

BEHAVIOR AND FEATHER STRUCTURE OF THE QUETZAL

A. LABASTILLE, D. G. ALLEN, AND L. W. DURRELL

THE first two authors studied the northern subspecies of Quetzal, *Pharomachrus mocinno mocinno*, during a 3-month expedition to Guatemala in 1968. Our behavioral data show interesting variations and differences from those Skutch (1944) collected in Costa Rica, 1937-38, on the southern subspecies, *P. m. costaricensis*. To our knowledge, this is the first reported examination and photographs of Quetzal feathers made under an electron microscope.

Little biological information about Quetzals has appeared in the literature, other than two semipopular articles in Audubon (Kern, 1968) and National Geographic (Bowes and Allen, 1969a), and two technical papers on the species' conservation and biology (Skutch, 1944; Bowes and Allen, 1969b).

METHODS

The field study took place from mid-March to mid-June 1968 at two sites. Site Atitlán covered about 300 acres between 5,000-6,000 feet on the southern slope of Volcano Atitlán (11,604 feet) in southwestern Guatemala. Virgin forest was extensive above the 5,000-foot contour. Site Cuchumatanes was some 600 acres in the karst Cuchumatanes Mountains of northern Guatemala between 9,000-10,500 feet in mixed oak and pine climax forest. Both locations receive 150 inches or more of rain per year, and frost is occasional at higher elevations November through April. As defined by Budowski (1965) both are classified as cloud forest or lower montane wet forest.

Laboratory analysis and electron microscope photography of a Quetzal feather were performed at the Department of Botany and Plant Pathology, Colorado State University, Fort Collins, Colorado.

RESULTS

HABITAT

Its occurrence on both igneous and limestone terrain shows the Quetzal is not restricted to any specific geological formation. The key requisite appears to be the presence of mature or virgin cloud forest. The lack or at least scarcity of hunters and trappers is also very important. Skutch (1944) states that "in Guatemala, the Quetzal does not—at least at the present time—appear to extend upwards beyond 7,000 feet." On Site Cuchumatanes, we found birds at 9,000 to 10,500 feet.

COLORATION

Skutch's (1944) field descriptions of male and female adult Quetzals in Costa Rica are carefully drawn. The following variations we noted

