Application of a noise model for environmental impact assessment of deep sea mining

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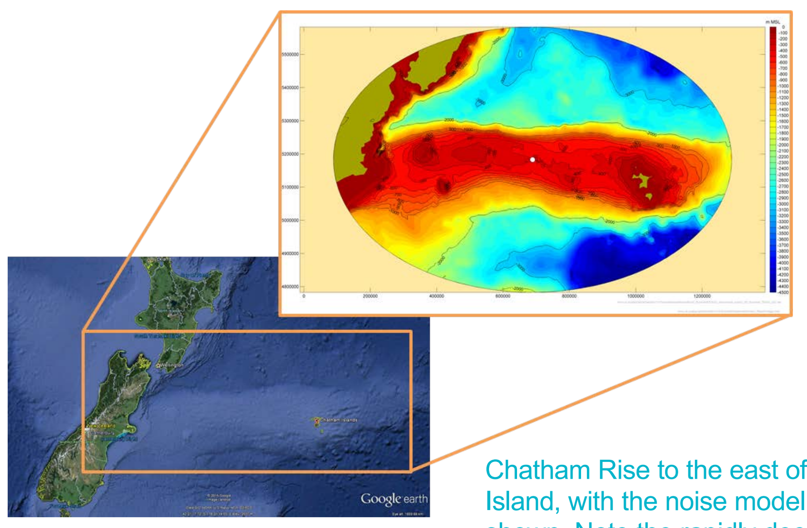
Introduction

- The Chatham Rise is a submarine feature extending eastward from the South Island of New Zealand.
- The rise has water depths of 80 - 500m and hosts economically significant amounts of rock phosphate nodules on/within the seabed.
- Chatham Rock Phosphate (CRP) are planning to mine the phosphate using conventional dredging methodology adapted for deep water.
- CRP commissioned HR Wallingford to undertake underwater sound modelling for the mining operation.
- The sound modelling was undertaken to inform the environmental impact assessment of potential effects on commercial fish in the area.
- The model used was the HAMMER tool developed by HR Wallingford, which is a parabolic equation model similar in principle to RAM.



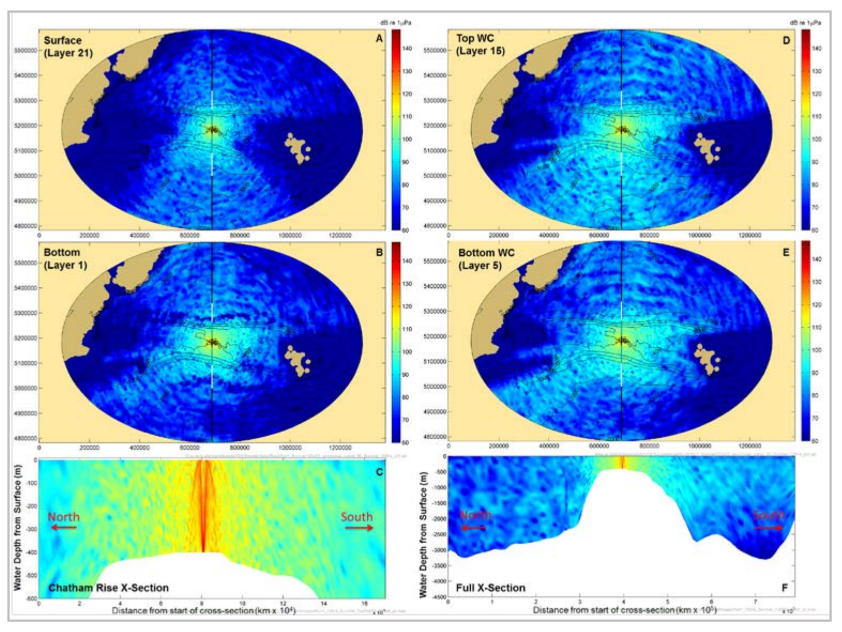
Chatham Rise to the east of NZ South Island, with the noise model bathymetry shown. Note the rapidly decreasing depths sloping away from the rise (400 to 4000 m)

