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1 **Changes to an urban marina soundscape associated with COVID-19 lockdown in Guadeloupe.**

2

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16

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18 **Abstract**

19 In 2020, the COVID-19 pandemic led to government-enforced limits on activities worldwide, causing  
20 a marked reduction of human presence in outdoors environments, including in coastal areas that  
21 normally support substantial levels of boat traffic. These restrictions provided a unique opportunity to  
22 quantify the degree to which anthropogenic noise contributes to and impacts underwater soundscapes.  
23 In Guadeloupe, French West Indies, a significantly lower number of motor boats were recorded at the  
24 major urban marina during the peak of the first COVID-19 lockdown (April-May 2020), compared  
25 with the number recorded post-lockdown. The resumption of human activities at the end of May, was  
26 correlated with a maximum increase of 6 decibels in the ambient noise levels underwater. The change  
27 in noise level did not impact daily sound production patterns of vocal fishes, with increased activity at  
28 dusk seen both during and after the lockdown period. However, during the lockdown, vocal activity  
29 was comprised of a reduced number of sounds, suggesting that levels of anthropogenic noise  
30 experienced by fishes have the potential to interfere with vocalization behaviours.

31

32

33 **Keywords:** Anthropophony; COVID-19; Ecoacoustics; Noise pollution; Soundscapes

## 34 INTRODUCTION

35 In 2020, the COVID-19 pandemic led to widespread government directives that forced people to  
36 isolate or restrict their movement to slow and contain the virus (Newland 2020). By April 2020, half  
37 of the world's population underwent some form of lockdown, with more than 3.9 billion people in  
38 more than 90 countries ordered to stay at home by their governments (Sandford, 2020). These actions  
39 corresponded with a marked reduction of human presence in public spaces, urban areas, and centers of  
40 tourism. With decreased movement, air pollution levels reduced (European Space Agency 2020), and  
41 daily CO<sub>2</sub> emissions declined globally by an average of 17% by April 2020 compared with the mean  
42 2019 levels (Le Quéré et al. 2020). In addition, changes to other sources of anthropogenic pollution,  
43 such as the noise generated as a result of human activities (i.e. anthropophony) (Slabbekoorn et al.  
44 2010; Kight and Swaddle 2011; Francis and Barber 2013) have also been observed (e.g. Asensio et al.  
45 2020; Basu et al. 2021; Čurović et al. 2021; Leon-Lopez et al. 2021; Mostafa et al. 2021). The  
46 reduction of anthropogenic noise should make the natural soundscape, and particularly sounds  
47 produced by animals, i.e. the biophony (Pijanowski et al. 2011a, b; Heenehan et al. 2017) more  
48 noticeable.

49 Underwater soundscapes can be defined as the spatial, temporal, and frequency attributes of  
50 ambient sound, and the sources of noise contributing to the sound field (ISO, 2017). The nature of  
51 underwater soundscapes are rapidly changing worldwide due to declines of sound-producing animals  
52 (biophony), changes to geophysical processes such as storms (geophony), and increases in human-  
53 associated noise (anthropophony) (Duarte et al. 2021). Sounds produced by human activities, termed  
54 'noise pollution' is present in many marine environments and can affect a wide range of taxa, from  
55 small invertebrates such as shrimps and bivalves, to fish and mammals (Duarte et al. 2021, Ferrier-  
56 Pagès et al. 2021). For this reason, underwater noise pollution is now the focus of greater research  
57 interest as activities and uses of the marine environment change and intensify (Slabbekoorn et al.  
58 2010, Williams et al. 2015). At a large scale, commercial operations such as offshore oil and gas  
59 installations and international shipping are known to produce substantial levels of noise pollution (e.g.  
60 Erbe et al. 2013; Southall et al. 2017). However, even less intensive activities in coastal areas, such as  
61 tourism and recreational boating have had an identifiable effect on underwater soundscapes, including

62 those associated with tropical coastal reefs (e.g. McDonald et al. 2006; Jensen et al. 2008; Dinh et al.  
63 2018; McCormick et al. 2018, 2019; Hermannsen et al. 2019). In the recent past, dramatic reductions  
64 in human activities have seen significant flow on effects on levels of noise pollution. For instance,  
65 after the events of September 11, 2001, levels of international shipping traffic rapidly declined. In the  
66 Bay of Fundy, Canada, this was correlated with a decrease in underwater noise by 6 dB, with a  
67 significant reduction below 150 Hz (Rolland et al. 2012). This noise reduction positively impacted  
68 Northern right whales (*Eubalaena glacialis*), which showed decreased levels of stress-related faecal  
69 hormone metabolites (Rolland et al. 2012).

70 Changes in human activities may therefore have rapid and measurable effects in underwater  
71 environments more broadly, potentially impacting a wide range of associated marine life. The coastal  
72 environment of many Caribbean Islands underwent such changes during early 2020 due to  
73 government-enforced restrictions on activity related to the COVID-19 pandemic. Due to the decrease  
74 in commercial and recreational marine activities underwater noise pollution is likely to have fallen  
75 significantly in these locations (Zambrano-Monserrate et al. 2020). Many studies have suggested  
76 positive and indirect effects of reductions in human activities on the environment (Chakraborty and  
77 Maity 2020; Pearson et al. 2020; Rosenbloom and Markard 2020; Zambrano-Monserrate et al., 2020),  
78 and provided experimental data (e.g. Cohen 2020; Molintas 2020; Kumar et al. 2021; Naqvi et al.  
79 2021). However, none have been done on coral reefs or associated environments. To this end, the  
80 present study aimed to examine the underwater soundscape, i.e. the ambient sound, of a human-  
81 impacted coral reef-associated area, close to the city of Pointe-à-Pitre in Guadeloupe, French West  
82 Indies during and after the island's COVID-19 lockdown.

83

## 84 **MATERIAL AND METHODS**

### 85 **COVID-19 lockdown and study site**

86 In France and its overseas departments, a government-imposed lockdown took place from March 16 to  
87 May 21, 2020 in an effort to control the COVID-19 virus. In Guadeloupe, all cruise ships left on  
88 March 15 and all flights were cancelled on March 23 which drastically reduced economic activity on

89 the island. Meanwhile, on March 19, all access to public beaches and leisure boating were forbidden.  
90 A curfew was set on April 01 from 20:00 to 05:00.

