FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

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Predicting Tidal Turbine Noise for Environmental Impact Assessment

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Background

• The development of tidal turbine technology is key to the capture of renewable energy, with an estimated 18TWh/year[1] available from the UK's tidal resource alone.

• In the design and implementation of such devices environmental impact assessment is mandatory, including an investigation of the noise generated by the turbine and its likely effect on marine animals (summarised in Figure 1).

• Modelling noise at the design stage will allow a better understanding of the mechanisms of generation, and save costs related to re-design and mitigation.

Aims

• Identify the key sources of flow-generated noise in a typical tidal turbine, such as that shown in Figure 2.

• Model these sources using analytical and numerical techniques.

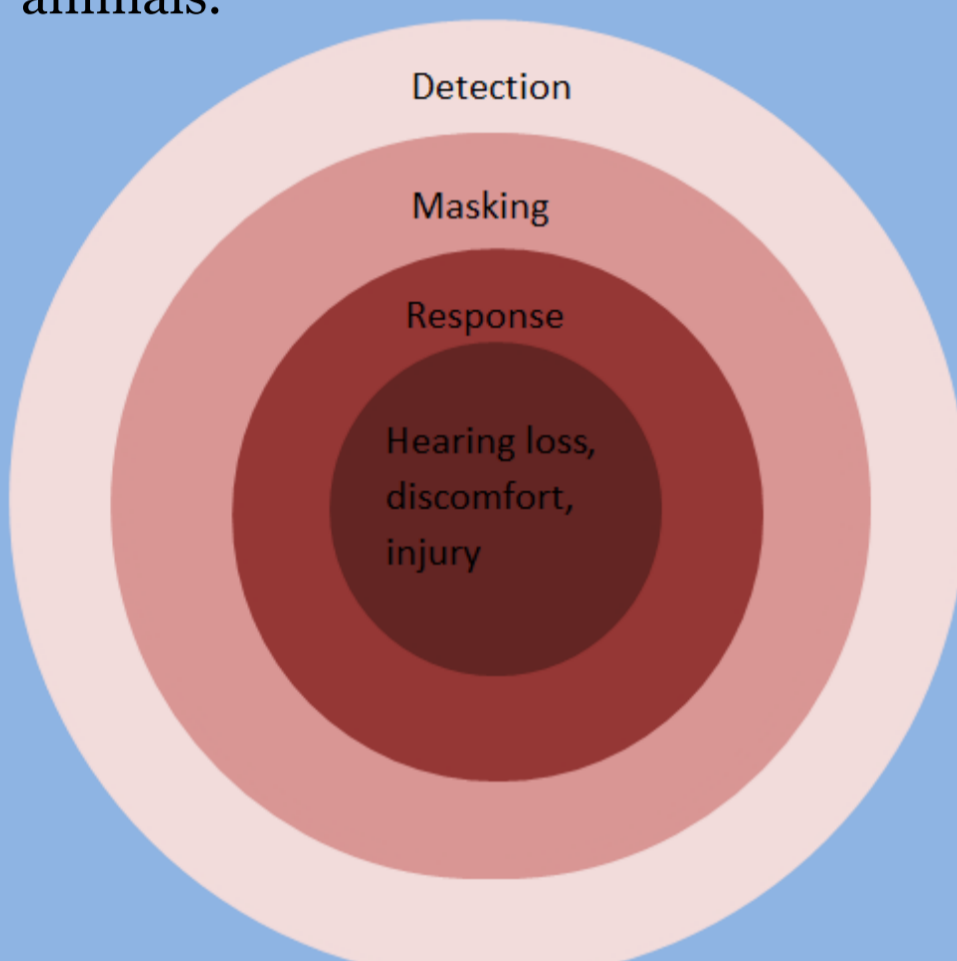• Estimate the propagation of the generated sound, and its effect on marine animals.

