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AGING AND SEXING GUIDE TO THE FOREST BIRDS OF HAWAI`I ISLAND

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Aging and sexing guide to the forest birds of Hawai'i Island



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INTRODUCTION

Hawai'i's forest birds are of considerable conservation concern, with over half the species listed as endangered with the possibility of extinction (USFWS 2006). Many factors threaten these populations, including degradation and loss of habitat, introduced disease, non-native predators, and competition from non-native birds for food and habitat (Pratt et al. 2009), all of which may reduce productivity and survival, and possibly influence movement patterns. To understand why a population is declining, and help managers identify key threats, accurate measures of survival and productivity, the vital rates of a population, are needed. Demographic studies involving the capture, banding, and re-encountering of marked birds are a key method for obtaining estimates of survival, productivity, and movement, which can vary considerably among age groups and sexes. Therefore, the ability to accurately age and sex birds is key to minimizing variation in these vital rate estimates.

There is currently no photographic aging and sexing guide for native birds of Hawai'i Island that live in montane forest habitats. Published studies (Ralph and Fancy 1994a, Ralph and Fancy 1994b, Vanderwerf 2001) and dichotomous keys developed by researchers over the past several decades provide a good reference for distinguishing age and sex, but do not consider relatively new approaches (e.g., molt limits), and photographs help ensure greater consistency among banders when applying the age criteria. We banded birds in Hakalau Forest National Wildlife Refuge from 2012 to 2016, collecting photographs of birds and making detailed observations on coloration, morphology, and molting patterns (Figs. 1–2). While we believe the criteria in this guide are applicable to forest birds across Hawai'i Island, as well as on other Hawaiian islands for 'Apapane, 'I'iwi, and Hawai'i 'Amakihi, certain characteristics such as morphometrics may vary across populations, and users should verify the guide's criteria with other available field data.

One of the challenges of accurately aging Hawai'i forest birds is through the application of the commonly used calendar aging system (e.g., hatch year [HY], after hatch year [AHY]). The aging system works well in temperate systems where breeding seasons have well defined periods (e.g., spring) separated by well-defined non-breeding periods (i.e., fall and winter). However, tropical Hawai'i is much less seasonal, and Hawai'i forest birds can breed at any time of year, varying from year to year and across elevations. Generally, peak breeding season for Hawai'i forest birds is during winter and spring months, and they undergo prebasic molt following the breeding season during summer and fall months (with the exception of 'Akiapōlā'au, whose peak breeding season appears to occur in the fall months and molt in the spring). These extended breeding and molting periods create challenges because plumages associated with certain ages (e.g., juvenal plumage, preformative plumage) can straddle years and therefore different "ages". For example, a bird that hatched December 1 would be aged as a hatch year (HY) until December 31, and a second year (SY) starting January 1. However, that "SY" bird would be indistinguishable from a bird that hatched January 1 and classified as a hatch year. Therefore, designating an age for a particular individual using the calendar-year system involves a combination of objective criteria and guesswork.

To move away from the ambiguity of the calendar based aging system, we have adopted an aging system for tropical birds based on plumages and molts (Wolfe et al. 2010). Most native Hawai'i forest birds have three different plumages: a juvenal plumage (first-cycle juvenile) that is complete or near complete by time of fledging; a sub-adult plumage (first-cycle formative); and an adult plumage (definitive) that is renewed every year thereafter in adults (Fig. 3). For some species (e.g., Hawai'i 'Ākepa, Hawai'i 'Elepaio) there is a second sub-adult plumage (second-cycle basic) before the molting in of the definitive adult plumage. The plumages are typically easy to identify and unambiguous, making an aging scheme based on plumages more consistent than a calendar-based system. However, the plumage-based system can be converted to the calendar-based age classification system with assumptions about time of year. To help eliminate some of the difficulty in connecting calendar-based age classifications to specific plumages, we have grouped months into seasons (winter: January–March, spring: April–May, summer: June–August, and fall: September–December), and provided seasons during which each plumage is most likely to be found for a given calendar-based age. We still caution users to bear in mind that these time periods are flexible, and there is potential for birds to appear in any plumage during all months of the year. Together, this guide is meant to not only provide a detailed guide for researchers on Hawai'i Island, but help spur development of aging and sexing guides for species endemic to the other islands of Hawai'i.

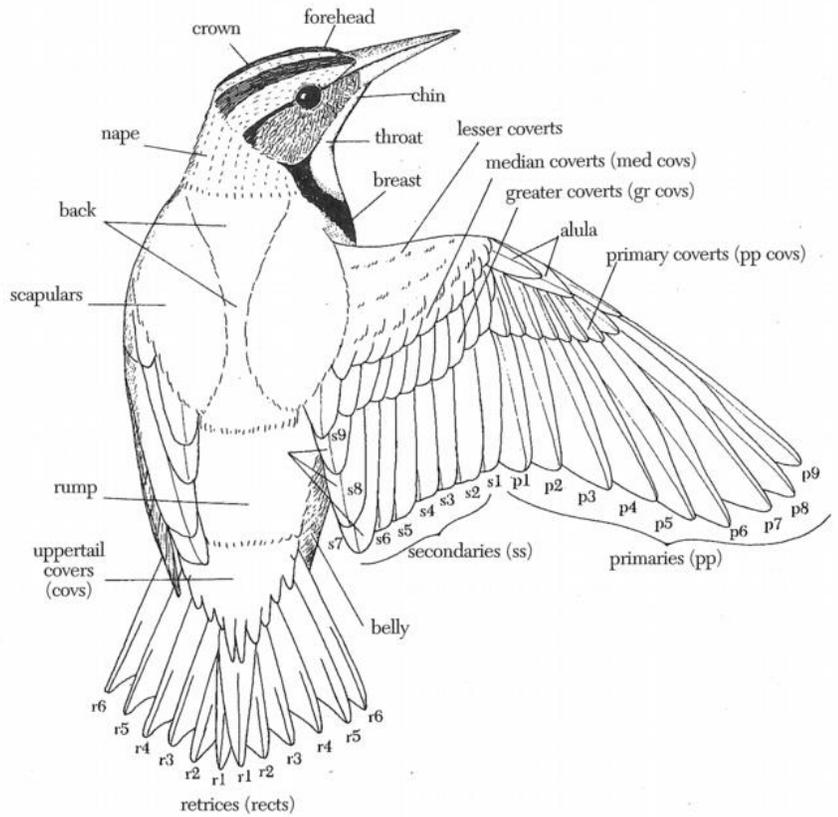


Figure 1. Names of the feathers and regions of a bird. Illustrations by Steve N. G. Howell from Identification Guide to North American Birds (<http://www.slatecreekpress.com/>)

How to use this guide

The guide covers 10 forest bird species, 8 native and 2 common non-native species, with each species account divided into four sections. The first section provides a detailed written description of the species, a description of the number of molts and plumages, and general information on aging and sexing the species. The second section provides a table for determining sex of adult individuals based on morphological measurements (wing and bill

length) when applicable. The third section consists of a table in the “Tabular Pyle” style (Sakai and Ralph 2001) that provides a quick method of distinguishing age and sex of individuals. The last section provides photographs of birds in different age and sex appearances with text highlighting key identification points. We followed aging and sexing methods as described in the Identification Guide to North American Birds (Pyle et al. 1997). In addition, there are valuable details on aging and sexing Hawai'i forest birds from published papers: (Ralph and Fancy 1994a, Ralph and Fancy 1994b, Vanderwerf 2001).

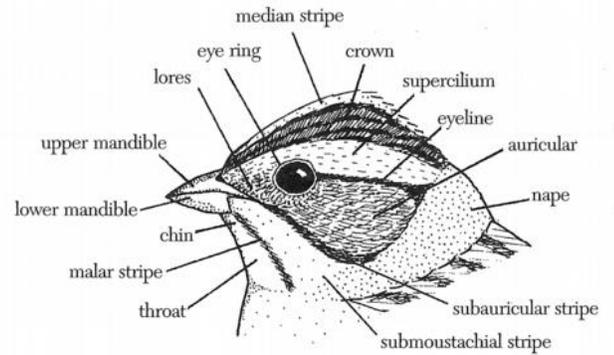


Figure 2. Names of the areas of a bird's head. Illustrations by Steve N. G. Howell from Identification Guide to North American Birds (<http://www.slatecreekpress.com/>).

Terminology

Calendar-based Age Classification Codes (Pyle et al. 1997):

- HY: Hatch year — individual hatched in the same year as captured
- AHY: After hatch year — adult, at least in second year of life, used when cannot determine more specific age
- SY: Second year — individual hatched previous calendar year
- ASY: After second year — individual at least three years old
- TY: Third year — individual three years old
- ATY: After third year — individual at least four years old
- U: Unknown — individual of unknown age

Molt-cycle Classification Codes (with possible calendar year age codes) (Wolfe et al. 2010):

FCJ — First-cycle juvenal (HY)

Used for birds in juvenal plumage

FPF — Preformative molt (HY)

Used for birds molting from juvenal plumage into formative plumage

FCF — First-cycle formative (HY/SY)

Used for birds in formative plumage

FCU — First-cycle unknown plumage (U)

Used if unsure whether bird is in juvenal or formative plumage

SPB — Second prebasic molt (SY)

Used for AKEP/HAEL molting from formative plumage into second basic plumage

Used for AKIP/APAP/HAAM/HCRE/IIWI/OMAO molting from formative plumage into definitive basic plumage

SCB — Second-cycle basic (SY/TY)

Used for AKEP/HAEL in second basic plumage

SCU — Second cycle unknown (AHY)

Used for AKEP/HAEL if unsure whether bird is in formative or second basic plumage

DPB — Definitive prebasic molt (ASY—AKIP/APAP/HAAM/HCRE/IIWI/OMAO, ATY - AKEP/HAEL)

Used for birds molting into definitive basic plumage, replacing either formative, second cycle basic, or another definitive basic plumage

DCB — Definitive cycle basic (SY/ASY—AKIP/APAP/HAAM/HCRE/IIWI/OMAO, TY/ATY - AKEP/HAEL)

Used for birds in definitive basic plumage

UCU — Unknown-cycle unknown plumage (U or AHY)

Most likely used for a species whose molts/plumages you know nothing about

UPB — Unknown prebasic molt (U or AHY)

Used when unsure whether birds are molting into second cycle basic or definitive cycle basic

