Underwater acoustic measurements of the WET-NZ device at Oregon State University's ocean test facility

An initial report for the:

Northwest National Marine Renewable Energy Center (NNMREC)
Oregon State University

Provided by:

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Background

Potential impacts from sound transmitted by wave energy conversion (WEC) devices on marine ecosystems are not well understood and remain an important environmental concern for the developing marine hydrokinetic renewable energy industry. On August 22, 2012 the Northwest National Marine Renewable Energy Center (NNMREC) began a test deployment of a WEC device at Oregon State University's ocean test facility (OTF) off the coast of Newport, Oregon (figure 1). The operational Wave Energy Technologies – New Zealand (WET-NZ) device provides the first opportunity to measure acoustic changes in the ambient sound field resulting from WEC technology testing at NNMREC's mobile OTF. The main objective of the acoustic measurements included in this initial report is to determine if the WET-NZ device under test transmits acoustic energy above National Marine Fisheries Service (NMFS) marine mammal harassment thresholds.

Comparisons of measured ambient noise levels in the vicinity of the WET-NZ device with year-long baseline recordings provide a context for changes in acoustic levels associated with WEC test. Continuous, background long-term passive acoustic measurements of ambient sound levels (1 Hz – 2 kHz) were collected from March 2010 – April 2011 at the OTF site (figure 2). These baseline recordings provide an acoustic characterization of background levels and sound sources over a range of sea states, environmental conditions and vessel traffic intensity. Baseline results indicate the ambient noise field in the area prior to WEC testing consists primarily of sounds emanating from breaking waves, winds, rain, ship and small boat traffic, and marine mammals (*Haxel et al., in review*).

The WET-NZ device was deployed at 44º41.702'N and 124º07.678'W within the designated OTF and nearby the mooring site of the long-term acoustic baseline recordings described in Haxel et al. (*2011*) and Haxel et al. (*in review*) (figure 1 & 2). Acoustic measurements of the WET-NZ device were made from 07:52 to 10:30 PDT on August 30, 2012 before winds began to increase, limiting the quality of the recordings.

Figure 1. The WET-NZ device and nearby OSU Ocean Sentinel buoy in operation at the NNMREC/OSU ocean test facility off the coast of Newport, Oregon.

Methods

Acoustic measurements were made from a 24 foot fiberglass vessel (*Gracie Lynn* – Oregon Coast Aquarium) using a cabled hydrophone lowered to a depth 10 m below the surface. The boats' engines and electronic instruments were powered down in free drifting mode in an effort to reduce noise contamination of the acoustic recordings. The cabled acoustic recording system consists of a Reson TC 4032 hydrophone with an effective sensitivity of -172.7 dB re 1 μPa V^{-1} @ 1 m routed through an RME Fireface 400 audio interface to a Windows 7 PC using Adobe Audition software for data acquisition and storage. The frequency response of the hydrophone system is flat up to 120 kHz with a low frequency cutoff at 10 Hz.

The day before field measurements the hydrophone and data acquisition system were calibrated in the lab with a G.R.A.S. Pistonphone Type 42AC. The following day, (August 30, 2012) WET-NZ test free-drift acoustic recordings were made with 64 kHz continuous sample rate and digitized at 16-bit resolution. Each of 5 drifts was started north of the WET-NZ device following the dominant current direction southward for up to 30 minutes and ranging from 10 m to 750 m of the WET-NZ device.

