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EGGS, NESTS, AND NESTING BEHAVIOR OF AKIAPOLAAU (DREPANIDINAE)

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ABSTRACT.—We describe the fifth verified nest and first verified egg of the Akiapolaau (*Hemignathus munroi*), an endangered Hawaiian honeycreeper. We dispute the validity of Bryan's (1905a) description of three eggs and two nests of the Akiapolaau. Eggs that he attributed to this species were much smaller than ours, and his nest descriptions did not match the only nest apparently belonging to the Akiapolaau in the B. P. Bishop Museum in Honolulu, where Bryan worked. Twigs and bark were distinctively combined in the nest that we examined. We compare eggs and nests of the Akiapolaau with those of other Hawaiian honeycreepers. *Received 18 Sept. 1992, accepted 11 Feb. 1993.*

Eggs of 16 species and subspecies of extant, endemic Hawaiian passerines, including the Akiapolaau (*Hemignathus munroi*), have yet to be described (Scott et al. 1980, Sakai and Johanos 1983). We report here on the first positively identified egg and fifth known active nest of the Akiapolaau, an endangered drepanidine (Hawaiian honeycreeper) inhabiting dry to wet forests on the Island of Hawaii. Bryan (1905a) attributed three eggs from two nests collected by C. E. Blacow to Akiapolaau, but Sakai and Ralph (1980), Scott et al. (1980), and Berger (1981) discounted the validity of this record. Based on our observations, we also discount Bryan's record. Because little is known about Akiapolaau breeding biology, we report here our limited observations of nesting behavior in some detail. Our goal in doing so is to help biologists recognize other Akiapolaau nests and to stimulate more research on the ecology of this rare species.

STUDY AREA AND METHODS

The nest was discovered near Puu Kipu (19°33′N, 155°20′W; 1750 m elevation) on the eastern flank of Mauna Loa in a mesic koa (*Acacia koa*)-ohia (*Metrosideros polymorpha*) forest with a 15-m-tall canopy. This locality is within the range of the windward population of Akiapolaau (900 ± 200 birds [95% CI]), constituting the majority of the 1500 ± 400 Akiapolaau estimated for the island (Scott et al. 1986).

Including the date of discovery, we visited the nest on 2, 7, 13, 15, 21, and 23 January 1987. We monitored activity at the nest with binoculars from a distance of about 20 m during each visit. A blind was not used, but observers concealed themselves behind vegetation. The egg was discovered when the nest tree was first found and climbed. Subsequent egg monitoring was accomplished with a pole-mounted mirror from an adjacent tree. We

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checked the nest contents only when the female was voluntarily off the nest. After we determined that the egg was abandoned, we collected the nest and egg. We calculated an index of egg shape (S) from egg length and breadth (see Romanoff and Romanoff 1949; S = (B ÷ L) 100).

RESULTS

J. Jacobi and L. Katahira discovered the nest on 2 January 1987. On 7 January (09:30–12:30 h HST), the female incubated for over an hour before recessing for 27 min. She then incubated for 45 min before departing for 18 min. Her departures and returns were by similar routes. As the female entered the nest, a male Akiapolaau, presumably her mate, called and sang from a perch about 30 m away. During the female's second absence, we observed the egg in the nest.

The weather was stormy 10–12 January and delayed our next visit until 13 January (11:10–12:30 h). The nest was unattended by the pair during 1.5 h of continuous monitoring on 13 January, but we observed a female silently foraging in a naio (*Myoporum sandwicense*) tree about 12 m from the nest. Before leaving the area, we briefly observed a foraging male about 90 m from the nest.

We resumed nest observation on 15 January (10:30–12:30 h) and found the egg intact but did not observe the female at the nest. When we failed to detect an Akiapolaau on 21 January (10:00–12:50 h), we concluded the nest was abandoned. We collected the nest and egg on 23 January.

The nest was placed in the junction of several small branches on a nearly vertical limb 7 m above ground in a 10 m ohia with an 8 cm diameter at breast height (dbh). Nest shape was somewhat irregular, conforming to the asymmetrical configuration of its location. The open, statant cup was circular and measured 6.5–7.0 cm in diameter at the inner edge and 4.5 cm deep with average rim thickness of 2.25 cm (10 measurements). Outside diameter of the nest was 11 cm × 14 cm at the broadest perpendicular points, and the entire structure was 15 cm tall.

