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IDENTIFYING SEX AND AGE OF APAPANE AND IIWI ON HAWAII

STEVEN G. FANCY, THANE K. PRATT, GERALD D. LINDSEY, CALVIN K. HARADA, ALFRED H. PARENT, JR., AND JAMES D. JACOBI

U.S. Fish and Wildlife Service
Patuxent Wildlife Research Center
Hawaii Research Group
P.O. Box 44
Hawaii National Park, Hawaii 96718 USA

Abstract.—Methods to determine the sex and age of Apapane (*Himatione sanguinea*) and Iiwi (*Vestiaria coccinea*) were developed on the basis of 189 museum specimens and 91 live birds captured in mist nets on the Island of Hawaii. Both species retain all juvenal primaries and some juvenal secondaries and body feathers after the first prebasic molt and attain full adult plumage after the second prebasic molt. Apapane in their first basic plumage retain some buff-edged juvenal secondaries (particularly secondaries five and six) and sometimes retain a few gray-brown feathers on the head. The first basic plumage of Iiwi is characterized by secondaries 6–9 being longer and darker than secondaries 1–4 and the presence of a few yellowish juvenal body feathers with black spots at the tips. Adult male Apapane and Iiwi have longer wing, tail, exposed culmen, culmen and tarso-metatarsus lengths than females. Linear discriminant functions are presented to sex adult Apapane and Iiwi from lengths of their wing chord and exposed culmen.

IDENTIFICACIÓN DE LA EDAD Y EL SEXO DE *HIMATIONE SANGUINEA* Y *VESTIARIA COCCINEA*

Sinopsis.—Se desarrolló la metodología para determinar el sexo y la edad de individuos de Apapane (*Himatione sanguinea*) y de Iiwi (*Vestiaria coccinea*), a partir de 189 especímenes de museo y 91 individuos capturados con redes en Hawaii. Ambas especies mantienen, luego de la primera muda prebásica, todas las primarias, algunas secundarias y otras plumas de contorno típicas de los juveniles, y adquieren el plumaje de adulto luego de la segunda muda prebásica. El Apapane, en su primer plumaje básico, retiene coloración crema en la punta de algunas secundarias (particularmente la quinta y la sexta) y en ocasiones algunas plumas pardo-grisáceo en la cabeza. El primer plumaje básico del Iiwi se caracteriza por la presencia de algunas plumas de contorno amarillentas con puntos negros en la punta, (típicas del plumaje juvenil) y por tener las secundarias 6–9 más largas y oscuras que las secundarias 1–4. Los machos adultos de Apapane e Iiwi tienen el ala, rabo, culmen expuesto, culmen y tarsometatarso más largos que los de las hembras. Se presentan funciones lineares discriminantes para sexar adultos de Apapane e Iiwi a partir de la longitud del ala y el culmen expuesto.

The Apapane (*Himatione sanguinea*) and Iiwi (*Vestiaria coccinea*) are closely related species of Hawaiian honeycreeper (Family Fringillidae, Subfamily Drepanidinae) found in forests of the Hawaiian Islands. Apapane are the most abundant Hawaiian honeycreeper and are found on all main islands. Iiwi are rare on Molokai and Oahu and became extinct on Lanai by 1929, but are common locally on Kauai, Maui and Hawaii (Scott et al. 1986). The long, decurved bill and scarlet plumage of the Iiwi make it one of the most spectacular of extant Hawaiian birds.

Previous studies by Amadon (1950) and Baldwin (1952, 1953) provided conflicting data on molting of the primary feathers of Apapane and Iiwi

during the first prebasic molt, and neither study provided methods for sexing and ageing these species. Amadon (1950) claimed that, for both species, all juvenal flight feathers, and usually all body feathers, were replaced during the first prebasic molt, and that replacement of primaries began once body molt was nearly complete. Amadon based his conclusions for Iiwi on careful examination of 68 specimens at the American Museum of Natural History and on preliminary study of 158 specimens at the Bishop Museum. Baldwin (1953), after studying his own collection of 54 Iiwi specimens, concluded that some Iiwi molt their primaries during the first prebasic molt. He found that only seven of 16 immature specimens had partially or completely molted their primaries. Baldwin (1953) found that molting of flight feathers in the first prebasic and subsequent molts began in June soon after body molt was initiated, and was completed in November when body feathers were still being molted. Baldwin (1952, 1953) also examined 113 Apapane specimens and concluded that Apapane retained their juvenal primaries until the second prebasic molt.

