

Short Communications

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Observations of Molt in an Endangered Rallid, the Hawaiian Moorhen

David W. DesRochers,^{1,3} Luke K. Butler,¹ Michael D. Silbernagle,² and
J. Michael Reed¹

ABSTRACT.—We used field and museum data to describe timing of flight feather molt in the endangered Hawaiian Moorhen (*Gallinula chloropus sandvicensis*). We evaluated 80 adults captured a total of 107 times at two study sites on Oahu from April 2005 to August 2007. Eighty-five of the birds were not molting, 13 had abraded remiges, and eight of the nine molting adults examined were simultaneously replacing their primaries, secondaries, and upper and lower wing coverts. We also scored molt for 28 Hawaiian Moorhen specimens from three museum collections, but no birds were molting. Molt in Hawaiian Moorhens, which lasts about 30 days, was not synchronous across individuals with molting birds recorded from June to September in the field. We observed non-molting individuals throughout the year including birds we captured and museum specimens. Molting and non-molting birds had similar body condition, as defined by mass/tarsometatarsal length. The flightless period during molt, which likely lasts about 25 days, may increase predation risk, a serious concern in Hawaii where introduced terrestrial predators pose a major threat to moorhen populations. Received 8 May 2008. Accepted 2 July 2008.

Understanding avian molt patterns is important because birds require significant energetic and protein resources to produce the new plumage (Panek and Majewski 1990, Earnst 1992, Murphy and King 1992, Bonier et al. 2007). Birds experience decreased flight performance during replacement of wing and tail feathers (Swaddle and Lockwood 2003). Some rallids and waterfowl replace all of their flight feathers simultaneously (Hohman et al. 1992, Taylor 1998) which, in some species can leave a bird flightless for >5 weeks (e.g., Summers 1983). Predation risk may be partic-

ularly high for species that exhibit this molt pattern (Panek and Majewski 1990). Consequently, many species exhibiting simultaneous replacement of flight feathers migrate to molt in refugia that provide both high food resources and low predation risk (e.g., Taylor 1995, Stout and Cooke 2003).

We describe flight feather molt in the volant Hawaiian Moorhen (*Gallinula chloropus sandvicensis*), a rallid listed as endangered under the U.S. Endangered Species Act and which is restricted to coastal wetlands on the islands of Kauai and Oahu (Taylor 1998, U.S. Fish and Wildlife Service 2005). Little is known about how, when, or where molt occurs in this species. Basic molt information has been published on the European (*G. c. chloropus*) and African (*G. c. meridionalis*) subspecies (Grant 1914, Fagan et al. 1976), but it is unknown whether individual or seasonal patterns are consistent across subspecies. Our objectives were to: (1) report numbers of primaries, secondaries, and rectrices, (2) estimate the duration of flightlessness and molt, (3) describe the timing of molt, and (4) test for differences in body condition between molting and non-molting birds. We also discuss molt in relation to the behavioral ecology and conservation of this species because, when birds are flightless, they are incapable of short, eruptive flights, which is one of their primary predator-escape tactics (Bannor and Kiviat 2002).

METHODS

Field Data.—Birds were captured from April 2005 to July 2007 (with the exception of Jun–Jul 2006) at James Campbell National Wildlife Refuge (James Campbell) (21° 41' N, 157° 55' W) and Waimea Falls Audubon Center (Waimea) (21° 38' N, 158° 63' W), which are both on Oahu. We categorized primaries as abraded, absent, growing, or completely new (fresh without sheath remnant) from June

¹ Department of Biology, Tufts University, Medford, MA 02155, USA.

² Oahu National Wildlife Refuge Complex, U.S. Fish and Wildlife Service, 66-590 Kamehameha Highway, Room 2C, Haleiwa, HI 96712, USA.

³ Corresponding author; e-mail: DavidW.DesRochers@gmail.com

to July 2007. It was necessary to score molt rapidly because of strict handling time limitations on these endangered birds. We approximated completeness of molt remiges in increments of 25% (e.g., 0–25, 26–50%, etc.) to shorten handling time, adapting the method of Newton (1966). We scored secondaries, tertials, rectrices, wing and rectrix coverts, and body and head feathers as molting or not molting.

