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STRIDULATION SOUNDS OF THE PACAMÃ *LOPHIOSILURUS ALEXANDRI* STEINDACHNER, 1876 (PSEUDOPIMELODIDAE), A THREATENED ENDEMIC BRAZILIAN CATFISH

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ABSTRACT

Pseudopimelodidae comprises 49 species of freshwater catfish endemic to South America, with limited research on their acoustic behavior. This study focuses on the pacamã *Lophiosilurus alexandri* Steindachner, 1876, a vulnerable catfish species endemic to the São Francisco River basin, known for its ecological and economic importance. Sound production by this species was analyzed for the first time. Three individuals were recorded while being held underwater revealing the production of two distinct sound types (Type *I* and Type *II*) associated with pectoral fin movements (abduction and adduction). Sounds were 85-135 ms long with a variable number of pulses or peaks. *Type II sounds* were longer and louder than *type I sounds*, with both types showing a similar peak frequency ranging between 200 and 500 Hz. The sounds were produced alternately by the pectoral fins, with occasional lateralization. More research is needed to determine whether these sounds can be used for monitoring or if they lack sufficient species-specific characteristics.

KEYWORDS: São Francisco River, fish sounds, bioacoustics, Siluriformes

1. INTRODUCTION

Pseudopimelodidae are freshwater catfishes found exclusively in South America. This family comprises 49 species across seven genera and is considered one of the least studied families of freshwater neotropical catfish (Barros *et al.*, 2007; Fricke *et al.*, 2024). Within this family, two soniferous species from two different genera have been identified: *Batrochoglanis raninus* (Valenciennes, 1840) (Kaatz, 1999; Kaatz *et al.*, 2010; Kaatz & Stewart, 2012) and *Microglanis iheringi* Gomes, 1946 (Kaatz *et al.*, 2010). These species have serrations on both the anterior and posterior sides of their pectoral spine, which are involved in the production of stridulation sounds (Kaatz *et al.*, 2010). While sound production in Pseudopimelodidae is poorly documented, catfish sound production has been known to the scientific community since at least 1829 (Fine & Ladich, 2003). Related families, such as Pimelodidae, have been much more extensively studied, with many stridulatory sounds described (Fine *et al.*, 1996; Ladich, 1997; Tellechea *et al.*, 2011). Stridulatory sounds are produced by the depression of ridges on the dorsal process of the pectoral spine, resulting in a series of pulses (Fine & Ladich, 2003).

Lophiosilurus alexandri Steindachner, 1876, also known as pacamã, is a Pseudopimelodidae catfish endemic to the São Francisco River basin in southeastern and northeastern Brazil (Carvalho *et al.*, 2016; dos Santos *et al.*, 2013; Travassos, 1960). Additionally, it can be found in the Doce River basin due to an introduction, though its impact on native species in this area is unknown (Vieira & Pompeu, 2001). This species is preferentially found in lentic environments (Travassos, 1959). It is benthic, sedentary, and nocturnal, (Sato *et al.*, 2003a, 2003b; Shibatta, 2003; Tenório *et al.*, 2006). The pacamã is an ambush predator that uses aggressive camouflage by burying itself in the sand to capture its prey (pers. obs.). This fish is significant in sport fishing (Sato *et al.*, 2003a), commercial fishing, aquaculture (Luz *et al.*, 2011; dos Santos Silva *et al.*, 2018), and ornamental aquariology (dos Santos & Luz, 2009). In addition to these impacts, a drastic population reduction has occurred in several stretches of São Francisco River (Lopes JP, Franca FL, 2013). This decline over the last several decades is due to environmental degradation and overfishing (dos Santos *et al.*, 2013). This species is now considered vulnerable (ICMBio, 2021) and it is part of the Ministry of Environment's National Action Plan (PAN São Francisco — Ordinance n.124 of January 16th, 2023). The aim of this study is to report and describe stridulation sounds produced by this vulnerable protected species, the pacamã, while being gently hand-held underwater.

