1/355 Manukau Road
Epsom, Auckland 1023
PO Box 26283
Epsom, Auckland 1344

T: 09 638 8414
E: hegley@acoustics.co.nz

TRANS-TASMAN RESOURCES LTD

OFFSHORE IRON SAND EXTRACTION AND PROCESSING

ASSESSMENT OF NOISE EFFECTS

Report No 9101

Prepared for:

Trans-Tasman Resources Ltd
Wellington
November 2015

Prepared by: ....

Nevil Hegley
MSc MICE CPEng IntPE, MIPENZ

CONTENTS

1 INTRODUCTION

Trans-Tasman Resources Limited (TTR) is proposing to extract iron sand from an area of 130.5km^2, extending 13 to 35km off the South Taranaki coastline as shown on Figure 1.

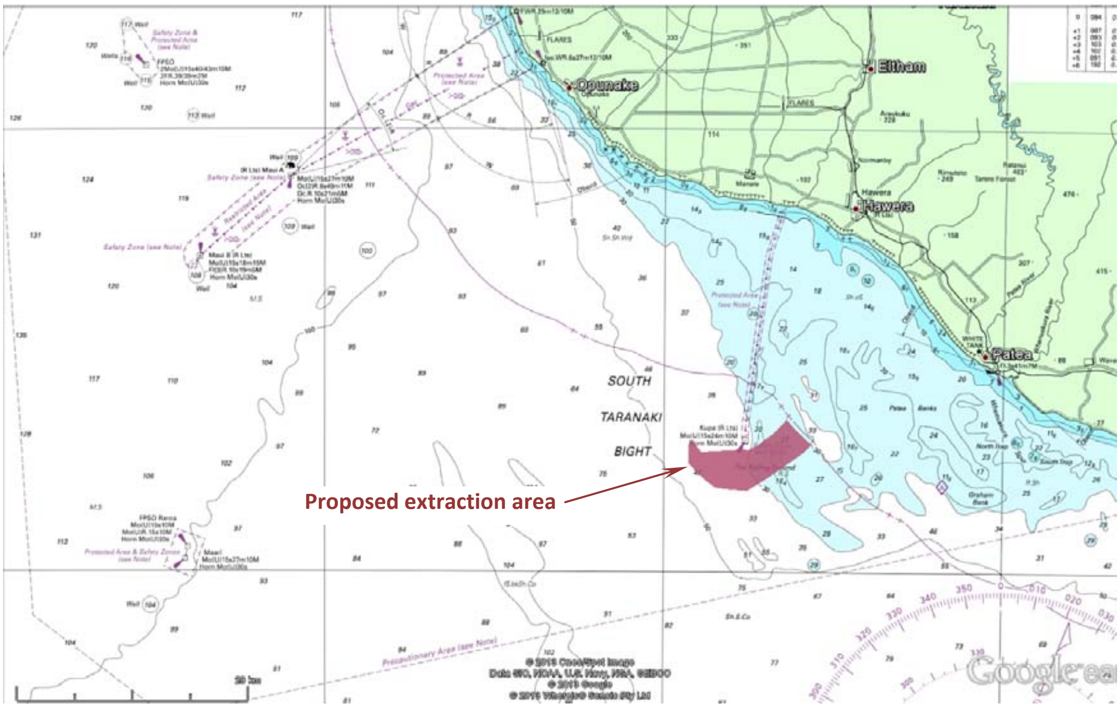


Figure 1. Location of Iron Sand Extraction Area

This report considers the noise effects from the proposed sand mining and the potential effects of any associated noise on marine mammals in the area.

We have been provided with information on the plume modelling, optics, primary productivity and the marine ecological effects relating to TTR's additional scientific work undertaken since 2014 and that the conclusions in this report remain valid.

2 PROPOSED WORK

The proposed work is summarised in this report. A full description of the process is given in the TTR Offshore Iron Sand Project Description report.

Seabed material will be excavated using a self-propelled Subsea Sediment Extraction Device ("SSED") such as shown on Figure 2. The SSED will be controlled remotely from the surface support vessel.

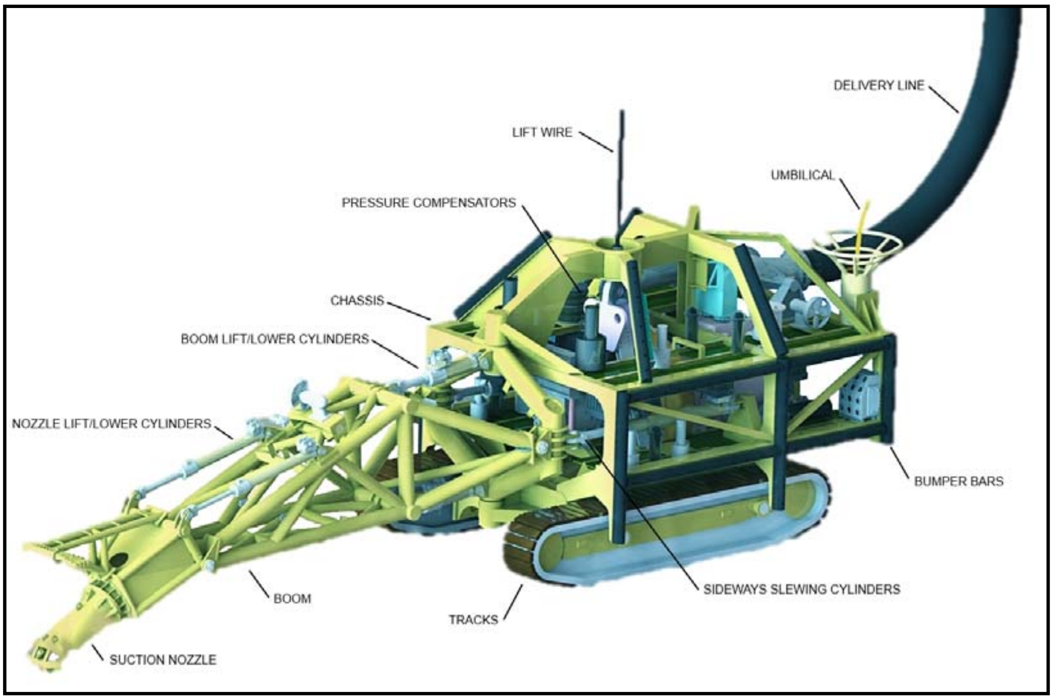


Figure 2. Remote Controlled SSED

The overall extraction system will include the following noise sources:

- Suction head
- Pump system
- Dredge pump; and
- Dredge pump electric motor.
- Mechanicals of SSED – tracks descriptions, hydraulics, gears.

It is expected the suction head will be a suction unit but if a cutter suction unit is used the level will be up to 8dB higher than for the suction head.

The SSED will mine approximately 10m wide allowing for an approximate 1m overlap on both sides of the cut to minimise losses as shown on Figure 3.