The nest cup had a woven lining of fern rootlets and ohia stamens. The body consisted primarily of closely interwoven ohia twigs interspersed with tree fern (*Cibotium glaucum*) secondary rachises, pulu (long, silky scales at the base of the fronds), and rhizomes from the trunk. A few leaves of ohia and a native sedge (*Uncinia uncinata*) and a frond of *Elaphoglossum* sp. were also in the upper third of the nest body. An unusual feature of construction was ohia bark strips incorporated into the body of the nest. These bark strips were spaced irregularly around the nest cup, their interior surfaces facing the center of the nest. Each bark strip was approximately 2 cm wide and extended vertically about 5 cm beyond the rim of the cup.

Material on the nest bottom appeared older and contrasted with the fresh pulu (golden and shiny) on the top, suggesting that either the nest was built on top of an older nest or that scavenged material from an older nest was used during the early phase of construction. We deposited the nest, including supporting branches, in the B. P. Bishop Museum, Honolulu (BPBM Specimen #1987.026).

The egg was 2.27 cm in length, 1.70 cm in maximum breadth, and subelliptical (Palmer 1962) with shape index of 74.9. Shell color (Palmer 1962) was pale cream with irregular light to medium brownish-red splotches, mainly located toward the broad end of the egg.

When collected on 23 January (21 days after nest discovery), the intact egg weighed 2.9 g. The egg was infertile (R. C. Fleischer, pers. comm.). We deposited the shell in the B. P. Bishop Museum (BPBM Specimen #1987.026).

DISCUSSION

The egg of the Akiapolaau is intermediate in size and shape among drepanidines (Table 1), and its colors and markings are little different from Common Amakihi (*Hemignathus virens*) and Palila (*Loxioides bailleui*). We were unable to locate Blacow's specimens or accession records of two nests and three eggs at Bishop Museum, where Bryan (1905a) described them. At Bishop Museum, however, we located an uncataloged nest attributed to Akiapolaau that was collected on 6 May 1904, probably by Blacow. This specimen did not resemble Bryan's published description of nest materials, composition, dimensions, or collection date (27 June 1904). Discrepancies between this undocumented specimen and Bryan's description of Blacow's two nests suggests miscommunication and confusion between the collector and describer. In fact, Bryan referred to earlier confusion about the identity of the nests and eggs he described by stating that Blacow originally told him that they belonged to the Palila.

We also agree with Berger's (1981) reasons for doubting the validity of Bryan's (1905a) descriptions of Akiapolaau eggs and nests. Blacow did not observe Akiapolaau building the nests, incubating the eggs, or feeding nestlings, and these activities are the most reliable indicators of nest identity (Eddinger 1970). He did see an Akiapolaau perched on the rim of the nest that contained one egg, but this is not sufficiently convincing evidence of ownership. At least some drepanidines scavenge material from old or inactive nests of the same or different species and forage in trees with active nests (Eddinger 1970; Sakai 1983; U.S.F.W.S., unpubl. data; pers. obs.).

Blacow also implied that he never saw a bird at the second nest which contained two eggs; he attributed the nest to Akiapolaau because the eggs

TABLE 1

AVERAGE DIMENSIONS (CM), VOLUME (CM^3), AND SHAPE OF DREPANIDINE EGGS

Species	N	Length	Breadth	Volume[a]	Shape index[b]	Source[c]
Laysan Finch (*Telespyza cantans*)	568	2.21	1.65	3.05[d]	74.7	a
Nihoa Finch (*Telespyza ultima*)	2	2.13	1.58	2.70	74.2	b
Palila (*Loxioides bailleui*)	8	2.50	1.68	3.58	67.2[e]	c
Common Amakihi (*Hemignathus*	90	1.90	1.39	1.86	73.2[f]	d
virens virens)	3	1.85	1.42	1.89	76.8	e
Kauai Amakihi (*H. v. stejnegeri*)	16	2.41	1.88	4.32	78.0	f
Anianiau (*H. parvus*)	21	2.21	1.80	3.63	81.4	f
Akiapolaau (*H. munroi*)	1	2.27	1.70	3.33	74.9	g
(putative Akiapolaau)	3	1.91	1.38	1.84	72.3	h
Kauai Creeper (*Oreomystis bairdi*)	1	2.33	1.83	2.16	78.5	i
Hawaii Creeper (*O. mana*)	2	1.96	1.44	2.06	73.5	j
Oahu Creeper (*Parereomyza maculata*)	2	2.01	1.50	2.29	74.6	k
Kauai Akepa (*Loxops coccineus caeruleirostris*)	2	1.66	1.32	1.47	79.5	l
Iiwi (*Vestiaria coccinea coccinea*)	10	2.07	1.55	2.52	74.9	f
Apapane (*Himatione sanguinea sanguinea*)	16	2.41	1.84	4.14	76.3	f

[a] Volume (cm^3) = 0.507 (length) $(breadth)^2$; Hoyt (1979).

