Acoustic Environmental Monitoring

International Centre for Island Technology

REPORT No. 2012/01/AQ

Wello Penguin Cooling System Noise Study

Cover Image: Wello Penguin wave energy converter device moored at Lyness pier on the date of study (from port side) - 7th December 2011 (R. Beharie).

REPORT No. 2012/01/AQ

Citation: Beharie, R. and Side, J., (2012) "*Acoustic Environmental Monitoring – Wello Penguin Cooling System Noise Study*." A report commissioned by Aquatera Limited. International Centre for Island Technology, Report No. 2012/01/AQ.

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ISSUE No.: 1 (30 Jan 2012)

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EXECUTIVE SUMMARY

The study examined the underwater sound pressure levels produced by the Wello Penguin's cooling system. The measured sound pressure levels suggest a source level of 140.5dBrms re 1μPa at 1m. Significant narrowband harmonics are evident generally at low frequencies although it is expected that ambient background noise levels to be reached within approximately 10m from the device. There was a degree of directionality of sound production due to the position of the equipment within the hull.

Airborne noise could not be examined due to the generator used to power the device but found to be unlikely to have any ecological impact when access hatches are normally shut during operation.

1. INTRODUCTION

This study details the underwater sound pressure levels produced by the Wello Penguin cooling system, consisting of two cooling fans and one pump operating continuously at full speed during the survey. The device was moored towards the Southern end of Lyness Wharf on the Island of Hoy in Orkney (see appendix B).

The ecology within the Orkney archipelago includes common and grey seal colonies mainly on uninhabited islands nearby but can also 'haul out' in isolated bays and rocky skerries throughout all the islands. Other mammals that have been recorded are White beaked dolphins, Harbour porpoise, and Minke whales. Pods of Orca (Killer whales) have also passed though Orkney waters in summer months. (Obis-Seamap, 2011). No marine mammals were observed or detected during the study although one Phalacrocorax carbo (Cormorant) was seen diving near to the device and the south end of the pier during the study.

Due to limitations on the local grid electricity supply on the pier, a diesel generator was positioned adjacent to the device to supply the required power to operate the cooling system (explained by Wello personnel on site). Operating during most of the survey airborne sound measurements were also taken of the generator. The cooling system noise could only be heard above the generator noise when next to either of the two open access hatches on deck (personal observation).

When conducting background underwater sound pressure levels all systems and equipment were turned off whilst also establishing that there were no movements of nearby shipping. At the time of the study two Pelamis P2 WEC devices were moored at the northern tip of Golden Wharf with the front ends of the other devices approximately 230 m from the Wello Penguin. As there were no personnel present it is assumed these were not producing any underwater sound sources. A passenger/vehicles ferry operates from the southern side of Lyness Wharf running to a scheduled timetable and featured in some recordings as well as two other small craft (see Appendix D).

Description of the Wello Penguin.

The penguin wave energy converter has a unique shape that is designed to react to waves in a pitching and rolling movement. This induces the asymmetrical weight inside the hull to rotate at the same frequency of the interacting waves. To help described the positions of the study points we can describe the unconventional shape as having a pointed end or 'beak' (bow) and a flat rear end (stern). The orientation of the device at the mooring was approximately bow facing south and stern to the north with the starboard side to the quay. Aligned north-south the port side is straighter than the rounded starboard side (see figure 1 below).

The cooling system evaluated in this study consists of two fans and one pump. On fan is positioned on the starboard side and one on the port side, adjacent to the main generator position, approximately amidships in the hull. The fans are each mounted within the fore bulkhead of the main generator room whilst the pump is mounted near to the port side of the hull within the generator room.

