The Wilson Journal *of Ornithology*

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Published by the
Wilson Ornithological Society

The Wilson Journal of Ornithology 123(3):588–594, 2011

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ABSTRACT.—Molt strategies and plumage development by age and gender are poorly understood for resident tropical landbirds. We used data from six banding stations on Saipan, Northern Mariana Islands, and examination of 267 museum specimens to describe patterns of molt and to establish criteria for assessing age and gender of nine native resident landbird species on the island. Feather replacement sequences in the majority of Saipan's resident landbirds were typical of related species. Preformative molts occurred in at least eight of the nine species; these and definitive prebasic molts were incomplete to complete, and prealternate molt appeared to be absent for all species. We developed criteria for classifying gender of sexually dimorphic species using plumage cues, presence of brood patch or cloacal protuberance, and biometrics. We confirmed whether or not both brood patch and cloacal protuberance were reliable indicators of gender during breeding in monomorphic species. Distinct periods or seasons of molt are not well defined and can vary between years. Age classification of first-cycle birds based on molt limits, feather shape and condition, and extent of skull pneumatization is possible for most landbird species sampled on Saipan. *Received 16 September 2010. Accepted 12 January 2011.*

Data concerning molt and plumage development indicate most tropical resident landbird species undergo a single annual prebasic molt that generally follows or partially overlaps their breeding seasons, whereas prealternate molts appear to be rare (Prŷs-Jones 1982; Avery 1985; Pyle et al. 2004; Ryder and Wolfe 2009; Wolfe et al. 2009a, b). Most available data relate to species of the Neotropics, but six species in the Hawaiian Archipelago exhibit a similar trend in seasonal molt strategies (e.g., Banks and Laybourne 1977, Fancy et al. 1993, Jeffery et al. 1993, Pratt et al. 1994, Ralph and Fancy 1994, Simon 1998, VanderWerf 2001). However, comparable literature regarding molt for avian species on oceanic islands in other tropical regions of the Pacific is entirely lacking.

Understanding a population's demographic parameters is critical when developing and implementing species conservation and management strategies (Anders and Marshall 2005, VanderWerf 2008, Saracco et al. 2009). Accurate assignment of age and gender of captured individuals, both of which may be based upon molt strategies, plumage development, and reproductive status is necessary to estimate vital rates of avian species. Vital rates are presently unknown for landbird species on Saipan, an oceanic island in the Mariana Archipelago of the western tropical Pacific Ocean. The Commonwealth of the Northern Mariana Islands' Division of Fish and Wildlife (CNMI-DFW) began collaboration with the Institute for Bird Populations (IBP) in 2007 to initiate the Tropical Monitoring of Avian Productivity and Survivorship (TMAPS) project on the island.

We established six TMAPS banding stations on Saipan in spring 2008 to collect baseline population data for landbirds in several cover types. The ultimate intent of the TMAPS Project on Saipan is to accrue data necessary to guide pre-emptive avian conservation efforts on the island, which focus on several species potentially threatened with extinction or extirpation by potential introduction of the brown tree snake (*Boiga irregularis*). This introduced snake was responsible for extinction or extirpation of nine of 12 species of native forest landbirds on Guam within the last half-century (Savidge 1987, Rodda and Savidge 2007), and is thought to be the single greatest threat to terrestrial ecosystems in the Northern Mariana Islands (Colvin et al. 2005).

We present information on molt and establish criteria for assignment of age and gender based on plumage, skull condition, eye color, wing chord, breeding condition, and relevant morphometric data for nine resident species of landbirds common to Saipan and other islands in the near vicinity. We update preliminary information

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based on specimen examination and initial banding data presented by Pyle et al. (2008).

