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Novel sounds, native responses: exploring the acoustic consequences of *Eleutherodactylus johnstonei's* invasion in urban areas

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Background: Biological invasions pose a critical threat to biodiversity, affecting ecological balance and native species' communication. *Eleutherodactylus johnstonei*, an exotic anuran in São Paulo, vocalizes at intensities that could interfere with native anuran species, potentially causing acoustic masking.

Methods: We evaluated the effects of *E. johnstonei's* calls on the vocalizations of two native species, *Scinax imbegue* and *Physalaemus cuvieri*, both with and without spectral overlap with the invasive species. Field playbacks were conducted using six versions of stimuli, including *E. johnstonei's* calls, the native *Boana bischoffi* (as a control), and white noise. We recorded response calls and behavioral changes of *S. imbegue* and *P. cuvieri males*.

Results: The calls of *E. johnstonei* did not affect the spectral or temporal parameters of the native species' announcement calls. However, *S. imbegue* males displayed behavioral responses such as cessation of vocalization or movement away from the noise source. Additionally, *B. bischoffi's* calls and white noise influenced native species' call parameters.

Discussion: Our findings reveal that exotic species' vocalizations may disrupt native anurans' acoustic behavior. This impact varies with species and context, underlining the need for further research on anuran acoustic interactions across different frequencies and acoustic environments to fully understand the effects of exotic acoustic interference.

1 Introduction

Biological invasions pose significant threats to biodiversity (Mack et al., 2000; McGeoch et al., 2010; Pyšek et al., 2020), reaching beyond conventional challenges like competition, predation, hybridization, disease transmission, and alterations in community composition (Mack et al., 2000; McGeoch et al., 2010; Blackburn et al., 2014). Exotic invasive species' impact extends to intricate challenges that might affect ecosystem functioning, including interference through vocalizations within the acoustic niche of native species, such as amphibians and birds (Both and Grant, 2012; Farina et al., 2013; Bleach et al., 2015).

Urbanization further amplifies the influence of invasive species on ecosystems by generating new niches and resources for their establishment and spread (e.g. Cadotte et al., 2017; Borden and Flory, 2021). Human activities linked to urbanization, such as trade and transportation, facilitate the introduction and spread of invasive species across regions, fostering increased connectivity between urban and natural habitats (e.g. Fonseca et al., 2019, 2021). This accelerated potential for disruption in local ecosystems is compounded by altered ecological dynamics. Given the constant rise in the introduction of invasive species by accidental pathways or as pets, it becomes imperative to focus on introductions in urban areas and anticipate potential consequences on native species naturally inhabiting these environments.

Communication is a cornerstone of evolutionary biology, mediating reproductive, social, and territorial interactions (Narins, 2001; Brumm, 2013). Successful communication involves encoding information into a signal, transmitting it to a receiver, and relies on acoustic properties, distance, and environmental factors influencing signal transmission (Shannon et al., 2016; Forrest, 1994; Ryan and Rand, 1993; Castellano et al., 2003).

Animals adjust vocalization parameters to minimize spectral or temporal overlap with other species, maximizing signal transmission chances (Krause, 1987). Interference in transmission or reception can lead to declines in species density and distribution (Sun and Narins, 2005). Exotic species also contribute to environmental noise through acoustic signals during reproduction, resulting in disruptions to intra-specific acoustic communication when their signals overlap with those of native species (Brumm and Slabbekoorn, 2005). This degradation of emitted signals hampers the communication of native species, which rely on acoustic signals for various aspects of their behavior (Brumm and Slabbekoorn, 2005).

The acoustic niche hypothesis (Krause, 1987) suggests that animals adjust parameters of their vocalizations to minimize spectral or temporal overlap with others, thereby maximizing the chances of signal transmission. The acoustic niche refers to the frequency and temporal patterns that a species occupies to communicate effectively within on the environment (Mullet et al., 2017). When different species share the same habitat, they often adapt their vocalizations to avoid mutual interference, allowing an efficient communication. Signal interference that hinders inter- and intra-specific communication can lead to declines in species density and distribution (Sun and Narins, 2005).

Acoustic signal masking caused by new sounds can affect communication, abundance, reproduction, physiological stress, energy demands, and other behaviors (Wells, 1977; Bradbury and Vehrencamp, 1998; Rheindt, 2003). This masking occurs when sounds from other sources, natural or anthropogenic, interfere with a species' vocalizations, disrupting its acoustic niche. In response, native species may quickly adjust their vocalizations (e.g., Cunnington and Fahrig, 2010) or may not immediately react to the acoustic niche interference, especially in the short term (e.g., Lengagne, 2008). Understanding the interaction between acoustic niche and acoustic masking is crucial for comprehending species' adaptations to changes in their sound environment and the implications for their survival and behavior.