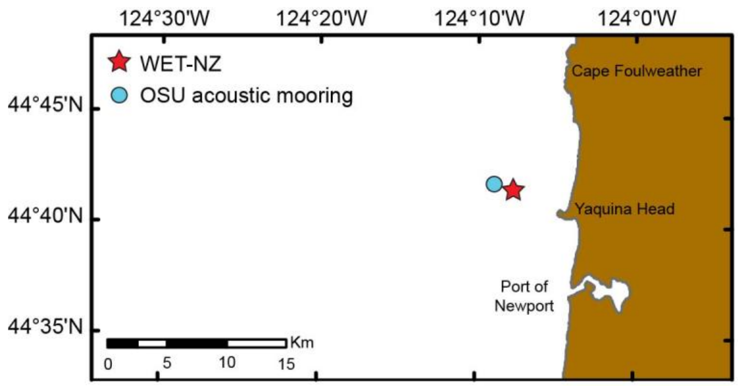

Figure 2. Map of the WET-NZ deployment location and Oregon State University long-term acoustic mooring (March 2010 – April 2011) at the NNMREC/OSU ocean test facility off the central Oregon coast.

Results

Various factors inherent to this cabled and free drifting acoustic data acquisition technique strongly influence noise contamination levels thereby limiting the capabilities of the system. Non-propagating pressure fluctuations at the hydrophone surface (flow noise) resulting from a towing effect caused by the difference in the drift speed of the boat verses the prevailing current, introduces significant non-acoustic low frequency energy below 100 Hz. Additionally, cable tug resulting from the heave and pitch of the vessel in swell and waves introduces sharp, broadband spikes in energy. Another strong source of system noise contamination occurs as waves interact with the vessel hull. Hull slap and turbulent flow noise around the boat induced by breaking wind waves and swell motion are nearly continuous, often masking the targeted acoustic signals. Environmental conditions largely influence the quality of the recording system, making comparative measurements from different recording conditions difficult. The low frequencies recorded (particularly below 1 kHz) with this method were frequently contaminated by system noise, significantly reducing the number of quality measurements of the WET-NZ device.

Thirty-second spectrograms of the underwater acoustic recordings near the WET-NZ device at distances of 10 m and 85 m are shown in figures 3 & 4. Power spectral densities (PSD) are calculated from 8192 point data windows, tapered using a Hanning window, overlapped 50% and Fast Fourier Transformed. Spectral levels at both 10 m and 85 m