91 Passive acoustic recordings were performed in the navigation channel of the Marina of Bas-du-Fort  
92 (16°22'N; 61°53'W) (Fig. 1). While the Marina is used by leisure boats, it is located less than 400m  
93 from the channel of the harbor of Pointe-à-Pitre where large commercial vessels and cruise ships  
94 navigate. The benthic substrate at the site was primarily muddy sand with rare patches of seagrass.  
95 High levels of water turbidity prevented visual surveys and description of the local fish community at  
96 the time of the recordings. Wind was moderate (4-5 Bf)  
97 ([https://www.meteoblue.com/fr/meteo/historyclimate/weatherarchive/guadeloupe\\_guadeloupe\\_35791](https://www.meteoblue.com/fr/meteo/historyclimate/weatherarchive/guadeloupe_guadeloupe_35791)  
98 44) and sea state was calm during all recording sessions since the channel is located between the  
99 mainland shore and a large embankment preventing waves and swell coming from the ocean. Tidal  
100 ranges (<https://maree.shom.fr/harbor/POINTE-A-PITRE/hlt/0?date=2021-07-15&utc=-4>) were 0.25-  
101 0.42 m from April 7-9, 0.14-0.28 m from April 20-22 and 0.06-0.40 m from May 21-23. We therefore  
102 considered environmental conditions to be relatively stable throughout the recording sessions and any  
103 differences detected will not be due to environmental conditions.

104

### 105 **Data acquisition**

106 Recordings were made by using an autonomous SNAP acoustic recorder (Loggerhead Instruments,  
107 Sarasota, FL, USA) connected to a HTI-96-min hydrophone (sensitivity: -170 dB re 1 V  $\mu$ Pa-1; flat  
108 frequency response range: 2 Hz - 30 kHz; High Tech Inc, Long Beach, MS, USA). The device was  
109 positioned on a weighted metallic frame placed on the bottom at a depth of 3-5 m by snorkeling and  
110 with the help of local fishermen. The device was deployed in the morning between 07:00 and 08:00,  
111 and was programmed to record for 1 minute every 10 minutes (sampling frequency of 44 kHz, 16-bit  
112 resolution). Recording sessions lasted for 48h and took place from April 7-9, 2020 and from April 20-  
113 22, 2020, with both sessions during the lockdown. A third recording session took place from May 21-  
114 23, 2020 after the lockdown had ended. Recordings were split into 8 periods of 3 hours in order to  
115 separate particular daily periods, i.e. dawn (05:00 – 08:00), day-time (08:00 – 11:00, 11:00 – 14:00

116 and 14:00 – 17:00), dusk (17:00 – 20:00) and night-time (20:00 – 23:00, 23:00 – 02:00 and 02:00 –  
117 05:00).

118 Spectrograms and power spectra (Fast Fourier Transform FFT, Hamming window, 1024 points, no  
119 overlap) were produced using the PAMGuide (Merchant et al. 2015) in RStudio version 1.2.5042  
120 (2020) which allowed the calculation of the relative Power Spectral Density graphics (PSD, dB re:  
121  $1\mu\text{Pa}^2\cdot\text{Hz}^{-1}$ ). Spectrograms and power spectra were plotted with a frequency range between 40 and  
122 2500 Hz (low frequency range), and a frequency range between 2500 and 22000 Hz (high frequency  
123 range). The low frequency band corresponds to the range in which most teleost fishes vocalize and can  
124 hear (Lobel et al. 2010; Tavalga et al. 2012). This band also includes sounds generated by the wind  
125 and waves. The high frequency band encompassed the range that is typically dominated by the noise  
126 produced by snapping shrimps (Hildebrand 2009). Boat sounds covers a large frequency band (e.g.  
127 Kaplan and Mooney 2015; Erbe et al. 2019) and may interfere with both bands examined. The Root  
128 Mean Square (RMS) levels of the PSD values of each frequency bin were calculated for all 3h-periods  
129 to present average power spectra of both frequency ranges for the lockdown and post-lockdown  
130 sessions. Recordings performed during the lockdown were merged to produce single averaged spectra.

131 Not all boats and crafts frequenting the present marina and coastal areas in general are equipped  
132 with Automatic Identification System (AIS) (Hermannsen et al. 2019). In addition, during the  
133 lockdown, people (including investigators of the present study) could only make short trips, within the  
134 limit of one hour per day and within a maximum radius of one kilometer around their home. Visual  
135 counting of boats was therefore impossible. Alternatively, the spectrograms (Fast Fourier Transform  
136 FFT, 128 points, Hamming window, 75% overlap) of each 1 minute recording were visually and  
137 aurally inspected and cross-checked by two investigators using the Avisoft-SASLab Pro software  
138 (version 5.2.10). The number of recordings during which at least one sound produced by boats was  
139 recorded were counted. Boat noises are long lasting sounds that cover both low and high frequency  
140 ranges with a broadband energy dominating at frequencies above several hundred Hertz (Barlett and  
141 Wilson 2002).

142 Visual and aural inspections of the spectrograms were also performed to detect biotic sounds. The  
143 most distinct biotic sounds observed were series of impulsive or grunt-like sounds in the low

144 frequency range (40-2500 Hz) produced by fishes, with these detected over a 24h period for the three  
145 sessions. These sounds were tagged using the insert label function of Avisoft-SASLab Pro software.

146

### 147 **Data analysis**

148 The Normality of the Root Mean Square (RMS) levels of the PSD values in 40-2500 Hz frequency  
149 range during and after the lockdown were checked by Shapiro-Wilk tests ( $W = 0.95 - 0.99$ , all  $P < 10^{-3}$ ).  
150 Non-parametric Kruskal-Wallis tests were performed to compare PSD levels (RMS, dB re:  $1\mu\text{Pa}^2$ .  
151  $\text{Hz}^{-1}$ ) between the 3h-periods for each recording session. Dunn's multiple pairwise comparisons post-  
152 hoc tests with Holm's adjustment method were subsequently used to identify significant differences.

153 The differences in the presence of boat between sessions were tested by comparing the proportion  
154 (%) of recording files of each 3h-period in which at least one boat sound was detected by means of  
155 Binomial exact tests with proportions observed during lockdown conditions as theory proportion. Boat  
156 noise here refers to all motor sounds that could be detected, from small crafts to large vessels.

157 Acoustic analysis was conducted with Avisoft-SASLab Pro software on  $N = 8-12$  sounds from the  
158 two most prominent sound types that showed a good signal-to-noise ratio allowing sounds to be  
159 analysed. The following acoustic characteristics were measured from oscillograms: the total duration  
160 of sounds (ms), the number of pulses within a sound, the period of pulses (peak-to-peak interval, ms)  
161 and the pulse duration (ms). The dominant frequency (Hz) was measured from logarithmic power  
162 spectra. The number of biotic sounds did not follow a Normal distribution (Shapiro-Wilk tests,  $W =$   
163  $0.52 - 0.58$ , all  $P < 10^{-3}$ ). Non-parametric Kruskal-Wallis tests were then performed to compare the  
164 number of sounds detected between the recording sessions and between the 3h-periods. Dunn's  
165 multiple pairwise comparisons post-hoc tests were subsequently used to identify significant  
166 differences.