Anuran amphibians, which primarily communicate through acoustic signals, serve as excellent models to study invasion impacts on the acoustic niche due to their sensitivity to environmental changes and responses to new sounds (Wells, 2007; Starnberger et al., 2014). Additionally, anuran amphibians possess adaptations related to sound communication, allowing them to emit and perceive sounds within a wide frequency range (Narins, 1995). Even though, their ability to adapt to novel sounds varies widely, and behavioral and physiological negative consequences can follow (e.g., Lengagne, 2008; Tennessen et al., 2018; Caorsi et al., 2023).

Eleutherodactylus johnstonei, a terrestrial anuran native to the Lesser Antilles, has a history of human-mediated introductions and established populations in urban areas in Central and South America, including Brazil (Kaiser et al., 2002; Lever, 2003; Melo et al., 2014; Yuan et al., 2022). The calling activity of *E. johnstonei* males can represent a significant source of noise in the environment, disturbing residents (Melo et al., 2014). In this study, we assess the potential effects of acoustic niche invasion by *E. johnstonei* (Barbour, 1914) on two native species that produce vocalizations with and without spectral overlap with the exotic species. Our hypotheses are: (1) when there is spectral overlap, the call of *E. johnstonei* induces changes in temporal and spectral parameters of the native species males' calls, negatively affecting the acoustic niche; (2) when there is no spectral overlap, the call of *E. johnstonei* induces changes in temporal parameters of the call, also impairing intra-specific communication of the native species.

2 Materials and methods

2.1 Study area

We conducted the experiments in the edges of artificial ponds within the visitor area of the Parque Estadual das Fontes do Ipiranga (PEFI), located in the city of São Paulo (23°38'32.7"S 46°37'32.0"W), Brazil. PEFI encompasses the São Paulo Zoo and the São Paulo Botanical Garden. Situated within the Atlantic Forest morphoclimatic domain (Ab'Saber, 1977), PEFI features vegetation at various successional stages (Gomes et al., 2003). The climate is characterized by a dry winter (April to September) and a rainy summer (October to March), with average temperatures ranging from 18°C in winter to 22°C in summer (Santos and Funari, 2002).

Currently, PEFI has records of 22 anuran species, none of which are threatened or endemic (Lisboa et al., 2021). There are no records of *E. johnstonei* However, the site is situated just 6 km from the known established population of *E. johnstonei* and exhibits favorable conditions for its occurrence (Brasileiro et al., 2021).

2.2 Exotic species

Eleutherodactylus johnstonei successfully inhabits disturbed environments once introduced (e.g., Ortega et al., 2005; Bomford et al., 2009; Ernst et al., 2011) and occupies anthropized areas, forest edges, open spaces, and urban environments such as gardens and greenhouses (Schwartz, 1967; Kaiser et al., 2002; Leonhardt et al., 2019). In Brazil, individuals from the exotic population of *E. johnstonei* were introduced at least as early as 1995, when its vocalization were first recorded (Toledo and Measey, 2018). Currently, *E. johnstonei* can be found both on the ground (among ornamental garden vegetation and rocks) and climbing in vegetation (herbaceous, shrubby) as well as on walls and hedges (personal observation). Reproduction takes place during the warm and rainy months (November to April), coinciding with the reproductive period of the native species selected in this study.

Eleutherodactylus johnstonei displays a vocal repertoire consisting of four distinct calls (Flechas et al., 2018). The advertisement call is the most common (Figure 1A) and consists of two adjacent notes with distinct temporal and spectral parameters (Tárano and Fuenmayor, 2008; Melo and Brasileiro, 2022). On average, the first note has a dominant frequency of 1.77 kHz, and the second note of 3.42 kHz (Melo and Brasileiro, 2022; Table 1). Both notes are tonal, with frequency modulation at the end of the first note and the beginning of the second note

(Figure 1A). The frequency range of the advertisement call varies from 1.6 kHz to 3.5 kHz (Melo and Brasileiro, 2022; Table 1).

2.3 Native species

In our study, we opted for native species based on the dominant frequency of their advertisement calls, their abundance at the study site and with their reproductive cycles aligning with those of *E. johnstonei*, i.e., showing similar calling activity patterns. Specifically, we chose *Scinax imbegue* and *Physalaemus cuvieri* because they represent species with and without spectral overlap with *E. johnstonei*, respectively. As a heterospecific control, we chose the advertisement call of the native species *Boana bischoffi*, coexisting with others in PEFI. We collected the call parameters for *S. imbegue*, *P. cuvieri*, *B. bischoffi*, and *E. johnstonei* from the literature (Pombal, 2010; Gambale and Bastos, 2014; Conte et al., 2016). Detailed characteristics are provided in Table 1.

