Using sea turtles' vocalization to reduce their bycatch?

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Despite the intensive investigation of many aspects of sea turtle life-history in the wild for over four decades, their underwater communication capacities and behavioral responses to sound have gone largely overlooked. Our recent findings about sounds produced by sea turtles in the French West Indies island of Martinique elicit strong interest and therefore present new opportunities to reduce harmful interactions between turtles and fishing gear.

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Abstract. Incidental capture of non-target species poses a pervasive threat to many marine species, with sometimes devastating consequences for both fisheries and conservation efforts. Because of the well-known importance of vocalizations in cetaceans, acoustic deterrents have been extensively used for these species. In contrast, acoustic communication for sea turtles has been considered negligible, and this question has been largely unexplored. Addressing this challenge therefore requires a comprehensive understanding of sea turtles' responses to sensory signals. In this study, we scrutinized the avenue of auditory cues, specifically the natural sounds produced by green turtles (*Chelonia mydas)* in Martinique, as a potential tool to reduce bycatch. We recorded 10 sounds produced by green turtles and identified those that appear to correspond to alerts, flight or social contact between individuals. Subsequently, these turtle sounds—as well synthetic and natural (earthquake) sounds—were presented to turtles in known foraging areas to assess the behavioral response of green turtles to these sounds. Our data highlighted that the playback of sounds produced by sea turtles was associated with alert or increased the vigilance of individuals. This therefore suggests novel opportunities for using sea turtle sounds to deter them from fishing gear or other potentially harmful areas, and highlights the potential of our research to improve sea turtles populations' conservation.

Sea turtle bycatch, a major threat to many species, occurs in industrial and artisanal fisheries using a variety of gear types including longlines; gill nets; trawls; traps; and pots[1,2,3,4,5]. Bycatch threatens sea turtles globally since the areas where fisheries operate overlap with sea turtle foraging habitats, breeding grounds and migratory corridors both spatially and temporally in coastal and offshore ocean areas. In the French West Indies, fishing holds immense economic significance, estimated at 20M€/year. The predominant artisanal fishing practices involve small, single-person fishing companies, utilizing vessels under ten meters in length. These operations encompass coastal operations, focused on demersal resources, and offshore operations targeting pelagic species (Scombridae, Istiophoridae, Coryphaenidae, etc.). Coastal fishing constituted 62% of active vessels in Martinique in 2019 and 65% in Guadeloupe in 2018. Various types of nets targeting different species (e.g., conch, lobster, reef fish) are used, including trammel nets and entangling gillnets set at the surface or ocean bottom. Although sea turtles are known to interact with all of these (and other) fishing gears, characterizing these interactions remains challenging. The prohibition of sea turtle fishing in Guadeloupe (1991) and Martinique (1993) has somewhat contributed to the preservation of sea turtle populations, but accidental captures of sea turtles persist. Bycatch represents a significant threat and risk of direct mortality for juvenile and adult green turtles frequenting coastal waters in these territories. Past studies[6] as well as first-hand accounts from fishermen (Topase team, pers. comm.) report bycatch of sea turtles, including green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and loggerhead sea turtles (*Caretta caretta*). For fishermen, these captures not only result in diminished earnings due to the reduced catch of target species but also incur additional costs (expenses and time) for repairing or replacing damaged gear. The complexity of this situation makes effective communication challenging, but requires strong collaboration with fishermen willing to contribute to finding solutions. The impact of bycatch on coastal fisheries management is substantial, sometimes leading to the closure of fisheries. Consequently, there is an urgent need to develop technologies to reduce bycatch, especially that of sea turtles. This is essential in order to protect sea turtles while also securing the livelihoods of local fisheries[7]. Existing literature highlights diverse techniques designed to contribute to the reduction of sea turtle bycatch in gillnets, while also maintaining an acceptable fishing yield[8,9,10,11,12,13]. The development of these technologies relies on differences in sensory systems of sea turtles and those of target species of fisheries. The use of visual deterring devices (Visual Deterrent Devices, VDD), particularly green and UV LEDs, appears to reduce turtle bycatch in some fisheries. However, understanding of the specific behavioral responses of turtles to these stimuli remains limited; i.e., whether illuminating gear alerts animals of its presence to avoid physical interactions or scares them away from the gear. Despite apparent success in reducing sea turtle bycatch, net illumination remains largely experimental, and has not been implemented at scale in commercial fisheries for turtle bycatch reduction purposes. The application of these devices presents challenges for fishers ranging from entanglement in nets, concerns over the durability of LEDs, and the associated financial burden of acquiring and maintaining them. Furthermore, the primary batteries employed in these devices are Li-ion batteries, raising environmental concerns due to disposal of spent batteries and water-intensive lithium extraction, resulting in issues such as soil pollution and the depletion of water reserves. In this context, experiments designed to evaluate the impact of low frequency Acoustic Deterrent Devices (ADDs) on sea turtle behavior might reveal a more efficient alternative solution to sea turtle bycatch reduction. Behavioral and electrophysiological studies explored the acoustic ecology of sea turtles, focusing on their auditory capabilities, their responses to acoustic stimuli and the implications of this knowledge for their conservation[7,14,15,16]. Their research measured the underwater hearing sensitivities of juvenile green, juvenile loggerhead, hatchling leatherback (*Dermochelys coriacea*), and hatchling hawksbill sea turtles by recording potential responses to synthetic tonal stimuli. They concluded that sea turtles are able to perceive sound signals in a range from 50 to 1600 Hz, with a maximum sensitivity between 10 and 400 Hz[7,16]. In addition, though sea turtles have long been believed to be silent, recent studies identified sound production in hatchling[17,18,19,20] and in juvenile green sea turtles[3]. Our primary objective in the present study was therefore to explore whether turtle sound production, especially those associated with alertness, escape behavior, or social contact, could provide a suitable tool for mitigating turtle bycatch. To accomplish this objective, we explored variation in behavioral responses of foraging sea turtles to synthetic sound signals and natural sounds produced by green turtles (online Methods and **Fig. 1**).

