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New biological data for two rare reedfrog species, *Hyperolius nimbae* Laurent, 1958, and *H. chlorosteus* (Boulenger, 1915) (Anura: Hyperoliidae)

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***Abstract.*—Our recent surveys have generated new biological data on *Hyperolius nimbae* and *H. chlorosteus*, two little-known West African reedfrog species of conservation concern. During fieldwork at the eastern foothills of the Ivorian part of the Nimba Mountains, *H. nimbae* and *H. chlorosteus* individuals were found by acoustic and visual encounter surveys. In addition, various natural history data were recorded, including clutch size and egg-deposition sites. *Hyperolius nimbae* males were found at the edges of a permanent swamp. The area was dominated by cocoa and coffee plantations, and used in small-scale subsistence farming, i.e., growing plantains, cassava, and rice. A new locality is reported here for the species, but our surveys failed to confirm its presence at some previously known sites. The entire range of the species is now confined to a small, non-protected, human-impacted area. Under these conditions, this species is facing high extinction risk. *Hyperolius chlorosteus* was found in a patch of dense, broadleaf and evergreen primary forest at a mid-elevation along a torrent stream, and in a degraded lowland forest edging a large stream. The habitats of both species are suffering from forest degradation and deforestation along streams, so we urgently recommend the strict protection of the habitats of both species. Given these concerns, we suggest that the IUCN threat status of *H. nimbae* should be updated to Critically Endangered. Considering the large range of *H. chlorosteus*, the current IUCN categorization of this species as Least Concern seems to be correct. However, based on the fact that in Ivory Coast it only occurs in the westernmost parts of the country, several of the few known national populations have been lost, and the remaining forest habitats are declining, so we feel that *H. chlorosteus* should be regarded as Endangered nationally.**

Keywords. Biodiversity hotspot, endemic, habitat protection, Mount Nimba Reedfrog, Threatened species, Upper Guinean forest area

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Introduction

Ivorian montane areas, such as Mount Péko, Mount Sangbé, and Mount Nimba, are small in extent but comprise a high diversity of amphibian species (e.g., Rödel 2003; Rödel and Ernst 2003; Kanga et al. 2021). Mount Nimba, in particular, hosts the richest amphibian fauna of West Africa including various rare and endemic species (Kanga et al. 2021; Rödel et al. 2021). For instance, this mountain is the only known region where the matrotrophic Nimba Toad, *Nimbaphrynoides occidentalis* (Angel, 1943), and the Mount Nimba Reedfrog, *Hyperolius nimbae* Laurent, 1958, are found. The biology of *N. occidentalis* has been investigated in detail (Lamotte 1959; Lamotte and Sanchez-Lamotte 1999; Xavier 2009; Sandberger et al. 2010; Sandberger-Loua et al. 2017, 2018), and this toad is considered to be the flagship species for the conservation of the Nimba mountains (Hillers et al. 2008a; Sandberger-Loua et al. 2016).

Much less attention has been directed toward various other little-known amphibian species which are, nevertheless, of high conservation concern in Ivory Coast. These include, two notable reedfrogs, the Mount Nimba Reedfrog *Hyperolius nimbae* and the Large Green Reedfrog *H. chlorosteus* (Boulenger, 1915), for which

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we know very little concerning their life histories.

Hyperolius nimbae is currently classified as Endangered on *The IUCN Red List of Threatened Species* (IUCN 2021). It is endemic to the lowlands of the eastern slopes of the Ivorian part of Mounts Nimba. After Schiøtz (1967) last collected this frog on 28 July 1963, the species was only recently rediscovered by Kouamé et al. (2016). This species is rare throughout its limited range in some swamp forests near Danané (Schiøtz 1967; Kouamé et al. 2016; Kanga et al. 2021). By contrast, *H. chlorosteus* inhabits rainforests in Sierra Leone, Guinea, Liberia, and western Ivory Coast (Rödel et al. 2004; Channing and Rödel 2019) and is categorized as Least Concern on the IUCN Red List (IUCN 2021). Despite a broad distribution, *H. chlorosteus* is confined to the edges of rivers in primary lowland forests (Schiøtz 1967; Rödel and Glos 2019), and thus must be regarded as threatened in Ivory Coast due to the decline of those habitats. A previously known population in Lakota (south-central Ivory Coast; Schiøtz 1967) no longer exists, and more may have been lost due to deforestation. For instance, Ivorian records of *H. chlorosteus* have been published from the classified forests (managed forests) of Cavally and Haute Dodo (Rödel and Branch 2002), and the national parks of Mount Sangbé (Rödel 2003), Mount Péko (Rödel and Ernst 2003), and Taï (e.g., Ernst and Rödel 2008; Kpan et al. 2021), as well as from Mount Nimba (Kanga et al. 2021), which are all situated in the south-western part of the country. However, during a decade of conflict, the gallery forests in Mount Péko as well as both classified forests have been destroyed (NG Kouamé, pers. obs.). These losses restrict the remaining known Ivorian range of *H. chlorosteus* to the southern part of Mount Sangbé, the lowland forests of Mount Nimba, and the Taï National Park.

The aim of this study was to search for the persisting populations of *H. nimbae* and *H. chlorosteus* at Mount Nimba, and to collect additional data on the morphology, call characteristics, breeding sites, and potential threats for these poorly-known species.

Material and Methods

Study site. Fieldwork was conducted in the Mount Nimba Integrated Nature Reserve (MNINR: 07°25'–07°45'N, 008°20'–008°35'W; Fig. 1) during both the rainy and dry seasons, and was carried out on 84 days between 2 August 2019 and 8 July 2020. The MNINR covers 5,000 ha of various habitats ranging from altered and former forests in the lowlands, through dense, broadleaf and evergreen forests stretching from the lower to mid-elevations, and montane grasslands at the highest elevations (Lamotte et al. 2003a,b; Lauginie 2007). Mean annual temperatures vary from 22–27 °C on the mountain bases, and 16–21 °C on the mountain ridge. The rainy season extends from eight to nine months and is only interrupted by a short dry season from November/December to February/March. The precipitation is highest on the mountain top, where it may reach up to 3,500 mm. During the dry season, the humidity is usually below 30%, but exceeds 80% in the rainy season (Lauginie 2007). The dry season is characterized by a warm, dry, and dusty wind known as Harmattan. For a detailed description of MNINR's amphibian fauna see Kanga et al. (2021).

Sampling. As previous research has shown that these two reedfrog species are only active at night (Kanga et al. 2021), searches took place from 1800–2200 h GMT. All searches were conducted by three people, totalling a search-effort of 1,008 person-hours. Search techniques focused on visual scanning of the terrain, supplemented by acoustic surveying to find the males, and examination of potential calling and breeding sites. Particular attention was given to searching the vegetation around and/or along forest streams and swamps. We investigated the area seven times per month and counted only individuals that were captured.

Hyperolius nimbae was found at one site at Yéalé, while *H. chlorosteus* was collected at one site at MNINR and another site at Yéalé. We visited each site 56 times in the rainy season and 28 times in the dry season (Table 1; Appendices 1 and 2). Frogs were photographed, measured, and sexed. To avoid re-counting frogs, individuals that were not collected were marked as vouchers by toe clipping following the recommendations of Grafe et al. (2011), and released at their respective sites of capture. Areas close to four villages (Dagbonpleu, Danipleu, Kouan-Houlé, and Zéalé), within the formerly known range of *H. nimbae,* were re-investigated seven times. These visits were in the rainy season, which is the presumed reproductive period of the species. We recorded potential threats to *H. nimbae* and *H. chlorosteus*, defined here as any anthropogenic activity that may negatively impact the two species and/or their habitats.