METHODS

Saipan (15° 12′ N, 145° 45′ E), a tropical Pacific island (122.9 km^2) in the Mariana Archipelago, is characterized by a rugged north-south limestone ridge which reaches an elevation of 436 m with low lying plateaus extending from its base. The island's major habitat cover types are native limestone evergreen forest, tangan-tangan (*Leucaena leucocephala*) scrub, mixed evergreen forests, tropical savannahs, and swordgrass (*Miscanthus floridulus*) thickets. Saipan's climate is marine tropical, hot and humid, and characterized by relatively high and uniform yearly temperatures. A wet season generally occurs from July through October, the last 2 months have increased incidence of typhoons.

CNMI-DFW and IBP established six banding stations on Saipan in 2008 to monitor productivity and survivorship of the island's landbird populations. Stations were specifically placed to facilitate sampling birds in all representative cover types or some combination thereof. Each station comprised 8–10 12-mm mist nets operated one morning during each of nine 10-day periods from 13 April to 17 July 2008 and 11 April to 15 July 2009. We captured 1,778 individuals of nine species of native resident landbirds 2,419 times over the two seasons. Standard measurements and morphometric data were collected for all birds captured; age and gender were assigned to each following criteria in Pyle (1997, 2008; and developed in this paper). We also operated the stations from 20 February to 15 October 2010 and collected additional data on molt, biometrics, and plumage patterns. Pyle reviewed 267 relevant museum specimens (range = 8–53/species) prior to the 2008 TMAPS season to establish preliminary criteria for age and gender classification (Pyle et al. 2008). Most specimens had been collected on Saipan but some were collected elsewhere in the Mariana Islands or Micronesia, provided they represented the same species and subspecies occurring on Saipan. The gender of most specimens examined had been previously established by gonadal examination; these specimens formed the basis for gender-specific measurement and plumage differences reported. Criteria for gender classification were further assessed based on presence or absence of reproductive characters (brood patch and cloacal protuberance) in birds captured during presumed periods of breeding for each species on Saipan.

Molt and plumage terminology is based upon Howell et al.'s (2003) revision of Humphrey and Parkes (1959) nomenclature, while feather-tract and age terminologies, flight-feather numbering, and other abbreviations follow Pyle (1997, 2008). Primaries and primary coverts are numbered from the innermost (primary 1) to outermost (primary 9 or 10), secondaries from the outermost (secondary 1) to innermost tertials (secondary 9, 10, or 11), and rectrices from the central pair (rectrix 1) to the outermost pair (rectrix 5 or 6). Abbreviations used include: PF = preformative (formerly considered 'first prebasic') molt, DPB = definitive prebasic molt, BP = brood patch, and CP = cloacal protuberance.

Accurate age classification may be complicated by an apparent lack of distinct, calendar-year breeding seasonality of birds on Saipan, a trait that can be exhibited by species resident in tropical latitudes (Wolfe et al. 2009a, b). Thus, age diagnostics and classifications follow the molt-cycle-based system devised by Wolf et al. (2010) for tropical species and include: FCJ, a bird in its first molt cycle and entirely in juvenal plumage; FCF, a bird in its first molt cycle and in formative plumage (or having begun the preformative molt); SCB, a bird in its second molt cycle (or having begun the second prebasic molt) and in basic plumage; TCB, a bird in its third molt cycle (or having begun the third prebasic molt) and in basic plumage; and DCB, a bird in its definitive molt cycle (or having begun the definitive prebasic molt) and in basic plumage.

We report our findings of molt and classification of age and gender for nine of 14 native landbirds resident to Saipan, four of which are endemic to the Mariana Archipelago. Sample sizes for each species indicate the number of specimens examined, the number of individuals captured and processed, and the total number of individual captures. We report feather-replacement sequence as 'typical' if it proceeded distally from primaries 1 to 10, and proximally from secondaries after the tertials had been replaced (*cf.* Pyle 1997); the two doves showed an extra center at secondary 5 as is typical in diastitaxic birds (Pyle 2008). We did not detect evidence of prealternate molts in any species.