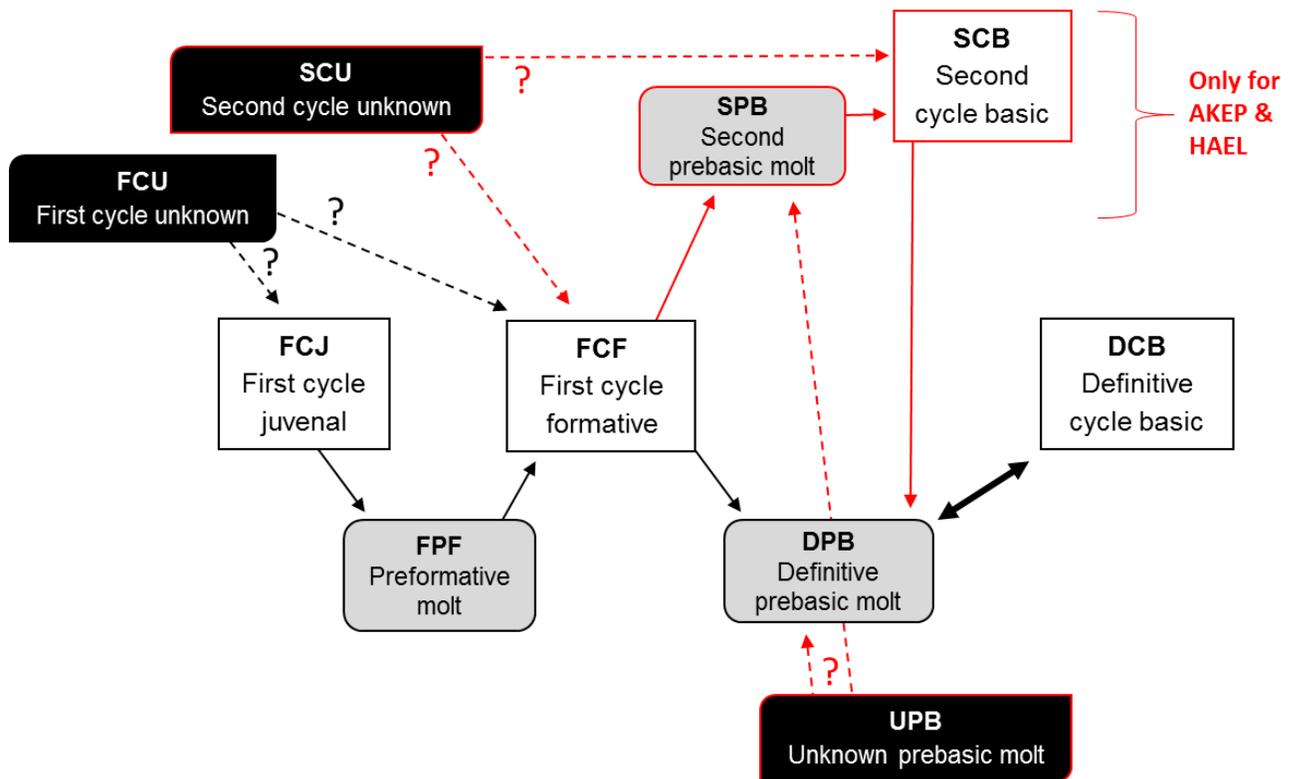


Figure 3. Flow diagram of plumages and molts for Hawaii forest birds, indicating the names and progression from one plumage to the next with intervening molts. Note two species (Hawai'i 'Ākepa [AKEP] and Hawai'i 'Elepaio [HAEL]) have an additional plumage (second cycle basic) which produces two possible pathways in the flow diagram.

Methods

There are several methods with which banders can age and sex native Hawaiian species. Some can easily be determined with overall plumage (Figs. 1–2), whether it be color or presence of retained juvenal body feathers, while others require weighing multiple lines of evidence. Below are the main methods for distinguishing age and sex in Hawai'i forest birds.

Plumage coloration — All native Hawai'i forest birds have plumage coloration differences between juveniles and adults. The difference is often distinct between first-cycle juvenal and adult definitive plumages, but sometime can be difficult when distinguishing between first-cycle juvenal and first-cycle formative plumages, or between formative and definitive plumages. Therefore, while the different coloration patterns of the plumage are presented in the following photographic guide, it is always best to use all possible characteristics and ensure that all criteria agree on age and sex.

Molt limits — Another method used for aging birds is molt limits, where young forest birds do not have complete molts, resulting in new feathers alongside old (retained) feathers. Molt limits are most often found within wing coverts (Fig. 4), but can occur in flight feathers as well. Detecting these limits can often be easily done by noting the difference in wear, sheen, and color between two generations of feathers, and is one of the most reliable methods for identifying age.

Skull pneumaticization — Nestlings hatch with a single layer of bone forming the skull. As they age, a second layer forms beneath the first and fuses together (ossifies) with small columns of bone, a process termed skull pneumaticization (Fig. 5). An unossified skull is an indication of a young bird, most likely less than one-year-old, but there is very little information on the rate of ossification in Hawaiian birds. For general comparison, North American passerines may take 4–12 months to complete skull pneumaticization, but a bird with a nearly ossified skull early in the calendar year may have hatched at the end of the previous year. Uncertainty in the rate of ossification and when an individual hatched presents a challenge of aging these birds based on the calendar year; however, when used in combination with plumage characteristics, skull ossification can help improve determining the age of birds at certain times of the year. For Japanese White-eye and Red-billed Leiothrix, this is the only method we know of to distinguish between HY and AHY individuals.

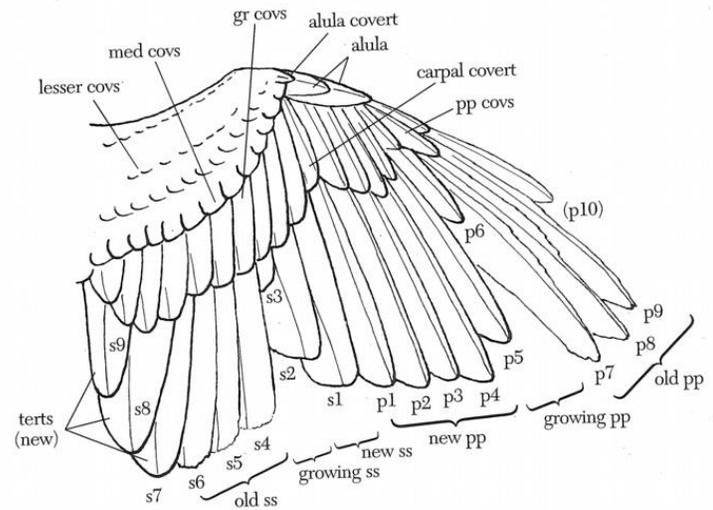


Figure 4. Names of feather tracts on the wing of a bird. Illustrations by Steve N. G. Howell from Identification Guide to North American Birds (<http://www.slatecreekpress.com/>).

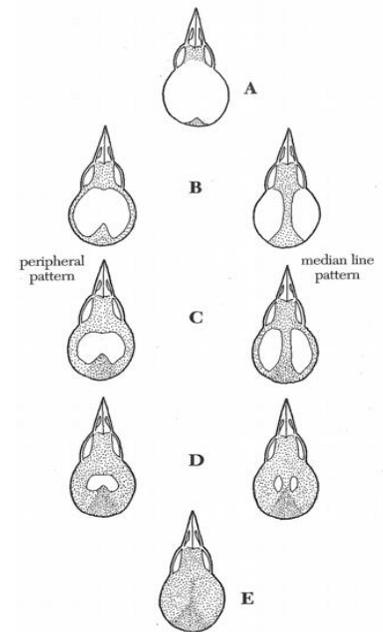


Figure 5. Patterns of skull pneumaticization in young birds. Individuals greater than 1 year of age will have fully ossified (E) or nearly ossified (D) skulls. Illustrations by Steve N. G. Howell from Identification Guide

Flight feather shape — Feather shape can also be useful for aging birds. Juvenal feathers tend to be more pointed and narrow, while adult feathers are typically broader and more truncate (Fig. 6). When using feather shape, look at the outer primaries, primary coverts and rectrices. In general, this can be applied to all the forest birds, but feather shape is relative to each species, and there is individual variation. This method should be used with caution and only as a supporting characteristic until more study has been conducted.

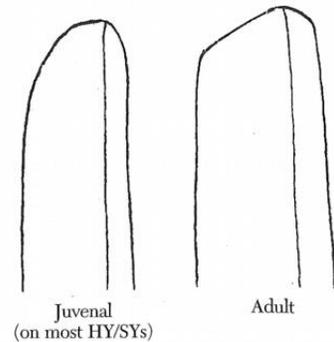


Figure 6. General difference in flight feather shape between juveniles and adults. Illustrations by Steve N. G. Howell from Identification Guide to North American Birds (<http://www.slatecreekpress.com/>).

Flight feather wear — Flight feather wear can be used as supporting evidence to help age birds. Feather wear is the abrasion and general degradation of a feather (Pyle et al. 1997), and habits of species and individuals, such as foraging and nesting behavior, as well as sun exposure, contribute to this process. Feather wear can be quantified by the amount of nicks and chips along the tips of a feather, specifically the outer primaries. A freshly grown feather will have a smooth whitish edge, which wears away quickly. As a feather is exposed to the elements, barbs can break and color and sheen can fade. While the amount of wear can help banders approximate the age of the feathers, molt strategy, timing of molt, and breeding season must be understood when using this criterion for aging birds. For example, fresh flight feathers on an individual during the breeding season of that species can indicate a recent fledgling, whereas during post-breeding season (when most adults are replacing their flight feathers) this can identify an adult bird since juveniles do not have complete pre-formative molts. Therefore, by the following breeding season, juvenal feathers should show more wear compared to adults because they are older and generally of poorer quality. Used in combination with other characteristics, feather wear can be helpful to age individuals, especially trying to establish a calendar-based age.

Sexual dimorphism — Many Hawai'i forest birds are sexually dimorphic based on plumage characteristics (e.g., Hawai'i 'Ākepa, Hawai'i 'Amakihi), while others are similar in plumage but differ in size (e.g., 'I'iwi, 'Apapane). For these latter species, wing chord length (the length of the wing, unflattened, in mm) and bill length (total culmen length from the tip of the bill to the base of the upper bill, in mm) (Fig. 7) can help separate males from females. There is overlap in size between males and females; for some species the overlap is very small ('Akiapōlā'au), but for others the overlap is large and only very small or very large individuals can be reliably classified based on measurements. We used a logistic regression to develop probability-based estimates of males and females using wing and bill lengths gathered at Hakalau Forest from 1995–1999 and 2012–2016. We considered each variable (i.e., wing length, bill length) and interaction of the two, and used AIC model selection to pick the most parsimonious model. The

resulting logistic models provided a probability of being either male or female based on wing and bill length. We provide three choices for users: if the probability for a given wing and bill

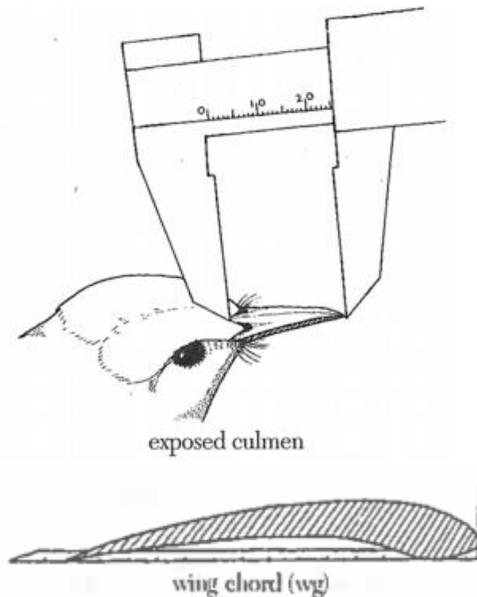


Figure 7. Illustrations of how to measure bill and wing length (mm) used in this guide. Illustrations by Steve N. G. Howell from Identification Guide to North American Birds (<http://www.slatecreekpress.com/>).

measurement is greater than 95%, then we provide the symbol for the sex (although keep in mind that on average 5% of individuals will be misidentified). If the probability is between 90–94%, we provide the probability and users can choose whether to use or not, and if below 90% we do not believe morphometrics should be used for sexing. Samples sizes for each species are provided in the species accounts. These measurements should only be used for adults, as juvenile birds typically have shorter wings and bill lengths than adults. While morphometric measurements can separate many individuals, sexually dimorphic plumage characterizes and presence of brood patches (BP)(females) or cloacal protuberance (CP)(male) are more reliable criteria for sex, if present. Importantly, different populations may have different average sizes, and our morphometric relationships derived from Hakalau Forest birds may not be valid in other places. We recommend that researchers record when sex is determined by morphometrics, and when they have sufficient samples sizes evaluate the relationships based on measurements from their own study population.

