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Baseline

Underwater noise pollution in a coastal tropical environment

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ABSTRACT

Underwater noise pollution has become a major concern in marine habitats. Guanabara Bay, southeastern Brazil, is an impacted area of economic importance with constant vessel traffic. One hundred acoustic recording sessions took place over ten locations. Sound sources operating within 1 km radius of each location were quantified during recordings. The highest mean sound pressure level near the surface was 111.56 ± 9.0 dB re 1 μPa at the frequency band of 187 Hz. Above 15 kHz, the highest mean sound pressure level was 76.21 ± 8.3 dB re 1 μPa at the frequency 15.89 kHz. Noise levels correlated with number of operating vessels and vessel traffic composition influenced noise profiles. Shipping locations had the highest noise levels, while small vessels locations had the lowest noise levels. Guanabara Bay showed noise pollution similar to that of other impacted coastal regions, which is related to shipping and vessel traffic.

Environmental noise in the ocean is an important aspect of marine habitats and is composed of natural and artificial sounds (Hildebrand, 2009). However, over the recent decades underwater noise pollution has come to the attention of scientists as a rising problem around the world's oceans (McDonald et al., 2006). The frequency band that in the past was dominated by wind, waves and biological sounds, is now under the influence of heavy vessel traffic (Andrew et al., 2011) and other artificial sound sources (Hildebrand, 2009). Shipping noise has become the main sound source in coastal areas and may have effects on the environment (Castellote et al., 2012; Richardson et al., 1995; Tyack, 2008).

Artificial sound sources in the marine environment such as dredging operations, marine constructions, oiling activities and seismic explorations usually have low frequency signals and high intensity (Richardson et al., 1995). Small vessels produce higher frequency signals, between 2 and 10 kHz. Large vessels produce signals both in bands below 1 kHz (Wenz, 1962) due to engine and electrical machinery noise, and in higher frequency bands due to cavitation noise (Aguilar Soto et al., 2006; Arveson and Vendittis, 2000).

Underwater noise pollution is a problem especially in areas inhabited by marine fauna sensitive to the acoustic environment. Sound is a key aspect of fish and marine mammal ecology, functioning as an important communication channel to group cohesion and reproductive aggregation (Myrberg, 1997). The constant input of artificial sounds that are within the hearing frequency range of these species may have implications to ecosystem's health (Slabbekoorn et al., 2010).

Brazil has grown economically in the past years and changes have been conducted in several coastal marine environments in the form of vessels traffic, port constructions, oil extraction and naval enterprises. All these factors are going to cause changes in the marine acoustical environment. To our knowledge there are no studies in Brazil that have performed underwater noise analysis. Therefore, the aim of this study was to provide a first description of underwater noise characteristics and the main anthropogenic sound sources in a coastal marine Brazilian environment.

Guanabara Bay (22°50′S; 43°10′W), located at southeastern Brazilian coast, is a highly impacted coastal area, surrounded by urban centres that contribute for water pollution (de Aguiar et al., 2011; Carreira et al., 2004). The bay has a water surface of 328 km^2 and depths vary between 1 and 50 m with an average of 20 m at the main channel. This environment has the physical characteristics of an estuarine complex, freshwater input comes from 35 rivers and sewage discharge (Kjerfve et al., 1997). Bottom sediment consists mainly of silt and mud at the northern portion and sand at the southern portion (Catanzaro et al., 2004).

There are multiple activities in the study area that can contribute to the acoustical environment. Guanabara Bay is an important transport area between the surrounding urban centres, with the

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constant presence of ferry lines in some locations. Large ships can be found anchored year round with many associated medium sized vessels navigating. There are intense commercial and military port activities and occasional marine construction operations that contribute to underwater noise. Also, some parts of the bay are used by fishing and recreational boats (Kjerfve et al., 1997), creating an environment with multiple, continuous anthropogenic sound sources.

Ten data collection locations were distributed to cover different areas inside Guanabara Bay (Fig. 1). The recording system consisted of an omnidirectional HTI-96MIN hydrophone with a flat frequency response ranging from 5 Hz to 30 kHz, with mean sensitivity of −170 dB re: 1 V/μPa, combined with a digital recorder Marantz PMD 671 with a 48 kHz sample rate and a 24-bit resolution. We calibrated the recording system with a 1 kHz tone. The calibration provided equipment noise gain for all possible input levels in the digital recorder. In addition, we plotted the hydrophone calibration curve and obtained the mean sensitivity to use in noise levels calculation.

A 5.5 m long boat with a 90 hp engine was used for covering the study area. The boat's engine remained off during the recordings so it would not add to the local noise. The hydrophone was deployed at two depths: 2 m below the surface and 2 m above marine floor. Ten recordings were made at each data collection site between May/2011 and September/2012. The recordings lasted two minutes each and occurred under similar sea state conditions (Beaufort ⩽ 2). The sampling effort was carried out during different times of the day to include diurnal variation patterns and register the widest possible number of situations at each area.