2. MATERIAL AND METHODS

2.1. Sound sampling

Three specimens of *Lophiosilurus alexandri* (total length: 474 – 641 mm) were sampled with gillnets in the Paraopeba River (São Francisco River Basin) downstream of the Retiro Baixo Hydropower Dam (18˚52’ 35’’S, 44˚46’ 49’’ W). The gillnet was installed on the evening of July 4th, 2018, and retrieved on the morning of July 5th, 2018, as part of a larger study on Serrasalmidae (Huby *et al.*, 2019; Raick *et al.*, 2020a, 2020b, 2021, 2023) and Loricarridae (Raick *et al.*, 2022). The specimens were recorded in the river with a hydrophone (HTI-96-Min, High Tech Inc., Long Beach, MS, USA; sensitivity: –164.4 dB re 1V µPa-1) connected to a TASCAM DR-05 recorder (TEAC Corporation, Montebello, CA, USA; mono-channel, sample frequency: 44.1 kHz, 16 bit-resolution). The recorder had been previously calibrated at the specific gain used, with an oscilloscope, at the University of Liège. The fish were gently hand-held without any pressure at approximatively five centimetres from the hydrophone. In addition, the smaller specimen was filmed while being hand-held in a glass-tank (108 L) to observe movements associated with sound production, as shown in supplementary material.

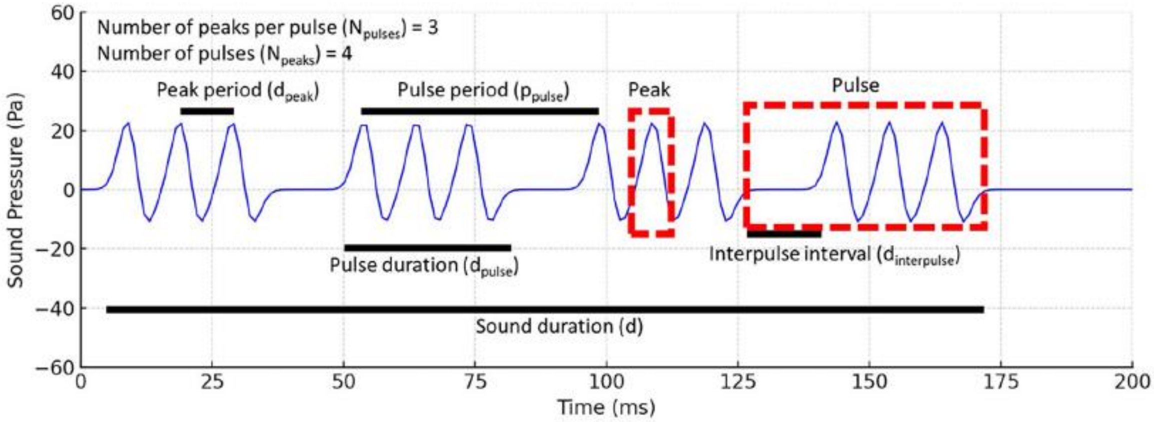

FIGURE 1 Schematization of the measurements performed on an oscillogram.

2.2. Sound analyses

For each specimen, 40 sounds (20 per sound type) were analysed using Avisoft SAS-Lab Pro 5.2 (Avisoft Bioacoustics, Glienicke/Nordbahn, Germany). Temporal features were measured on oscillograms (Fig. 1). The temporal features included sound duration (**d**, in s); the number of peaks or pulses in a sound ($\mathbf{N_{peaks}}$, $\mathbf{N_{pulses}}$), the peak or pulse period between consecutive peaks or pulses ($\mathbf{p_{peak}}$, $\mathbf{p_{pulse}}$, in ms), and the duration of pulses and interpulse intervals **(**$\mathbf{d_{pulse}}$, $\mathbf{d_{interpulse}}$). When sounds were made by pulses with only one peak, this information was also noted. Frequency features were measured on power spectra. The frequency features included peak frequency (**F_{AmpMax}**, in Hz, Fig. 2), the amplitude at F_{AmpMax} (**$AmpF_{AmpMax}$**, in Pa converted in dB re 1 µPa @ 5 cm) and the repartition of the energy (**F_{Q1}** = first quartile frequency, **F_{Q2}** = median frequency, and **F_{Q3}** = third quartile frequency). In the presence of harmonics, the fundamental frequency (**F_0**, in Hz), the amplitude corresponding to F_0 (**$AmpF_0$**, in Pa converted in dB re 1 µPa @ 5 cm), and the harmonics interval (**HI**, in Hz) were also measured (Di Iorio *et al.*, 2018; Raick *et al.*, 2020a, 2020b, 2021).

