AMBIENT NOISE IN THE WESTERN ENGLISH CHANNEL: TEMPORAL VARIABILITY DUE TO SHIPPING AND BIOLOGICAL SOURCES

ND Merchant Department of Physics, University of Bath, Bath, UK
MJ Witt College of Life & Environmental Sciences, University of Exeter, UK
Ph Blondel Department of Physics, University of Bath, Bath, UK
BJ Godley College of Life & Environmental Sciences, University of Exeter, UK
GH Smith College of Engineering, Mathematics & Physical Sciences, University of Exeter, UK

1 INTRODUCTION

Marine Renewable Energy (MRE) will be a key asset in meeting the UK's 15% energy production target for renewable sources by 2020 [1]. To date, offshore wind energy has dominated the MRE sector, but wave and tidal energy extraction are rapidly developing on a global scale. Existing and proposed legislation [2] call for assessment of the potential effects of these activities on the marine environment, including disturbance due to noise. We present the first medium-term study of broadband ambient noise near the Falmouth Bay test site (FAB), UK, which will provide baseline data for the monitoring of future MRE activity.

2 METHODS

2.1 Deployment

Falmouth Bay (Fig. 1) is located at the western entrance to the English Channel, one of the busiest shipping channels in the world. The Harbour area and its immediate surroundings support a diverse range of species and habitats, a Habitat Directive listed site and the FAB test facility. For 20 days in July and August 2010, an Autonomous Multichannel Acoustic Recorder (AMAR; Jasco Applied Sciences Ltd) was deployed in the bay, 1.8 km offshore from Nare Head and near the South West Mooring Test Facility (SWMTF) operated by the Peninsula Research Institute for Marine Renewable Energy (PRIMaRE). The AMAR was programmed to record continuously in 30-minute blocks, using a GeoSpectrum M8E-132 hydrophone (effective bandwidth 5 Hz to 150 kHz) and sampling at 16 kHz. Hardware were deployed to the seabed (~30 m, sand/muddy sand) using a custom-fabricated frame containing an acoustically triggered pop-up buoy system and an archival CTD device recording at 5-second intervals.

2.2 Data Analysis

Acoustic data were calibrated via the hydrophone sensitivity (-165 dB re 1 V μPa^{-1}) and the AMAR pre-amplifier gain, then analysed with custom-written MATLAB scripts using parallel- and batch-processing techniques. The power spectrum density (PSD) was calculated using a 2-s Dirichlet window with 50% overlap for each 30-minute measurement. Data were then concatenated, downsampled, and converted to logarithmic units. Using a Dell R710 server with 2 quad-core 2.93-GHz processors and 72 GB of RAM, all 78 GB (472.5 hours) of data were processed in under 90 minutes. Twelve non-consecutive measurements were discarded due to anomalous bit rates. 165 short (< 1 s) bursts of system noise, with exceptionally high amplitudes below 10 Hz, were purged using a frequency-sensitive noise gate. Automated Identification System (AIS) shipping data were provided by Ian McConnell (ShipAIS.com). Hourly wind speed and rainfall data from Culdrose, 14 km to the west, were provided by the UK Met Office. Tides were derived from CTD data using the UNESCO equation [3], and agreed well with the National Oceanographic Centre POLPRED high-resolution UK CS20 model for the region (Licenses 23045/23418 to PRIMaRE).

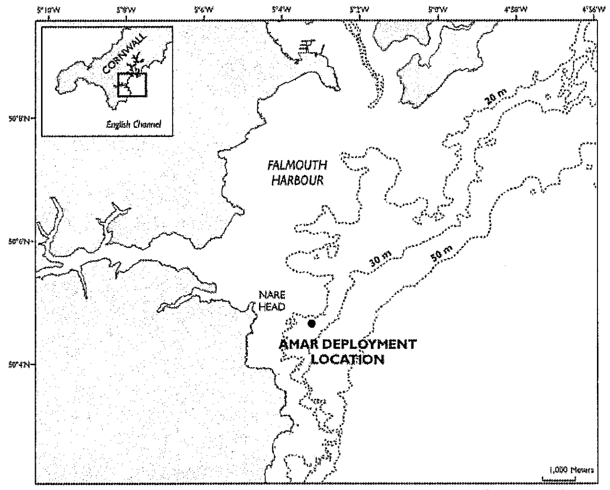

Figure 1: Deployment site. The AMAR device is located at 50° 4.7' N, 05° 3.0' W.