In a first step, we recorded the sounds produced by free-ranging juvenile green turtles and their behaviors using on-board camera devices and hydrophones attached to their carapace in Martinique (detailed methodology described in[21,22]). Overall, we recorded and described 10 sounds produced by green turtles and we identified four main sound categories for sounds produced: Pulses, Low Amplitude Calls (LAC), Frequency Modulation Sounds (FMS), and Squeaks[21]. In a second step, we examined the behavioral responses of green sea turtles foraging in their natural environment to sounds which could potentially be associated with fear, flight or social contact: Rumble (LAC category) and Squeak (**Fig. 2a**). Five different recordings of the Squeak signal were presented to the turtles, varying in frequency, duration or intensity (see details in **Table 2**). These five recordings were presented as a single acoustic signal in the tests. A geophonic sound (Earthquake) and three synthetic sound signals (Synth FML, Synth FMA and Heavy Metal playback) were additionally tested (**Fig. 2a**). We used two small vessels to broadcast signals and observe behavioral responses. One vessel, referred to as the "observation platform" (POBS) was employed by a diver responsible for spotting and locating turtles underwater. Upon spotting an individual, the POBS informed the second vessel, equipped with the acoustic platform (PACO). The PACO then positioned itself in proximity of the observed turtle as the diver looked on and activated the speaker and initiated sound playback. The POBS's diver observed and recorded (using a GoPro Hero 10 device) the behavior of the target individual (**Fig. 1**). Visual observations were quantified using two metrics: *(i)* assessing the immediate impact of sound playback on the behavior of green turtles (referred to as "shot" hereafter), with reaction intensity rated on a scale of 0 (no reaction), 1 (significant reaction with alertness or watchfulness, *i.e.* turtle raises suddenly its head and look around, **Fig. 1**), to 2 (escaping, *i.e.* turtle swimming rapidly away from the test area); **Fig. 1**) and *(ii)* assessing the change in activity by comparing the behavior recorded before and after each shot. Several trials were performed, each one involved the repetition of shots of a given signal on an individual turtle at variable distance (5-250 m), and the PACO moved then closer to the animal, but always remained at a distance greater than five meters. Two alternative versions of this protocol were used 1) to determine which sound signal triggered the turtle behavioral responses and 2) to measure the distance and habituation effect to this sound. For the first aim, if the turtle did not react within the first three shots, the trial was stopped. We then tested the immediate reaction of a given individual to a defined signal within a trial. For the second aim, only sounds that elicited the highest number of behavioral responses were tested with up to 13 shots per trial, on a wide range of distances (40-500m).

A total number of 75 initial trials to assess turtle response to each tested sound were performed on 68 individuals to assess the reaction of turtles to the different signals, with an average of 2.63±0.65 shots per trial. Secondly, 20 trials on 20 individuals were carried out to test the distance and habituation effect of particular sounds that elicited the highest level of behavioral responses, involving a mean of 5.40±2.76 shots per trial.

