Rev. Biol. Trop., 11(1): 1-23, 1963

A New Species of Tree Frog, Genus Phyllomedusa, from Costa Rica

by

William E. Duellman*

(Received for publication February 1, 1963)

Most of the Middle American species of *Phyllomedusa* (including those of the genus *Agalychnis*) have a green dorsum and variously colored flanks and thighs. In some species the flanks and thighs are bright yellow or blue. These colors, as well as the color of the eye, either fade or disappear in preservative. Consequently, species that are strikingly different in life often have similar colors after a short time in preservative. Experience with the living animals provides the basis for ascertaining the relationships of the various populations.

During the course of field studies on hylid frogs in Costa Rica in 1961, I became aware of the presence of an undescribed species, specimens of which had been referred to *Phyllomedusa moreleti* by TAYLOR (3) and FUNKHOUSER (1). The living Costa Rican frogs differ strikingly from *P. moreleti* as it occurs in Mexico and northern Central America (type locality - Cobán, Alta Verapaz, Guatemala). Aside from series of adult specimens, complete life history data and recordings of breeding calls were obtained. All of these data have been utilized in the following description.

My wife, Ann S. Duellman, who has accompanied me in the field in Middle America and has contributed to my studies on hylid frogs, obtained the first specimen of the new species in 1961. I take pleasure in associating her name with this beautiful species of frog.

Phyllomedusa annae new species

HOLOTYPE.— University of Kansas Museum of Natural History (KU) No. 64020, from Tapantí, Cartago Province, Costa Rica, 1200 meters; obtained on April 19, 1961, by Ann S. Duellman.

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* Museum of Natural History, The University of Kansas, Lawrence, Kansas, U.S.A.

PARATYPES.— All from Tapantí: KU 64021-4, collected with the holotype by Ann S. and William E. Duellman; KU 64025, obtained on April 21, 1961, by William E. Duellman; KU 64026-48, obtained on April 29, 1961, by William E. Duellman and Jerome B. Tulecke; MCZ 35002-3, KU 64055-8, UIMNH 50965, obtained on June 6, 1961, by William E. Duellman, Craig E. Nelson, and Jerome B. Tulecke.

DIAGNOSIS.— A species of *Phyllomedusa* most closely resembling *P. moreleti,* but differing from that species in having a larger size, smaller tympanum, an orange, instead of scarlet red, eye, and in having blue, instead of orange, flanks and concealed parts of the limbs.

The coloration distinguishes this species from all other members of the genus.

DESCRIPTION OF HOLOTYPE.— Adult male having a snout-vent length of 67.4 mm.; tibia length, 30.0 mm., 44.5 per cent of snout-vent length; foot length (measured from proximal edge of inner metatarsal tubercle to tip of longest toe), 24.9 mm., 36.9 per cent of snout-vent length; head length, 21.1 mm., 31.3 per cent of snout-vent length; head width, 19.8 mm., 27.8 per cent of snout-vent length; diameter of eye, 6.0 mm.; diameter of tympanum, 3.7 mm., 61.7 per cent of diameter of eye; interorbital distance, 6.9 mm., 34.8 per cent of head width; width of eyelid, 4.4 mm., 22.2 per cent of head width. Head narrower than body; top of head slightly convex; snout in dorsal profile narrowed and acuminate, in lateral profile sloping from eyes to nostrils, then further inclined to tip of snout; canthus rounded, indistinct; nostrils slightly protuberant, situated about two-thirds distance from eyes to tip of snout; loreal region slightly concave; lips thin, not flared. A heavy dermal fold from posterior corner of eye to angle of jaw, concealing upper and posterior edges of tympanum; tympanum distinct, situated posteroventrad to eye and separated from eye by a distance equal to one-half diameter of tympanum. Upper arms slender; forearms robust; fingers short; relative length of fingers from shortest to longest, 1-2-4-3; discs large, equal to diameter of tympanum; fingers two-thirds webbed (Fig. 1); distal subarticular tubercles on third and fourth fingers large and bifid; other subarticular tubercles small and round; pollex moderately enlarged, having a large, non-spinous, horny nuptial excrescence. Hind limbs slender; heels of adpressed limbs broadly overlaping; tibiotarsal articulation extending to posterior corner of eye; tarsal fold weak; outer metatarsal tubercle absent; inner metatarsal tubercle large, flat, and elliptical; toes of moderate length; relative length of toes from shortest to longest, 1-2-3-5-4; subarticular tubercles large, flat, and round; discs about one-half size of those on fingers; toes three-fourths webbed (Fig. 2). Anal flap long; anal opening directed ventrally at level of ventral surfaces of thighs. Skin of dorsum, chin, and ventral surfaces of limbs, except thighs, smooth; skin of belly and ventral surfaces of thighs moderately granular. Lower jaw having single median denticle; tongue half again as long as wide, notched anteriorly and posteriorly, barely free behind; choanae elliptical; vomer-

ine teeth 5-5, situated on narrow elevations extending posteromedially from level of anterior edges of choanae; vocal slits small, each situated about one-half distance from posterolateral edge of tongue to angle of jaw.

Color (in alcohol) on dorsal surfaces of body, forearms, hind legs, fourth fingers, and fifth toes dull purple; flanks, anterior and posterior surfaces of thighs, lateral surfaces of tarsi, dorsal surfaces of fourth toes, median surfaces of forearms, and dorsal surfaces of third fingers brown; all ventral surfaces and dorsal surfaces of first and second fingers and first, second, and third toes creamy yellow.