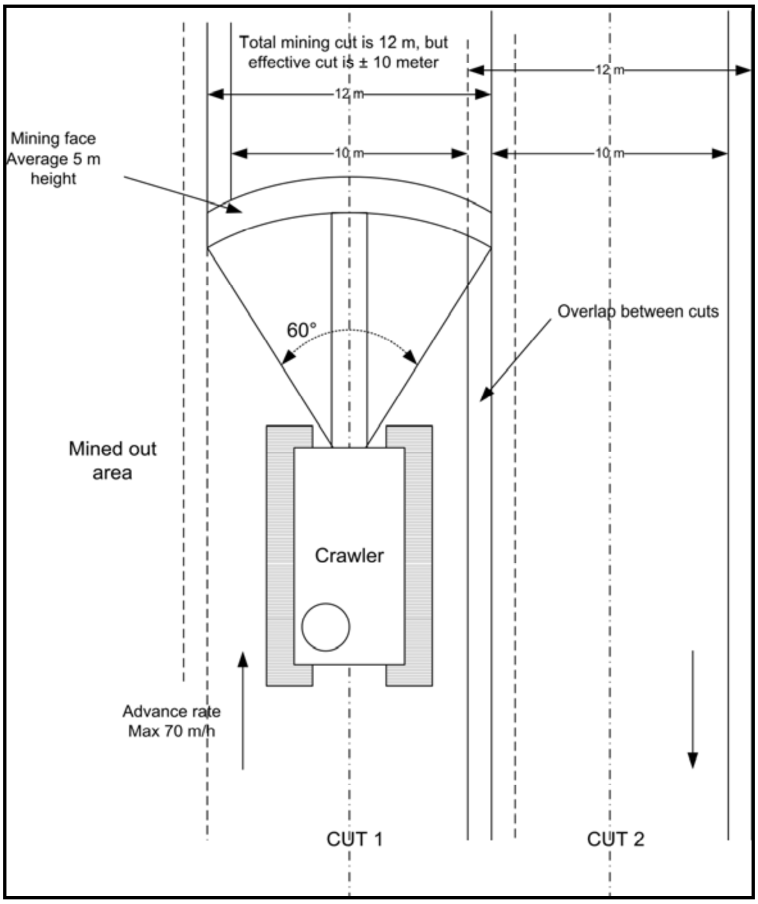


Figure 3: Remote SSED Cut

The SSED will transfer the extracted sediment to the Floating Production Storage and Offloading vessel ("FPSO") and once processed into iron ore concentrate the de-ored sand will be discharged to the seabed into previously worked-over areas. The concentrated ore will then be transhipped to a Floating Storage and Offloading vessel ("FSO") which will store and de-water the concentrate, and in turn trans-ship it on to standard Cape-size export vessels for delivery.

The vessels used for the iron or recovery and processing are:

- Floating Production, Storage and Offloading Vessel (FPSO) (≈180,000 tonnes deadweight length of 330 metres, a beam of 55 metres and a maximum draft of 12 metres) used to host the sediment processing plant. Figure 3 shows a typical 180,000t vessel.

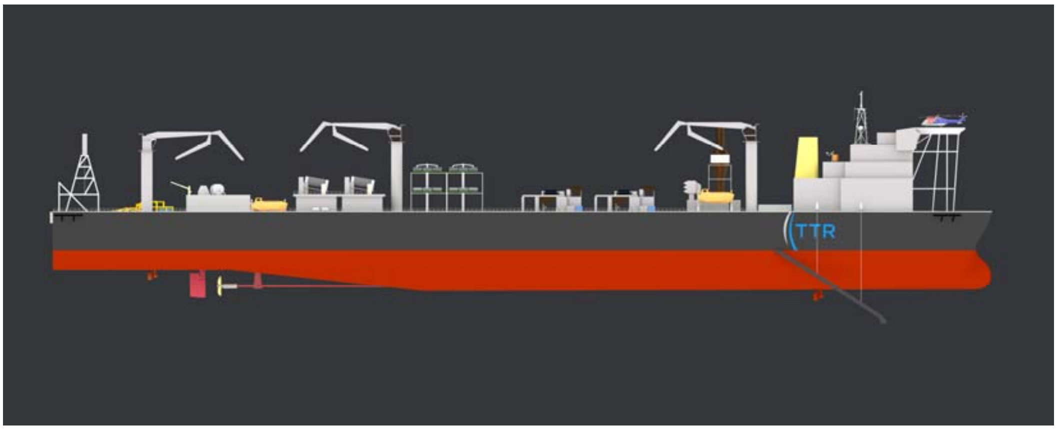


Figure 4. Floating Production, Storage and Offloading Vessel

- Anchor Handling Tug, such as shown on Figure 5, to assist with positioning of the FPSO) and FSO, assist with the connection of floating hoses and anchor moving, provide refuelling assistance and provide support in case of any fuel spillage and fire.

Figure 5. Anchor Handling Tug

- Floating Storage and Offloading Vessel (FSO) which will be approximately 60,000t (Figure 6) used to dewater and temporarily store the iron ore concentrate before offloading it on to the Cape-size export vessels.

Figure 6. Floating Storage and Offloading Vessel (FSO)

Operations on the FPSO will require a total installed power capacity of 80MW, which will be met by installing a number of modular gas turbine generators such as the Siemens SGT-500 (Figure 7).

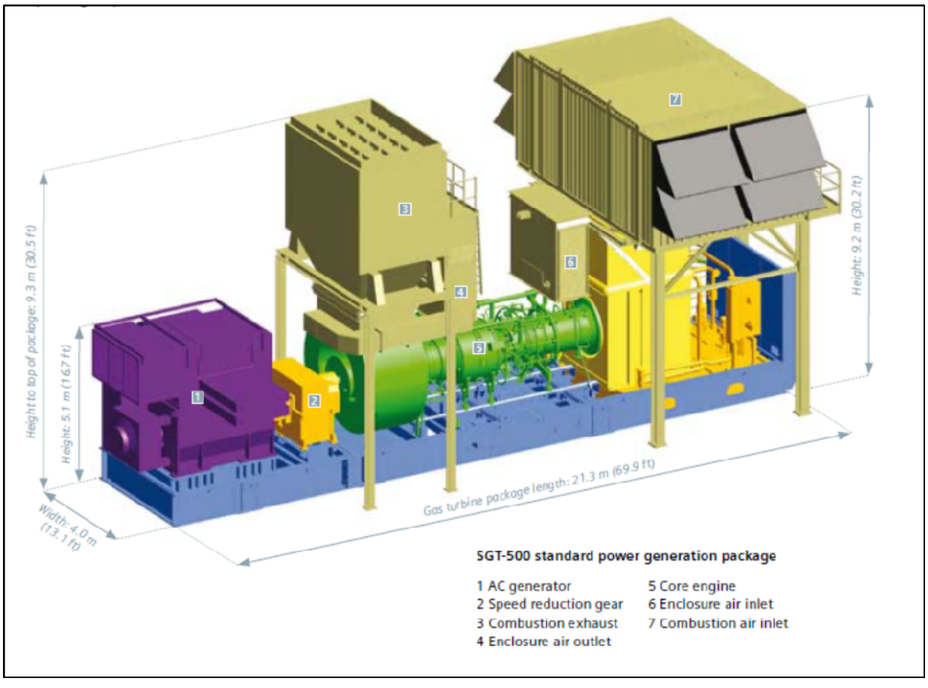


Figure 7. Example of a Modular Gas Turbine Generator

3 EXISTING NOISE ENVIRONMENT

Due to adverse sea conditions no reliable measurements have been undertaken of the existing underwater noise environment on site. However, a measurement undertaken in a harbour mouth situation in calm conditions and no shipping in the area is shown below to provide an example of calm sea conditions.

