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Influence of Wind- and Ship-generated Sound on Ocean Ambient Noise in Shallow Water

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1. Introduction

Ambient noise level (ANL) is the product of many oceanic noise sources, including natural and man-made sources.[1)] Noises caused by natural sources are commonly generated by physical or biological processes. Examples of physical processes that occur include tides, seismic disturbances, ocean turbulence, surface waves, and thermal noise.[2)] Biological noise sources comprise the vocalizations of marine mammals and fish. Examples of man-made noise sources include those caused by ship traffic, underwater construction, and wind farms.

As interest in protecting marine ecosystems has increased worldwide, studies have been conducted on the effects of man-made noise on marine mammals and fish. It is assumed that underwater sound would be familiar to marine animals, as much as visual landscapes are for humans, and that the ocean is filled with various sounds forming the soundscape.[3)] The marine soundscape is commonly measured with a hydrophone.

In this study, we measured the effects of ambient noise generated by wind and ship traffic on the ocean sounscape, with a focus on low-frequency bands (<1 kHz). The speed and direction of the wind were measured from a weather buoy operated by the Korea Institute of Ocean Science and Technology (KIOST). The hydrophone near the weather buoy was moored for one month to measure ambient noise. The measured ambient noise was analyzed using wind data from the weather buoy and automatic identification system (AIS) data, i.e., navigation information, of sailing vessels in the vicinity of the study area. From the analysis results, we confirmed that the measured ANL at 1 kHz increased as ships approached the hydrophone and fluctuated according to the speed and direction of the wind.

2. Field Measurements

The study area was located about 9 km northeast from Jukbyeon Port in Uljin-gun, Gyeongsangbuk-do, Korea. The weather buoy operated by KIOST is moored in the study area, as shown in **Fig. 1**, and collects weather, conductivity–temperature–depth (CTD), and acoustic Doppler current profiler (ADCP) data. The weather buoy, powered by solar panels, operated non-stop, transmiting measured data to the operation server every 10 min. The buoy was located in shallow water at a depth of 130–140 m.

Fig. 1 Weather buoy operated by the Korea Institute of Ocean Science and Technology.

The ambient sound recorder was an SM3M Submersible (Wildlife Acoustics, Inc., Maynard, MA) and was moored near the weather buoy. The hydrophone (High Tech, Inc., Long Beach, MS) used to measure the ANL has a recording bandwidth of 2 Hz to 48 kHz and a receiving voltage sensitivity (RVS) of 165 dB at 100 Hz to 10 kHz. The SM3M was set to record ambient sound for 5 min at 10-min intervals. The receiver gain was set to 12 dB, and the sampling frequency was set to 24 kHz. The hydrophone was moored from April 6 to May 1, 2018, at a depth of about 70 m. AIS data on vessel traffic around the study area during the ambient noise measurement period were obtained through the Marine Traffic website and used for noise level (NL) analysis.

3. Results

The power spectral density (rectangular window; fast Fourier transform (FFT) size: 12,000; 50% overlap) was calculated using the acoustic data measured at the hydrophone. **Figure 2** shows the ANL measured at a frequency of 1 kHz. The ANL shown in **Fig. 2** indicated a strong impact noise due to mooring of the hydrophone on April 6. The average ANL measured in the study area was 73.7 dB.

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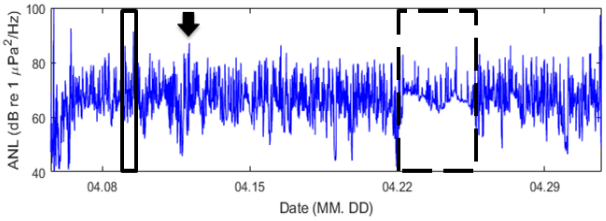

Fig. 2 Ambient noise level measured using the hydrophone at 1 kHz.

The ANL peak indicated by the arrow in **Fig. 2** was due to ship noise. The measured ship noise is shown as a power spectrogram (rectangular window; FFT size: 12,000; 50% overlap, **Fig. 3**). The bathtub pattern, due to the noise generated when the ship sailed, was confirmed. Most of the ANL peaks were observed when vessels were present in the proximity of the hydrophone. The ANL of a ship was measured at 70–90 dB at 1 kHz.