Color [in life, from field notes of William E. Duellman, April 19, 1961 (Fig. 4)] of dorsal surfaces of head, body, thighs, shanks, tarsi, and forearms bright leaf-green; anal region pale leaf-green; flanks, anterior and posterior surfaces of forearms, dorsal surfaces of third fingers (except discs), dorsal surfaces of discs of fourth fingers, dorsal surfaces of fourth toes and discs of fifth toes, and web between fourth and fifth toes blue. Stripe along edge of tarsus from heel to tip of fifth toe and stripe along lateral edge of forearm from elbow to fourth finger bright creamy yellow; proximal dorsal surfaces of upper arms pink, distal part blue; dorsal surfaces of fingers, toes, discs, and webbing (except as noted above) deep orange. Belly and ventral surfaces of limbs pinkish orange; chest and throat creamy yellow; lower lip creamy white; iris yellowish orange with copper-colored periphery and reticulations; upper half of lower eyelid having greenish gold reticulations; nuptial adspersities brownish black.

VARIATION.— There is little variation in coloration. Individuals found sleeping by day had a pale green dorsum and pale blue flanks and thighs, whereas when the frogs were active at night, they had a darker green dorsum. Likewise, the flanks and thighs were darker blue or purple. There is slight variation in the amount of webbing and relative sizes of the discs on fingers and toes. Variation in measurements and proportions in adult males is given in Table 1.

TABLE 1

Comparison of Size and Proportions in Males of Phyllomedusa annae *and* Phyllomedusa moreleti

(Mean and one standard error of mean in parentheses after observed range)

Character	*P. annae*	*P. moreleti*
Number of specimens	35	25
Snout-vent length (mm)	57.0-73.9 (67.8±0.61)	55.9-65.7 (60.6±0.57)
Tibia length/snout-vent length (%)	41.8-47.8 (44.7±0.03)	39.5-49.2 (45.4±0.35)
Foot length/snout-vent length (%)	34.1-40.4 (37.0±0.33)	33.2-39.0 (36.7±0.38)
Head length/snout-vent length (%)	29.0-32.8 (31.3±0.16)	31.1-34.4 (32.8±0.22)
Head width/snout-vent length (%)	27.4-30.9 (29.4±0.06)	29.5-33.0 (30.9±0.17)
Interorbital distance/head width (%)	30.1-35.8 (33.5±0.28)	30.1-34.6 (32.0±0.32)
Eyelid/head width (%)	22.2-26.5 (24.2±0.26)	21.6-25.9 (24.3±0.22)
Tympanum/eye (%)	43.1-62.7 (56.3±0.68)	60.3-71.4 (67.0±0.46)

Males are notably smaller than females; 35 males have snout-vent lengths of 55.9 to 65.7 (average 60.6) mm. Five females have snout-vent lengths of 81.6 to 84.2 (average 82.9) mm. There are no significant differences in body proportions, but females have more vomerine teeth (9-12, as compared with 4-10 in males) and have a relatively blunt snout in lateral profile, as compared to the sloping snout in males.

OSTEOLOGY.— The skull of *Phyllomedusa annae* is typical for the genus (Fig. 3). Maxillary forming a sharp angle with premaxillary; premaxillary having long nasal process; nasals large, in broad contact medially and sutured to ethmoid; cartilage covering frontoparietal fontanelle partially ossifield; definite fontanelle persisting in adults; frontoparietal broad and flat posteriorly; occipital condyles small, widely separated; foramen magnum twice as wide as high; proötics massive, in broad contact with squamosal; squamosal T-shaped, having broad and flat base; quadratojugal slender and strongly sutured to maxillary; vomers having long anterior processes and somewhat shorter lateral and posterolateral processes; vomerine elevations elliptical and situated close to mid-line; palatines slender medially, broader laterally, and in contact with maxillary; pterygoid rounded, in broad contact with maxillary, and strongly sutured to exoccipital. Maxillary and premaxillary teeth bluntly spatulate and bifid; 72-82 teeth on each maxillary, 10-12 on each premaxillary; vomerine teeth blunt and weakly bifid; 4-12 teeth on each vomerine process. Sacral diapophyses flattened and expanded, especially posteriorly.

ECOLOGY AND DISTRIBUTION

All localities where *Phyllomedusa annae* was found are characterized by lush tropical vegetation, moderately warm diurnal temperatures, and high humidity. *Phyllomedusa annae* apparently is an inhabitant of the coffee-zone; it has been taken at elevations of 1200 to 1600 meters. Associated with *Phyllomedusa annae at* Tapantí were *Bufo marinus, Bufo melanochloris, Hyla pseudopuma, Phyllomedusa lemur, Cochranella fleischmanni, Rana pipiens,* and *Rana warschewitschi.* Of these, *Hyla pseudopuma* and *Rana warschewitschi* had left the breeding pond by the time *Phyllomedusa annae* arrived in numbers. The breeding time of *Cochranella fleischmanni* and *Bufo marinus* encompassed that of *Phyllomedusa annae. Phyllomedusa lemur* started breeding when *P. annae* was nearly finished. At La Palma *Phyllomedusa annae* was found in association with *Hyla pseudopuma, Phyllomedusa lemur, Centrolene prosoblepon, Cochranella fleischmanni,* and *Rana warschewitschi;* at Moravia de Turrialba *Phyllomedusa annae* was found with *Bufo coniferus, Hyla ebraccata, Hyla loquax,* and *Smilisca phaeota phaeota.*

Phyllomedusa annae is presently known only from the Meseta Central and the Caribbean slopes of the Cordillera Central and the Cordillera de Talamanca in Costa Rica. The following specimens have been examined and referred to this species:

ALAJUELA PROVINCE: Cinchona, KU 68537-8 (tadpoles). CARTAGO PROVINCE: Cartago, CNHM 101164-74, 101795-6, KU 24584-96, 24598-9, 31100-9, 31127-31, 32730-54, 36679-80, 38999-39001; 2 km. S of Cartago, KU 31110-25, 41065 (skeleton); Moravia de Turrialba, KU 32729, 64061-3, 68548 (eggs), 68549 (tadpoles); Tapantí, MCZ 35002-3, KU 64020-58, 68167-71 (skeletons), 68532 (eggs), 68533-6 (tadpoles), 68545-7 (tadpoles), 68550 (eggs), 70022 (tadpoles), 70023 (young), UIMNH 50965. SAN JOSÉ PROVINCE: Guadalupe, KU 64064; La Palma, KU 64065, 68539 (eggs), 68540-4 (tadpoles), 68551 (eggs), 70024 (tadpoles), 70025 (young); San José, CNHM 134229, KU 36681-2, UMMZ 122668 (8), 122789.

LIFE HISTORY

Field and laboratory studies of *Phyllomedusa annae* have resulted in the accumulation of considerable information pertaining to the life history of the species. In the following pages the breeding habits, mating call, eggs, and tadpoles are described and discussed.

BREEDING HABITS.— Breeding activity in *Phyllomedusa annae* was first observed on April 19, 1961, at Tapantí; calling males were found there through June 6, and as late as July 8 at Moravia de Turrialba. Clasping pairs were observed at Tapantí from July 29 through May 2, but the presence of eggs at Moravia de Turrialba on July 8 indicates that the breeding season probably lasts more than two months.

At Tapantí, males were observed to call from branches of bushes and small trees beside and over-hanging a spring-fed marshy pond. At La Palma males were calling from branches of trees above a sluggish stream, and at Moravia de Turrialba males were calling from bushes by a pond in the forest. There is no evidence of territoriality in calling males, for at times of greatest vocal activity calling males were found sitting within a few centimeters of one another. At each of the breeding sites males always greatly out-numbered females, which were observed sitting on branches above the water. No individuals of either sex were seen in the water.

Observations were made on three gravid females that were approached by males. In each case the males walked towards the females. In one case the female leaped to another branch when the male had approached to a distance of about 20 centimeters. He did not pursue the female. In the second instance of observed approach, the female, who was sitting at right angles to the axis of a small branch, remained motionless. The approaching male walked to the female, climbed on her back, and clasped her. In the third observed case, the female was sitting like the preceding one, but upon the approach of the male, she turned to face him. The male climbed over her, turned around, and clasped her. Amplexus is axillary; in some instances the male's outer fingers are placed above the base of the female's arm. When in amplexus the female grasps the branch on which she is sitting. The male's hind limbs are closely drawn in against his flanks.

Usually the male's head is bent downward, so that his chin is resting on top of the female's head.

Breeding activity begins at dusk, but some males call before dark. During the day both males and females were found on the undersides of large leaves of bushes and trees near the pond. At this time the limbs are closely drawn against the body, the hands are placed beneath the chin, and the eyes are closed. When in this position, these brightly colored frogs are inconspicuous.

MATING CALL.—The mating call consists of a single note, "wor-or-orp", repeated at intervals of 40 seconds to 2 minutes and 25 seconds. The duration of each note is from 0.16 to 0.44 of a second (Table 2). Each note consists of 6 to 17 (average 11.5) pulses, the last of which is emphasized in intensity (Fig. 6). Aside from the dominant frequency, six or seven other harmonics are emphasized. In a typical call of *Phyllomedusa annae* the dominant frequency is at 1134 cycles per second (cps); other emphasized harmonics are at about 2100, 3200, 4399, 5400, 6500, 7700, and 8800 cps.

TABLE 2

Comparison of Mating Calls of Phyllomedusa annae *and* Phyllomedusa moreleti

Species	Number	Duration in Seconds	Pulses per Second	Fundamental Frequency	Dominant Frequency
P. annae	13	0.16-0.44 (0.31)	38-50 (42)	140-185 (161)	1044-1295 (1165)
P. moreleti	8	0.09-0.27 (0.13)	55-61 (58)	160-185 (172)	1110-1260 (1171)

EGGS.— Egg deposition was not observed. Egg masses were found as early as April 29 and as late as July 8. The eggs are deposited as irregularly shaped masses of jelly on leaves, branches, or vines from 35 to 250 centimeters above water. Sixteen clutches of eggs contained from 47 to 162 (average 106) eggs. The jelly is clear; individual egg membranes are visible. In the early stages of development the yolk is pale green, and the animal pole is brown; in later stages the yolk is cream color, and the embryo is grayish yellow.

In studying the development of eggs and tadpoles I have used the simplified table of developmental stages of GOSNER (2). Measurements of ten eggs in Stage 4 of development (4 cells) show that the diameter of the embryo varies from 3.36 to 3.44 (average 3.41) mm.; fertilization (vitelline) membrane, 3.51 to 3.65 ,average 3.59) mm.; outer envelope, 3.93 to 4.26 (average 4.12) mm. (Fig. 7). Embryos in Stage 20 have well-defined eyes, well-developed external gills, and total lengths of 4.8 to 5.6 (average 5.1) mm. (Fig. 8). Developing embryos usually are oriented with the yolk downward in the egg capsule. Rotation of the eggs results in slow reorientation in young embryonic stages and rapid, sometimes vigorous, reorientation in most embryos in later stages of development.

Eggs apparently hatch in about six days after deposition. One clutch of eggs in Stage 4 found at La Palma on May 8 hatched on May 13. Hatching is accomplished by vigorous wriggling of the tadpole through the egg capsule. Some tadpoles adhere to the surfaces of the egg mass; by vigorous tail flipping they free themselves and drop into the water. Other tadpoles were observed to break through the membranes and to slide down the egg mass and drop into the water.