Although the panzootic chytrid fungus *Batrachochytrium dendrobatidis* (*Bd*) seems to be absent from West Africa, west of the Dahomey Gap (Penner et al. 2013), newly sterilized equipment was always used at each site. Geographical coordinates were recorded with a GPS (datum: WGS84). A few vouchers were euthanized in a 1,1,1-trichloro-2-methyl-2-propanol hemihydrate (MS222) solution and thereafter preserved in 80% ethanol. These frogs are deposited in the research collection of NGK at the Université Jean Lorougnon Guédé, Daloa, Ivory Coast, and will serve as the bases of a national reference collection and for research and teaching purposes.

Morphological characteristics and advertisement calls. Measurements of morphological features (in mm) were taken by one person (BAIG) with a dial calliper (accuracy ± 0.1 mm), and are given as means ($\bar{X}$) with standard deviations (SD). They comprise: snout-urostyle length, head width and length both at the level of jaw

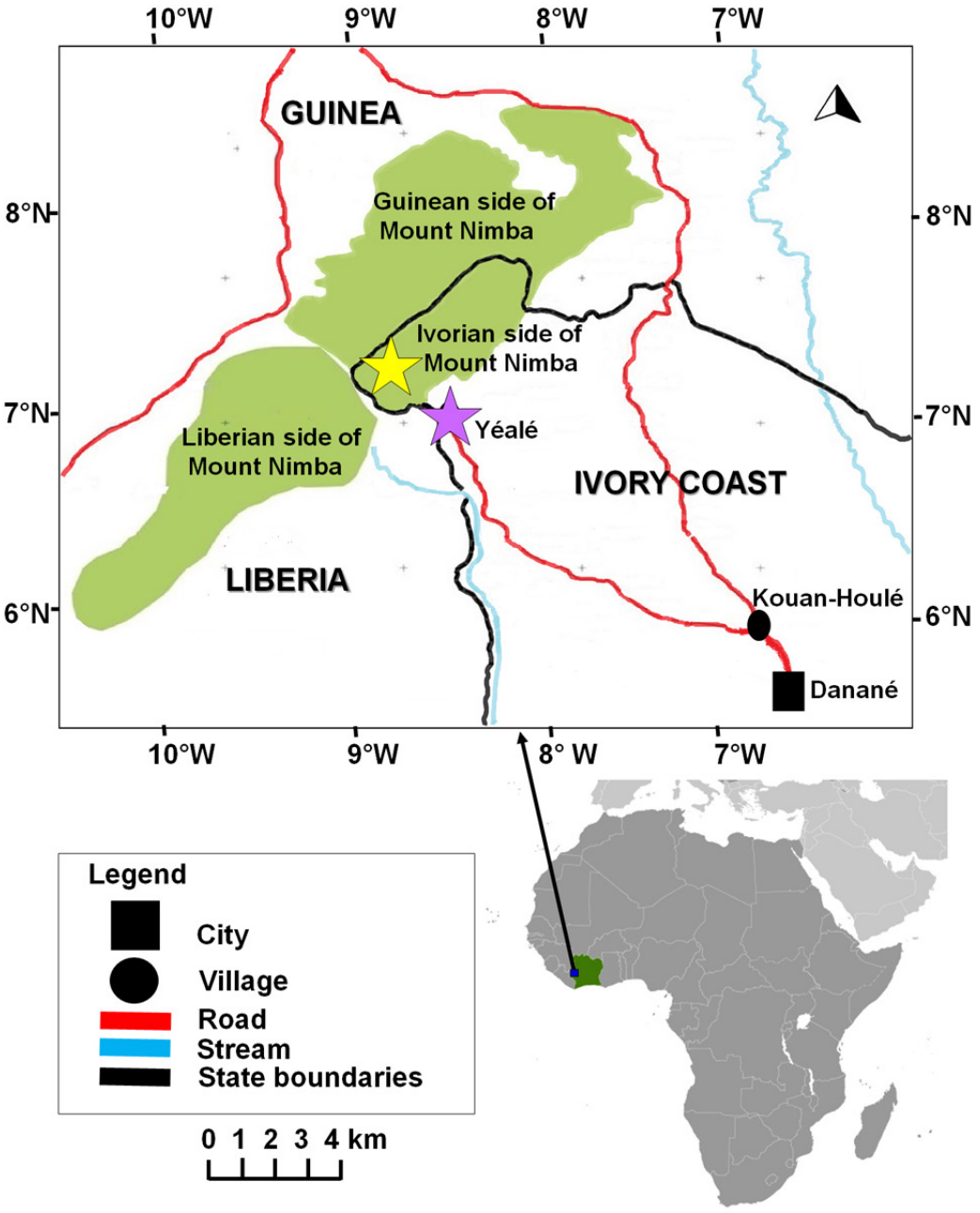

Fig. 1. Geographical location of the Mount Nimba Integrated Nature Reserve within the westernmost extension of Ivory Coast at the border crossing point with Guinea and Liberia. The altered forest area where *Hyperolius nimbae* and *H. chlorosteus* were found at Yéalé is represented by a purple star; the habitats of *H. chlorosteus* ranged from dense, broadleaf and evergreen forests from lower to mid-elevations (yellow star). The inset figure indicates the location of Ivory Coast (green patch) on the African continent.

articulation, interorbital space, distance between eye and nostril, distance from nostril to tip of snout, eye diameter, internarial distance, tympanum diameter, crus length, thigh length, and foot length including the tarsus and the longest toe.

Other characters recorded included color pattern variation following the definitions by Schiøtz (1967) and Channing and Rödel (2019). To ensure that clutches of *H. nimbae* and *H. chlorosteus* could not be confused with those of other sympatric reedfrogs, couples were collected and kept separately in a plastic terrarium (25 × 15 cm, 16 cm depth) with water (8.5 cm) and submerged and floating vegetation until eggs were laid. Egg numbers and diameters (accuracy ± 0.1 mm) were determined for each clutch. For comparison, further *H. chlorosteus* clutch data collected between 1999 and 2001 in Taï National Park by MOR are also reported here.

Hyperolius nimbae was not included in a phylogeny of the genus (Portik et al. 2019), but is assumed to be a member of the *H. viridiflavus* complex (Schiøtz 1999; Channing 2022). Very recently, this was confirmed by genetic data, and it was shown to be the sister species to

Table 1. Numbers of daily searches for *Hyperolius nimbae* and *H. chlorosteus*, during the 84-night period from 2 August 2019 to 8 July 2020, in Mount Nimba Integrated Nature Reserve and Yéalé.

	Hyperolius nimbae	***Hyperolius chlorosteus***	
Site of capture	Yéalé (07°31.928'N, 008°25.401'W; 425 m asl)	MNINR (07°34.652'N, 008°24.966'W; 716 m asl)	Yéalé (07°31.932'N, 008°25.508'W; 387 m asl)
Number of visits during the rainy season	56	56	56
Number of visits during the dry season	28	28	28

the Central African *H. tuberculatus* (Kouamé et al. 2022). Nine sequential advertisement calls were collected from one male, in order to compare these data with those presented by Schiøtz (1967). Five advertisement calls were also recorded from a *H. chlorosteus* male.

All calls were recorded with a Huawei recorder (44.1 kHz sample ratio, 16 bits of resolution, FFT length = 256) and analyzed with the software Soundruler 0.9.6 (Gridi-Papp 2007; Köhler et al. 2017; Emmrich et al. 2020). For each advertisement call, the following measurements were recorded: call duration (s), dominant frequency (Hz), fundamental frequency (Hz), minimum frequency (Hz), maximum frequency (Hz), duration intervals between calls (s), duration intervals between notes (s), and overall frequency bandwidth (Hz).