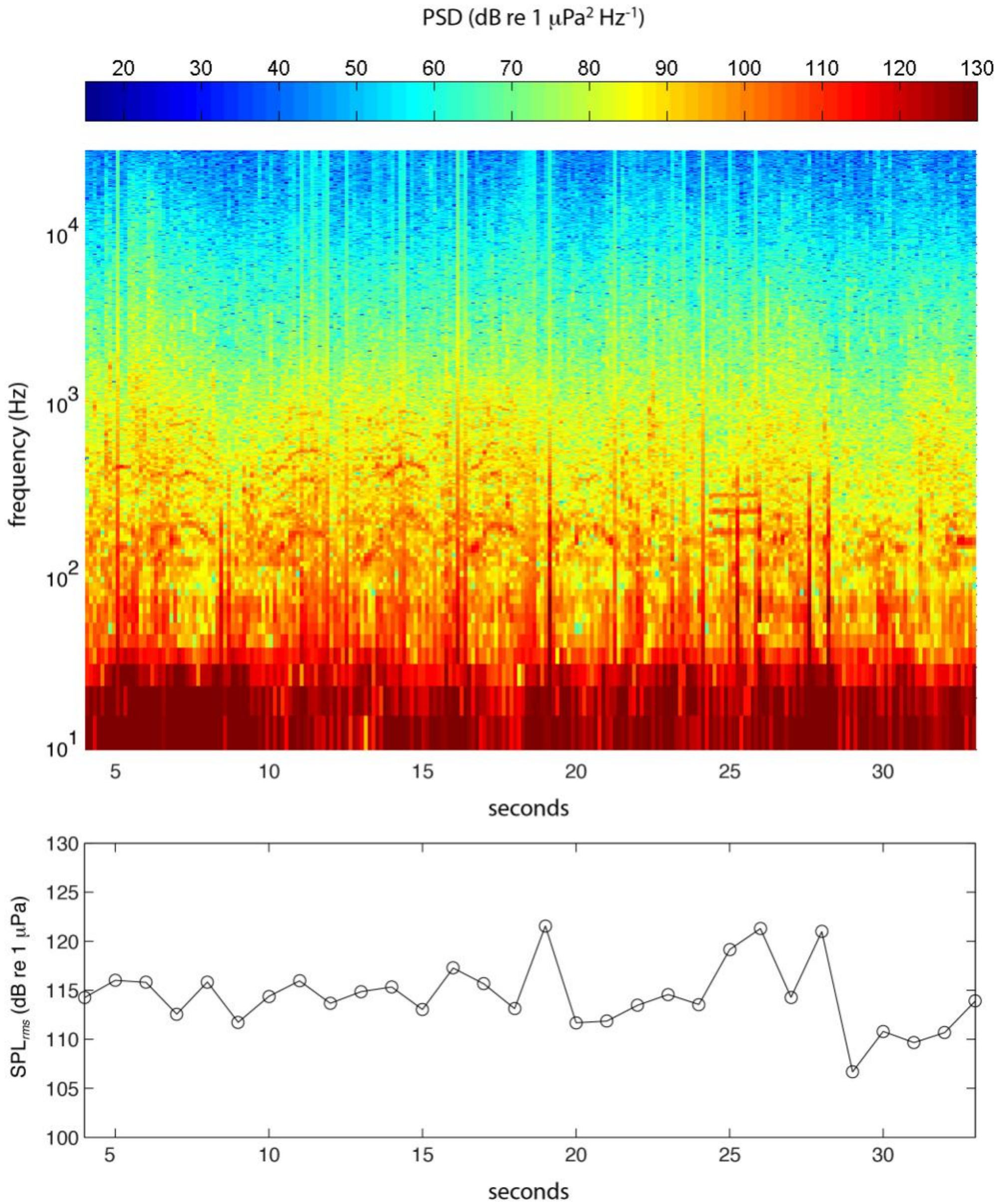

Figure 3. (top) Spectrogram from a recording made at 10 m distance from the WET-NZ test device. (bottom) the broadband (60 Hz – 32 kHz) SPL_{rms} calculated from 1 second intervals.

distances indicate acoustic transmissions from the WET-NZ device primarily occur in frequencies below 1 kHz. The harmonic frequency structure modulations transmitted by the operational device are assumed to oscillate as a function of the incident wave period similar to acoustic results from a $1/7^{th}$ scale WEC test presented by Bassett et al. (*2011*). Contamination from previously mentioned noise sources (e.g. flow noise, cable tug) is readily observed in frequencies below 100 Hz, potentially masking signals in these lower frequencies.

