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Amphibian diversity in Mauritania: a bioacoustics survey in the Diawling National Park

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Focussing on biodiversity issues, we must keep in mind that African biodiversity is poorly known compared with other continents (e.g., Jenkins et al. 2013). The diversity of African amphibians deserves intensified investigations (Duellman 1999, Blackburn 2008). This is especially true in arid Saharian and Sahelian areas such as Mauritania, where annual precipitations are low (200–300 mm/year) and rainy seasons short (ca. two months; Escoriza & Ben Hassine 2019). Species depending on water for reproduction and larval development, as most amphibians do, are more difficult to detect during most parts of the year, as is exemplified in arid Mauritania (Naia & Brito 2020). Current species accounts suggest that Mauritania is inhabited by sixteen amphibian species (Naia & Brito 2020, Sampaio et al. 2021), of which six have been recorded from within the Diawling National Park (Sow et al. 2017). Diversity assessments of Mauritanian amphibians are based on morphological or molecular features, whereas bioacoustic features such as advertisement calls have not been studied yet. Acoustic monitoring has become an important tool to infer anuran diversity based on the calls of breeding anurans (e.g., Obrist et al. 2010, Sinsch et al. 2012, Sugai et al. 2021). Aims of our study were to describe the anuran soundscape at a selected breeding pond, to identify the species involved, and to provide the first quantitative description of the advertisement call of frogs tentatively assigned to *Tomopterna milletihorsini* (Sow et al. 2017, Escoriza & Ben Hassine 2019, Ayoro et al. 2020, Naia & Brito 2020, Sampaio et al. 2021).

Our bioacoustic survey was conducted at night during the rainy period in the Diawling National Park, 6–11 September 2007, at a temporary pond filled by previous rain (Fig. 1). The pond was shallow with a maximal water depth of 20–30 cm. The study site was situated in an inland dune valley composed of compact yellow sand, close to the seat of the park administration (Maison du Parc, 16°18'10" N, 16°24'02" W; Fig. 1). We recorded calls and calling individuals with a video camera with a built-in microphone (JVC GZ-MG21E) in Dolby Digital audio format (48 kHz, 384 kbit/s). Subsequently, we collected the males and preserved one specimen per species (collection of the Univ. Angers, 2007-1: *Tomopterna milletihorsini*; 2007-2: *Sclerophrys regularis*; 2007-3: *S. xeros;* 2007-4: *Hoplobatrachus occipitalis*) in alcohol for morphological identification (Naia & Brito 2020, Channing & Rödel 2019). Snout–vent length (SVL) measurements refer to the preserved specimens. For quantitative call descriptions, we analysed the spectral and temporal structures of advertisement calls with Adobe Audition 1.0. Stereo recordings were converted to mono using a sampling rate of 44.1 kHz and a resolution of 16 bits. Audiospectrograms and frequency analyses were prepared applying Blackman-Harris Fast Fourier transformation with a FFT size of 1024 Hz. Each advertisement call was characterized by eight variables (definitions according to Köhler et al. 2017): (1) call duration [ms]; (2) inter-call interval [ms]; (3) call repetition rate [N/min]; (4) absolute number of pulses per call [N]; (5) pulse duration [ms]; (6) inter-pulse interval [ms]; (7) pulse repetition rate = ratio of the absolute number of pulses and call duration [N/s]; and (8) dominant frequency of the complete call [Hz]. Data are given as means, standard deviations, and the ranges of variation for the calls of each species. All calculations were performed using the statistical package Statgraphics Centurion, version XVIII (Statpoint Inc. 2018).