Results

Observations on *H. nimbae*

Habitat, population size, and activity of *H. nimbae*. The Mount Nimba Reedfrog was found only in the Yéalé village (07°31.928'N, 008°25.401'W; 425 m asl) at the periphery of MNINR. Our efforts to confirm the species around village forests at Dagbonpleu, Danipleu, Kouan-Houlé, and Zéalé were unsuccessful. The forest areas formerly at these sites were destroyed and replaced by roads and new settlements. At Yéalé, the habitat comprised altered forest bordered by patches of bamboo, intact forests, degraded forests with large clearings, and thick grassy and shrubby vegetation around the settlement. Large parts of the village's surroundings were dominated by small-scale subsistence farming, mainly plantings of corn, cassava, plantains, cocoa, and coffee, as well as rice in swamps. During the entire study, the vegetation around swamps was checked at seven sites without detecting any sign of *H. nimbae*'s presence.

Specimens of *H. nimbae* were found only in a mixed cocoa and coffee plantation (including plantains) edging a large and deep pond (greater than 100 x 70 m; Fig. 2), where males started calling at dusk, usually around 1810 h GMT. Calling males were active in each month of our study and congregated in large choruses, particularly during the rainy season. Calling activity never stopped, but was low during the dry season, as indicated by the much lower numbers of frogs caught during that time (Fig. 3). The calling males were mostly well concealed, perching between thick branches and leaves of cocoa and coffee trees at ~1.80–2.10 m above the ground. Througout the study, a total of 305 frogs were captured (Fig. 3; Appendix 1). They comprised 277 individuals, including one couple, caught in the rainy season and 28 males caught in the dry season. Generally, additional calling males were inaccessible, calling from high up in tall trees close to the deep pond.

Sympatric amphibian species in Yéalé were the White-lipped Frogs *Amnirana* sp. "albolabris west", *Afrixalus dorsalis*, *A. fulvovittatus*, *Hyperolius concolor*, *H. fusciventris fusciventris*, *H. picturatus*, *Phrynobatrachus gutturosus*, and *P. latifrons*, thus representing a typical composition of a farmbush anuran community (Schiøtz 1967).

Morphology of *H. nimbae*. We retained 13 males and one female *H. nimbae* as vouchers. Snout-urostyle lengths of the voucher males ranged from 28.8–35.0 mm (32.3 ± 1.8 mm), thus slightly exceeding the known range of *H. nimbae* (Schiøtz 1967). The head was slightly longer (12.0 ± 1.1 mm; range: 10.0–13.5 mm) than broad (10.8 ± 0.8 mm; range: 9.9–12.5 mm); interorbital space ranged from 5.0–7.5 mm (6.4 ± 0.7 mm); the distance between eye and nostril (2.1 ± 0.3 mm; range: 2.0–3.0 mm) approximated the distance from nostril to tip of snout (2.2 ± 0.3; range: 1.5–2.0 mm); eye diameter (4.6 ± 0.4 mm; range: 4.0–5.1 mm) was larger than internarial space (3.2 ± 0.3 mm; range: 3.0–4.0 mm) and tympanum diameter (2.3 ± 0.3 mm; range: 2.0–3.0 mm); crus length (16.5 ± 1.0 mm; range: 15.1–18.9 mm) slightly exceeded thigh length (15.0 ± 0.8 mm; range: 13.5–16.1 mm); and foot length including the longest toe ranged from 21.0–26.9 mm (23.1 ± 1.6 mm).

The female measured 34.0 mm SUL (Fig. 4A). Its head was slightly longer (14.0 mm) than broad (12.1 mm); the interorbital space reached 8.0 mm; the distance between eye and nostril (3.4 mm) was longer than the distance from nostril to tip of snout (1.8 mm); eye diameter (5.0 mm) was larger than internarial space (3.0 mm) and tympanum diameter (2.9 mm); crus length (18.0 mm) slightly exceeded thigh length (17.1 mm); and foot length including the tarsus and the longest toe reached 24.5 mm.

Mount Nimba reedfrogs have a brief and truncated

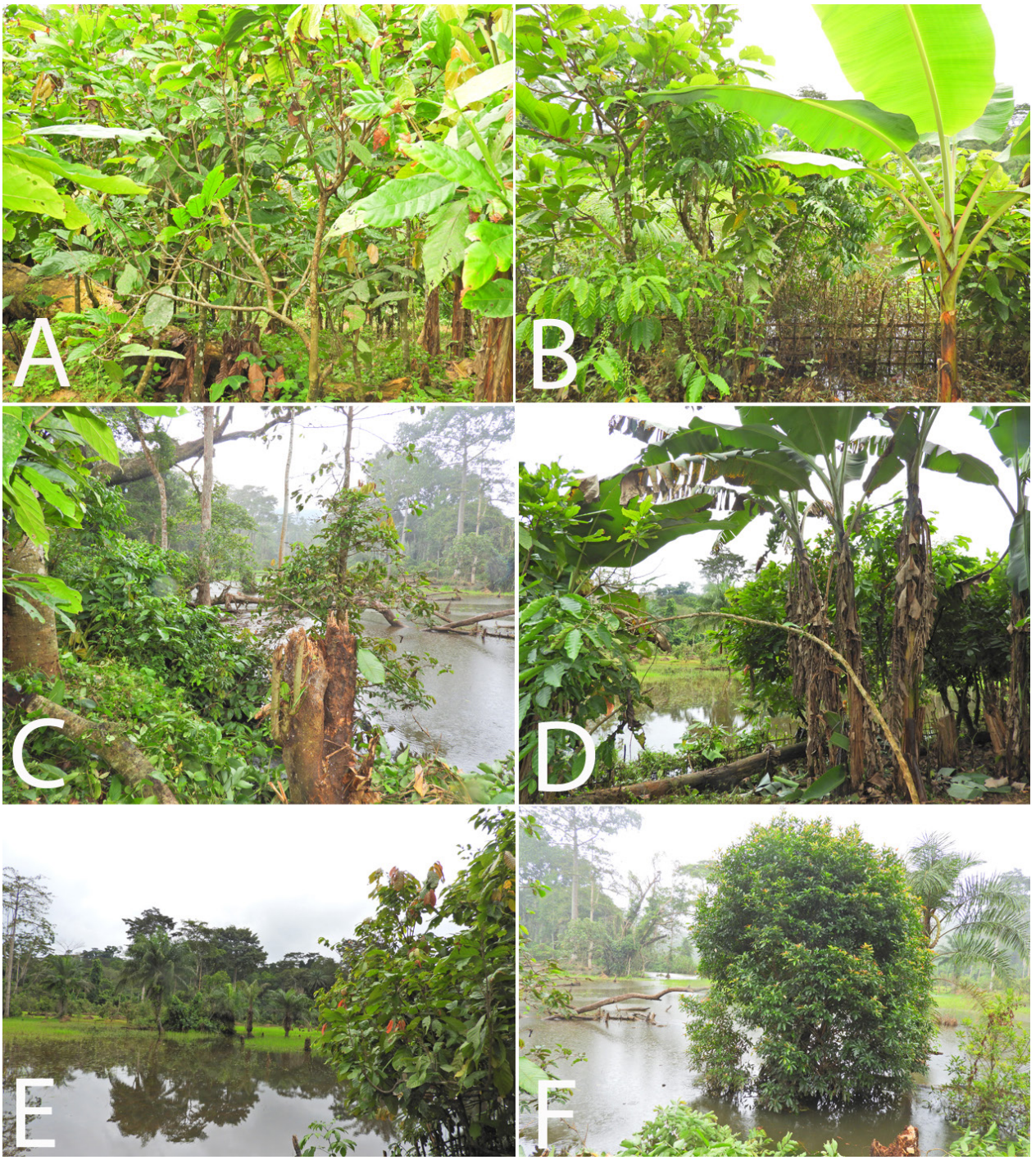

Fig. 2. Habitats of *Hyperolius nimbae* at the foothills of the Ivorian part of the Nimba Mountains. In Yéalé, the species was found in heavily degraded habitats at the edge of large swamps.