When measured over a 15 minute period the L_{eq} level was 129dB re 1μPa with a waterfall sound spectrum shown on Figure 8.

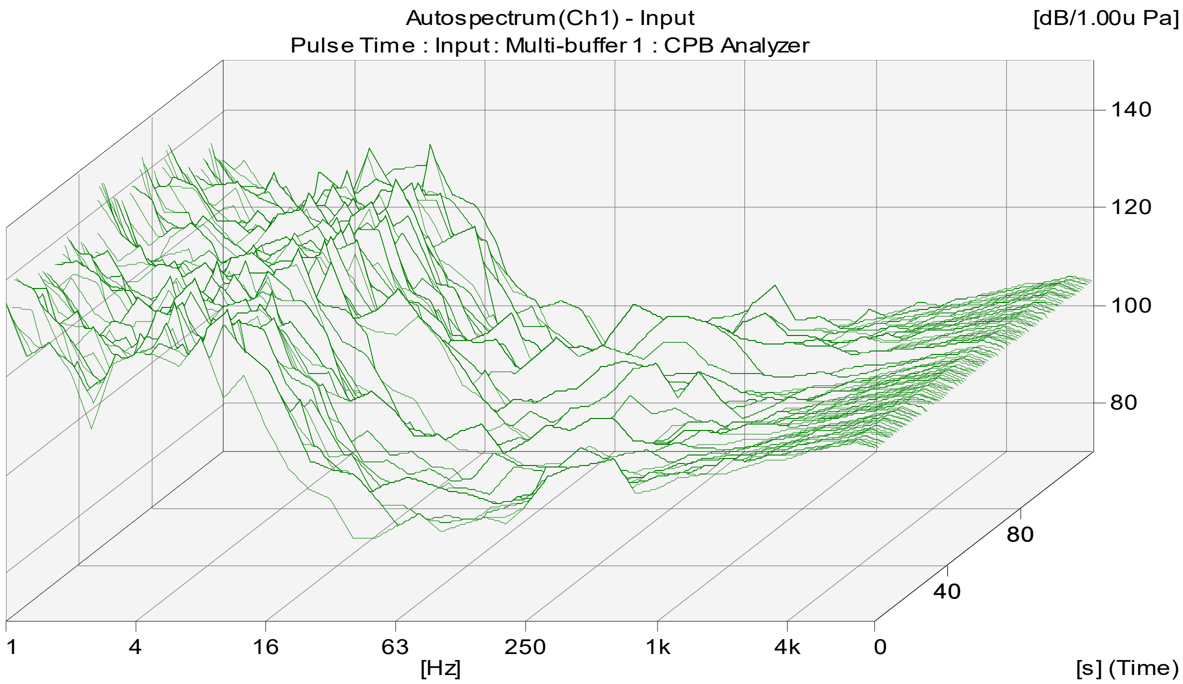


Figure 8. Ambient Sound Spectrum

Measurements undertaken at Lyttelton Port of cargo ships arriving and departing showed sound peaks at approximately 158dB re 1μPa as the ship passed at low speed within 100m of the receiver position within the harbour.

As shown on Figure 9[1] there is a significant number of ship movements within 10nm of the proposed iron sand extraction site. These ships will have an effect on the existing noise environment with levels of up to 132dB as a ship passes.

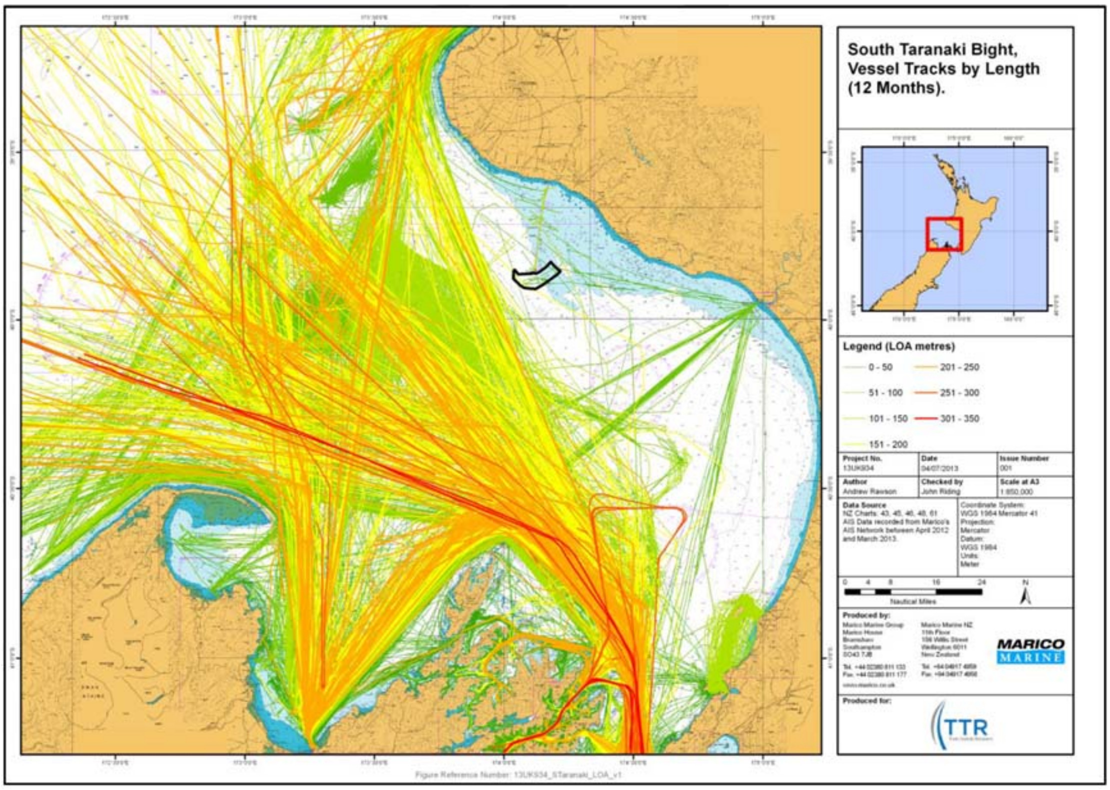


Figure 9. Vessel Tracks by Length over all (LOA)

To understand the existing noise environment that is experienced in the sea, the following sets out some typical sounds that can occur from shipping activities and from sea mammals.

The source levels for some natural sounds generated by marine life are given in the following Table 1.

[1] South Taranaki Bight Shipping Study, Marine and Risk Consultants Ltd, July 2013

Source	Broadband Source Level (dB re 1µPa at 1m)
Sperm Whale clicks	163 - 223
Beluga Whale Echolocation click	206 - 225 (peak-to-peak)
White-beaked Dolphin Echolocation clicks	194 - 219 (peak-to-peak)
Spinner Dolphin pulse bursts	108 - 115
Bottlenose Dolphin whistles	125 - 173
Fin Whale moans	155 - 186
Blue Whale moans	155 - 188
Gray Whale moans	142 - 185
Bowhead Whale tonals, moans and song	128 - 189
Humpback Whale song	144 - 174
Humpback Whale fluke and flipper slap	183 - 192
Right Whale	172 - 175
Southern Right Whale pulse call	172 - 187
Snapping Shrimp	183 - 189 (peak-to-peak)

Table 1. Natural Underwater Sounds

Table 2 sets out noise levels experienced from human-made sounds.