The soundscape of the breeding pond included the vocalizations of four anuran species, representing 2/3 of the species known to occur in the Diawling National Park: *Sclerophrys regularis* (Reuss, 1833), *S. xeros* (Tandy, Tandy, Keith & Duff-MacKay, 1976), *Hoplobatrachus occipitalis* (Daudin, 1802), and *Tomopterna milletihorsini* (Angel, 1922) (Fig. 2). The first three species were identified on the basis of the typical structures of their advertisement calls, whereas the fourth call appeared to be as yet unknown to science. Species assignment was then corroborated by eval-

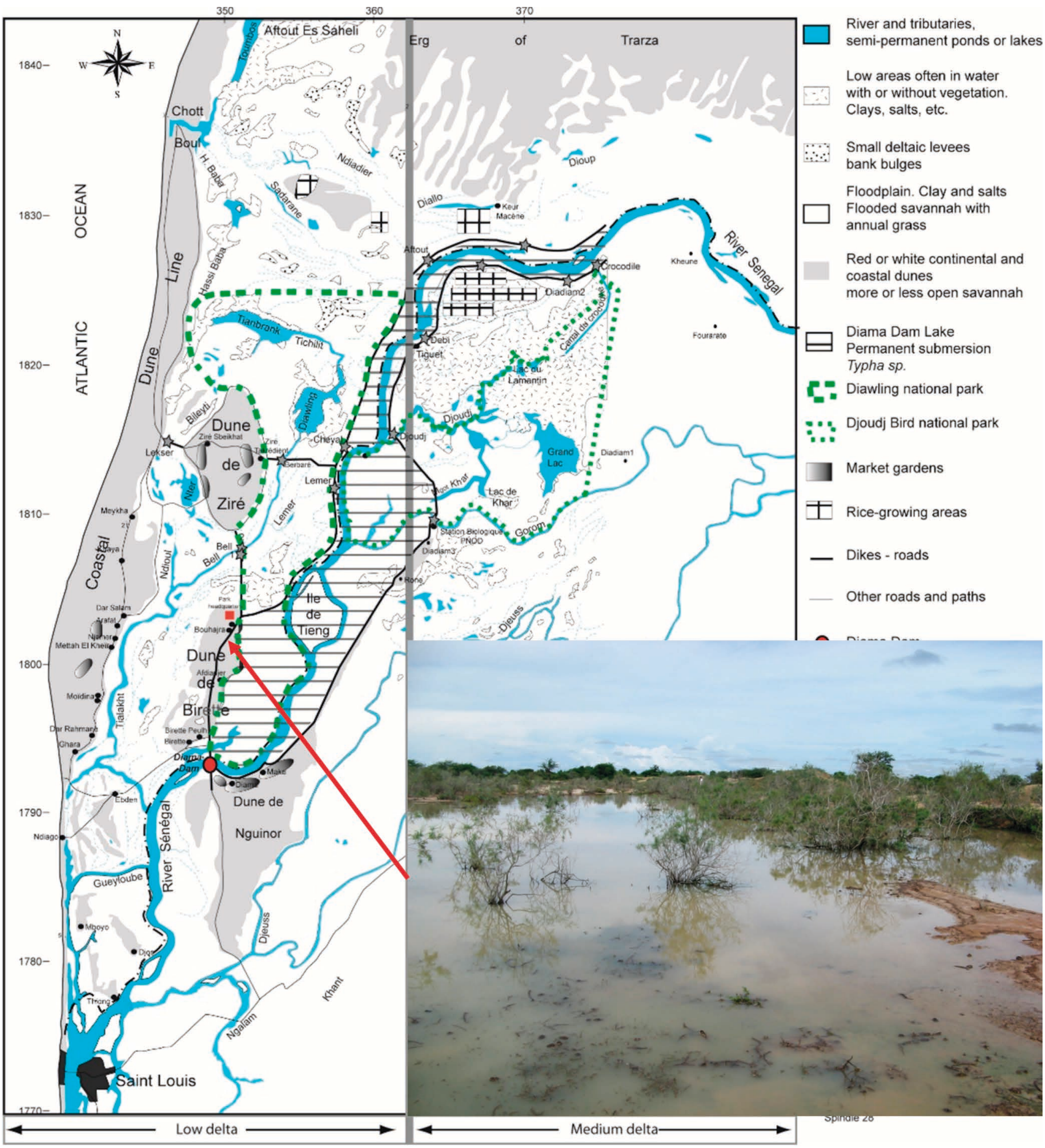

Figure 1. Map of the Diawling National Park in Mauritania close to the Senegal's delta (the grey vertical line divides the figure between low delta on the left and medium delta on the right). Our study site is located close to the headquarters (red square) in the Birette dune. The insert photograph depicts the studied temporary pond during the rainy period. Source of the map: A. N. Taïbi and M. H. Barry.