Conclusion

There is still much to learn on the plumages and morphology of Hawai'i's forest birds that could improve these aging and sexing keys. Several areas that need more study include timing and duration of molts. For instance, we have captured a few 'Iwi with molt limits in the primary coverts, something not typical for species with simple molt strategies. Additionally, fledglings begin replacing juvenal feathers quickly after leaving the nest, but we do not know how long it takes to complete this transition (possibly three or more months). Therefore, we do not have estimates of how long a juvenal plumage is retained or how old birds are when they first reach their formative plumage.

Our hope is that this aging and sexing guide serves as a starting point for more detailed discrimination in the future, and as a template for researchers on other Hawaiian Islands to develop companion guides for species not covered here. We encourage researchers to take notes, and record new criteria for aging, and we hope that over time this aging guide can be expanded to include new species and new criteria, and further refine existing criteria.

Acknowledgements

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Additional useful resources:

- Froehlich, D. (2003). Ageing North American Landbirds by Molt Limits and Plumage Criteria: A photographic companion to the Identification Guide to North American Birds, Part 1. URL: <http://www.birdpop.org/docs/misc/Froehlich-Ageing-North-American-Landbirds.pdf>
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HAWAI'I 'ELEPAIO*(Chasiempis sandwichensis ridgwayi)***Band size: 1****Color band size: XCS****Code: HAEL**

10 primaries (p10 reduced), 9 secondaries, 12 rectrices

Species: Dull brown juveniles to dark brown adults with black and white wings.

4 Plumages:

Juvenal (Figs. 1–3): Complete; occurs in nest. Upperparts drab brown, throat and breast pale gray without streaking. Wing coverts tipped cinnamon with no white. Little to no buffy white tips in rectrices.

Formative (Figs. 4–6): Partial; peak molt occurs June to October. All body feathers replaced paler and grayer. No flight feathers or wing coverts replaced.

Second basic (Figs. 7–8): Incomplete; peak molt occurs June to October. Most to all body and flight feathers replaced. Breast white with light brown streaks, rump partially to mostly white mixed with cinnamon. Usually replace inner median and greater coverts; new feathers black and broad white, or white/cinnamon mixed, tips. Females have mostly white throats; males have mostly black throats.

Definitive basic (Figs. 9–11): Complete; peak molt occurs June to October. All body and flight feathers replaced. Breast white with moderate brown streaks, rump white. All median and greater coverts black with broad white tips. Patterning of throat and rectrices same as second basic plumage.

Age: Can be reliably aged by plumage. When separating formative plumage from second basic plumage, look for retained juvenal body and flight feathers, as well as molt limits in the wing coverts. When separating second basic plumage from definitive basic plumage, look at the extent of white in the greater coverts, rump, and rectrices. However, use caution with calendar year system. Since extent of molt and timing of breeding varies among individuals, use multiple aging criteria, such as feather wear or an unossified skull.

Feather wear: While all age classes of birds will start to show worn feathers within a few months of molting, juvenal flight feathers will be much more worn than adult flight feathers. Use caution as the amount of wear varies by individual.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication that it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age. Keep in mind that there may be HY birds at any time of year.

Sex: Sexual dimorphism discernible after second prebasic molt, sexable by color of the throat.

Male throat: Chin black, throat mostly black; white tips short/nonexistent, revealing black feather bases, especially on chin. White is visible, sometimes white patches on posterior corners of throat.

Female throat: Chin and throat mostly white; feathers with longer white overlapping tips, obscuring the black base of the feathers below.

CAUTION: Wide range of intermediate chin and throat colors.

Table 1. Sex determination of adult Hawai'i 'Elepaio from morphometric measurements. A logistic regression was used to relate the length of white tipping (mm) on the throat feather directly below the bill to the probability of being either male (orange) or female (blue). High confidence of being a particular sex ($\geq 95\%$ probability) is indicated by appropriate gender symbol; moderate confidence ($\geq 90\%$ to $< 95\%$) is indicated by actual probability; low confidence ($< 90\%$, area of overlap among sexes) is marked "Unk". Logistic regression based on measurements of 44 known males and 22 known females from Hakalau Forest NWR. This table can only be used on adult birds in second basic and definitive basic plumage.

♂	♂	♂	91%	Unk	Unk	3%	1%	0%	0%	0%
0%	0%	2%	9%	Unk	Unk	♀	♀	♀	♀	♀
0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Length of white tipping on throat feathers (mm)										

Table 2. Rapid classification table of key traits for aging and distinguishing among sexes for adult Hawai'i 'Elepaio. Use multiple traits to determine age/sex, and consult pictures in following section. Both plumage-based and calendar-based age codes are presented for each distinguishable category.

	Juvenal plumage (HY) ♂ = ♀	Formative plumage (HY: Summer/Fall SY: Winter/Spring) ♂ = ♀	Second basic plumage (SY: Summer/Fall TY: Winter/Spring) ♂ ≠ ♀	Definitive basic plumage (ASY: Summer/Fall TY: Winter/Spring) ♂ ≠ ♀
Molt-cycle Classification Codes	FCJ = first-cycle juvenal	FPF = preformative molt FCF = first-cycle formative	SPB = second prebasic molt SCB = second-cycle basic	DPB = definitive prebasic molt DCB = definitive cycle basic
Molt limits in greater and median coverts (Fig. 8)	None; uniformly dull brown with cinnamon tips	None; uniformly dull brown with faded cinnamon tips	Retained feathers possible: covert tips cinnamon, white, or mixed cinnamon/white	None; uniformly black with broad white tips
Breast (Fig. 1, 4, 7, 9, 12)	Pale gray and un-streaked	Pale gray and un-streaked	White with brown streaks	White with brown streaks
Rump	Brown	Cinnamon	Up to 80% white, mixed with cinnamon	White
Throat (Fig. 1, 4, 7, 9, 12)	Pale gray	Pale gray	<u>Male</u> : mostly black <u>Female</u> : mostly white	<u>Male</u> : mostly black <u>Female</u> : mostly white
Tail feathers (Fig. 3, 6, 11)	White tips 0-10mm	White tips 0-10mm	White tips >10mm	White tips >10mm
Base of lower mandible	Buffy yellow	Buffy yellow	Dark gray to blackish	Dark gray to blackish
Skull	Unossified	HY: Unossified SY: Ossified	Ossified	Ossified
Feather wear	Unworn	HY: Worn SY: Very worn	SY: Unworn TY: Worn	ASY: Unworn ATY: Worn

Juvenal plumage-FCJ (HY)



Figure 1: Juvenal plumage, Hawai'i Elepaio

Overall drab brown, underparts pale gray, rump brown.



Figure 2: Juvenal wing, Hawai'i Elepaio

Secondary coverts with buffy brown tipping, no white tipping.



Figure 3: Juvenal tail, Hawai'i Elepaio

Dull brown with buffy white tips on outermost feathers.

Formative plumage- FCF (HY: Summer/Fall, SY: Winter/Spring)



Figure 4: Formative plumage, Hawai'i 'Elepaio

Replaced body feathers paler and grayer than juvenal plumage. Upperparts drab brown, underparts grayish white, breast unstreaked. Base of lower mandible is yellow.



Figure 5: Formative wing, Hawai'i 'Elepaio

Flight feathers dull (faded) brown, wing coverts tipped cinnamon.



Figure 6: Formative tail, Hawai'i 'Elepaio

Pale (faded) brown with buffy white tips on outermost feathers.

Second basic plumage – SCB/DPB (SY: Summer/Fall, TY: Winter/Spring)



Figure 7: Second basic plumage, Hawai'i 'Elepaio

Replaced feathers brighter/bolder than formative plumage. Covert tips white mixed with cinnamon, breast white with brown streaks, rump white mixed with cinnamon, throat white (female) to black (male) with a range of intermediates, although the length of the white tips on the throat feathers is usually a good indicator of sex.



Figure 8: Second basic wing, Hawai'i 'Elepaio

Retained or new outer coverts with cinnamon tipping (may be worn off), replaced inner coverts black with broad white tipping.

Definitive Basic Plumage- DPB/DCB (ASY: Summer/Fall, ATY: Winter/Spring)



Figure 9: Definitive basic plumage, Hawai'i 'Elepaio

Upperparts dark brown, breast white with heavy brown streaks, rump white, throat white (female) to black (male) with a range of intermediates, although the length of the white tips on the throat feathers is usually a good indicator of sex.



Figure 10: Definitive basic wing, Hawai'i 'Elepaio

Greater coverts black with bold white tipping. Tertials with white/tawny edging when fresh.



Figure 11: Definitive basic tail, Hawai'i 'Elepaio

Dark brown to black with broad white tips.

Figure 12: Comparison of Hawai'i 'Elepaio throats

Second basic female



Second basic male



Definitive basic female



Definitive basic male



ʻŌMAʻŌ
(*Myadestes obscurus*)

Band size: 1A-2
Color band size: XCL-XB

Code: OMAO

10 primaries (p10 reduced), 9 secondaries, 12 rectrices

Species: Brown juveniles with buffy speckling to plain olive brown adults with ashy gray underparts. Not confused with any other Hawai'i forest bird.

3 Plumages:

Juvenal (Figs. 1, 2): Complete; occurs in nest. Body feathers and wing coverts brown with buffy tipping. Breast buffy gray with dark scalloping. Flight feathers brown without buffy tips.

Formative (Figs. 3, 4): Partial; peak molt occurs June to October. Most to all body feathers replaced, may retain juvenal feathers on head, nape, breast, and back; look for buffy speckling on wings from retained juvenal wing coverts. Sometimes replace a few secondary coverts, but no flight feathers replaced.

Definitive basic (Figs. 5, 6): Complete; peak molt occurs June to October. All body and flight feathers replaced. Upperparts olive brown, head more gray than back. Underparts ashy gray fading to white on vent. Flight feathers and wing coverts dark brown.

Age: Can be reliably aged by plumage. When separating formative plumage from definitive basic plumage, look for retained juvenal body and flight feathers, as well as molt limits in wing coverts. However, use caution with calendar year system as birds can breed anytime of the year. Since extent of molt varies among individuals, use multiple aging criteria, such as feather wear or an unossified skull.

Feather wear: While all age classes of birds will start to show worn feathers within a few months of molting, juvenal flight feathers will be much more worn than adult flight feathers. Use caution as the amount of wear varies by individual.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication that it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age. Keep in mind that there may be HY birds at any time of year.

Sex: Monomorphic; use CP/BP, or morphometric table (Table 1) to separate non-breeding individuals.

Table 1. Sex determination of adult 'Ōma'o from morphometric measurements. A logistic regression was used to relate wing (x-axis) and bill length (y-axis) to the probability of being either male (orange) or female (blue). High confidence of being a particular sex ($\geq 95\%$ probability) is indicated by appropriate gender symbol; moderate confidence ($\geq 90\%$ to $< 95\%$) is indicated by actual probability; low confidence ($< 90\%$, area of overlap among sexes) is marked "Unk". Logistic regression based on measurements of 279 known males and 64 known females from Hakalau Forest NWR. This table should only be used for adults, as juveniles can have shorter wing and bill lengths.