Noise Source	Maximum Source Level	Remarks	Reference
Undersea Earthquake	272dB	Magnitude 4.0 on Richter scale (energy integrated over 50Hz bandwidth)	Wenz, 1962.
Seafloor Volcano Eruption	255dB+	Massive steam explosions	Deitz & Sheehy, 1954; Kibblewhite, 1965; Northrop, 1974; Shepard & Robson, 1967; Nishimura, NRL-DC, pers. comm., 1995.
Airgun Array (Seismic)	255dB	Compressed air discharged into piston assembly	Johnston and Cain, 1981; Barger and Hamblen, 1980; Kramer et al., 1968.
Lightning Strike on Water Surface	250dB	Random events during storms at sea	Hill, 1985; Nishimura, NRL-DC, pers. com., 1995.
Seismic Exploration	212 - 230dB	Includes vibroseis, sparker, gas sleeve, exploder, water	Johnston and Cain, 1981; Holiday et al., 1984.

Devices		gun and boomer seismic profiling methods.	
Container Ship	198dB	Length 274 meters; Speed 23 knots	Buck and Chalfant, 1972; Ross, 1976; Brown, 1982b; Thiele and Ødegaard, 1983.
Super tanker	190dB	Length 340 meters; Speed 20 knots	Buck and Chalfant, 1972; Ross, 1976; Brown, 1982b; Thiele and Ødegaard, 1983.
Offshore Drill Rig	185dB	Motor Vessel KULLUK; oil/gas exploration	Greene, 1987b.
Offshore Dredge	185dB	Motor Vessel AQUARIUS	Greene, 1987b.

Note: These are the levels that would be measured by a single hydrophone (reference 1 μPa at 1m) in the water.

Table 2. Human-made Source Noise Comparisons

Type of vessel	Frequency (kHz)	Source level dB re 1uPa	Reference
Rigid inflatable (rescue craft)	6.3	152	Malme et al. 1989
7m outboard motor boat	0.63	156	Malme et al. 1989
Tug pulling empty barge	0.037, 1.0, 5.0	166, 164, 145	Buck & Chalfant 1972; Miles et al. 1989
Tug pulling loaded barge	1.0, 5.0	170, 161	Miles et al. 1989
34m (twin diesel engine) workboat	0.63	159	Malme et al. 1989
Tanker (135m)	0.43	169	Buck & Chalfant 1972
Tanker (179m)	0.06	180	Ross 1976
Super tanker (266m)	0.008	187	Thilele and Odengaard 1983
Container ship (219m)	0.033	181	Buck & Chalfant 1972
Container ship (274m)	0.008	181	Ross 1975
Freighter (135m)	0.041	172	Thilele & Odengaard 1983

Table 3[1]. Summary of sound frequencies produced by shipping traffic and their source levels.

Figure 10 shows the typical sound levels of ocean background noises at different frequencies, as measured by Wenz (1962).

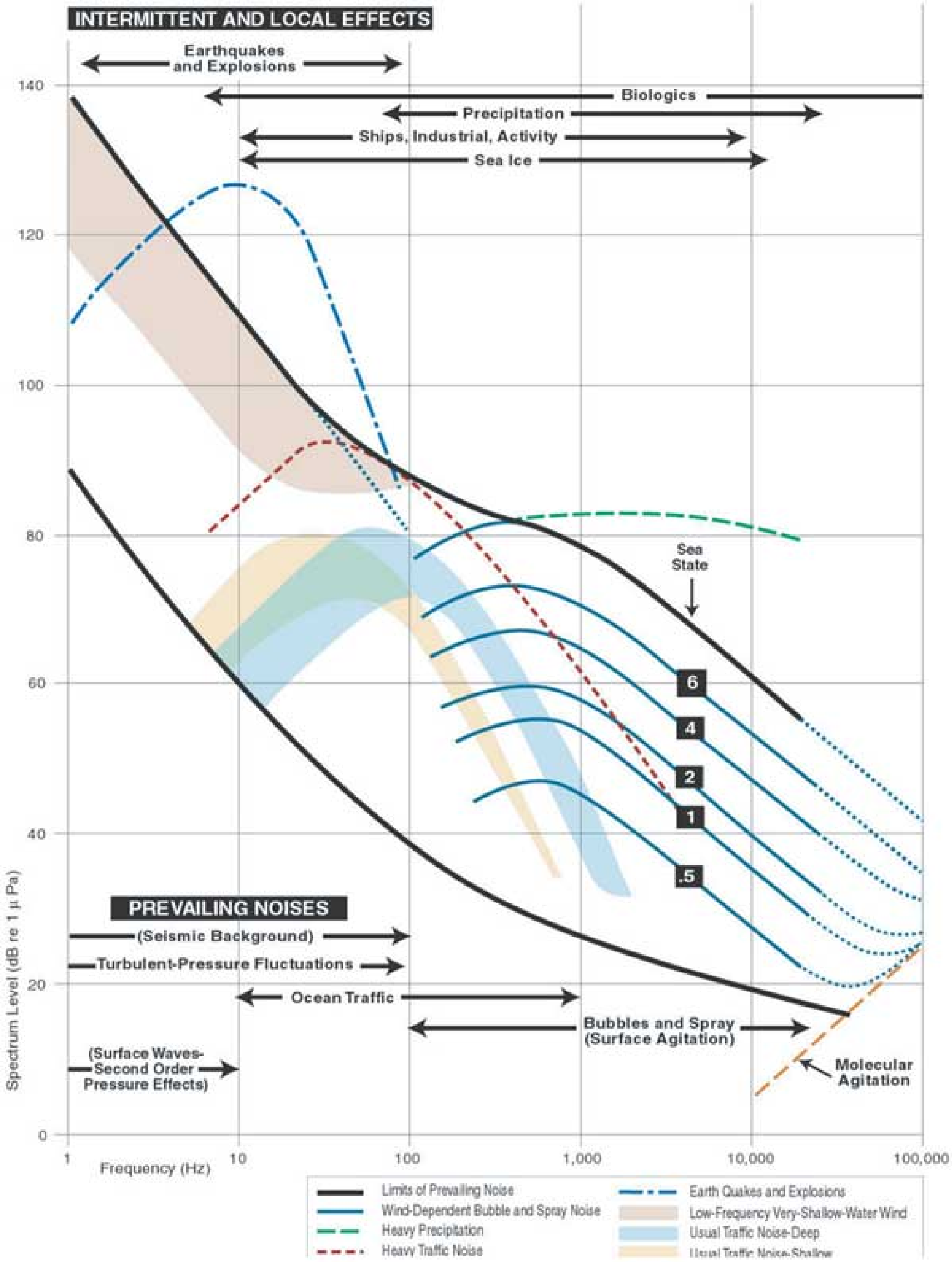


Figure 10. Typical Sound Levels of Ocean Background Noises

4 Noise from Dredging

Very little information is available on the noise generated from dredges operating and no specific information is available on the noise level from a suction dredge. However, the noise from the pump motor drive and dredge pump booster of a cutter suction dredge (excluding the cutter head) has a combined sound power level of 117dB re 20µPa. This equates to an underwater level of approximately 172dB re 1µPa at 1m. That is, the level would be approximately 129dB at 200m when taking into account the limited depth of the water within the work area. From this, the noise from the dredge operating has been predicted at typically 130dB at 200m, 121dB at 500m, 115dB at 1km and 108dB at 2km.

