Received: 7 March 2024 | Revised: 18 July 2024 | Accepted: 21 August 2024

DOI: 10.1002/ecy.4440

THE SCIENTIFIC NATURALIST

ECOLOGY
ECOLOGICAL SOCIETY OF AMERICA

Sound production in wild Mediterranean blonde ray *Raja brachyura*

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Funding information
Agence de l'Eau Rhône Méditerranée Corse

Handling Editor: John Pastor

KEYWORDS: aggressive display, batoids, bioacoustics, communication, elasmobranch, warning signal

Sound production, or soniferous behavior, is linked to an active and intentional communication process between individuals of the same or different species, rather than being a by-product of activities like feeding or locomotion (i.e., incidental sounds). In ray-finned fishes (Actinopterygii), a clade comprising 34,200 species (Froese & Pauly, 2019) from 488 families (Fricke et al., 2019), sound production has independently evolved approximately 33 times, encompassing nearly 29,000 species (Rice et al., 2022). More precisely, intentional sound production has been identified in 989 bony fish species, belonging to 133 families and 33 orders (Looby et al., 2022; Rice et al., 2022). Based on approximation, half of the fish families of coral reefs for example have at least one known sound producing species (Parmentier et al., 2021). Sound production is therefore a key behavioral feature of bony fish, and the ever-increasing number of reports on sound production in various species and contexts continues to highlight this important aspect (Amorim, 2006; Ladich & Schulz-Mirbach, 2016).

In comparison, evidence for active sound production in elasmobranchs (cartilaginous fish), that is, sharks, rays, and skates, remains scarce (Looby et al., 2022). The first case of active sound production was reported more than 50 years ago in captive cownose rays *Rhinoptera bonasus* which produced clicks as a result of human harassment (Fish & Mowbray, 1970). Subsequently there have been no proven and confirmed examples of active sound production in any species of elasmobranchs. Although recently, Fetterplace, Esteban, et al. (2022) reported the first evidence of active sound production in two species of stingray, that is, the mangrove whipray *Urogymnus granulatus* (Macleay 1883) and the cowtail stingray *Pastinachus ater* (Macleay 1883), recorded in the wild in Indonesia and Australia. Both species produced a series of short broadband loud clicks in response to an observer's approach and ceased producing sound when the distance with the observer increased. This founding paper therefore paved the way and encouraged further research on sound production in elasmobranchs. Here we present the first evidence of active sound production in a new species, that is, the blonde ray *Raja brachyura* (Lafont 1873) opportunistically recorded off the coast of Corsica in the Mediterranean (Figure 1).

Sound was extracted from a video recording made on 30 March 2023 with a Hero 8 Black action camera (GoPro, Inc., USA) placed at the end of a rope and lowered at −40 m depth from a boat in the first instance

FIGURE 1 Picture of a blonde ray *Raja brachyura*, from a screenshot of the video (Barroil, 2024) acquired in the field after the sound was heard. Photograph by Adèle Barroil.

in order to find *Spicara smaris* (L. 1758) spawning grounds off the eastern coast of Corsica (42°14.720′ N; 9°35.330′ E). *S. smaris* males build their nest on soft bottoms seabed. Spawning ground covers large areas (2.2–28 ha) from the lower limit of *Posidonia oceanica* (Delile 1813) seagrass meadows to near −50 m depth (Andromède océanologie, 2023, 2024; Deter et al., 2024). This video was therefore captured in this zone, over a substrate made of coarse sand. When touching the ground, and after an initial move to the left, the camera landed next to a first individual whose pectoral fin could be seen while another individual is visible in the distance. In a second movement, the camera is moved between these two individuals and a series of high-pitched pulses can be heard as the substrate is agitated. As the gravel settles, the camera is moved again and an individual that was standing near the camera flees. Three individuals present in the area were observed when the camera finally moved away (Barroil, 2024). No other species were observed on the video. The sound track was digitized at 44.1 kHz (16-bit resolution) using Goldwave v6.80 (Goldwave Inc) and analyzed with RavenPro 1.6.5 software (The Cornell Lab of Ornithology, Ithaca, NY). A band-pass filter between 20 Hz and 15 kHz was applied. Sound consisted of a series of pulses, and the following acoustic features were measured: the sound duration (from the beginning of the first pulse to the end of the last pulse), the number of pulses in the sound, the pulse duration, the pulse period (peak-to-peak interval between two consecutive pulses), and the dominant frequency of the pulses (Figure 2). Temporal features were measured from oscillograms, whereas frequencies were obtained from power spectra (Fast Fourier Transform FFT, 1024 points, Hamming window, no overlap). The sound lasted 5.86 s and was made of a series of 11 pulses which lasted 0.015 ± 0.003 s (mean ± SD; min–max = 0.010–0.020 s) with a pulse period of 0.58 ± 0.10 s (0.50–0.83 s). The pulses' dominant frequency was 6.93 ± 0.26 kHz (6.28–7.22 kHz) (Figure 2).