[b] Shape index = (breadth ÷ length)100; Romanoff and Romanoff (1949).

[c] a = Morin (1992a); b = Berger (1981); c = van Riper (1980); d = van Riper (1987); e = Bryan (1905b); f = Eddinger (1970); g = this study; h = Bryan (1905c); i = Eddinger (1972b); j = Sakai and Johanos (1983); k = Bryan (1905a); l = Eddinger (1972a).

[d] Reported value was 3.07 (Morin 1992b) which is <0.7% greater than our calculated value.

[e] Reported value was 67.1 (van Riper 1980) which is <0.2% less than our value calculated from average length and width.

[f] Reported value was 68.1 (van Riper 1987) which is 7% less than our value calculated from average length and width.

seemed similar to the egg in the first nest (Bryan 1905a). However, definitive species-specific colors, markings, and shapes of drepanidine eggs have not yet been identified, so it is not surprising that Blacow thought the eggs in both nests seemed similar. Furthermore, the three eggs Blacow collected differed in volume (after Hoyt 1979) by only 8% and thus would have seemed similar in size.

What, then, does size reveal about the identity of the eggs collected by Blacow? The eggs he collected were only 55% of the volume of the Akiapolaau egg that we collected (1.84 cm^2 vs 3.33 cm^2; $t = 15.33$, $P < 0.001$; test comparing single observation with mean of a sample, Sokal and Rohlf 1981:231). Such large intraspecific egg size variation seems unlikely in only a four-egg sample and raises doubt that Blacow's eggs were produced by Akiapolaau. Although Blacow collected the eggs in dry mamane (*Sophora chrysophylla*)-naio (*Myoporum sandwicense*) forest at

TABLE 2
AVERAGE DIMENSIONS (CM) OF DREPANIDINE NESTS

Species	N	Nest Height	Nest Diameter	Cup Diameter	Cup Depth	Rim thickness	Source[a]
Laysan Finch	44	6.9	15.8	7.1	3.8	—	a
Palila	26	7.7	14.7	7.4	3.9	1.5–6.9	b
Common Amakihi	52	5.7	11.2	5.1	2.6	2.82	c
Kauai Amakihi	25	6.3	11.3	6.3	3.8	2.54	d
Anianiau	33	7.5	8.8	5.1	3.3	2.54	d
Akiapolaau	1	15.0	12.5	6.8	4.5	2.25	e
(putative Akiapolaau)	1	6.5	12.7	4.4	3.8	—	f
(uncataloged Akiapolaau)	1	9.5	11.6	6.5	3.3	—	g
Iiwi	22	7.3	9.4	5.3	3.7	2.55	d
Apapane	53	10.0	9.4	5.1	3.8	2.54	d

[a] a = Morin (1992a); b = van Riper (1980); c = Kern and van Riper (1984); d = Eddinger (1970); e = this study, verified nest; f = Bryan (1905a); g = this study, uncataloged nest at Bishop Museum.

high elevation (2286 m) on Mauna Kea (Bryan 1905a) and we collected ours from mesic ohia-koa forest at lower elevation (1750 m) on Mauna Loa, we doubt that habitat effects would account for so large a difference in egg volume. Ojanen (1983), for instance, concluded that habitat exerts only a minor influence on intraspecific egg size variation. Furthermore, geographical variation in Akiapolaau body size seems insufficient to account for so great a difference in egg size (T. K. Pratt, pers. comm.). In fact, the eggs described by Bryan (1905a) and eggs of Common Amakihi are most similar in volume (Table 1). We conclude, therefore, that Bryan probably described the eggs of Common Amakihi, the most common species on Mauna Kea, rather than Akiapolaau.

Dimensions of other Akiapolaau nests have not been measured, but ours was generally in the range of other drepanidine nests (Eddinger 1970; van Riper 1980, 1987; Kern and van Riper 1984; Table 2). However, four of our five measurements were larger than other species' nests except the Palila's. Our nest was particularly tall, suggesting that an older nest was used as a foundation. Apapane (van Riper 1973a), Common Amakihi (van Riper 1976), and Palila (U.S.F.W.S., unpubl. data; pers. obs.) occasionally build nests on top of old ones, thus resulting in structures that are taller than normal. The presence of old material in the base and newer material toward the top of our nest also suggests the use of an older nest, either intact as a foundation or as a source of scavenged material during nest construction. Eddinger (1970) observed that other drepanidines scavenge material from old nests and steal from active nests and that at least some birds reoccupy the same tree during different years, but build new nests each time.