167 All statistical analysis were performed with RStudio (R version 4.0.3) at the significance level  $\alpha =$   
168 0.05. In addition to probabilities (P-values), effect sizes of statistical measures made to compare PSD  
169 levels and number of biotic sounds were estimated as the difference between medians of data obtained  
170 during and after the lockdown using the R package "dabestr" (Ho et al. 2019) before inferences and  
171 conclusions were drawn.



172

## 173 **RESULTS**

### 174 **Soundscape's characteristics**

175 During the lockdown, power spectrum density levels (RMS, dB re:  $1\mu\text{Pa}^2\cdot\text{Hz}^{-1}$ ) did not show  
176 significant diel variations in the frequency range below 1000 Hz (Kruskal-Wallis test,  $\chi^2_7 = 2.84$ ,  $P =$   
177  $0.89$ ) (Fig. 2A). Even if a *ca.* 5 dB (re:  $1\mu\text{Pa}^2\cdot\text{Hz}^{-1}$ ) decrease could be observed between recordings  
178 performed at night ( $74.1 \pm 1.2$  dB from 20:00 to 08:00, mean  $\pm$  S.D) and during day-time ( $79.0 \pm 1.4$   
179 dB from 08:00 to 20:00) (Fig. 3). In other words, there were no diel differences in PSD levels during  
180 the lockdown period. In contrast, following the lockdown the acoustic analysis of the 40-2500 Hz  
181 frequency range showed a marked diel pattern in the spectra (Fig 3), with higher levels being recorded  
182 during the day, likely owing to the resumption of human activities. Most variability occurred below  
183 1000 Hz (Kruskal-Wallis tests,  $\chi^2_7 = 68.60$ ,  $P < 10^{-3}$ ). The significantly highest Power Spectral Density  
184 (PSD) levels below 1000 Hz were obtained during the 17:00-20:00 period with an average value of  
185  $85.2 \pm 3.6$  dB (Table 1). Periods showing the lowest PSD levels were recorded during night-time  
186 (from 20:00 to 05:00). Both the 23:00-02:00 and 02:00-05:00 periods showed the lowest PSD levels in  
187 the frequency range below 1000 Hz with  $77.5 \pm 3.7$  dB and  $78.2 \pm 3.4$  dB respectively (Dunn tests,  $Z$   
188  $= 3.12 - 6.04$ , all  $P < 0.05$ ) (Table 1).

189 Comparison of PSD levels indicated that night-time periods (20:00 – 05:00) possessed the same  
190 levels during and post-lockdown, with differences of 0.7 – 1.4 dB (Fig 2B, Table 1). However,  
191 recordings made during day-time (05:00 – 20:00) were of higher levels after the lockdown (Fig 2B,  
192 Table 1). Recordings showed a maximum difference (effect size) of 6.0 dB in frequencies below 1000  
193 Hz between 17:00 and 20:00 (95% CI = 3.93 – 7.97) (Fig 2B, Table 1). PSD levels differences during  
194 the remaining 3h-periods varied from 2.7 dB (05:00 – 08:00) to 5.2 dB (08:00 – 11:00) (Fig 2B, Table  
195 1).

196 Lastly, spectra in the higher frequency range (from 2500 to 22000 Hz) showed no differences with  
197 no diel variations between recordings performed during or post-lockdown (Supplementary Material 1).

198

### 199 **Temporal variation of boat presence**

200 A low occurrence of boat sounds was detected during the lockdown in the marina of Bas-du-Fort  
201 (Supplementary Material 2). In the recording sessions performed during the lockdown, the most  
202 regular occurrence of boat sounds appeared from 09:30 to 12:00 (Fig. 4A) and from 12:00 to 15:30  
203 (Fig. 4B). Boat sounds were absent between 19:00 and 20:00, likely due to the imminent curfew  
204 (20:00 – 05:00). Boat sounds were rarely detected during the night, until either 05:00 (Fig. 4A) or  
205 06:00 (Fig. 4B). The highest proportion of recordings in which at least one boat could be detected was  
206 from between 08:00 to 11:00, with 51% of recordings containing boat sounds (Table 2). After the  
207 lockdown (May 21 to May 23) recordings were characterized by increased and sustained boat traffic in  
208 the marina of Bas-du-Fort. The proportion of recordings with a least one boat sound were significantly  
209 higher (Binomial tests, all P values < 0.05) for all time periods except between 02:00 and 05:00,  
210 reaching a maximum of 100% and 89% of recordings containing boat sounds during 08:00 – 11:00  
211 and 11:00 – 14:00 respectively (Table 2). Boat sound presence was almost continuous, occurring  
212 during a longer period than during the lockdown, from 05:00 to 19:00 (Fig. 4C). Even though boat  
213 sound presence decreased at night (Fig. 4C), the proportion of recordings with at least one boat sound  
214 varied from 11% to 20% compared to only 3% to 7% during the lockdown (Table 2).

215

### 216 **Temporal variation of fish sounds**

217 Sounds from biological sources were recorded both during and post-lockdown, identified as originating  
218 from fishes. These primarily consisted of short, low frequency sounds that were produced either as  
219 isolated units or in series. The first type of sound that was often detected was defined as ‘growls’ (Fig.  
220 5A). These sounds lasted  $280 \pm 173$  ms (mean  $\pm$  SD, N = 8 sounds analysed) and had a dominant  
221 frequency of  $158 \pm 64$  Hz (Supplementary Material 3). The second defined type of sound consisted of  
222 a series of ‘knocks’ produced in chorus (Fig. 5B). These series (N = 12 series analysed) had a duration  
223 of  $533 \pm 193$  ms and were made of  $6 \pm 2$  pulses. Pulses lasted  $24 \pm 5$  ms with a period of  $107 \pm 5$  ms  
224 and a dominant frequency of  $471 \pm 47$  Hz (Supplementary Material 4). These series of knock sounds  
225 drastically increased in number at night, from 20:00 to 23:00 while they were rarely detected during  
226 the day. Other less common sound types consisted of fast series of low frequency pulses and higher  
227 pitched stridulations.

