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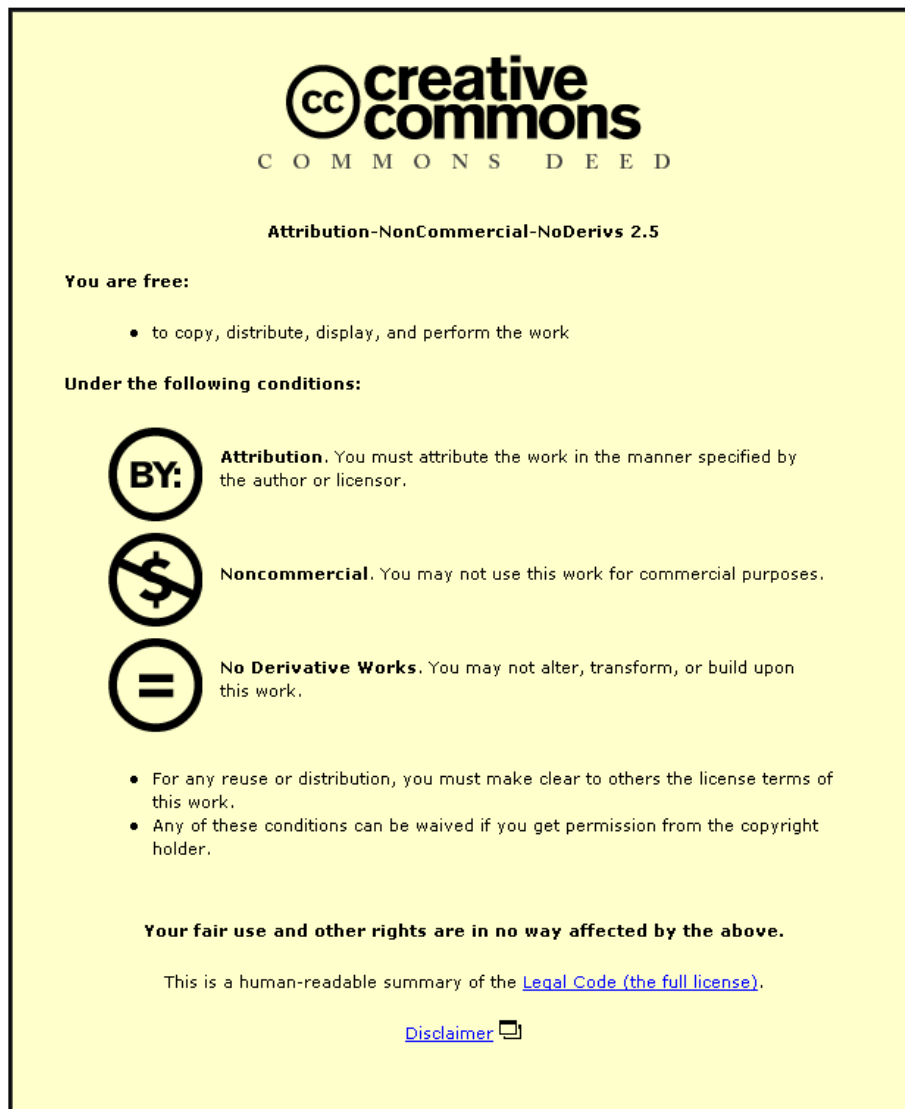
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Underwater noise measurement of dredging vessels during aggregate extraction operations

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Extraction of marine aggregates in UK waters can exceed 20 million tonnes each year, with dredging activity taking place at any given point in time within the licensed areas. There is concern that the noise generated during the extraction of this aggregate has the potential to negatively impact marine species in or around the dredging area. For aggregate extraction, the type of vessel used is a trailing suction hopper dredger, which lowers a drag head and suction pipe to the sea floor to extract the sand or gravel, depositing it in a hopper on the vessel, whilst returning unwanted material and water over the side of the vessel. The potential sound sources during this type of dredging activity are numerous and this paper considers some initial results of a series of systematic noise measurements performed in shallow UK coastal waters of a large dredging vessel, under different operating configurations. The measurements are performed in such a way as to allow propagation loss and the source level to be estimated. The provisional results are compared to background noise measurements performed in the area in the absence of the dredging operations and will ultimately be used to assess the impact of the radiated noise on marine life.