Bill																			
19.0	Unk	94%	♂	♂	♂	♂	♂	♂	♂	♂	♂								
18.5	Unk	93%	♂	♂	♂	♂	♂	♂	♂	♂	♂								
18.0	Unk	93%	♂	♂	♂	♂	♂	♂	♂	♂	♂								
17.5	Unk	92%	♂	♂	♂	♂	♂	♂	♂	♂	♂								
17.0	Unk	92%	♂	♂	♂	♂	♂	♂	♂	♂	♂								
16.5	Unk	91%	♂	♂	♂	♂	♂	♂	♂	♂	♂								
16.0	Unk	90%	94%	♂	♂	♂	♂	♂	♂	♂	♂								
15.5	Unk	94%	♂	♂	♂	♂	♂	♂	♂	♂									
15.0	91%	Unk	93%	♂	♂	♂	♂	♂	♂	♂	♂								
14.5	91%	Unk	93%	♂	♂	♂	♂	♂	♂	♂	♂								
14.0	92%	Unk	92%	♂	♂	♂	♂	♂	♂	♂	♂								
13.5	92%	Unk	92%	♂	♂	♂	♂	♂	♂	♂	♂								
13.0	93%	Unk	91%	95%	♂	♂	♂	♂	♂	♂	♂								
12.5	93%	Unk	91%	94%	♂	♂	♂	♂	♂	♂	♂								
12.0	94%	Unk	94%	♂	♂	♂	♂	♂	♂	♂									
	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	
																			Wing

Table 2. Rapid classification table of key traits for aging 'Ōma'o. Use multiple traits to determine age, and consult pictures in following section. Both plumage-based and calendar-based age codes are presented for each distinguishable category.

	Juvenal plumage (HY) ♂ = ♀	Formative plumage (HY: Summer/Fall SY: Winter/Spring) ♂ = ♀	Definitive basic plumage (AHY Summer/Fall ASY: Winter/Spring) ♂ = ♀
Molt-cycle Classification Codes	FCJ = first-cycle juvenal	FPF = preformative molt FCF = first-cycle formative	DPB = definitive prebasic molt DCB = definitive cycle basic
Molt limit in greater coverts (Figs. 2, 4, 6)	None; uniformly brown with buffy tips	Retained outer greater coverts brown with buffy tips, replaced inner greater coverts dark brown without tipping <i>(Note: buffy tips wear easily and may be absent in older feathers)</i>	None; uniformly dark brown
Molt limit between greater coverts and primary coverts (Figs. 2, 4, 6)	None; all coverts uniformly brown	Retained primary coverts brown, more narrow and worn compared to fresher, dark brown replaced greater coverts	None; all coverts uniformly dark brown
Body feathers (Fig. 1, 3, 5)	Brown upperparts with buffy tipping, buffy gray breast with dark scalloping	Retained juvenal feathers on head, nape, breast, and back, mottling with replaced brown to gray formative feathers	Upperparts olive brown, underparts ashy gray
Skull	Unossified	HY: unossified SY: ossified	Ossified
Feather wear	Unworn	HY: unworn SY: very worn	AHY: unworn ASY: worn

Juvenal Plumage- FCJ (HY)



Figure 1: Juvenal plumage, 'Ōma'o

Upperparts brown with buffy tipping, breast buffy gray with dark scalloping.



Figure 2: Juvenal wing, 'Ōma'o

All feathers brown, median and greater coverts with buffy tipping.

Formative Plumage- FPF/FCF (HY: Summer/Fall, SY: Winter/Spring)



Figure 3: Formative plumage, 'Ōma'o

Upperparts olive brown mottled with retained juvenal feathers, head slightly grayer than back. Underparts ashy gray.



Figure 4: Molt limit in greater coverts, 'Ōma'o

Retained outer greater coverts very worn and brown with buffy tips, replaced inner greater coverts fresher and dark brown without buffy tips.

Note: buffy tips wear easily and may be absent in older feathers

Definitive Basic Plumage- DPB/DCB (AHY: Summer/Fall, ASY: Winter/Spring)



Figure 5: Definitive basic plumage, 'Ōma'o

Upperparts olive brown, head more gray than back. Underparts ashy gray.



Figure 6: Definitive basic wing, 'Ōma'o

All feathers uniformly dark brown.

`AKIAPŌLĀ`AU
(*Hemignathus wilsoni*)

Band size: 1A
Color band size: XCL

Code: AKIP

9 primaries, 9 secondaries, 12 rectrices

Species: Dull olive brown juveniles to bright yellow males with black lores and bright olive green females with gray lores. Larger, stockier body than Hawai'i 'Amakihi, with unmistakable elongated decurved upper bill and shorter, blunt lower bill.

3 Plumages:

Juvenal (Figs. 1–3): Complete; occurs in nest. Fledglings may be found from fall through spring, depending on the breeding season. Upperparts grayish green, underparts pale yellowish gray with dark scalloping. Flight feathers edged yellowish green. Median and greater coverts with buffy tips, creating two wing bars. Lores dark gray.

Formative (Figs. 4, 5): Partial; peak molt possibly spring to summer, but can occur at any time of the year; more study is needed. Some to most body feathers replaced more yellow, but similar to greenish gray juvenal plumage. Underparts pale gray mottled dull yellow. Usually replace inner greater (and sometimes median) coverts. Flight feathers edged yellowish green. Lores dark gray.

Definitive basic (Figs. 6–8): Complete; peak molt possibly spring to summer, but can occur at any time of the year; more study is needed. All body and flight feathers replaced.

Male plumage: Yellowish green upperparts, bright yellow underparts, and black lores.

Female plumage: Olive green upperparts, pale yellowish gray underparts with yellow breast.

Age: Can be aged by plumage. When separating formative plumage from definitive basic plumage, look for retained juvenal body and flight feathers, as well as molt limits in wing coverts. However, use extreme caution with calendar year system as these birds are thought to breed from late fall to early spring. Since extent of molt varies among individuals, use multiple aging criteria, such as feather wear or an unossified skull.

Feather wear: While all age classes of birds will start to show worn feathers within a few months of molting, juvenal flight feathers will be much more worn than adult flight feathers. Use caution as the amount of wear varies with age of feathers and by individual.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication that it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age. Keep in mind that there may be HY birds at any time of year.

Sex: Dimorphic in plumage; adult males are bright yellow with bold black lores; adult females are olive with yellow breast and dark gray lores. Use CP/BP, and bill length is a reliable method to separate non-breeding individuals:

Bill length: Males have longer bills than females; bill length \geq 24.0mm is likely male, while a bill length < 23.0mm is likely female; use caution with measurements around 23–24.0mm. DO NOT use bill measurements to sex juvenile birds, they are shorter than adults.

Table 1: Rapid classification table of key traits for aging and sexing adult 'Akiapōlā'au. Use multiple traits to determine age and sex, and consult pictures in following section. Both plumage-based and calendar-based age codes are presented for each distinguishable category.

	Juvenal plumage (HY) ♂ = ♀	Formative plumage (HY: Summer/Fall SY: Winter/Spring) ♂ = ♀	Definitive basic plumage (AHY: Summer/Fall ASY: Winter/Spring) ♂ ≠ ♀
Molt-cycle age categorization codes	FCJ = first-cycle juvenal	FPF = preformative molt FCF = first-cycle formative	DPB = definitive prebasic molt DCB = definitive cycle basic
Molt limits in greater and median coverts (fig. 3, 5, 8)	None; secondary coverts with buffy yellow edging	Retained outer coverts dull greenish gray with pale tipping (wing bar), replaced inner coverts more yellowish green	None; uniformly adult coverts with yellowish green (male) to olive green (female) edging
Molt limit in secondaries (fig. 3, 5, 8)	None; uniform with dull green edging	Retained secondaries dull brown with pale edging, replaced secondaries with yellowish green edging	None; uniform secondaries edged yellowish green (male) to olive green (female)
Body feathers (fig. 1, 4, 6, 7)	Upperparts greenish gray, underparts pale yellowish gray, often with dark scalloping	Retained juvenal feathers greenish gray, mottling with more yellowish replaced feathers	Bright yellow (male) or olive green (female)
Feather wear	Unworn	HY: worn SY: very worn	AHY: unworn ASY: worn
Skull	Unossified	HY: unossified SY: ossified	Ossified

Juvenal Plumage—FCJ (HY)



Figure 1: Juvenal plumage, 'Akiapōlā'au

Upperparts greenish gray, underparts pale yellowish gray often with dark scalloping (not shown).



Figure 2: Juvenal face, 'Akiapōlā'au

Lores blackish gray; bill is still growing and often shows paler color at the base, in contrast to all black bill of adults; orangish gape often very noticeable



Figure 3: Juvenal wing, 'Akiapōlā'au

Secondary coverts with yellowish green edging, forming two wing bars. Flight feathers with narrow yellowish green edging.

Formative Plumage—FPF/FCF (HY: Fall, SY: Winter/Spring)



Figure 4: Formative plumage, 'Akiapōlā'au

Upperparts greenish gray, underparts pale yellowish gray, and lores dark gray. Shown here is a female; males are typically more yellow and mottled with dull olive brown retained juvenal feathers.



Figure 5: Formative wing (active molt), 'Akiapōlā'au

May have molt limit in secondary coverts, with retained juvenal feathers that have buff tipping contrasting with replaced dark green with olive edging feathers.

Definitive Basic Plumage—DPB/DCB (AHY: Summer/Fall, ASY: Winter/Spring)



Figure 6: Male 'Akiapōlā'au in definitive basic plumage

Overall bright yellow with black lores.



Figure 7: Female 'Akiapōlā'au in definitive basic plumage

Overall olive green with dark gray lores.
Underparts pale yellowish gray with yellow breast, but highly variable amounts of yellow.



Figure 8: Definitive basic wing, 'Akiapōlā'au

Wing coverts and flight feathers uniformly adult with broad olive edging.

HAWAII 'AMAKIHI
(*Chlorodrepanis virens*)

Band size: 1
Color band size: XCS

Code: HAAM

9 primaries, 9 secondaries, 12 rectrices

Species: Dull juveniles to bright yellowish green males with black mask and olive-green females with dark gray mask. Juveniles and dull females may be confused with juvenile and female Hawai'i Creeper or Hawai'i 'Ākepa (see section on distinguishing among the three species). Hawai'i 'Amakihi have a more sharply decurved, blacker bill than Hawai'i Creeper, whose bill is more sharply pointed, straighter, and slate gray, and Hawai'i 'Ākepa, whose bill is shorter and more conical. Hawai'i 'Amakihi have a thin black mask that extends through, but not around the eyes (not "raccoon" mask like Hawai'i Creeper). Hawai'i 'Amakihi are overall larger in body size than both Hawai'i Creeper and Hawai'i 'Ākepa.

3 Plumages:

Juvenal (Figs. 1–2): Complete; occurs in nest. Overall drab in appearance. Upperparts grayish olive, underparts whitish green with some yellow. Median and greater coverts tipped buffy white. Flight feathers dull brown with green edging.

Formative (Figs. 3–5): Incomplete; peak molt occurs June to October. Most to all body feathers replaced yellowish olive to greenish olive, may retain juvenal feathers on head, nape, and back. Usually replace inner median and greater coverts (rarely replace all); may have partial retained wing bar. New feathers darker with green edging. No primary coverts replaced.

Definitive basic (Figs. 6–8): Complete; peak molt occurs June to October. All body and flight feathers replaced. Males more yellowish green, females more olive green. All median and greater coverts fresh with green edging.