Reaction to signals. The three *synthetic sound signals* were also tested in 17 (Synth FML), five (Synth FMA) and three (Heavy Metal playback) trials performed on 23 different feeding turtles. We observed no reaction to any of these synthetic sounds. The geophonic sound (Earthquake) was tested on four feeding turtles, triggering no reaction in any of the tested individuals. We presented the natural sounds produced by sea turtles, the Rumble (**Fig. 2b**) and the Squeak (**Fig. 2b**), in playback tests to 18 and 28 feeding turtles, respectively. There was then a significant difference in the proportion of turtles reacting to the sounds produced by sea turtles (Fisher's Exact test, p = <0.0001), with 17 of total 18 turtles (94.4%) reacting to the Rumble and 17 of total 28 (60.7%) to the Squeak by exhibiting either a vigilance posture, escaping, or a combination of the two. More precisely, Rumbles triggered only vigilance in 55.6% of observed responses, immediate escape or vigilance followed by an escape in 38.9% of observations, and triggered no reaction in 5.6% of the tested individuals (**Fig. 2c**). Squeaks triggered vigilance in 53.6%, immediate escape or vigilance followed by an escape in 7.1%, and no reaction in 39.3% of the tested turtles (**Fig. 2c**). The proportions of each behavioral reaction varied significantly between the broadcast of Rumbles and Squeaks (Fisher's Exact test, p = 0.0044) with higher probability of escape behavior for Rumble and a higher frequency of no reactions for Squeak (Post-hoc test for Fisher's Exact test, p = 0.0022).

Distance and habituation effect. Shots were played at different distances using the Rumble signal. When the Rumble signal was played from a distance of >300 m from the target individual (n=17 shots), all shots resulted in no reaction. When the playback tests were performed from a distance between 200 and 300m (n=23 shots), 26.1% of turtles changed their behavior, 45.9% changed their behavior from a distance between 100 and 200m (n = 37) and 38.7% from a distance <100m (n=38 shots) from the focal individual. The distance between the focal turtle and the source of sound had thus a significant effect on the likelihood of turtles to react, with an increasing probability of reaction when this distance decreased (p= 0.0087, **Fig. 3a**). Turtle's reactions occurred mainly for the first, the second and the third shots with 70% (n=20), 60% (n=20) and 29.4% (n=17) of reactions respectively, regardless of the distance at which the shots were played. Turtles seemed to react less frequently after the fourth, fifth and sixth shots with 6.2% (n=16), 18.2% (n=11) and 12.5% (n=8) of reactions respectively. Beyond six shots, turtles stopped reacting to Rumble signal. The probability of turtles' responsiveness was inversely related to the number of shots ($p < 0.0001$, **Fig. 3b**).

The use of acoustic deterrents for cetacean bycatch reduction has been successful because of the reliance of these species on acoustics for their general ecology and life history. In contrast, there was a general assumption that acoustic communication is negligible in sea turtles. For our knowledge, our study then demonstrates for the first time that sea turtles behaviorally respond to the sounds they produce, and that their vocal repertoire is more functional than previously thought. These findings therefore open new possibilities to reduce bycatch since acoustic signals could be deployed with various fishing gears to potentially reduce sea turtle interactions. The applicability of these results might extend to other sea turtle species, and possibly to other marine species. Moreover, it has the potential for diverse applications beyond reducing bycatch. For example, synchronized nesting behavior, specifically the massive arrivals of olive ridley sea turtles (*Lepidochelys olivacea*), might be coordinated in some way by vocal communications among these turtles. In studies around the world that utilize acoustic receivers to record sounds of marine species, these data could be examined to identify the sound produced by sea turtles as well. Thus, targeted studies on recording, analyzing, and cataloging sea turtle sounds and associated visual, swimming/diving behaviors should be a research priority, particularly for researchers working on fine-scale underwater turtle behavior. Once the sounds produced by sea turtles are identified, the automated detection of those natural sounds emitted by each species might then enable the establishment of an automated alert system to inform fishermen, enabling them to anticipate and reduce bycatch by removing their nets before the arrival of these hundreds or thousands individuals. Thus, the reduction in accidental captures could be effective not only for juveniles in feeding areas, but also for adults in breeding areas.

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AUTHOR CONTRIBUTIONS

D.C., team leader of the TOPASE project, designed and performed the study in the field, worked on the analyses and wrote the paper. Y.L.G., E.M. performed the acoustic test in laboratory. Y.L.M. co-wrote the paper. P.L., L.M., I.C., worked on the analyses and added useful modifications to the manuscript. Y.L.G. performed the physiological impact assessment. B.W., O.V., M.G., L.J., E.L., T.C, P.C, P.F., C.F.C, A.L., S.M., M.N. added useful modifications to the manuscript. Y.L.G., E.M, S.R., N.L., F.L., N.A, J.M., C.D., M.P., O.B., P.L., M.A., M.L., N.M., M-C.B. participated the study in the field.

COMPETITING FINANCIAL INTERESTS

The authors declare no competing financial interests.

DATA AVAILABILITY

The data that support the findings of this study are available from Damien CHEVALLIER but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available.

Data are however available from Damien CHEVALLIER (damien.chevallier@cnrs.fr) upon reasonable request and with permission of Damien CHEVALLIER.

