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UNDERWATER NOISE FROM TOURIST OPERATIONS

(Short Answers in Conservation Science)

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UNDERWATER NOISE FROM TOURIST OPERATIONS

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Background

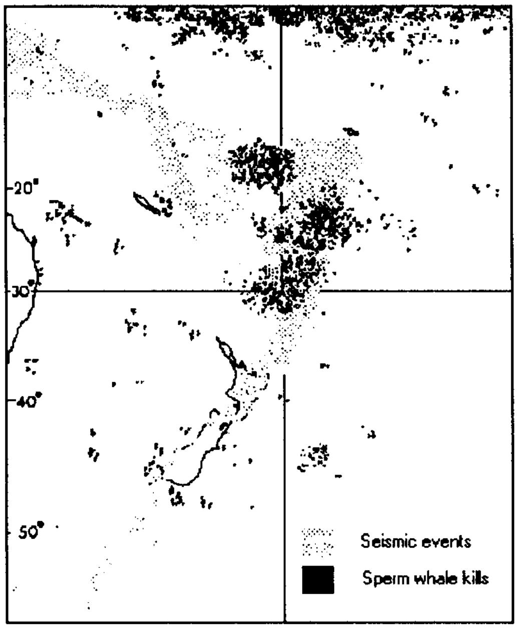
In conjunction with studies on the impact of tourist operations on the whale population off the Kaikoura coast, the Department of Conservation commissioned a noise analysis study to be carried out at the RNZN Noise Ranging Facility at Great Barrier Island. The results of the noise analysis have been published [1]. A brief study to determine the probable levels of noise produced by tourist helicopter operations had been commissioned by commercial interests [2] and was augmented by the Defence Scientific Establishment [3]. This summary has been commissioned by the Department of Conservation [4] to provide a guide to the analysis results published so far.

Cetaceans and acoustics

Cetaceans produce and respond to noise over a wide frequency spectrum. Many of the noises are within the normal range of human hearing, that is, about 20Hz to 20kHz. Minke Whales, for example, produce trains of noise in the frequency range 100 to 200 Hz and above which can be heard for considerable distances. Some species produce very low frequencies. Fin Whales produce relatively pure 20 Hz sounds at high levels which can travel across oceans and which can be heard almost everywhere in temperate waters [5]. Frequencies above the human hearing range are strongly attenuated in sea water and are used by Cetaceans for short range high precision echolocation tasks. The Bottlenose Dolphin, for example, uses high frequency broad band noise with peak energy between 30 and 60 kHz [5]. Sperm Whales produce trains of 'clicks' with a broad spectral content over the band 200Hz to 30kHz and above.

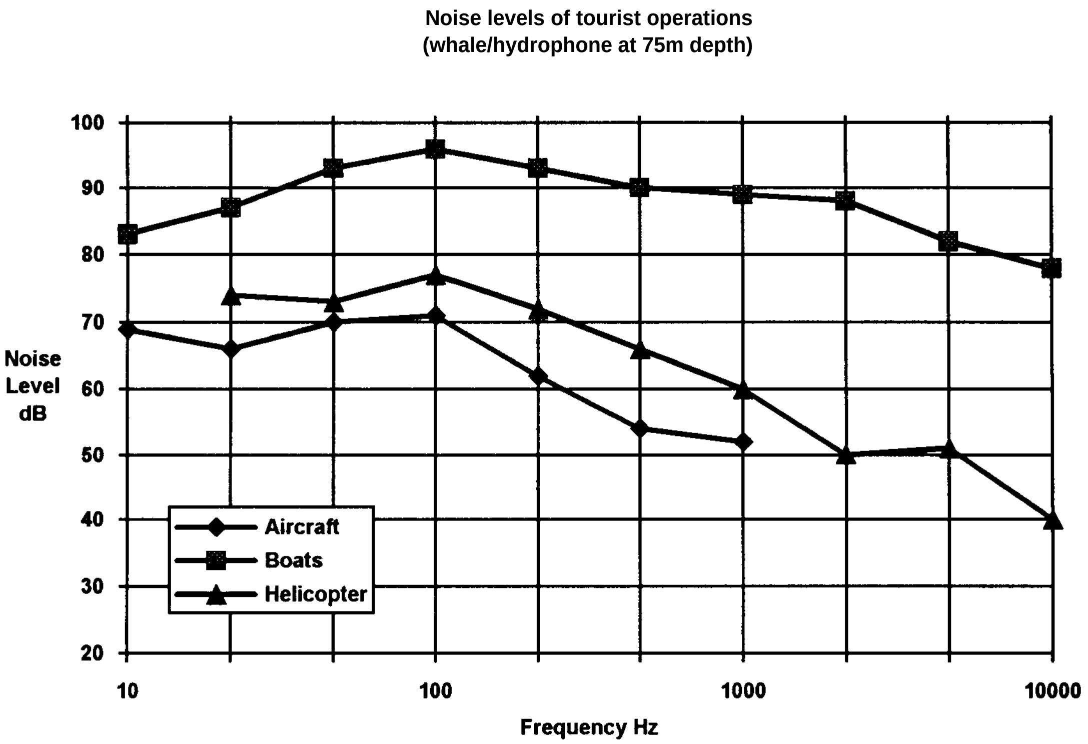
The response of Cetaceans to sound varies with context. Early whalemen knew from practical experience, for example, that Sperm Whales have excellent hearing, and were extremely careful to approach a whale in silence as any abrupt sound stimulus would put the animal to flight. On the other hand "the sound of an approaching motor, which grows slowly but progressively louder, does not seem to startle whales.." [6].