uating the morphological features of the voucher individuals, which corresponded to those given in the key of Naia & Brito (2020), the field guide of Channing & Rödel (2019), and in the original descriptions of the respective species. The toad species were represented by a male each of *Sclerophrys regularis* (SVL 77 mm) and *Sclerophrys xeros* (SVL 69 mm) (Reuss 1933, Tandy et al. 1976, Lamotte & Xavier 1981, Naia & Brito 2020). The red spots on the posterior faces of the thighs of *S. xeros* distinguish these toads readily from *S. regularis*. The Tiger Frog male *Hoplobatrachus occipitalis* (SVL 90 mm) was unmistakably the only African member of this genus with its large size and characteristic lateral vocal sacs (Daudin 1802, Channing & Rödel 2019). The species emitting the unknown advertisement call was morphologically identified as the Sand Frog *Tomopterna milletihorsini*, a name currently used for all West African populations by implication (Ayoro et al. 2020, Frost 2021). The voucher specimen was a reproductive adult male (SVL 34 mm) with a light brown dorsal ground colour and dark brown blotches, much like the specimen figured by Naia & Brito (2020). It disagreed in size (SVL 18 mm) and the uniform brownish dorsal coloration quoted in the original description by Angel (1922), which probably was due to the holotype possibly being a juvenile (Ohler & Fretey 2008).

The advertisement calls of all species were pulsed and did not exhibit significant frequency modulation (Fig. 3). In most recordings, males of three different species called simultaneously, with little spectral superposition due to the fact that their dominant frequencies differed considerably. The temporal and spectral features allowed for an unequivocal identification of each species based on a single advertisement call (Table 1). The Common African Toad *S. regularis* produced long series of low-pitched calls (up to

Figure 2. Anuran species advertising at the study pond, in life. (A) *Sclerophrys regularis;* (B) *S. xeros;* (C) *Hoplobatrachus occipitalis;* (D) *Tomopterna milletihorsini*.

32 calls per series), which were repeated at a rate of 80–90 calls per minute. Each call started with pulses of the maximum amplitude that was maintained at the same level until the last 3–4 pulses, which significantly decreased in amplitude. While the loud pulses were equally spaced (Figs 3A, B), the inter-pulse intervals between the last pulses decreased to 2–4 ms. These call features agree fully with those described from specimens recorded elsewhere (e.g., Schiøtz 1964, Amiet 1976). In contrast, the Desert Toad *S. xeros* produced long series of very low-pitched calls, which were repeated at a similar rate as those of *S. regularis*, with males often calling in duets. There were several features distinguishing the two toad species, such as amplitude modulation (slow rise at the beginning, slow decrease at the end), short pulses always equally spaced, high pulse repetition rate, and very low dominant frequency (Figs 3C,