The prominence of ohia bark in our nest suggests that this may be a characteristic feature of Akiapolaau nests in mesic koa-ohia forests. Sakai and Ralph (1980) remarked that a large quantity of ohia bark distinguished their Akiapolaau nest from all other Hawaiian bird nests. Whether bark was used in two other nests located by Ralph et al. is not known, because they could not climb to the nests and examine them closely (C. J. Ralph, pers. comm.). Bark was not reported in the partially completed nest described by van Riper (1973b).

By his description, Blacow's two putative Akiapolaau nests from Mauna Kea (Bryan 1905a) differ from the five verified nests and from Blacow's uncataloged, undescribed nest in Bishop Museum. Bryan reported that Blacow's nests were composed of mamane leaves and petioles and were thickly lined with lichen. In contrast, the body of the uncataloged nest was constructed of *Chamaesyce* sp. twigs with possibly some mamane twigs in the base, and the cup was lined with lichen and grass; at least two long hairs, probably from a horse, were in the cup lining and the nest body (J. D. Jacobi, pers. comm.). Twigs, and sometimes bark, comprised the bulk of the verified nests. Ours is the only nest retrieved of the five verified nests, and its cup was not lined with lichen, even though that material was available in the habitat. The composition of the two nests described by Bryan (1905a) is most similar to Common Amakihi nests as constructed on Mauna Kea (Kern and van Riper 1984; U.S.F.W.S., unpubl. data; pers. obs.). In addition, both nests were smaller than our Akiapolaau nest (Table 2) and more closely resembled the dimensions of Common Amakihi nests. The uncataloged nest more closely resembled our nest in size. However, not having a verified Akiapolaau nest from the dry mamane-naio forest of Mauna Kea for comparison, we do not know how nest construction of Akiapolaau differs from that of Common Amakihi in this habitat.

Although nesting apparently occurs primarily between January and June (C. J. Ralph, pers. comm.), Akiapolaau may breed throughout much of the year, as indicated by the range of dates when active nests have been discovered: January (van Riper 1973b, this study), February (C. J. Ralph, pers. comm.), July (C. J. Ralph, pers. comm.), and October (Sakai and Ralph 1980). Ralph (pers. comm.) found females with active brood patches, indicating nest building or incubation from January through August. Lengthy breeding seasons are characteristic of many drepanidines (Berger 1981).

Modal clutch sizes for drepanidines are two or three eggs (Berger 1981). We do not know whether the single egg in our Akiapolaau nest represents an incomplete clutch or if single-egg clutches are typical for the species.

TABLE 3

CHARACTERISTICS OF AKIAPOLAAU NEST SITES AND NESTS

Tree	Tree height (m)	Tree dbh[a] (cm)	Forest stratum	Nest height (m)	Open statant cup[b]	Nest placement	Source[c]
Ōhia	>20	—	canopy	>12	yes	lateral fork	a
Ōhia	18	—	canopy	17	yes	small branches	b
Koa	20	—	canopy	19.5	yes	small branches	c
Ōhia	20	—	sub-canopy	11	yes	cavity[d]	c
Ōhia	10	8	sub-canopy	7	yes	small branches	d
				Putative nest:			
Mamane	—	—	canopy	2.7	yes	outside branches	e

[a] dbh = diameter at breast height.

[b] Open statant cup: cupped nests which are supported underneath, have rim standing firmly upright and not arched over the top (Pettingill 1970).

[c] a = van Riper (1973b), J. Jacobi (pers. comm.); b = Sakai and Ralph (1980); c = C. J. Ralph (pers. comm.); d = this study; e = Bryan (1905a).

[d] Cavity was formed when a large limb split from the trunk.

However, Eddinger (1970) found single-egg clutches among Kaua'i Amakihi, Apapane, and Iiwi, as did van Riper (1980, 1987) among Palila and Common Amakihi. Furthermore, Akiapolaau rarely fledge more than a single young per nest attempt (C. J. Ralph, pers. comm.), although Jacobi (1974) reported two fledglings on two occasions in late 1972.

The few observed nests suggest that only the female Akiapolaau incubates. This is typical of other drepanidines (Eddinger 1970), although van Riper (1980) reported a male Palila that occupied the nest and possibly incubated for nearly four hours after the first egg of the clutch had been laid.