HAMMER Noise Model Results

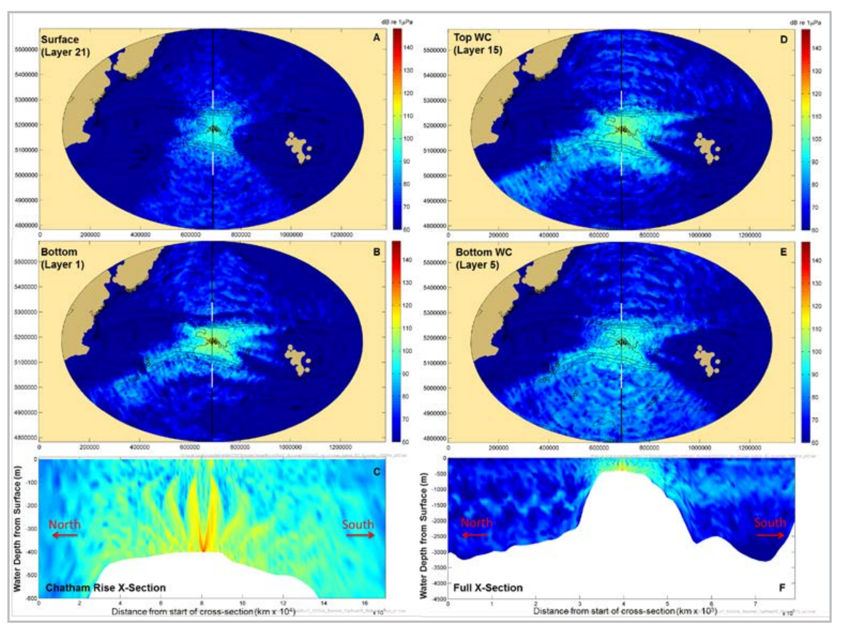
The HAMMER tool was run for a number of discrete frequencies between 125 and 1 kHz. The frequency range used covered the peak sensitivities of the fish species present at Chatham Rise. The propagation of 'above ambient' sound away from the simulated mining location is generally limited to the Chatham Rise itself, however, lower frequency sound propagates as far as the mainland of New Zealand and the Chatham Islands.

The wide extent of underwater sound occurs because of the depth of the water at the site - low frequency sound, particularly under 1 kHz, does not dissipate as quickly in deep water compared to higher frequencies, due to the more rapid attenuation of sound waves at smaller wavelengths. The effect of the density variation is to set up a 'deep sound channel', through which sound propagates more efficiently.

Though the response of fish species to these sound levels is not covered here, the results have shown that while there will be a potentially large area of audibility from the mining operations for the local fish species, there is not expected to be an adverse behavioural response.



Hammer tool RMS received level (dB re 1μPa) for 125Hz in summer.



Hammer tool RMS received level (dB re 1μPa) for 1000Hz in summer.

Panels A and B show the surface and bottom planes; panel C is a north-south cross-section of Chatham Rise; panels D and E show the top and bottom sections of the water column WC); while panel F is a north-south cross-section across the whole domain.

References

Ainslie, M.A., de Jong, C.A.F., Dol, H.S., Blacquière, G. and Marasini, C. (2009). Assessment of natural and anthropogenic sound sources and acoustic propagation in the North Sea, TNO Report TNO-DV 2009 C085.

Coates, R.F.W., (1989). Underwater acoustic systems. Vol. New York, Halsted Press