Age: Can be reliably aged by plumage. When separating formative plumage from definitive basic plumage, look for retained juvenal body and flight feathers, as well as molt limits in wing coverts. However, use caution with calendar year system as birds can breed year-round. Since extent of molt varies among individuals, use multiple aging criteria, such as feather wear or an unossified skull.

Feather wear: While all age classes of birds will start to show worn feathers within a few months of molting, juvenal flight feathers will be much more worn than adult flight feathers. Use caution as the amount of wear varies by individual.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication that it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age. Keep in mind that there may be HY birds at any time of year.

Sex: Dimorphic; adult males are yellowish green with bold black mask; adult females are olive-green with duller mask. Use CP/BP, or morphometric table (Table 1) to separate non-breeding individuals.

Table 1. Sex determination of adult Hawai'i 'Amakihi from morphometric measurements. A logistic regression was used to relate wing (x-axis) and bill length (y-axis) and their interaction to the probability of being either male (orange) or female (blue). High confidence of being a particular sex ($\geq 95\%$ probability) is indicated by appropriate gender symbol; moderate confidence ($\geq 90\%$ to $< 95\%$) is indicated by actual probability; low confidence ($< 90\%$, area of overlap among sexes) is marked "Unk". Logistic regression based on measurements of 1,270 known males and 443 known females from Hakalau Forest NWR. This table should only be used for adults, as juveniles can have shorter wing and bill lengths.

Bill															
18.0	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂
17.5	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂
17.0	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂
16.5	94%	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂
16.0	Unk	91%	94%	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂
15.5	Unk	Unk	Unk	90%	94%	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂
15.0	Unk	Unk	Unk	Unk	Unk	90%	94%	♂	♂	♂	♂	♂	♂	♂	♂
14.5	Unk	Unk	Unk	Unk	Unk	Unk	Unk	91%	94%	♂	♂	♂	♂	♂	♂
14.0	Unk	Unk	Unk	Unk	Unk	Unk	Unk	Unk	Unk	91%	94%	♂	♂	♂	♂
13.5	93%	90%	Unk	92%	♂	♂	♂								
13.0	♀	♀	93%	90%	Unk	92%	♂								
12.5	♀	♀	♀	♀	93%	Unk	90%								
12.0	♀	♀	♀	♀	♀	♀	92%	Unk							
11.5	♀	♀	♀	♀	♀	♀	♀	94%	91%	Unk	Unk	Unk	Unk	Unk	Unk
11.0	♀	♀	♀	♀	♀	♀	♀	♀	♀	94%	90%	Unk	Unk	Unk	Unk
	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
	Wing														

Table 2. Rapid classification table of key traits for aging Hawai'i 'Amakihi. Use multiple traits to determine age, and consult pictures in following section. Both plumage-based and calendar-based age codes are presented for each distinguishable category.

	Juvenal plumage (HY) ♂ = ♀	Formative plumage (HY: Summer/Fall SY: Winter/Spring) ♂ ≠ ♀	Definitive basic plumage (AHY: Summer/Fall ASY: Winter/Spring) ♂ ≠ ♀
Molt-cycle Classification Codes	FCJ = first-cycle juvenal	FPF = preformative molt FCF = first-cycle formative	DPB = definitive prebasic molt DCB = definitive cycle basic
Molt limits in greater and median coverts (Fig. 2, 5, 8)	None; uniformly dull brown with buffy white tipping	Retained outer coverts dull with buffy white tipping, replaced inner coverts with green edging (<i>Note: beware of pseudolimits, i.e. feather tracts that always appear different from adjacent feathers</i>)	None; uniformly brown with olive edging
Molt limit in secondaries (Fig. 2, 5, 8)	None; uniformly dull brown secondaries and primaries, inner secondaries with narrow olive edging	Retained secondaries dull brown, more faded and worn; replaced tertials (s6-9) darker and fresher with olive edging	None; uniformly brown secondaries and primaries, inner secondaries with broad olive edging
Lores, eyeline (Fig. 1, 3, 4, 6, 7)	Indistinct or absent	Dull gray (female) to dark gray (male)	Distinct; dark gray (female) to black (male)
Upperparts (Fig. 1, 3, 4, 6, 7)	Grayish olive	Retained juvenal feathers grayish olive, mottling with replaced greenish olive (female) to yellowish olive (male) feathers (<i>Note: overlap in plumage among sexes</i>)	Olive green (female) to bright yellowish green (male)
Skull	Unossified	HY: unossified SY: ossified	Ossified
Feather wear	Unworn	HY: worn SY: very worn	AHY: unworn ASY: worn

Juvenal plumage—FCJ (HY)



Figure 1: Juvenal plumage, Hawai'i 'Amakihi

Overall drab grayish olive, underparts whitish green and may be streaked yellow; lores and eyeline dull gray indistinct, but may be absent; faint pale eye-ring and no black feathers at base of bill.



Figure 2: Juvenal wing, Hawai'i 'Amakihi

Distinctive buffy white wing bars on median and greater coverts. Flight feathers narrow and dull brown with green edging.

Formative plumage—FPF/FCF (HY: Summer/Fall, SY: Winter/Spring)



Figure 3: Male Hawai'i 'Amakihi in formative plumage

Upperparts yellowish olive mottled with retained juvenal body feathers; slightly brighter than females and juveniles. Mask dark gray and more extensive than that of females.



Figure 4: Female Hawai'i 'Amakihi in formative plumage

Upperparts greenish olive mottled with retained juvenal body feathers. Mask dull gray and less extensive.

Females in formative plumage often only sexable by BP or morphometrics.



Figure 5: Molt limit in greater coverts and secondaries, Hawai'i 'Amakihi

Replaced inner greater coverts and tertials with bright green edging, retained outer coverts and secondaries dull brown with faded and worn edging. Outer coverts may also have dull white tipping.

Note: caution with pseudolimits; some replaced coverts may look like they have remnant wing bars after they are worn.

Definitive Basic Plumage—DPB/DCB (AHY: Summer/Fall, ASY: Winter/Spring)



Figure 6: Male Hawai'i 'Amakihi in definitive basic plumage

Overall bright yellowish green, lores, and eyeline black.



Figure 7: Female Hawai'i 'Amakihi in definitive basic plumage

Overall olive green, with dark gray lores, and eyeline.



Figure 8: Definitive basic wing, Hawai'i 'Amakihi

Wing coverts and flight feathers uniformly brown with olive edging; no wing bars.

Note: some ASY individuals have lighter tipping on coverts, so falsely appear to have retained juvenal wing bars. Use multiple criteria to age some individuals.

HAWAI'I CREEPER
(*Oreomystis mana*)

Band size: 1–0
Color band size: XCS

Code: HCRE

9 primaries, 9 secondaries, 12 rectrices

Species: Drab brown juveniles to olive green males with black mask and pale olive females with gray mask. Juveniles and females may be easily confused with juvenile and female Hawai'i 'Amakihi or Hawai'i 'Ākepa (see section on distinguishing among the three species). Hawai'i Creeper have a black "raccoon" mask that extends across the lores and around the eyes, as opposed to Hawai'i 'Amakihi, whose mask is thinner, extending through, but not around the eyes. Hawai'i Creeper have more sharply pointed, straighter, slate gray bill than Hawai'i 'Amakihi, whose bill is more sharply decurved and black and from Hawai'i 'Ākepa, whose bill which yellowish gray with black tip, only slightly decurved, and shorter and more conical.

3 Plumages:

Juvenal (Figs. 1, 2): Complete; occurs in nest. Upperparts drab olive brown, underparts pale creamy gray. Median and greater coverts tipped buffy white, creating two wing bars. Mask absent.

Formative (Figs. 3, 4): Incomplete; peak molt occurs June to October. Most body feathers replaced, may retain juvenal feathers on crown and nape. Replaced body feathers green, underparts cream with some yellow. May replace some inner median and greater coverts without tips, and retain a few outer feathers with faded buff tips. Mask dark gray, moderately darker than face.

Definitive basic (Figs. 5–7): Complete; peak molt occurs June to October. All body and flight feathers replaced. Overall plumage olive green, with males brighter than females, but can be difficult to separate intermediates; distinctive gray mask around eyes.

Age: Can be reliably aged by plumage. When separating formative plumage from definitive basic plumage, look for retained juvenal body and flight feathers, as well as molt limits in wing coverts. However, use caution with calendar year system as breeding can occur year-round. Since extent of molt varies among individuals, use multiple aging criteria, such as feather wear or an unossified skull.

Feather wear: While all age classes of birds will start to show worn feathers within a few months of molting, juvenal flight feathers will be much more worn than adult flight feathers. Use caution as the amount of wear varies with age of feathers and by individual.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication that it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age. Keep in mind that there may be HY birds at any time of year.

Sex: Dimorphic in plumage by definitive basic; males have bright olive plumage, females have paler olive plumage. Loral mask is typically darker and broader in males than females (dark gray vs. smoky gray, respectively). It can be difficult to separate sexes in formative plumage; may not be possible with intermediate individuals. Use CP/BP, or morphometric table (Table 1) to separate non-breeding individuals.

Table 1. Sex determination of adult Hawai'i Creeper from morphometric measurements. A logistic regression was used to relate wing (x-axis) and bill length (y-axis) and their interaction to the probability of being either male (orange) or female (blue). High confidence of being a particular sex ($\geq 95\%$ probability) is indicated by appropriate gender symbol; moderate confidence ($\geq 90\%$ to $< 95\%$) is indicated by actual probability; low confidence ($< 90\%$, area of overlap among sexes) is marked "Unk". Logistic regression based on measurements of 131 known males and 73 known females from Hakalau Forest NWR. This table should only be used for adults, as juveniles can have shorter wing and bill lengths.

Bill												
16.0	Unk	Unk	Unk	Unk	Unk	Unk	Unk	Unk	Unk	91%	94%	♂
15.5	90%	Unk	90%	94%	♂							
15.0	90%	Unk	93%	♂								
14.5	91%	Unk	93%	♂								
14.0	92%	Unk	92%	♂								
13.5	92%	Unk	91%	94%								
13.0	93%	Unk	90%	94%								
12.5	94%	90%	Unk	90%	93%							
12.0	94%	91%	Unk	93%								
11.5	♀	91%	Unk	92%								
11.0	♀	92%	Unk	92%								
	58	59	60	61	62	63	64	65	66	67	68	69
	Wing											

Table 2: Rapid classification table of key traits for aging Hawai'i Creeper. Use multiple traits to determine age, and consult pictures in following section. Both plumage-based and calendar-based age codes are presented for each distinguishable category.

	Juvenal plumage (HY) ♂ = ♀	Formative plumage (HY: Summer/Fall SY: Winter/Spring) ♂ = ♀	Definitive basic plumage (AHY Summer/Fall ASY: Winter/Spring) ♂ ≠ ♀
Molt-cycle age categorization codes	FCJ = first-cycle juvenal	FPF = preformative molt FCF = first-cycle formative	SPB = second prebasic molt DPB = definitive prebasic molt DCB = definitive cycle basic
Molt limits in greater and median coverts (Fig. 2, 4, 7)	None; uniformly dull olive with buffy white tips	Retained outer coverts dull olive with buffy white tips, replaced inner coverts olive without tips	None; uniformly grayish brown with olive edging; broad and truncate
Mask (Fig. 1, 3, 5, 6)	Absent; face pale, buffy white	Absent or dull and indistinct	Distinct; dark gray (male) smoky gray (female)
Skull	Unossified	HY: unossified SY: ossified	Ossified
Feather wear	Fresh	HY: worn SY: very worn	AHY: fresher ASY: worn

Juvenile plumage—FCJ (HY)



Figure 1: Juvenal plumage, Hawai'i Creeper

Overall drab olive brown, pale face and underparts.