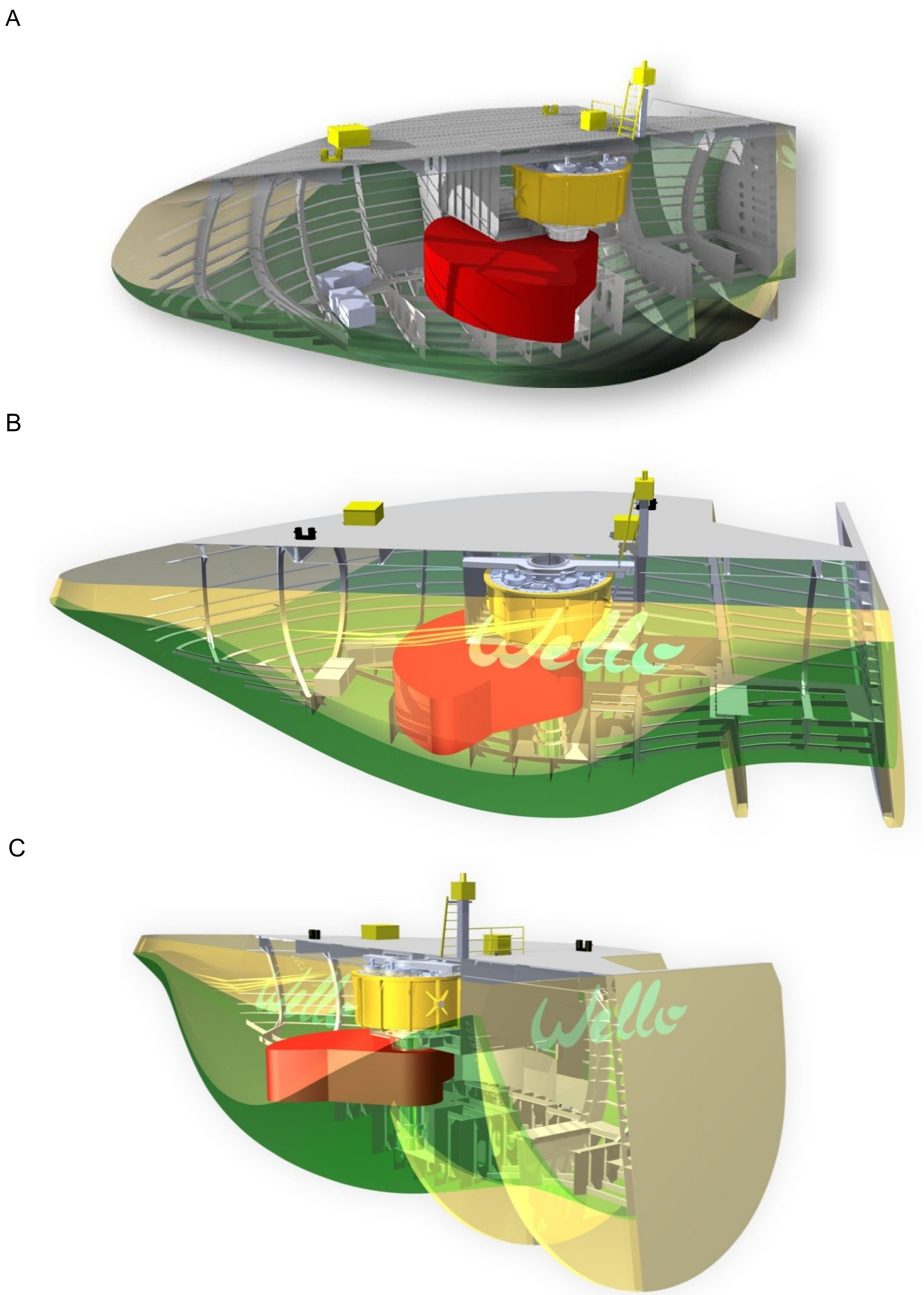

Figure 1. Layout diagrams of the Wello Penguin. A - Off the port bow. B – Abeam to port. C – Off the port quarter (images courtesy of Wello, www.wello.fi).

2. METHODS

Equipment
Underwater acoustic data acquisition was carried out using ICIT's Hydata sonobuoy. Data recording was controlled remotely from a laptop PC unit located within a vehicle on the pier. Notes on time, position, distance and other notable occurrences were taken throughout the survey. Times were taken from the surveyors watch (checked via atomic-clock.org.uk prior to survey). A continuous dataset of positional coordinates, in one second intervals, for the sonobuoy were acquired using an on-board GPS data logger mounted vertically above the hydrophone. This GPS unit is equipped with inbuilt 'European Geostationary Navigation Overlay Service' (EGNOS) calibration which currently enables positioning accuracy within 1.5 m (ESA, 2011).

Specification
Recordings were taken at 44.1 kHz sample rate and a 16 bit depth (5 digit numerical accuracy of the signal measurement by A/D converter - signal to noise ratio increasing with bit depth) giving a theoretical maximum dynamic range (ratio of largest to smallest measureable signal) of 96 dB and a frequency detection rate of up to 22 kHz. Data was stored during the survey using the on-board sonobuoy computer system as .wav files. The pre-amplified, cylindrical hydrophone is designed for the detection of infrasonic, audible, and ultrasonic sounds. In addition to typical underwater use, this hydrophone can also be used for the detection of airborne and subterranean sounds and vibrations. It is encapsulated in a rugged polyurethane material.

Survey depths
The hydrophone depth (adjustable up to 28m) was set and fixed for the study duration at 4m below sea level and the water depth within the study site is approximately 9 to 10 m below chart datum.

Recording Tracks
Recording were first taken at 12:30pm and continued over a period of approximately 3 hours. Overall 6 underwater recordings were taken around the hull of the device. In 3 recordings the sonobuoy was gently towed by a rope to measure sound levels at various positions and distances for the sound source. Two of the recordings involved the use of the Wello RIB to place the sonobuoy away from the device and obtaining data while the sonobuoy was slowly pulled back towards the device. The sonobuoy was positioned for these two distance measurements to the south-east to minimise any reflection of sound energy from the quayside.

1. 12:30 Stationary position at corner of pier – 23 mins.
2. 12:53 Sonobuoy pulled around device hull anticlockwise from south to north– 27 mins.
3. 13:38 Slow pull in towards the devices south end from 60m SE – 20 mins.
4. 14:05 Stationary position at south end of device – 5 mins.
5. 14:27 Stationary position between south end of device and pier – 14 mins.
6. 14:46 Slow pull in towards the devices south end from 60m SE (repeat) – 14 mins.

3. RESULTS AND ANALYSIS

3.1 Background Noise Levels

A measure of the ambient noise environment is particularly useful in assessing the influence of noise from point source maritime activities but it should be emphasised that it is dependent upon the natural variability of precipitation, wind, waves, tidal currents and marine life. The ambient sound level can only be described as being within a range of levels that were experienced at one location at one moment in time and subject to particular meteorological conditions and therefore it is not a stable parameter. By providing a measurement of the lowest recorded level during a particular study of noise impact will only indicate the lowest ambient noise at that time and would certainly not relate to the absolute minimum level that may be experienced at that site. At the other end of the scale it would seem acceptable not to incorporate sporadic loud sound sources such as produced by random shipping activity as background noise unless present for a large percentage of the time such as in busy ports. But, stationary and repetitive loud sound sources such as an acoustic deterrent device (ADD) or 'seal scarer' widely used on fish farms (two farms are within one kilometre of the study site) could be a significant anthropogenic contributor to elevated background noise levels if included in the analysis, although it should be noted that in this study no ADD's were detected.