Our objective was to develop methods for sexing and aging Apapane and Iiwi on the Island of Hawaii from plumage and external morphometric characteristics, and to describe molt patterns for these species. Methods to sex and age individuals are needed for most demographic and behavioral studies of birds before meaningful inferences can be made from field data.

METHODS

We recorded plumage characteristics and external measurements for 76 Apapane and 73 Iiwi specimens from the Island of Hawaii at the Bernice P. Bishop Museum, and for 24 immature Apapane and 16 immature Iiwi specimens collected on Hawaii and analyzed by Baldwin (1953). Our sample included all specimens from the Island of Hawaii for which the bird's sex was indicated on the label. We assumed that birds were correctly sexed by examination of their gonads during specimen preparation. Additional samples of 53 Apapane and 38 Iiwi were captured in mist nets on Hawaii at Hawaii Volcanoes National Park or Kulani Correctional Facility and sexed by presence of a brood patch or cloacal swell.

For each specimen, we measured the length of the wing chord (WING) to the nearest millimeter with a metal rule, from the bend to the tip of the longest primary of the unflattened, folded wing. WINGTIP was measured from the tip of the longest primary to the tip of the longest secondary of the folded wing with a plastic rule. Exposed culmen (EXPCUL), CULMEN (distance from anterior of nares to bill tip) and tarso-metatarsus (TARSUS) lengths were measured to the nearest 0.1 mm with dial calipers (Pyle et al. 1987). Tail length (TAIL) was measured to the nearest millimeter by inserting a plastic rule between the two central rectrices and pushing it firmly against the point of insertion of the feathers. Our numbering system for primaries and secondaries follows that in Pyle et al. (1987).

We used plumage characteristics and capture month to assign an age class to each museum specimen based on the calendar year, following conventions at the U.S. Fish and Wildlife Service Bird Banding Laboratory, Laurel, Maryland (Canadian Wildlife Service 1984). For the purpose of this paper, we classified any bird that had completed its second prebasic molt as an adult. For each age class, we used stepwise discriminant analyses to determine the best set of variables for sexing Apapane and Iiwi, and classified each specimen 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.—Apapane and Iiwi undergo a single annual molt following or partially overlapping their extended breeding season. Birds have been found breeding during all months of the year (Amadon 1950; Baldwin 1953; C. Atkinson, unpubl. data), but molting of flight feathers and coverts occurs primarily between June and November (Baldwin 1953). During the first prebasic molt, both species retain their juvenal primaries and some juvenal secondaries and body feathers; therefore, we were able to distinguish between juvenal, first basic and adult (i.e., second and subsequent basic) plumages for each species.

The juvenal plumage of Apapane is characterized by gray-brown and buff body feathers and by secondaries and some greater coverts with rufous or buff outer vanes. Some Apapane in juvenal plumage have a pink or orange wash on the auriculars, throat or scapulars that is distinct from the crimson color of adults. During their first prebasic molt, Apapane attain the crimson body plumage of adults, but retain their juvenal primaries, all or some buff-edged secondaries (particularly secondaries five and six), and, frequently, a few gray-brown feathers on the head. After the complete second prebasic molt, the outer vanes of all secondaries and greater coverts become crimson.

The juvenal plumage of Iiwi is characterized by black-tipped, green body feathers that fade with age to pale yellowish. As with Apapane, some Iiwi in juvenal plumage may have feathers with a reddish blush on the face or scapulars. The primary, secondary, and tail feathers are grayish black. Five of the specimens we examined were in juvenal plumage without molt. During the first prebasic molt (22 specimens), most juvenal body feathers are replaced with brilliant scarlet feathers characteristic of adults. The breast and belly feathers molt first and are nearly or entirely replaced (Baldwin 1953; this study). The head (particularly the nape), back and scapulars molt last and incompletely. Also retained are all primaries, secondaries 1–4 (sometimes 5 and 6) and all rectrices. Secondaries 6–9 (and sometimes others) are usually replaced near the end of the first prebasic molt (8 of 10 specimens). These new secondaries are larger and darker than the ones replaced. As a result, the new secondaries,