TADPOLES.— Hatchling tadpoles sink to the bottom of the pond or container and remain motionless for several minutes before making faint swimming movements and sinking to the bottom again. At Tapantí, tadpoles in various stages of development to Stage 36 were found in a spring-fed pond partly filled with aquatic vegetation. Small tadpoles (up to Stage 31) most frequently were found in vegetation-choked parts of the pond, whereas larges tadpoles were observed most often in deeper, open water. The large tadpoles orient themselves with their heads up and bodies at about a 45 degree angle to the surface of the water. The tip of the tail is curved slightly upwards and is fluttering continuously. The large tadpoles are wary; upon the slightest disturbance they swim downward or into dense vegetation.

The duration of tadpole development under natural conditions is unknown. Tadpoles were raised from eggs brought into the laboratory in San José. The tadpoles were kept there in containers until late July, when they were transported to Kansas. The tadpoles that survived were 247 days old at metamorphosis (Table 3). Tadpoles were last collected at Tapantí on July 19, when the largest individuals were in Stage 36; these tadpoles could have had a maximum age of 82 days (first eggs found on April 29). The approximate age of tadpoles in

TABLE 3

Growth and Development of Tadpoles of Phyllomedusa annae

Stage	Number	Age	Body Length	Tail Length
23	10	Hatchling	3.2- 4.4 (3.9)	6.6- 8.5 (7.7)
25	10	10 days	5.7- 6.5 (6.1)	9.7-12.6 (11.4)
27	4	19-22 days	7.5- 8.4 (8.0)	12.5-15.2 (14.2)
29	10	38 days	9.3-10.6 (9.9)	16.6-20.4 (18.3)
31	5	56 days	11.0-12.4 (11.5)	21.0-23.1 (21.7)
36	5	72 days	15.0-18.0 (15.7)	27.0-27.5 (27.2)
39	2	230 days	17.5-19.0 (18.3)	28.2-29.0 (28.6)
41	3	235 days	18.0-19.8 (19.2)	27.6-28.5 (28.1)
43	1	239 days	20.5	18.7
45	1	243 days	21.0	7.1
46	4	247 days		20.7-22.8 (21.7)

this stage of development compares favorably with a known age of 72 days for tadpoles in Stage 36 that were raised in the laboratory. Probably under natural conditions metamorphosis is reached at a somewhat younger age than indicated by the tadpoles that were kept in the laboratory and transported to Kansas.

In the following description of development in tadpoles, the general structural features and details of the mouth are described for four stages. Tadpoles in Stage 36 have fully developed mouth parts and are described in greatest detail. The size of the tadpoles is correlated with developmental stages in Figure 9.

STAGE 23.— Hatchlings having rounded yolk mass, giving body slightly greater depth than width; external gills filamentous and unbranched; nasal capsules visible, but external nares absent; anal tube present. Caudal musculature extending nearly to tip of caudal fin and slightly curved upward posteriorly; at mid-length of tail depth of caudal musculature about one-third depth of tail; ventral fin about half again as deep as dorsal fin (Fig. 10). Belly sparsely pigmented; sides of body and top of head more heavily pigmented; antero-ventral part of caudal musculature sparsely pigmented; rest of caudal musculature moderately pigmented; caudal fins, except anterior one-fourth of ventral fin, sparsely pigmented; pigment cells clumped, forming small flecks on fins. Mouth, except for median anterior edge, bordered by aingle row of small papillae; lateral folds absent; beaks present, but poorly developed; teeth absent, but faint ridges visible (Fig. 14).

STAGE 25.— Tadpoles having some yolk present, although gut beginning to form; external gills lost; sinistral, ventro-lateral spiracle present; external nares present. At mid-length of tail depth of caudal musculature less than one-third depth of tail; caudal musculature distinctly curved upwards posteriorly (Fig. 11). Top of head, orbital region, and abdomen moderately pigmented; caudal musculature and fins, except anterior one-third of ventral fin, sparsely pigmentedá small flecks present on caudal fin. Mouth, except median anterior edge, bordered by two rows of small papillae laterally and one row posteriorly; both beaks moderately developed and bearing small serrations; two upper and three lower tooth-rows; second upper row broadly interrupted medially; first lower row slightly shorter than upper rows; second lower row as long as first and interrupted medially: third lower row short and composed of small teeth (Fig. 15).

STAGE 36.— Tadpoles having mouth parts fully developed and toe buds on hind limb bud; body as wide as deep, widest at level of eyes; snout in lateral profile rounded, in dorsal profile nearly square; mouth in antero-ventral position, but directed anteriorly; nostrils situated dorsolaterally and directed anterolaterally, located about one-third distance from snout to eye; eyes situated dorsolaterally and directed laterally; diameter of eye about one-third depth of body; spiracle ventral, sinistral to mid-line, its opening slightly more than one-third distance from snout to posterior end of body; cloacal tube short, dextral. Depth of caudal musculature at mid-length of tail about one-third depth of tail; caudal musculature not quite reaching tip of tail and curved dorsally; dorsal fin deepest at mid-length of tail, not extending onto body; ventral fin deepest anteriorly (Fig. 12). Lateral line organs in a curved line between nostril and eye and thence posteriorly just median to eye, having a branch extending downward posterior to eye, curving

anteriorly below eye, and extending nearly to snout; lateral line continuing posteriorly on doroslateral surface of body and thence on side of anterior half of tail. Snout and top of head and body heavily pigmented. In life, snout and dorsum grayish brown, sides of body bluish gray, venter silvery blue, caudal musculature pale grayish brown, caudal fin transparent with brown flecks on proximal edges of anterior one- half of both dorsal and ventral fins. Mouth having shallow lateral fold; median part of upper lip bare; rest of mouth bordered by two rows of papillae; scattered small papillae median to fringing rows laterally; upper beak deep and in form of broad arch having slightly expanded wings; lower beak massive; both beaks having short, moderately pointed serrations; tooth-rows 2/3; upper rows about equal in length; second upper row interrupted medially; first and second lower rows nearly as long as upper rows; second lower row interrupted medially; third lower row noticeably shorter than others (Fig. 16).