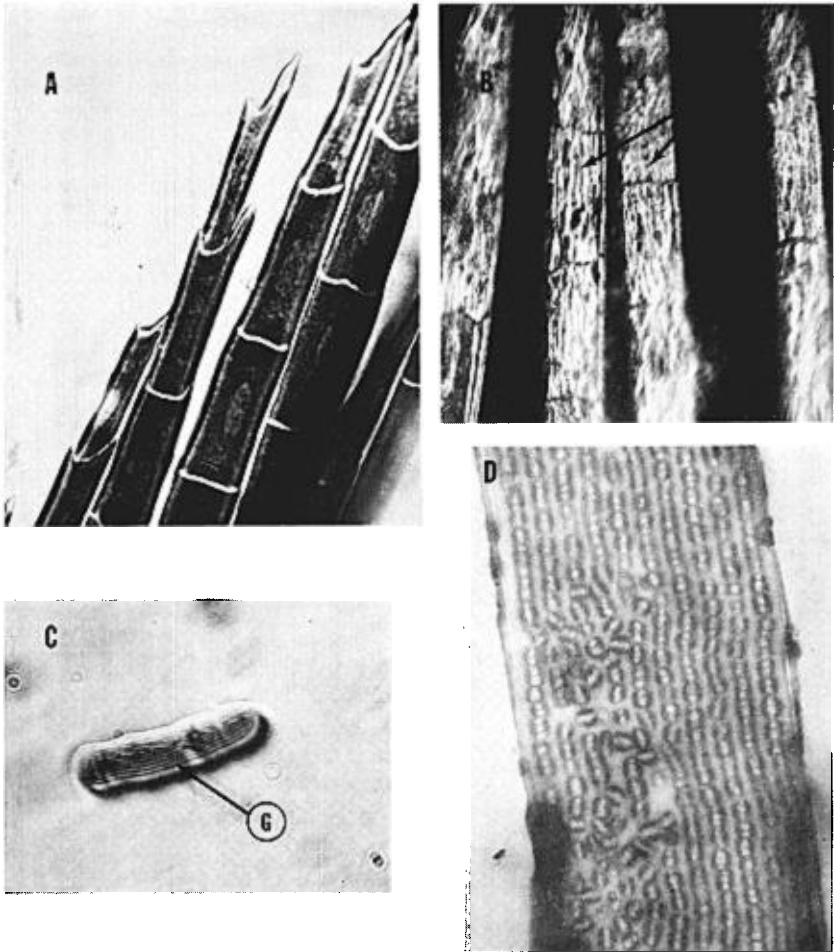


Figure 1. A, ends of barbules showing segmented structure. B, barbules as seen under the intense light of mercury arc lamp. Strands of melanin granules shine green under oblique light of dark field condenser. C, longitudinal section of a barbule cut $\frac{1}{4}$ micron thick, magnification at $1,700\times$ under light microscope. The barbules are curved, so the cut is tangent to a curve. This shows the layers of granules of melanin that cause the iridescence. D, electron micrograph of melanin granules in barbule of Quetzal feather. Magnified approximately $10,000\times$. Granules globular to elliptical in regular rows. Rows approximately 5400 \AA apart, the wavelength of green light. Section cut about 600 \AA thick. (Photos by L. W. Durrell.)

in Guatemalan birds are probably of subspecific character. Bill color in the adult female appeared darkish gray rather than black as stated by Skutch. The head was a golden buffy brown color with a slight crest rather than a smoky gray color and crestless as described for *costaricensis*.

In Guatemalan adult females the breast band seemed more smoke gray than dull yellow-lime as described for Costa Rican birds. The longest outer tail covert of an adult male bird in Guatemala measured up to 1070 mm. Ridgway (1911) gives an average length of 822.1 mm for *P. m. mocinno* from Guatemala and 660.6 mm for the Costa Rican subspecies.

The plumage of the Quetzal seems ideally suited for camouflage under rainy conditions. Feathers show little iridescence and do not glint golden so that the bird blends remarkably with wet and shiny green vegetation. As the angle of light falling on the feather changes, the apparent color shifts rather widely from green to yellow-green, lime, emerald, turquoise, cobalt, and ultramarine (keyed to A.O.U. color chart in Palmer, 1962: 4) with an occasional golden or coppery cast.

Feather structure.—Durrell studied a 560-mm male Quetzal tail plume chemically and microscopically. Grossly the feather is made up of a main shaft from which grow barbs about 38 mm long. The barbules, attached by paddlelike bases, are segmented, tapered, and forked at the tip (Figure 1A). No aftershaft is present, but a V-shaped section of charcoal gray lies at the bottom of the shaft. If moistened deliberately, the barbules clump together and become a dull charcoal brown or gray. Unsuccessful attempts to extract a pigment from the green feather by use of various organic solvents suggest that the feather color results from some cause other than a pigment. A chemical test for melanin was positive.

Microscopic examination of the barbules using polarized light, ultraviolet light, and light of various wavelengths, showed nothing of significance. Sections of the barbules cut $\frac{1}{4}$ micron (longitudinal section) examined with light microscope at high magnification showed parallel rows of granules (Figure 1B and 1C). Further examination with the electron microscope of sections cut 600 Å thick at magnification of 10,000 times clearly showed these granules in orderly rows spaced at approximately 5400 Å apart (Figure 1D). As the wavelength of green light is in this range the physical phenomenon of interference makes light striking the barbules reflect green. This phenomenon was first noted in 1960 by Greenewalt et al. in the study of hummingbird feathers. The physical mechanism of iridescence is common in bird feathers and has been investigated by Mason et al. (1923a, 1923b), Fox (1953), Fox and Vevers (1960), Greenewalt et al. (1960), and many others.

MOVEMENTS

As Skutch (1944) noted, Quetzals are wary. They stay high in the forest canopy, generally between 75 and 200 feet, and spend long periods sitting motionless and looking slowly from side to side. We believe that

the birds never touch ground in their natural life, although they move considerably lower during the nesting season to make use of rotten stumps for nest holes. The lowest elevation at which we saw a Quetzal was 12 feet.

Quetzals commonly take flight by dropping backward off a branch before flying forward. Skutch attributes this behavior only to male birds, who do so to keep from dragging their long tail feathers over the branch. We saw both male and female Quetzals perform it.

