Monitoring the Soundscape of Paraiso Reef, Cozumel: A Tool for Assessment and Conservation Planning

Monitoreo del Sonido Ambientale de Arrecife de Paraíso, Cozumel: Un Método para Evaluar y Planificar la Conservación

Surveillance des sons Environnementaux de Paraiso Reef, Cozumel: Un Outil D'évaluation et de Planification de la Conservation

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EXTENDED ABSTRACT

Introduction

Coral reefs are under stress globally from increasing ocean temperatures, overfishing, invasive species, recreational impacts, and pollution. Evaluation and monitoring of the ecological state of coral reefs provides necessary information for resource managers to better understand fish and invertebrate populations. An emerging method to monitor and measure the health of, and impacts to, coral reefs is the use of non-invasive, passive acoustic monitoring (PAM) for recording reef soundscapes. A passive acoustic monitoring study was conducted in Arrecifes de Cozumel National Park to evaluate the marine acoustic environment in the park and demonstrate the potential research and management applications of passive acoustic survey approaches for monitoring Cozumel coral reefs.

The study objectives were to:

i) Measure the soundscape of a Cozumel coral reef site, documenting ambient sound and anthropogenic inputs from tourism activities, primarily ship traffic, and
ii) Attempt to capture the first scientific recording of Splendid toadfish (*Sanopus splendidus*) vocalizations. Information from this research will be shared with local resource managers and can be used in future ecological surveys focused on understanding and conserving the species.

Methods

The passive acoustic research study was conducted on Paraiso (Paradise) Reef in the Arrecifes de Cozumel National Park from July 14 to September 3, 2017. One Autonomous Multichannel Acoustic Recorder (AMAR) with four hydrophones continuously recorded for 52 days during the deployment. The AMAR was set to record at a 32 kHz sampling rate for 835 seconds followed by a 375 kHz sampling rate for 65 seconds; a cycle that continued throughout the monitoring period.

The AMAR was deployed by scuba divers in a sandy site among sparsely distributed corals and rocky ledges containing several observed splendid toadfish dens. Two pairs of hydrophones were placed opposite one another at distances of 14.3 and 10.9 m, at 60° angles from the central recorder. This configuration minimized potential damage by cables to protected corals.

Recorded data were analysed to determine sound levels throughout the recording period, including: broadband sound pressure level (SPL) and SPL spectral level for defined frequency bands (Figure 1), exceedance percentiles of the 1/3-octave-band SPL, exceedance percentiles of the power spectral density (PSD) levels, and cumulative sound exposure level (SEL). Vessel contribution to the total measured sound levels were also estimated.

Sound files were visually displayed as spectrograms to look for putative toadfish calls. Because *S. splendidus* has never been recorded for acoustic analyses, we inferred the species identification to a family or species level based on the similarity with other toadfish species calls (Mosharo and Lobel 2012, Rice and Bass 2009): harmonically structured sounds, lasting approximately 0.5 - 1.5 s, with a fundamental frequency around 100-200 Hz. Toadfish calls are acoustically distinct from most other reef fish species, and often dominate the acoustic environment where they occur (Rice et al. 2016, Staaterman et al. 2017).

To identify temporal patterns in toadfish calling, an unsupervised automated detection approach was employed using a spectrogram matched filter (also known as template detection; e.g., Kaewtip et al. 2016, Mellinger and Clark 1997) in Raven 2.0 (Bioacoustics Research Program, Cornell University, Ithaca, NY).

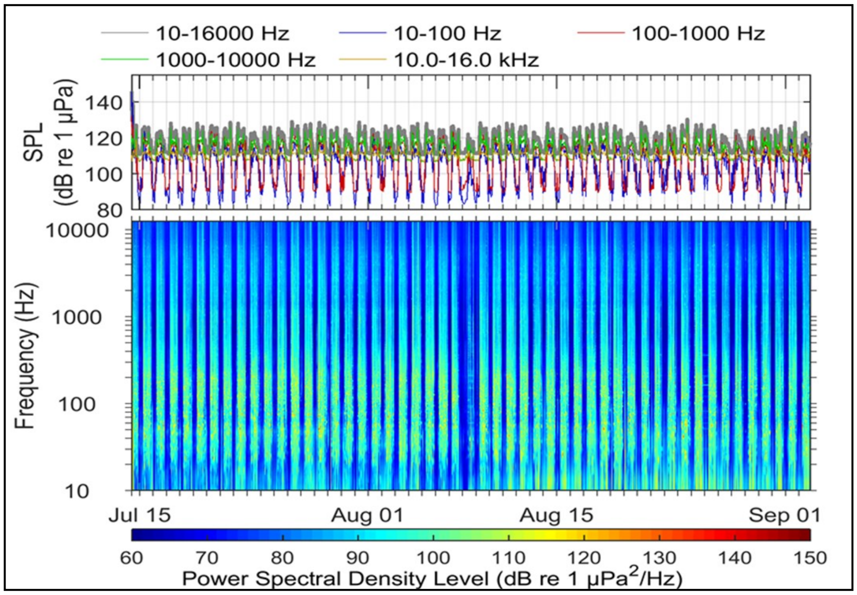

Figure 1. (Top) In-band SPL and (bottom) spectrogram of underwater sound including common biologic, anthropogenic, and geologic sound sources for the 52-day deployment.

Results

Vessel noise dominated the soundscape < 10 kHz throughout the 52 recording days. The maximum and minimum broadband SPL measured were 159 and 107.8 dB re 1 µPa, respectively with the 10 - 1,000 Hz spectral level, associated with vessel noise, ranging from 78.8 to 158.8 dB re 1 µPa. Analysis of the entire sound recording shows a repeating pattern of higher sound levels during the day and lower sound levels at night, with vessel noise being the main contributor to the local soundscape during daylight. High-frequency crustacean noise also occurs throughout the day.