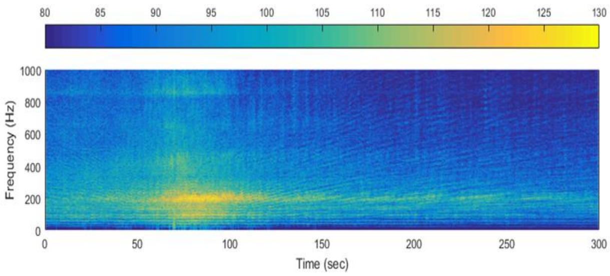

Fig. 3 Power spectrogram (the unit of color bar is dB re 1 μPa^2/Hz).

The ANL other than ship noise was analyzed using weather data. **Figure 4** shows the wind speed, wind direction (0° corresponds to the south wind, 180° is the north wind, counterclockwise), wave height, and rainfall data measured from the weather buoy. From April 22 to April 25 (black dashed line), it was confirmed that the north winds were generated continuously, and the wind speed was more than 5 m/s; as a result, the wave height increased to 3 m. On the other days, it was confirmed that the wave height did not exceed 2 m because the wind speed and the wind direction had changed. A comparison of the measured ANL with weather data showed that the wave height and ANL increased with the wind speed. In particular, from April 22 to April 25 (black dashed line), the ANL was higher than on other days. When the wind was blowing at less than 1 m/s, most of the ANL was lower than 60 dB. The unusual item was that the ANL was higher than 60 dB, even though the wind speed was lower than 1 m/s around April 9 (black solid line). The reason for this is related to the wind direction. In the study area, the current flows from the southwest to the northeast at a speed of about 2 knots, such that when the northeast wind blows, the wave period changes irregularly due to friction between the wind and waves, as shown in **Fig. 5**. Therefore, when the north wind or the northeast wind blows, the wave breaking phenomenon appears as a strong effect. The ANL caused by rainfall is considered to have no effect on the analysis results at 1 kHz.

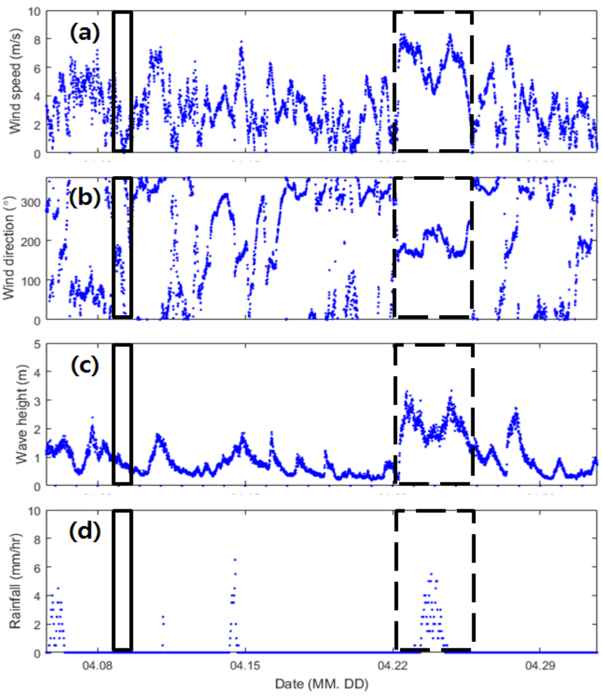

Fig. 4 Weather data measured on the buoy: (a) wind speed, (b) wind direction, (c) wave height, and (d) rainfall.

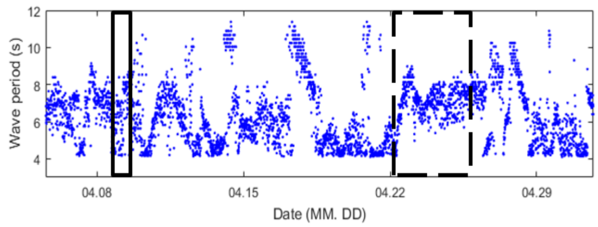

Fig. 5 Wave periods measured on the buoy.

Acknowledgment

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References

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3. P. Jennings and R. Cain: Applied acoustics **74** (2013) 293.