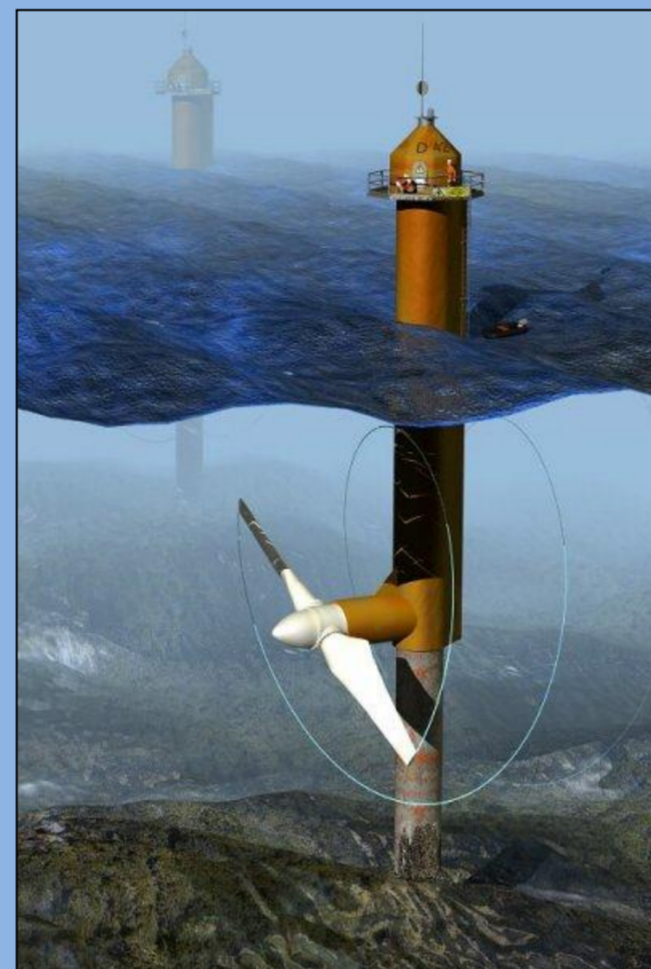Figure 1: Zones of noise influence for marine animals[2]

Figure 2: Typical horizontal axis tidal turbine (http://www.rise.org.au/info/Tech/tidal/index.html)

Modelling Methodology

• This project focuses on modelling flow generated noise, where the predominant sources are expected to be due to unsteady loading and turbulent boundary layer flow at the trailing edge (see Figure 3).

• Whilst 'high-level' techniques, such as Large Eddy Simulation (LES) will be used later to model acoustic sources, the approach adopted thus far utilises empirical formulae intended for application to ship propellers[3] .

• The sound pressure level is calculated from a wave number frequency spectrum of pressures, $\varphi_{pp}(r,\omega)$, where for:

1. Turbulent boundary layer flow:

$\varphi_{pp}(r,\omega) = f$(rotor geometry, boundary layer profile and rotational speed)