228 In total, 434 and 588 biological sounds were detected over 24h respectively during and after the  
229 lockdown. The diel pattern of biological sound detection appeared similar with a maximum of 9  
230 sounds.min<sup>-1</sup> from 02:00 to 17:00 both during and after the lockdown, followed by an increase  
231 following the onset of night, primarily driven by knocking sounds, to a maximum of 35 sounds.min<sup>-1</sup>  
232 and 34 sounds.min<sup>-1</sup> from 20:00 to 02:00, before and after the lockdown respectively (Kruskal-Wallis  
233 test,  $\chi^2_7 = 22.33-97.76$ , all  $P < 0.05$  ; Dunn tests,  $Z = 3.06-7.19$ , all  $P < 0.05$ ) (Fig. 6A). The total  
234 number of sounds detected during night-time hours was significantly higher after the lockdown than  
235 during it (Kruskal-Wallis test,  $\chi^2_2 = 14.20-21.69$ ,  $P < 10^{-3}$  ; Dunn tests,  $Z = 2.37-4.20$ , all  $P < 0.05$ )  
236 (Fig. 6A), with a maximum difference of 12 sounds.min<sup>-1</sup> (95% CI = 1 – 21) from 20:00 to 23:00 and  
237 4 sounds.min<sup>-1</sup> (95% CI = 1 – 5.5) from 23:00 to 02:00 (Fig 6B). No significant difference between the  
238 recordings made during and after the lockdown was observed from 02:00 to 20:00 with differences  
239 ranging from -1.5 to 1.5 sounds.min<sup>-1</sup> (Fig 6B).

240

## 241 **DISCUSSION**

242 The COVID-19 crisis was an unprecedented social and economic catastrophe, resulting in millions  
243 of deaths worldwide. The resulting government-imposed lockdowns provided an unprecedented  
244 opportunity to investigate the impact of noise pollution worldwide and to quantify how the world may  
245 sound with minimal human activity. The present study showed that the reduction in human activities  
246 during the first COVID-19 lockdown of 2020 resulted in a reduction in ambient noise during the day-  
247 time at the studied marina. Changes in the level of noise and boat traffic did not change the acoustic  
248 diel activity of fishes. However, more sounds were detected after the lockdown, following the  
249 resumption of boat activities.

250 Reductions in human activities can rapidly lead to behavioral changes in associated wildlife. For  
251 instance, during the 2020 lockdown, many wild species, including Sika deer in Japan, monkeys in  
252 Thailand, and harbor dolphins in Italy, were observed exploring urban spaces where they were usually  
253 rare (Arora et al. 2020). However, our results suggest that reductions in noise pollution during the day  
254 due to less boat traffic did not result in variation in the diel patterns of fish vocal activity at our study  
255 site (Nedelec et al. 2016; Currie et al. 2020; Staaterman et al. 2020). Diel patterns of vocalization may

256 be minimally affected by changes to day-time boat noise as the species present at the study site  
257 primarily vocalize during the night when human activity and boat traffic was consistently low.

258 Many teleost fishes produce and hear social sounds between 20 Hz and 3 kHz (Lindseth and Lobel  
259 2018; Ladich 2019; Popper and Hawkins 2019) which falls into the frequency range that is mostly  
260 occupied by boat noise. Particularly large vessels may generate noise levels up to 188 dB re: 1 $\mu$ Pa at  
261 1m (McKenna et al. 2013) which may then radiate over wide distances in the ocean. Smaller boats  
262 also increase local sound intensities in shallow waters over a wider frequency range, from 5 to 1000  
263 Hz (Holles et al. 2013; Nedelec et al. 2016; McCormick et al. 2019), potentially interfering with the  
264 acoustic communication range of both fishes and other marine species (Slabbekoorn et al. 2010). High  
265 levels of boat noise have therefore been proposed to have a masking effect, giving the impression that  
266 fishes produce less sound overall (Luczkovich et al. 2016) or reduce their sound production in loud  
267 environments. However, in the present study a lower absolute number of signals was detected during  
268 the two recording sessions performed during the lockdown, suggesting that environments with less  
269 noise pollution may reduce the need to produce as much sound to communicate information (Picciulin  
270 et al. 2012). Without elevated anthropogenic noise, sounds could potentially more easily reach  
271 potential receivers, increasing communication efficiency.

272 However, the opportunistic nature of the study, the relatively short duration of the lockdown at  
273 Guadeloupe, lack of data from previous years, and the potential seasonality in acoustic behaviour did  
274 not enable us to fully qualify the effect of noise pollution on sound production by fishes at the study  
275 site. In addition, while human activities resumed at the end of the lockdown period, these were still  
276 reduced compared to prior to the COVID 19 pandemic. Local economic activity remained lower than  
277 in previous years, due to the continued lack of international tourists and subsequent restrictions on  
278 movement. Future investigations should include temporal replicates and associated playback  
279 experiments in order to confidently link the reduction of boat presence and associated noise to changes  
280 in fish sound production.

281 The fishes responsible for the production of the main sound types used in temporal comparisons  
282 remain to be fully identified. The series of pulses produced in chorus, that is, by large number of  
283 individuals concurrently at night, were the primary contribution to the observed biophony. Their

284 percussive nature, together with their dominant frequency, would suggest that these sounds were  
285 produced by drumfish (Scianidae) (Lagardère and Mariani 2006, Parmentier et al. 2014; Parmentier et  
286 al. 2017). The two species found in Guadeloupe, the spotted drum *Equetus punctatus* (Bloch &  
287 Schneider 1801) and the Jack-knifefish *Equetus lanceolatus* (L. 1758) are therefore good candidates  
288 although their vocalizations have yet to be formally described. While the chorusing nature of this  
289 vocal activity suggests the presence of several individuals in the study area, we were unable to  
290 estimate the number of the sound producers.

291         The present results clearly illustrate how quickly anthropogenic noise pollution can be reduced  
292 in marine environments when activity is restricted. The present study is a good case study that could  
293 persuade local stakeholders to evaluate the impacts of noise associated to human activities on coastal  
294 environment as this is critical for an effective and sustainable management of such anthropised areas,  
295 with findings such as these highlighting the importance of considering noise mitigation in urban  
296 planning and development.

297

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308

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426 [europe-spain-s-death-toll-hits-10-000-after-record-950-new-deaths-in-24-hou.](https://www.euronews.com/2020/04/02/coronavirus-in-europe-spain-s-death-toll-hits-10-000-after-record-950-new-deaths-in-24-hou)

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449 **Figure captions**

450

451 **Figure 1 – A.** Location of the Guadeloupe archipelago in the Lesser Antilles. **B.** Map of the  
452 Guadeloupe archipelago with location of the study site. **C.** Position of the recorder (red spot) in the  
453 navigation channel of the Marina of Bas-du-Fort (16°22'N; 61°53'W), close to the city of Pointe-à-  
454 Pitre

455

456 **Figure 2 – A.** Power spectrum density levels (RMS, dB re:  $1\mu\text{Pa}^2\cdot\text{Hz}^{-1}$ ) recorded below 1000 Hz for  
457 each 3h-period during (red) and after lockdown (blue). Boxes are the first and third quartiles, thick  
458 horizontal bars are the median and whiskers correspond to 95 % confidence interval of the  
459 distributions. Dots represent outliers. **B.** Effect sizes calculated as the median differences (black dots)  
460 between levels recorded after and during lockdown. Whiskers correspond to 95 % confidence interval  
461 of the median difference. Top horizontal bar represents day-time (white) and night-time (black)