Figure 2: Juvenal wing, Hawai'i Creeper

Distinctive whitish yellow wing bars on median and greater coverts.

Formative plumage—FPF/FCF (HY: Summer/Fall, SY: Winter/Spring)



Figure 3: Formative plumage, Hawai'i Creeper

Upperparts olive green, underparts cream with some yellow. Loral mask light gray and indistinct.



Figure 4: Formative wing, Hawai'i Creeper

May have retained wing bars or molt limit in greater coverts, although wing bars may wear away before the prebasic molt.

Definitive basic plumage—DPB/DCB (AHY: Summer/Fall, ASY: Winter/Spring)



Figure 5: Male Hawai'i Creeper in definitive basic plumage

Upperparts olive green, underparts yellow, loral mask dark gray.



Figure 6: Female Hawai'i Creeper in definitive basic plumage

Upperparts dull olive, underparts pale yellow, loral mask lighter gray than male mask.



Figure 7: Definitive basic wing, Hawai'i Creeper

No wing bars, secondary coverts dark gray with green edging that is uniform in color to upperparts.

HAWAI'I 'ĀKEPA
(*Loxops coccineus*)

Band size: 0
Color band size: XF

Code: AKEP

9 primaries, 9 secondaries, 12 rectrices

Species: Dull juveniles to bright orange males and pale olive green females. Juveniles and dull females may be confused with juvenile and female Hawai'i Creeper or Hawai'i 'Amakihi (see section on distinguishing among the three species). Hawai'i 'Ākepa are smaller in size, with a slightly forked tail. Bill is yellowish gray with black tip, only slightly decurved, shorter and more conical, whereas Hawai'i 'Amakihi have a more sharply decurved, blacker bill, and Hawai'i Creeper have a bill that is more sharply pointed, straighter, and slate gray. Older Hawai'i 'Ākepa often have slightly crossed mandibles at tip.

4 Plumages:

Juvenal (Figs. 1–2): Complete; occurs in nest. Upperparts pale olive green or grayish olive, underparts pale gray to cream with gray mottling. Supercilium whitish with pale gray face. Dark median crown stripe with whitish forehead. Wing coverts dark brown with dusty yellow edging. Bill color pearl gray to straw yellow, usually with extensive black tip.

Formative (Figs. 3–4): Partial; peak molt occurs June to October. Most body feathers replaced grayish olive, may retain juvenal feathers on nape and head. Most to all wing coverts and all flight feathers retained. Faint supercilium, no yellow wash on breast. Bill color pearl gray to straw yellow, may have black tip.

Second basic (Figs. 5–11): Incomplete; peak molt occurs June to October. Most body feathers replaced, may retain formative feathers on nape, head, and back. Most to all flight feathers replaced. Bill color yellow with black tip.

Male plumage: 50–75% orange body feathers mottled with retained gray formative feathers. Flight feathers and wing coverts dark brown with dull orange edging.

Female plumage: Similar to formative plumage, although may have narrow pale yellow breast band. New flight feathers have olive green edging. No supercilium.

Definitive basic (Figs. 12–16): Complete; peak molt occurs June to October. All body and flight feathers replaced. Bill color yellow with black tip.

Male plumage: 100% bright orange, flight feathers and wing coverts dark brown with orange edging.

Female plumage: Upperparts olive green, underparts pale gray. Yellow to orange breast band 5–15 mm wide. Flight feathers and wing coverts dark brown with olive green edging. Some have dull orange or yellow on face, throat, breast, and belly, with more robust olive green upperparts.

Age: Can be reliably aged by plumage. When separating formative plumage from second basic plumage, look for retained juvenal or formative body feathers and retained juvenal flight feathers, as well as molt limits in wing coverts. Use multiple aging criteria, such as feather wear or an unossified skull, in combination with sex to age reliably.

Feather wear: While all age classes of birds will start to show worn feathers within a few months of molting, juvenal flight feathers will be much more worn than adult flight feathers. Use caution as the amount of wear varies with age of feathers and by individual.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication that it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age. Keep in mind that there may be HY birds at any time of year.

Sex: Sexual dimorphism discernible after second pre-basic molt. Use plumage or CP/BP to separate individuals, as well as Table 1.

Table 1. Sex determination of adult Hawai'i 'Ākepa from morphometric measurements. A logistic regression was used to relate wing (x-axis) and bill length (y-axis) to the probability of being either male (orange) or female (blue). High confidence of being a particular sex ($\geq 95\%$ probability) is indicated by appropriate gender symbol; moderate confidence ($\geq 90\%$ to $< 95\%$) is indicated by actual probability; low confidence ($< 90\%$, area of overlap among sexes) is marked "Unk". Logistic regression based on measurements of 158 known males and 71 known females from Hakalau Forest NWR. This table should only be used for adults, as juveniles can have short wing and bill length

Bill												
14.0	Unk	Unk	Unk	Unk	Unk	93%	♂	♂	♂	♂	♂	♂
13.5	90%	Unk	Unk	Unk	Unk	91%	♂	♂	♂	♂	♂	♂
13.0	92%	Unk	Unk	Unk	Unk	Unk	♂	♂	♂	♂	♂	♂
12.5	94%	Unk	Unk	Unk	Unk	Unk	93%	♂	♂	♂	♂	♂
12.0	♀	Unk	Unk	Unk	Unk	Unk	92%	♂	♂	♂	♂	♂
11.5	♀	91%	Unk	Unk	Unk	Unk	Unk	♂	♂	♂	♂	♂
11.0	♀	93%	Unk	Unk	Unk	Unk	Unk	94%	♂	♂	♂	♂
10.5	♀	♀	Unk	Unk	Unk	Unk	Unk	92%	♂	♂	♂	♂
10.0	♀	♀	90%	Unk	Unk	Unk	Unk	90%	♂	♂	♂	♂
9.5	♀	♀	92%	Unk	Unk	Unk	Unk	Unk	♂	♂	♂	♂
9.0	♀	♀	94%	Unk	Unk	Unk	Unk	Unk	93%	♂	♂	♂
8.5	♀	♀	♀	Unk	Unk	Unk	Unk	Unk	91%	♂	♂	♂
8.0	♀	♀	♀	92%	Unk	Unk	Unk	Unk	Unk	♂	♂	♂
	56	57	58	59	60	61	62	63	64	65	66	67

Wing

Table 2. Rapid classification table of key traits for aging Hawai'i Ākepa. Use multiple trait to determine age, and consult pictures in following section. Both plumage-based and calendar-based age codes are presented for each distinguishable category.

	Juvenal plumage (HY) ♂ = ♀	Formative plumage (HY: Summer/Fall SY: Winter/Spring) ♂ = ♀	Second basic plumage (SY: Summer/Fall TY: Winter/Spring) ♂ ≠ ♀	Definitive basic plumage (ASY: Summer/Fall ATY: Winter/Spring) ♂ ≠ ♀
Molt-cycle age categorization codes	FCJ = first-cycle juvenal (HY)	FPF = preformative molt FCF = first-cycle formative	SPB = second prebasic molt SCB = second-cycle basic	DPB= definitive prebasic DCB= definitive cycle basic
Molt limits in greater coverts (Figs. 2, 4, 9–11, 15, 16)	None; uniformly dull brown with pale olive green edging	Retained juvenal coverts dark brown with faded/ worn yellowish olive edging; replaced coverts dark brown with olive green edging (<i>Note: some may retain all juvenal coverts</i>)	May have mixed retained and replaced coverts, or may be uniformly adult. Replaced coverts have: <u>Male</u> : dull orange edging <u>Female</u> : olive green edging	None; <u>Male</u> : dark brown with broad orange edging <u>Female</u> : dark brown with olive green edging
Molt limits in secondaries (Figs. 2, 4, 9–11, 15, 16)	None; uniformly dark brown with olive green edging	Uniformly retained juvenal secondaries; brown with light olive edging	May have mixed retained and replaced secondaries, or may be uniformly adult. Replaced secondaries have: <u>Male</u> : dull orange edging <u>Female</u> : olive green edging	None; <u>Male</u> : dark brown with broad orange edging <u>Female</u> : dark brown with olive green edging
Body feathers (Figs. 1, 3, 5–8, 12–14)	Olive gray upperparts, greenish beige underparts with gray mottling	Grayish olive, no orange or yellow feathers	<u>Male</u> : 50-75% orange, mottled with grayish olive <u>Female</u> : grayish olive, may have yellow breast band	<u>Male</u> : 100% bright orange <u>Female</u> : olive green upperparts, pale gray underparts, yellow or orange breast band
Supercilium and Auriculars (Figs. 1, 3, 5–7, 12–14)	Pale whitish yellow to pale gray	Pale gray; lighter than crown	More similar to crown, may be slightly paler or mottled with formative feathers	Same color as crown; females have supercilium paler than the crown
Skull	Unossified	HY: unossified; SY: ossified	Ossified	Ossified
Feather wear	Unworn	HY: worn; SY: very worn	SY: unworn; TY: worn	ASY: worn; ATY: unworn

Juvenal plumage—FCJ (HY)



Figure 1: Juvenal plumage, Hawai'i Ākepa
Olive gray upperparts, pale greenish beige underparts with gray mottling. Nape and crown gray, and distinctive pale whitish yellow supercilium, lores, and auriculars.



Figure 2: Juvenal wing, Hawai'i Ākepa
Wing coverts dark brown with olive yellow edging.

Formative plumage—FPF/FCF (HY: Summer/Fall, SY: Winter/Spring)



Figure 3: Formative plumage, Hawai'i 'Ākepa
Upperparts dull grayish olive, underparts and auriculars pale gray, underparts dull grayish olive with no yellow or orange.



Figure 4: Formative wing, Hawai'i 'Ākepa
May have molt limit in greater coverts, but may retain all juvenal coverts and have no molt limit.

Second basic plumage—SPB/SCB (SY: Summer/Fall, TY: Winter/Spring)



Figure 5: Male in second basic plumage, Hawai'i 'Ākepa
Body feathers 50–75% orange, mottled with retained grayish olive feathers.



Figure 6: Female in second basic plumage, Hawai'i 'Ākepa
Upperparts grayish olive, may have indistinct yellow breast band.



Figure 7: Second basic female breast, Hawai'i 'Ākepa
Some individuals may have a narrow, dull yellow breast band.



Figure 8: Upperparts of female in second basic plumage, Hawai'i 'Ākepa

Crown gray, back olive green with no yellow wash.



Figure 9: Second basic male wing — molt limits in greater coverts and secondaries, Hawai'i 'Ākepa

Replaced feathers dark brown with dull orange edging, retained feathers with dull olive green edging.



Figure 10: Second basic male wing – no molt limits, Hawai'i 'Ākepa

May have uniform dark brown coverts and flight feathers with dull orange edging.



Figure 11: Second basic female wing, Hawai'i 'Ākepa

May have molt limits in greater coverts and secondaries, but not always. Replaced feathers with olive green edging, retained feathers with faded or worn buffy yellow edging.

Definitive basic plumage—DPB/DCB (ASY: Summer/Fall, ATY: Winter/Spring)



Figure 12: Male Hawai'i 'Ākepa in definitive basic plumage

Body feathers 100% bright orange.