In shallow coastal regions background noise levels can vary from 90-155dB re 1µPa (Nedwell et al., 2003). In recent studies in the Moray Firth background noise levels ranged from 104-121dB re 1µPa (Bailey et al., 2010) and in a Strangford Lough study from 115-125dB re 1µPa (Nedwell and Brooker, 2008). Maritime traffic can have a significant influence on these levels and thus in the vicinity of construction vessel traffic for the Beatrice Wind Farm in the Moray Firth Bailey *et al.* record background noise levels increasing to 138dB re 1µPa.

Recording Track 5 was used to sample ambient noise levels, with the generator and Penguin systems shut down. Throughout the recording the chain rattling of the pier fenders are clearly audible, and as often happens during background noise recording a small 5m aluminium hulled craft with a single outboard passed across the buoy track. Figure 2 shows the distribution of 1s sound pressure levels in extracts from the recording with and without the small craft present.

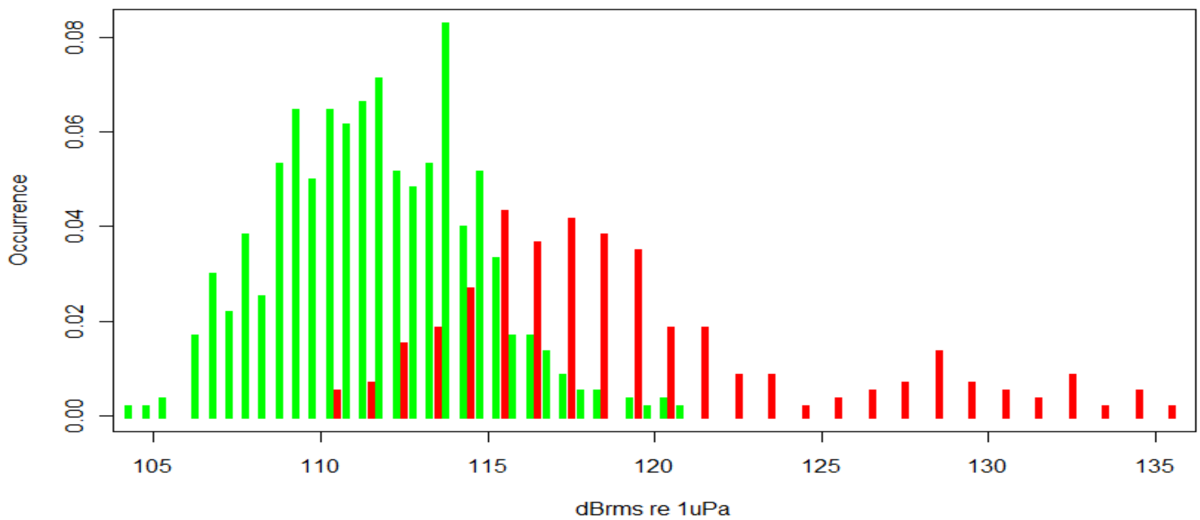

Figure 2. Histogram of background levels recorded during track 5, in green without other traffic present, in red during the passage of a small 5m craft.

The ambient noise values, without the small boat present ranged from 104-121dBrms re 1µPa with a mean of around 112dBrms re 1µPa. These values are rather lower than recorded in other parts of Orkney coastal waters, such as the Fall of Warness, and reflect the relatively sheltered aspect of the site. The presence of the small craft's outboard is readily detectable in the sample and the spectrogram of this is shown in Figure 3.

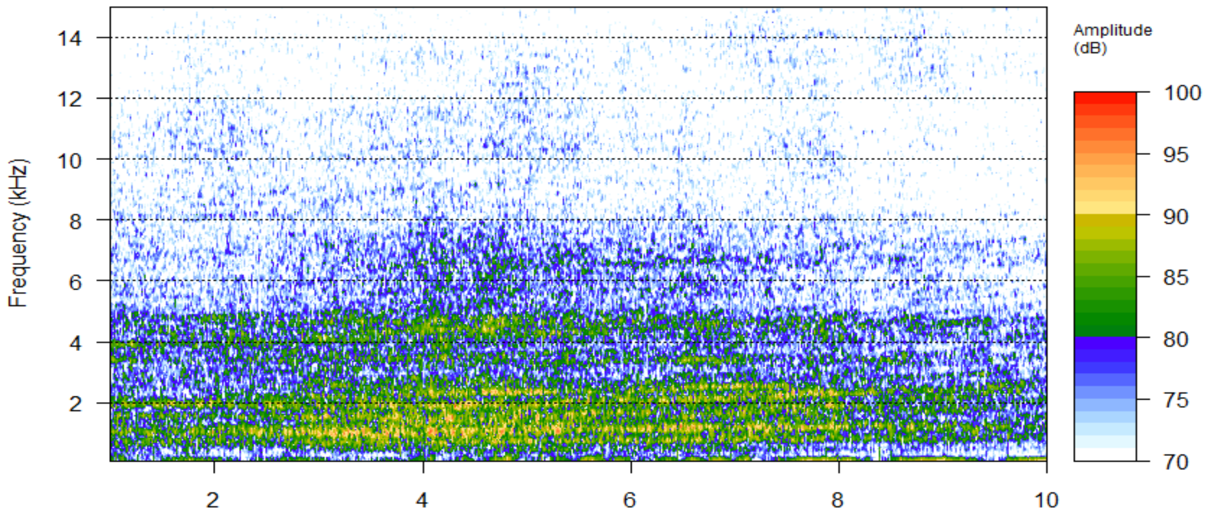

Figure 3. Spectrogram of a 10 second extract of noise from the small 5m craft outboard engine.

