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Ambient Noise and Marine Mammal Acoustics

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Introduction: The Littoral Acoustic Demonstration Center (LADC) is an Office of Naval Research funded consortium of scientists from the University of Southern Mississippi (USM), the University of New Orleans (UNO), the Naval Research Laboratory at Stennis Space Center (NRL-SSC), and the University of Louisiana at Lafayette (ULL). LADC was formed to conduct ambient noise and marine mammal acoustic measurements and analyses. Some of the marine mammal goals are to 1) investigate detection, identification, and tracking using bottom-moored hydrophones; 2) coordinate with scientists making visual observations and other acoustic measurements; and 3) evaluate, and modify if necessary, automatic detection and characterization computer algorithms when applied to marine mammal signals received on bottom-mounted hydrophones. The underlying desire is to provide products that will help to assess the effects of anthropogenic noise on marine mammal behavior and the development of mitigation procedures. Due to recent court rulings, the Navy has become concerned with the possible negative effects of sonar on marine mammals and the development of mitigation procedures. Not only do mitigation procedures have Navy applications, but they also apply to some aspects of commercial or scientific exploration of the oceans.

LADC has conducted experiments in the northern Gulf of Mexico and in the Ligurian Sea in cooperation with other organizations. Environmental Acoustic Recording System (EARS) buoys were deployed at sites with historically abundant sightings of marine mammals. EARS buoys are autonomous self-recording, single-channel, bottom-moored acoustic buoys developed by the Naval Oceanographic Office. Analysis approaches have included click production analysis, propagation modeling of sperm whale clicks, and spectral and wavelet transforms of sperm whale clicks.

Spectral Analysis Results: Often, data filtering and spectral analysis are the first steps toward the more complex analyses mentioned above. These two processes can allow the researcher to ascertain details of the data not readily apparent. Transient signals, such as marine mammal phonations, are often buried in the background ambient noise. The following illustrations are examples of some of the results of the spectral analysis from one of the Gulf of Mexico experiments conducted by LADC.

Figure 1 illustrates data from a time period that had a considerable diversity of noise. The upper plot illustrates 120 s of acoustic data from the EARS buoy. The lower left plot is a calibrated spectrogram of these data. Intensity in the spectrogram is represented by color, blue being the lowest and red being the highest intensities. It is well known that most distant shipping noise is below 300 Hz.[1] Thus, the higher intensity red in the lower frequencies of this spectrogram is considered to be due to distant shipping. There are some high-level peaks at the very lowest frequencies of this plot. The lower right plot is a spectrogram of the same data zoomed onto the lower frequencies. The red peaks at the lower frequencies can now be seen to occur every 10 s and are caused by a seismic survey airgun approximately 107 km distant. The lower right plot illustrates that the majority of the noise from the airgun at this distance is below 300 Hz.

Figure 2 illustrates a 15-s segment of data from the same exercise taken approximately 3 h later, after the seismic survey vessel has left the area. The upper left plot represents the acoustic time series data from the hydrophone. The lower left plot is the corresponding spectrogram. There are spikes in the upper plot that are not clearly distinguishable in the spectrogram. Again, note the higher intensities at the lower frequencies in the spectrogram. The upper right plot represents the same 15-s segment of data after the data were filtered to eliminate most of the distant shipping noise (i.e., frequencies below 300 Hz). The lower right plot is the corresponding spectrogram. The spikes, noted earlier in the unfiltered data, can easily be seen to be an entire series of spikes in the filtered acoustic data (upper right plot). These spikes are the clicks produced by a sperm whale and are referred to as a "click train." Again, the spikes are not easily distinguishable in the spectrogram (lower right plot).

Figure 3 illustrates a 5-s segment of data near the middle of the previous segment. This data segment has been filtered to eliminate the frequencies below 300 Hz. At this time scale, the click train is easily distinguishable from the filtered acoustic data (upper plot). In addition, the click train is readily apparent in the spectrogram (lower plot). As can be seen from the spectrogram, the clicks are very broadband and contain data from near 300 Hz up to above the upper frequency limit of the plot (about 5.8 kHz).

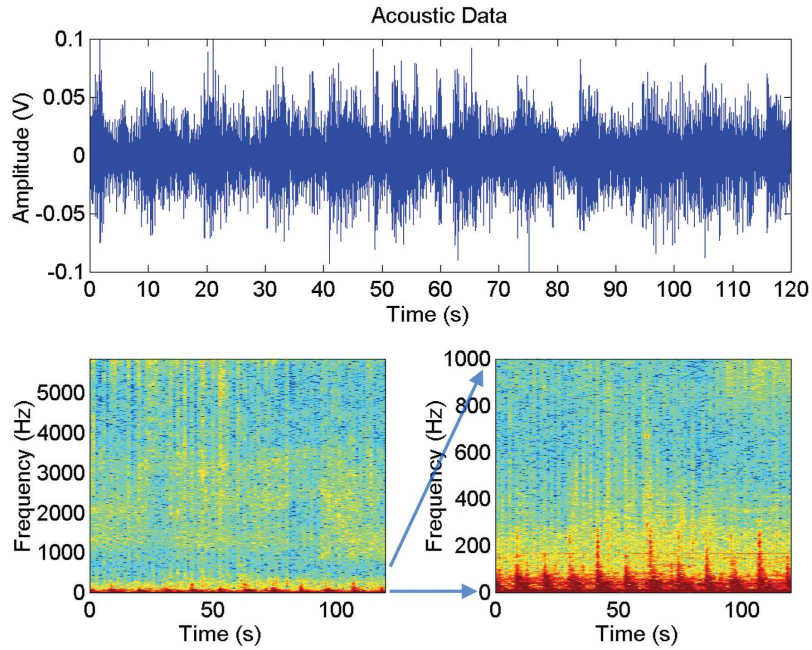

FIGURE 1
Example of 120 s of ambient noise (top plot) and corresponding spectrograms (lower plots). In the spectrograms, red indicates higher intensities and blue indicates lower intensities. The lower left plot displays the full bandwidth of the data and implies many different noise sources. The lower right plot displays only the lower 1000 Hz of the data, clearly showing shipping noise and seismic prospecting at the lowest frequencies.