Figure 13: Female Hawai'i 'Ākepa in definitive basic plumage

Upperparts olive green, often with yellow wash, underparts pale gray with yellow band on breast.



Figure 14: Definitive basic female breast, Hawai'i 'Ākepa

Yellowish orange breast band 5–15mm wide.

The extent of orange varies among individuals. Older females may show more extensive orange plumage than younger females. More study is needed on this subject.





Figure 15: Definitive basic male wing, Hawai'i 'Ākepa

Uniform coverts and flight feathers dark brown with broad orange edging. There may be variation among individuals in extent of orange, which may vary with age.

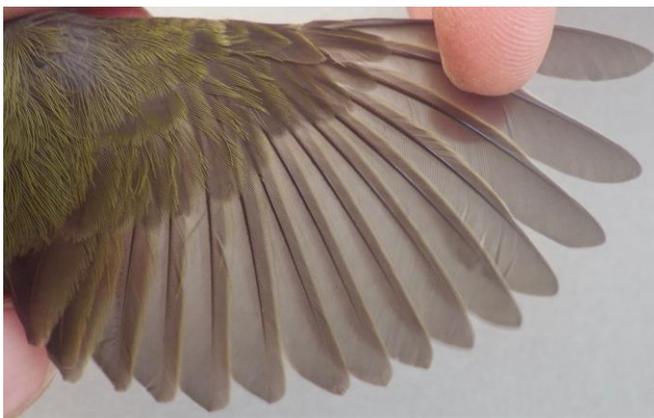


Figure 16: Definitive basic female wing, Hawai'i 'Ākepa

Uniform coverts and flight feathers dark brown with broad, olive green edging.

ʻIʻIWI
(*Drepanis coccinea*)

Band size: 1B
Color band size: XCS

Code: IIWI

9 primaries, 9 secondaries, 12 rectrices

Species: Greenish yellow juveniles to bright red adults with black flight feathers. Not confused with any other Hawai'i forest bird with their unmistakable strongly decurved bill.

3 Plumages:

Juvenal (Figs 1–2): Complete; occurs in nest. Body feathers greenish yellow with black tipping. Flight feathers dull black. Greater coverts dull black with dull yellow edging. Bill brown to orange.

Formative (Figs. 3–7): Incomplete; peak molt occurs June to October. Most to all body feathers replaced red, may retain juvenal feathers on head, nape, throat, and back. Often replace inner greater coverts (some replace none), sometimes replace secondaries among 5–9 (usually in a block), occasionally replace a few primary coverts, but no primaries or rectrices replaced.

Definitive basic (Figs. 8–9): Complete; peak molt occurs June to October. All body and flight feathers replaced. Body entirely scarlet red, flight feathers black, greater coverts black with red edging.

Age: Can be reliably aged by plumage. When separating formative plumage from definitive basic plumage, look for retained juvenal body and flight feathers, as well as molt limits in the wing. However, use caution with calendar year system as birds can breed year-round. Since extent of molt varies among individuals, use multiple aging criteria, such as feather wear or an unossified skull.

Feather wear: While all age classes of birds will start to show worn feathers within a few months of molting, juvenal flight feathers will be much more worn than adult flight feathers. Use caution as the amount of wear varies by individual.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication that it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age. Keep in mind that there may be HY birds at any time of year.

Sex: Monomorphic by plumage; males larger than females, but there is much overlap and is often difficult to discern. Use CP/BP, or morphometric table (Table 1) to separate non-breeding individuals.

Table 2. Rapid classification table of key traits for aging. Use multiple traits to determine age, and consult pictures in following section. Both plumage-based and calendar-based age codes are presented for each distinguishable category.

	Juvenal plumage (HY) ♂ = ♀	Formative plumage (HY: Summer/Fall SY: Winter/Spring) ♂ = ♀	Definitive basic plumage (AHY: Summer/Fall ASY: Winter/Spring) ♂ = ♀
Molt-cycle Classification Codes	FCJ = first-cycle juvenal	FPF = preformative molt FCF = first-cycle formative	DPB = definitive prebasic molt DCB = definitive cycle basic
Molt limit in greater coverts (Figs. 4–7, 9)	None; uniformly dull black with dull yellow edging	Retained outer greater coverts dull black with yellow edging, replaced inner greater coverts black with red edging	None; uniformly black with red edging
Molt limit in primary coverts (Figs. 4–7, 9)	None; uniformly dull black	Retained outer primary coverts dull black, more narrow and worn compared to fresher, black replaced inner primary coverts	None; uniformly black
Molt limit in secondaries (Figs. 4–7, 9)	None; uniformly dull black	Replaced secondaries (usually among secondaries 5–9) black with remaining secondaries retained dull black	None; uniformly black
Body feathers (Fig. 1, 3, 8)	Greenish yellow with black tipping	Retained juvenal feathers on head, nape, throat, and back, mottling with replaced red formative feathers. <i>Note: some individuals replace all body feathers in pre- formative molt</i>	Uniformly scarlet red
Skull	Unossified	HY: unossified SY: ossified	Ossified
Feather wear	Unworn	HY: unworn SY: very worn	AHY: unworn ASY: worn

Juvenal Plumage—FCJ (HY)



Figure 1: Juvenal plumage, 'Iwi
Body feathers greenish yellow with black tipping.



Figure 2: Juvenal wing, 'Iwi
All feathers narrow and dull black, greater coverts with dull yellow edging.

Formative Plumage—FPF/FCF (HY: Summer/Fall, SY: Winter/Spring)



Figure 3: Retained juvenal body feathers, 'Iwi

Red body feathers sometimes mottled with retained juvenal feathers. Look for retained feathers on head, nape, throat, and back.



Figure 4: Formative wing, 'Iwi

Retained feathers narrow and dull black, replaced feathers broader and black. See Figures 5–7 for detailed molt limits.



Figure 5: Molt limit in greater coverts, formative plumage, 'Iwi

Retained coverts very worn and dull black with faded yellow edging, replaced coverts fresher and black with red edging.



Figure 6: Molt limit in primary coverts, formative plumage, 'Iwi

Retained feathers narrow and dull black, replaced feathers broader and black.



Figure 7: Molt limit in secondaries, formative plumage, 'Iwi

Some secondaries may be replaced (often tertials and outer secondaries). Retained feathers dull black, replaced feathers black.

Definitive Basic Plumage—DPB/DCB (AHY: Summer/Fall, ASY: Winter/Spring)



Figure 8: Definitive basic plumage, 'Iwi
Body feathers scarlet red.



Figure 9: Definitive basic wing, 'Iwi
All feathers broad and black, greater
coverts with red edging.

`APAPANE
(*Himatione sanguinea*)

Band size: 1–1B
Color band size: XCS

Code: APAP

9 primaries, 9 secondaries, 12 rectrices

Species: Dull brown juveniles to crimson red adults with white vent. Not confused with any other Hawai'i forest bird with their black decurved bill.

3 Plumages:

Juvenal (Figs. 1–4): Complete; occurs in nest. Upperparts olive brown to buffy brown with no crimson. Underparts pale gray to grayish brown. Secondaries and greater coverts are dull black with edging ranging from buffy brown to rusty olive.

Formative (Figs. 5–7): Partial; peak flight feather molt occurs June to October. Most to all body feathers replaced crimson, may retain juvenal feathers on nape, head, throat and back. Some to all greater and median coverts replaced, but no primary coverts. Tertiaries often replaced, but no other flight feathers.

Definitive basic (Figs. 8–10): Complete; peak molt occurs June to October. All body and flight feathers replaced. Body entirely crimson, undertail coverts white, flight feathers dark black, greater coverts and inner secondaries black with red edging.

Age: Can be reliably aged. When separating formative plumage from definitive basic plumage, look for retained juvenal body and flight feathers, as well as molt limits in the wing. However, use caution with calendar year system as breeding can occur year-round. Since extent of molt and timing of breeding varies among individuals, use multiple aging criteria, such as feather wear or an unossified skull.

Feather wear: While all age classes of birds will start to show worn feathers within a few months of molting, juvenal flight feathers will be much more worn than adult flight feathers. Use caution as the amount of wear varies with age of feathers and by individual.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication that it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age. Keep in mind that there may be HY birds at any time of year.

Sex: Monomorphic in plumage; males larger and more red than females, but there is much overlap and is often difficult to discern. Use CP/BP, or Table 1 to separate non-breeding individuals.

Table 1. Sex determination of adult 'Apapane from morphometric measurements. A logistic regression was used to relate wing (x-axis) and bill length (y-axis) and their interaction to the probability of being either male (orange) or female (blue). High confidence of being a particular sex ($\geq 95\%$ probability) is indicated by appropriate gender symbol; moderate confidence ($\geq 90\%$ to $< 95\%$) is indicated by actual probability; low confidence ($< 90\%$, area of overlap among sexes) is marked "Unk". Logistic regression based on measurements of 417 known males and 280 known females from Hakalau Forest NWR. This table should only be used for adults, as juveniles can have shorter wing and bill lengths.

Bill																				
19.0	♀	♀	♀	94%	Unk	Unk	Unk	Unk	91%	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	
18.5	♀	♀	♀	♀	Unk	Unk	Unk	Unk	Unk	93%	♂	♂	♂	♂	♂	♂	♂	♂	♂	
18.0	♀	♀	♀	♀	91%	Unk	Unk	Unk	Unk	Unk	94%	♂	♂	♂	♂	♂	♂	♂	♂	
17.5	♀	♀	♀	♀	93%	Unk	Unk	Unk	Unk	Unk	Unk	♂	♂	♂	♂	♂	♂	♂	♂	
17.0	♀	♀	♀	♀	♀	90%	Unk	94%	♂	♂	♂	♂	♂							
16.5	♀	♀	♀	♀	♀	93%	Unk	92%	♂	♂	♂	♂	♂							
16.0	♀	♀	♀	♀	♀	♀	91%	Unk	93%	♂	♂	♂								
15.5	♀	♀	♀	♀	♀	♀	94%	91%	Unk	92%										
15.0	♀	♀	♀	♀	♀	♀	♀	94%	92%	Unk										
14.5	♀	♀	♀	♀	♀	♀	♀	♀	♀	93%	91%	Unk								
14.0	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	94%	93%	91%	Unk	Unk	Unk	Unk	Unk	
13.5	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	94%	93%
13.0	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀
	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	Wing	

Table 2. Rapid classification table of key traits for aging. Use multiple traits to determine age, and consult pictures in following section. Both plumage-based and calendar-based age codes are presented for each distinguishable category.

	Juvenal plumage (HY) ♂ = ♀	Formative plumage (HY: Summer/Fall SY: Winter/Spring) ♂ = ♀	Definitive basic plumage (AHY: Summer/Fall ASY: Winter/Spring) ♂ = ♀
Molt-cycle age categorization codes	FCJ = first-cycle juvenal	FPF = preformative molt FCF = first-cycle formative	DPB = definitive prebasic molt DCB = definitive cycle basic
Molt limit in greater coverts (Figs. 2, 4, 7)	None; uniformly dull black with yellowish olive edging	Retained outer greater coverts dull black with buffy yellow edging, replaced inner greater coverts black with red edging (<i>Note: some HY replace all greater coverts in preformative molt</i>)	None; uniformly black with red edging
Molt limit between greater coverts and primary coverts (Figs. 2, 4, 7)	None; all coverts uniformly dull black	Retained primary coverts dull, narrow and worn; replaced greater coverts black, broad and fresh	None; all coverts uniformly fresh and black
Molt limit in secondaries (Figs. 2, 4, 7)	None; uniformly dull black, inner secondaries with buffy yellow edging	Retained secondaries dull black with some or no buffy yellow edging, replaced tertials black with red edging	None; uniformly black secondaries, inner secondaries with red edging
Body feathers (Figs. 1, 3, 6)	Grayish brown	Retained juvenal feathers with yellowish olive edging on head, nape, throat, and back, mottling with replaced red formative feathers (<i>Note: some HY replace all body feathers in preformative molt</i>)	Uniformly crimson
Skull	Unossified	HY: unossified; SY: ossified	Ossified
Feather wear	Unworn	HY: unworn; SY: very worn	AHY: unworn; ASY: worn

Juvenal plumage- FCJ (HY)



Figure 1: Juvenal plumage, 'Apapane
Overall drab grayish brown. Inner secondaries and greater coverts edged buff to yellowish white.