especially secondary 6, may extend beyond adjacent juvenal secondaries and have a darker, matte-black color contrasting with the grey-black juvenal secondaries and primaries. Two specimens out of 53 all-red Iiwi had newly-replaced secondaries 6–9, contrasting with old secondaries 1–5; these may have been birds in first prebasic plumage that had lost all juvenal body feathers. Iiwi in their first basic plumage (10 specimens) are predominately scarlet, with a few yellowish juvenal feathers on the head, back and scapulars, and usually have newly-replaced secondaries 6–9 contrasting with juvenal secondaries 1–5 (eight specimens).

Iiwi replace their primaries and tail feathers during the complete, second prebasic molt. Iiwi in advanced first prebasic or second prebasic molt are difficult to age because specimens in either molt are mostly scarlet yet retain a few worn juvenal body feathers, especially on the nape. During the second prebasic and later molts, primaries molt in sequence from primary 1 to primary 9; secondaries 1–6 begin molting when primary molt is almost complete (Baldwin 1953; this study).

Of the seven specimens that Baldwin (1953) reported as undergoing or having completed first prebasic primary molt, we determined that only three were actually in primary molt and another was molting primaries in only one wing. All others retained juvenal primaries. These molting birds may have been in first or second prebasic molt. As a result of the difficulty in distinguishing between Iiwi in late first or second prebasic molt, we caution against aging molting Iiwi with scarlet breasts and mixed yellow and scarlet feathering in the dorsal plumage.

Sex determination.—We found no reliable means to sex Apapane or Iiwi from plumage color or soft parts. All body measurements of adult male Apapane and Iiwi were significantly larger than those for females (Tables 1–2), however, and most specimens can be accurately sexed from measurements.

The following discriminant function correctly sexed 39 of 41 (95%) adult Apapane museum specimens, and all adult Apapane (28 adult males and 25 adult females) captured in mist nets and sexed by the presence of a brood patch or cloacal swell, using only WING and EXPCUL

$$D = 1.266(\text{WING}) + 2.393(\text{EXPCUL}) - 131.653,$$

where D is the discriminant score for an individual (Fig. 1). Apapane with negative scores should be classified as females, and those with positive scores should be classified as males.

The wing, tail, and tarsus measurements for male hatch-year (HY) Apapane were longer than those for females (Table 1), and 27 of 31 HY museum specimens were correctly sexed by the function

$$D = 1.176(\text{WING}) + 1.364(\text{TARSUS}) - 113.000.$$

The wings and tails of second-year (SY) male Apapane were also significantly longer than those for females (Table 1), but only WING entered the following discriminant function that correctly sexed 16 of 17 (94%) museum specimens

TABLE 1. Measurements (mm) of Apapane specimens from the Island of Hawaii.

	Males			Females			*t*-test	
	n	Mean	SE	*n*	Mean	SE	*t*	*P*
Hatch-year								
Wing	15	71.4	0.49	22	67.9	0.62	4.11	0.000
Tail	14	45.8	0.50	18	44.2	0.48	2.24	0.033
Exposed culmen	15	15.8	0.18	22	15.8	0.17	0.08	0.935
Culmen	14	12.4	0.16	18	12.3	0.10	0.51	0.614
Tarsus	14	23.5	0.22	17	22.5	0.01	4.02	0.000
Second-year								
Wing	5	74.4	1.08	12	68.3	0.53	5.71	0.000
Tail	5	47.6	1.60	11	44.3	0.62	2.39	0.032
Exposed culmen	5	16.0	0.22	10	15.4	0.18	1.88	0.083
Culmen	5	12.6	0.19	9	12.4	0.20	0.59	0.565
Tarsus	5	23.7	0.41	10	22.9	0.25	1.84	0.089
Adults								
Wing	20	76.1	0.51	23	70.6	0.41	8.51	0.000
Tail	19	51.2	0.44	18	47.0	0.37	7.25	0.000
Exposed culmen	21	16.6	0.16	21	15.8	0.10	4.40	0.000
Culmen	19	13.2	0.13	16	12.7	0.11	3.22	0.003
Tarsus	19	23.4	0.16	18	22.3	0.15	4.83	0.000

$$D = 1.520(WING) - 109.356.$$

Simplified, any SY Apapane with a wing chord ≥72 mm should be classified as a male.