462

463 **Figure 3 –** Average power spectra in the 40-2500 Hz frequency band for each 3h-period during (red  
464 dashed lines) and after lockdown (blue lines)

465

466 **Figure 4 –**Diel pattern of boat sound detection in recordings made during the 2 lockdown sessions  
467 (**A.**, **B.**) and after the lockdown (**C.**). Grey bars represent the detection of a boat sound with a 10  
468 minute resolution. Top horizontal bars represent day-times (white) and night-times (black)

469

470 **Figure 5 –** Spectrograms (top) and oscillograms (bottom) of **A.** a single low frequency growl and **B.** a  
471 series of pulsed sounds detected in the study area (made with R-studio using the Seewave package,  
472 Sueur et al. 2008)

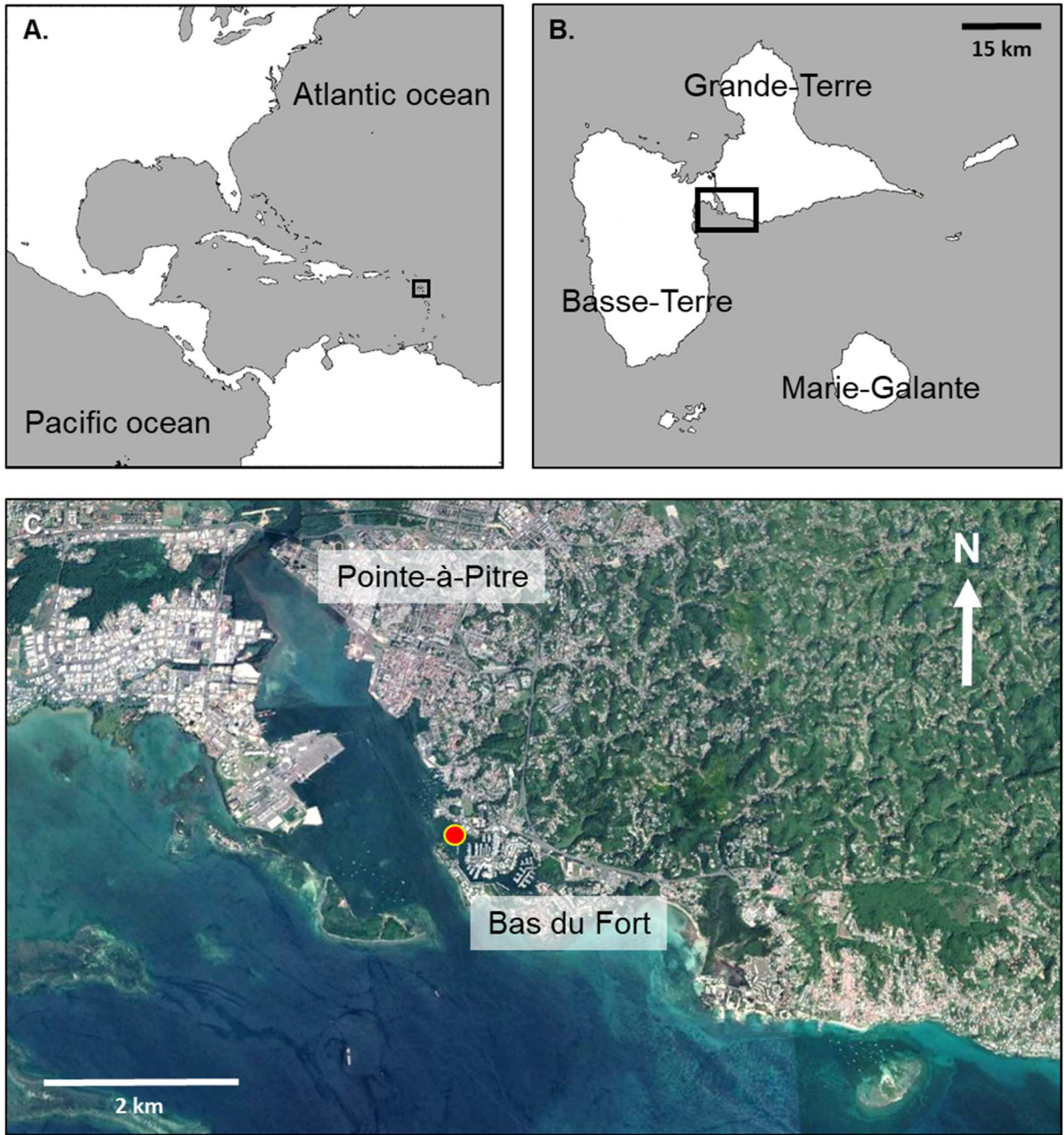
473

474 **Figure 6 – A.** Total number of fish sounds per minute detected for each 3h-period during (red) and  
475 after lockdown (blue). Boxes are the first and third quartiles, thick horizontal bars are the median and  
476 whiskers correspond to 95 % confidence interval of the distributions. Dots represent outliers. **B.** Effect

477 sizes calculated as the median differences (black dots) between fish sounds detected after and during  
478 lockdown. Whiskers correspond to 95 % confidence interval of the median difference. Top horizontal  
479 bar represents day-time (white) and night-time (black)