Museum Data.—We investigated molt in museum specimens at the Harvard Museum of Comparative Zoology ($n = 12$), American Museum of Natural History ($n = 9$), and the Smithsonian National Museum of Natural History ($n = 7$). Specimens were collected across the species' historic range (Hawaii, Kauai, Maui, Molokai, and Oahu) from the 1890s to 1900s with a single specimen collected in 1981. We also counted numbers of primaries, secondaries, and rectrices on two moorhen carcasses provided by the U.S. Geological Survey in Hawaii.

We estimated duration of flightlessness and calculated this period using an equation developed for ducks ($n = 8$ species, $r = 0.97$) (Dean 1978): duration of flightlessness (in days) = $0.071 \cdot \text{wing length (mm)} + 13.45$. Wing length refers to wing chord length (based on Dean's [1978] wing length data and Madge and Burn [1988]). We used mean wing chord length from wild adults captured in our study to calculate the duration of flightlessness for Hawaiian Moorhens. We used the longest value when we had multiple measurements from the same individual, assuming that shorter measurements reflected feather wear. We estimated duration of molt using the mean length of the longest primary (P8) from two adult Hawaiian Moorhens, an average growth rate for moorhen primaries of 5.15 mm/day (Fagan et al. 1976), plus 2 days required for blood quills to emerge after feather shedding (Panek and Majewski 1990). We gathered data on when birds were molting during the year, but our research protocol did not allow for uniform capture effort across the year.

We tested the hypothesis that mean body condition index (BCI = body mass/tarsometatarsal length) (Freeman and Jackson 1990) of molting birds differed from non-molters. We made two separate comparisons of BCI because we did not know precisely when birds

with highly abraded feathers would begin molting. We first compared BCI between molting and non-molting birds, including those with abraded feathers, and then combined molting birds and those with abraded feathers. We excluded a bird from analysis if a subsequent capture occurred within 30 days to ensure sample independence. We used a t -test (proc ttest) in SAS Version 9.1.3 to compare BCI.

There might be concern that growing neighboring feathers represent replacement of accidentally-lost feathers rather than replacement as part of a simultaneous molt. This did not appear to be a problem because we presumed that symmetrical wing feather replacement was unlikely to be accidental, and all wing molters were replacing feathers on both wings. In addition, one of two birds molting rectrices was also molting other regions of the wings or body symmetrically. Thus, we presumed this bird was in molt and not replacing accidentally-lost feathers.

RESULTS

We captured 80 adult moorhens, and recaptured 19 at least 30 days apart (range: 2–4 recaptures/individual) for a total of 107 captures. Eighty-five of 107 adults captured were not molting, 13 had abraded remiges, and nine were molting. We captured molting moorhens from June to September and birds with highly abraded feathers in February, May, June, August, and October to December. We also caught non-molting adults in every month except March (Fig. 1). Images of molting and non-molting birds, and individuals with abraded remiges can be viewed at <http://ase.tufts.edu/biology/labs/reed/res-pub-suppl.html>.

We scored primary molt for 11 adults captured at James Campbell from June to July 2007. Six of the birds did not appear to be molting, and the other five were in various stages of molt (Table 1). One of the five molting birds had abraded remiges and was molting some of its rectrices. Two birds were simultaneously molting their remiges (<25% complete), including all upper and lower wing coverts. One of these two molters had remiges growing simultaneously while the second bird's remiges and coverts were not being replaced in a systematic order. The two other moorhens had completed the majority of their