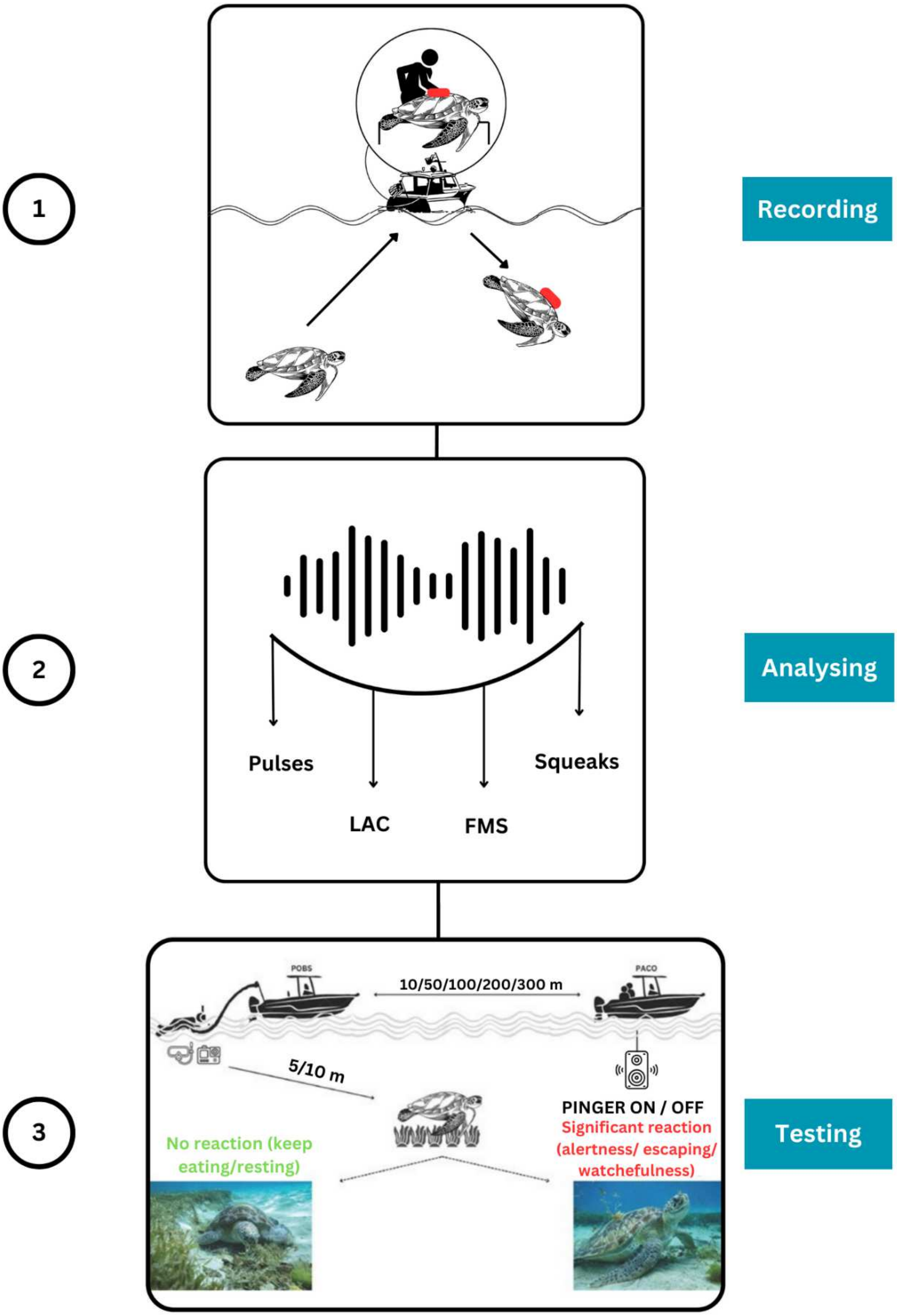


Figure 1 Schematic illustration of playback tests (POBS : observation platform; PACO : acoustic platform) and illustration of immediate response types (0 = no reaction ; 1 = significant reaction).