Figure 11[2] shows the sound levels based on 593 container ship transits, 45% of the measured ships making two or more transits and 5% had four or more transits.

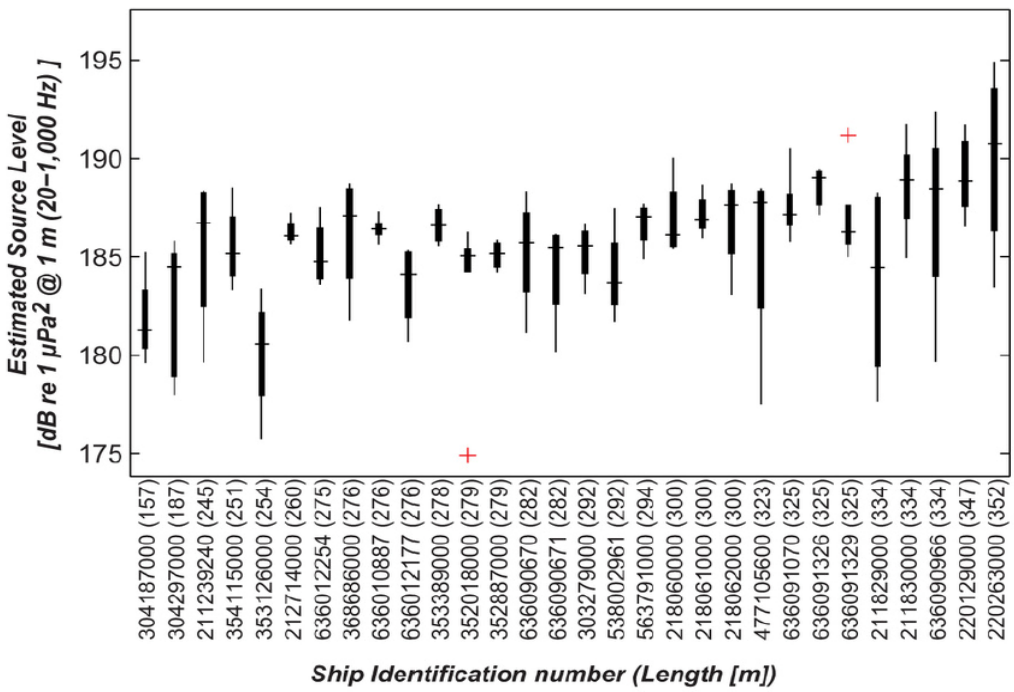


Figure 11. Variability of individual container ships estimated SL from ships that transited on four or more different occasions

[2] Relationship between container ship underwater noise levels and ship design, operational and oceanographic conditions, Megan F. McKenna, Sean M. Wiggins & John A. Hildebrand, Published 02 May 2013

The boxes shown on Figure 11 bound the 25th and 75th percentiles with the horizontal line at the median. Ends of the vertical whiskers are the highest and lowest values of the data set that are within 1.5 times the inter-quartile range of the box edges. The plus signs represent data outside the range of the whiskers.

Based on the above, the noise level from the FPSO, which is the largest vessel, will be typically 188dB at 1m when transiting. The FSO is a smaller vessel and will have a predicted level of typically 185dB at 1m when transiting and the tug will be typically 170dB at 1m.

The source of noise from the ships is shown on Figure 12.

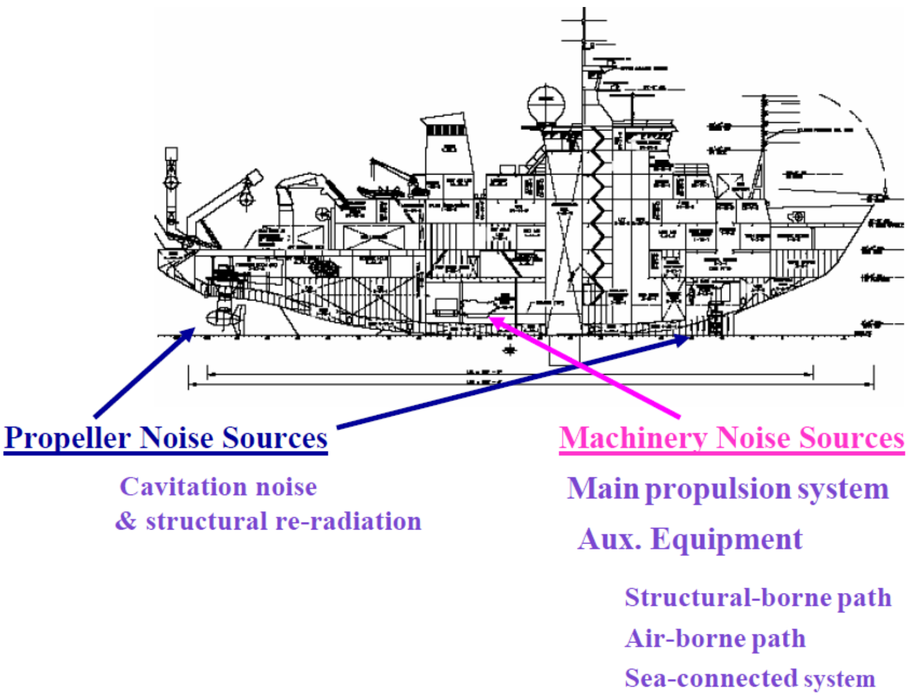


Figure 12. Ship Noise Sources

Measurements of the sound spectrum that were made[3] of the radiated noise of M/V Overseas Harriette, a bulk cargo ship (length 173m displacement 25,515

3 Radiated noise characteristics of a modern cargo ship, Paul T. Arveson David J. Vendittis, J. Acoust. Soc. Amer. 107(1), 118-129 (January 2000)

tons) powered by a direct drive low-speed diesel engine, are shown on Figure 13. This sound spectrum has a lower level than the transiting ships used for this project although the shape of the spectrum will be the same. What Figure 13 demonstrate is that when on site and the boat speed is very low the noise will be approximately 14dB below that of a ship travelling.

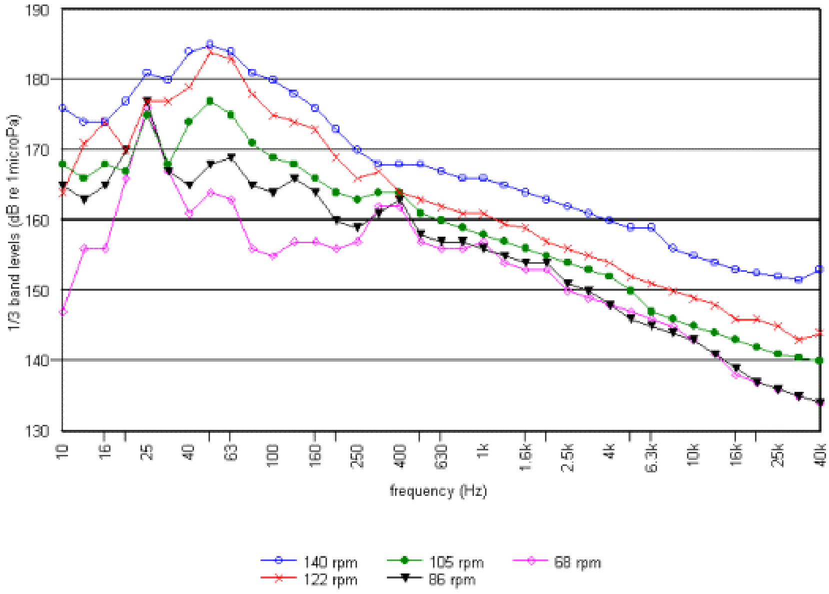


Figure 13. Sound Spectrum of MV Overseas Harriette

5 EFFECTS OF UNDERWATER NOISE

Noise generated by the proposed sand excavation has the potential to affect the underwater environment for fish and sea mammals such as dolphins, porpoise and whales. It is noted that the information available on sea mammals relies on international research and is not related specifically to the iron sand extract area. However, a similar pattern of noise effects is expected in the area as found internationally and has been adopted for this site.