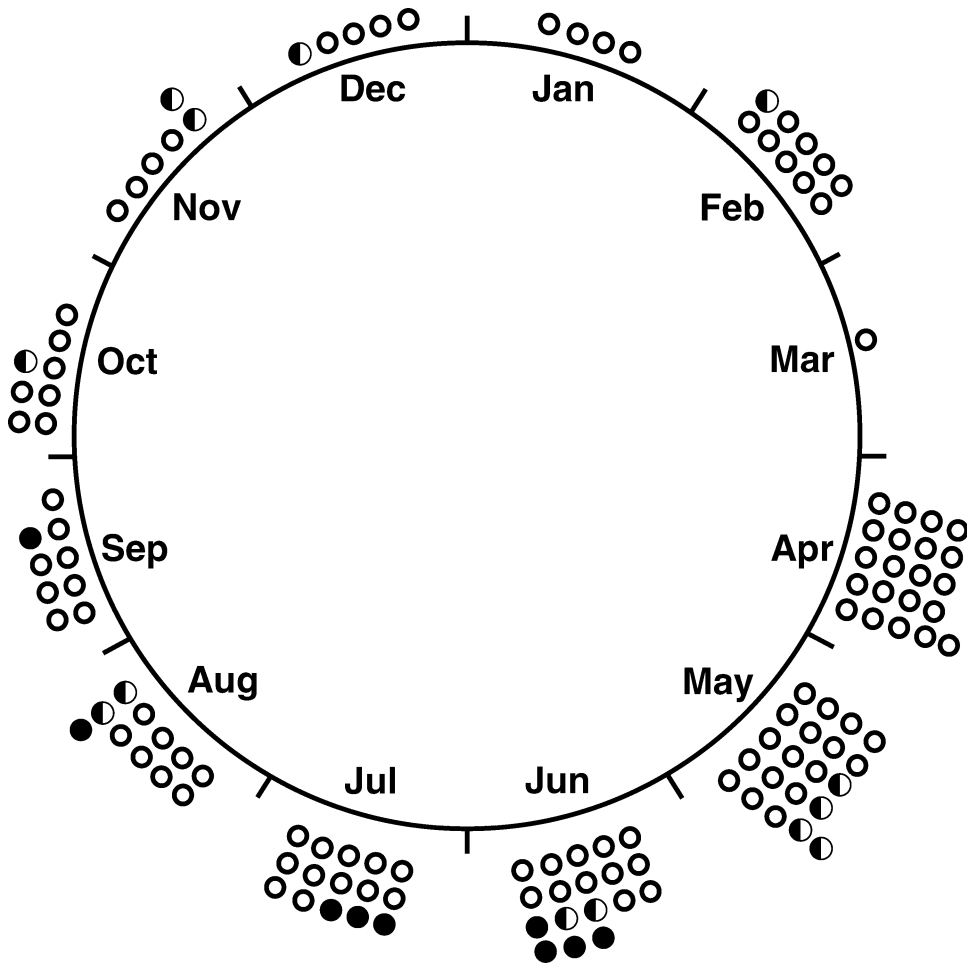


FIG. 1. Molt status of Hawaiian Moorhens captured at James Campbell National Wildlife Refuge and Wai-
mea Valley Audubon Center, Oahu, Hawaii, and museum specimens from Harvard Museum of Comparative
Zoology, American Museum of Natural History, and Smithsonian National Museum of Natural History. Closed
circles = molting birds, half-circles = birds with worn remiges, and open circles = non-molting birds.

TABLE 1. Qualitative assessment of molt for five adult Hawaiian Moorhens captured at James Campbell
National Wildlife Refuge. Molt score adapted from Newton (1966) is given for left and right primaries. Values
were the same for the left and right wings. Yes = molt was between 0 and 100% complete. No = no discernible
sign of current or recent molt.

Date (2007)	Primaries	Secondaries	Tertials	Wing coverts	Rectrices	Rectrix coverts	Body Dorsal	Ventral	Head
26 Jun	0–25%	Yes	Yes	Yes	No	No	No	No	No
27 Jun	0–25%	Yes	Yes	Yes	Yes	No	No	No	No
2 Jul	Complete	Complete	Complete	Complete	Complete	Yes	No	No	No
3 Jul	Complete	Complete	Complete	Complete	Complete	Yes	No	No	No
3 Jul	Abraded	Abraded	Abraded	Abraded	Yes	No	Yes	No	No

molt with only the undertail coverts still growing, and all other feathers new. One non-molter had new flight feathers and no sheath wax was present, three had recently completed molt, which was apparent from the sheath wax found throughout the birds' plumage, and two had exceptionally abraded flight feathers.