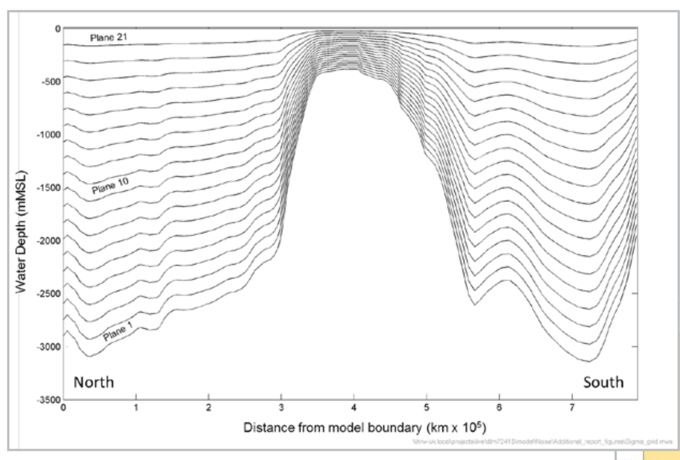
Robinson, S.P., Theobald, P.D., Hayman, G., Wang, L.S., Lepper, P.A., et al. (2011). Measurement of noise arising from marine aggregate dredging operations, MALSF (MEPF Ref no. 09/P108),

Wales, S.C. and Heitmeyer, R.M., (2002). An ensemble source spectra model for merchant ship-radiated noise. The Journal of the Acoustical Society of America, 111, pp:1211-1211.

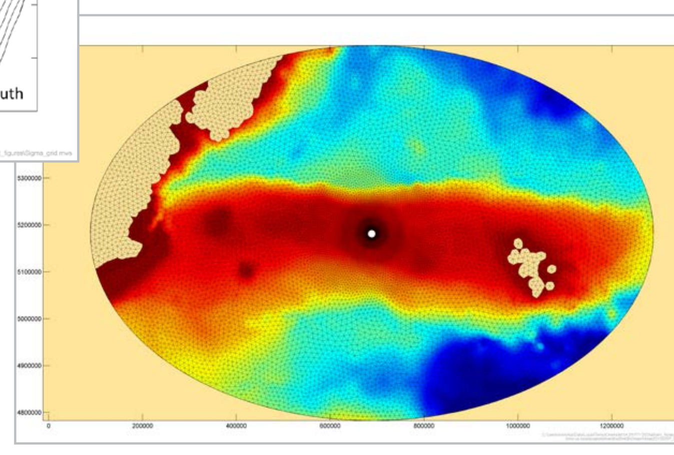
HAMMER Noise Model Inputs

Model bathymetry and mesh

- Model bathymetry comprises bathymetry data collected on Chatham Rise, as well as NOAA data.
- Unstructured mesh with triangular elements focussed on the mining location in the centre of Chatham Rise (white circle).
- Results in mesh resolution of 250m at the mining location, with 10% scaling producing approximate 10km mesh size at the model boundaries.
- The 3D model set up includes a vertical resolution of 21 horizontal sigma planes spaced uniformly between the seabed and the sea surface.
- The individual planes do not represent a constant depth, but rather a proportion of the water column position across the whole model domain.



Vertical resolution of 3D model (21 sigma planes), showing how plane thickness varies north-south across Chatham Rise.



Unstructured model mesh, with mining location shown as the white circle.