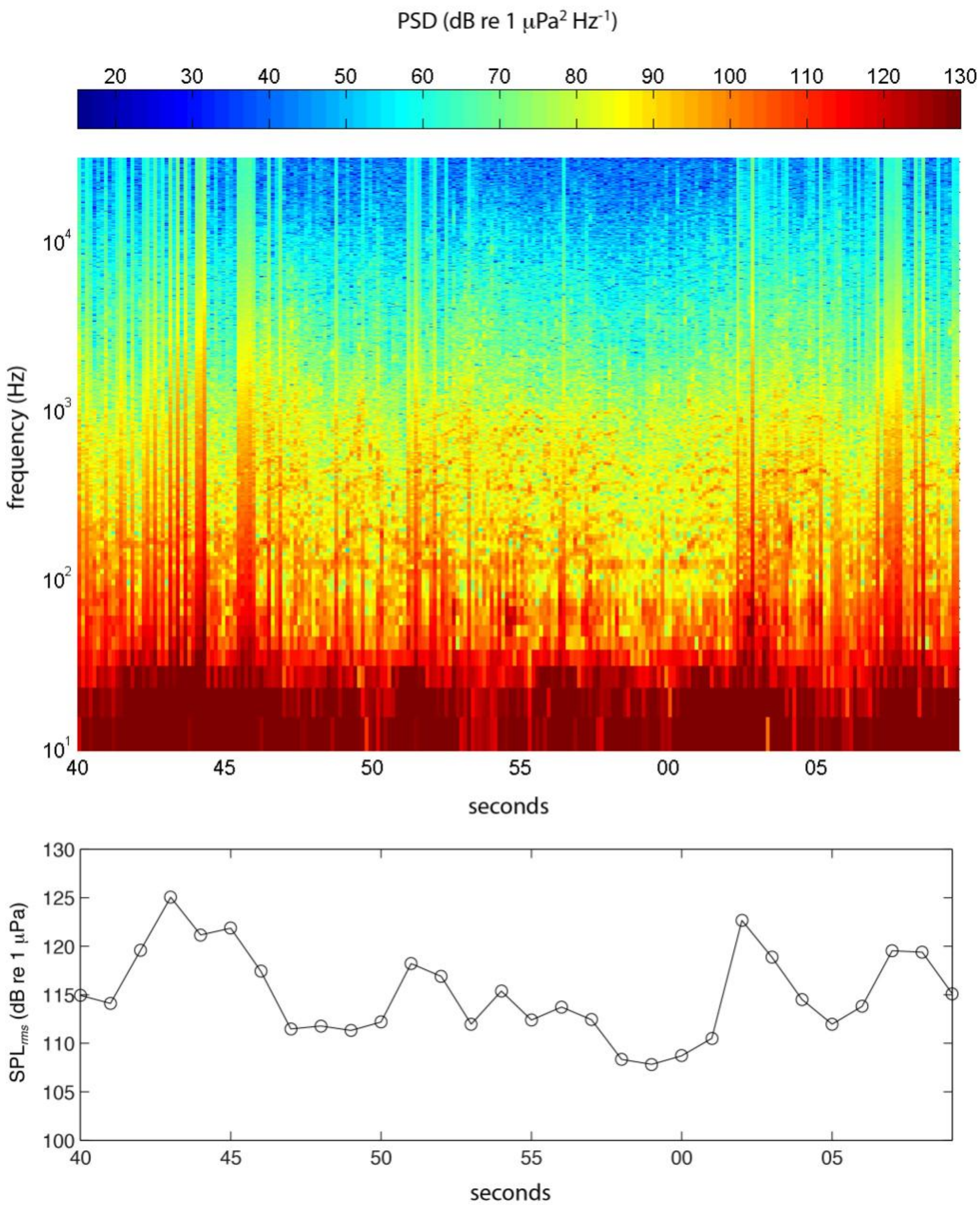

Figure 4. (top) Spectrogram from a recording made at 85 m distance from the WET-NZ test device. (bottom) the broadband (60 Hz – 32 kHz) SPL_{rms} calculated from 1 second intervals.

The bottom panels in figures 3 & 4 show the broadband (60 Hz to 32 kHz) received root mean square sound pressure level SPL_{rms} (dB re 1 uPa @ 1 m) calculated over 1 second intervals associated with thirty-second spectrograms. SPL_{rms} is calculated as:

$$SPL_{rms} = 20 \log_{10} (p_{rms}/p_{ref})$$

Where p_{rms} is the root mean square pressure calculated over one second and p_{ref} is the standard underwater reference pressure 1 μPa @ 1 m. One-second SPL_{rms} values associated with the WET-NZ harmonic signals during peak signal to noise ratio intervals (times with the least amount of low frequency contamination) average around 115 dB at 10 m and 112 dB at 85 m. SPL_{rms} levels exceed 120 dB only during instances where broadband spikes and other system noise contaminate the record. Additionally, average values of 115 dB at 10 m and 112 dB at 85 m likely represent an overestimate of the actual sound pressure levels at the receiver produced solely by the WET-NZ device. Despite using maximum signal to noise ratio sound intervals, a significant amount of energy in frequencies above 60 Hz from system noise is still included within these estimates.