Ethical statement

The capture and the recording of the specimens was conducted under license 10306–1 from the Brazilian Ministry of the Environment. Access to the sampling site was granted with authorisation n° PT-04/07/2018 issued by Retiro Baixo Energética.

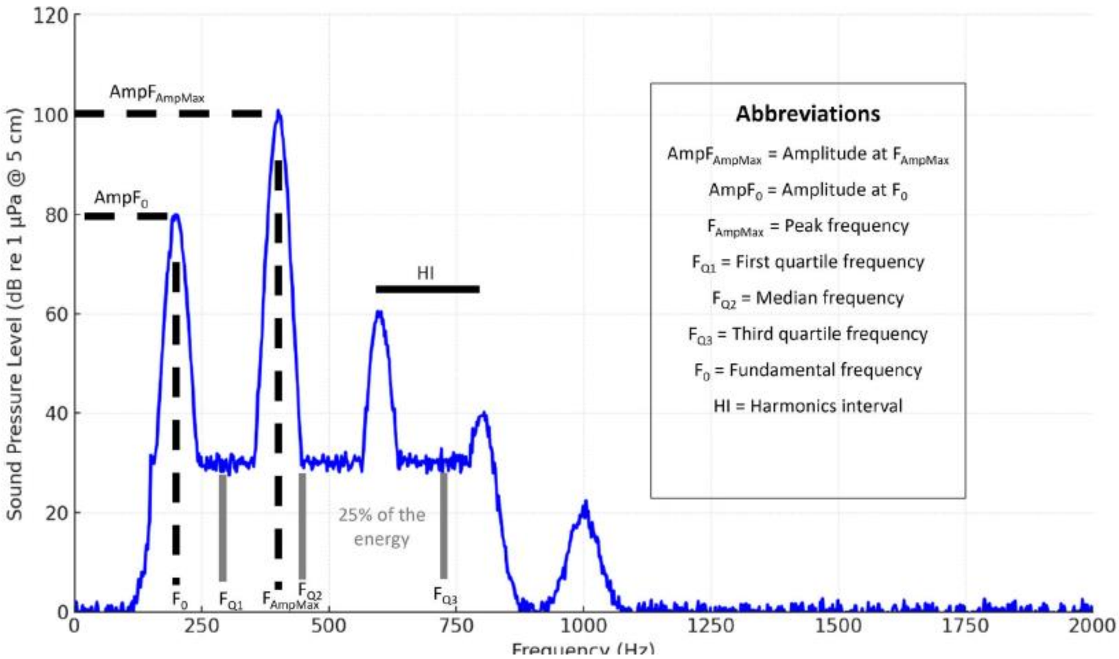

FIGURE 2 Schematization of the measurements performed on a power spectrum.

3. RESULTS

All specimens of *Lophiosilurus alexandri* produced sounds when handheld (Fig. 3). The sounds were 0.105 ± 0.024 s long (mean ± SD) with a peak frequency of 305 ± 212 Hz and a corresponding spectral level of 112 ± 4 dB re 1 µPa @ 5 cm (Fig. 4 and 5). The sounds were categorized into two types: *type I sound* and *type II sound*, which appeared to be associated with the forward and backward movements of the fin. Generally, these sounds were produced alternately (97% of the time). This alternation was not linked to the pectoral fin used (right or left). For example, one specimen predominantly moved one pectoral fin during the entire session. Another alternated movement of the right and left pectoral fins. The last specimen exhibited an intermediate pattern: it produced sounds first with the left pectoral fin, then with both, and finally only with the left one. The duration between sounds was 0.55 ± 0.29 s, with the interval between *Type I sound* and *Type II sound* being longer (0.71 ± 0.30 s) than the interval between *Type II sound* and *Type I sound* (0.40 ± 0.18 s).

