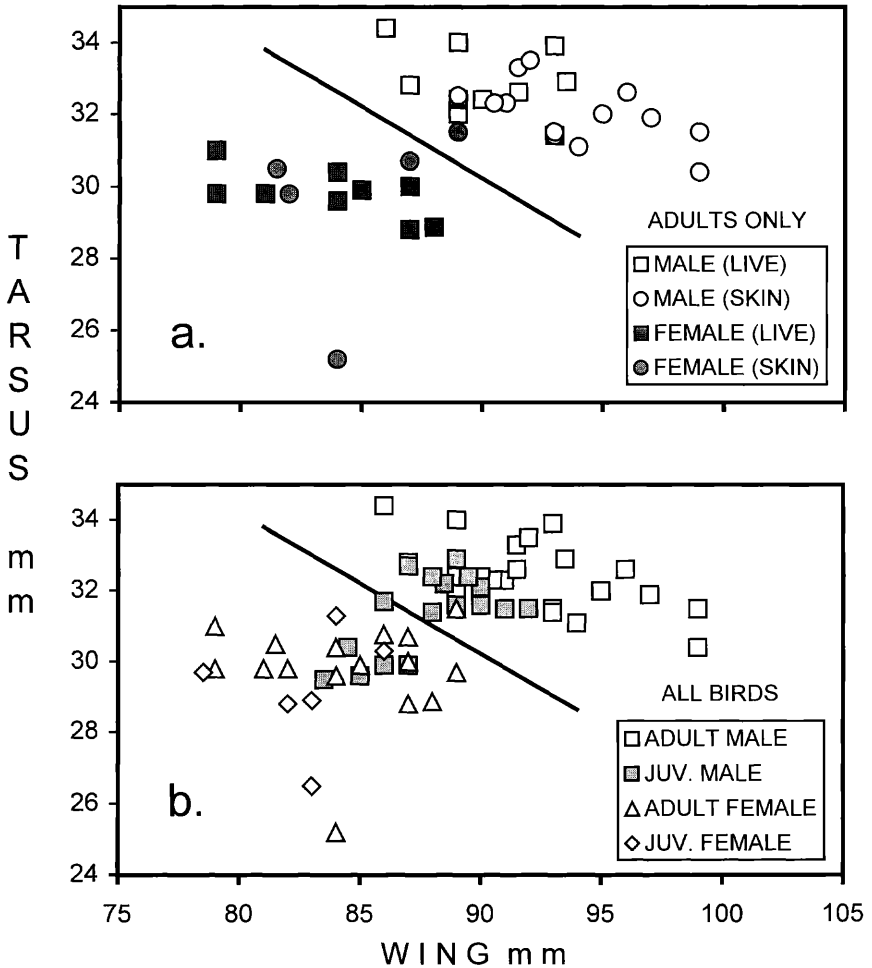


FIGURE 2. Wing chord and tarsus lengths (mm) from adult (a) and all (b) known sex Akohekohe, taken from museum specimens and live birds captured in mist nets on Maui. Line represents the linear discriminant function $D = 1.03(WING) + 2.59(TARSUS) - 171.00$.

Sexing Akohekohe using WING and TARSUS measurements was less reliable for juvenile males than for adults or juvenile females. The overall error rate of 14% for males was reduced to 9%, however, by excluding all birds in their first prebasic plumage. Additionally, some error may have been introduced by the use of study skins whose TARSUS measurements may have shrunk post-mortem (Herremans 1985), as all but one of the incorrectly sexed juvenile males were museum specimens.

While it was not a focus of our field research, a secondary method of

distinguishing sexes in the field, using calls, should be mentioned, if only as an area of future investigation. Our observations suggest that Akohekohe, like several other Drepanids, have calls that appear to be restricted to males. Of these, the most frequently heard might be described as *AAHHH-gluk-gluk-gluk*, *KREE-ko*, *PETER-PETER*, *KERR-KERR-ko-ko*, and a call from which its name is probably derived, *AH-KOWE-KOWE*.

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