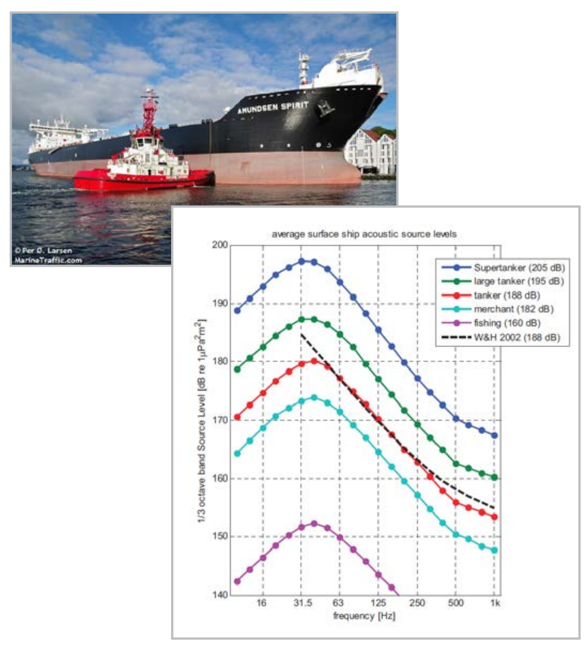
Source levels

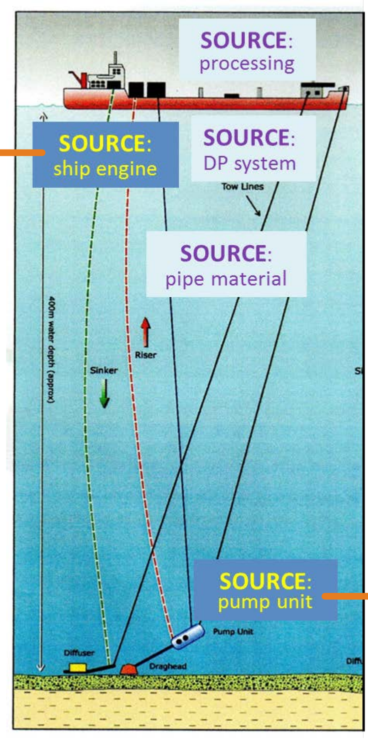
There are a variety of potential sound sources from the mining vessel selected for the CRP project (see image). Some of these were disregarded as being either a) relatively insignificant; or b) mainly airborne sound.

The main two sound sources are determined as (1) that of the ship engine near the surface; and (2) that of the pump unit near the bed. HR Wallingford used both the available literature, as well as developing an extrapolation procedure, to determine the loudness of these two main sound sources.

SURFACE SOURCE: ship engine

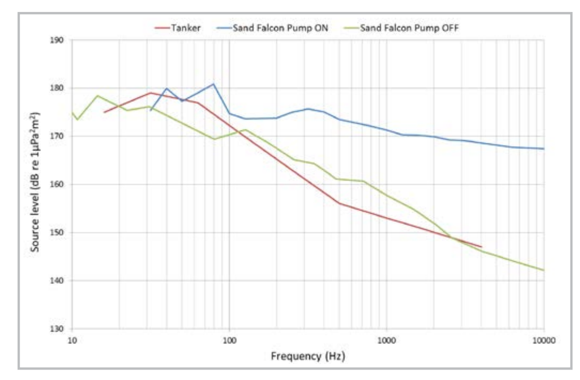
- Ainslie et al. (2009) compared their sound models for various vessels to recordings made of different vessels.
- These were then averaged to produce a single sound spectra for various vessel types (Wales and Heitmeyer, 2002).
- The vessel to be used for mining 'Amundsen Spirit' most similar to the TANKER spectrum.





BED SOURCE: pump unit

- The total pump power required to move the mined material to the vessel could be up to 12MW, of which there are no known sound recordings.
- As such the source levels for the pump have been scaled up, based on Robinson et al. (2011).
- The dredger 'Sand Falcon' had the largest pump power (2.7MW) of those dredgers assessed by Robinson, and was the basis for extrapolation.
- The figure below shows the similarity of the tanker spectrum to that of the Sand Falcon when the pump is switched off.
- Note also the large contribution of the pump.



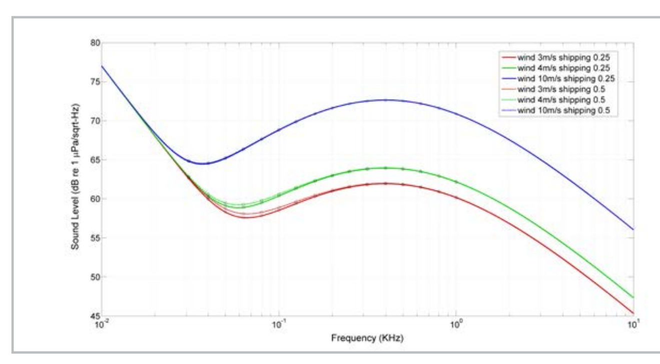
Bed sediments and ambient noise

The physical properties of the seabed sediment influence how sound is refracted and absorbed as it propagates away from a sound source, and so bed sediment is parameterised in the model. Also important is the level of ambient sound in the region, which provides a baseline for calculated received levels.