We observed slight to moderate wear on flight feathers for 12 of 28 (43%) moorhens in museum collections; 10 had no noticeable feather abrasion, and six birds were missing date of collection. Specimens with light to moderately abraded wing feathers, faded tips, and barbs missing from about the distal 1 cm of rachis occurred in every month except July and September (Fig. 1).

Hawaiian Moorhens have 10 primaries, eight secondaries (confirmed by investigating ulnar attachment points), and 12 rectrices. Mean adult moorhen wing chord length (not flattened) was 170.8 ± 8.7 mm (\pm SD; $n = 80$ birds). We estimated that moorhens would be flightless for 25 days after molting their flight feathers using this value. We estimated that molt would take 30 days to complete based on an average length of primary 8 of 142.2 ± 1.2 mm ($n = 4$ feathers from 2 birds).

There was no significant difference in mean body condition between molting and non-molting birds. The BCI for non-molting + abraded feathers was 5.68 ± 0.68 , $n = 98$, while BCI for molting birds was 6.01 ± 1.07 , $n = 9$ ($t_{105} = -1.31$, $P = 0.19$). The BCI for non-molting birds was 5.59 ± 0.82 (mean \pm SD), $n = 85$, and for molting + abraded feathers: 5.24 ± 1.20 , $n = 22$ ($t_{105} = 0.70$, $P = 0.48$).

DISCUSSION

Hawaiian Moorhens typically molt all of their flight feathers and associated wing coverts simultaneously; all but one bird in our study with molting flight feathers was molting them simultaneously. This is consistent with the simultaneous flight feather molt reported for European and African subspecies of Common Moorhen (*G. c. chloropus* and *G. c. meridionalis*) (Grant 1914, Fagan et al. 1976, Cramp and Simmons 1980). Numbers of the different types of flight feathers of Hawaiian Moorhens are within the range reported for other rail species (Proctor and Lynch 1993).

Molt in Hawaiian Moorhens, based on our

data, appears to occur primarily from June through September. One possible explanation for this timing is that molt in Hawaiian Moorhens may follow breeding, as has been observed in northern populations of the European subspecies of Common Moorhen, where breeding is seasonal (Cramp and Simmons 1980). Post-breeding simultaneous flight feather molt also occurs in other rallids (e.g., some *Rallus*, *Porphyrio*, and *Fulica* spp. [Taylor 1998]). Most of these examples are from species that are considered seasonal breeders. It would be reasonable, therefore, to test whether molt in Hawaiian Moorhens tends to follow peak breeding time. Unfortunately, Hawaiian Moorhens can breed at any time of the year (Byrd and Zeillemaker 1981, U.S. Fish and Wildlife Service 2005) and, although peaks have been reported, they can occur almost any time of year. Peak breeding has been reported from March–August (Shallenberger 1977) and April–June (Byrd and Zeillemaker 1981); bimodal peaks have been reported in February and November (Nagata 1983), March and October (Chang 1990), and April and December (MDS, unpubl. data). Taylor (1998) suggests timing of molt in tropical rail species is irregular and may not be associated with end of the breeding season. Consequently, we were not able to test an *a priori* hypothesis about timing of molt relative to peak breeding, and it appears that identifying the relative timing of breeding and molt in Hawaiian Moorhens will require tracking individually marked birds.

We estimate that Hawaiian Moorhens complete their primary molt in ~ 30 days. This estimate is slightly higher than the 20–27 days required to complete molt for the African subspecies (Fagan et al. 1976) but is well within estimated molt rates for nine other rail species (range: 21–54 days) reported by Taylor (1998). We predict Hawaiian Moorhens are capable of flight 25 days after onset of molt if this subspecies matches flight capability of waterfowl that undergo the same molt pattern (Dean 1978). We predicted molt would be associated with a change in body condition, either poorer condition due to the costs of molt or better condition if birds added mass before molting, but body condition was unrelated to molt.