In the following the potential effects from the extraction of iron sand have been considered based on comparing existing noise environments and the noise predicted from the extraction activities.

To assist with understanding the impact of the iron sand extraction noise it is also necessary to understand the ability of marine mammals to hear the sound. Figure 14 shows audiograms[4] of three dolphins and whales (odontocete) species found in coastal waters off northern Europe. The audiogram of the Harbour Porpoise has been taken as a provisional representative for Hector's dolphins as they are both similar in their physiology and sound repertoire. It is noted the Hectors dolphins are unique from other dolphins in that they produce very few sounds and those that they do are basically clicks that are short in duration and very high-frequency around 120kHz. They do not whistle like Bottlenose dolphins to communicate. Instead they just change their rate of clicking. Also shown on Figure 14 is the frequency range where the majority of the noise from iron sand extraction is predicted.

It can be seen that all audiograms exhibit the characteristic U-shaped form with relatively high thresholds at and below 1kHz and areas of best hearing in the ultrasonic range (>20kHz). That is, the hearing ability of these mammals is relatively poor below about 1kHz, which is that part of the sound spectrum

[4] Effects of offshore wind farm noise on marine mammals and fish Frank Thomsen, Karin Lüdemann, Rudolf Kafemann and Werner Piper July 06, 2006

where the majority of noise from dredging typically occurs which is the 125 – 1kHz region. In simple terms, at 1kHz the hearing threshold of these underwater mammals is 80dB and 100dB at 500Hz so any sound below these levels is unlikely to be heard.

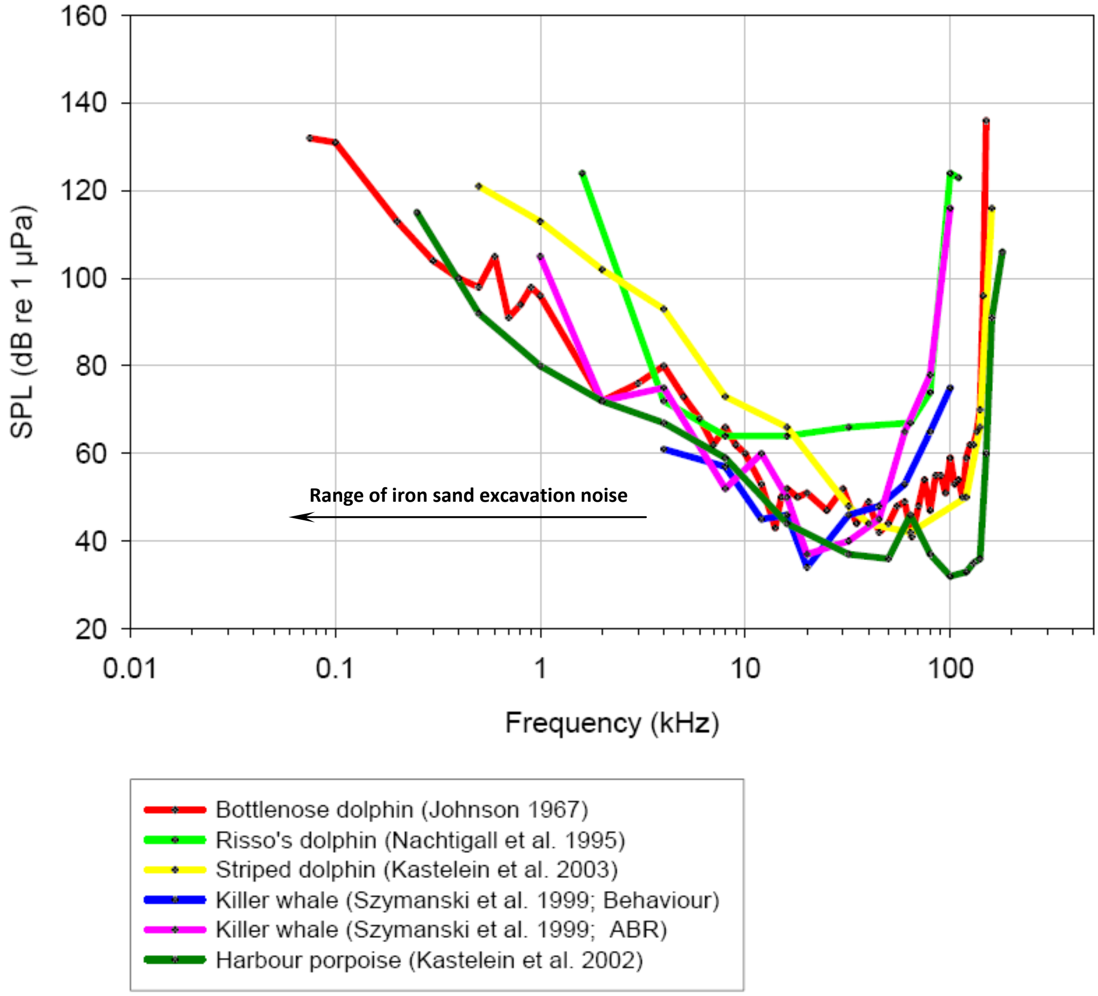
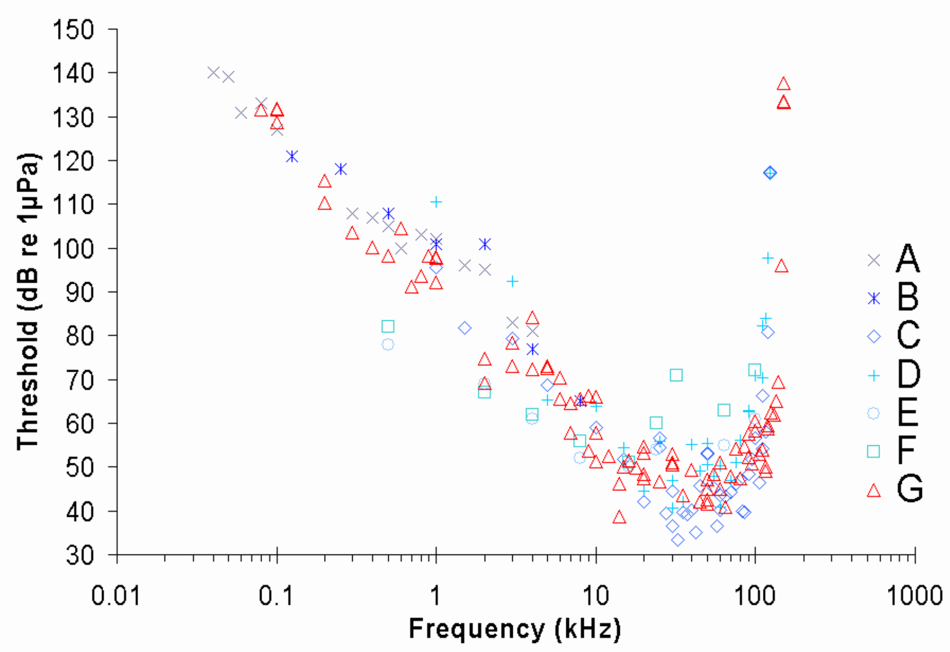


Figure 14. Exemplary Audiograms of Odontocete Species

Figure 15 shows reported hearing thresholds for bottlenose dolphins and white whales (Beluga)[5].