Type I sound lasted 85 to 113 ms (minimum and maximum individual-mean values, Table 1). Each sound consisted of 10 to 17 peaks with a peak period of 6.7 to 7.1 ms each (Figure 4A and B, Figure 6A and B), with a peak frequency of 259 to 342 Hz at 112 to 118 dB re 1 µPa @ 5 cm (Figure. 4C). The energy of the sound was predominantly between 263 to 356 Hz (F_{Q1}) and 1.1 to 1.8 kHz (F_{Q3}), with a median frequency (F_{Q2}) of 510 to 607 Hz. The peak period decreased over time (Figure 4A and B, Figure 6A and B). The sound exhibited a harmonic structure with a F_0 around 145–154 Hz, a peak frequency equivalent to F_1, a HI around 145–156 Hz, and an ampF_0 around 107 dB re 1 µPa @ 5 cm.

Type II sound lasted 90 to 135 ms and consisted of 3 to 6 pulses (Table 1). For specimen N°1, the first and last pulses were consistently longer than the intermediate pulses (37 ± 9 ms and 46 ± 9 ms compared to 13 ± 2 ms and 14 ± 2 ms, respectively; Figure 5A, Table SP1). On oscillogram representations, the final part of the first pulse resembles the second and third pulses. Similarly, the initial part of the last pulse resembles the second and third pulses. The extremities of the sounds (i.e., the beginning and the end) exhibited distinct peaks (Fig. 5A). The interpulse intervals were 12 ± 1 ms, 13 ± 7 ms, and 7 ± 2 ms, with associated pulse periods of 49 ± 15 ms, 27 ± 8 ms and 21 ± 2 ms, respectively. The power-spectrum of the second sound type showed a peak frequency at 460 ± 416 Hz at 109 ± 4 dB re 1 µPa @ 5 cm and a frequency quartile distribution of 476 ± 241 Hz, 1276 ± 511 Hz, and 5357 ± 1061 Hz respectively (Fig. 5B and C). For specimens N°2 and N°3, *type II sound* was a series of pulses made of one peak (Table 1). The last pulse generally exceeded the duration of the preceding one, indicating an increase in pulse period over time (Fig 6C).

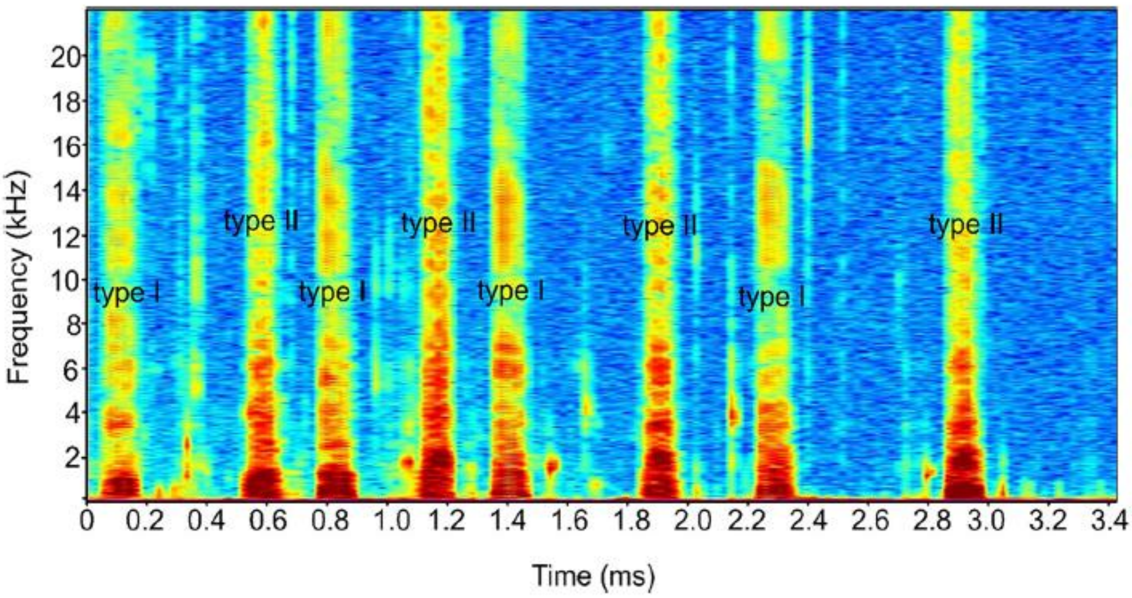

FIGURE 3 Spectrograms of sounds produced by *Lophiosilurus alexandri* Steindachner, 1876 (specimen 1). Series of eight sounds. The sounds are the same as those used in the next figure. Sampling frequency, 44.1 kHz; number of Fast Fourier Transform (FFT) points, 2048; frequency resolution, 21.53.