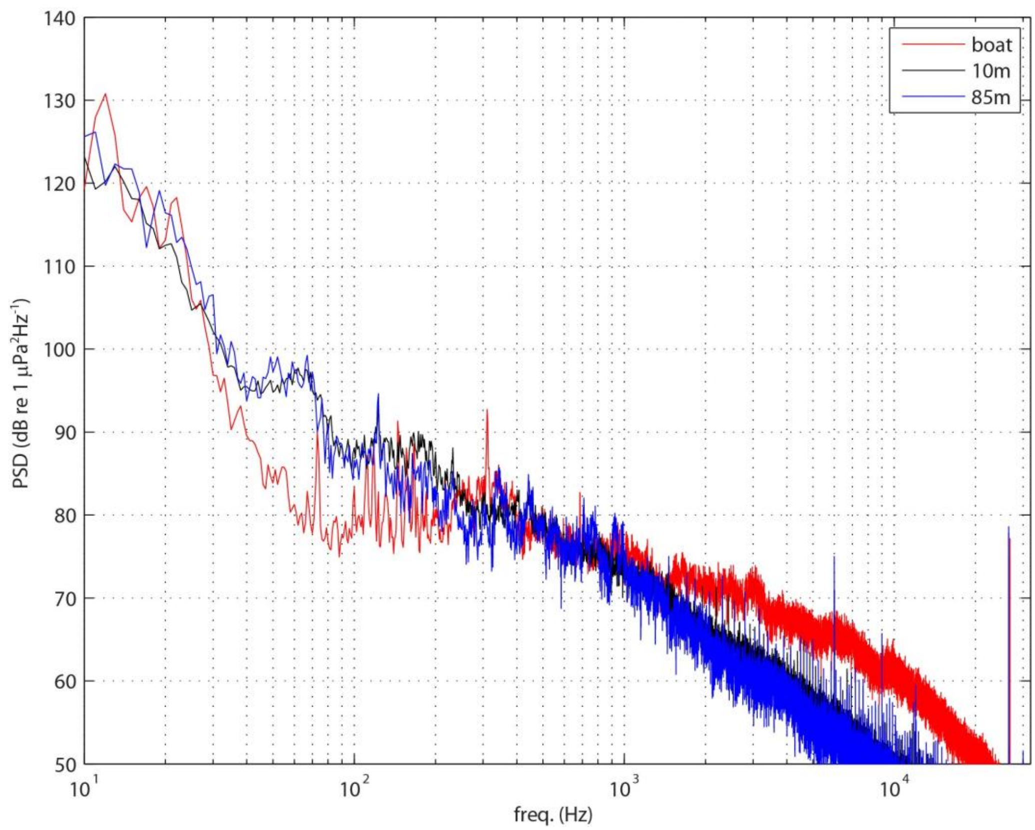

Figure 5. Power spectral density (PSD) estimates averaged over 30 seconds at 10 m (black) and 85 m (blue) distances from the WET-NZ wave energy converter. Also shown is a PSD from baseline data at the ocean test facility recorded on July 31, 2012 that includes noise from an approaching fishing vessel (red).

A comparison of time averaged acoustic energy levels and frequency structure from the WET-NZ device at distances of 10 m and 85 m averaged over 30 seconds is shown in figure 5. Time averaging effectively reduces the resolution of frequency modulations from the PSD estimates observed in figures 3 & 4. The power spectral density (PSD) estimate from the 10 m recording is on average slightly higher (~ 2-3 dB) than the 85 m recording as expected from attenuation and scattering during propagation from the WET-NZ device. A PSD from a recording made on July 31, 2012 using this system at the OTF site that includes nearby small boat traffic provides a reference for ambient levels during the WET-NZ test. Spectral levels diverge between the WET-NZ and boat recordings beginning around 30 Hz. Higher energy levels associated with the WET-NZ recordings in these lower frequencies are attributed to a difference in environmental conditions during recording and therefore levels of system noise. Spectral levels begin to converge again around 200 Hz with energy levels from the July 31, 2012 record exceeding both WET-NZ estimates in frequencies beyond 1 kHz.