Despite *R. brachyura* not being visible when the sound was recorded, the sound is similar to the ones already reported in *U. granulatus* in terms of pulse duration, that is, 0.010–0.025 s and number of pulses within a series, that is, 5–11 pulses. Sound frequency appears higher than in both *U. granulatus* and *P. ater*, which showed frequencies ranging from 1031 to 1875 Hz, and from 1406 to 1500 Hz, respectively (Figure 3). In addition, this sound is different from boat noise that could be heard and clearly identified on the video when the clutch is engaged (BN, Figure 2). It is also unlikely that the sound results from the movement and fall of the camera, which continues to be shaken or hit the substrate after the rays have left without any sound being detected. We are therefore confident in stating that this sound was indeed produced by the blonde ray.

Subsequently to our observations, similar soniferous behaviors were observed later in 2023 in two other batoid species in the Mediterranean, that is, the rough skate *Raja radula* (Delaroche 1809) and the marbled electric ray *Torpedo marmorata* (Risso 1810) (Rodriguez & Barría, 2024). Sounds also consist of series of broadband clicks lasting 0.025–0.082 s with a mean peak frequency of 3146 Hz in *R. radula*, and lasting 0.004–0.013 s with a peak frequency of 8387 Hz in *T. marmorata*.

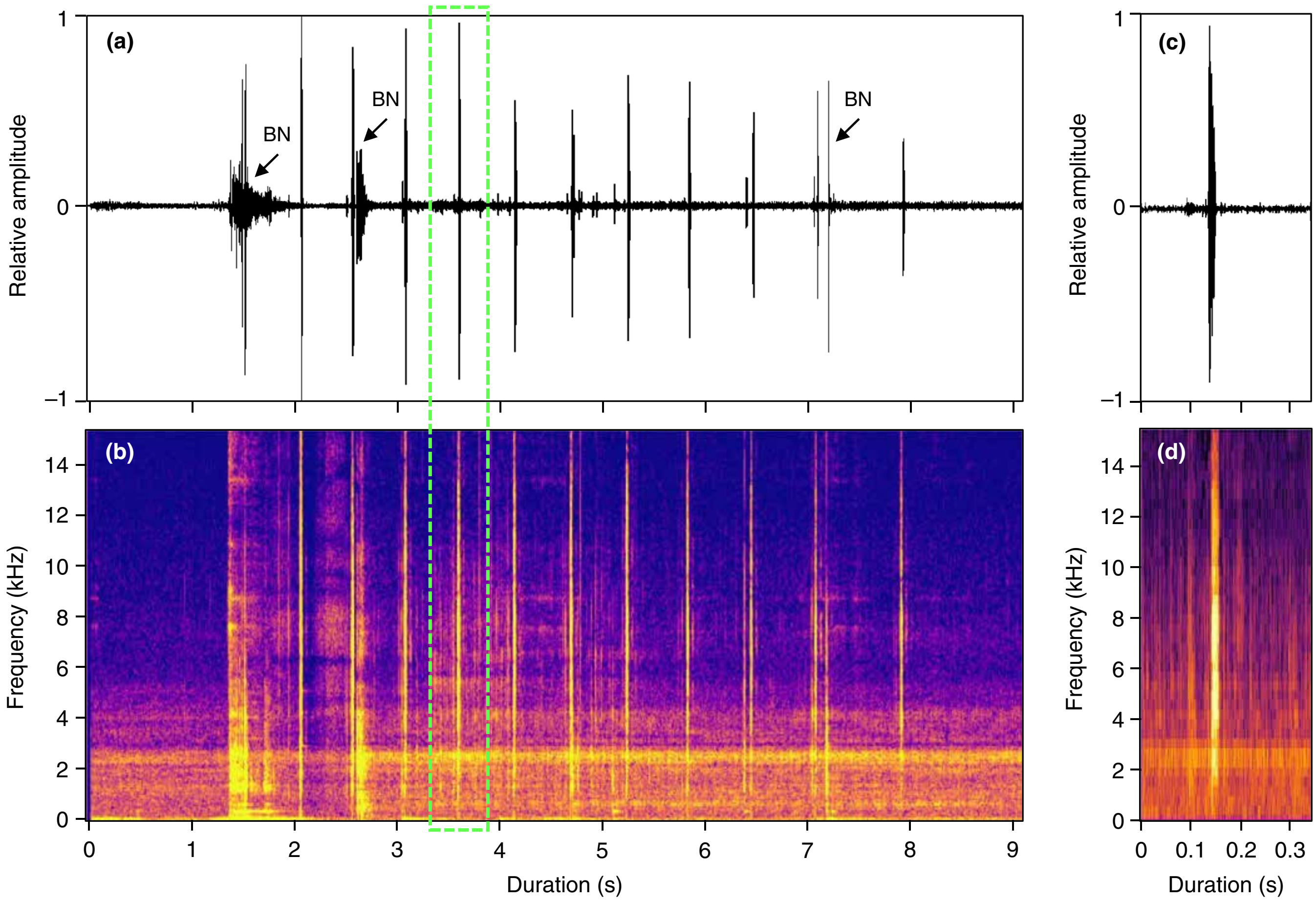

FIGURE 2 Oscillograms (top) and spectrograms (bottom) of (a, b) the series of eleven pulses produced by a blonde ray *Raja brachyura* and (c, d) of the third pulse highlighted by green dashed lines. BN, boat noise.