RESULTS

White-throated Ground Dove (*Gallicolumba xanthonura*; n = 21 specimens, 38 individuals, 43 captures). Both PF and DPB are incomplete to

TABLE 1. Select biometrics useful for gender classification for nine species captured on Saipan, 2008–2009, including 267 museum specimens examined prior to initial field work in 2008. Mass of Mariana Fruit Dove and female Nightingale Reed Warbler was excluded because of small sample sizes.

		Male		Female	
Species	Measurement	Mean ± SD (*n*)	Range	Mean ± SD (*n*)	Range
White-throated Ground Dove	Wing chord (mm)	142.3 ± 6.0 (26)	130–152	132.8 ± 4.2 (26)	126–141
	Mass (g)	114.4 ± 13.8 (15)	100.9–139.7	100.3 ± 10.4 (18)	78.5–126.1
Mariana Fruit Dove	Wing chord (mm)	127.9 ± 2.9 (18)	124–137	123.3 ± 2.9 (14)	118–128
Collared Kingfisher	Wing chord (mm)	113.6 ± 3.1 (24)	108–118	116.2 ± 3.2 (29)	110–125
	Mass (g)	79.3 ± 5.4 (16)	66.4–86.1	84.3 ± 5.6 (19)	75.4–94.8
Micronesian Myzomela	Wing chord (mm)	71.8 ± 2.9 (72)	62–79	64.9 ± 1.9 (45)	61–73
	Mass (g)	14.2 ± 1.5 (56)	10.0–17.5	11.8 ± 1.5 (37)	9.9–16.8
Rufous Fantail	Wing chord (mm)	67.3 ± 1.6 (67)	62–70	65.0 ± 1.5 (94)	60–69
	Mass (g)	8.2 ± 0.4 (56)	7.1–9.0	7.9 ± 0.6 (81)	6.8–9.5
Nightingale Reed Warbler	Wing chord (mm)	87.6 ± 2.2 (9)	84–91	82.0 ± 2.9 (4)	79–86
	Mass (g)	34.6 ± 1.0 (4)	33.5–35.5		
Bridled White-eye	Wing chord (mm)	52.3 ± 1.6 (64)	48–61	51.5 ± 1.4 (70)	49–55
	Mass (g)	7.4 ± 0.5 (48)	6.1–8.7	8.0 ± 0.7 (59)	6.6–9.6
Golden White-eye	Wing chord (mm)	75.3 ± 3.1 (125)	64–83	70.5 ± 2.7 (90)	63–78
	Mass (g)	20.3 ± 1.7 (113)	14.7–25.1	16.2 ± 1.5 (80)	13–21
	Culmen (mm)	15.6 ± 0.8 (35)	14.4–16.4	13.1 ± 0.7 (17)	11.4–14.2
	Nares to tip (mm)	10.5 ± 0.6 (35)	9.8–12.2	8.9 ± 0.4 (21)	8.0–9.5
Micronesian Starling	Wing chord (mm)	129.5 ± 3.6 (26)	124–137	121.0 ± 2.6 (16)	115–124
	Mass (g)	84.8 ± 3.0 (13)	78.7–88.0	80.8 ± 9.0 (4)	72.1–93.2

complete. One to three secondaries between secondaries 1 and 7 (of 11 total) can be retained during both PF and DPB. FCF birds often exhibit limits between formative and juvenal secondaries and, at times, within the greater coverts. Older birds often have one generation of feathers but can show retained juvenal (in SCB birds) or definitive (in TCB or older birds) secondaries, often among secondary 4 and secondaries 7–9. Juvenile females are brown with a broad cinnamon tail band and broad rufous to cinnamon edging on the primary and secondary coverts. DCB females are similar to juveniles in appearance but have narrower and paler edging on the primary and secondary coverts. Juvenile males are similar to juvenile females but lack a cinnamon tail band. FCF males are distinctive and have variable amounts of gray on the head and nape, and white on the throat and breast. The grayish-brown juvenal body plumage is largely retained and mottled with purple formative feathers on the back. DCB males have brown body plumage with purplish and copper iridescence on the back and wings, and varying amounts of white on the head, throat, and upper breast. The amount of white plumage in males may be age-dependent with more brown or gray mottling in younger (e.g., SCB and TCB) birds and less in older birds, but confirmation of plumage maturation rates is needed. Both males and females may have BPs and biometrics may be helpful with ascertaining gender (Table 1).