All operating sound sources within 1 km radius of the recording site during data collection were quantified. Sound sources were separated into five categories: ships, medium sized vessels (trawlers and other boats with length ranging from 10 to 20 m), small boats (zodiacs, outboard vessels smaller than 10 m and artisanal fishing boats), supply fuel station for ships and airports.

Software Adobe Audition 1.5 was used in all sound analysis. Spectrograms were generated with a 512-point Hanning window. From each recording of two minutes duration, ten periods of ten seconds were extracted randomly, totalizing 1000 acoustic samples to calculate sound pressure levels in Guanabara Bay, 100 samples per location. A frequency analysis provided peak levels of 512 frequency points between 10 and 24,000 Hz to be inserted in the calculation for each 10s sample. The following formulae (1) were used to calculate rms sound pressure levels (Au and Hastings, 2008).

$$SPL = RL - Hs \quad (1)$$

where RL is the recording level, which has been corrected by recording system calibration; and Hs is the hydrophone mean sensitivity.

To apply statistical data treatment six frequency intervals were separated: <1 kHz; 1.1–2 kHz; 2.1–5 kHz; 5.1–10 kHz; 10.1–15 kHz; and 15.1–24 kHz. Out of the 512 frequency points, we identified the point with the highest sound pressure levels in each of these six frequency intervals to be inserted in the statistical analysis. We then applied a Spearman Rank analysis to investigate if the number of operating artificial sound sources counted in each recording session correlated with the highest noise levels in the six frequency intervals. To visualize which recording locations were more similar to others, we applied a complete linkage cluster analysis, with cluster groups based on Euclidean distances.

During the study period, 605 vessels of various sizes and types were quantified trafficking within a 1 km radius of the recording

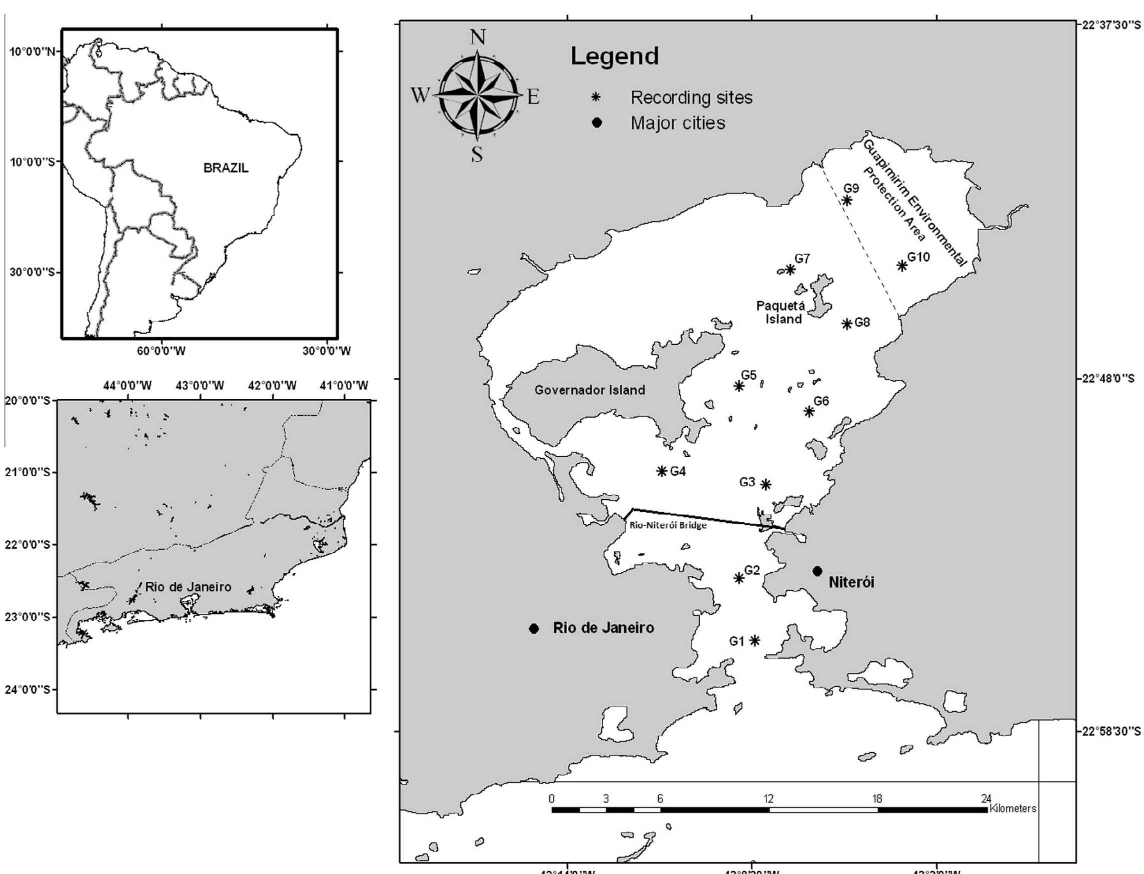

Fig. 1. Distribution of underwater noise sampling locations in Guanabara Bay (22°50'S; 43°10'W), southeastern Brazilian coast. On the northeastern side of the bay is Guapimirim Environmental Protection Area.