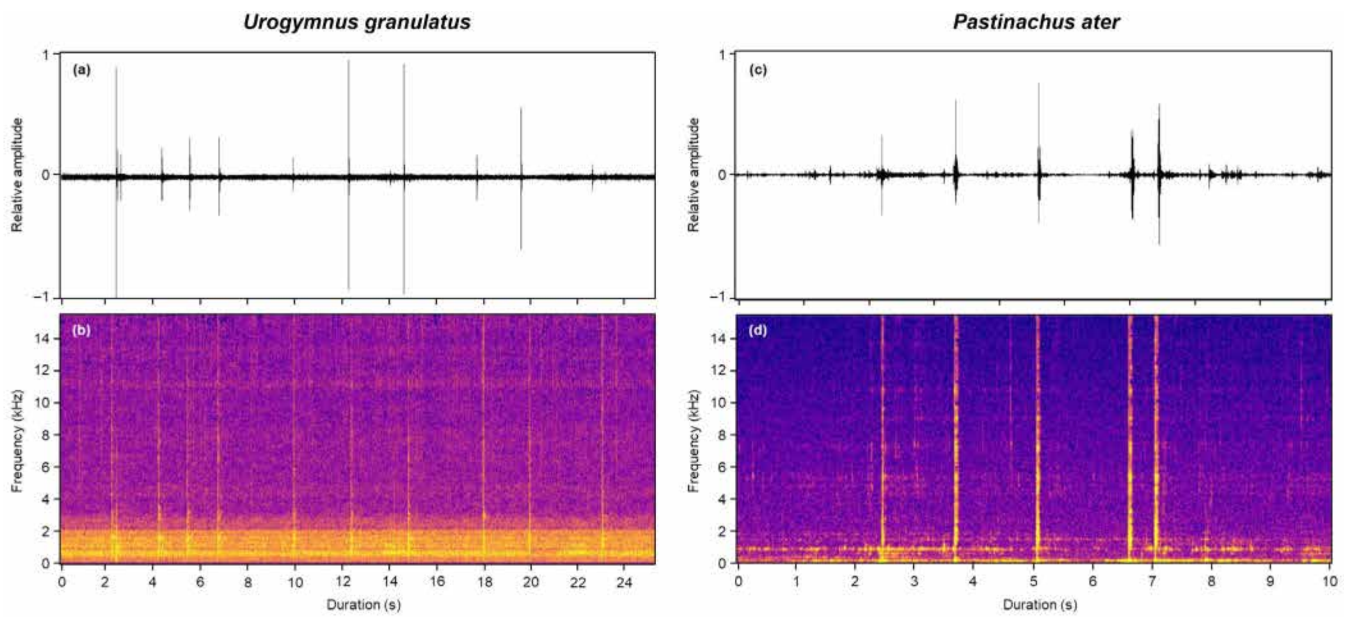

FIGURE 3 Oscillograms (top) and spectrograms (bottom) of (a, b) the sound produced by a mangrove whipray *Urogymnus granulatus* and (c, d) of the sound produced by cowtail stingray *Pastinachus ater*. Sounds were extracted from videographic data from Fetterplace, Wueringer, et al. (2022).

Elasmobranchs are sensitive to frequencies between 40 and 1500 Hz, with peak sensitivities between 200 and 400 Hz (Chapuis & Collin, 2022; Mickle et al., 2020; Myrberg, 2001; Parmentier et al., 2020). While the high frequency of *R. brachyura*'s sound may fall outside its hearing range, suggesting this signal is intended to other species (e.g., marine mammals), the large bandwidth of the sound spans the hearing range of elasmobranchs which may allow conspecifics or predators (e.g., sharks) to hear this sound. As in the mangrove whipray and the cowtail stingray, sound production in the blonde ray is probably related to the warning of conspecifics present in the area or intended to repel a threat. In *U. granulatus* and *P. ater*, conspecifics have been observed to approach the emitter in response to sound and to flee from divers (Fetterplace, Esteban, et al., 2022). Likewise, in the rough skate and the marbled electric ray, sound production was presumably associated with agonistic displays directed toward the divers when they were close (Rodriguez & Barría, 2024). Many sharks are known to respond to sounds, either being attracted by the sounds produced by preys or being repelled by the sounds of their predators (e.g., Chapuis et al., 2019; Gardiner et al., 2012; Myrberg, 2001). Besides the fleeing behavior of what may be the sound-producing individual, one individual could subsequently be observed to come quickly close to the camera. Divers also reported being "charged" by rays (*Raja* sp.) or by common smooth-hounds *Mustelus mustelus* (L. 1758) when they hit a metallic post with a hammer (Holon, personal observation). This may align with the fact that free-ranging sharks were attracted to broadband and irregularly pulsed sounds (which may become repulsive when transmitted with a sudden 20-dB increase or more in intensity) (Myrberg, 