The control species, *Boana bischoffi*, is native to the southeastern and southern regions of Brazil (Teixeira et al., 2022), with a thriving population in PEFI (Lisboa et al., 2021). These individuals are commonly found in permanent ponds within or in proximity to forest fragments (Lisboa et al., 2021) and are observed climbing on ornamental vegetation (personal observation). Furthermore, they exhibit an extended reproductive period, with a reduction in vocalization activity during winter (Pombal, 2010). The advertisement call comprises one or two multi-pulsed notes, occupying a frequency range (Pombal, 2010) similar to *E. johnstonei* (Table 1; Figure 1B).

Scinax imbegue, native to the Atlantic Forest in the southeast and south of Brazil (Nunes et al., 2012), thrives in semi-open and open environments featuring lentic water bodies (Nunes et al., 2012;
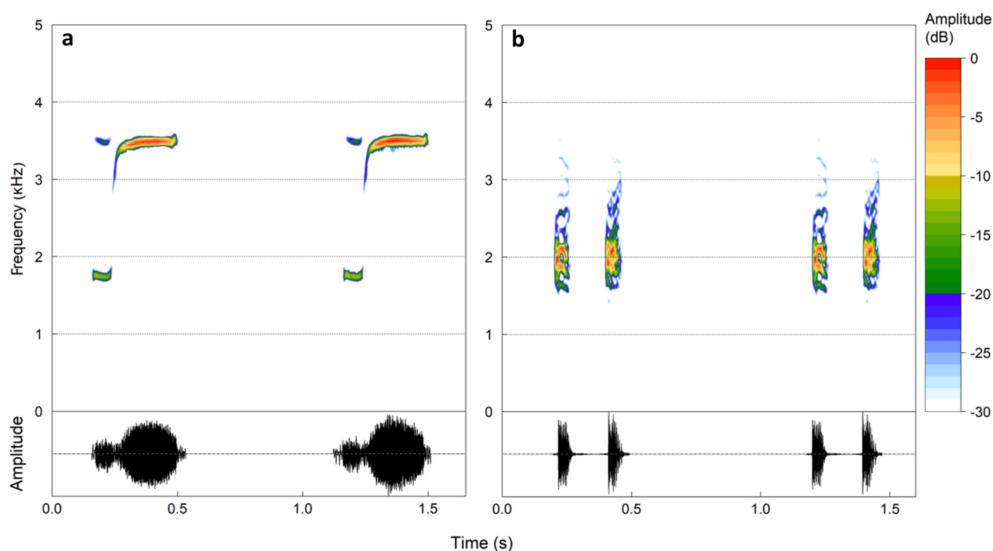

FIGURE 1
Spectrograms (above) and oscillograms (below) of the advertisement calls of the anurans that were used as stimuli, **(A)** *Eleutherodactylus johnstonei* and **(B)** *Boana bischoffi*. Spectrogram parameters: window size = 1,024, overlap = 90%, window type = "Hann". Figure created using the R package 'seewave' (Sueur et al., 2008).

TABLE 1 Duration of note (s), interval between notes (s), frequency range (Hz), and dominant frequency (Hz) of the advertisement call of *Eleutherodactylus johnstonei* (exotic species) and native species from Fontes do Ipiranga State Park used in the study (*Scinax imbegue* (native species with overlap), *Physalaemus cuvieri* (native species without overlap), and *Boana bischoffi* (native species used as a control).

Species	Call Duration (s)	Interval between notes (s)	Frequency Range (Hz)	Dominant Frequency (Hz)
E. johnstonei	0.29 ± 0.03	0.99 ± 0.2	1610 – 3540	3420 ± 130
S. imbegue	0.37 ± 0.07	0.65 ± 0.16	1200 – 6300	2600 ± 1000
P. cuvieri	0.29 – 0.4	–	300 – 1800	400 – 1100
B. bischoffi	0.05 – 0.1	–	1100–2500	1400–2100

Fiorillo et al., 2018). The species engages in continuous reproduction throughout the year (Santos and Conte, 2014; Fiorillo et al., 2018), with heightened vocalization activity during the rainy season (personal observation). Within PEFI, these individuals exhibit habitat versatility, occupying artificial lakes and their peripheries (Lisboa et al., 2021) while vocalizing on the ground, climbing on rocks, branches, low plants, ornamental plants, and in aquatic environments (personal observation). *Scinax imbegue*'s acoustic repertoire comprises territorial, courtship, and advertisement calls. The advertisement call is characterized by a single multi-pulsed note, featuring a dominant frequency of 2.6 ± 1 kHz (Conte et al., 2016; Table 1; Figure 2A).