snout and rough to warty dorsal skin with a varied color pattern. The basic dorsal pattern varied from silver-grey to chocolate brown. The dark pattern on the back varied in intensity, but the general pattern was always similar and recognizable (Fig. 4). The female coloration was within the variation of the males (Fig. 4), but the discs on toes and fingers were more reddish than in most males (Fig. 4A). Likewise, the ventral color differed slightly between individuals, but the female was not different from the males (Fig. 5). However, instead of a dark vocal sac and yellowish gular gland, the female had a white throat, with the edges beset by orange and black speckles. The armpits and inner parts of limbs including webbing were blood red (Fig. 5C). Some males had similarly reddish skin parts (Fig. 5A), areas which are used for water uptake, see Rödel (2000), whereas others had blue-grey skin instead (Fig. 5B).

Reproduction of *H. nimbae*. At Yéalé, a couple of *H. nimbae* in amplexus was captured on a *Raphia* Palm in

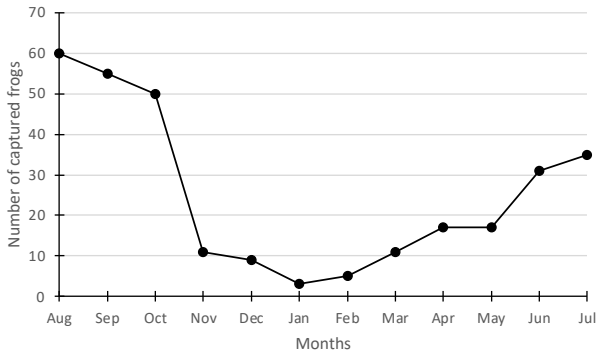

Fig. 3. Number of *Hyperolius nimbae* individuals recorded from 2 August 2019 to 8 July 2020 at Yéalé.

deeper water (> 1 m). The couple was placed into a terrarium, and the following morning, 227 eggs were found attached to a leaf above the water surface. The eggs had a dark and light green pole that was surrounded by a thin transparent jelly (Fig. 5D). Egg diameter varied from 1.6–2.5 mm, with a mean value of 1.99 mm (SD: ± 0.18 mm).

Vocalization of *H. nimbae*. The acoustic properties of nine advertisement calls of one *H. nimbae* male were analyzed (Fig. 6). *Hyperolius nimbae* call in a long, fast series of pulse groups (notes), thus confirming the call descriptions provided by Schiøtz (1967). The call duration averaged 2.77 ± 0.56 s (range: 1.89–3.25 s). The duration intervals between calls averaged 0.44 ± 0.23 s (range: 0.22–0.87 s, N = 8). Intervals between notes within each call were 0.15 ± 0.03 s (range: 0.09–3.48 s, N = 131). The mean fundamental frequency was 1,359.37 Hz (N = 9), while the dominant frequency reached 2,718.75 Hz (N = 9). The maximum frequency intensity was at 2,906.25 Hz (N = 9), and the minimum frequency intensity averaged 2,718.75 Hz (N = 9).

Threats to *H. nimbae*. We failed to confirm the species presence at all sites where we had recorded it only a few years before (see above). In addition, we observed various signs of habitat degradation in the habitats of *H. nimbae* at Yéalé. Aside from the close proximity to a human settlement, the frogs' habitats were dominated by cocoa and coffee plants, and used for small-scale subsistence farming, i.e., plantains and cassava. Large parts of the breeding area of *H. nimbae* were used to establish rice paddies. Bamboo patches were steadily harvested by the local human population as construction materials. The rainforest edges were impacted by logging (Fig. 2).

Observations on *H. chlorosteus*

Habitat, population size, and activity of *H. chlorosteus*. Specimens of *H. chlorosteus* were found in MNINR in a patch of dense, broadleaf and evergreen primary forest at a mid-elevation along a torrent stream (07°34.652'N, 008°24.966'W; 716 m asl; Fig. 7A), as well as in a degraded forest edging a large stream at Yéalé village (07°31.932'N, 008°25.508'W; 387 m asl; Fig. 7B). From April–November, the rainy season, a total of 341 *H. chlorosteus* were captured in the two sites, always at night along the streams (Fig. 8; Appendix 2). In the dry season, from December to March, no signs of the species' presence were observed. Males started calling at around 1800 h GMT, most often after heavy rainfall. In a patch of primary forest, 327 calling males perched on leaves and branches of small shrubs at ~1.5–2.0 m height above the ground (e.g., Fig. 7C) were captured. The other recorded males were heard calling from very high up in tall trees along the forest stream. A few calling males (N = 11) were also found in a degraded forest, edging a large stream at Yéalé village (07°31.932'N, 008°25.508'W; 387 m asl; Fig. 7B). There, they called on shrubs, with the calling sites ranging from 1.80 m above the ground to much higher. Sympatric frogs were *Leptopelis macrotis*, *Hyperolius picturatus*, and White-lipped Frogs *Amnirana* sp. "albolabris west."

Morphology of *H. chlorosteus*. The snout-urostyle lengths of 15 males, retained as vouchers, ranged from 31.5–35.0 mm (33.8 ± 1.3 mm), thus occurring within the known range of *H. chlorosteus* (Schiøtz 1967). The head was slightly longer (12.0 ± 0.1 mm; range: 12.0–12.2 mm) than broad (11.5 ± 0.7 mm; range: 10.5–13.0 mm); the interorbital space ranged from 5.9–7.2 mm (6.5 ± 0.4 mm); the distance between eye and nostril (3.0 ± 0.2 mm; range: 2.5–3.5 mm) was approximately twice the distance from nostril to tip of snout (1.4 ± 0.6; range: 0.6–2.4 mm); the eye diamter (5.1 ± 0.3 mm; range: 4.4–5.5 mm) was larger than internarial space (2.6 ± 0.4 mm; range: 2.1–3.0 mm) and tympanum diameter (2.8 ± 0.2 mm; range: 2.2–3.0 mm); the crus length (17.0 ± 0.7 mm; range: 15.4–18.1 mm) slightly exceeded the thigh length (15.9 ± 0.8 mm; range: 14.9–16.9 mm); and foot length including the longest toe ranged from 21.5–23.5 mm (22.2 ± 0.8 mm).

Two females measured 36.8 and 37.5 mm in SUL. As in the males, their heads were slightly longer (13.5 mm) than broad (13.2 mm); interorbital spaces were 7.0 and 7.2 mm; the distance between eye and nostril was longer (3.3 ± 0.3 mm; range: 3.1–3.5 mm) than the distance from nostril to tip of snout (1.9 ± 0.1 mm; range: 1.9–2.0 mm); the eye diamter (5.0 ± 0.1 mm; range: 5.0–5.1 mm) exceeded the internarial space (2.9 ± 0.1 mm; range: 2.9–3.0 mm) and tympanum diameter (2.9 ± 0.1 mm; range: 2.8–3.0 mm); the crus length (17.7 ± 0.3 mm; range: 17.5–17.9 mm) slightly exceeded thigh length (16.9 ± 1.5 mm; range: 15.9–18.0 mm); and foot length including the tarsus and longest toe ranged from 23.5–23.8 mm (23.6 ± 0.2 mm).