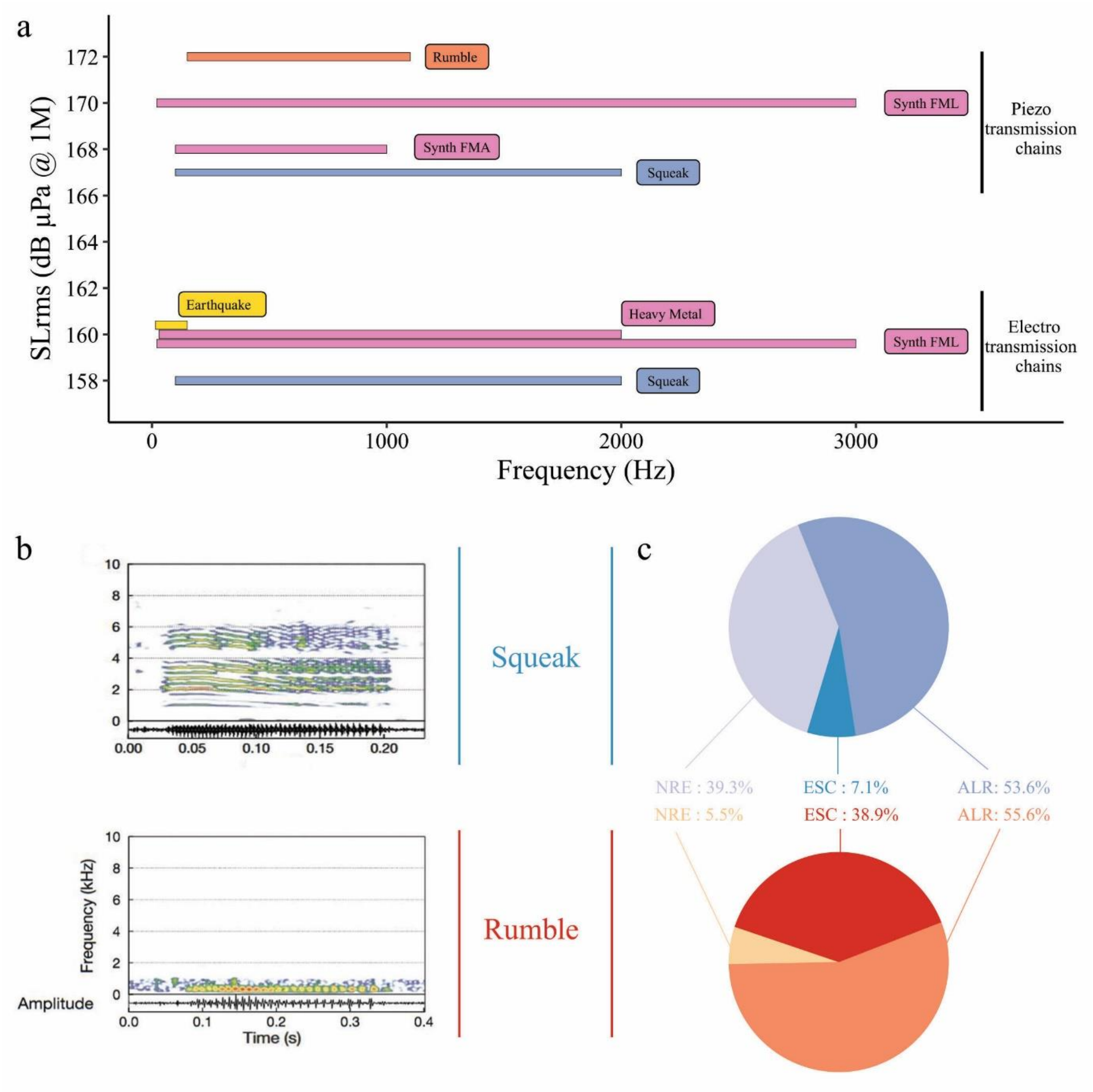


Figure 2 (**a**) Frequency (Hz) and sound level (mean dB µPa @1m rms) of the presented signals tested during the study (Synthetic sounds are represented by pink rectangles), (**b**) Spectrograms of Squeak (top) and Rumble (bottom) recorded from wild green turtles[21] and (**c**) percent of turtles for each type of reaction to these two signals (respectively: Squeak in blue shades and Rumble in orange shades).