The chain noise associated with the pier fenders is also detectable during most of the background recording track, and the spectrogram of a short extract of chain noise is shown in Figure 4.

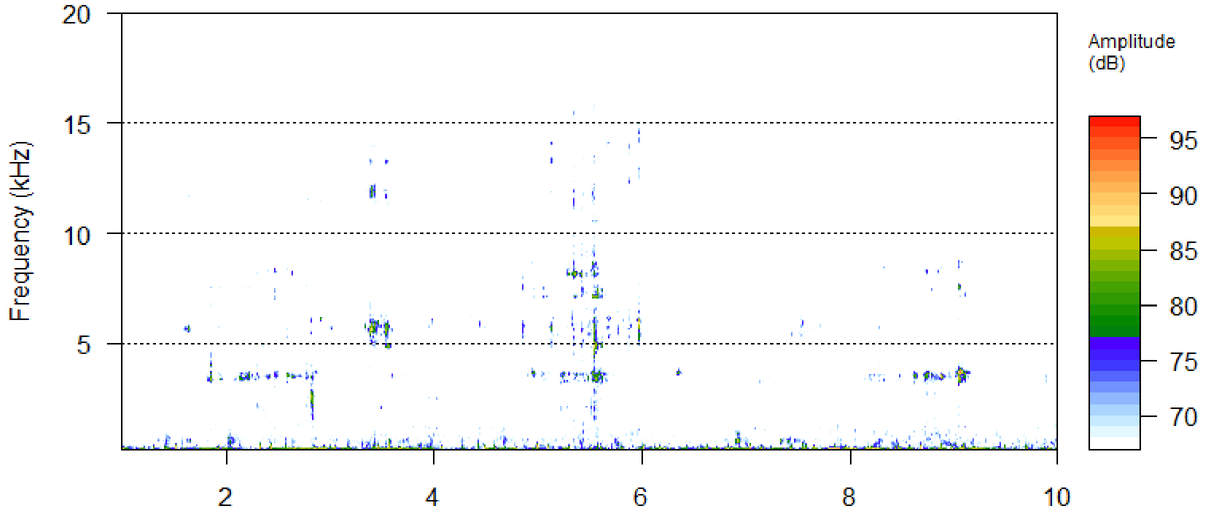

Figure 4. Spectrogram of short extract of chain jangling from the pier fenders

Unfortunately other recording tracks were also contaminated by vessel traffic, most notably the Hoy Head ferry. When close to the site the ferry noise dominates all recordings as shown in Figure 5.

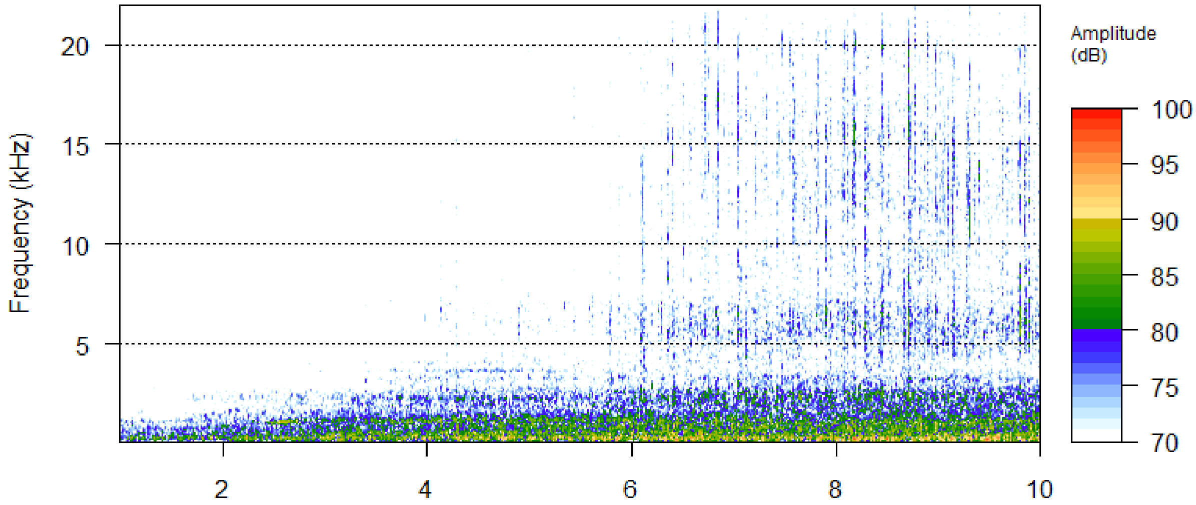

Figure 5. Spectrogram from Recording Track 3 of Hoy Ferry arriving on site

A spectral analysis of the principal contributions to background noise is shown in Figure 6. For this extracts from Track 5, without chain noise and with chain noise, and one with the small 5m boat present were used. An extract from recording track 3 was used for the Hoy Head ferry. From this it can be seen that the mooring chain noise is clearly distinguishable from ambient background noise above 2kHz, but makes little contribution at lower frequencies, whereas the ferry contributes to all frequencies above about 60Hz, with the small boat outboard engine being most pronounced at around 2kHz and above.