The color pattern of *H. chlorosteus* showed some variations (see Figs. 7 and 9), however, all were within the range known for the species (compare Schiøtz 1967; Rödel 2003; Channing and Rödel 2019).

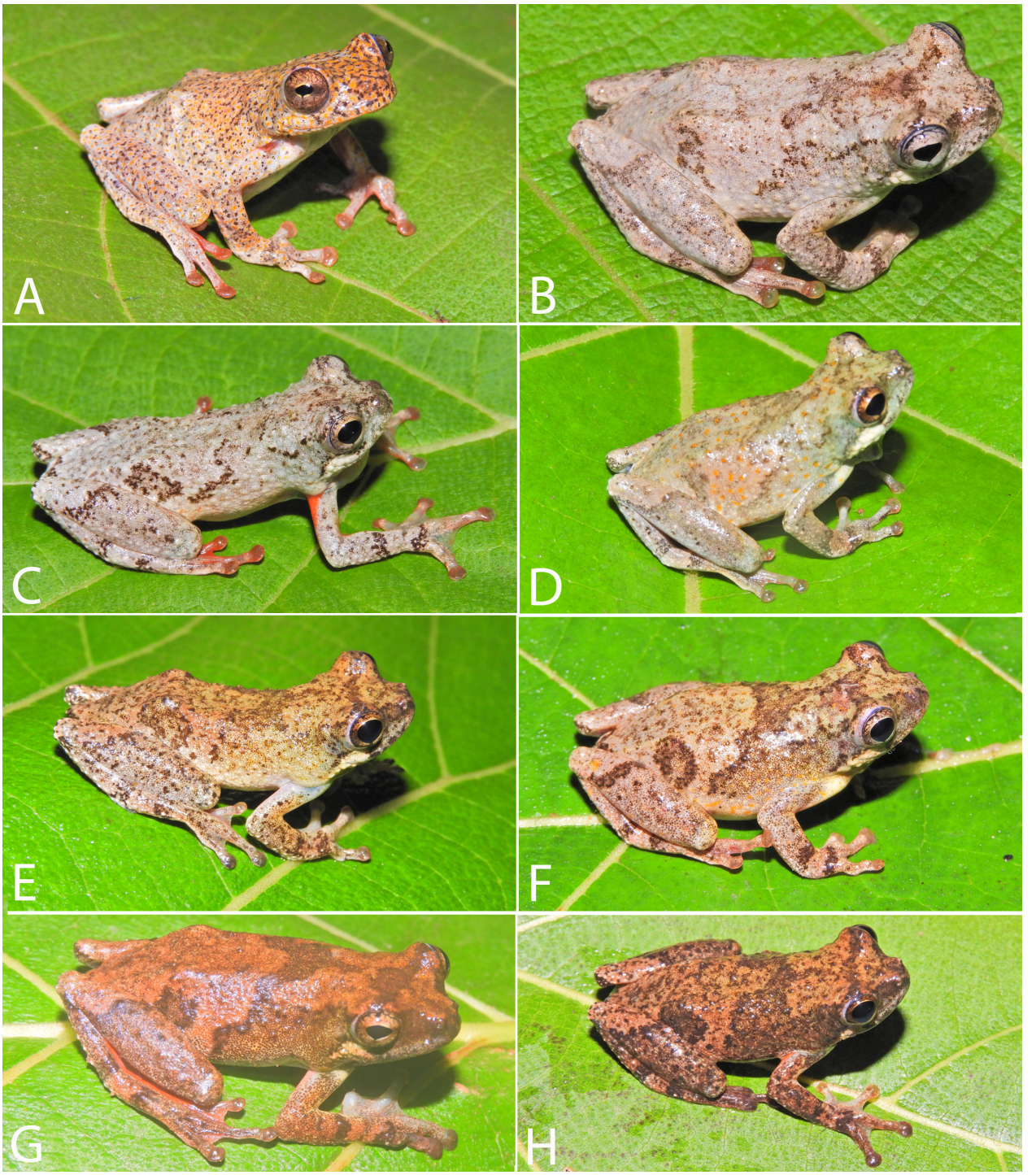

Fig. 4. Dorsolateral views of the *Hyperolius nimbae* female **(A)** and males **(B–H)** from Yéalé, western Ivory Coast. Note the variation in coloration.

Reproduction of *H. chlorosteus*. One female perched on a broad leaf of a shrub overhanging a forest stream, at ~1.5 m height, was captured. Eggs were visible through its ventral skin (Figs. 7D and 9F). An amplectant couple was seen sitting on low vegetation in this site (Fig. 7E). This couple was placed in a terrarium and a clutch of 62 eggs was present the next morning. The eggs were attached to the glass above the water. They had beige and dark poles surrounded by a thin transparent capsule (Fig. 7F). Egg diameters varied from 2.0–2.5 mm, mean 2.2 mm (SD: ± 0.25 mm). The jelly of *H. chlorosteus* eggs is slightly opaque. Six additional *H. chlorosteus* clutches observed in Taï National Park, south-west of Ivory Coast, ranged from 54–122 eggs (86.2 ± 28.8 eggs; Table 2).

Vocalization of *H. chlorosteus*. Five advertisement calls were recorded from one male (Fig. 10). The calls were repeated 2–7 times (Fig. 10B). The acoustic impression

Table 2. Data for *Hyperolius chlorosteus* clutches from Taï National Park, Ivory Coast.

Clutch number	Date	Number of eggs	Location of clutch	Remarks
1	14 March 1999	54	On tree above stream	None
2	16 March 1999	120	Attached to leaf, 2 m above stream	Clutch looks like a blackberry
3	16 March 1999	85	Attached to leaf, 2 m above stream	None
4	16 March 1999	65	1.4 m above stream	None
5	23 March 1999	122	Not recorded	Egg size 3–6 mm, nucleus 1.9–2 mm; clutch looks like a blackberry
6	4 February 1999	71	Clutch on stone covered with mosses above water	Egg size 3–6 mm, nucleus 2.2 mm; looks like a blackberry