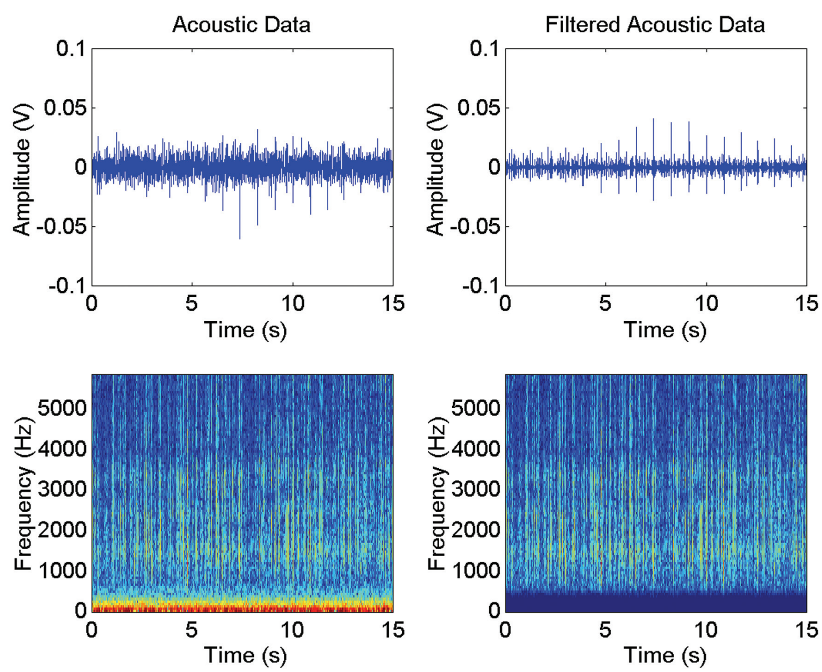

FIGURE 2
Examples of 15 s of ambient noise including a sperm whale click train (upper plots) with the corresponding spectrograms (lower plots). In the spectrograms, red indicates higher intensities and blue indicates lower intensities. The left plots are unfiltered data, and the right plots have been high pass filtered to eliminate contributions below 300 Hz. The click train is very evident in the filtered data.

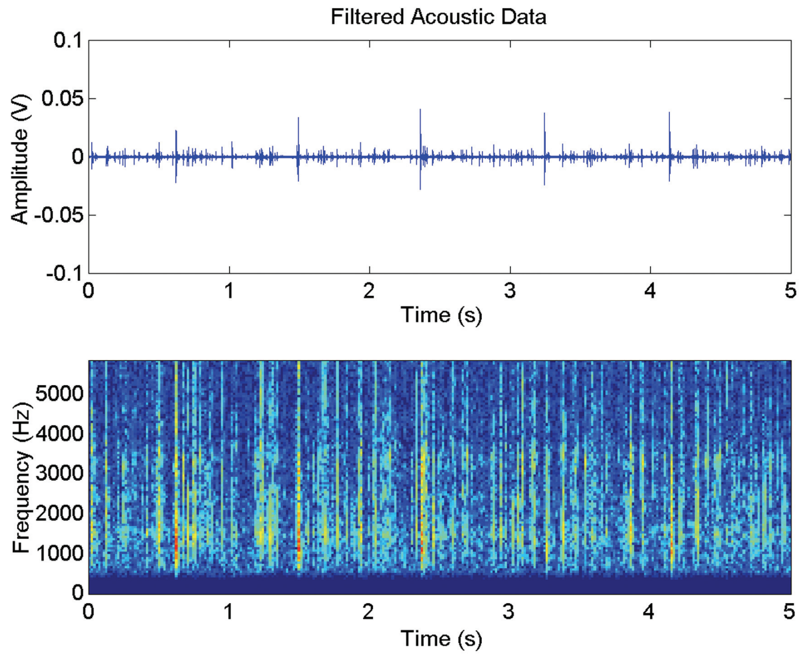

FIGURE 3
Exploded view of the middle 5 s of ambient noise shown in Fig. 2 (upper plot) with the corresponding spectrogram (lower plot). In the spectrogram, red indicates higher intensities and blue indicates lower intensities. The click train can now be seen clearly as broadband high intensity vertical lines in the spectrogram.

Summary: LADC has participated in four major marine mammal field experiments in cooperation with several other government and research scientists. LADC scientist and students are analyzing the data. To date, one Ph.D. and four M.S. degrees have been awarded to students working with these data. There are at least seven more students working toward their degrees. Preliminary results have shown the possibility of identifying individual sperm whale groupings from the spectral content of the click trains. This leads to the intriguing concept of eventually identifying individual mammals from their acoustic signature.

[Sponsored by ONR]

Reference

[1] G.M. Wenz, "Acoustic Ambient Noise in the Ocean: Spectra and Sources," *J. Acoust. Soc. Amer.* 34, 1936-1956 (1962).