- The seabed at Chatham can be represented as a chalk ooze, overlaid by a thin layer of silty fine sand.
- When considering sound propagation, the thin layer (~1m) of looser sediments will have very little effect on attenuation.
- As a result, it is the chalk ooze properties that have been applied to the model domain.
- It is acknowledged that the bed sediment on the flanks of the Rise is likely to be different to that of the Rise itself.
- However, these changes are will be insignificant as we move away from sound source, when the density profiles become more important.

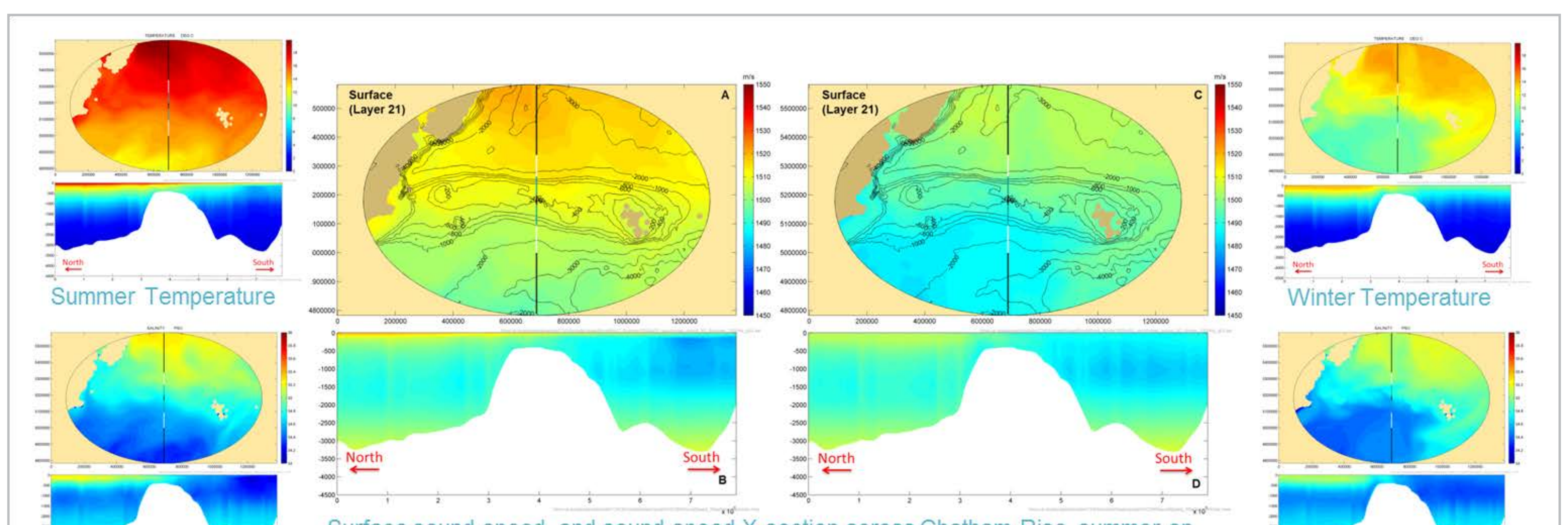
Physical Property	Value
Density (kg/m³)	1850
Sound speed (m/s)	1630
Attenuation coefficient (dB/λ)	0.77

- Ambient sound is specific to where it is measured and ideally requires direct measurement.
- However, no direct measurements are available in the Chatham Rise area.
- As a result, the predictive expression of Coates (1989) was used to determine ambient sound.
- The main contributing terms include: (i) Wind speed; (ii) Shipping density; (iii) Temperature



Density profiles for sound speed

The propagation of sound is dependent on the sound speed, which is dependent on the apparent density variation, both spatially and vertically through the water column. The density variation is in turn dependent on predominantly the water temperature and water salinity. Both of these quantities were extracted from the 3D HYCOM model, using winter (July 2011) and summer (January 2011) scenarios to provide seasonal variation.



Surface sound speed, and sound speed X-section across Chatham Rise, summer on right, winter on left. Note the difference thicknesses of the 'deep-sound channel'