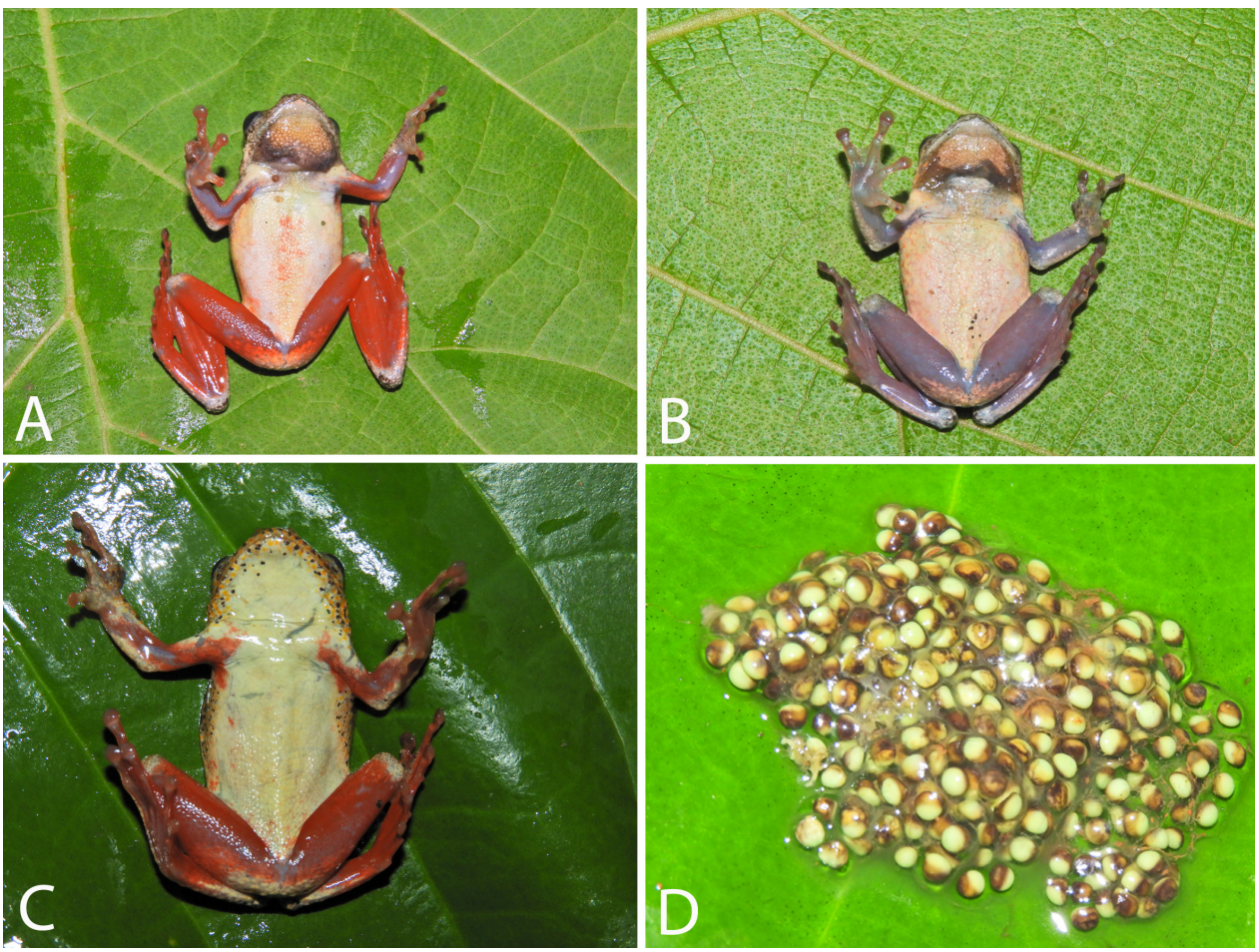

Fig. 5. Ventral views of *Hyperolius nimbae* males **(A** and **B)** and female **(C)** adults, and the eggs **(D)** from Yéalé, western Ivory Coast.

of the call is a low-pitched, far ranging metallic click with a mean duration of 0.87 ± 0.34 s (range: 0.51–1.41 s). The duration intervals between calls averaged 2.90 ± 1.27 s (range: 1.36–4.0 s, $N = 4$). The mean fundamental frequency was 1,303.12 ± 83.85 Hz (range: 1,265.62–1,453.12 Hz, $N = 5$), while the dominant frequency reached 2,606.3 ± 167.70 Hz (range: 2,531.25–2,906.25 Hz, $N = 5$). The maximum frequency intensity was at 2,643.75 ± 167.70 Hz (range: 2,531.25–2,906.25 Hz, $N = 5$), and the minimum frequency intensity averaged at 2,531.25 ± 229.64 Hz (range: 2,343.75–2,906.25 Hz, $N = 5$).

Threats to *H. chlorosteus*. Major threats to *H.*

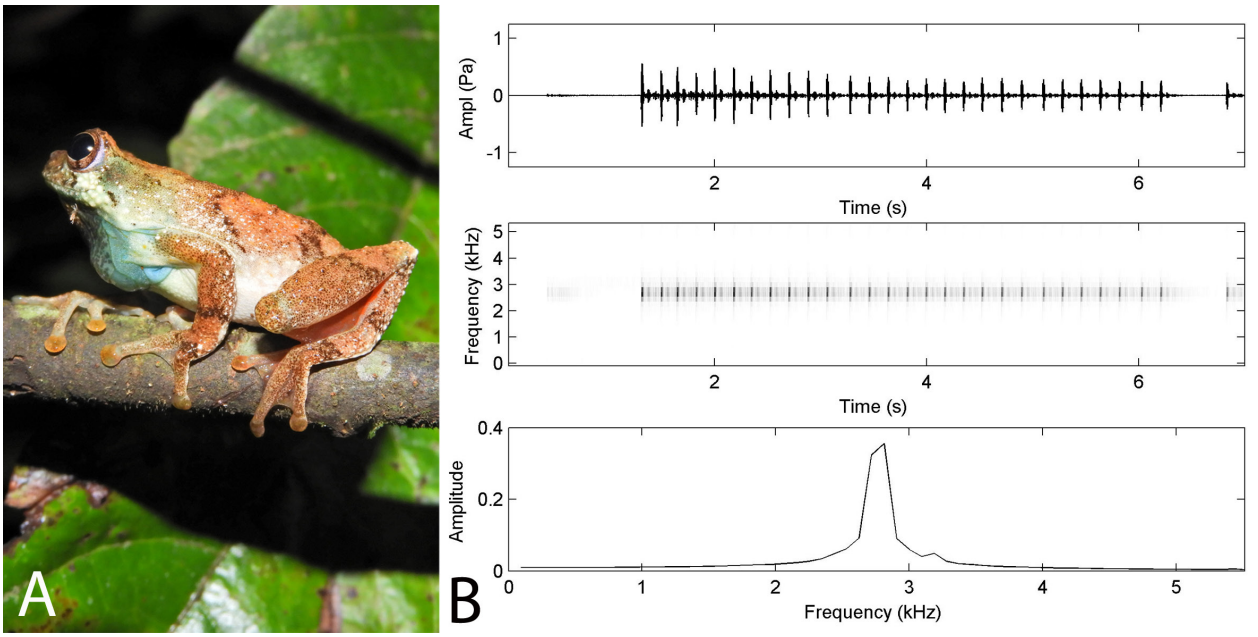

Fig. 6. (A) *Hyperolius nimbae* usually calls perched between branches and leaves of trees. **(B)** Waveform (above), spectogram (center), and powerspectrogram (below) of the advertisement calls of a *H. nimbae* male from Yéalé, western Ivory Coast.

chlorosteus were observed at Yéalé, where some forest pockets along streams had been cleared and converted to cocoa and coffee plantations, as well as rice cultivation.

Discussion

This study gathered new data on the biology and distribution of two rare reedfrog species, *Hyperolius nimbae* and *H. chlorosteus*, living in different forest habitats in the western Upper Guinea forest zone (Channing and Rödel 2019). *Hyperolius nimbae* has been documented only from a few individuals and populations on the Ivorian part of the Nimba Mountains (Schiøtz 1967; Kouamé et al. 2016; Kanga et al. 2021), and little was known about its phenotypic variation, biology, and habitat requirements prior to this study. A recent study based on 16S rRNA sequences of members of the *H. viridiflavus* clade revealed that *H. nimbae* is a member of the *H. viridiflavus* clade and sister species to the Central African *H. tuberculatus* (Kouamé et al. 2022).

At Yéalé, a relatively large population of *H. nimbae* was found in patches of heavily degraded forest area, partly neighboring human settlements. This habitat fit well with the earlier habitat description, i.e., from the villages at Dagbonpleu, Danipleu, Kouan-Houlé, and Zéalé (Kouamé et al. 2016). However, an alarming result of this study is that due to ongoing development of the area, all formerly known sites have been destroyed, restricting the currently known range of *H. nimbae* to Yéalé alone.