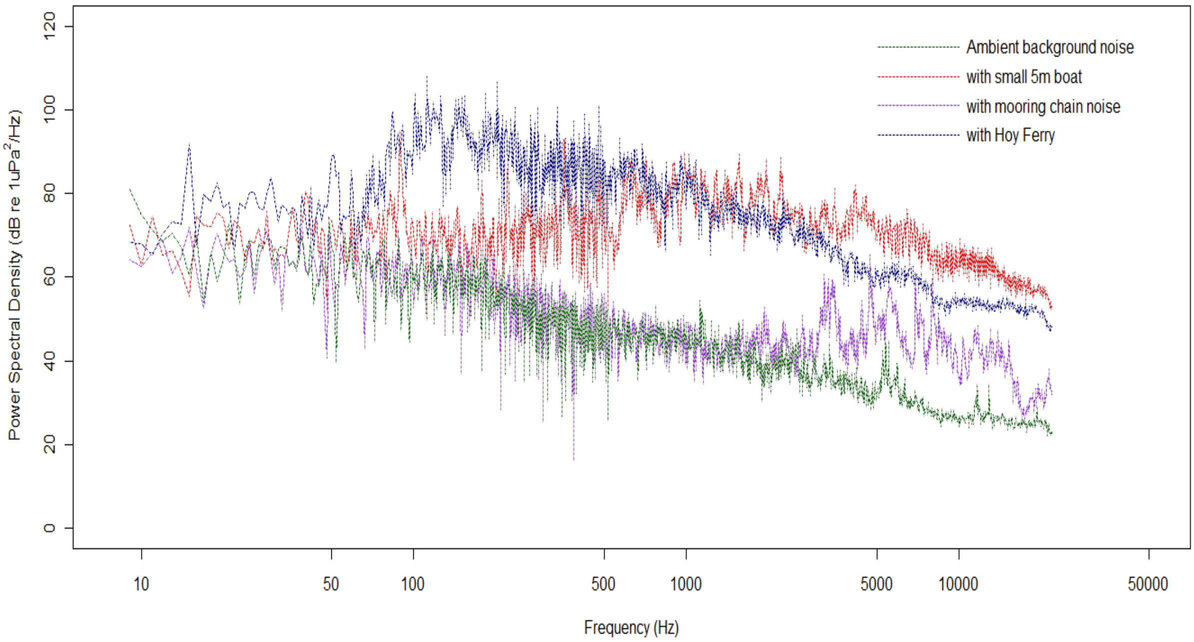

Figure 6. Power Spectral Density plots of ambient background noise and contribution of known sources. Green: Ambient background, Red: 5m boat, Purple: Chain & Blue: Hoy Head ferry.

These preliminary analyses were used to inform the selection of extracts for further examination of the Penguin cooling system noise, and provide a useful indication of whether other sources of noise have contaminated the targeted recordings. However as the noise from the mooring chains is pretty much continuous throughout the recording tracks it is not possible to isolate this contribution completely.

3.2 Cooling Fan Noise from the Penguin

Figure 7 shows the spectral distribution of noise from the cooling fans on the Penguin.

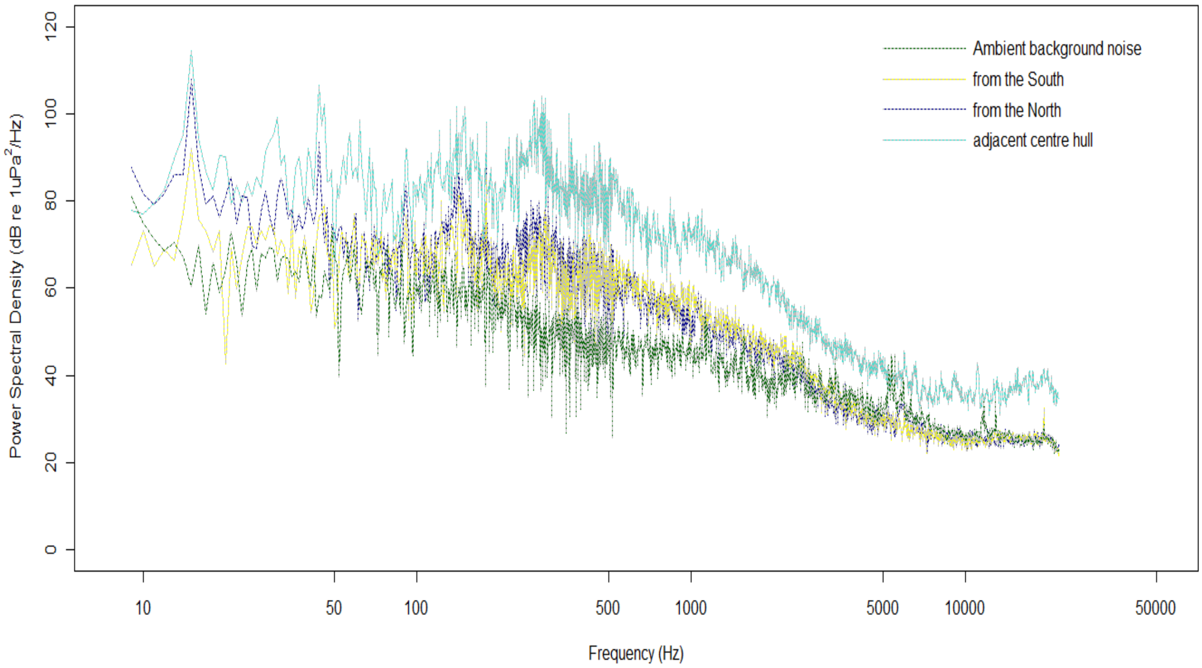

Figure 7. Power Spectral Density plots of extracts of cooling fan noise from the Penguin, sampled from the North, South and adjacent to the hull centre, with background noise for comparison. Green: Ambient background, Yellow: Bow position, Blue: Stern position & Light blue: Amidships port side.