Mariana Fruit Dove (*Ptilinopus roseicapilla*; *n* = 33 specimens, four individuals, four captures). Both PF and DPB are incomplete to complete. Most apparent limits in the primaries or secondaries may be due to protracted or suspended molt, but retention of one to three secondaries (of 10 total) during incomplete molt also occurs, most often among secondaries 7 and 8. Juvenal primary 10 is thick, rounded, and dull brown in juveniles (FCJ) and molting FCF birds, and the juvenal rectrices and secondaries are narrow. Primary10 in DCB and complete FCF birds is thinner and more pointed, and the rectrices and secondaries are broader. Older DCB birds (at least TCB) can show mixed generations of definitive secondaries. FCF and DCB males have more extensive magenta on the crown, a bluish-tinge on the nape, and a broader yellow tail band whereas FCF and DCB females have less magenta in the crown, little to no bluish-coloring on the nape, and a faint yellow tail band. Both males and females may have BPs and biometrics appear to be of limited use for assigning gender (Table 1).

Collared Kingfisher (*Todiramphus chloris*; *n* = 17 specimens, 72 individuals, 91 captures). PF is absent and the DPB is complete and proceeds in typical sequence. Juveniles exhibit white scalloping on the secondary coverts and light gray scalloping on the breast. The covert scalloping is more reliable for assigning age of worn birds than the breast scalloping, which can wear off. The blue or turquoise color on the inner vane of the flight feathers is reduced in juveniles, whereas in adults the coloring extends almost to the edge of the feather on both the inner and outer vanes. Females have greenish-olive backs and turquoise-green wings, tail, and eye-stripe, whereas males have turquoise backs and bright blue wings, tail, and eye-stripe. These plumage traits occur in all age classes but colors average brighter in DCB than in FCJ individuals. Juvenal outer primaries are narrow and tapered, whereas basic primaries are broad but are, on average, narrower for females than for males. Females exhibit BPs, which may also occur for males. It is not known whether CPs occur in males. Biometrics suggests slight reverse sexual size dimorphism and appears to be of limited use for assigning gender (Table 1).

Micronesian Myzomela (*Myzomela rubratra*; $n = 32$ specimens, 121 individuals, 142 captures). The PF is incomplete to complete and includes body feathers, secondary coverts, and some to all primaries, secondaries, primary coverts, and rectrices in typical sequence. The DPB is complete but can be protracted and suspended. Juveniles (FCJ) often exhibit fleshy yellow gapes and have not yet initiated molt. Contrasts are often observed between inner primaries and outer secondaries due to protracted and/or suspended molt and normal fading and wear. FCF individuals often retain blocks of middle secondaries, and, less often, outer primaries and primary coverts, which are more tapered, worn, and faded than replaced feathers. FCF females have brown formative flight feathers and mottled brown and red body plumage, whereas FCF males have dark brown formative flight feathers and red body plumage mottled brown. DCB birds have one feather generation, although a gradient of fading and wearing is often evident within the primaries and secondaries. DCB females can be quite red with brown mottling and medium brown wings while DCB males are bright red with black wings. Plumage is useful for assigning age and gender, whereas biometrics appear to be of little help with the latter (Table 1). The extent of skull pneumatization is difficult to ascertain because of the species' dark, non-transparent skin. BPs and CPs are reliable for classification of males and females during breeding periods.