STAGE 41.— Tadpoles having well-developed hind limbs; forelimbs visible through body wall; body about one-third again as wide as deep; upper eyelids and canthal ridges present; spiracle persistent; dorsal caudal fin low; ventral fin absent anteriorly (Fig. 13). Dorsum grayish brown; caudal musculature pale tan; belly white; caudal fin transparent. Lips turned inward; only part of outer row of papillae present; inner row of papillae lost; larval teeth and lower break absent; upper beak slender (Fig. 17).

STAGE 46.— Recently metamorphosed young having snout-vent lengths of 20.7 to 22.8 (average 21.7) mm.; average proportions of four young: tibia length/snout-vent length, 45.7 per cent; head length/snout-vent length, 38.1 per cent; head width/snout-vent length, 39.2 per cent (compare with proportions for adults in Table 1). Discs on fingers and toes well developed; all subarticular tubercles present; fingers about one-fourth webbed; toes about one-third webbed (Fig. 8). In preservative, dorsum reddish brown and ventral surfaces white; in life, dorsum green, hands and feet yellow, line along outer edge of forearm and tarsus white, pupil vertical, iris yellow; no blue color on limbs or flanks.

Changes proceed in a definite pattern during the growth and development of tadpoles. In hatchling tadpoles larval teeth are absent; only the upper beak is present. From this point the sequence of development is: lower beak, first lower tooth row, second upper row, second lower row, first upper row, and third lower row. Development of the mouth parts begins with the median or proximal structures and proceeds to the distal structures. At time of metamorphosis the opposite sequence is noted; the third lower tooth-row is lost first, then the first upper row, second lower row, second upper row, firts lower row, lower beak, and upper beak. Throughout development there is a gradual change in the relative length of the body to the tail. In hatchlings the length of the body is about one half the length of the tail (49.8% in ten specimens). Tadpoles in Stage 39 have relatively longer bodies (63.8% in two specimens). In later stages the tail becomes increasingly shorter through absorption. Changes in coloration are evident. Most noticeable is the increase in the amount of pigment

on the caudal musculature and on the dorsum of the head and body whereas the amount of pigment in the caudal fin decreases.

Recently metamorphosed young differ from adults in having proportionately larger heads and less webbing on the hands and feet. In juveniles the tympanum is barely discernible. In coloration the young resemble the adults, except that the young lack the blue flanks and thighs characteristic of the adults. Post-metamorphic stages are lacking; consequently time of development of the blue color is unknown. In life the young and adults are green above. In preservative the dorsum in adults becomes dull purple and that in recently metamorphosed young, reddish brown. Apparently there is a change in the nature of the pigment during development, which results in different chemical reactions to preservative in adults and young.

COMPARISONS

Phyllomedusa annae most closely resembles *Phyllomedusa moreleti,* but differs in larger size and certain proportions (Table 1), in having an orange eye and blue flanks and thighs instead of a red eye and orange flanks and thighs (Figs. 4 and 5), and in having a mating call that consists of longer notes repeated less frequently than in *P. moreleti* (Table 2).

The mating call of *P. annae* has been described; the call of *P. moreleti* consists of short notes having a duration of 0.09 to 0.27 of a second and repeated at intervals of 15 to 40 seconds. Each note consists of 3 to 8 (average 4.8) pulses, the last of which is emphasized in intensity. Aside from the dominant frequency, five or six harmonics are emphasized. In a typical call of *P. moreleti* the dominant frequency is at 1130 cps. Other emphasized harmonics are at about 2200, 3400, 4500, 5700, 7000, and 8300 cps.

FUNKHOUSER (1) placed *P. moreleti* in the unspecialized "*Agalychnis* section" of *Phyllomedusa.* From all members in this group, *P. annae* differs in having uniformly blue flanks and a yellow eye. The following key is provided to aid in the identification of Middle American frogs of the genus *Phyllomedusa.*

KEY TO THE SPECIES AND SUBSPECIES OF *PHYLLOMEDUSA* IN MIDDLE AMERICA

1. Fingers fully webbed; dorsum green with white spots bordered by black; males to 88 mm.; Panamá and northwestern South America ..... *P. spurrelli*

   Fingers not fully webbed; dorsum not market with black-bordered white spots 2

2. Fingers free; dorsum lavender-brown or reddish brown (when active at night); flanks and thighs yellow; iris bronze; males to 40 mm.; Costa Rica ..... *P. lemur*

   Fingers having some webbing; coloration not as described 3

3. Flanks marked with blue or purple 4

   Flanks green, orange, or yellow 7

4. Flanks and concealed surfaces of limbs uniform blue; fingers two-thirds webbed; iris orange-yellow; males to 74 mm.; Costa Rica ..... *P. annae*

   Flanks blue with vertical creamy yellow bars; color of thighs variable; webbing between fingers variable iris red 5

5. Longitudinal cream colored stripe separating blue flanks from green dorsum; posterior surfaces of thighs deep blue; fingers two-thirds webbed; males to 65 mm.; Caribbean lowlands, Nicaragua and Costa Rica ..... *P. helenae*

   No longitudinal cream colored stripe separating blue flanks from green dorsum; posterior surface of thighs orange-yellow; fingers less than two-thirds webbed 6