In Figure 6 noise from the cooling fans shows pronounced frequencies at 15Hz, at around 45Hz, and 90Hz, with more complex peaks at 140-150Hz and 250 to 300Hz.

3.3 Underwater Sound Pressure Levels

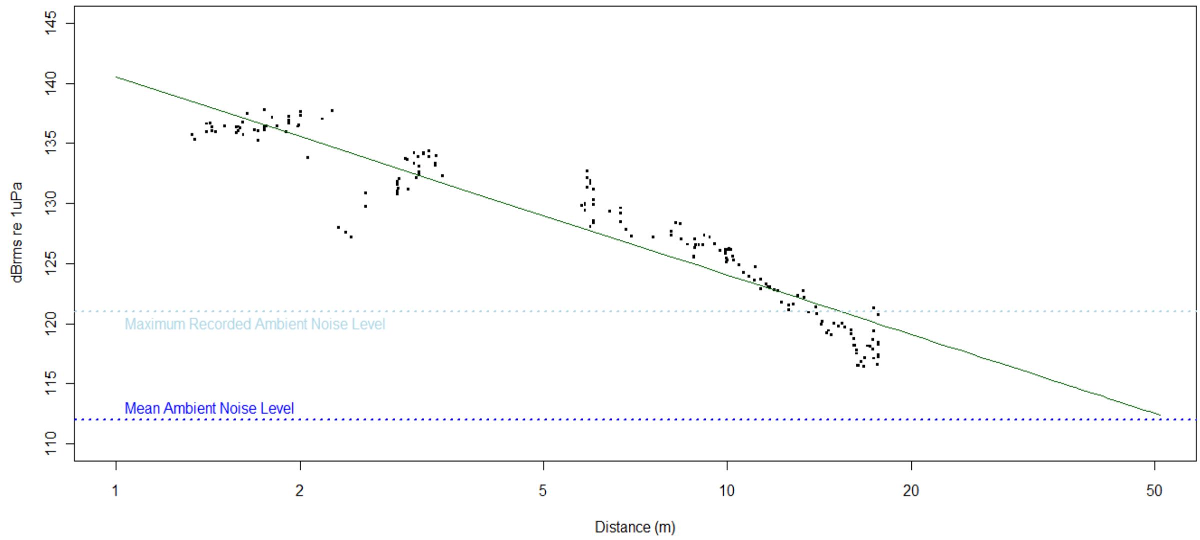

Figure 8. Best fit transmission loss model of measured data. Logarithmic scale on x axis.

A number of extracts of the recording tracks were isolated at differing distances from the hull, with the aim of selecting samples that were free of chain noise from the mooring system and influence of other anthropogenic noise sources such as the Hoy Head ferry. The sound pressure levels for these are plotted against distance in Figure 8.

The best fit to the data suggests a source sound pressure level of 140.5dBrms re 1µPa at 1m, with a transmission loss of $16.5\log_{10}$(Distance). This is consistent with the expected textbook shallow water transmission loss with distance of $15\log_{10}$(Distance). At the Lyness site background levels were reached at around 50m distance from the device, and it is likely that in noisier wave energy environments background levels would be reached at distances less than this, probably within 10m or so from the device.

The spread of values suggests that the entire hull can be considered the noise source, rather than any specific point on it, but it is likely that there will be some variability across the hull surface. The position fixing systems used in this study were not sufficient to enable a further investigation of this, but a rig could be constructed to allow such an assessment if it is considered necessary.

3.4 Airborne Noise Levels

The sound level of the cooling system could only be heard above that of the generator adjacent to the open companion ways of the WEC device. Since the cooling system could not be operated without the power supplied by the generator the airborne noise specific to the cooling system could not be measured during this study, although, it was deemed necessary that the sound levels produced by the generator should be measured in the event that it may affect the underwater study close to the device. The position of the yellow towable generator on the pier can be seen behind the penguin device in the cover image. Measurements were taken during a period of low to calm wind along a westward track toward the ferry terminal.
Transmission spreading loss at this site provided figures of $18.3 \log_{10} r$ within dBA weighted frequencies and $17.5 \log_{10} r$ at dBC weighted frequencies (see figure 9 below). 'A' weighted levels optimise analysis to perceived human hearing by attenuating high and low frequencies whilst 'C' weighted levels incorporate the lower frequencies typically below 100Hz. The higher rate of the 'A' weighted transmission loss is consistent with increased attenuation at higher frequencies whilst the lower loss yet higher amplitude 'C' weighted levels are due to the inclusion of the low frequencies.