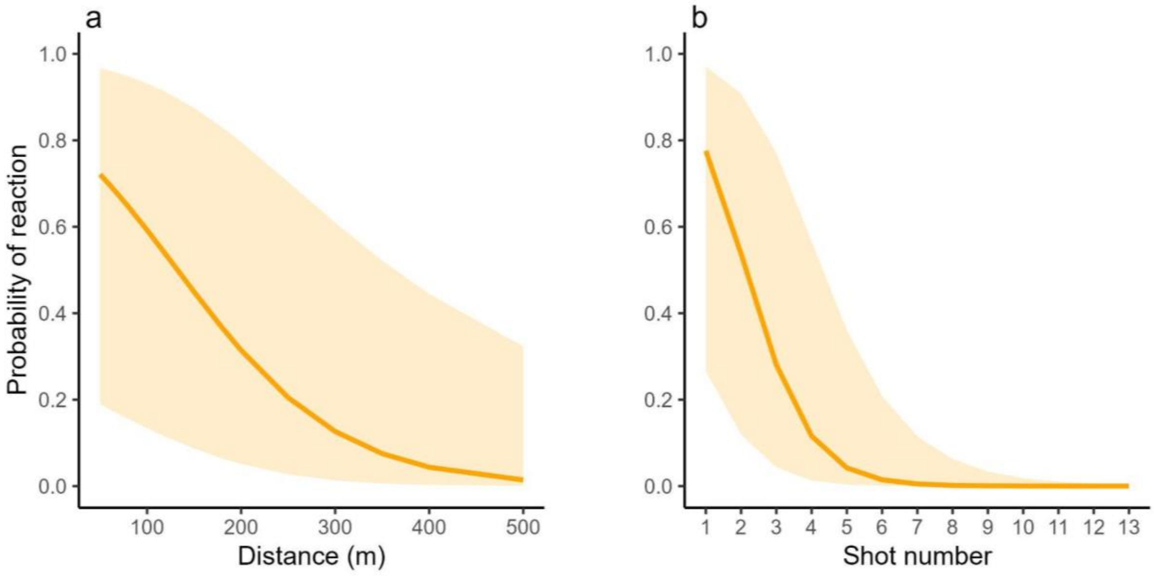


Figure 3 Probability of response to Rumbles with 95% CI obtained from generalized linear mixed model according to distance (m) (a) and shot number (b).

ONLINE METHODS

Methods and any associated references are available in the online version of the paper.

Study area and permits. This study was carried out March 2023 in Anses d’Arlet (14° 50’ N, 61° 9’ W), Martinique Island (French West Indies, France). We conducted our study in five bays of Les Anses d’Arlet (14◦30′ 9.64′′ N, 61◦5′11.85′′ W): Anse Noire, Anse Dufour, Grande Anse, Anse du Bourg and Anse Chaudière. The intentional disturbance of green sea turtles met French ethical and legal requirements. The CNRS protocol was indeed approved by the “Conseil National de la Protection de la Nature” and the “Ministère français de l’Ecologie, du Développement Durable et de l’Energie (permit number: 971-2022-11-24-00004). The fieldwork was carried out under the certification of Damien Chevallier (prefectural authorizations’ owner) under strict compliance of the Policy of Martinique’s recommendations in order to minimize animal disruption.

Green sea turtle sound production. We first characterized the sounds produced by green sea turtles during associated behaviors in individual sea turtles equipped with underwater video cameras and hydrophones attached to their carapace, as previously described[21,22]. The audio recordings were analyzed and the recorded sounds were categorized according to the behavior associated with these (Pulse, Low Amplitude Call (LAC), Frequency Modulation Sound (FMS), and Squeaks). Subsequently, the highest quality sound samples were selected in some sound categories (LAC and Squeak), and acoustic parameters were measured for each signal (Table 2). Then, these sounds were played using a speaker in the presence of green sea turtles foraging in their natural environment to examine behavioral responses to these signals.

Acoustic signals protocols.

Characteristics of the two transmission chains. Two autonomous very low frequency transmission chains with internal battery have been developed:

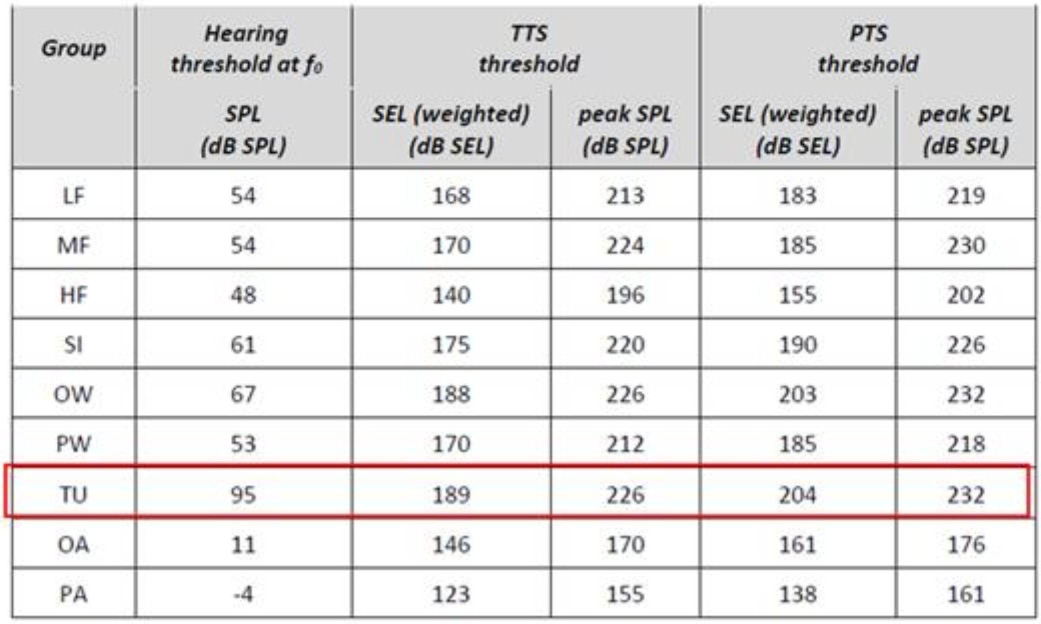
- A so-called electrodynamic chain consisting of a prototype electrodynamic loudspeaker resonating at 70 Hz and dedicated custom-made power supply and electronics. This chain can sweep the frequency band [20-500 Hz], with a maximum peak sound level (SL_{pk}) of 169 dB (ref. 1 µPa @ 1 m). A broadband prototype speaker [20-3000 Hz] can also be used. In this case, the very low frequency energy ([20-500 Hz]) is attenuated compared to that obtained with the nominal loudspeaker (emission level reduced by approximately 5 dB in the VLF band).
- A so-called piezoelectric chain made up of a piezoelectric transducer resonating at 180 Hz (Geospectrum Bender M21-325-200) and specific custom-made power supply and electronics. This chain can sweep the frequency band [100-1000 Hz], with a maximum peak sound level (SL_{pk}) of 173 dB (ref. 1 µPa @ 1 m). This piezoelectric source is less energetic in the band [20-150 Hz] than the electrodynamic source, but works up to 1 kHz, for an identical average emission level. The emission levels given in Table 2 come from measurements made from a hydrophone (OceanSonics IcListen HF) deployed from the PACO acoustic platform during the experiment.