Physalaemus cuvieri is distributed across the Northeast, Midwest, and South of Brazil (Frost, 2024). Within PEFI, these individuals are situated in artificial lakes, along their peripheries, and in puddles within the forest (Lisboa et al., 2021). Reproduction occurs during the rainy season (November to March) in temporary ponds and puddles, with individuals typically located in sheltered spots, vocalizing in flooded environments, on the water surface, and on damp soil (Barreto and Andrade, 1995; Bastos et al., 2003; Brasileiro et al., 2005). The advertisement call of *P. cuvieri* comprises a single note with harmonic structures (Figure 2B)

(Gambale and Bastos, 2014), featuring a dominant frequency ranging between 0.4 kHz and 1.1 kHz (Table 1; Figure 2B). The spectral overlap between the advertisement calls of the native and exotic species is showed in Figure 3.

2.4 Playback calls preparation

We recorded all advertisement calls used to prepare the playback calls in 2020 before conducting the experiments. All recordings were taken from solitary males. We recorded the advertisement calls of six solitary males of *E. johnstonei* and five solitary males of *B. bischoffi* to create stimulus playbacks. We conducted the recordings of *E. johnstonei* calls in the Jardim Cordeiro neighborhood, southern region of São Paulo city, Brazil, in March 2020, and the calls of *B. bischoffi* in PEFI in November 2020. We utilized a TASCAM DR-22WL portable recorder and a Sennheiser ME 66 unidirectional microphone to capture all calls. We use a portable decibel meter measured the average amplitude (dB) of the calls (INS-135, Introsul). In addition to the calls of *E. johnstonei* and *B. bischoffi*, we employed white noise as a stimulus to test whether the potential changes were a specific response to the
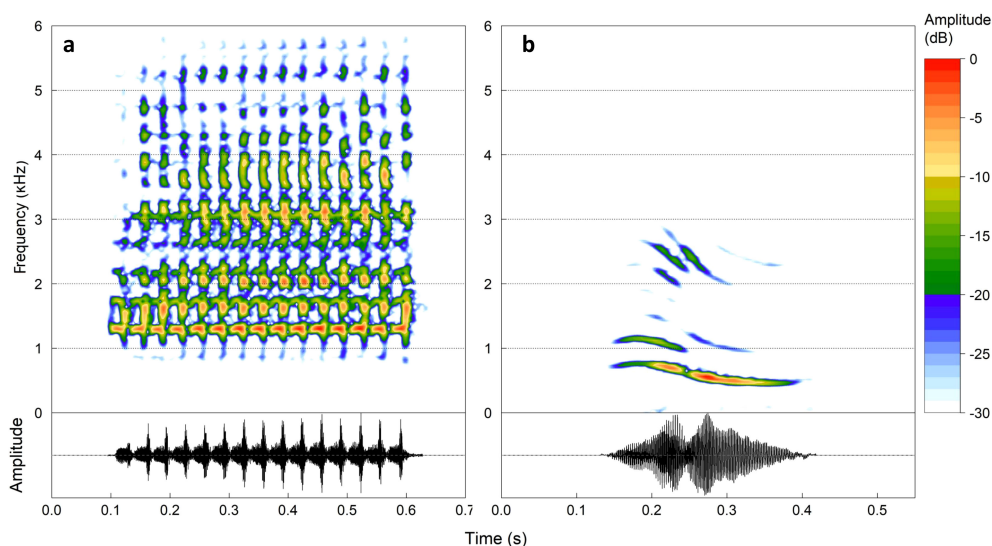