Our morphological assessments of a larger number of individuals confirmed former descriptions, but slightly increased our knowledge about color variability (Schiøtz 1967; Kouamé et al. 2016; Figs. 3 and 4). *Hyperolius nimbae* apparently is another reedfrog species that lacks sex specific color dimorphism (compare Schiøtz 1967; Veith et al. 2009; Portik et al. 2019). The new data herein also confirms previous descriptions of the advertisement calls of *H. nimbae* (Schiøtz 1967). In contrast to most other *Hyperolius* (Schiøtz 1967, 1999), *H. nimbae* males always produce a succession of continuous clicks and thus much longer calls.

Most *Hyperolius* species are "prolonged breeders" (Schiøtz 1967, 1999; Lötters et al. 2004; Rödel et al. 2006; Kouamé et al. 2015). *Hyperolius nimbae* is no exception to that rule, with males calling during all months of the rainy season, usually at the edges of large and permanent water bodies. We documented the first known clutch for this species (Fig. 5D). The eggs were attached to a leaf above the water surface, a feature which is common to forest species within *Hyperolius*. Savannah dwelling *Hyperolius* species deposit eggs under water, most likely as a response to the higher desiccation risk (Rödel 2000). We take the egg deposition above water as a further hint that this species depends on forest, at least to some extent.

It remains a mystery why *H. nimbae* apparently tolerates degraded forests but only occurs in the Ivorian foothills of Mount Nimba, as comparable habitats are available beyond its range (Schiøtz 1967). Most likely this species was trapped at these sites when the Nimba mountains were surrounded by savannah during drier periods, representing a refugium for the survival of forest species during unfavorable Pleistocene periods (Maley 1996).

The new *Hyperolius chlorosteus* data reported herein confirmed previous descriptions of the morphology and advertisement call (Schiøtz 1967, 1999; Channing and Rödel 2019). This species is morphologically similar to

Fig. 7. (A–B) Typical forest streams in the Mount Nimba Integrated Nature Reserve where *Hyperolius chlorosteus* breeds. A calling male **(C)**, a female **(D)**, a couple in amplexus **(E)**, and their clutch **(F)** which was deposited on a leaf above a forest stream.

H. laurenti (from the eastern parts of the Upper Guinea forest zone; Schiøtz 1967, 1999; Channing and Rödel 2019), with which it also shares habitat requirements, i.e., perching on branches above small to medium-sized streams in primary or only slightly degraded forests, often at considerable height (Rödel et al. 2005; Kouamé et al. 2014). The breeding period of *H. chlorosteus* is confined to the rainy season, and clutches are attached at various heights on leaves, branches, and stones above flowing water.

The habitat characteristics of *H. chlorosteus* encountered in MNINR were similar to those reported from previous sites, i.e., dense forests with streams or small rivers (Schiøtz 1967; Rödel 2003; Ernst and Rödel 2008). Unfortunately, some of the known Ivorian sites for *H. chlorosteus* no longer exist, such as Lakota (e.g., Schiøtz 1967), the Mount Péko National Park (Rödel and Ernst 2003), and the Cavally and Haute Dodo lowland forests in the western part of the country (Rödel and Branch 2002). In MNINR, the species was still found in abundance, but this study also registered the increasing and continuous degradation of its forest habitat.

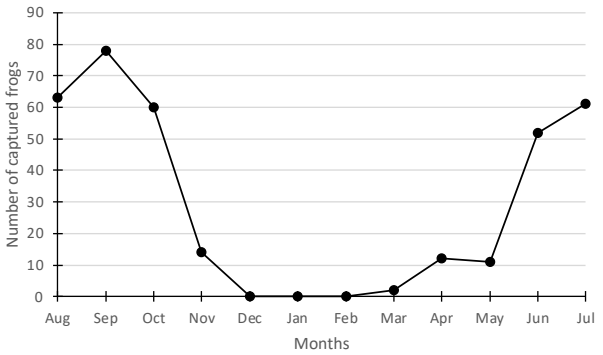

Fig. 8. Number of *Hyperolius chlorosteus* captured from 2 August 2019 to 8 July 2020 along lowland forest streams at Mount Nimba.

Conclusions and Threat Status

This study revealed the most viable and largest population of *H. nimbae* known thus far. However, it also revealed that formely known sites are most likely gone, and the one reported herein might be the last site where the species is thriving. Amphibians currently have no official protection status in Ivory Coast, and no dedicated conservation policies apply to them. The only existing conservation measures for their protection are the designations of protected areas (Rödel et al. 2021). Unfortunately, the small pocket of forest zone where *H. nimbae* was found falls entirely within a non-protected area, and consequently it is exposed to increasing and

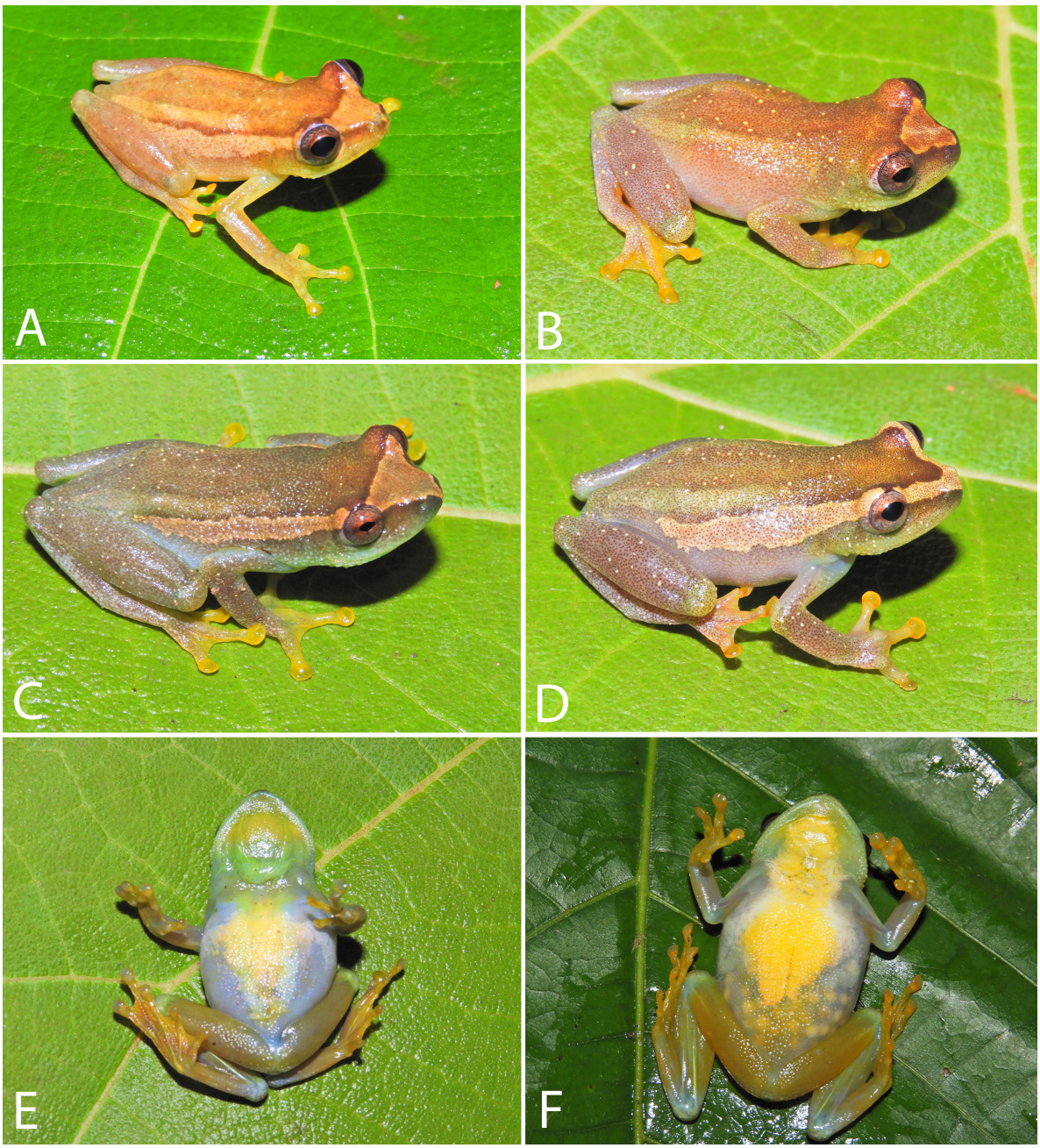

Fig. 9. Variation of color pattern of *Hyperolius chlorosteus* from Mount Nimba Integrated Nature Reserve, western Ivory Coast.