6. Flanks purple with vertical cream colored bars, dorsum mottled dark and pale green; fingers one-half webbed; males to 50 mm; lowlands from Nicaragua to Panamá ..... *P. callidryas callidryas*

   Flanks blue with vertical cream colored bars; dorsum pale green; fingers one-third webbed; males to 47 mm.; Atlantic lowlands from Veracruz, México to Honduras ..... *P. callidryas taylori*

7. Flanks orange, with or without vertical black bars; fingers two-thirds webbed..... 8

   Flanks green; fingers not more than one-third webbed 9

8. Vertical black bars on flanks and thighs; iris gray; males to 55 mm.; Costa Rica to northwestern South America ..... *P. calcarifer*

   No vertical black bars on flanks and thighs; iris red; males to 66 mm.; Veracruz, México, to Guatemala and El Salvador ..... *P. moreleti*

9. Dark wavy transverse lines on green dorsum; white spot behind eye; iris red; fingers one-third webbed; males to 50 mm.; Pacific slopes in Costa Rica ..... *P. saltator*

   Dorsum green, with or without small yellowish white spots; no white spot behind eye; iris black with gold flecks; trace of web between fingers; males to 75 mm.; Pacific lowlands of México ..... *P. dacnicolor*

ACKNOWLEDGMENTS

I am grateful to the authorities of the Universidad de Costa Rica for their many courtesies, especially Dr. Alvaro Wille, who acted as my official host in Costa Rica. Permits for collecting were generously issued by Ing. Milton H. López of the Ministerio de Agricultura e Industrias. My field studies were furthered by the assistance of Ann S. Duellman, Craig E. Nelson, and Jerome B. Tulecke. For permission to examine specimens in their care I am indebted to Robert F. Inger, Chicago Natural History Museum, and Charles F. Walker, Museum of Zoology at the University of Michigan. I am grateful to Priscilla Starrett, who aided in the raising of tadpoles.

My field work in Costa Rica was made possible by a grant from the National Science Foundation (NSF-G9827) an the cooperation of the Museum of Natural History at the University of Kansas.

SUMMARY

A new species of tree frog, *Phyllomedusa annae,* is described from Tapantí, Cartago Province, Costa Rica. The new species has blue flanks and thighs and an orange eye; it is closely related to *P. moreleti,* which has orange flanks and thighs and a red eye. Eggs, tadpole development, and call are also described and illustrated

RESUMEN

Se describe una nueva especie de rana, *Phyllomedusa annae,* de Tapantí, Provincia de Cartago, Costa Rica. La especie nueva se caracteriza por las ijadas y los muslos azules y el iris amarillo. *Phyllomedusa annae* tiene relaciones con *P. moreleti,* de El Salvador, Guatemala y México, que se caracteriza por las ijadas y los muslos naranja y el iris escarlata. Se describen e ilustran también los huevos, los renacuajos y el canto.

ZUSAMMENFASSUNG

In der vorliegenden Arbeit wird es eine neue Laubfroschart *Phyllomedusa annae* aus Tapantí, einer Gegend der Provinz Cartago, Costa Rica beschrieben. Die durch die gelben Augen, die blauen Weichen und Schenkel ausgezeichnete neue Art ist mit *P. moreleti* verwandt, die in El Salvador, Guatemala und Mexiko angetroffen wird. Diese Art unterscheidet sich von der ersten dadurch, dass die Weichen und Schenkel orangegelb, die Augen scharlachrot sind. Der Verfasser beschreibt und zeichnet die Eier und Larven des neuen Frosches, und berichtet auch über das Quaken desselben.

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1960. A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica,* 16: 183-190.

3. TAYLOR, E. H.
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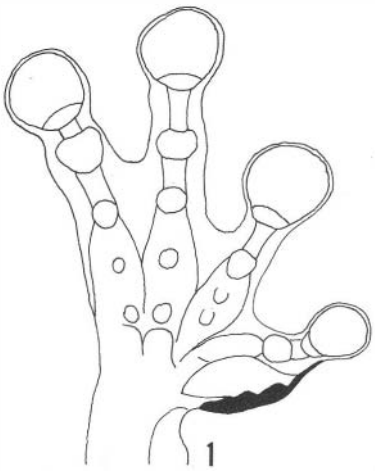
Figs. 1 - 3: *Phyllomedusa annae* n. sp.

Fig. 1: Palmar view of right hand. KU 64020 (× 3).

Fig. 2: Palmar view of right foot. KU 64020 (× 3).

Fig. 3: Dorsal view of skull. KU 68167 (× 3).



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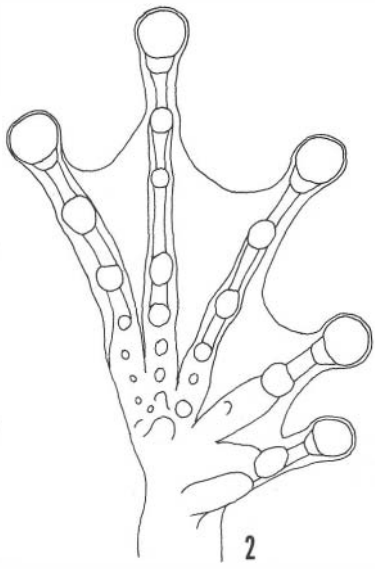

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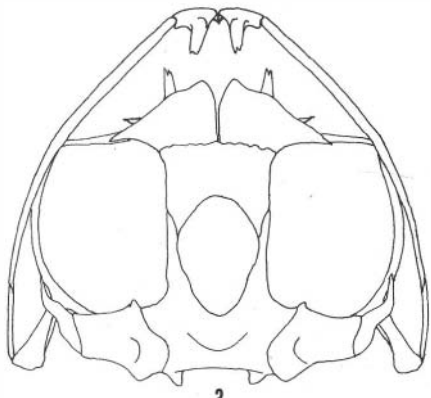