Preening, noted occasionally, involved pecking and stropping under and around the wings and breast. Once a female that had been incubating for 5 hours emerged in a pouring rain and sat upon a branch. Here she preened and fluttered her wings almost as if bathing. After about 5 minutes she returned to the nest hole.

VOCALIZATIONS

Skutch describes five different vocal displays for the Costa Rican Quetzal. We heard Guatemalan birds utter all five, plus three additional calls. All are described below, using the terminology proposed by Tucker (*in* Witherby et al., 1938: xv-xix). An asterisk (*) denotes that tape recordings and sonograms we obtained are deposited in the Cornell Library of Natural Sounds.

Male calls.—1. Two-note whistle*. A two-note, melodius, high whistle uttered early in the day, especially 05:30 to 06:30, from the treetops. When calling, the male holds his head high, crest raised slightly, head compressed, bill barely open, and breast puffed out. He averages a series of calls every 8 to 10 minutes. This whistle probably functions as male territorial advertising.

2. Gee-gee. A high-pitched call held on the same note as the highest part of the two-note whistle. We heard it three or four times given by a male high in the trees. No function has been determined for this.

Calls common to both sexes.—1. Wahc-ah-wahc. Skutch describes this as "wac-wac" and considers it to function as a flight call. We believe it is a recognition call, as we heard it while a pair was flying together and when a pair was reunited after being separated for a few hours.

2. Wec-wec. A single, monotonous, and irritating note given when birds seemed suspicious of an object, or were alarmed or threatened. Each utterance is accompanied by a quick flick of the tail, opening fanlike at intervals of 1 second.

3. Cooūee whistle. A series of soprano notes that rise up the scale like a distant police siren, or rise and fall like a soft "wolf-whistle," heard high in the trees as well as from the nest hole. Also described by Skutch,

it may function as a mating call, or as a signal in nestling care or in nest exchange.

4. Ūwāc. A call that begins low and rises smoothly up the scale, heard on two occasions when pairs were courtship chasing.

5. Chatter. A short, turbulent, guttural chatter given from the tree-tops when birds seemed to be disturbed.

6. Buzzing*. A high nasal whining buzz made by chicks when begging for food.

TERRITORY AND NESTING BEHAVIOR

Bowes and Allen (1969b) describe territory and home range in detail. To summarize briefly, home range at Site Atitlán is estimated at 15 to 25 acres per pair in cloud forest canopy. The average territory defended during the nesting season is approximately a 1,000-foot horizontal radius around the nest stub. Vertically it may vary from 12 to about 200 feet.

Courtship.—The vibrant aerial courtship flight that Skutch describes (1944) we saw twice in Guatemalan Quetzals, plus two incidents of courtship chasing not noted previously in the literature. The “cooūee” whistle, “wahc-ah-wahc,” and “ūwāc” calls were given in the latter display, and the birds appeared quite animated.

Nests.—The height and dimensions of 10 nests at Site Atitlán, and 1 at Site Cuchumatanes (Bowes and Allen, 1969b) agree generally with Skutch's measurements. Nest stubs average 41 feet high and the nest holes 31 feet high. The favored tree for nest holes at Site Atitlán was a wild mulberry, *Brosimum costaricanum*. At the higher site, a single nest tree was probably a dead white pine, *Pinus psuedostrobus*. Some stubs had one to four holes near their tops. Apparently the stump rots progressively downwards, and the birds have to shift their nest site lower accordingly. Stubs were usually so rotten and decayed that hand pressure set them atremble.

We glimpsed birds digging at nest sites twice and found six nest stubs with fresh signs. This was apparent from the lighter edges of entrance holes in the weathered, dark trunks, and from the chips or sawdust on the ground below. Evidently a pair is capable of removing several inches of material. One nest we measured on 15 April was only 3 inches deep. We deliberately deepened the cavity another 7 inches with a knife. On 12 May the nest hole was 12 inches deep and contained two eggs. We feel that the role of digging may play an important part in the Quetzal's reproductive cycle. Table 1 gives the reproductive timing and activities of three pairs of Quetzals.