1 Introduction

Marine aggregate extraction is the dredging of sand and gravel from the seabed, specifically used in the building and construction industry. It is vital to UK industry with marine aggregate accounting for 19% of sand and gravel sales in England and 46% in Wales. The area of seabed dredged in 2008 was 137.9 km², with over 20 million tonnes of sand and gravel typically extracted per year in licensed areas around UK waters [1]. When considering the licensing of areas, the potential impact on the environment is considered and underwater noise is one way which can potentially impact the marine life. The assessment of underwater noise has been of increasing importance in recent years with the increase of marine construction associated with windfarms [2-6]. This has also coincided with a raised awareness for underwater noise from shipping and other marine activities and its potential for impact on marine life, leading to the recent development of impact criteria [7]. However, consideration of the noise radiated during marine aggregate extraction operations has been limited, particularly in UK waters, with the most extensive measurements being undertaken in the Beaufort Sea during oil exploration in the 1980's [8-10]. Other measurements have been undertaken in the literature around Sakhalin Island, which were compared by Ainslie et al. [11] to other vessels including the Overseas Harriette measured by Arveson and Vendittis [12]. Much of this work indicates that these type of dredging activities generate noise levels which are dominant in the lower frequency regions, with levels comparable to those of a large cargo carrier whilst underway. The type of vessel used for marine aggregate extraction, particularly in the

UK, is the trailing suction hopper dredger (TSHD). This type of dredger lowers a drag head and suction pipe to the sea floor, in water depths of up to 50 m, to extract the sand or gravel, depositing it in a hopper on the vessel for dockside unloading. The vessel will often screen the dredged material for granular size and return the unwanted material and water over the side of the vessel. Such an operation can take anything from as little as 3 hours to anything up to 12 hours, concentrated to a relatively small area. The vessels measured during the studies in the Beaufort Sea were of a different type to the TSHD used in the UK and those around Sakhalin Island were for a much larger vessel. The vessels used in the UK are generally smaller. This paper reports some initial results from measurements of one of the largest trailing suction hopper dredger vessels in the UK fleet, the *Sand Falcon* (Cemex UK), and considers the noise it generates under different operating conditions.

2 Underwater noise sources from marine aggregate extraction operations

The *Sand Falcon* (Cemex UK) measured during this study is a 120 m long vessel with a 5000 m³ cargo capacity, capable of drawing 2600 tonnes per hour from the seabed at depths of up to 50 m. To do this, the vessel employs both an onboard pump and an overboard pump which is positioned along the suction pipe, whilst pulling the drag-head along the seabed at speeds of around 1.5 knots. The potential sound sources during this type of activity are numerous and their relative contributions to the overall noise are generally unknown. Due to the suction pipe, overboard pump, drag head, and the return of high volumes

of excess water from the vessels hopper over the sides from both spillways and screening towers, the noise generated by this type of vessel is very different from that of conventional vessel. Even though their transit speed is very slow whilst dredging, other dredging vessels have been shown to generate third-octave source levels at lower frequencies that are comparable to larger tankers and cargo vessels whilst underway at speed Ainslie et al. [11] and Richardson et al. [10].

The possible source mechanisms for a TSHD vessel whilst dredging will include propeller (very low speed) and thruster noise, general radiated hull noise (this could include internal pumps) which are common to other surface vessels. However, drag head noise, overboard pump noise, suction pipe noise and water and sediment discharge noise are potential sources of underwater noise which are unique to this type of dredging vessel and could radiate sound into the water at higher frequencies than those normally associated with surface vessels. The water and sediment discharge has the potential to generate bubbles in the water and therefore broadband noise. The suction pipe and overboard pump also have the potential to generate broadband noise through friction and cavitation respectively. It is also possible that vibrations in the seabed are generated by the action of the draghead.