480 **Figure 1**

481

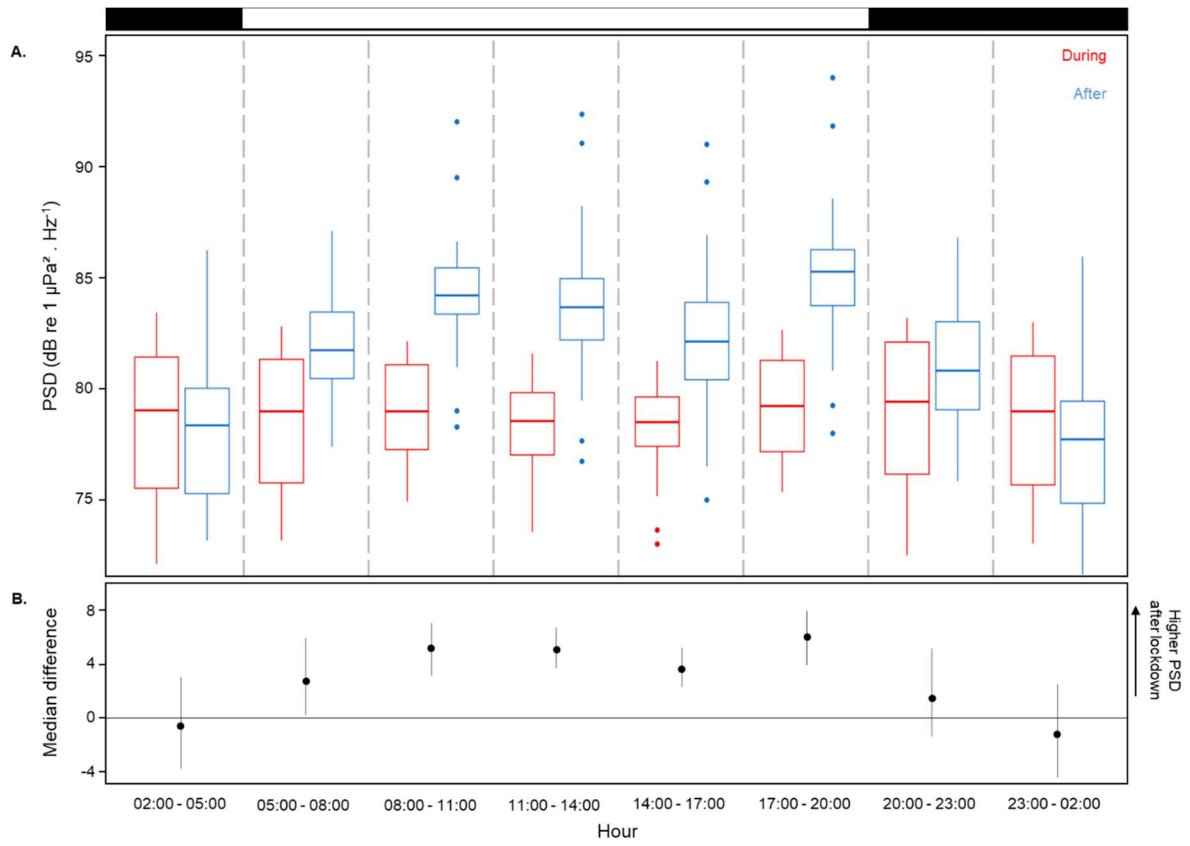


482

483

484 **Figure 2**

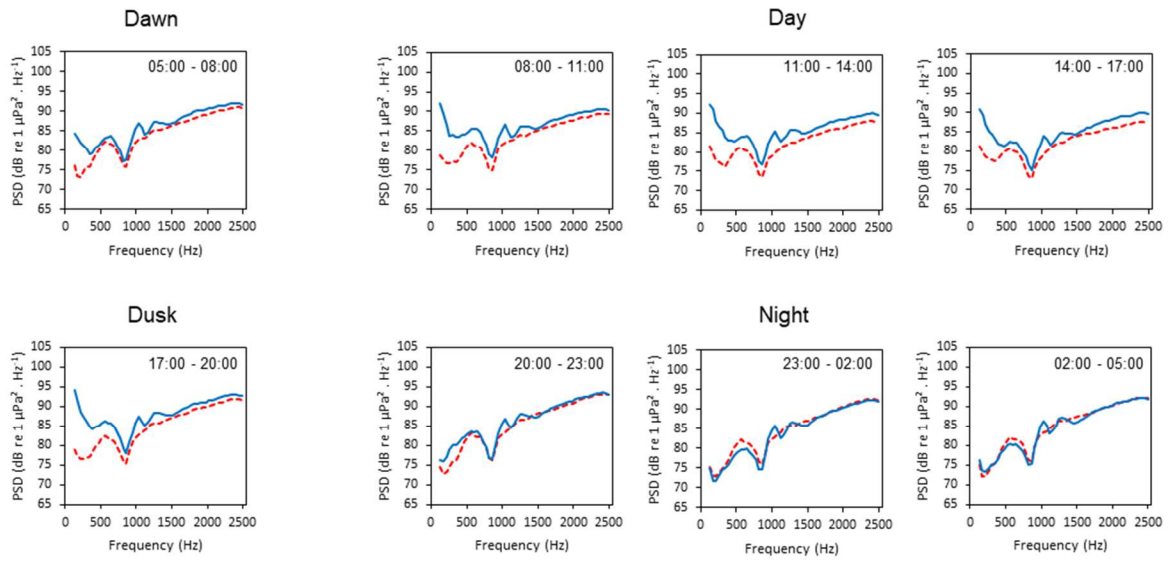
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487 **Figure 3**

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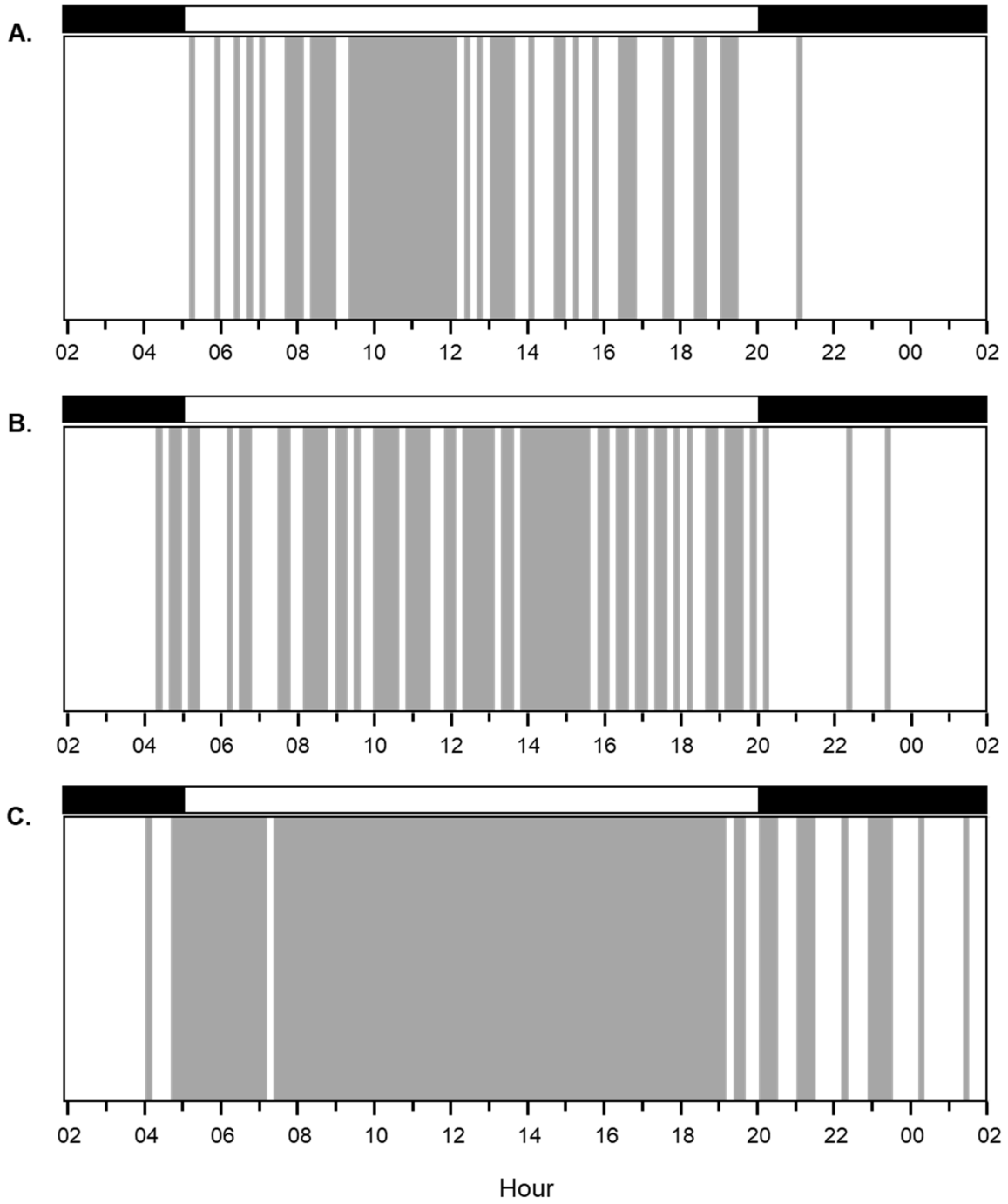