Forty-two of 45 (93%) adult Iiwi museum specimens and 37 of 38 (97%) adult Iiwi (10 males, 28 females) captured in mist nets and sexed by the presence of a brood patch or cloacal swell were correctly sexed by the function

$$D = 0.800(WING) + 1.846(EXPCUL) - 111.387,$$

where D is the discriminant score for an individual (Fig. 1).

Male HY Iiwi had significantly longer WING, TAIL, and TARSUS measurements than did females. The discriminant function

$$D = 0.973(WING) - 70.975$$

correctly classified 25 of 29 HY (86%) Iiwi. Thus, all HY Iiwi with wing chords ≥73 mm should be classified as males. Male SY Iiwi had longer exposed culmens than did females; nine of 10 (90%) SY Iiwi were correctly classified by the function

$$D = 3.910(EXPCUL) - 99.704.$$

DISCUSSION

Our findings indicate that molting patterns are similar for the two species; Apapane and Iiwi both retain their juvenal primaries and some

TABLE 2. Measurements (mm) of Iiwi specimens from the Island of Hawaii.

	Males			Females			*t*-test	
	n	Mean	SE	*n*	Mean	SE	*t*	*P*
Hatch-year								
Wing	15	75.3	0.63	14	70.7	0.50	5.70	0.000
Tail	11	47.6	0.80	7	44.7	0.84	2.42	0.028
Exposed culmen	12	25.0	0.63	14	24.3	0.25	1.01	0.327
Culmen	8	20.0	0.88	7	20.0	0.18	0.02	0.985
Tarsus	11	25.2	0.47	7	23.6	0.47	2.65	0.018
Second-year								
Wing	7	75.7	0.71	2	73.5	1.50	1.43	0.194
Tail	2	48.0	2.00	2	46.5	1.50	0.60	0.609
Exposed culmen	8	27.4	0.27	2	24.3	1.10	4.41	0.002
Culmen	3	21.5	0.79	2	19.2	0.55	2.13	0.123
Tarsus	3	24.7	0.25	2	23.4	0.55	2.39	0.097
Adults								
Wing	33	80.9	0.33	14	76.0	0.71	7.12	0.000
Tail	32	51.9	0.38	13	49.2	0.54	3.97	0.000
Exposed culmen	32	27.5	0.17	14	25.2	0.28	7.29	0.000
Culmen	31	22.4	0.19	14	20.4	0.23	6.18	0.000
Tarsus	33	25.8	0.16	11	23.9	0.22	6.04	0.000

secondaries until the second prebasic molt. The difficulty in distinguishing between birds undergoing the first and second prebasic molts probably accounts for the conflicting results reported by Amadon (1950) and Baldwin (1952, 1953). Specimens undergoing the second prebasic molt are molting their primaries and have red underparts, but may still retain juvenal body and flight feathers and may be mistaken for HY birds. If Iiwi were to normally molt some or all of their primaries during the first prebasic molt, the species would be unique among drepanidines studied to date: Apapane and Amakihi (*Loxops virens*; Baldwin 1953; USFWS, unpubl. data), Palila (*Loxioides bailleui*; USFWS, unpubl. data), and Laysan Finch (*Telespiza cantans*; Banks and Laybourne 1977) all retain their primaries until the second prebasic molt. In both Iiwi and Palila, a few individuals do molt their primaries during the first prebasic molt; further research is needed to determine whether these individuals fledge earlier than those that retain their primaries.

Iiwi males and females in first basic plumage have been reported in breeding condition (Amadon 1950, Baldwin 1953, Perkins 1903). Replacement of secondaries 7–9 by Iiwi may enhance their value in behavioral signalling by these brightly contrasting feathers.