---

5 Testing the Hearing of Whales and Dolphins, Information by Wesley R Elsberry and Diane Blackwood 2003.



(A) White whale from Johnson et al. (1989).
(B) White whale from Awbrey et al. (1988).
(C)&(D) White whale female and male from White et al. (1978).
(E)&(F) White whale female and male from Ridgway et al. (2001).
(G) Bottlenose dolphin from Johnson (1967).

Figure 15. Hearing Thresholds for Bottlenose Dolphins and White Whales

It has been reported[6] that marine mammals tend to be adapted for living in noisy underwater environments, and typically have hearing thresholds that are much less sensitive than those adapted for the atmospheric environment, such as humans. For this reason marine species are able to tolerate much higher levels of noise.

The frequencies used by porpoise (and assumed to be similar for Hector's dolphin) are:

- Low frequency sounds at 1.4 – 2.5kHz for communication
- Sonar-clicks (echolocation) at 110 – 140kHz
- Low-energy sounds at 30 – 60kHz
- Broadband signals at 13 – 100kHz

---

6 Assessment of Tidal Current Turbine Noise at the Lynmouth site and predicted impact of underwater noise at Strangford Lough. Report No. 628 R 0102 by Mr S J Parvin, Mr R Workman, Mr P Bourke and Dr J R Nedwell 10th May 2005.

As set out above, Hectors dolphins produce very few sounds and those that they do are basically clicks, short in duration with a frequency of around 120kHz

While the hearing of the dolphin and whales is best between about 10 – 100kHz they can hear to relatively low frequencies, providing the noise level generated is relatively high. As an example, for the sound to appear as loud for the dolphin at 1kHz as at 10kHz it would need to be approximately 40dB louder at 1kHz than 10kHz. As dredging noise is generally toward the lower end of the hearing threshold for dolphins and at the lower end of their vocalisation range, the effects will be less than had the sound been above 10kHz.

The frequency range used by Baleen whales is relatively wide and although various ranges are given Baleen whales generally vocalise in the lower frequencies, between 10 and 4000Hz. The audiograms for three Baleen whales[7] are shown on Figure 16.

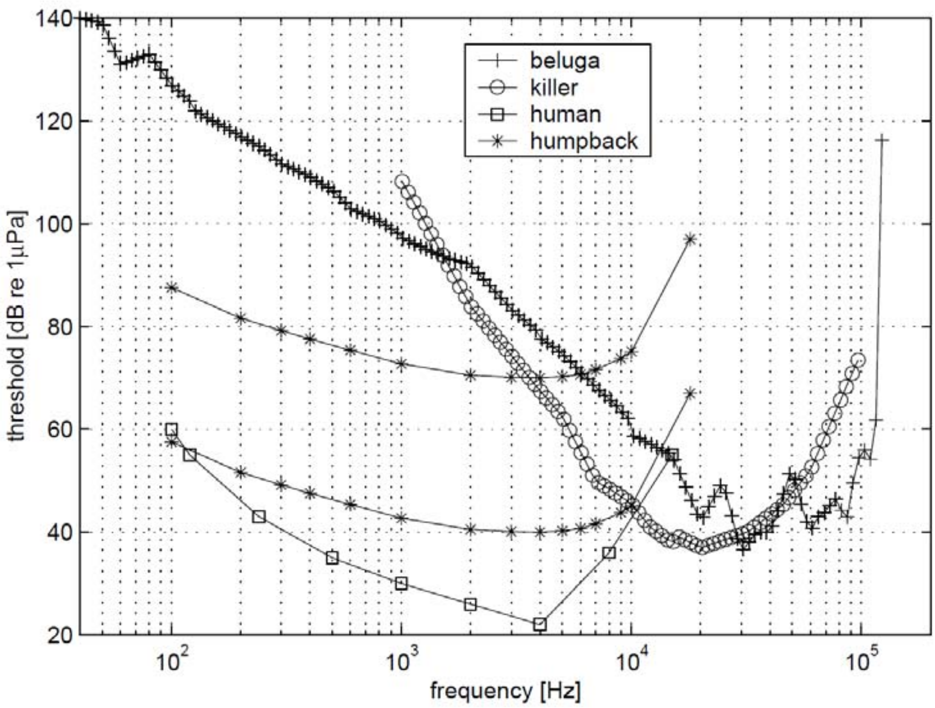


Figure 16. Audiograms of Baleen Whales and the Human

In summary, assuming there are mammals present, there is not expected to be any more than some temporary alteration to the behavior of sea mammals in the vicinity of the proposed iron sand excavation.

For fish there is an extraordinary diversity in hearing resulting in different auditory capabilities across species. While many fish species hear in the range of about 30Hz to 1kHz some fish can hear up to 3kHz. An audiogram[8] of some species of fish is shown on Figure 17. However, the actual level expected to be generated by the turbines will not generate any negative communication effects for fish.

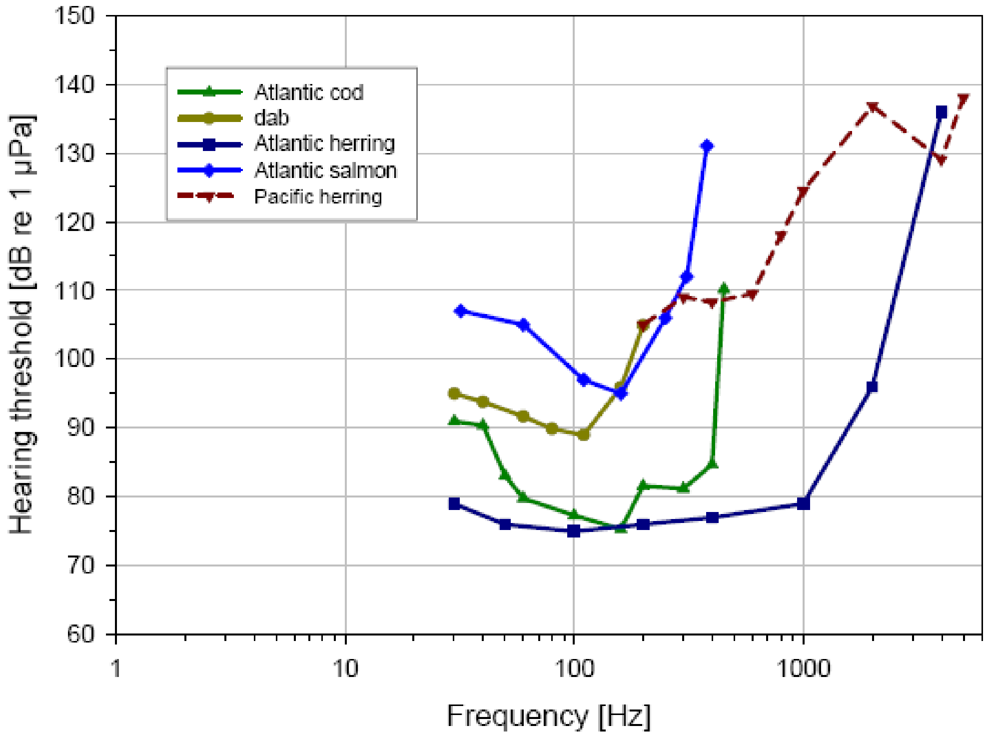


Figure 17. Audiograms of Selected Fish

---

[7] Hearing Abilities of Baleen Whales, Defence R&D Canada – Atlantic, October 2002

