THE MEASUREMENT OF UNDERWATER NOISE RADIATED BY DREDGING VESSELS DURING AGGREGATE EXTRACTION OPERATIONS

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Abstract: *The total marine aggregate extracted from the seabed in UK waters can exceed 20 million tonnes each year, and there is a need to understand the noise generated during the extraction process in order to evaluate any potential impact on the marine environment. 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. There are a number of potential noise generation mechanisms during this type of dredging activity. This paper presents the results of underwater noise measurements for six different dredgers measured in three locations around the UK, with aggregate type varying from sand to coarse gravel. One vessel was measured in two different areas with different aggregate types. The methodology used to derive the source level for the dredgers is described, and the results of an investigation undertaken into the origin of the radiated noise is given. Measurements were made at frequencies up to 100 kHz. Noise levels are shown for the same dredger under different operational modes, illustrating that the noise output level is partially dependent upon the mode of operation and the aggregate type being extracted.*

Keywords: *source level, noise, dredging, ANSI S12.64.*

1. INTRODUCTION

Around 20 million tonnes of sand and gravel is extracted from licensed areas of the seabed around UK coastal waters each year for use in the construction and building industry [1]. It is of vital importance to both UK and continental industry, accounting for around 20% of sand and gravel sales in England and Wales, with around a one third of the extraction being exported to France, the Netherlands and Belgian [2]. The potential impact this activity has on the environment (and the seabed) is considered as part of the licensing process and underwater sound is one of the mechanisms which could potentially have an impact on marine fauna [3]. The assessment of underwater noise has been of increasing importance in recent years with the rapid increase of marine construction associated with wind farms [4-8]. This has also coincided with a raised awareness for underwater noise from shipping and other marine activities and the potential it has for impact on marine life, leading to the recent development of impact criteria [9]. 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 [10,11]. Other measurements have been undertaken in the literature around Sakhalin Island, which were compared by Ainslie et al. [12] to other vessels including the Overseas Harriette [13]. This paper reports some noise measurements of a number of UK dredging vessels which form part of the UK's marine aggregate extraction fleet.

2. MARINE AGGREGATE EXTRACTION OPERATIONS

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, with the vessels typically operating at speeds of around 1.5 knots.

Noise measurements were performed on six of the TSHD vessels from the UK's fleet, across three different coastal areas of the UK. One of the vessels, the Sand Falcon, was measured in two of the three areas considered during this study. One of the areas where the Sand Falcon was measured contained gravel rather than sand. Two other vessels were also measured in this gravelly area (City of Westminster and City of London). The aggregate type has implications for the noise levels/characteristics generated.

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 potentially different from that of conventional surface vessel.

The possible source mechanisms for a TSHD vessel whilst dredging include propeller (very low speed) and thruster noise, general radiated hull noise which are common to other surface vessels. However, drag head noise, overboard/inboard 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.

3. MEASUREMENT OF RADIATED UNDERWATER NOISE

For each vessel, hydrophone measurements were performed as a function of range from the TSHD vessel, at between 2 and 4 positions along a transect normal to the track of the vessel. These ranges varied for each vessel measured but typically did not exceed 1 km and were not less than 100 m for the estimation of source level (although closer ranges were measured for source characterisation purposes).

To extract aggregate, the TSHD vessel runs up and down along the same dredging lane, which has a lane length of around 1.5 km, with only limited lateral deviation. This dredging pattern allowed repeat measurements of each vessel, in some cases of both port and starboard sides of the vessel. To help identify the sources of noise generated by the vessels, different operational characteristics were used on some passes. This included lifting the draghead to pump only water during one pass and then turning off the pump with the draghead down on the seabed during another pass. In the first case, with the draghead raised, the vessel still pumps water up the suction pipe and returns it over side so all other noise sources should remain the same. In the second case, with the pumps switched off, the dredger still dragged its draghead along the seabed but with no aggregate passing up the suction pipe.