Amadon (1950) found no evidence of geographic variation in measurements of Apapane and Iiwi and noted that both species are strong fliers. All of the Apapane and Iiwi we analyzed were from the Island of Hawaii, however, and we caution that our criteria may not apply to

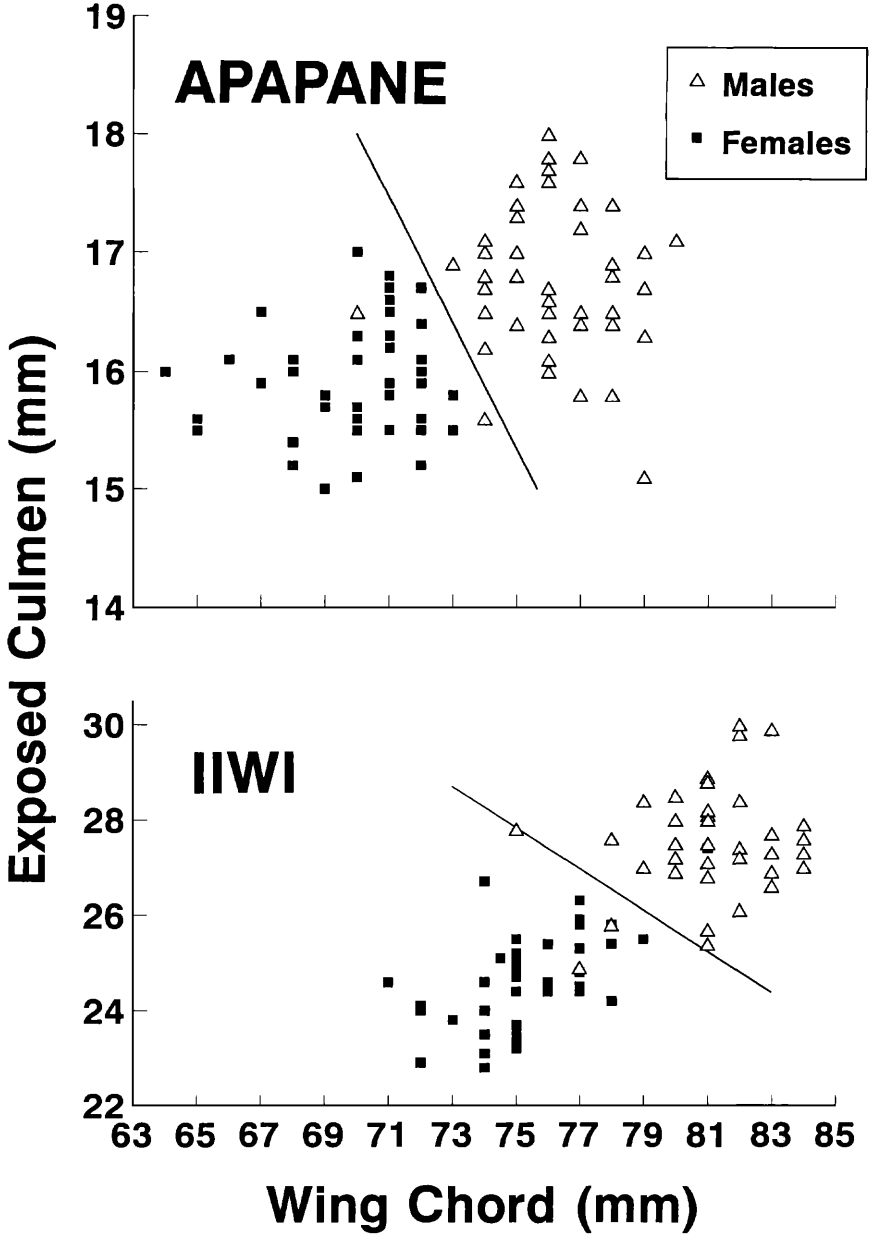

FIGURE 1. Wing chord and exposed culmen length (mm) of adult Apapane and Iiwi museum specimens and live birds captured in mist nets on Hawaii. Lines represent the linear discriminant functions D = 1.266(WING) + 2.393(EXPCUL) − 131.653 for Apapane and D = 0.800(WING) + 1.846(EXPCUL) − 111.387 for Iiwi.

individuals from other islands. The degree of inter-island variation for these two species awaits further study.

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