The acoustic capabilities of Cetaceans have evolved against a noise background which can still be found in areas of low shipping density such as exist in many areas around New Zealand. In such areas, normal background noise over most of the frequency spectrum is largely produced by surface wind and wave action and noise from distant storms. Noises from shipping and other relatively recent phenomena, however, are by no means the only source of loud or abrupt sounds. Whales and dolphins have always had to cope with sounds from seismic events and underwater volcanoes which considerably exceed the levels produced by shipping. Only activities such as seismic prospecting or nuclear testing produce equivalent levels of sound. Nonetheless, whales are apparently able to live quite happily in areas where there is a high occurence of seismic sounds. This is shown in the accompanying figure where Sperm Whale kills in winter months over the period 1761 to 1920 (from log book records) have been superimposed on a chart showing earthquake epicentres over a recent twelve-year period. It can be seen that the occurrence of seismic events does not appear to deter the whales from frequenting their preferred feeding areas.



Measurements of noise levels

Measurements of the underwater noise levels from various tourist craft, aircraft and a helicopter are shown in the chart below. The noise levels were measured using a hydrophone at 75 metres depth. The results were averaged over a number of runs with the boats and aircraft essentially directly overhead. The results as originally presented [1,3] have been adjusted to facilitate comparison (see appendix for further comments).



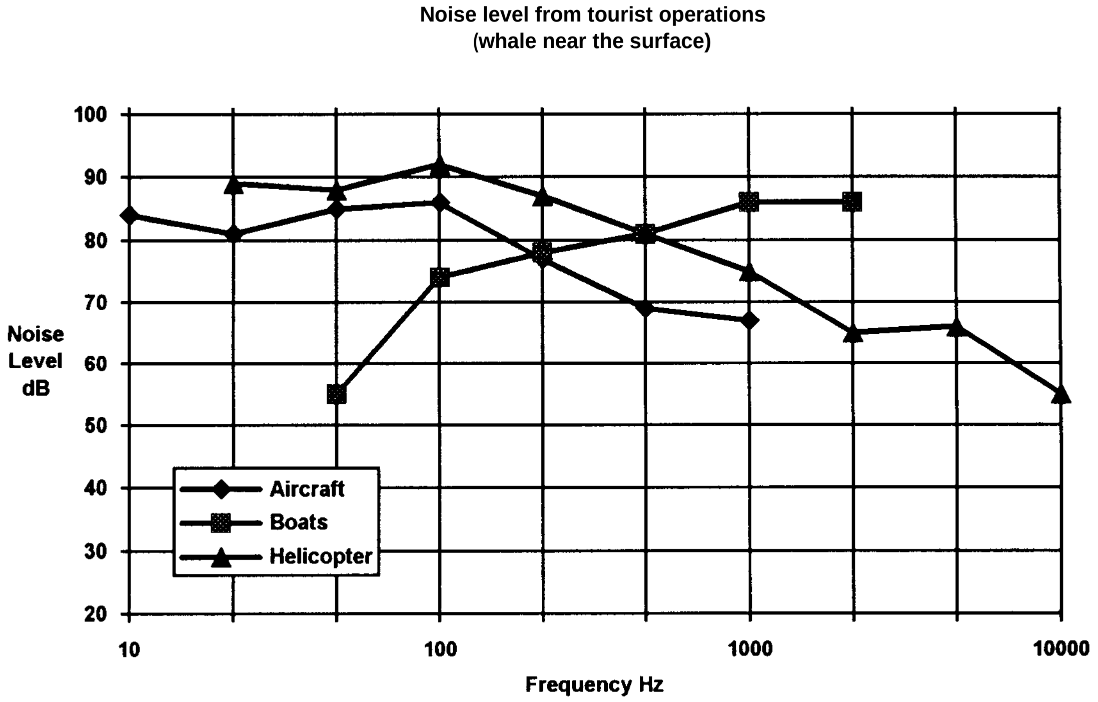
In order to provide a relatively simple chart no indication of the variability of the likely noise levels has been shown. Individual craft typically varied by 5dB to l0dB from the levels shown (10dB is 10 times as loud). The height of the aircraft for a hydrophone (or whale) at 75m depth causes, by comparison, much less variation. Only 2dB or so less noise would be expected in this situation from an aircraft at 150 metres than from an aircraft at 30 metres. (Note that the situation is different when the whale is at or near the surface as is discussed in the next section).