New nesting record.—A female we found incubating or brooding young on 19 April 1968 at Site Cuchumatanes, elevation approximately 10,000

TABLE 1
REPRODUCTIVE ACTIVITIES OF THREE PAIRS OF QUETZALS

Date	Activity
Nest No. 4, site Atitlán	
12 April 1968	Pair looks over nest hole; female inside for 20 minutes
Late April	Eggs probably present
4 May	Male inside; fresh carving at nest hole entrance
11 May	Male brings first food to chicks
20 May	Nest examined; 2 chicks, 7 to 9 days old
22 May	Nest stub falls due to absorption of water from heavy rains; 2 chicks recovered, 9 to 11 days old
25 May	Pair digging at new nest 600 feet away
28 May	Pair working and sitting at nest stub
29 May	Male inside; female nearby
Nest No. 5, site Atitlán	
15 April	Nest examined; hole 3 inches deep; birds nearby; 7 inches removed artificially
6 May	Male on nest; female nearby; nest hole 12 inches deep
12 May	Two eggs inside when checked
28 May	Nest abandoned, cause unknown
Nest No. 6, site Atitlán	
10 March	Pair seen around stub
26 March	Female inside nest; eggs probably present
4 April	Male inside nest
7 April	First food brought to chicks
11 April	Nest abandoned due to predation and disappearance of chicks
5 May	Birds around nest stub 800 feet away; fresh digging
7 May	Birds back to original nest tree
11 May	Male inside original nest hole
21 May	Two eggs inside when nest checked
28 May	Nest abandoned; cause unknown

feet, probably constitutes a new altitude record. Skutch states that in Guatemala the Quetzal does not "appear to extend upward beyond 7,000 feet," and definite records near 10,000 feet in Costa Rica are lacking.

Eggs.—We examined four light blue, short, subelliptical eggs that measured 38×31 mm, 39×34 mm, 41.5×32.5 mm, and 37×32 mm; mean = 38.9×32.4 . (Skutch's one egg specimen measured 38.9 mm \times 30.2 mm.) Eggs were judged to have been laid on or about 26 March, late April, 10 May, and 21 May 1968 (see Table 1).

Incubation.—The 24-hour schedule our pairs followed corresponded roughly with what Skutch (1944) recorded, i.e. each bird incubating twice during this period. We found, additionally, that parents seldom left their clutch uncovered for more than 2 to 13 minutes. No nest exchange rites were seen. The incubating bird seems to detect its mate's approach,

probably by light wing vibrations or low calls, even while snuggled deep within the stub. No instance was noted of the modified flight call and display Skutch describes for males leaving the nest.

When approaching the nest hole, a parent usually swooped to its edge, landed with a thump, then quietly surveyed the landscape with a side-to-side head movement. After 1 to 3 minutes, the bird made one to several attempts to enter without going inside. We called this "bowing-in." After the eggs hatched, parents stopped this behavior and entered the nest directly.

Care of nestlings.—Initially parents brought food at infrequent intervals and spent long periods brooding the young. Later they alternated bringing food every hour in the early morning, this service lengthening to every 2 hours by noontime. (Example: 06:45, female; 07:46, male; 08:42, female; 10:10, male; 12:25, female.) The first food offerings noted consisted of a dark berry and a yellow grub. Other items carried to the chicks included green applelike fruits (wild avocados?), orange-winged termites, white spiders, a gray moth, blue snout beetle, and a greenish mass of unidentified material.

Skutch states that Costa Rican nestlings are fed almost, if not quite exclusively, on small insects during the first days of life. We found that the northern subspecies' diet apparently includes both animal and vegetable materials from the day of hatching. The large intestine contents of a dead chick (10 days old) contained two shiny large green-blue scarabs identified to genus *Plusiotis*, by Cartwright (pers. comm.). Two intact thorax shields measured 23 mm each, one abdomen 23 mm, and one carapace 23 mm. Skutch also lists these beetles as chick food in Costa Rica.

At one nest chicks were always fed within the hole up to 11 days after hatching. This contrasts with Kern's report (1968) that Costa Rican chicks are fed from outside the nest hole after the first few days.

Our observations of nestling development differ considerably from those of Skutch and Kern. In young Costa Rican birds the eyes were reported open at about 8 days. In two Guatemalan nestlings (Figure 2) the eyes were still tightly shut to about 14 days after hatching, i.e. the number of days parents were seen bringing food to the nest hole plus the time they were hand-reared after destruction of the nest stub. Table 2 gives the measurements of the two chicks at time of death. A general description of chick A includes a very broad bill of pale-gray color with mandible tip white and the culmen blackish-gray. An egg tooth was present. Toes heterodactyl; tarsi scutellate; tibiotarsi long and strong, flesh to pink color. Skutch records both bill and feet blackish in Costa Rican chicks 10 days old. The chick had a grotesquely protuberant belly



Figure 2. Quetzal chick of approximately 14 days. Note that eyes are shut tightly, the belly protuberant, secondary wing quills breaking open, and the upright posture it assumes, even in the hand. (Photo by David G. Allen.)

in which portions of undigested chitinous material could be seen through the very thin skin, moving slowly with the large intestine.