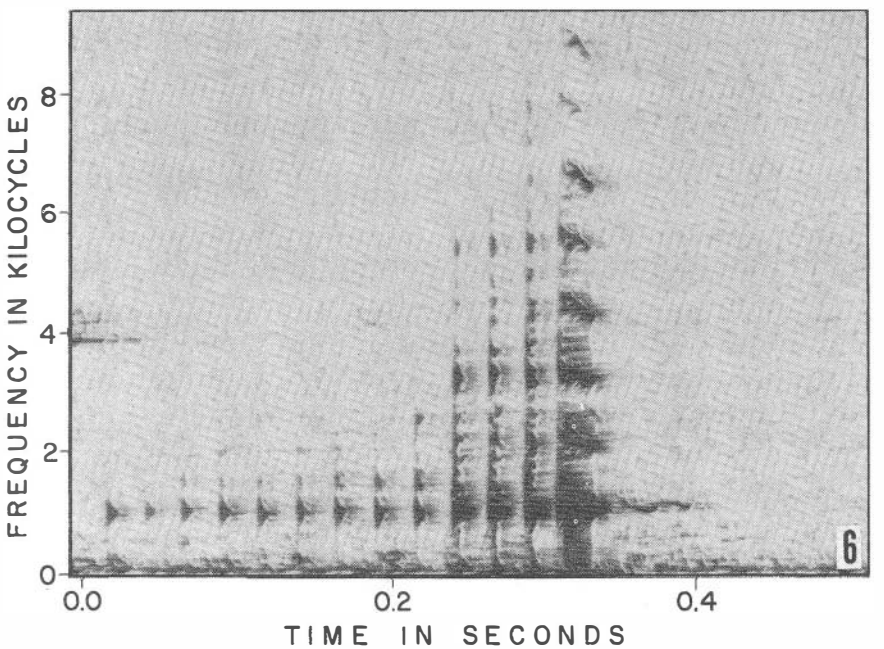
3

Fig. 4: *Phyllomedusa annae* n. sp.
Adult male holotype, KU 64020 (× 1).

Fig. 5: *Phyllomedusa moreleti*. Adult. male from Cobán, Alta Verapaz, Guatemala, KU 58932 (× 1).


4
5

Fig. 6: Sound-spectrograph of mating call of *Phyllomedusa annae* (KU Tape No. 55).

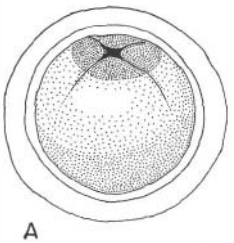

FREQUENCY IN KILOCYCLES
8
6
4
2
0
0.0
0.2
0.4
TIME IN SECONDS
6

Figs. 7-8: Embryonic development of *Phyllomedusa annae*.

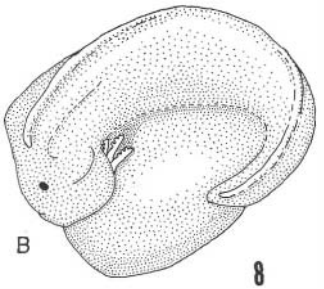
Fig. 7: Four-cell egg, stage 4 (× 6).

Fig. 8: Embryo, stage 20 (× 12).

Fig. 9: Correlation of body length and stage of development in tadpoles of *Phyllomedusa annae*.


A

7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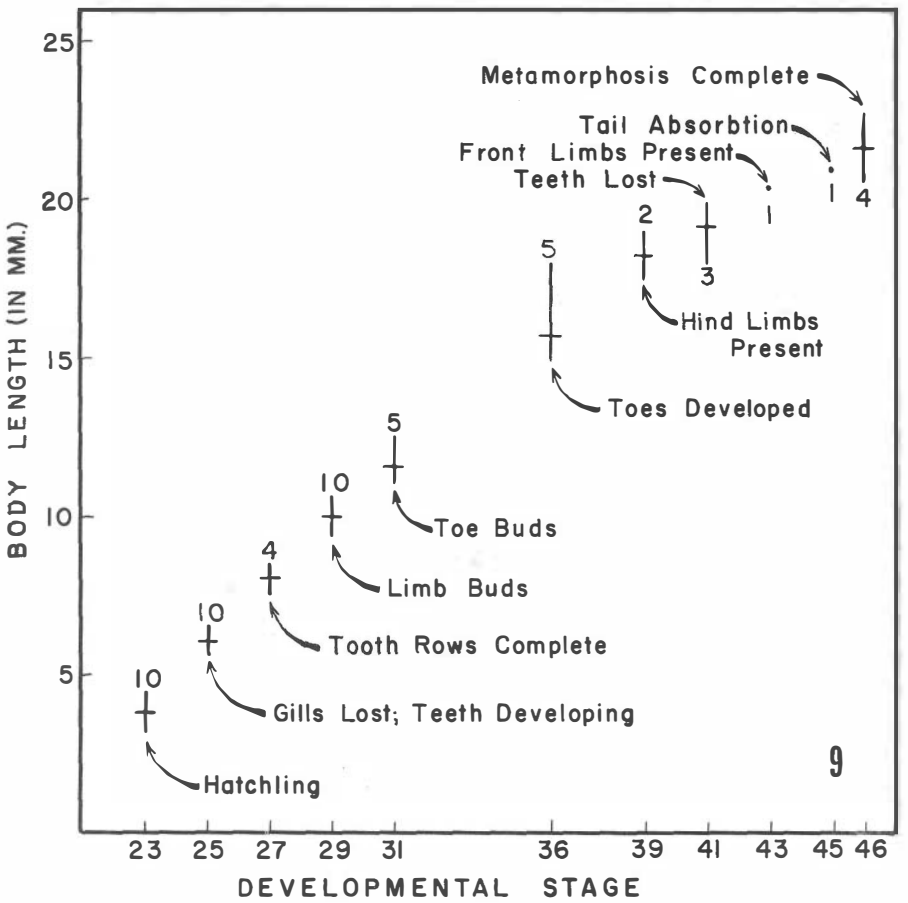