489



490 **Figure 4**

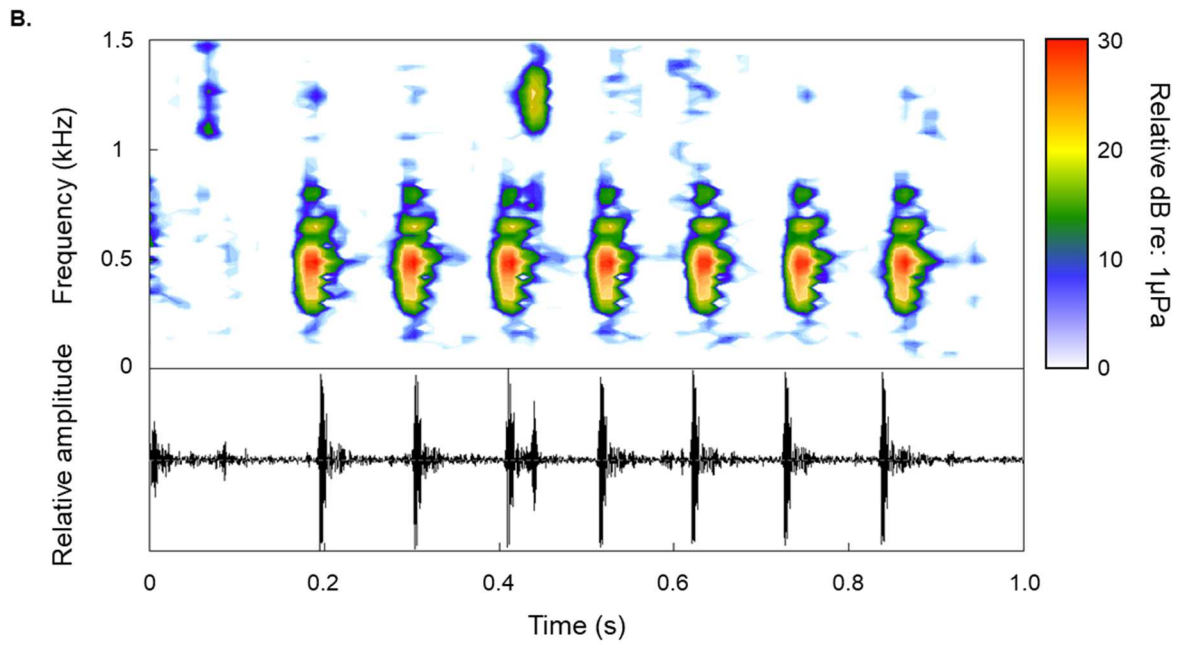
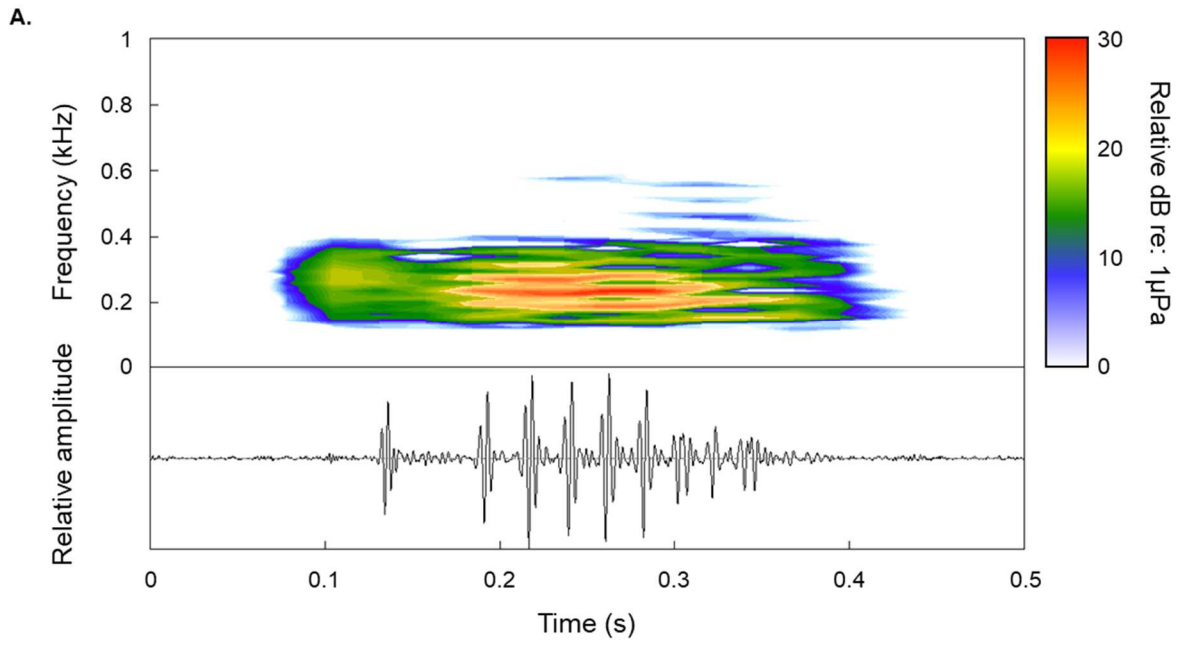
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492