3 Measurement of radiated underwater noise

3.1 Measurement methodology

To assess the noise radiated by the *Sand Falcon*, hydrophone measurements were performed at 3 distances from the vessels position. These were arranged along a transect which ran perpendicular to the track of the vessel, at distances of i) less than 50 m, ii) approximately 100 m and iii) at 500 m. As the dredging vessel runs up and down along the same lane, with a lane length of around 1.5 km, this arrangement allowed multiple measurements of both port and starboard sides of the vessel. To help identify the sources of radiated noise generated by the vessel, the *Sand Falcon* lifted its draghead on one pass and then turned off its pumps on another pass. With the draghead raised, the vessel still pumps water up the suction pipe and returns it over side (see Figure 1) so all other noise sources should remain the same. With the pumps switched off, the dredger still dragged its draghead along the seabed but with no aggregate passing up the suction pipe.



Figure 1 *Sand Falcon* whilst pumping water only (draghead raised)

The static measurement locations were provided by noise monitoring buoys at the < 50 m and 500 m positions, and by a survey vessel anchored at the 100 m position. The use of buoys provided range dependent measurement points without the time dependent variability introduced by the use of a mobile survey vessel. The position of the buoys and measurement vessel were marked using GPS whilst the complete track for the dredging vessel, the *Sand Falcon* was provided by the vessel operators, Cemex UK, for the entire duration of dredging.

The survey vessel was also used to deploy a broadband acoustic measurement system and a CTD to determine the sound speed profile.

3.2 Measurement equipment

The acoustic measurement system deployed from the survey vessel consisted of two Reson TC4032 low noise hydrophones suspended from an anti-heave buoy to reduce the low frequency influence of the wave motion. This decoupler used a bungee cord strung from a surface float, to pull on a sub-surface disc type damper, from which the weighted hydrophone arrangement was suspended. The water depth was approximately 30 m and the hydrophones were each at a depth of around 6.5 m and 10 m. The hydrophones were attached to a B&K Pulse system and sampled with a 24-bit resolution at a sample rate of 262 kS/s on each channel, providing a measurement bandwidth of around 131 kHz. The hydrophones were deployed throughout the measurement period for around 6 hours whilst the survey vessel was anchored and silent. The tidal flow peaked at around 3 knots during the measurements and although some of the measurements were performed over a slack tide, local conditions resulted in relatively high flow conditions even around this time. The sea-state was relatively flat during the measurements at around Force 2. The water temperature was measured, using the CTD, to be approximately 4.6 °C and showed negligible change over a depth of 20 m.

The static noise measurement buoys, designed and manufactured by Loughborough University, UK, were anchored to the sea floor in approximately 30 m of water

and were each equipped with two SRD H70 hydrophones at approximately 5 m and 10 m from the seabed. These hydrophones were attached to a sub-surface recording unit which sampled the data with a 16-bit resolution at a rate of 96 kS/s on each channel, providing a measurement bandwidth of 48 kHz. These buoys were deployed and measured for around 6 hours. The use of both a sub-surface float for the hydrophones and a separate surface pick-up buoy for the anchor provided measurements which were decoupled from surface wave motion and surface tidal effects.

4 Initial measurement results

The data gathered were extensive and so only a small sample of the data is analysed here and provide only initial observations from the measurements. Given that full analysis has not been completed at this stage in the project, only the receive level data from the survey vessel are presented, with source level data having not been validated at this time. To assess the characteristics of the noise generated by the dredging activity, the receive levels are shown (see Figure 2) for the different operational conditions of the *Sand Falcon* compared with an ambient noise measurement. These are presented in the one-third octave bands (TOB) as specified by ISO and IEC [13-14] with the spectral levels being calculated using the method outlined in the ANSI standard S1.1-1986 [15]. These are for full dredging (sucking sand and gravel from the seabed and up the suction pipe), pumping only water (with drag head lifted but all pumps still running), no pumping but still dragging the draghead along the seabed (inboard and overboard pumps off). Several ambient noise measurements were also performed on the following day once the *Sand Falcon* had left the area and one of these, selected arbitrarily, is included in Figure 2 for comparison.