[8] Effects of offshore wind farm noise on marine mammals and fish Frank Thomsen, Karin Lüdemann, Rudolf Kafemann and Werner Piper July 06, 2006

Most of the studies[9] have shown that rapid, irregularly pulsed, broad-band sounds with spectral frequencies below 600Hz can attract sharks. Experiments with various species by Myrberg and his co-workers have revealed that sharks are most attracted to irregular, pulsed sounds of relatively low frequencies. Field and laboratory experiments have demonstrated that sharks can hear sounds with frequencies ranging from about 10Hz to about 800Hz, but are most responsive to sounds less than 375Hz. Where there is no increase in the ambient airborne sound and water-borne vibration levels, then there should be no adverse effect on sharks. There is no information on rays, but as they are of the same family as sharks it is assumed their reaction to noise will be similar.

Behavioural effects, such as a fish or porpoise avoiding or fleeing an area as a result of underwater sound, is not expected to occur as a result of noise from the proposed iron sand excavations. It has been reported[10] that marine mammals and fish tend to be adapted for living in noisy underwater environments, and typically have hearing thresholds that are much less sensitive than animals adapted for the atmospheric environment, such as humans. For this reason marine species are able to tolerate much higher levels of noise.

The frequencies used by porpoise are:

- Low frequency sounds at 1.4 – 2.5kHz for communication
- Sonar-clicks (echolocation) at 110 – 140kHz
- Low-energy sounds at 30 – 60kHz
- Broadband signals at 13 – 100kHz

---

[9] Approaches to the Study of the Behavior of Sharks Samuel H. Gruber and Arthur A. Myrberg, Jr. Rosenstiel School of Marine and Atmospheric Science, University of Miami Miami.

[10] Assessment of Tidal Current Turbine Noise at the Lynmouth site and predicted impact of underwater noise at Strangford Lough. Report No. 628 R 0102 by Mr S J Parvin, Mr R Workman, Mr P Bourke and Dr J R Nedwell 10th May 2005

All of these frequencies are well above those predicted from the proposed iron sand excavations. Thus, based on the predicted noise from the excavations it is not expected there will be any adverse behavioural effect for sea life in the area.

Figure 18[11] shows a comparison of the relationship between various noise sources and marine life.

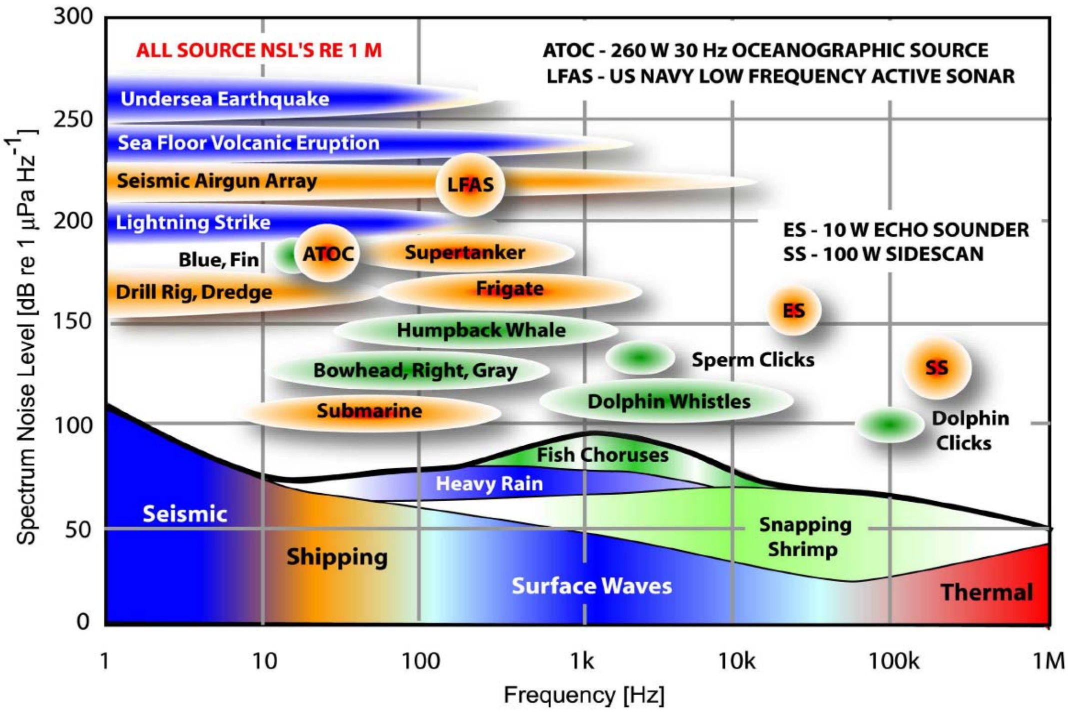


Figure 18. Comparison of Noise Sources

[11] National Physical Laboratory, UK, October 13th, 2005

The following Table 4 sets out the approximate noise levels of the iron sand extraction (including if a cutter suction dredge is used) above the threshold of hearing for dolphins and whales:

Distance from extraction	Level above the threshold of hearing	
	Suction dredge	Cutter suction
50m	51	59
100m	45	53
250m	37	45
500m	31	39
1000m	25	33
1500m	21	29

Note: Shaded areas indicate general iron sand extraction noise is expected to be masked by the ambient sound.

Table 4. Noise Level (dB re 1μPa) above the Threshold of Hearing

In order to hear the sound it is necessary for that sound to either be above the background sound (ambient sound) or if below the background sound the sound of interest must have a distinct spectrum content for it to be picked out amongst the background sound. Without a detailed spectrum analysis of the various sounds more general guidelines must be used. To be conservative it has been assumed that if the dredge noise is at least at the background sound less 10dB it will be heard. Thus, the masking effects of the existing noise environment can be predicted based on the sea noise being around 132dB. This means if the dredge is no more than about 122dB the sea noise will mask most dredge noise. A level of 122dB will be achieved at approximately 300m from the suction dredge and 900m from a cutter suction dredge.

6 CONCLUSIONS

No hearing hazard or communication masking for marine mammals from the proposed iron sand excavation is expected in the vicinity of dredging. Therefore, no change to the migration or lifestyle of dolphins or whales due to noise is anticipated from the dredging.

If marine mammals are close to the dredging (≈50m) the environment will be noisy at 47dB above the threshold of hearing for the suction dredge and, if used, 55dB for the cutter suction dredge. However, these levels are not believed to be sufficient to cause any unacceptable disturbance for marine life.

There is no past evidence of any adverse effects of noise for marine mammals in the area from the existing shipping lanes.

When taking the above into account the effects of noise on marine mammals and fish is predicted to be no more than minor.

* * *