493 **Figure 5**

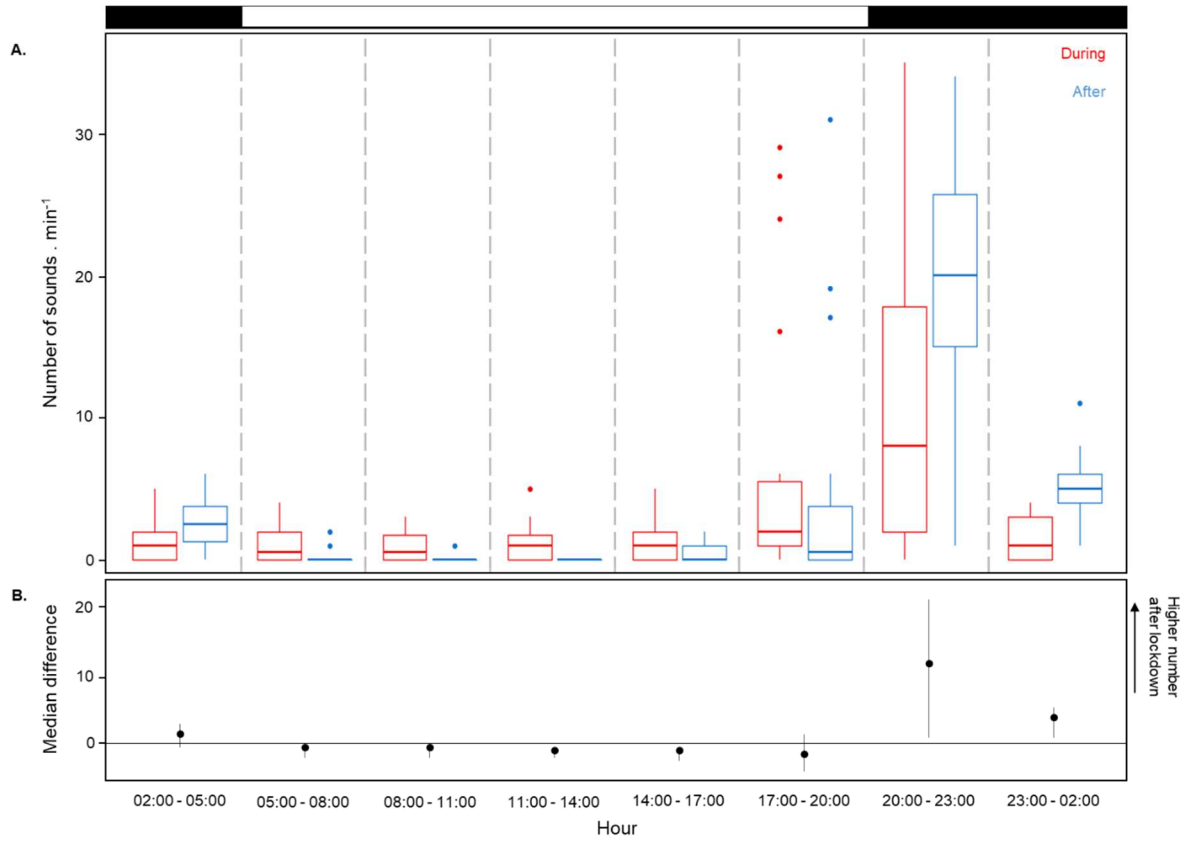
494



495

496 **Figure 6**

497



498

499 **Table 1** – Average power spectrum density levels (RMS, dB re 1 $\mu$ Pa<sup>2</sup>.Hz<sup>-1</sup>) calculated as the mean of all frequency bins below 1000 Hz for each  
500 3h-period during and after lockdown (values are mean  $\pm$  S.D). Effect sizes are calculated as the median differences between levels recorded after  
501 and during the lockdown.

502

	02:00 - 05:00	05:00 - 08:00	08:00 - 11:00	11:00 - 14:00	14:00 - 17:00	17:00 - 20:00	20:00 - 23:00	23:00 - 02:00
<b>During</b>	78.4 $\pm$ 3.5	78.5 $\pm$ 3.1	78.9 $\pm$ 2.2	78.3 $\pm$ 2.2	78.2 $\pm$ 2.2	79.2 $\pm$ 2.3	78.9 $\pm$ 3.5	78.5 $\pm$ 3.2
<b>After</b>	78.2 $\pm$ 3.4	81.8 $\pm$ 2.4	84.3 $\pm$ 3.0	83.7 $\pm$ 3.7	82.2 $\pm$ 3.8	85.2 $\pm$ 3.6	80.8 $\pm$ 3.0	77.5 $\pm$ 3.7
<b>Effect size</b>	-0.7	2.7	5.2	5.1	3.6	6.0	1.4	-1.3
<b>95% CI</b>	-3.9 – 3.0	0.1 – 5.9	3.1 – 7.1	3.7 – 6.7	2.3 – 5.2	3.9 – 7.9	-1.4 – 5.2	-4.5 – 2.4

503

504

505 **Table 2** – Proportion of recordings with at least one boat sound detected during and after the lockdown. Confidence intervals (C.I.) and P values  
 506 are the results of exact Binomial tests comparing proportions after the lockdown with during lockdown’s theoretical proportions. N.S. = non-  
 507 significant difference.

508

	<b>02:00 - 05:00</b>	<b>05:00 - 08:00</b>	<b>08:00 - 11:00</b>	<b>11:00 - 14:00</b>	<b>14:00 - 17:00</b>	<b>17:00 - 20:00</b>	<b>20:00 - 23:00</b>	<b>23:00 - 02:00</b>
<b>During</b>	5/72 (7 %)	16/72 (22 %)	37/72 (51 %)	32/80 (40 %)	30/72 (42 %)	20/72 (28 %)	3/72 (4 %)	2/72 (3 %)
<b>After</b>	6/54 (11 %)	24/47 (51 %)	36/36 (100 %)	43/48 (89 %)	43/54 (79 %)	35/54 (65 %)	11/54 (20 %)	6/54 (11 %)
<b>95 % C.I.</b>	4 % - 23 %	36 % - 66 %	90 % - 100 %	77 % - 96 %	66 % - 89 %	51 % - 77 %	11 % - 33 %	4 % - 23 %
<b>P values</b>	N.S.	<10 <sup>-3</sup>	<10 <sup>-3</sup>	<10 <sup>-3</sup>	<10 <sup>-3</sup>	<10 <sup>-3</sup>	<10 <sup>-3</sup>	0.005

509



# Decreased boat traffic during COVID-19 lockdown reduced underwater noise in an urban marina in Guadeloupe.

## During lockdown

- **Boat traffic was low** due to restrictions.
- **No diel variations** in noise level (average value of PSD levels below 1000 Hz) were observed.
- From 08:00 to 20:00, noise level had an average value of **79.0 dB re:  $1\mu\text{Pa}^2\cdot\text{Hz}^{-1}$** .

## After lockdown

- Boat traffic **increased** and became **continuous**.
- Noise level below 1000 Hz **peaked from 17:00 to 20:00**.
- From 17:00 to 20:00, noise level increased to an average value of **85.2 dB re:  $1\mu\text{Pa}^2\cdot\text{Hz}^{-1}$** .

**Less sounds produced by fishes were detected during the lockdown.**