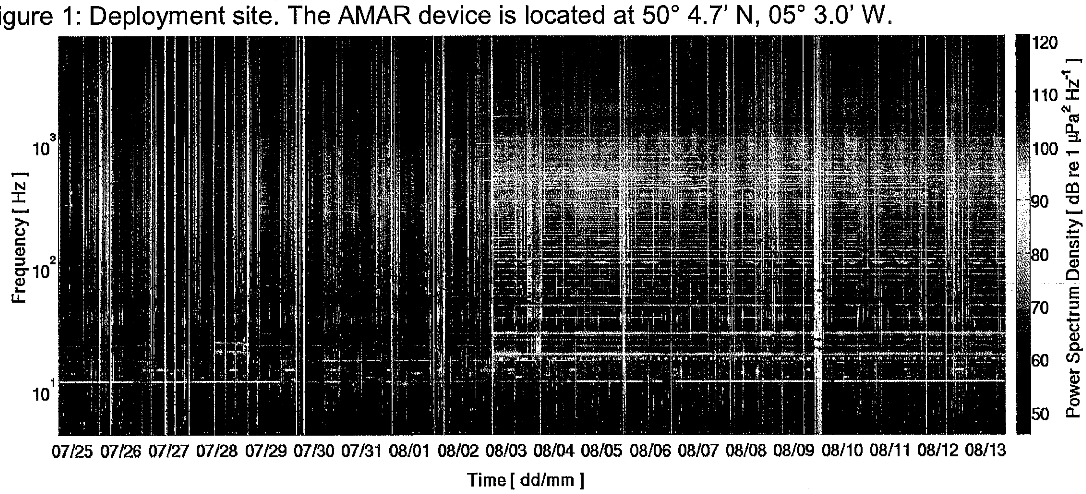

Figure 2: PSD from continuous monitoring at 16 kHz, downsampled to 15-minute resolution.

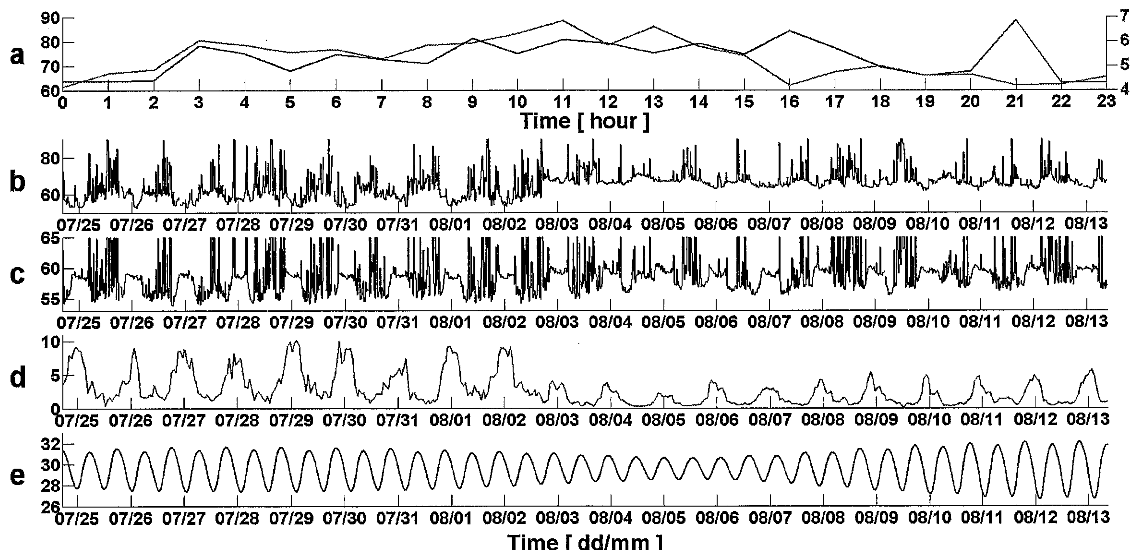

Figure 3: **a)** Blue: mean 24-hr sound pressure level (SPL) in range 5 Hz-2 kHz [dB re 1 µPa^2]; Red: mean 24-hr ship count within 10 km **b)** SPL, 5 Hz-2 kHz [dB re 1 µPa^2] **c)** SPL, 2-8 kHz [dB re 1 µPa^2] **d)** Number of impulses per second [s^{-1}] **e)** Hydrophone depth [m] (from CTD data)