Figure 2: Juvenal wing, 'Apapane
All feathers dull black, greater coverts edged yellowish olive, median coverts tipped buff, primary coverts narrow.

Formative plumage- FPF/FCF (HY: Summer/Fall, SY: Winter/Spring)



Figure 3: Formative plumage, 'Apapane

Crimson body feathers sometimes mottled with retained juvenal feathers. Look for retained feathers on head, nape, throat, and back.



Figure 4: Molt limit in greater coverts, 'Apapane

Retained coverts dull black with buffy yellow edging while replaced inner greater and median coverts black with red edging. Buffy yellow edging is often worn away by the following year. Buffy edging on tertials.



Figure 5: Molt limit in secondaries, 'Apapane

Retained juvenal secondaries (yellow and white edging) contrasting with replaced secondaries (red edging). Juvenal feathers wear more quickly, particularly tertials.

Definitive basic plumage- DPB/DCB (AHY: Summer/Fall ASY: Winter/Spring)



Figure 6: Definitive basic plumage, 'Apapane

Completely crimson body feathers with white vent.



Figure 7: Definitive basic wing, 'Apapane

Black flight feathers; greater coverts with broad red edging, secondaries and tertials edged in red.

RED-BILLED LEIOTHRIX
(*Leiothrix lutea*)

Band size: 1B
Color band size: XCS

Code: RBLE

9 primaries, 9 secondaries, 12 rectrices

Species: Bright yellow and orange on inner primaries, pale buffy to yellow eye ring and lores. Not confused with any other Hawai'i forest bird.

2 Plumages:

Juvenal: Complete; occurs in nest. Upperparts and head olive gray, underparts pale yellow. Dull red and yellow on flight feathers; bill black that changes to red. Appears to molt from juvenal to definitive basic plumage post-fledging; there does not appear to be an intermediate plumage between juvenal and definitive basic plumages, but more study is needed.

Definitive basic: Complete; peak molt occurs July to October. Head and back dull olive green; bright yellow throat and rusty orange breast band, underparts dull yellow. Yellow to red on outer secondaries outward to primaries. White eye ring with white to yellow lores; bill bright red.

Age: Cannot be reliably aged by plumage. Use skull or breeding characteristics to differentiate between HY and AHY.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age.

Sex: Monomorphic; use CP to identify males, or morphometric table for non-breeding individuals. Both sexes develop BPs, so they cannot be used to reliably sex individual.

Table 1. Sex determination of adult Red-billed Leiothrix from morphometric measurements. A logistic regression was used to relate wing (x-axis) and bill length (y-axis) and their interaction to the probability of being either male (orange) or female (blue). High confidence of being a particular sex ($\geq 95\%$ probability) is indicated by appropriate gender symbol; moderate confidence ($\geq 90\%$ to $< 95\%$) is indicated by actual probability; low confidence ($< 90\%$, area of overlap among sexes) is marked "Unk". Logistic regression based on measurements of 209 known males and 125 known females from Hakalau Forest NWR. This table should only be used for adults, as juveniles can have shorter wing and bill lengths.

Bill																
15.0	90%	90%	91%	91%	92%	92%	93%	93%	94%	94%	♂	♂	♂	♂	♂	
14.5	Unk	90%	91%	92%	93%	94%	94%	♂	♂							
14.0	Unk	91%	92%	93%	94%	♂										
13.5	Unk	90%	92%	93%	94%											
13.0	Unk	90%	92%	94%												
12.5	Unk	91%	93%													
12.0	91%	Unk	90%	93%												
11.5	♀	94%	91%	Unk	92%											
11.0	♀	♀	♀	92%	Unk	91%										
10.5	♀	♀	♀	♀	93%	Unk	91%									
10.0	♀	♀	♀	♀	♀	93%	Unk	90%								
	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	
																Wing

Juvenal—FCJ (HY) and Definitive Basic Plumage—DPB/DCB (HY / AHY)



Figure 1: Juvenal Plumage (HY), Red-billed Leiothrix

Upperparts and head olive gray, underparts pale yellow. Dull red and yellow on flight feathers; bill black that changes to red.



Figure 2: Definitive basic plumage (HY/AHY), Red-billed Leiothrix

Head and back dull olive green; bright yellow throat and rusty orange breast band, underparts dull yellow. White eye ring with white to yellow lores; bill bright red.



Figure 3: Definitive Basic wing (HY/AHY), Red-billed Leiothrix

Yellow and orange on outer secondaries outward to primaries.

JAPANESE WHITE-EYE
(*Zosterops japonicus*)

Band size: 0
Color band size: XF

Code: JAWE

9 primaries, 9 secondaries, 12 rectrices

Species: Shouldn't be confused with any other forest bird; distinctive white eye ring. Yellow on throat, chin, and undertail coverts is widely variable and may be related to age, sex, location, or subspecies.

2 Plumages:

Juvenal (Fig. 1): Complete; occurs in nest. Juveniles may fledge with partially bald heads or with head feathers all in pin. Eye ring completes within 3–4 weeks of fledging. Upperparts and head slate gray or dull olive green. Appears to molt from juvenile to definitive basic plumage post-fledging; there does not appear to be an intermediate plumage between juvenile and definitive basic plumages, but more study is needed. Look for potentially retained juvenile feathers on body, wing, and wing coverts on birds with unossified skulls that are no longer in juvenal plumage (Figs. 3, 4)

Definitive basic (Fig. 2): Complete; peak molt occurs July to October. Upperparts and wing coverts olive green, head yellowish green, throat and undertail coverts yellow; underparts pale with dusky brown on flanks and breast. Bold white eye ring broken by black feathers directly in front of eye. Bill and legs black.

Age: Cannot be reliably aged by plumage. Use skull or breeding characteristics to age as HY or AHY. Record any data that may be related to formative plumage, as little is known. Eye color may change with age, but need more investigation.

Skull: Little is known about the time frame of ossification, so use discretion with unossified skulls. In general, if a bird's skull is < 80% ossified, it is usually a good indication it is a HY bird. Some birds (SY or older HY) may retain small windows (between 80–100% ossified), so use other criteria to aid in determining age.

Sex: Monomorphic in plumage and size; use CP to identify males, but both sexes develop BPs, so they cannot be used to reliably sex individuals.

Juvenile—FCJ (HY) and Definitive Basic Plumages—DPB/DCB (HY/AHY)



Figure 1: Juvenal Plumage (HY), Japanese White-eye

Pictured individual is undergoing prebasic molt. Juvenal plumage lacks white eye ring. Note that birds undergo molt and are indistinguishable from adults 30 days after leaving the nest.



Figure 2: Definitive basic plumage (HY/AHY), Japanese White-eye

Upperparts olive green, yellowish green head, buffy flanks, white underparts.

Possible Formative Plumage (HY/SY)



Figure 3: Possible retained juvenal feathers, Japanese White-eye

Some individuals may retain juvenal body or flight feathers during post-fledging molt, with dull greenish or slate gray retained body feathers and olive green replaced feathers. This may indicate presence of a formative plumage, but more study is needed.



Figure 4: Possible molt limit, Japanese White-eye

Some individuals may retain juvenal wing coverts and/or flight feathers, showing molt limits within the tracts with slate gray retained feathers and olive green replaced feathers. More study is needed.

COMPARISON OF HAWAII‘I ‘AMAKIHI, HAWAII‘I CREEPER AND HAWAII‘I ‘ĀKEPA

Table 1. Juvenile and female Hawaii‘i ‘Amakihi, Hawaii‘i Creeper, and Hawaii‘i ‘Ākepa can be easily confused with each other. There may be variability among individuals, so use multiple characters when identifying species.

	Hawaii‘i ‘Amakihi (HAAM)	Hawaii‘i Creeper (HCRE)	Hawaii‘i ‘Ākepa (AKEP)
Juvenal Face	Overall dull gray head, dark gray lores, dark gray eyeline may be present, lacking any patterning on face	Dull light gray head, buffy gray auriculars and supercilium (lighter than crown) and distinctive whitish throat lighter than other species.	Distinct whitish supercilium with overall pale greenish gray face. Dark median crown stripe and whitish forehead sometimes present. Plainer face than HAAM or HCRE.
Bill Shape	More sharply decurved than others, becoming slightly more decurved near distal half of upper bill.	Slightly decurved, shorter, thinner, straighter, and sharper-tipped than HAAM.	Shorter, deeper, wider, and more “finch-like” than others. Tips crossed, but difficult to see in some individuals.
Bill Color	Silver gray overall, upper bill may be darker than lower bill.	Slate gray to pale horn colored, upper and lower mandibles relatively similar in color.	Varies with age; straw yellow to yellowish gray with black tip; lower mandible lighter than upper.
Mask & Lores—adult females in definitive plumage	Dark gray eyeline and lores, thinner than HCRE; extends through and past eyes, but not around the eyes as in HCRE	In adults light to dark gray mask extends across lores and around eyes, giving “raccoon mask” appearance.	No distinctive mask, face and crown same color, although birds may have darker eyeline before reaching definitive basic plumage.
Tail	Tail not forked	Tail not forked	Slightly forked tail.

Table 2. Hawai'i 'Amakihi and Hawai'i Creeper largely overlap one another, but have larger wing and bill lengths than Hawai'i 'Ākepa, and are heavier. For a given wing and bill length (mm), and weight (g), the table provides a probability of being a Hawai'i 'Ākepa versus the other two species based on a logistic regression analysis. Additionally, we used a Tolerance Interval analysis to indicate the range of measurements that we would expect 90% of individuals to be within, with 95% confidence. Individuals with low probability of being Hawai'i 'Ākepa and outside the normal range of measurements are likely either Hawai'i 'Amakihi and Hawai'i Creeper, but note there are substantial overlap in measurements. Use multiple line of evidence to identify species. Measurements are from juvenal and formative plumage individuals captured and measured at Hakalau Forest NWR.

AKEP	98%	96%	90%	80%	64%	43%	25%	13%	6%	3%	1%	1%	0%	0%	0%
	<-----90% of individual AKEP will have wing lengths within this range ----->														
Wing	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
AKEP	100%	100%	99%	96%	82%	47%	14%	3%	1%	0%	0%	0%	0%	0%	0%
	<-----90% of individual AKEP will have bill lengths within this range ----->														
Bill Length	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	15.5
AKEP	99%	96%	76%	30%	6%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	<----90% of individual AKEP will weight within this range ---->														
Weight	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

	Hawai'i 'Amakihi	Hawai'i Creeper	Hawai'i 'Ākepa
Juvenal Plumage			
Formative plumage			
Adult females			