2001). Finally, in Fetterplace, Esteban, et al. (2022), sound production was associated with movements of the spiracles and cranial area, while in Rodriguez and Barría (2024), clicks were produced when individuals open and closed their mouths, accompanied by the movement of their pectoral fins. Unfortunately, the present sound production event could not be captured on film. Further observations may thus help to clarify both the emitter's behavior (e.g., sound production mechanism) and the behavioral response of the receivers (e.g., auditory capacities and social role of sound).

Further standardized recordings with proper hydrophones are required to better describe sound signals and their social role in elasmobranchs. The present paper as well as those of Fetterplace, Esteban, et al. (2022) and Rodriguez and Barría (2024) highlight the usefulness of using passive acoustic monitoring in biodiversity assessment and management plans as it may provide valuable information on a so far overlooked portion of bioacoustic diversity in fish.

AUTHOR CONTRIBUTIONS

Video contribution was made by Adèle Barroil and Julie Deter. The original draft was written by Adèle Barroil and Frédéric Bertucci, with further review and editing by Julie Deter and Florian Holon. Analysis of the video and sounds was made by Frédéric Bertucci.

ACKNOWLEDGMENTS

Thanks to the staff of Andromède Océanologie for the fieldwork and video recordings and to the French Water Agency (Agence de l'Eau Rhône Méditerranée Corse) for funding the Spicara Circus project during which the video was recorded. We would like to thank the team who took part in the Spicara Circus fieldwork. The opportunistic nature of the study prevented us from drawing up an ethics document.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Video supporting these findings is available from Barroil (2024) in Figshare at https://doi.org/10.6084/m9.figshare.25341733.v2.

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How to cite this article: Barroil, Adèle, Julie Deter, Florian Holon, and Frédéric Bertucci. 2024. "Sound Production in Wild Mediterranean Blonde Ray *Raja Brachyura*." *Ecology* 105(11): e4440. https://doi.org/10.1002/ecy.4440