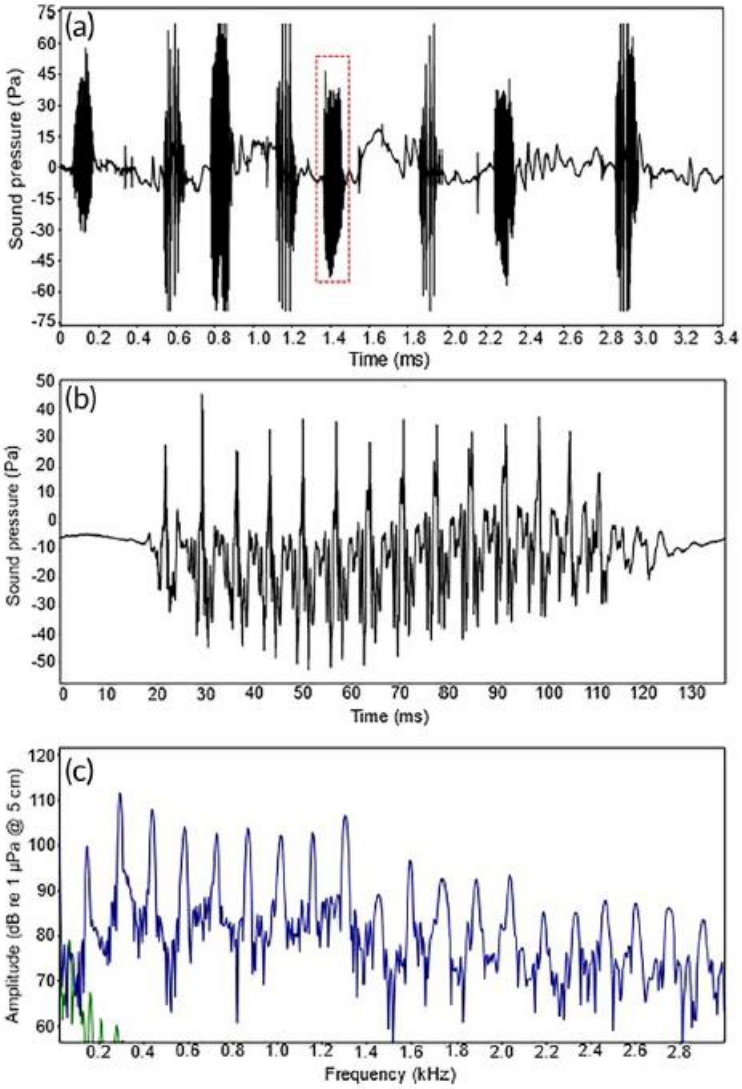

FIGURE 4 Sounds produced by *Lophiosilurus alexandri* Steindachner, 1876 (specimen 1). (a) Oscillogram of a series of eight sounds. (b) Zoom on the red dashed box showing the oscillogram of a type I sound. (c) Power spectrum (0.02–3 kHz, Hamming window) of the same sound (in blue) and background noise (in green) measured on the same duration interval.