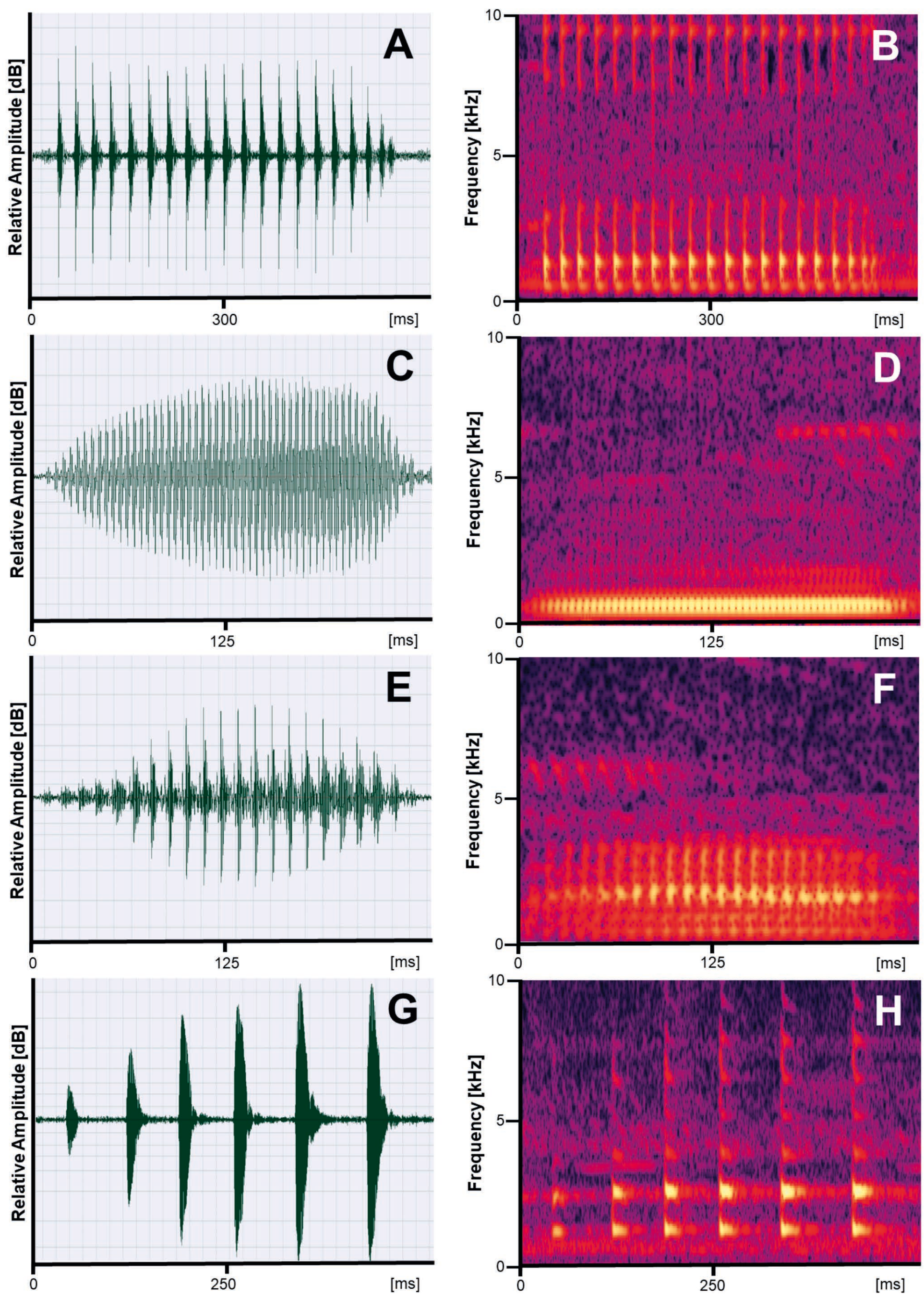

Figure 3. Oscillograms and corresponding spectrograms of the anuran species advertising at the study pond. (A, B) *Sclerophrys regularis*; (C, D) *S. xeros*; (E, F) *Hoplobatrachus occipitalis*; (G, H) *Tomopterna milletihorsini*.

Table 1. Features of the advertisement calls of four anuran species recorded in the Diawling National Park, Mauritania. Data are given as arithmetic means and corresponding standard deviations. The ranges of the data measured in single calls are given in parenthesis.