The measurement positions along the transect were obtained using a combination of bottom mounted noise monitoring systems and hydrophones deployed from an anchored survey vessel. The use of multiple measurement positions provided range dependent measurement points without the time dependent variability introduced by the use of a mobile survey vessel. The position of the bottom mounted systems and the survey vessel were marked using GPS whilst the complete track for the TSHD vessel was recorded by the vessel operators, using the onboard Electronic Monitoring System (EMS), for the entire duration of dredging. The survey vessel was also used to deploy a CTD to determine the sound speed profile and a vertical hydrophone array to provide source characteristic/positional information, which is further considered by Wang *et al* [14]. The TSHD is a relatively complex sound source, with a pump, suction pipe and draghead in the water column, along with water overspills, in addition to any hull/propeller noise normally associated with surface vessels.

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 de-coupler 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 typically 25-35 m and the hydrophones were each at a depth of at least 6.5 m and at least 10 m, depending on the water depth at each site. 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 survey duration (around 3 to 6 hours) whilst the survey vessel was anchored and silent. The static noise measurement systems, designed and manufactured by Loughborough University, UK, were anchored to the sea floor 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 also deployed and measured for entire survey duration. 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. All the hydrophones were calibrated over their entire frequency range of use at the UK's National Physical Laboratory with traceability to international standards.

4. MEASUREMENT RESULTS

To assess the characteristics of the noise generated by the dredging activity, some received levels are shown (see Fig. 1) for different operational conditions of the Sand Falcon. These are full dredging (sucking sand and gravel from the seabed), pumping water only (with drag head lifted but all pumps still running), pumps off but still dragging the draghead (pumps off with the draghead on the seabed). Ambient noise measurements were also performed on the following day once the Sand Falcon has left the area and these are also included in Fig. 1.

The results shown in Fig. 1 are for the Sand Falcon at its position of closest approach to the survey vessel for each pass, measured 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 20 dB higher above 16 kHz when compared with pumping water only or dragging the drag head with no pumping. This does indicate that the aggregate passing through the suction pipe and pump is a significant contributor to the higher frequency noise.

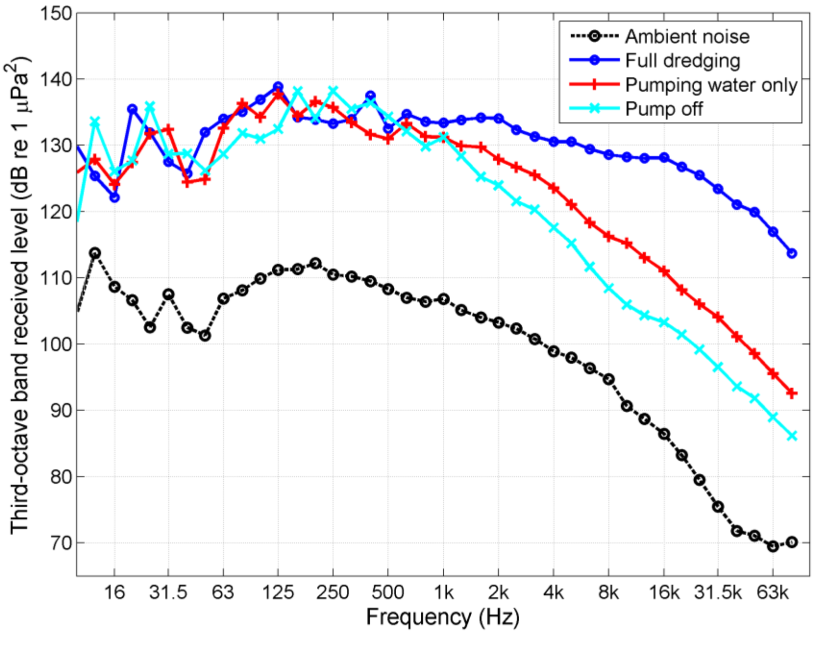

Fig. 1: Third-octave band received levels of the Sand Falcon at approximately 100 m range plotted against ambient noise measured in the area.

The source levels for each vessel were calculated for each receiver position (at a specific depth) using a propagation loss model based on the source-image approach (the implementation of which is referred to as ImTL in this paper) which models the sound field of a source as the sum of the acoustic radiation from the source and a series of images of the source reflected in the medium boundaries: in this case, the water surface and seabed [15]. The source is modelled as an ideal point source. Running the model for each of the source-receiver combinations, for each vessel pass, for the environment which existed during the measurement, allowed an average monopole source level to be obtained for each vessel, based on a source depth of 4 m (this was based on typical propeller depths for the range of vessels measured). For consistency with ANSI S12.64 [16], the source levels were converted from monopole to dipole or "affected" source levels using the conversion method described by Ainslie [17]. These third-octave band dipole source levels for each TSHD vessel measured are shown in Fig. 2. Further detail on the calculation of source levels is provided in the MALSF report [18].