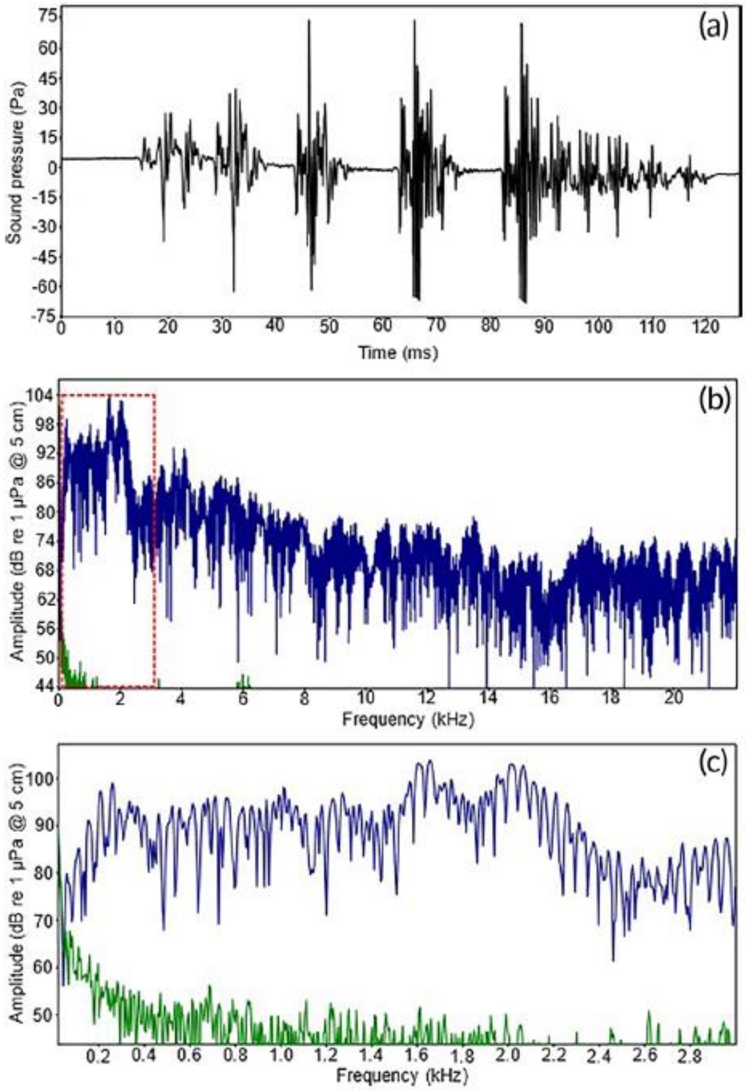

FIGURE 5 Sounds produced by *Lophiosilurus alexandri* Steindachner, 1876 (specimen 1). (a) Oscillogram of type II sound. (b) Power spectrum (Hamming window) of the same sound (in blue) and background noise (in green) measured over the same duration. (c) Zoom on the red dashed box (0.02–3 kHz, Hamming window) of the same power spectrum.

TABLE 1 Measurements on the two sound types of *Lophiosilurus alexandri* Steindachner, 1876.

	Duration (ms)		Peak period (ms)		N_{pulses} with 1 peak		N_{peaks}		$AmpF_{AmpMax}$ (dB re 1 μPa at 5 cm)		F_{AmpMax} (Hz)		F_{Q1} (Hz)		F_{Q2} (Hz)		F_{Q3} (Hz)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Specimen 1 ($n = 40$)	124.02	18.15							113.37	5.96	400.68	309.79	416.22	190.09	919.12	544.22	3562.12	2206.59
Type I sound ($n = 20$)	113.4	7.51	6.66	0.58			17.25	1.62	117.72	4.37	341.74	129.08	356.00	91.94	561.80	279.98	1766.75	1443.34
Type II sound ($n = 20$)	134.64	19.55			N/A	N/A			109.02	3.72	459.61	415.95	476.45	241.01	1276.45	510.64	5357.50	1060.68
Specimen 2 ($n = 40$)	104.93	18.43							111.09	3.36	279.32	128.09	293.12	88.55	906.62	619.30	2980.70	2138.86
Type I sound ($n = 20$)	94.96	15.69	8.95	0.97			10.05	1.70	112.28	2.13	333.28	105.10	263.20	55.73	509.80	152.08	1135.50	493.80
Type II sound ($n = 20$)	114.90	15.56			5.55	0.69			109.90	3.96	225.35	128.45	323.05	105.37	1303.45	657.73	4825.90	1406.58
Specimen 3 ($n = 40$)	87.52	18.79							112.06	2.86	234.18	98.31	311.50	38.70	637.15	119.75	1709.47	723.06
Type I sound ($n = 20$)	84.98	10.57	7.10	0.73			10.8	1.20	114.18	1.57	259.15	100.43	321.05	31.82	606.80	110.90	1652.25	887.09
Type II sound ($n = 20$)	90.06	24.48			5.85	2.11			109.95	2.23	209.20	91.85	301.95	43.24	667.50	123.27	1766.70	528.51
All	105.49	23.64	7.57	1.26	5.70	1.56	12.7	3.59	112.18	4.35	304.72	212.09	340.28	133.67	820.97	494.50	2750.77	1967.20

