Underwater noise from cruise ships

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1 INTRODUCTION

Of the various sources of anthropogenic noise in the marine environment, shipping noise is the most pervasive. It serves to inflate the ambient noise field over the vast majority of the Earth's oceans. The effects of this noise are expected to be chronic, rather than acute, and most concern affects wide-spread behavioral impacts as opposed to the possibility of local physical impacts. The results of this study provide additional evidence that this ordering of priorities is indeed justified.

In the military context underwater noise from surface vessels has been of great interest for many decades and reducing it has been an area of considerable research activity. Whereas in the commercial sector the absence of direct financial implications of emitting underwater noise has meant that, historically, it has not been perceived as priority. The example of cruise ships provides one instance where such an imperative has, to a limited extent, previously existed, with the issues surrounding underwater noise becoming even more crucial in recent years.

The indirect reason behind reducing underwater noise from cruise ships is a by-product of the importance of maintaining passenger comfort: which is a primary motivating factor in the sector. As a consequence of the drive to enhance passenger comfort efforts have been made to minimize on-board vibrations through, for example, isolating machinery. Such efforts have the indirect benefit of tending to reduce underwater radiated noise. Recently the advent of restrictions of ship movements in some Marine Protected Areas (MPAs) has provided direct impetus to cruise ship builders and operators in this regard.

Ship noise arises through several physical mechanisms [1]. The relative importance of these mechanisms clearly depends on a vessel's design, but also critically depends on the prevailing operating conditions: including the ship's status (e.g. ladened or unladened), ship speed and weather conditions. The main physical noise sources usually considered are: cavitation noise, primarily from the propeller(s), on-board machinery noise and flow noise. Typically, at low speeds, prior to the onset of propeller cavitation, it is machinery noise which dominates the underwater noise signature, whereas once the ship reaches a critical speed, at which propeller cavitation begins, then it is cavitation noise which dominates in many frequency bands. Flow noise contributes primarily in the low frequency band and in most cases is not a primary noise source. Evidently operating a vessel at low speed, so avoiding cavitation, is one method to significantly reduce ship noise, however, this is generally commercially unrealistic. Conversely designing a vessel such that cavitation is avoided through a range of realistic operating speeds is attractive. Allied with vibration isolation of on-board machinery this can produce vessels with greatly reduced acoustic signatures, the challenge is to achieve this in a commercially competitive manner and in a way that is robust enough to avoid expensive maintenance regimes.

An important aspect of being able to build and design vessels in a manner that accounts for underwater noise is being able to make effective measurements from vessels under realistic operating conditions. Standardized procedures for making such measurements are now available [2,3]. These measurements cannot typically be undertaken at dedicated facilities, such as those available to the military, but by necessity are normally conducted using a small number of hydrophones distributed over a limited area. In order to rank the relative noise contributions of the various noise sources one approach is to separate a received signal into components distinguished by the different signal characteristics. These characteristics approximately map to the different source mechanisms and can be used as a proxy for the contributions of each mechanism.

2 IMPACT OF CRUISE SHIP NOISE ON MARINE MAMMALS

To illustrate the chronic (as opposed to acute) nature of the potential impact of shipping noise a dataset of recorded noise from cruise ships is analyzed. Figure 1 shows the 1/3rd octave spectrum measured from a cruise ship, collected when the vessel was at a speed of 10 knots. The plot depicts the raw 1/3rd octave spectrum derived from data measured at a range of 650 m. The levels shown are computed by referred back to a reference distance of 1 m using a spherical spreading model. Four associated weighted spectra are presented; the weighted being conducted according to the M-functions defined for 4 species groups defined in Southall *et al*. [4].