Rufous Fantail (*Rhipidura rufifrons*; $n = 41$ specimens, 821 individuals, 1,299 captures). The PF is usually partial and includes some body feathers, some to all (range = 2–9) greater coverts and, at times, the carpal covert. Some individuals undergoing a complete molt in September–October 2010 appeared to be young and were possibly undergoing a complete PF but may also have been hatched in late winter and undergoing a second prebasic molt after a PF in the spring. The DPB is complete but can be protracted and/or suspended. Molt can be in typical sequence or occasionally primaries can commence replacement within the tract and proceed both proximally and distally. Juvenal greater coverts, and occasionally carpal covert and alula, are brown with distinct rufous-buff tips and edging that fade with age, whereas basic coverts are uniformly brown with or without thin rufous edging. FCF in both males and females shows molt limits within the greater coverts, between the outer greater coverts and the carpal covert, or occasionally between the carpal covert and the alula. Neither males nor females show suspension limits or molt clines in the primaries, as can be shown by DCB individuals. Juvenal flight feathers and primary coverts on FCF birds are duller brown and more tapered than basic feathers on DCB birds. Extent of skull pneumatization can be useful for assigning age classes. Juveniles exhibit large skull windows that slowly pneumatize resulting in small windows being visible in some FCF individuals post-PF; skulls in all DCB individuals are completely pneumatized. Males and females are similar in both plumage and biometrics (Table 1), but both CPs and BPs are reliable for assigning gender of breeding birds.

Nightingale Reed Warbler (*Acrocephalus luscinius*; $n = 8$ specimens, 14 individuals, 17 captures). Both PF and DPB are complete and appear to proceed in typical sequence. FCJ and DCB are similar, but juvenal primaries and secondaries are slightly more rounded and rectrices are thinner and more tapered than basic rectrices. Skulling can be reliable for separating FCJ and FCF birds but timing of reliability needs to be examined. Sample sizes are small, but wing chord may be useful for assigning gender; some overlap likely occurs (Table 1). BPs and CPs are useful for assigning gender of breeding individuals.

Bridled White-eye (*Zosterops conspicillatus*; *n* = 53 specimens, 360 individuals, 389 captures). The PF is complete to incomplete and DPB is complete. Feather-replacement sequence among primaries (at least) appears to be irregular. Incomplete PF includes all body feathers, all wing coverts, and most flight feathers, with some FCF individuals retaining small blocks of juvenal secondaries. The DPB occurs primarily post-breeding, but potentially can occur before or during the breeding season. FCF and DCB of both males and females are similar in size and plumage following the PF, but FCF can often be identified by extent of skull pneumatization (timing of reliability needs to be examined). Males and females are similar in plumage and metrics (Table 1; the apparent dimorphism in mass is likely an artifact of assigning gender by breeding condition only; i.e., heavier females were gravid) but CP and BP are reliable for assigning gender during breeding seasons.

Golden White-eye (*Cleptornis marchei*; *n* = 16 specimens, 324 individuals, 410 captures). The PF is partial and the DPB is complete; the feather-replacement sequence may or may not be irregular as in Bridled White-eye. The PF includes body feathers and possibly some lesser, median, and inner greater coverts on some birds. Replaced feathers are darker and more yellowish-green than retained greenish-brown juvenal feathers, the latter becoming increasingly faded and worn as the plumage ages. DCB birds have yellow heads, orange bills, and yellowish-green wing and back plumage. Juveniles have white mottling and paler yellow feathers on the head and face prior to the PF, and often have largely unpneumatized skulls. Very young juveniles exhibit dusky coloring at the base of the bill and, at times, on the tarsi. Some FCF birds also have partially unpneumatized skulls, but timing of reliability in relation to PF needs to be examined. Length of wing chord, exposed culmen, and nares to tip of bill are useful for assigning gender (Table 1). BPs and CPs are reliable for assigning gender during breeding, although some males can develop partial BPs.

Micronesian Starling (*Aplonis opaca*; *n* = 46 specimens, 24 individuals, 24 captures). The PF is partial and the DPB is complete and proceeds in typical sequence. The PF includes body feathers and some lesser and median coverts. Juveniles (FCJ) and FCF are dark with lighter-streaked breast and belly feathers. DCB individuals are glossy black with males being glossier than females. Wing chord and CP/BP (during breeding) are reliable for assigning gender (Table 1).