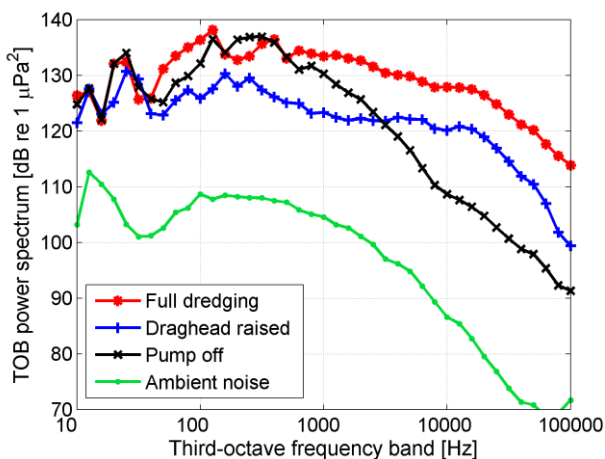


Figure 2 Third-octave band power spectra for received levels measured at approximate 100 m from the *Sand Falcon* whilst varying operational conditions.

The results shown in Figure 2 are for when the *Sand Falcon* was at its position of approximate closest approach

to the survey vessel and are taken using approximately 90 seconds of data in each case, except for the background noise which was from 20 seconds of measurement data. These were measured from the survey vessel using the shallower of the two Reson TC4032 hydrophones. The data clearly shows a difference in the higher frequency noise levels (above 1 kHz) with full dredging approaching levels that are 10 dB higher above 2 kHz when compared with pumping water only or dragging the drag head with no pumping. The overall level of the 'draghead raised' data, which could be due to other factors, is slightly lower overall. Although this has not been fully analysed, this initial data does indicate that the effect of the sand and gravel passing through the suction pipe and pump do contribute some higher frequency noise. It should be noted that dragging the draghead with no pumping is not an actual operational state for dredging activities and was done as part of this exercise to help identify the different source which contribute to the spectra.

The same data is also presented as a power spectral density using narrow band analysis (see Figure 3). This was obtained using a Welch average method [16] with a 1 Hz analysis window and 357 averages. This shows some lower frequency tonal components in the Figure 3 spectra which could be associated with the *Sand Falcon* propeller, although given the slow speed whilst dredging, the blade rate would be expected to be relatively low when compared to other large vessels. There are additional tonal components between around 200 Hz and 2 kHz which were only present when the pump was on. When the pump is off, the higher frequencies also seem to drop off more rapidly indicating that the pump could be a dominant contributor to the higher frequency radiated noise.

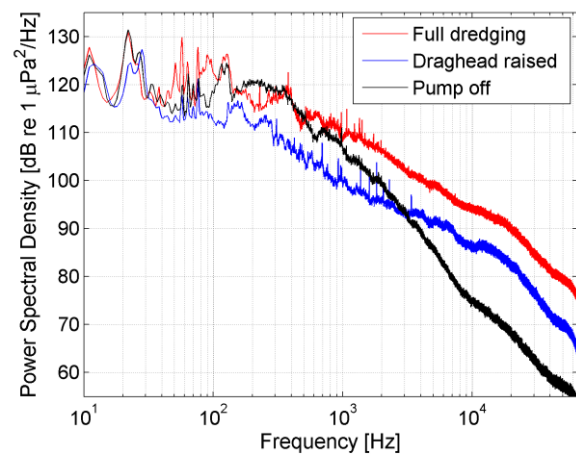


Figure 3 Power spectral density spectra for received levels measured at approximate 100 m from the *Sand Falcon* whilst varying operational conditions.