2. Turbulent inflow:

$\varphi_{pp}(r,\omega) = f$(rotor geometry, inflow parameters and rotational speed).
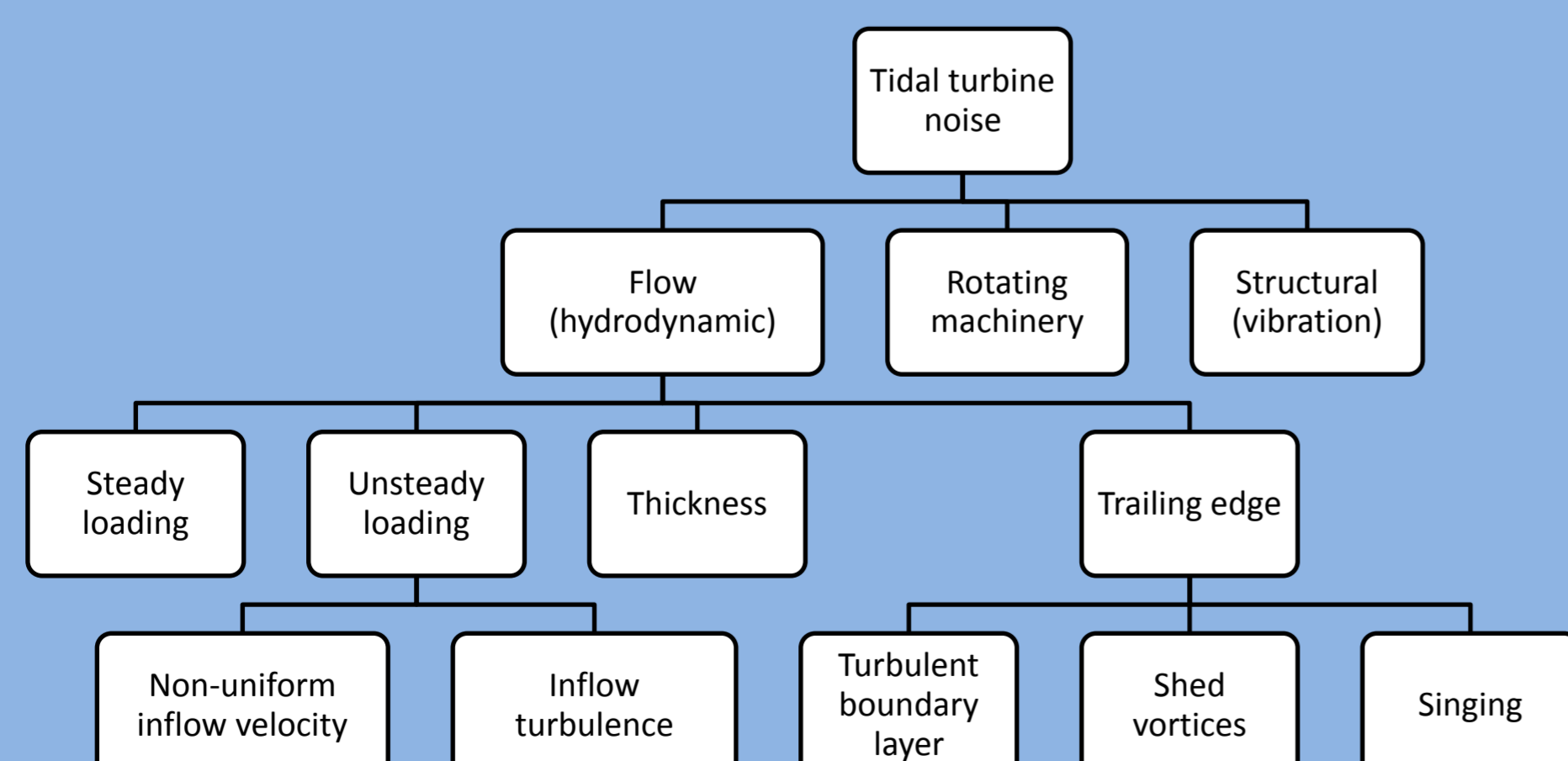

Figure 3: Classification of noise sources associated with tidal turbine

Results

• Noise is computed based on the outlined approach using the parameters in Table 1.

Table 1: Key parameters for noise computation

Rotor diameter [m]	20	Rotational speed [rads⁻¹]	1.75
Tip chord [m]	0.62	Turbulence length scale [m]	2.30
Number of blades	3	Turbulence intensity [%]	10

• The sound pressure level (SPL) is calculated as:

$$SPL = 10\log_{10}\left(\frac{\overline{p^2}}{p_{ref}^2}\right)$$

where $\overline{p^2}$ is the mean square pressure, calculated from $\varphi_{pp}(r,\omega)$ and p_{ref} is the reference pressure of $1\,\mu Pa$. The evaluation has been carried out at a distance of 20 metres from the turbine hub, assuming this is the start of the far field region, and that animals will not approach to within a rotor diameter.
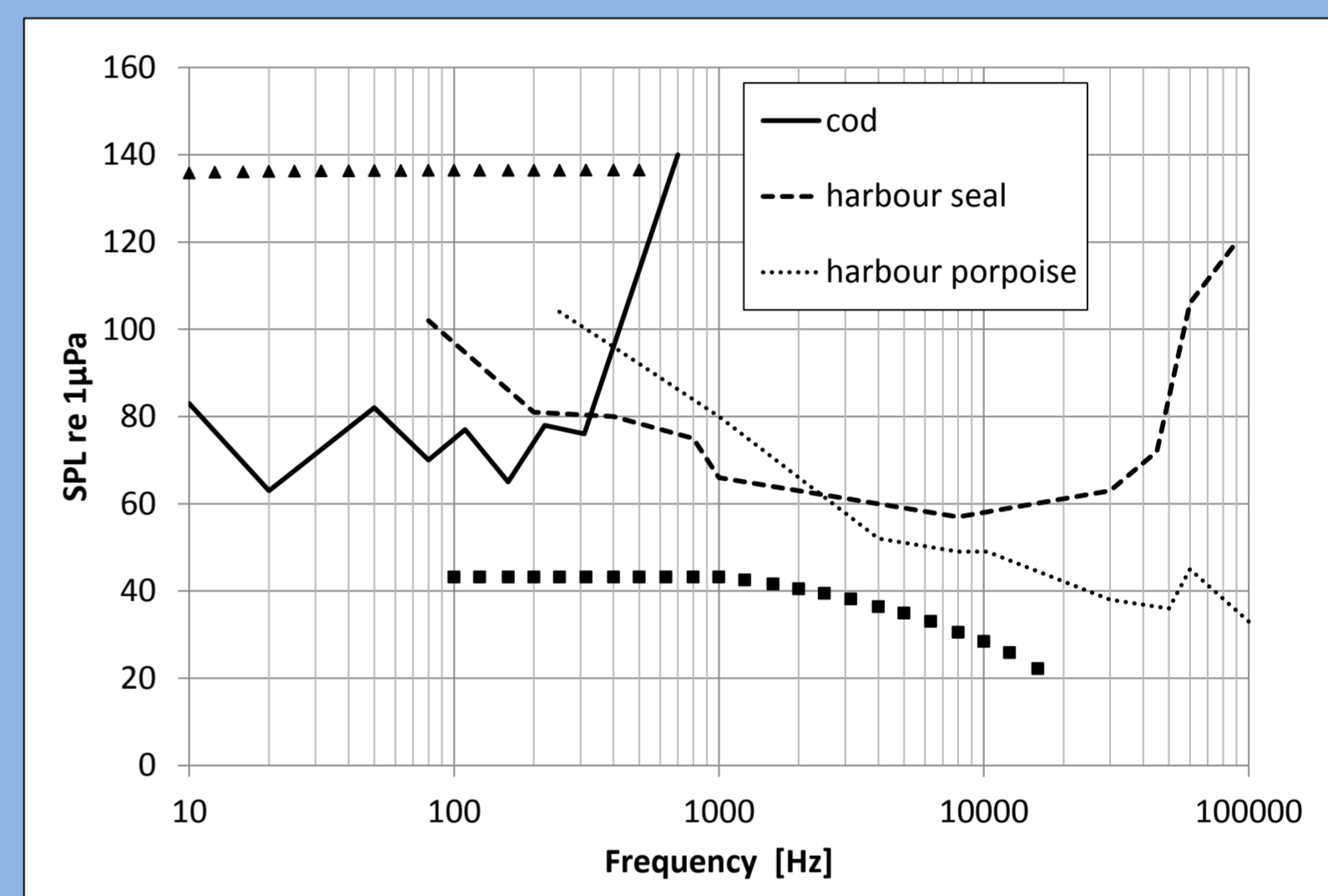

Figure 4: Predicted sound pressure level for turbulent noise sources at 20 metres from the source. Values calculated on the rotor axis for one-third-octave bandwidths: triangle (inflow turbulence); square (boundary layer turbulence). Comparison made to hearing threshold data for three marine animals[4]

• Figure 4 reveals that the dominant noise source is due to inflow turbulence at low frequency. The estimated SPL is significantly larger than the hearing threshold of all three animals included and thus noise influence could be expected at this location.

• A more detailed study would include the effects of directionality, exposure time and ambient noise to predict the likely effects within the 'zones of influence' framework.

• It should be noted that shallow water effects have not been included. If they were to be, SPL will be modified by transmission losses and refraction effects.

Conclusions and Further Work

• The preliminary modelling of flow-generated sound relating to a tidal turbine has revealed that inflow turbulence is a dominant noise source.

• A more comprehensive assessment of the likely effects on marine animals is required, and should account for environmental factors such as ambient noise and shallow water effects.

• Improved modelling accuracy may be achieved using LES to estimate noise sources due to turbulent flow.

• Other sound sources may also need to be modelled, such as cavitation and vortex noise.

References:
1: Couch, S.J. and Bryden, I. Tidal current energy extraction: hydrodynamic resource characteristics. *Proc. IMechE.*, **220**, Part M: J. Engineering for the Maritime Environment. pp. 185-194. 2006.
2: Richardson, W.J., Malme, C.I., Green, C.R. Jr. and Thomson, D.H. *Marine mammals and noise,* Academic Press, San Diego. pp. 576. 1995.
3: Blake, W.K. Aero-hydroacoustics for ships, Vol. II. DTNSRDC-84/010, David W. Taylor Naval Ship Research and Development Centre, Bethesda. 1984.
4: Ainslie, M.A., De Jong, C.A.F., Dol, H.S., Blacquiere, G and Marasini, C. Assessment of natural and anthropogenic sound sources and acoustic propagation in the North Sea. TNO-DV 2009 C085. TNO, The Hague.

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