Observations at this and four other verified nests indicate that Akiapolaau do not require specialized nesting sites, such as tree cavities or particular size classes of trees (Table 3). The extensive use of bark in the construction of the nest is distinctive among drepanidines examined so far but is unlikely to limit nesting activity in the population.

Observers particularly should avoid disturbing birds during nest construction, because two of the five verified Akiapolaau nests were abandoned during later stages of construction (van Riper 1973b, Sakai and Ralph 1980). As a precaution, we recommend that workers conceal themselves in blinds when observing nests of this and other Hawaiian species.

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LITERATURE CITED

BERGER, A. J. 1981. Hawaiian birdlife (2nd ed.). Univ. Press Hawaii, Honolulu, Hawaii.

BRYAN, W. A. 1905a. Nest and eggs of *Heterorhyncus wilsoni* (Roths.). Bishop Mus. Occ. Pap. 3:253–254.

———. 1905b. Description of the nest and eggs of *Chlorodrepanis virens* (Gmel.). Bishop Mus. Occ. Pap. 2:243–244.

———. 1905c. Notes of the birds of the Waianae Mountains. Bishop Mus. Occ. Pap. 2:229–241.

EDDINGER, C. R. 1970. A study of the breeding behavior of four species of Hawaiian Honeycreepers (Drepanididae). Ph.D. diss., Univ. Hawaii, Honolulu, Hawaii.

———. 1972a. Discovery of the nest of the Kauai Akepa. Wilson Bull. 84:95–97.

———. 1972b. Discovery of the nest of the Kauai Creeper. Auk 89:673–674.

HOYT, D. F. 1979. Practical methods of estimating volume and fresh weight of bird eggs. Auk 96:73–77.

JACOBI, J. D. 1974. 'Akiapola'au and its remaining habitat. 'Elepaio 34:74–76.

KERN, M. D. AND C. VAN RIPER III. 1984. Altitudinal variations in nests of the Hawaiian honeycreeper *Hemignathus virens virens*. Condor 86:443–454.

MORIN, M. P. 1992a. Laysan Finch nest characteristics, nest spacing and reproductive success in two vegetative types. Condor 94:344–357.

———. 1992b. Breeding biology of an endangered Hawaiian Honeycreeper, the Laysan Finch. Condor 94:646–667.

OJANEN, M. 1983. Significance of variation in egg traits in birds, with special reference to passerines. Acta Univ. Ouluensis A154. Biol 20:1–61.

PALMER, R. S. (ED.). 1962. Handbook of North American birds. Vol. 1. Yale Univ. Press, New Haven, Connecticut, and London, England.

PETTINGILL, O. S., JR. 1970. Ornithology in laboratory and field (4th ed.). Burgess Publ. Co., Minneapolis, Minnesota.

ROMANOFF, A. L. AND A. J. ROMANOFF. 1949. The avian egg. John Wiley and Sons, Inc., New York, New York.

SAKAI, H. F. 1983. The diversity of nesting sites utilized by the 'Apapane. 'Elepaio 44: 2–5.

——— AND C. J. RALPH. 1980. An observation of 'Akiapola'au nest construction. 'Elepaio 41:4–5.

——— AND T. JOHANOS. 1983. The nest, egg, young, and aspects of the life history of the endangered Hawaii Creeper. Western Birds 14:73–84.

SCOTT, J. M., J. L. SINCOCK, AND A. J. BERGER. 1980. Records of nests, eggs, nestlings, and cavity nesting of endemic passerine birds in Hawaii. 'Elepaio 40:165–168.

———, S. MOUNTAINSPRING, F. L. RAMSEY, AND C. B. KEPLER. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Stud. Avian Biology 9.

SOKAL, R. R. AND F. J. ROHLF. 1981. Biometry (2nd ed.). W. H. Freeman, New York, New York.

VAN RIPER, C., III. 1973a. The nesting of the Apapane in lava caves on the island of Hawaii. Wilson Bull. 85:238–240.
———. 1973b. Island of Hawaii land bird distribution and abundance. 'Elepaio 34:1–3.
———. 1976. Superimposition of an Amakihi nest on one of an Elepaio. Condor 78:267–269.
———. 1980. Observations on the breeding biology of the Palila *Loxioides bailleui* of Hawaii. Ibis 122:462–475.
———. 1987. Breeding ecology of the Hawaii Common Amakihi. Condor 89:85–102.