Figure 4 shows the power spectral density spectrogram of time plotted against frequency for the point where the draghead was lowered back down to the seabed to resume full dredging. This occurred after the *Sand Falcon* had passed the survey vessel (i.e. stern on) and so distance and directionality might influence the results to some extent.

On the plot shown in Figure 4, the draghead was lowered at just around 100 s where an increase in the higher frequency levels (particularly above 60 kHz) can be observed from the increased yellow content. In Figure 4, before 100 s, the *Sand Falcon* is pumping only water and is full dredging after 100 s when the draghead is lowered. When full dredging, some structure can be observed with time which is not evident before the draghead is lowered. It is not clear at this early stage if this effect is due to the source or due to propagation. It should be noted that with the draghead on the seabed, the source characteristics can be influenced by either the physical effect of it being dragged along the seabed, or from the contribution of sand and gravel travelling up the suction pipe.

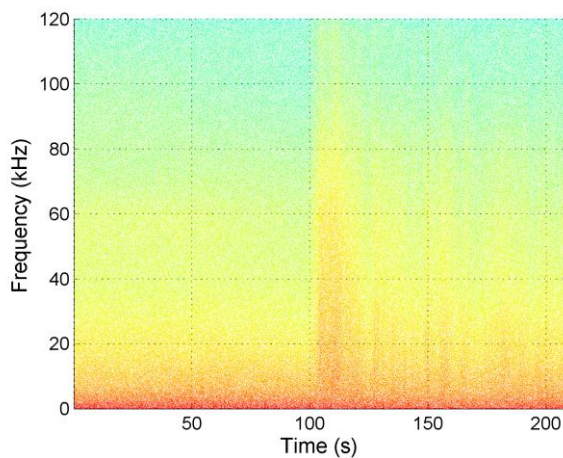


Figure 4 Power spectral density spectrogram showing the noise characteristics of the draghead both raised (pumping only water) and lowered (on sea-bed pumping sand and gravel)

Figure 5 shows the power spectral density spectrogram of time plotted against frequency for the point when the pumps were turned off. This occurred before the *Sand Falcon* reached the survey vessel (i.e. bow on) and so again, the distance and directionality could influence the results. The pumps were turned off at around 120 seconds on the time scale shown in Figure 5, where there is a drop in the level of the higher frequency components above a few kilohertz. Before this 120 s point, the *Sand Falcon* is full dredging and after the 120 s, it is dragging the drag head only with no material or water being pulled through the suction pipe. There appears to be some variation with time at the higher frequencies whilst the pump is. The reason for this is unknown but it could be due to changes in the pump operation or changes in the material being extracted up the suction pipe. It should also be noted that the overboard pump is positioned at around one-third depth in the water column and so it could be a propagation/interference effect.

It should be remembered when comparing the results between Figure 4 and 5 that the *Sand Falcon* position relative to the survey vessel was different and are also plotted on a relative scale.

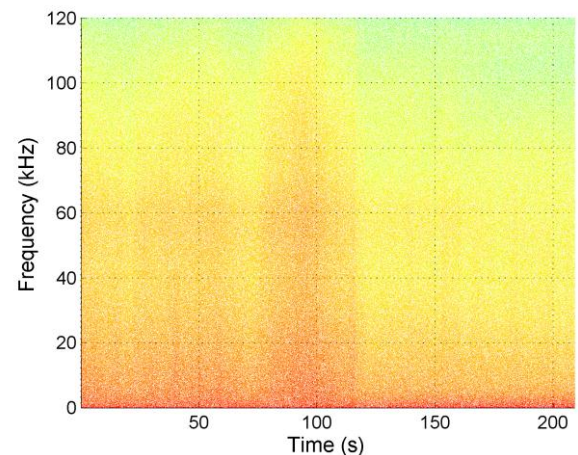


Figure 5 Power spectral density spectrogram showing the noise characteristics with the pumps on and off (but still dragging the draghead along the seabed)