Abbreviations: $AmpF_{AmpMax}$, amplitude at F_{AmpMax}; F_{AmpMax}, peak frequency; F_{Q1}, first-quartile frequency; F_{Q2}, median frequency; F_{Q3}, third-quartile frequency; N/A, not applicable; N_{peaks}, number of peaks; N_{pulses}, number of pulses.

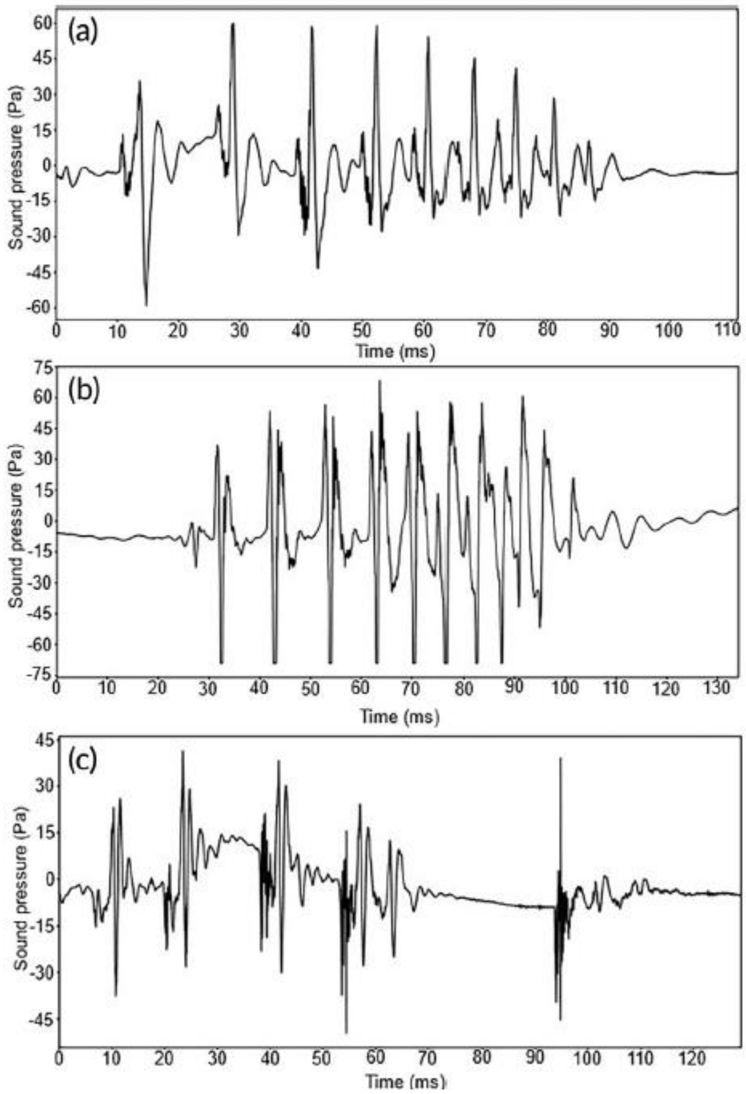

FIGURE 6 Oscillograms of sounds produced by *Lophiosilurus alexandri* Steindachner, 1876 (specimens 2 and 3). (a) Type I sound produced by specimen 2. (b) Type I sound produced by specimen 3. (c) Type II sound produced by specimen 2.