PSD estimates from the 10 m and 85 m WET-NZ acoustic recordings are plotted with percentile distributions of ambient sound levels from year-long baseline recordings in figure 6. Percentile PSD distributions are calculated from 200 second averages of 1 second FFT windows during an entire year of recording at the OTF. The long-term acoustic recordings were made from a bottom mounted mooring system and autonomous hydrophone instrument package (*Haxel et al., 2011*). WET-NZ recorded levels are significantly higher than ambient levels from the long-term moored system in frequencies below 200 Hz. This is an artifact of the large discrepancies in system noise between the drifting and moored data acquisition techniques. In frequencies above 200 Hz, the WET-NZ recordings more closely approach long-term mean levels of ambient noise in the region.

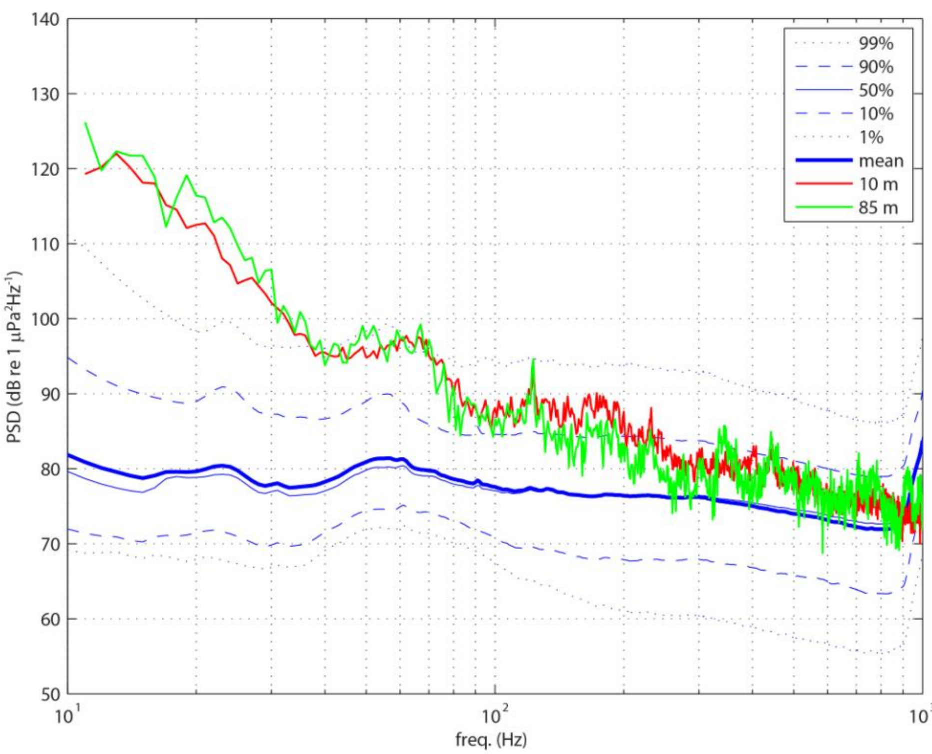

Figure 6. Percentile distributions of power spectral density (PSD) estimates from moored long-term acoustic measurements (Mar. 2010 – Apr. 2011) at the NNMREC/OSU ocean test facility. PSD's from recordings made at 10 m (red) and 85 m (green) distances to the WET-NZ test device on August 30, 2012.

Conclusions

Underwater sound pressure levels recorded at 10 m and 85 m from the WET-NZ wave energy converter at the NNMREC/OSU ocean test facility are below NMFS threshold criteria for marine mammal harassment (120 dB). The acoustic signature of the WET-NZ device has a modulated harmonic frequency structure most likely oscillating as a function of wave period. Although the free-drifting cabled hydrophone approach provides the capability for rapid acoustic data acquisition and assessment of sound pressure levels, it is severely limited in the lower frequency range (< 300 Hz) by system noise contamination. Long-term assessment of underwater acoustic impacts of WEC operations is best performed with moored instrumentation.

Acknowledgements

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