5 Conclusions

A comprehensive set of acoustic measurements have been completed of the underwater noise radiated from a large trailing suction hopper dredger, the *Sand Falcon*, in shallow UK coastal waters whilst extracting sand and gravel from the seabed. Initial analysis of the receive level data in third octave-bands shows significant variation between operational dredger conditions at higher frequencies, which also indicates that the sand and gravel passing through the suction pipe and pump contributes to the noise source at frequencies above. Further narrow band spectral analysis also indicate that the pump radiates at higher frequencies with tonal components generated between around 200 Hz and 2 kHz. The higher frequency levels above this also drop off more rapidly when the pump is off. The overall peak levels however do occur below a few hundred Hz and are consistent with other vessel noise. Further analysis is required and ultimately, source levels should be established so that true comparisons can be made.

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References

- [1] The Crown Estate/BMAPA, Marine aggregate dredging 2008 – The area involved – 11th Annual report (2009)
- [2] P. T. Madsen, M. Wahlberg, J. Tougaard, K. Lucke, P. Tyack, “Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs” *Marine ecology progress series*, 309, 279-295 (2006)
- [3] R. B. Rodkin and J. A. Reyff, “Underwater sound pressures from marine pile-driving”, *J. Acoust. Soc. Am.*, 116, 2648 (2004)
- [4] P. A. Lepper, S. P. Robinson, J. Ablitt and S. Dible, “Temporal and Spectral Characteristics of a Marine Piling Operation in Shallow Water” *Proc. NAG/DAGA Int. Conference on Acoustics*, 266-268, Rotterdam, (2009)
- [5] S. P. Robinson, P. A. Lepper, J. Ablitt, G. Hayman, G. A. Beamiss, P. D. Theobald and S. Dible, “A methodology for the measurement of radiated noise from marine piling”. *Proceedings of the 3rd International Conference & Exhibition on "Underwater Acoustic Measurements: Technologies & Results"*, Napfion, Greece, ISBN; 978-960-98883-4-9 (2009).
- [6] J. D. Nedwell, J. Langworthy & D. Howell, “Assessment of sub sea acoustic noise and vibration from offshore wind turbines and its impact on marine life”, COWRIE Rep. 544 R 0424:1-68 (2003)
- [7] B. L. Southall, A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, and P. L. Tyack, " Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations", *Aquatic Mammals*, 33, 411-509, Number 4 (2007)
- [8] C. R. Greene, “Characteristics of oil industry dredge and drilling sounds in Beaufort Sea”, *J. Acoust. Soc. Am.*, 82, 1315-1324 (1987)
- [9] W. J. Richardson, B. Würsig, C. R. Greene, "Reactions of Bowhead Whales, *Balaena mysticetus*, to Drilling and Dredging Noise in the Canadian Beaufort Sea", *Marine Environmental Research*, 29, 135-160 (1990)
- [10] W. J. Richardson, C. R. J. Greene, C. I. Malme and D. D. Thomson, “*Marine mammals and noise*”. San Diego: Academic Press (1995)
- [11] M. A. Ainslie, C. A. F. de Jong, H. S. Dol, G. Blacquièrre, and C. Marasini “*Assessment of natural and anthropogenic sound sources and acoustic propagation in the North Sea*”, TNO Report TNO-DV 2009 C085 (2009)
- [12] P. T. Arveson and D J Vendittis, “Radiated noise characteristics of a modern cargo ship”, *J. Acoust. Soc. Am.*, 107, 118 – 129 (2009)
- [13] ISO 266:1997. Acoustics -- Preferred frequencies (2008)
- [14] IEC 61260 Ed. 1.0 b:1995 Electroacoustics - Octave-band and fractional-octave-band filters (2005)
- [15] ANSI S1.1-1986 (ASA 65-1986): Specifications for Octave-Band and Fractional-Octave-Band Analog and Digital Filters, Acoustical Society of America, NY, (1993)
- [16] F. J. Harris, "On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform." *Proceedings of the IEEE.*, 66 (1978).