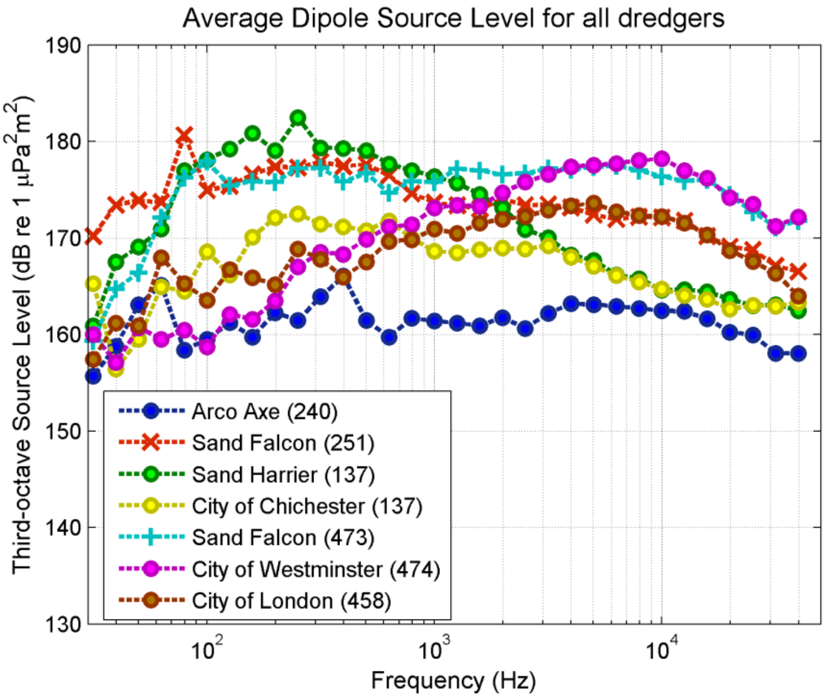

Fig.2: Dipole or "affected" third-octave band source levels calculated for all the TSHD vessels measured.

There is considerable variation between the individual vessels at frequencies less than 500 Hz, with the Sand Falcon and Sand Harrier being the noisiest. The Arco Axe appears to be the quietest vessel and is the only measured vessel to employ a Kort nozzle type propulsion system. Overall, there appears to be a higher level of broadband noise at higher frequencies (5 kHz to 40 kHz) than would normally be expected for a surface vessel operating at slow speeds (typical; speeds during dredging being about 1.5 knots). The appearance of such high frequency signals is normally associated with the onset of propeller cavitation, which is normally only seen at higher speeds. This feature is particularly prominent for the vessels measured in the gravelly area: Sand Falcon (Area 473), City of Westminster (Area 474) and City of London (Area 458). The Sand Falcon when measured in an area with gravel rather than sand, exhibited higher third-octave band source levels at higher frequencies than it did for sand, even though the lower frequency levels below 1 kHz are comparable in both areas. This supports the findings discussed for Fig. 1 and indicates that the aggregate being dredged influences the high frequency noise generated during extraction. At lower frequencies, the TSHD vessels have source levels which are comparable to those presented in the literature for the cargo vessel Overseas Harriette at modest speed [13].

5. CONCLUSIONS

The dipole source levels of six TSHD vessels operating in UK waters were measured across three regions around the UK's coast. One vessel, the Sand Falcon, was measured twice, once in an area dredging sand, and once in an area dredging gravel. The measurements from all the vessels show that the source levels for a TSHD vessel at frequencies below 500 Hz are generally in line with those expected for a cargo ship travelling at modest speed (between 8 and 16 knots for the Overseas Harriette) whilst source levels at frequencies above 1 kHz show elevated levels of broadband noise generated by the aggregate extraction process. Based on measurements of the Sand Falcon in two different areas, it was also found that the elevated broadband noise is dependent on the aggregate type being extracted – coarse gravel generating higher noise levels than sand.

6. ACKNOWLEDGEMENTS

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