Flightlessness from simultaneous replace-

ment of primaries leaves molting birds vulnerable to predation. Moorhens typically use two escape tactics to evade predators: running into vegetation (Greij 1994) and short, eruptive flights (Bannor and Kiviat 2002). Running is unlikely to be affected by loss of flight feathers during molt because moorhens do not flap their wings during escape runs (DWD, pers. obs.). However, the inability to fly is likely to increase predation risk (McLennan et al. 1996) because short, eruptive flight is a common behavior in Hawaiian Moorhens in response to threats. In addition, Hawaiian Moorhens flap their wings to escape a predator (DWD, pers. obs.). Introduced mammalian predators, including rats (*Rattus* spp.), house cats (*Felis catus*), domestic dogs (*Canis familiaris*), and small Indian mongoose (*Herpestes javanicus*), pose serious threats to molting moorhens in Hawaii (U.S. Fish and Wildlife Service 2005). Steadman (2006) posits that as many as 1,600 flightless rail species have gone extinct in the tropical Pacific, including species in Hawaii, partly due to introduced predators associated with human colonization.

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Habitat Associations and Nests of Band-tailed Antbirds (*Hypocnemoides maculicauda*) in the Brazilian Pantanal

João Batista de Pinho,^{1,4} Leonardo Esteves Lopes,² Marcos Maldonado-Coelho,³
Tatiana Colombo Rubio,¹ and Bianca Bernardon¹

ABSTRACT.—We studied the habitat association of Band-tailed Antbirds (*Hypocnemoides maculicauda*) in four forest types in the Brazilian Pantanal between 1999 and 2006. Birds were sampled with standardized mist nets during 20 months and point count censuses during 14 months. Band-tailed Antbirds exhibited a preference for seasonally flooded forests (*Landi* and *Cambarazal*) with no capture or detection in drier forests (*Cordilheira* and *Carvoeiro*), even during the wet season. We found no evidence of regular local movements between different forest types. The 21 recaptures were normally in the same forest patch as capture, indicating strong site fidelity and defense of year-round territories. The 10 nests observed were pouch shaped and constructed with plant fibers; each contained two eggs. Nests were found between January and April when the Pantanal is flooded. The unusual breeding season of the Band-tailed Antbird appears to

be closely associated with the flooding regime. *Received 9 January 2008. Accepted 2 June 2008.*

Habitat associations of many neotropical birds are poorly known and the two species in the genus *Hypocnemoides*, Band-tailed Antbird (*H. maculicauda*) and Black-chinned Antbird (*H. melanopogon*), are no exception. The range of Band-tailed Antbirds, although largely confined to the southern Amazon region (Zimmer and Isler 2003), reaches the northern and northwestern border areas of the Pantanal floodplain (Dubs 1992, Tubelis and Tomas 2003). Species in the genus *Hypocnemoides* are known to be insectivorous, inhabiting humid forest, generally near water, where a suspended pouch nest is constructed (Davis 1949, Schubart et al. 1965, Parker 1982, Remsen and Parker 1983, Willis 1984, Terborgh et al. 1990, Ridgely and Tudor 1994, Zimmer and Isler 2003). Band-tailed Antbirds are normally found near water in the undergrowth of *várzea* and swampy forests near the wooded margins of sluggish lakes and streams, but also inhabit gallery forests (Remsen and Parker 1983, Terborgh et al. 1990, Ridgely and

¹ Núcleo de Estudos Ecológicos do Pantanal Matogrossense, Instituto de Biociências, Universidade Federal de Mato Grosso, 78075-960, Cuiabá, MT, Brazil.

² Laboratório de Ornitologia, Departamento de Zoologia, ICB, Universidade Federal de Minas Gerais, Avenida Antônio Carlos, 6627, Pampulha, 31270-910, Belo Horizonte, MG, Brazil.

³ Department of Biology, University of Missouri, St. Louis, One University Boulevard, St. Louis, Missouri 63121, USA.

⁴ Corresponding author; e-mail: pinho@cpd.ufmt.br