FIGURE 2
Spectrograms (above) and oscillograms (below) of the advertisement calls of native species exposed to playback stimuli. Species with spectral overlap with *E. johnstonei*, **(A)** *Scinax imbegue*, and species without spectral overlap **(B)** *Physalaemus cuvieri*. Spectrogram parameters: window size = 1,024, overlap = 90%, window type = "Hann". Figure created using the R package 'seewave' (Sueur et al., 2008).
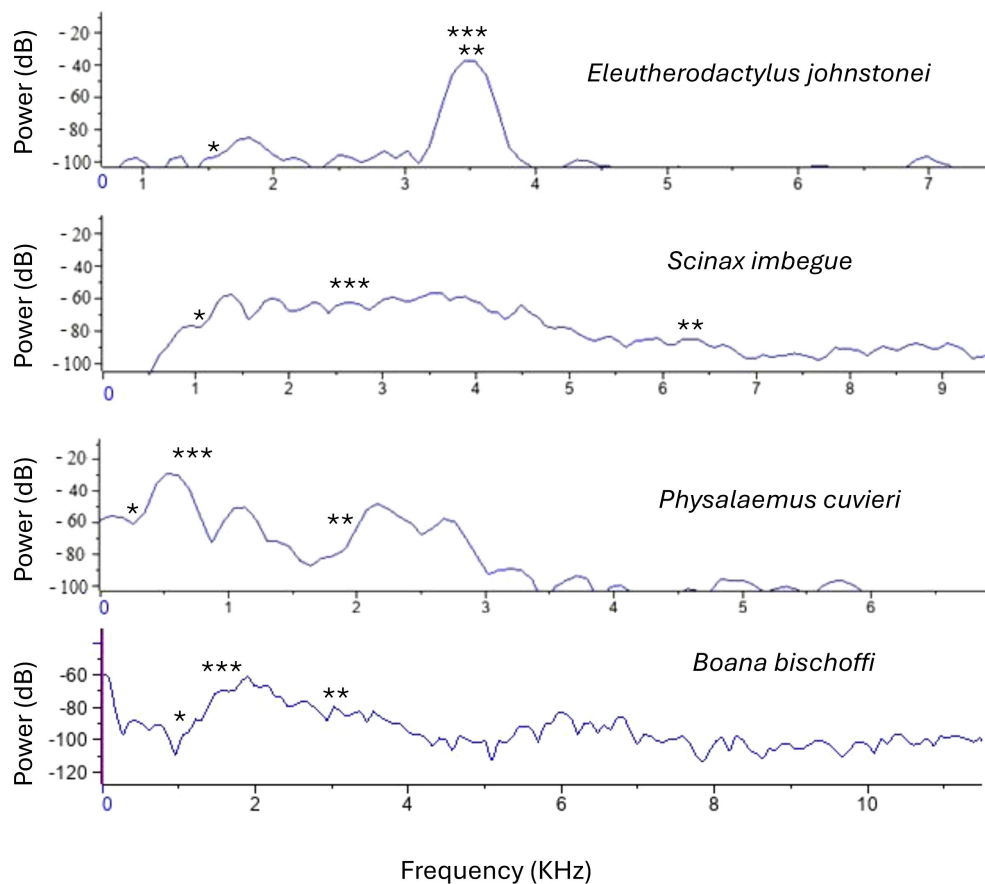
FIGURE 3
Power spectrum of the advertisement calls of *Eleutherodactylus johnstonei*, *Scinax imbegue*, *Physalaemus cuvieri*, and *Boana bischoffi*. *minimum frequency, **maximum frequency and ***dominant frequency.

vocalizations of *E. johnstonei* or a general response to noises (Medeiros et al., 2017). We have deposited our audio files used to organize the playbacks in the audio archive of Fonoteca Neotropical Jacques Vielliard (FNJV), Universidade Estadual de Campinas, State of São Paulo, Brazil (*E. johnstonei* FNJV 50605–50610; *B. bischoffi* FNJV 124328-124330, *P. cuvieri* FNJV124325-124326; *S. imbegue* FNJV 50617-50621).
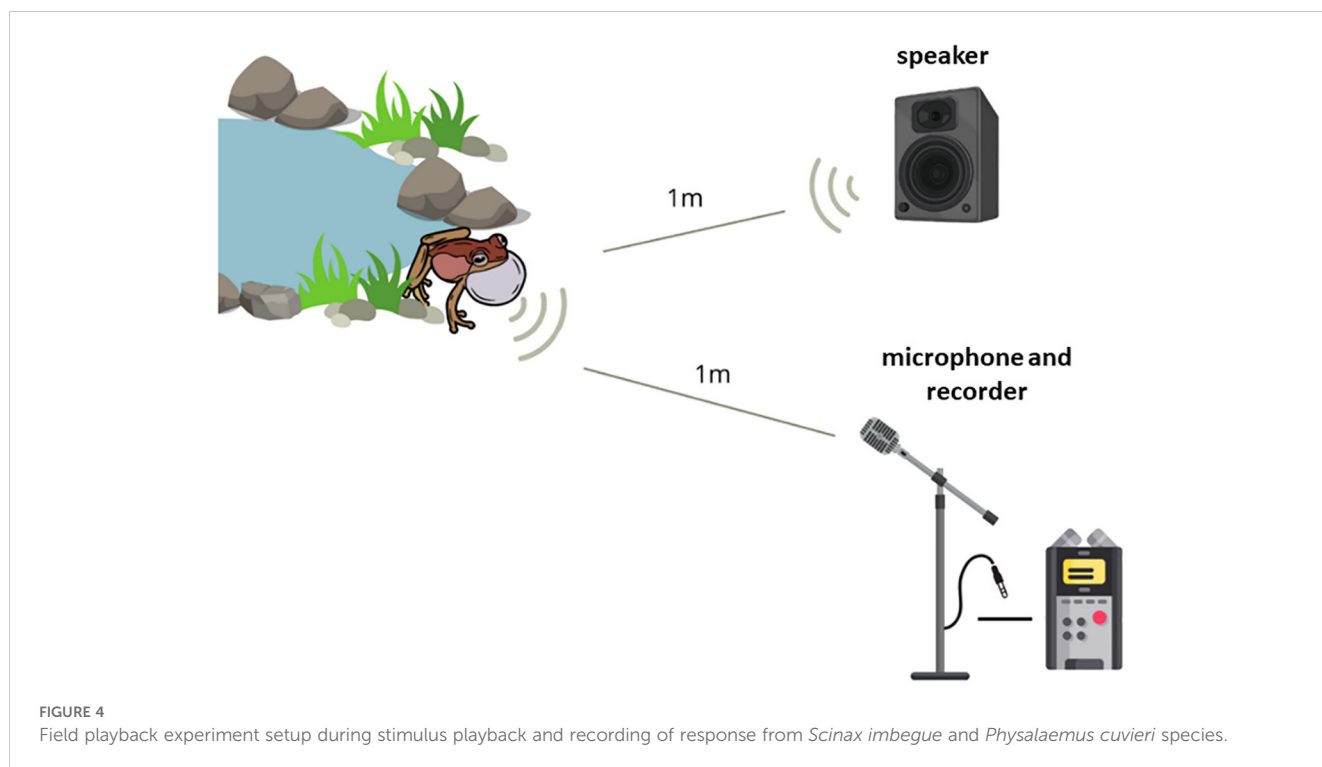
We visually inspected the quality of the recordings of *E. johnstonei* and *B. bischoffi* in the RAVEN PRO v. 1.5 software (Bioacoustics Research Program, 2014) and subsequently randomly selected notes emitted by males of both species to compose the three-minute stimulus playbacks. We constructed the stimulus playbacks in the Audacity 2.4.1 program. We standardized the sound pressure level at 75 dB for all stimuli at approximately 1 m from the source. The *E. johnstonei* stimulus playback (n = 6; mean CRC = 22.24 mm; temperature = 25.3 ± 0.6°C; humidity = 64 ± 3%) has a mean call duration of 288 ± 30 seconds and a dominant frequency of 3.42 ± 0.13 kHz. The *B. bischoffi* stimulus playback (n = 5; temperature = 19.6 ± 2.8°C; humidity = 71 ± 1%) has a mean call duration of 0.07 ± 0.03 seconds and a dominant frequency of 1.72 ± 0.05 kHz.

