Ambient noise and marine animals

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I. Introduction

Ambient noise provides a basic limitation on the use of sound by marine animals since signals of interest must be detected against the noise. Marine animals have evolved to use sound within the limitations imposed by the natural ambient noise, and comparison of natural noise with the underwater noise from human activities may help understand the effects of anthropogenic noise. There are concerns that increased noise from human activities may be limiting the ability of animals to communicate (by masking) or may be affecting their hearing (through long term exposure). In particular, the noise of distant shipping, usually referred to as "traffic noise" [1], is a wide spread and pervasive component of ambient noise and has been considered a potential problem for baleen whales which use sounds at the low frequencies where traffic noise is dominant (mainly below 200 Hz). Note that traffic noise as defined by Wenz [1] is the contribution to the ambient noise of a large number of distant ships, and does not include noise from ships close enough to be distinguished individually. Little is known about baleen whale hearing apart from what can be inferred from the characteristics of sounds on the assumption that their hearing must be adequate to detect their own sounds. For example, sounds of blue and fin whales have most energy between 20 and 100 Hz, while those of humpback and right whales, most energy is between 50 and 1000 Hz [2]. More is known about the hearing of toothed whales and it is relatively poor at the frequencies of traffic noise [2].

II. Traffic Noise Compared with Low Frequency Wind Dependent Noise

Most ambient noise prediction methods are based on the curves developed by Wenz [1], which show wind-dependent noise spectra as having a broad peak at around 500 Hz and extending down to about 200 Hz where the curves cease and below which the noise is dominated by traffic noise. Extrapolation of the wind dependent curves to lower frequencies suggested that ambient noise might have been very low at these frequencies before the advent of powered shipping. This led to the idea that there was a "noise notch" at low frequencies that was exploited for communication by baleen whales, especially the blue and fin whales, and that traffic noise has severely compromised their ability to communicate, at least over long distances. The difficulty in assessing this is that most measurements of ambient noise have been made in areas of high shipping densities and thus high traffic noise, and it has been difficult to determine the characteristics of natural ambient noise at these frequencies.

Measurements in areas near Australia where shipping densities are very low have allowed us to make reliable estimates of wind dependent noise below 200 Hz. These show that wind dependent noise has a different character below 200 Hz, with noise level rising rather than falling with decreasing frequency. These results are consistent with the few results in earlier and recent work in high shipping areas around North America where there is evidence of wind dependent noise at low frequencies [3]. The measurements show that at high wind speeds (say 30 knots or so), wind dependent noise levels reach levels comparable to traffic noise levels in high shipping areas in prediction curves. Some areas, however, may show higher levels of traffic noise. For example, ambient noise measurements off Pt. Sur, California show higher noise levels at low frequencies at the 50 percentile and they considered that a large proportion of this is due to shipping [4]. Although this includes contributions from all shipping (not just traffic noise) as well as biological and wind dependent noise, it may well be that these imply higher traffic noise levels than those of the Wenz curves, especially since the results indicate that noise levels have increased compared to Wenz's measurements.

These results suggest that baleen whales were always subject to noise levels that at times reached levels comparable to high levels of traffic noise. The difference with the present ambient noise in high shipping areas is that there would also have been times of relatively low noise level, though the lowest levels would have been significantly higher than estimated by extrapolation of Wenz's curves. Traffic noise is a non-descript sound from the contributions from many ships, so any characteristic modulation or line structure is averaged out. It has a similar spectral shape to the low frequency component of wind dependent noise and could not be distinguished from wind dependent noise by the mammalian ear. Much of the world's oceans have relatively low levels of traffic noise and low frequency noise compared to the high shipping density areas of the northern hemisphere where most ambient noise measurements have been made and consequently low frequency noise levels would usually be dominated by wind dependent noise.

This discussion has been confined to the effects of traffic noise. Higher levels of exposure would result from all shipping noise, i.e., traffic noise and the intermittent exposure to noise from passing ships, which for a short time will well exceed traffic noise levels.

III. The Biological Contribution to Ambient Noise

The contribution of biological noise to the total ambient noise has often been underestimated, whereas it is a major contributor. Biological choruses that result when large numbers of animals are calling commonly increase noise levels by 20 dB or more over typical background noise at low to moderate wind speeds and may extend over significant areas [5] – [9]. Choruses from fish and invertebrates are common and are also produced by whales [6], [10], [11]. These choruses contribute at significant distances from the aggregation of calling animals. Some fish choruses extend down to frequencies of about 40 Hz with levels that at times would exceed those of traffic noise in high shipping areas. Hence both wind dependent noise and biological noise levels at low frequencies may be comparable to high traffic noise levels.

The variation in wind dependent noise and biological choruses results in ambient noise levels commonly varying by more than 20 dB. Such variation can occur over time scales of hours as the weather conditions change or as a result of the rise or fall of a biological chorus. This corresponds, for propagation by spherical spreading, to a variation of a factor of 10 in aural detection range. Propagation conditions also change with time and location and further add to the natural variation in aural detection range experienced by marine animals. Surface noise (wind dependent noise and rain noise) is not well correlated with long distance propagation because the sources radiate downwards. Hence marine animals experience substantial variation in their aural detection range. The high source levels of whales, therefore, may not be to allow communication over great distances under unusually good conditions, but to allow reliable communication over modest distances for most of the time.

Marine animals produce their own ambient noise when they call in large aggregations. In this case they are within the chorusing aggregation where the noise levels are highest and since the noise consists of large numbers of sounds from their conspecifics it will have a greater masking effect than most other sounds. Levels are likely to be much higher than those from traffic noise. Chorusing is a sufficiently common event from a wide range of species of invertebrates, fish and marine mammals to be considered an important component of the long-term noise exposure experienced by the animals, whether from surrounding conspecifics or from choruses by other species. These levels are comparable to and higher than traffic noise, and it seems unlikely that added contribution of traffic noise has significantly increased long term hearing loss.

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