The soundscape in the low- to mid-frequency bands is driven by human activity with SPL spectral levels ranging from 78.8 to 142.5 dB re 1 µPa in 10 - 100 and 100 - 1,000 Hz bands. Broadband SPL during cruise ship passage by Paraiso reef can reach levels > 120 dB re 1 µPa for several minutes. Throughout the day (approximately 12 hours), high volumes of small boat traffic are recorded on the hydrophones with an average broadband SPL of 117 dB re 1 µPa. A second spike in noise levels is recorded at dusk when cruise ships depart Cozumel. After dusk, and through the night, there is a constant level of reef sounds occurring at frequencies > 5kHz. On average, there is a 3 dB difference (representing a doubling in acoustic energy) in soundscape during the daylight hours versus night time.

We discovered a number of putative toadfish calls (Figure 2A) throughout the recording. Calls were produced every day, and were most frequent at night. The most commonly encountered calls were frequency modulated up-sweeps, with the fundamental frequency starting at 50 Hz and increasing to ~120 Hz. Initial calls were approximately 500-600 ms in duration, but were occasionally followed by shorter duration signals (approximately 200 - 250 ms). We observed a second class of call (Figure 2B), that was also an up-sweep, but longer in duration (approximately 1s) and lower in fundamental frequency (30 - 80 Hz). It is unclear whether this is a second call-type within the repertoire of *Sanopus splendidus* or another toadfish species.

Discussion

Knowing the species identity of fish sounds allows scientists to use these vocalizations to understand the occurrence, behavior and ecology of soniferous fish species. We targeted the sounds produced by *S. splendidus*, and placed the hydrophones near visually identified nests. Thus, it is likely that the highest signal-to-noise ratio sounds observed throughout the recording are produced by *S. splendidus*. However, because a second endemic species of toadfish is also found in Cozumel, *Sanopus johnsoni* (Collette 1974), it is possible that the two different call types that we observe (Figure 2A,B) represent calls from each species. Toadfish calls occur within the frequency range of ship noise, and likely the range of their peak hearing sensitivity (Vasconcelos et al. 2007), thus masking from ship noise may decrease toadfish conspecific detection range, and ultimately lead to decreased reproductive success (Francis and Barber 2013).

Understanding the soundscape context of toadfish calls can inform conservation and management strategies. The record of a particular sound provides information on when, where and why that call as produced, and which species it came from. A lack of baseline data on the splendid toadfish and predicted ongoing habitat degradation were the impetus for this initial study. Additional research is needed to better understand the habitat distribution, abundance and possible threats to the species (Collette et al. 2015), including the potential impact of anthropogenic noise on communications essential to reproduction and dispersion. Recording the vocalizations of the splendid toadfish can be effectively used in future ecological surveys focused on increased understanding and conservation of the species. Future deployments along the Mesoamerican reef would provide insight into the answers to these questions.

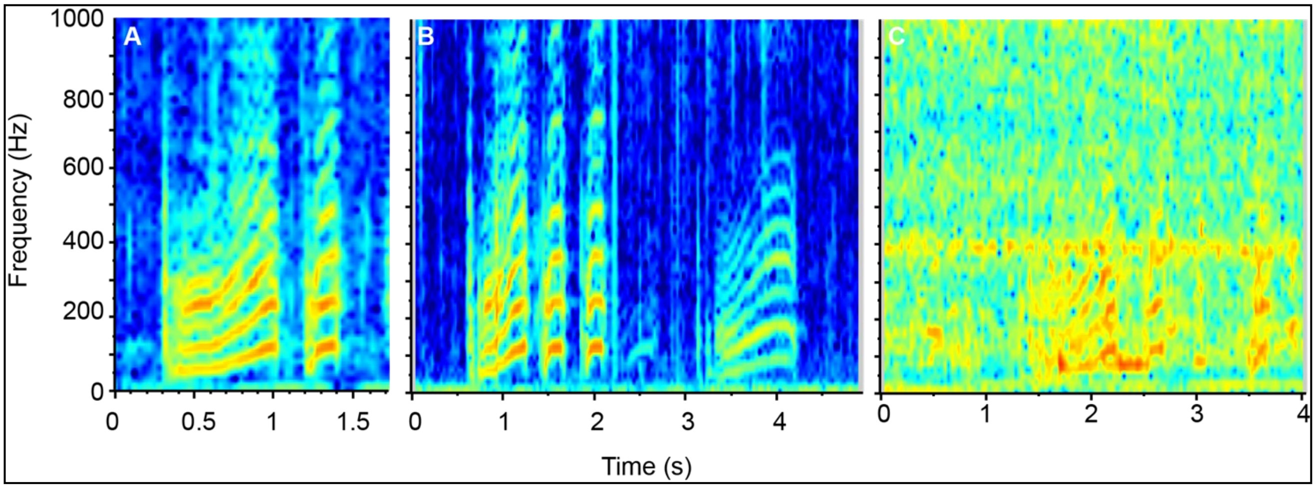

Figure 2. A) Representative spectrogram of putative *S. splendidus* call. **B)** Spectrogram showing potentially two different toadfish species calling in succession. **C)** Spectrogram of example of a toadfish call masked by shipping noise. Spectrograms were created in Raven 2.0, with FFT=2048 points, 50% overlap, using a Hann window.

KEYWORDS: Biodiversity, ecosystem services, soundscapes, passive acoustic monitoring, conservation

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