We organized the playbacks according to the A-B-A protocol (McGregor et al., 1992) following the structure of three minutes of pre-stimulus silence (S1), nine minutes of stimulus (three minutes for each stimulus – E1, E2, E3), and three minutes of post-stimulus silence (S2), totaling 15 minutes. We created six different versions of the playback, only changing the order of the three stimuli (E1, E2, E3) between the three minutes of pre-stimulus silence (S1) and the three minutes of post-stimulus silence (S2). Stimuli E1, E2, and E3 correspond to the advertisement calls of *E. johnstonei*, the advertisement calls of *B. bischoffi*, and white noise, respectively. Each target male was exposed to only one version of the playback, with the first target individual assigned to version 1, the second to version 2, and so on (see Caorsi et al., 2017).

2.5 Playback experiments

We located males of the target species through active search and removed the nearby conspecific males to avoid interference in the recording. We positioned the directional microphone and the speaker at approximately 1 meter from the focal male (Figure 4). Before conducting the recordings, we stepped back and waited until the male resumed normal vocalization (5-10 min). We adjusted the field playbacks using a decibel meter, considering the distance between the focal male and the speaker, and played the playback.

FIGURE 4
Field playback experiment setup during stimulus playback and recording of response from *Scinax imbegue* and *Physalaemus cuvieri* species.

We measured the air temperature and relative humidity for each recording.

At the end of the recording, we captured the focal male, measured the rostro-cloacal length (CRC, mm), and mass (g) with the aid of a digital caliper and a semi-analytical scale. To prevent males from being resampled, we marked individuals by amputating the third toe of the right foot (Phillott et al., 2007; Correa et al., 2013). We also maintained a minimum distance of 5 meters between individuals recorded on the same night. All experiments were approved by the Chico Mendes Institute for Biodiversity Conservation (ICMBIO - Permit No. 73346-2) and the Committee on Ethics in the Use of Animals (CEUA/Unifesp – No. 1005160320).