4. DISCUSSION

This study on *Lophiosilurus* support the soniferous ability of Pseudopimelodidae, previously reported in *Batrochoglanis* and *Microglanis* genera (Kaatz, 1999; Kaatz *et al.*, 2010; Kaatz & Stewart, 2012). *Lophiosilurus* produces two generally consecutive sound types. *Type II sounds* seemed 6–21% longer and 2.4–8.7 dB louder than *type I sounds*, with both types showing a similar peak frequency ranging between 200 and 500 Hz. Differences in sound duration between abduction and adduction are also observed in other catfish, such as those in the family Mochokidae (Ladich, 1997; Parmentier *et al.*, 2010). Despite the extensive variety of stridulation sounds in catfish, the sounds produced by *Lophiosilurus alexandri* differed from most known types. They were shorter and louder than sounds from *Hypostomus* species found in the same river – 105.5 ms vs. 212 ms; 112.18 dB vs. 106 dB re 1 µPa @ 5 cm (Raick *et al.*, 2022). The dominant frequency of *L. alexandri* sounds was also higher than that of *Hypostomus* species – 305 Hz vs. 170 Hz (Raick *et al.*, 2022) – but lower than in other catfish species, such as some *Synodontis* (520–2900 Hz) and *Iheringichthys* (656 Hz) (Parmentier *et al.*, 2010; Tellechea *et al.*, 2011)

Pseudopimelodidae are known to have serrations on both the anterior and posterior sides of their pectoral spine (Kaatz *et al.*, 2010). This characteristic is also found in other catfish families, such as Aspredinidae, Auchenipteridae, Callichthyidae, Doradidae, Erethistidae, Horabagridae, Ictaluridae, and Mochokidae. In the Mochokidae family, it has been shown that the sound is produced during a spine sweep (Parmentier *et al.*, 2010). Contractions of the adductors allow the sweep of the spine, while contractions of the arrectors of the pectoral spine press the ridges of the dorsal process onto the so-called "spinal fossa" (Parmentier *et al.*, 2010). This sound production results in two different sound types separated by a pause (Parmentier *et al.*, 2010). Contrary to what is observed in Mochokidae and Doradidae, in other catfish families such as Pimelodidae, stridulatory sounds are produced during the abduction of the fin spine only (Fine *et al.*, 1996; Ladich, 1997; Tellechea *et al.*, 2011).

During some portions of the recordings, an alternation between the use of the right and the left pectoral fin by *Lophiosilurus alexandri* was observed (Video SP1). This is also known in other taxa such as Triglidae (Connaughton, 2004) and Balistidae (Parmentier *et al.*, 2017; Raick *et al.*, 2018). However, the sound production during the alternation between fins differ among those groups. In Balistidae, each sound results from several alternations of the two fins (Raick, 2015), whereas in Triglidae, it is the result of relaxation of one muscle while the other contracts (Connaughton, 2004). In contrast, in the studied catfish, the alternation is responsible for the production of consecutive sounds. Additionally, the recorded specimens showed a fin preference for producing the recorded sounds. This lateralization of pectoral stridulation sound production has been studied in detail in Ictaluridae (Fine *et al.*, 1996). These authors showed that although sounds could be made with either fin, many individuals exhibited a fin preference. This preference was not just caused by an morphological asymmetry but reflected a preference between two equally structured fins (Fine *et al.*, 1996).

From a theoretical conservation point of view, it could be beneficial to implement passive acoustic monitoring surveys to focus on this vulnerable species in the São Francisco River. However, several issues are met. Firstly, the species-specific nature of *Lophiosilurus alexandri* stridulation sound requires evaluation. In other catfish species, the stridulation sounds have been shown to not be species-specific (Raick *et al.*, 2022), which is not surprising for this kind of sound. Secondly, the occurrence of stridulatory sound and their related behavioural context still need to be addressed for *Lophiosilurus alexandri* as well as for other fish species that produce similar sounds. While passive acoustics appears to be an ideal tool for monitoring non-stridulatory spawning sounds emitted by freshwater fish, such as Prochilodontidae (Godinho *et al.*, 2017; Muñoz-Duque *et al.*, 2021; Smith *et al.*, 2018) and Sciaenidae (Borie *et al.*, 2014), as well as riverine dolphins (Campbell *et al.*, 2017; Erbs *et al.*, 2023; Yamamoto *et al.*, 2015), more research is needed to determine if this method is feasible for *Lophiosilurus alexandri*, which is not the case at the moment.

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