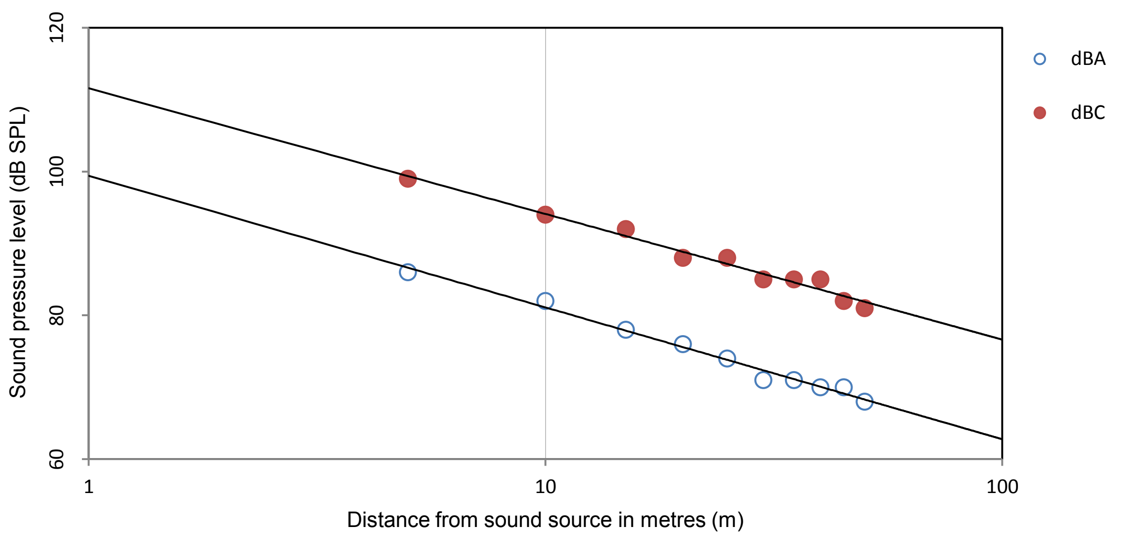

Figure 9. Transmission spreading loss fitted to measured field data. Logarithmic scale on x axis.

4. DISCUSSION

4.1 Sonobuoy Measurements and Analyses

Underwater noise transmitted from the cooling fans on the Penguin shows pronounced frequencies at 15Hz, at around 45Hz, and 90Hz, with more complex peaks at 140-150Hz and 250 to 300Hz. The measured sound pressure levels suggest a source level of 140.5dBrms re 1µPa at 1m. At different points close to the hull surface there may be some variation in the sound pressure levels transmitted. In noisier wave energy environments, with the cooling fans as the only noise source, we would expect ambient background noise levels to be reached within 10m or so from the device.

4.2 Airborne Noise Measurements

Sound levels of the cooling fans were not measured due to the far louder influence of the generator required to run them. As the generator had the possibility of some influence over the underwater sound level by transference through the device hull it was deemed necessary to take measurements. Even though there was found to be some transmission of noise through the pier, after analysis, it was found to be unlikely to have any significant influence on the underwater results.

5. REFERENCES

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ESA, (2011) European Space Agency, The European Geostationary Navigation Overlay Service (EGNOS) http://www.esa.int/esaNA/GGG63950NDC_egnos_0.html [accessed August 2011].

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APPENDIX A – Site Layout Details

A.1 Site Layout

Lyness Wharf and Golden Wharf line the South-East extremity of the small peninsula of Lyness.

Lyness Wharf can accommodate vessels not exceeding 7.6m in draught at MLWS and consists of east and south faces of stone construction; East face aligned north-south is 123m long with a 8 degree slope from the vertical, The south face is about 69m long and feature a Ro-Ro link span.

Golden Wharf extends 190m north from the inner side of the north end of Lyness Wharf. The southern end dries but there are depths of 5.7m towards the north end.

(Above information from: UKHO, 2006).

Figure A1. (Left) Diagram of Lyness Wharf and Golden Wharf with moored location of Penguin other WEC devices and ferry terminal. (Right) SE corner of Lyness Wharf (during redevelopment) looking SSW.