2.6 Acoustic analyses

We divided the 15-minute recordings into files of three minutes each for each individual according to the following segments: (1) pre-stimulus, (3) during the stimulus, and (1) post-stimulus, using the Audacity 2.4.1 program. We digitized the recordings at 44.1 kHz, with a resolution of 16 bits and a Fast Fourier Transform of 1024 points, at Raven Pro. We followed the note-centered approach and the concepts of notes, pulses, and calls as defined by Köhler et al. (2017). To calculate the calling rate (notes – 1)/min, we counted the calls emitted at each time segment during the three-minute recording. To measure other parameters of the advertisement call [note interval and duration (s), dominant frequency (Hz), maximum and minimum frequency (Hz)], we selected 9 notes in each time period, choosing the first three notes at the beginning of the recording, the three notes emitted from the middle of the period (starting from 1 minute and 30 seconds), and the last three notes. In cases where males emitted fewer than 9 notes, we used all observed notes in the period to measure the acoustic parameters.

2.7 Statistical analyses

We utilized a Permutational Multivariate Analysis of Variance with Distance Matrices to investigate the potential impact of stimuli on various call parameters within both species. Subsequently, *post-hoc* pairwise comparisons were conducted to evaluate distinctions between groups. The fixed factors encompassed the type of stimulus and the time periods (S1 – E1 – E2 – E3 – S2), with individuals serving as blocks. Also, the exposure order (e.g. E1-E2-E3; E1-E3-E2;…) was included as a fixed factor. We executed the analyses in the R program utilizing the "Vegan: Community Ecology" package (Oksanen et al., 2013), and employed the "Seewave" package (Sueur et al., 2008) for the generation of spectrograms and oscillograms.

3 Results

3.1 *Scinax imbegue* – species with spectral overlap with *E. johnstonei*

We recorded 21 males of *Scinax imbegue*. Seven individuals stopped calling when exposed to the stimulus playback (call of *E. johnstonei*) but resumed after approximately one minute. One individual stopped calling during the experiment, and six changed positions by moving away from the speaker but continued calling. We discarded the calls from three males due to the low quality of the recordings.

The treatment rate affected the calling (F=2.7; p < 0.05) but not the treatment order (p > 0.05). The males' calling rate decreased from an average of 29.7 calls/minute during the white noise stimulus (E3) to 19.5 calls/minute during the post-stimulus silence (F = 1.7; p < 0.05) Males did not alter the note duration of the advertisement call (F = 1.4; p > 0.05) or the interval between notes (F = 0.6; p > 0.05) in response to the stimuli, and the treatment order was also not significant (p > 0.05 for all). The dominant frequency, minimum frequency, and maximum frequency did not change in response to the stimuli (p > 0.05), and the order was not significant (p > 0.05).

3.2 *Physalaemus cuvieri* – species without spectral overlap with *E. johnstonei*

We recorded 17 males of *Physalaemus cuvieri*. No individual changed its initial position, and all called throughout the experiment without interruptions. We discarded one call record of *P. cuvieri*, due to external interferences in one recording.

The treatment did not affect the calling rate (F = 2.06; p > 0.05) or the treatment order (p > 0.05). Males progressively increased the duration of notes during the experiment (F = 2.7; p < 0.05), with an average of 0.27 seconds during the pre-stimulus silence (S1) to 0.30 seconds during the post-stimulus silence (S2). *P. cuvieri* males did not change the note interval or dominant frequency of the call (p > 0.05 for all) in response to the stimuli. The maximum frequency significantly increased during the E2 stimulus (call of *B. bischoffi*) (F = 0.6; p < 0.05), and the minimum frequency changed during the stimuli (F = 3.02; p < 0.05), decreasing from an average of 416 Hz during the pre-stimulus silence (S1) to 405 Hz during the post-stimulus silence (S2).

4 Discussion

In this study, the advertisement call of the exotic species *E. johnstonei* did not induce changes in the spectral and temporal parameters of the advertisement calls of the native species *Scinax imbegue* and *Physalaemus cuvieri*. However, when exposed to the advertisement calls of *Boana bischoffi* and white noise, the target native species modified parameters of their advertisement calls. This is the first study to assess the effect of a high-frequency call of an exotic species on native species. Studies on the invasive bullfrog and the invasive Cuban treefrog *Osteopilus septentrionalis* have focused on frequencies lower than 2500 Hz (Capranica, 1968; Both and Grant, 2012; Tennessen et al., 2016; Medeiros et al., 2017), and frequencies lower than 1200 Hz for the invasive species *Rhinella marina* (Bleach et al., 2015). All these previous studies reported changes induced by the exotic species calls on native species. Our study suggests that to understand how acoustic species will respond to novel invasive sounds we should focus in the call features of both the invasive and the native species.

Males of *S. imbegue* decreased the calling rate after exposure to white noise but maintained the duration and interval between notes constant during playback. The calling rate is easily altered by

individuals in the presence of acoustic interferences (Wong et al., 2009) and can be modulated by some species to avoid signal overlap or influenced by energy availability, social context, and vocalization strategies (Wells and Taigen, 1986; Köhler et al., 2017). Changes in the calling rate have been observed in response to invasive species (Bleach et al., 2015; Tennessen et al., 2016; Medeiros et al., 2017) and anthropogenic noises (Sun and Narins, 2005; Parris et al., 2009; Kaiser et al., 2011). Among these modifications, species exhibit either an increase or decrease in the calling rate, but they do not seem to follow a clear pattern and vary according to the species and noise characteristics (Caorsi et al., 2023).