Feather tracts appeared at follows: Capital—poorly developed extending only to crown, feathers sheathed; humeral—well-developed feathers 10 mm long, black and fluffy; dorsal—one short length at mid-lower spinal area of black feathers, 12 mm long; caudal—a few blackish feathers just breaking out; alar—mostly sheathed except for secondaries and greater coverts which were just breaking through as black and tawny fluffy feathers; femoral—blackish feathers, 16 mm long; crural—not present; ventral—well-developed feathers of tawny, smoke-gray, and blackish-gray color, about 11 mm long. Apterium bare and covered with tissue-like, almost transparent skin.

At Nest No. 6, Site Atitlán, we saw what appeared to be a young male Quetzal in company with the mated pair over a period of 1½ months. His beak was yellow like an adult male's, his breast feathers were smoke-gray to ruby color, and he had no long tail plumes. The adult male was not seen to act agonistically towards this individual even when it flew to the nest hole while the female was incubating within. Once he clung to the rim for 1½ minutes. He did not enter and the female did not peer

TABLE 2
MEASUREMENTS (IN MM) OF TWO QUETZAL CHICKS

Measurement	Chick A 13-14 days old	Chick B 10-11 days old
Total length		
Tip bill to toes	153	142
Tip bill to tip tail	116	111
Wing length		
Full length body to tip primaries	51	41
Chord	27	21.5
Bill		
From base	15.5	14.5
Gape	23.5	18.5
Tibiotarsus	38.5	33
Tarsus	17	15
Claw, longest	4.5	4.0

out. At this time the adult male appeared for a few seconds and left again. During the next 2 minutes this individual returned to the nest hole five times. Another time, this young bird sidled close to the adult female and "cooëe'd" to and with her. After this nest was abandoned, the young Quetzal remained with the pair as they began a new nest about 800 feet away in a higher stub. Skutch reports nothing of this nature, and we are uncertain how to interpret it.

Decoy.—In an attempt to attract wild birds close to our cameras we used a stuffed male Quetzal. First we tied it near Nest No. 5 on a moveable string about 8 feet below and horizontal to the nest hole. When lowered near or on the ground, the female paid no attention, but when raised near the nest hole she attacked it vigorously, aiming at the neck and head area. She dived at it four times, then fluttered around the decoy before returning to her perch. Insufficient testing was done with this tool, but we feel it is a useful technique for eliciting agonistic behavior.

We noted no other intraspecific agonistic behavior. Woodhewers, motmots, toucans, and flycatchers were seen on or around Quetzal nest sites and territories, but no agonistic encounters were observed between these or other species.

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SUMMARY

The northern subspecies of Quetzal, *Pharomachrus mocinno mocinno*, was studied in the highlands of Guatemala between mid-March to mid-

June 1968 at 5,000–6,000 and 9,600–10,500-foot elevations. A number of variations are described between characteristics attributed to the southern subspecies, *P. m. costaricensis*, by Skutch (1944) and the northern subspecies. A tail covert is described in detail, including examination under the electron microscope. Green color seems the result of the interference of light by melanin granules spaced approximately 5400 Å apart, the wavelength of green light. Certain movements, habits, and seven vocal displays are described. A brief summary of territory and home range is included. Courtship behavior, description of nests, nesting activities, a new nesting record at 10,000 feet, and care and descriptions of nestlings are included under reproduction section. Miscellaneous observations are given on a juvenile male, reaction to a Quetzal decoy, and intra- and interspecific agonistic encounters.

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ANNE LABASTILLE (formerly BOWES), *c/o Laboratory of Ornithology, Cornell University, Ithaca, New York 14850*; DAVID G. ALLEN, *Bird Photos, Inc., Sapsucker Woods Road, Ithaca, New York 14850*; and L. W. DURRELL, *Department of Botany and Plant Pathology, Colorado State University, Fort Collins, Colorado 80521*. Accepted 26 March 1971.