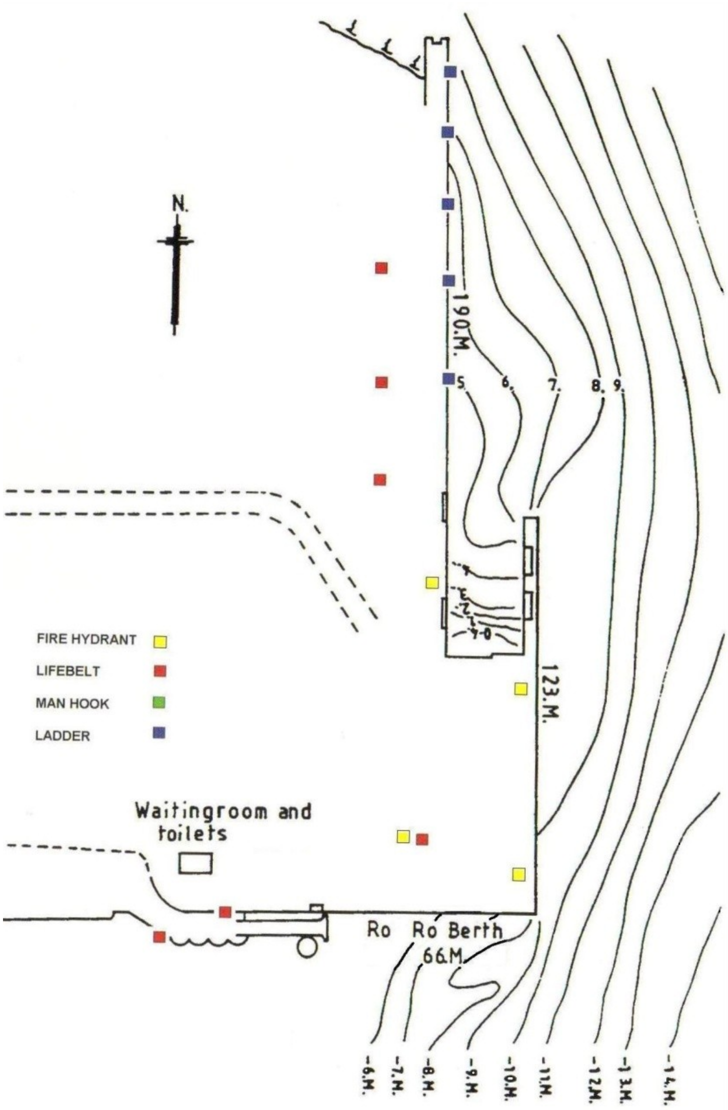

Figure A2. Bathymetry of seabed within study area (redrawn from: Orkney Islands Council, Lyness site layout details)

A.2 Other Sources of Noise Detected During the Survey

Chain noise from mooring fenders attached to the pier side increased with wave action over the study period.

The electrical generator transmitted vibrations through the pier producing underwater noise detectable when the sonobuoy was moved near the pier adjacent to the generator at the end of recording 2.

Appendix References

United Kingdom Hydrographic Office (UKHO) (2006) North Coast of Scotland Pilot: Sixth Edition, North and North-East Coasts of Scotland from Cape Wrath to Rattray Head Including the Caledonian Canal, Orkney Islands, Shetland Islands, and Føroyar (Færoe Islands). Somerset, England. ISBN: 9780707716220

APPENDIX B – Airborne Noise Measurement Details

Table B1. Airborne Noise from on-site generator

Date	Time	Distance (m)	dBA	dBC
7 Dec 2011	12:24	5	86	99
		10	82	94
		15	78	92
		20	76	88
		25	74	88
		30	71	85
		35	71	85
		40	70	85
		45	70	82
		50	68	81

Measurements taken using a Mastech MS6700 sound level meter. For description of this work see Section 3.4 page 9.

APPENDIX C – Meteorological Data

Table C1. Meteorological Data for Kirkwall – 7th December 2011

Time (GMT)	Temp °C	Dew °C	Humidity	Pressure	Visibility	Wind Dir.	WindSpeed m/s	Conditions
10:20	4	-1	70%	989	10	East	2.1	Partly Cloudy
10:50	4	0	75%	990	10	Variable	1	Partly Cloudy
11:20	4	0	75%	990	10	-	0	Partly Cloudy
11:50	4	0	75%	991	10	West	1	Partly Cloudy
12:20	4	0	75%	992	10	South	1	Partly Cloudy
12:50	4	0	75%	992	10	South	1	Partly Cloudy
13:20	4	1	81%	992	10	West	4.1	Scattered Clouds
13:50	3	1	87%	994	10	WNW	7.7	Light Sleet Showers
14:20	1	0	93%	994	4	NNW	9.8	Snow Showers
14:50	2	1	93%	995	10	NNW	8.2	Light Sleet Showers
15:20	2	0	87%	995	10	Variable	1.5	Scattered Clouds
15:50	1	0	93%	995	10	WNW	2.6	Scattered Clouds

MET Station 21 km bearing 051° (true North) *from* research site.
(**Source:** Kirkwall Airport (EGPA) MET data World Meteorological Organization number 03017, measurements taken 21m above sea level)

Air temperature at study site

Time	Temp.
12:40	4°C
13:10	3°C
13:40	1°C
14:10	1°C
14:40	2°C
15:10	1°C

Sea surface temperature (SST) over study adjacent to device = 8°C.
Site temperature measurements taken with a Fisons THL-220-051K mercury thermometer.

Sea-State Conditions

The first half of the survey period was calm, featuring very low wind speeds and small water ripples. After approximately 13:00 the wind picked up with squally showers on a light breeze. Initially an offshore westerly breeze with sea state 1 increased to sea state 2 when wind veered to a northerly direction after approximately 14:00.

Tidal information for 7th December 2011

High tide - Flood to Ebb	07:16 - 3.1m
Low tide - Ebb to Flood	13:19 - 1.1m
High tide - Flood to Ebb	19:26 - 3.1m

(Based upon Orkney Islands Council, Marine Services Tide Tables for Widewall Bay)

APPENDIX D – Vessels and Marine Traffic Details.

Wello Service Vessel.
7m Rigid inflatable boat. With twin 50HP outboard motors. Features in recordings 3 and 6. Used to position sonobuoy offshore for slow draw-in using rope.

HOY HEAD, MMSI: 235018919, IMO: 9081722.
Running to a set timetable the vessel was recorded in Tracks 1,3 & 4

Figure D1. Local ferry (Hoy Head) approaching Lyness pier at 13:53. Sonobuoy can be seen in foreground at southern tip of device. This vessel features in recordings 1,3 & 4.

Ship Type: MCA Class IV - Passenger and Ro-Ro Vehicle/Cargo Ferry
Built: April 1994
Speed recorded (Max / Average): 11.7 / 10.1 knots
Call Sign: MSQD2
Engines: 2 x Volvos @ 370kW each
Drive: 2 x Schottel azimuth stern drive units
Length: 39.5 m
Breadth: 9.8 m
Draught: 2.1 m
Max draught: 2.5 m
Dead weight: 137 t
Gross tonnage: 358 t

Fishing/Service Vessel
5m aluminium hull with single outboard. Arrived from the North and then returned a two minutes later featuring in Recording 5.

Media Disk: This audio disk contains samples of data recorded during the site survey.

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