Signals tested. Table 2 summarizes the different sound signals used for the first playback tests. Different frequency modulations (FM) were tested on the green sea turtles: linear FM (FML), random FM (FMA) and summation of linear FM (NFML). Different frequency bands were scanned depending on the transmission chain: [20-500 Hz], [20-3000 Hz] and [100, 1000 Hz], with acoustic energies distributed differently in the band depending on the transmitter used. For these FMs, the maximum peak sound level (SL_{pk}) was of the order of 173 dB (ref. 1 µPa at 1 m). This is a very moderate emission level.

In addition to these frequency modulations, the following were tested:

- A sound of the geophony, an earthquake (TT), covering the range 15-150 Hz, with an energy peak at 50 Hz. The emission level of this sound sequence was lower than that of the FM mode.
- Sounds produced by sea turtles (Squeak and Rumble) and broadcast on one of the transmission channels (the choice of channel and HP depends on the frequency content of these signals).

Physiological impact of the selected signals. Published literature on the physiological impact thresholds of sea turtles is notably scarce. However, the US Navy has proposed threshold values for sea turtles (Table 1[23]), in function of PTS (Permanent Threshold Shift) and TTS (Temporary Threshold Shift). In an animal, exposure to sufficiently intense sound can result in an elevation of hearing threshold. The duration of this threshold increase primarily hinges on factors such as exposure time, signal amplitude and its frequency. This change in hearing threshold can be either temporary (TTS) or permanent (PTS). To estimate the impact radius of an acoustic source, calculations are derived from these thresholds and the levels at the source (at the reference distance of 1 m). Two metrics, “peak level” and “cumulative sound exposure level”, have been used during this study. The cumulative sound exposure level (SEL_{CUM}) integrates all the sound sequences received by the animal, taking into account transmission losses based on the distance between the sound source and the exposed turtle.



Group	Hearing threshold at f_0	TTS threshold		PTS threshold	
	SPL (dB SPL)	SEL (weighted) (dB SEL)	peak SPL (dB SPL)	SEL (weighted) (dB SEL)	peak SPL (dB SPL)
LF	54	168	213	183	219
MF	54	170	224	185	230
HF	48	140	196	155	202
SI	61	175	220	190	226
OW	67	188	226	203	232
PW	53	170	212	185	218
TU	95	189	226	204	232
OA	11	146	170	161	176
PA	-4	123	155	138	161

Table 1 Sea turtle PTS and TTS thresholds (red box)[23].

Peak level impact received by the animal. The received peak level TTS threshold was therefore estimated to: 226 dB ref. 1µPa. Since sound levels (SL_{pk}) were very moderate (maximum 175 dB ref. 1 µPa @ 1 m by taking 2 dB safety factor for the sound risk analysis), the threshold was never reached. There was therefore no predicted deleterious impact on sea turtles, even temporary, regardless of the distance.

Impact in cumulative sound exposure level received by the animal. The TTS threshold in cumulative sound exposure level was therefore 189 dB ref. 1 $\mu Pa^2.s$. For one acoustic emission, the maximum sound exposure level (SEL_{1shot}) was 178 dB ref. 1 $\mu Pa^2.s$ at 1 m. For a turtle at 1 m from the acoustic source, the cumulative sound exposure level threshold was reached after 13 emissions. For a turtle at 5 m from the acoustic source, the cumulative noise exposure level threshold was reached after approximately 300 emissions. For a turtle at 10 m from the acoustic source, the cumulative sound exposure level threshold was reached after approximately 1300 emissions. In view of these data, we decided very cautiously not to use acoustic sources within five meters of sea turtles. The levels of peak and sound exposure implemented during these tests were low enough to guarantee that no physiological impact, even temporary, could be induced for the targeted species. Importantly, this study was interested in turtle reactions function of signal type (synthetic vs sound produced by turtles). Thus, the reaction of turtles induce by a level of signal emissions beyond threshold could bias the results, and should be avoided. In this study, we favor the particular structure of an alert signal over the amplitude of a repulsive signal.