BODY LENGTH (IN MM.)
25
20
15
10
5
Metamorphosis Complete
Tail Absorbtion
Front Limbs Present
Teeth Lost
1
4
2
3
5
Hind Limbs Present
Toes Developed
5
Toe Buds
10
Limb Buds
4
Tooth Rows Complete
10
Gills Lost; Teeth Developing
10
Hatchling
23
25
27
29
31
36
39
41
43
45
46
DEVELOPMENTAL STAGE

9

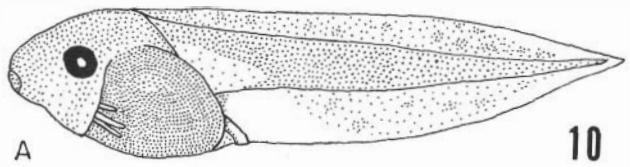
Figs. 10-13: Tadpoles of *Phyllomedusa annae*.

Fig. 10: Stage 23, KU 68533 (× 8.5).

Fig. 11: Stage 25, KU 68534 (× 4.2).

Fig. 12: Stage 36, KU 68546 (× 2).

Fig. 13: Stage 41, KU 70022 (× 2.5).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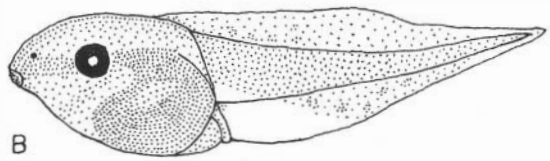
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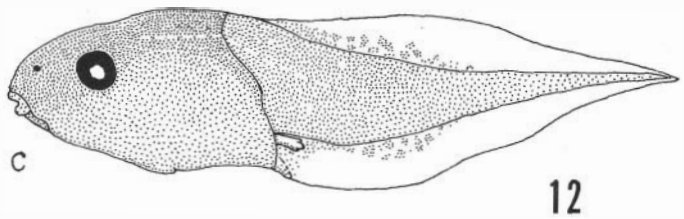
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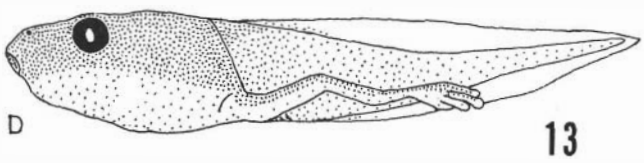

D
13

Figs. 14-17: Mouth parts of tadpoles of *Phyllomedusa annae*.

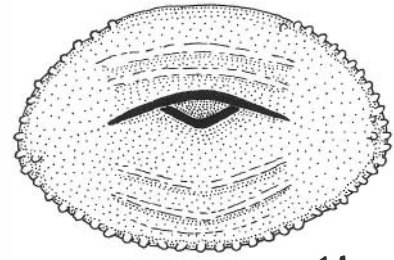
Fig. 14: Stage 23, KU 68533 (× 60).

Fig. 15: Stage 25, KU 68534 (× 30).

Fig. 16: Stage 36, KU 68546 (× 12).

Fig. 17: Stage 41, KU 70022 (× 15).

Fig. 18: Recently metamorphosed young of *Phyllomedusa annae*, KU 70025. X 2.



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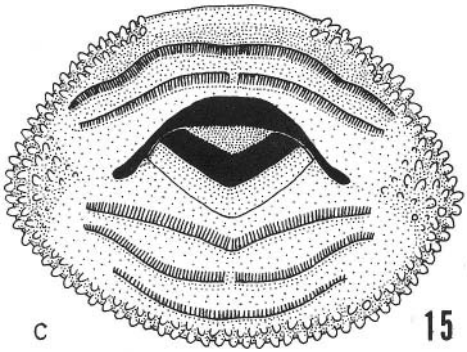

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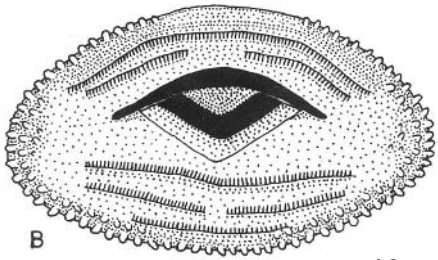

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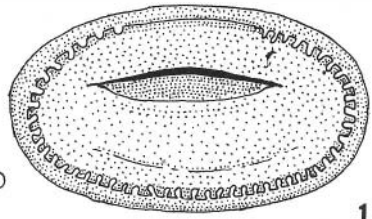

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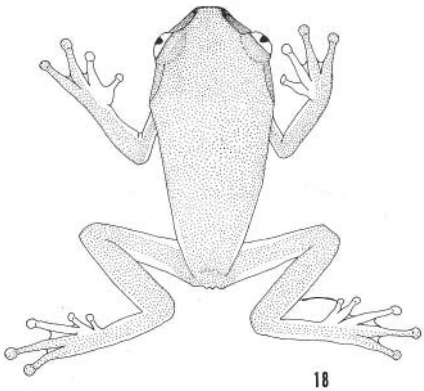

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