DISCUSSION

We provide previously unknown information on molt patterns and age and gender delineation for nine species of resident landbirds that commonly occur on Saipan. Our data indicate that molt strategies of most birds captured on the island are like those of resident landbirds in other tropical locations (Banks and Laybourne 1977; Prŷs-Jones 1982; Avery 1985; Fancy et al. 1993; Jeffery et al. 1993; Pratt et al. 1994; Ralph and Fancy 1994; Simon et al. 1998; VanderWerf 2001; Pyle et al. 2004; Ryder and Wolfe 2009; Wolfe et al. 2009a, b) and in North American temperate locations (Pyle 1997, Howell et al. 2003). Preformative molt occurred in all species except Collared Kingfisher, while definitive prebasic molt was incomplete to complete across all nine species and prealternate molt appeared to be absent.

Separation of birds in juvenal, formative, and definitive plumages was possible for all nine landbird species captured on Saipan, based upon plumage patterns, molt limits, feather shape and condition, and extent of skull pneumatization; some individuals of the two dove species can be identified in third-basic or later plumages. Accurately classifying age of resident birds on Saipan, similar to resident species in most other tropical locations (e.g., Wolf et al. 2009a, b), can be challenging because of a lack of distinct seasonality in breeding and the difference in breeding season duration when compared to their temperate counterparts. Breeding and molt were observed to overlap in at least one species (i.e., Bridled White-eye) and timing of molt and breeding between 2008 and 2009 was not consistent. Some species on Saipan are known to breed more than once in a calendar-year or to be capable of breeding year-round (e.g., Craig 1996, Mosher and Fancy 2002). The temperate calendar-based age classification system could not properly be used to classify age of birds captured on Saipan. Likewise, the months in which age classes could be reliably ascertained (i.e., 'age brackets'; Wolfe et al. 2010) for each species cannot yet accurately be estimated. We need more data to establish age brackets for each species, which will be used in combination with calendar-based age codes and information on molt strategies and breeding seasons, to most accurately reflect age of individuals and age structure within populations.

Criteria presented to discriminate age class and gender serve as a baseline for assessing vital rates of the majority of avian species on Saipan. This improves our ability to guide targeted conservation strategies, including species conservation introductions or translocations (IUCN 1987, 1998) to establish self-sustaining, satellite populations on islands in the Mariana Archipelago safe from the brown tree snake. DFW currently executes conservation measures for avian species in the Marianas with little or no baseline natural history information to guide decision making. The ability to accurately identify gender of individuals will help ensure even sex ratios during translocation, increasing the long-term success of such efforts. Knowledge of which cover types promote the best overall survival, productivity, and recruitment in landbird populations on Saipan should enable us to better match species with suitable islands and increase the likelihood of success of translocation strategies in the Northern Mariana Islands.

ACKNOWLEDGMENTS

We thank the U.S. Fish and Wildlife Service for funding (via the State Wildlife and Wildlife Restoration Grants) necessary to establish and operate TMAPS on Saipan. Staff at the Museum of Vertebrate Zoology, Berkeley, California; Brigham-Young University at Hawaii, Laie, Hawaii; and B. P. Bishop Museum, Honolulu, Hawaii assisted Pyle with specimen examination. We thank Sylvan Igisomar, Gayle Martin, and Laura Williams of CNMI-DFW for securing project funds; Julie Duenas and Kathy Yuknavage of the CNMI Coastal Resource Management Office for guidance with land ownership to assist in TMAPS station site selection; James Junda, Caroline Poli, Nathan Banfield, Lauren Helton, and Daniel Webb for collecting supplemental capture data; and Jim Saracco, David DeSante, and Rodney Siegel of IBP for logistical and administrative support. We thank C. E. Braun, E. A.VanderWerf, and an anonymous reviewer for valuable suggestions and editing of this manuscript. This is contribution Number 401 of The Institute for Bird Populations.

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