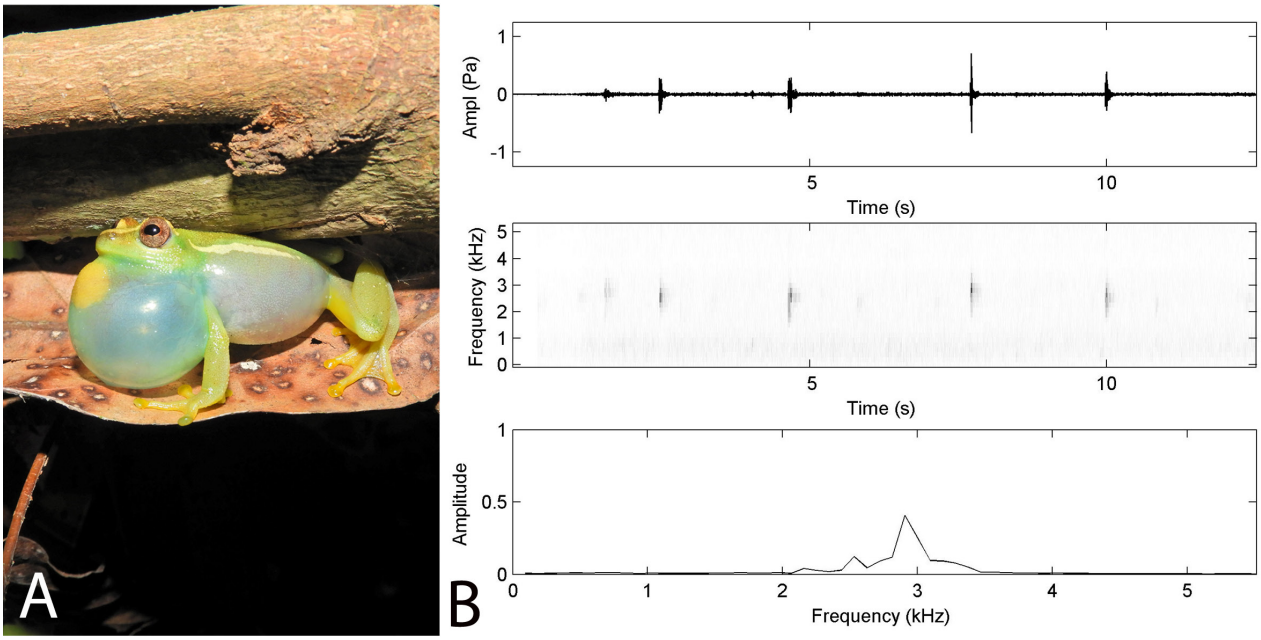

Fig. 10. Calling male of *Hyperolius chlorosteus* **(A)** with **(B)** waveform (above), spectogram (centre) and powerspectrogram (below), of the species' advertisement call, from Mount Nimba Integrated Nature Reserve. Note that the data for five calls are shown.

ongoing human influence. This species is thus facing an alarming risk of extinction, and the long-term persistence of its population in the forthcoming years is unlikely. The most important conservation action would be the immediate protection of its habitat at Yéalé, possibly accompanied by the establishment of a captive rescue population. Currently, *H. nimbae* is classified as Endangered (IUCN 2017). However, based on *IUCN Red List of Threatened Species* criteria A1(a) (population decline directly observed, only one known population remaining), B1 (extent of occurrence less than 100 km²), and B2 (area of occupancy less than 10 km², a: only one population known, b: population globally declining), we believe that the threat status of this species should be updated to Critically Endangered.

The second study species, *H. chlorosteus*, is similarly exposed to habitat loss due to intensive deforestation. The few remaining primary forests on which it depends do not enjoy sufficient protection or sustainable management (e.g., Chatelain et al. 1996; Wood 2003; Bakarr et al. 2004). The MNINR, Mount Sangbé, and the lowland rainforest of Taï National Park remain the three known Ivorian sites of *H. chlorosteus* at present (Rödel 2003; Ernst and Rödel 2008; Kanga et al. 2021). The recent *IUCN Red List* (2020) classifies *H. chlorosteus* as Least Concern. Given its large range, that category appears to be correct. However, based on the facts that in Ivory Coast the species only occurs in the westernmost parts of the country, several of the few national populations are gone, and the remaining forest habitats are declining, we think that *H. chlorosteus* should be regarded as Endangered nationally.

In summary, we urgently recommend the strict protection of the habitats of both species.

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Appendix 1. Counts of *Hyperolius nimbae* individuals captured in a heavily degraded site (07°31.928'N, 008°25.401'W; 425 m asl) at Yéalé from 2 August 2019 to 8 July 2020.

	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Night 1	11	7	10	4	2	1	1	2	2	4	5	7
Night 2	7	5	8	2	0	1	1	3	1	2	3	6
Night 3	9	9	5	1	0	1	2	2	3	4	5	3
Night 4	10	10	7	1	3	0	1	1	4	1	5	1
Night 5	11	11	5	1	2	0	0	1	3	2	6	7
Night 6	6	7	9	1	0	0	0	1	2	3	6	5
Night 7	7	6	6	1	2	0	0	1	2	1	1	6
Total	61	55	50	11	9	3	5	11	17	17	31	35

Appendix 2. Counts of *Hyperolius chlorosteus* individuals captured along forest streams at Mount Nimba Integrated Nature Reserve (MNINR: 07°34.652'N, 008°24.966'W; 716 m asl) and Yéalé (07°31.932'N, 008°25.508'W; 387 m asl) from 2 August 2019 to 8 July 2020.

		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Night 1	MNINR	9	10	8	0	0	0	0	0	0	0	8	6
	Yéalé	1	0	1	0	0	0	0	0	0	0	0	0
Night 2	MNINR	7	9	7	1	0	0	0	0	1	0	9	7
	Yéalé	0	1	1	0	0	0	0	0	0	0	0	0
Night 3	MNINR	9	13	6	1	0	0	0	0	4	3	5	9
	Yéalé	0	0	0	0	0	0	0	0	0	0	0	0
Night 4	MNINR	7	12	10	1	0	0	0	0	2	3	12	9
	Yéalé	0	1	0	0	0	0	0	0	0	0	0	0
Night 5	MNINR	8	9	10	3	0	0	0	0	1	1	3	14
	Yéalé	2	0	0	0	0	0	0	0	0	0	0	0
Night 6	MNINR	7	9	8	5	0	0	0	1	0	1	8	9
	Yéalé	3	0	0	0	0	0	0	0	0	0	0	0
Night 7	MNINR	9	13	9	3	0	0	0	1	4	3	7	7
	Yéalé	2	0	0	0	0	0	0	0	0	0	0	0
Total		64	77	60	14	0	0	0	2	12	11	52	61