Call parameter	*Sclerophrys regularis* N = 1 individual (n = 10 calls)	*Sclerophrys xeros* N = 6 individuals (n = 22 calls)	*Hoplobatrachus occipitalis* N = 3 individuals (n = 17 calls)	*Tomopterna milletihorsini* N = 7 individuals (n = 19 calls)
Call duration [ms]	401 ± 14 (377–427)	330 ± 46 (222–440)	244 ± 39 (206–333)	675 ± 253 (392–1137)
Inter–call interval [ms]	315 ± 11 (299–333)	481 ± 200 (259–1063)	1102 ± 746 (221– 2707)	686 ± 202 (407–940)
Call repetition rate [N/min]	84 ± 2 (81–85)	77 ± 15 (44–101)	60 ± 36 (21–126)	47 ± 10 (30–67)
Number of pulses per call [N]	20 ± 1 (18–21)	60 ± 9 (44–81)	23 ± 4 (18–30)	8 ± 3 (5–13)
Pulse duration [ms]	10.5 ± 0.7 (10–12)	3.1 ± 0.4 (2–4)	5.6 ± 0.8 (4–7)	21.6 ± 3.1 (15–28)
Inter-pulse interval [ms]	10.7 ± 1.1 (10–13)	1.1 ± 0.3 (1–2)	3.6 ± 0.9 (3–5)	69.8 ± 7.8 (56–87)
Pulse repetition rate [N/s]	50 ± 1 (48–51)	183 ± 10 (163–200)	92 ± 4 (86–100)	12 ± 1 (10–16)
Dominant frequency [Hz]	1401 ± 16 (1378–1421)	684 ± 89 (550–826)	1706 ± 106 (1608–1937)	2794 ± 35 (2756–2842)

D; Table 1). These features are consistent with those of the only other semi-quantitative call analysis in the species description (Tandy et al. 1976). The African Tiger Frog *H. occipitalis* gave off long series (up to 14 calls per series) of low-pitched calls, with a call repetition rate of 60 per minute. The amplitude envelope was similar to that of *S. xeros* (Figs 3E, F), but pulse features such as the pulse repetition rate and pulse duration were significantly different (Table 1). These call features agree largely with those published before (e.g., Amiet 1974, van den Elzen & Kreulen 1979, Rödel 2000).

So far, our bioacoustic survey demonstrated that analysing the advertisement calls of Mauritanian anurans has the power of precise species identification and can be employed as an alternative to much more expensive molecular methods. Considering that the variation of external morphological and chromatological features is often wide and has the potential of introducing ambiguity, the bioacoustic method provides a cost-efficient and precise tool for species identification, even though there are exceptions (e.g., Schneider & Sinsch 2007, Köhler et al. 2017).

In contrast to the data on the three widespread toad and frog species, we describe here for the first time the advertisement call of Horsin's Sand Frog *Tomopterna milletihorsini*, which is considered data deficient and poorly known (Padial & de la Riva 2004, Wilson & Channing 2019, Ayoro et al. 2020). These frogs emitted short series (up to 6 calls) of medium-pitched calls with two almost equally loud frequency bands of 1300–1400 and 2700–2800 Hz, respectively (Figs 3G, H). The amplitude of pulses rose gradually from the first to the last one of a call. The pulses were much longer than those of any of the other local species and equally spaced from each other (Table 1). The call differed from that of *Tomopterna delalandii* from Nigeria by having considerably fewer pulses per call (comp. Schiøtz 1964). Thus, we here provide bioacoustic evidence for the specific distinction between *T. delalandii* and *T. milletihorsini*, which has previously been based only on molecular data (Wilson & Channing 2019).

In conclusion, our pilot study for Mauritania emphasizes the value of non-invasive recordings of advertisement calls at breeding ponds for detecting anurans in arid areas, as did similar studies before (e.g., Channing & Vences 1999). The scarce resource that breeding ponds typically constitute here serves as a means of concentrating the local amphibians in single spots (e.g., Kiesow & Griffis-Kyle (2017).

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