Acoustic Deterrent Device Behavioral Tracking and Trials. The effectiveness tests of the signals used on the sea turtles were carried out using two light boats:

- A boat called "platform observation" (POBS) to tow an underwater observer responsible for spotting turtles underwater. Once a turtle had been spotted, the POBS informed the acoustic platform (PACO). The POBS underwater observer observed and recorded video (GoPro Hero 10) of any immediate changes in behavior (**Fig. 1**).
- A boat called "acoustic platform" (PACO) from which the sound sources were implemented. The loudspeaker was deployed as a pendulum at a depth of 1.5 (electrodynamic) to 5 meters

(piezoelectric) providing that the water depth was sufficient. The autonomous electronics box was on board. The choice of the signal and its amplitude level were controlled from an onboard PC and a Bluetooth connection with the box. Different signals could be tested on the same animal. The test of a signal on an animal is called a “trial”, which is constituted of several “shots” corresponding to signal emissions. Each “shot” last between 3 and 12 seconds, depending of the signal (Table. 2). The interval between two shots was 12 seconds.
The visual observation of the turtles' reactions was carried out at 2 levels:

- Measurement of the immediate effect on behavior at the time of the "shot", with estimated intensity (0= no reaction; 1=significant reaction) (**Fig. 1**)
- Analysis of the change in activity rhythm by comparison of the behavioral observation sequences before and after "shooting".

For each type of sound signal, the initial source-animal distance was approximately 100 meters and there was only one initial transmission. Depending on the behavior of the animal, several identical shots at the same distance might be emitted. PACO boat would then come closer to the animal, however remaining at a distance greater than 5 m.

This method was then used a second time using a single signal, with a wider range of distance from 40 to 500m and up to 13 repetitions, in order to obtain dataset for distance and habituation effects testing. Taking into account the specific propagation conditions in very shallow waters, it is estimated that the SPL_{rms} (i.e. the sound level received by the turtles) from which behavioral reactions are observed on green turtles with "Rumble" type signals are of the order of 135 dB ref.1 µPa.

Statistical analyses. In order to test the behavioral reaction to the different acoustic signals, only the three first shots are kept in the analysis, since we want to test for immediate turtle’s reaction. First, the number of turtles that actively responded to the different signal types was counted. A response in this sense could be alertness or escaping (as opposed to no response observed), and only one reaction is taken into account per trial, even if the turtle reacted to several shots in the same trial. Secondly, for the signals to which turtles responded the most, the number of turtles is counted for each type of possible response as well as for non-response. Inside a trial, only the strongest response behavior to a signal was retained (ordered by increasing strength: 0: “no reaction”, 1: “alertness”, 2: “escaping”). Variations of the proportion of turtles that responded among the different signal categories, as well as significance of difference between proportions of turtles among three possible response behaviors (no reaction, alertness, escaping) are tested using nonparametric tests (Fisher’s Exact test). The second dataset, created only with the signal eliciting the strongest behavioral response, is used to model the distance and the habituation effect on turtle reaction. The turtle behavioral response variable is binomial (1: alertness or escaping, 0: no reaction). A Generalized Linear Mixed Model was set up accounting for distance of the shot to the turtle and shot number as fixed effects. Trials ID, which is the ID of the series of shots on the same individual, was included as a random effect. Model was fitted using package ‘lme4’[24] and goodness-of-fit was assessed using package ‘DHARMa’[25] in R v4.2.2[26].

Transmission chains	Track	Signals tested	Frequency band (Hz)	Duration (s)	SPL$_{rms}$ (dB µPa @ 1m)	Test date (March 2023)	Number of trials
ELECTRO LB	TRACK 7	SQUEAK	100-2000	4	158	14	3
	TRACK 10	SQUEAK	100-2000	12	158	14	5
	TRACK 9	SQUEAK	150-1100	3	158	14	3
	TRACK 4	SYNTH FML	20-3000	5	160	14	1
	TRACK 11	SQUEAK	100-2000	5	158	15-16	11
	TRACK 13	HEAVY METAL	30-2000	5	160	15	3
ELECTRO V5	TRACK 1	NAT TT	15-150	11	160	16	4
PIEZO	TRACK 3	SYNTH FMA	100-1000	5	168	16-17-21	4
	TRACK 1	SYNTH FML	100-1000	5	170	17-20	4
	TRACK 2	SYNTH FML	100-1000	7	170	16-17-20	12
	TRACK 4	SYNTH FML	100-1000	5	170	17	1
	TRACK 5	RUMBLE	150-1100	3	172	17-20-21-22	38
	TRACK 6	SQUEAK	100-1300	4	169	20-21	6
						Total	**95**

Table 2 Acoustic characteristics of some signals (not exhaustive) tested on green sea turtles in the wild.

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