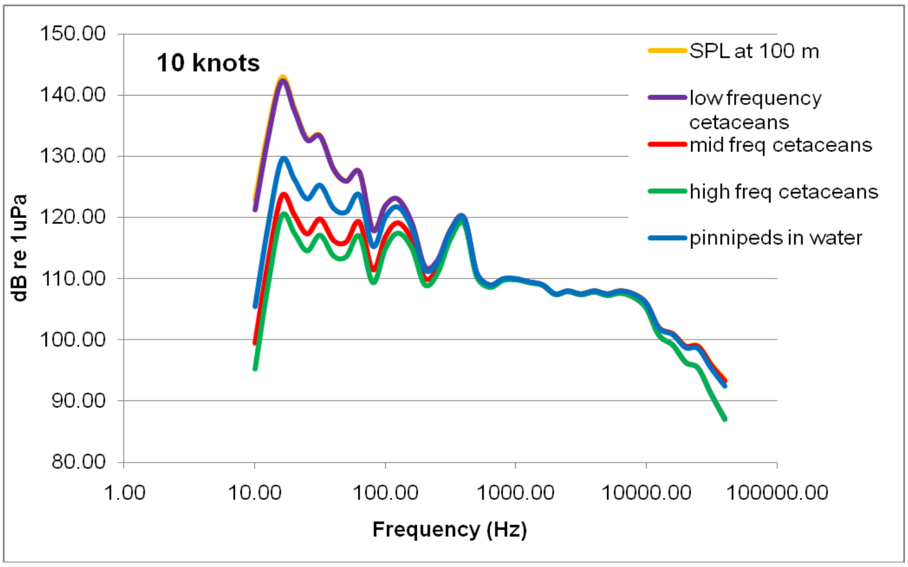

Figure 1: Third octave sound pressure levels (SPLs) (dB re 1 µPa$_{rms}$) for an example cruise vessel, measured at 650 m and back-calculated to a range of 1 m using a spherical spreading model. The graph depicts the raw and M-weighted spectra.

Spectra such as there are used to compute the time over which an animal can remain at 100 m before the suggested limit [4] of a weighted SEL (Sound Exposure Level) of 195 dB re 1 µPa$_{rms}$ s is exceeded. The distance 100 m is chosen purely for illustrative reasons. The limit of 195 dB re 1 µPa$_{rms}$ s is based on the measured thresholds for Temporary Threshold Shift (TTS) when animals are exposed to continuous sounds. This is based on TTS experiments conducted on mid-frequency cetacean species [5] and is extrapolated to low frequency species, for which experimentation is impractical.

	Low freq	Med freq	High freq	Pinnipeds
10 knots	140.1	93.9	93.7	94.4
20 knots	144.1	94.5	94.3	94.9

Table 1: Weighted SELs (dB re 1 µPa$_{rms}$ s) computed for averages across a range of cruisers at two speeds (averages across 9 vessels for 10 knots and 5 vessels for 20 knots). The SELs are quoted at a range of 100 m. Results are shown for the 4 different M-weighting functions.

Using these weighted averages it is evident that SELs for the low frequency cetaceans greatly exceeds that of the other species groups. This is a reflection of the fact that a considerable proportion of the energy from these vessels is concentrated the low frequency band. Further it is clear that, as one might anticipate, the SELs increase as the ship speed increases: an effect which is most evident in the low frequency region.

According to the criteria a low frequency cetacean, i.e. a Mysticete species, would have to remain at a range of 100 m from a cruise ship travelling at 10 knots for a period of 3.5 days to exceed the threshold. If the ship is travelling at 20 knots then this period is reduced to 1.5 days. Evidently an animal may approach closer than 100 m, but is unlike to remain in the proximity of a vessel for such extended periods when the vessel is travelling at these speeds. Whilst a speed of 20 knots may be possible for, say, a fin whale to achieve, it is unlikely it is capable of maintaining that speed and there is no clear motivation as to why it should endeavor to do so in the vicinity of vessel. The corresponding exposure times for the other species groups are considerably longer.

3 CONCLUSIONS

The preceding results reinforces that the noise from the passage of a cruise ship is extremely unlikely to result in direct injury to a marine mammal. It is difficult to model a realistic pattern of exposure of an individual animal over an extended period of time. To do so one would need good models of animal's behavior in the presence and absence of ships, data this is largely unavailable. Further models of the hearing organ's recovery between exposures to noise are poorly understood in marine mammals. However, even in crowded shipping lanes it seems unlikely that animals will spend periods of hours in close vicinity to vessels moving at the speeds considered here (10 and 20 knots).

It is important to recognize that this analysis only provides evidence suggesting that cruise ship noise does not directly injury cetaceans. As already discussed the primary concern surrounding ship noise is not that it causes direct injury, but that it may cause behavioral reactions, which can have negative impacts upon individuals and, more concerningly, impacts on populations. This study does not address behavioral effects and so does not provide information regarding this aspect of the problem.

4 REFERENCES

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