3 RESULTS

The sound field is punctuated by wide bands of noise, some spanning the entire frequency range, forming periodic patterns (Fig. 2). Below 2 kHz, a diurnal trend is observed with maxima during daylight hours, broadly corresponding to the number of ships within a 10 km range (Fig. 3a, b). Anomalous peaks in the daily-averaged spectrum (Fig. 3a) at 16:00 and 21:00 (UTC) were identified as unusually loud ship transits (on 02/08 and 27/07, respectively) dominating the mean level. Above 2 kHz, the inverse is observed: diurnal periodicity with a raised noise floor during the night (Fig. 3c). Close examination of sample spectra indicates this high-frequency content, presumed biological [4], consists of impulsive sounds with peak frequencies around 5 kHz and durations < 2 ms. The rate of impulses was measured (Fig. 3d), where an impulse was defined as a spike > 12 dB and < 2 ms in the broadband level between 2 and 8 kHz. The noise floor above 2 kHz and the impulse detection rate agree strongly (Fig. 3c, d), though the low impulse rate during daylight hours could in part be due to masking by ship noise in this frequency range. [5] reported a correlation coefficient of 0.56 between wind speed and ambient noise in the range 200-400 Hz in coastal waters. Based on hourly 1/3 octave band levels, the correlation coefficients in the 375-Hz band are 0.24 (mean wind speed) and 0.32 (maximum gust speed), with maxima in the 1500-Hz band of 0.36 and 0.44, respectively. The high volume of shipping traffic may contribute to a diminished correlation at low frequencies. No prevalent tidal dependence is apparent (Fig. 3e), though negative correlation is observed above 1 kHz with a maximum of -0.45 in the 3750-Hz band. A single ship signature features persistently from 02/08 onwards (Fig. 2), identified from AIS data as a tug. Its spectral components above 2 kHz significantly reduce the impulse detection rate (Fig. 3d).

4 DISCUSSION AND CONCLUSIONS

Diurnal periodicity dominates any correlation to tidal cycles throughout the observed bandwidth. Shipping noise is predominant below 2 kHz; AIS data indicates its diurnal periodicity is attributable to local traffic (< 10 km from the deployment location). Above 2 kHz, impulsive noise, which is more frequent during the night, prevails. Further work is needed to confirm its presumed biological source. The results demonstrate some of the advantages of continuous noise monitoring, especially when coupled to high-resolution supplementary data (AIS, weather and tides). Noise levels averaged from continuous measurements are more reliable than figures derived from short, widely spaced samples, especially in temporally dynamic coastal areas. This study and ongoing deployments provide robust baseline acoustic data for this site, and contribute to the development of noise assessment methodologies relevant to MRE sites worldwide.

5 ACKNOWLEDGEMENTS

NDM is funded by an EPSRC Doctoral Training Award (#EP/P505399/1). MJW is a PRIMaRE Research Fellow. BJG and GHS are funded by PRIMaRE and the South West Regional Development Agency. We thank L. Johanning, D. Parish and D. Raymond for technical assistance and access to the SWMTF, and Falmouth Harbour Commissioners for their continued support.

6 REFERENCES

1. DECC, The UK Renewable Energy Strategy. (2009).
2. HMSO, UK Marine Policy Statement. (March 2011).
3. Fofonoff, N.P., and R. C. Millard Jr., UNESCO Tech. Papers in Mar. Sci. 44, p. 53. (1983).
4. Finfer, D.C., et al., On clicking sounds in UK waters and a preliminary study of their possible biological origin, Proc. Institute of Acoustics 23 (3), pp. 209-216. (2007).
5. Curtis, K.R., et al., 'Low-frequency ambient sound in the North Pacific: Long time series observations', J. Acoust. Soc. Am. 106 (6), pp. 3189-3200. (1999).