Males of *Scinax imbegue* did not alter spectral parameters in the presence of acoustic stimuli. The advertisement call of *S. imbegue* covers a broad range of frequencies with relatively low spectral overlap with the high-frequency call of *E. johnstonei*. Furthermore, the population of *S. imbegue* in the study is located in an urban area, with constant presence of anthropogenic noises, and therefore, may be more tolerant to sound stimuli and consequently have higher fitness in disturbed environments (Ghalambor et al., 2007; Wells and Schwartz, 2007). These characteristics may explain the absence of changes in the spectral parameters of the advertisement calls of *S. imbegue* males. To understand the effects of the advertisement call of *E. johnstonei* on the spectral parameters of the calls of native species, we suggest testing species with higher frequency overlap and present in different acoustic landscapes.

When exposed to the calls of *Boana bischoffi* and white noise, males of *Physalaemus cuvieri* altered temporal and spectral parameters of the advertisement call. *Physalaemus cuvieri* males emitted longer notes after the playback, similar to males of the species *Dendropsophus minutus* and *Boana leptolineata* after exposure to the call of the bullfrog and white noise, respectively (Medeiros et al., 2017). This temporal alteration may be a generic response to noise, eliciting different effects on species. However, the maximum and minimum frequencies changed in response to the call of *B. bischoffi* and white noise, while the dominant frequency remained constant. Similar frequency variations were observed for *Scinax nasicus* in ponds near roads, where traffic noise is present (Leon et al., 2019). Variability in frequency range and dominant frequency is often related to an attempt to avoid signal overlap; however, the absence of modifications in these parameters during noise exposure has been documented (Lengagne, 2008). This demonstrates that the impact caused by noise is variable among species and contexts, requiring further studies with species vocalizing at different frequencies.

Regarding behavior, males of *S. imbegue* ceased vocalizing and/ or moved away from the noise source during the experiment (pers. Obs). This behavior was observed for *B. bischoffi* and *Boana leptolineata* during experiments using anthropogenic noise (Caorsi et al., 2017). However we did not observe any behavior changes for *P. cuvieri* during the playback of stimuli. Reversible modifications in behavior are short-term mechanisms employed by signal emitters to reduce acoustic signal masking (Brumm and Slabbekoorn, 2005). For example, individuals may switch the emitted calls, causing their vocalizations to coincide with periods of low noise and thus avoiding masking by conspecifics (Zelick and Narins, 1982; Grafe, 1996), heterospecifics (Brumm, 2006; Wong

et al., 2009), or abiotic noises (Sun and Narins, 2005; Vargas-Salinas and Amézquita, 2013). These behavioral results are consistent with the hypothesis that species with a higher degree of signal overlap with noise are more affected (Parris et al., 2009; Cunnington and Fahrig, 2010) and reinforce that individuals' responses to new sounds in the environment (anthropogenic noise or calls of exotic species) vary among species and acoustic landscapes.

Finally, effects of novel invasive sounds might affect native species at metabolic and or physiological level, even when calling is not altered (Shine, 2014; Still et al., 2019; Mitchell et al., 2020). The results obtained in this study underscore the potential for new sounds in the environment to influence the acoustic behavior of individuals. Given the large populations of *E. johnstonei* in exotic habitats, the chorus produced by males could potentially amplify noise, but this effect remains untested. Moreover, this study aimed to assess the threat that *E. johnstonei* poses to native species, but it sets up artificial encounters between the invader and two pond-breeders, interactions may rare or never occur in natural settings. However, these stimulations provide valuable insights into possible ecological impacts under controlled conditions. When acoustic interferences disrupt the communication between individuals, species density and distribution can be reduced (Sun and Narins, 2005), since spectral and temporal parameters play a crucial role in partner selection and localization, and consequently, reproduction. (Gerhardt and Schwartz, 2001). Like anthropogenic noises, invasive species can induce changes in the calling parameters of native species, a mechanism that warrant further attention, as species introductions continue to increase globally (Pyšek et al., 2020).

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

The animal study was approved by Chico Mendes Institute for Biodiversity Conservation (ICMBIO - Permit No. 73346-2) and the Committee on Ethics in the Use of Animals (CEUA/Unifesp – No. 1005160320). The study was conducted in accordance with the local legislation and institutional requirements.

Author contributions

Funding

Acknowledgments

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/famrs.2024.1457928/full#supplementary-material

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