The noise levels measured in all cases are not unusually loud. Cetaceans are likely to be well adapted to handling such noise levels since these levels are to be expected from a number of natural phenomena. A later section will discuss this in more detail and provide expected levels from a variety of commonly occurring noise sources to provide a comparison.

Noise levels near the surface

When the whale is near the surface the situation changes somewhat. The noise from surface craft is reduced, particularly at lower frequencies, by the proximity of the surface itself. A whale, therefore, reduces the impact of noise from boats by surfacing, or swimming near the surface. This is not the case for the noise from aircraft or helicopters.

Although this kind of effect is difficult to quantify because it is heavily dependent on assumptions (noise source depth, the distance of boats and aircraft from the whale and the depth of the whale itself), an indication of the change in noise levels is shown in the chart below. Here the whale is 1 metre from the surface, the boat is 75 metres away and the aircraft and helicopter are 75 metres overhead. The chart shows that if a whale were to swim nearer the surface when a helicopter was hovering overhead, it would find that the noise level would, in contrast to that from surface vessels, increase.



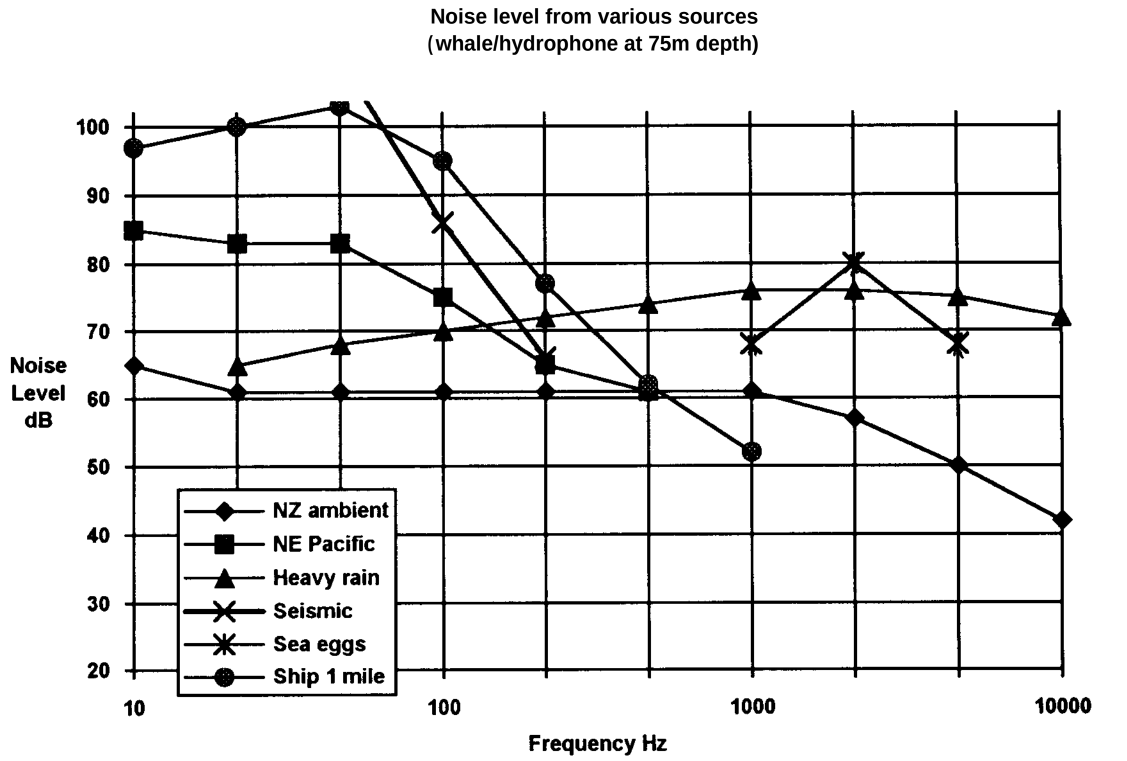
It is also important to note here that for a whale near the surface, the height of an overhead aircraft has much more effect on the noise perceived by the whale. Although measurements made on the hydrophone at 75 metres depth showed little difference between aircraft flying at 30 metres and 150 metres (expected difference only 2.5dB), for a whale on or near the surface the difference between aircraft at these heights would be 14dB. The lower aircraft would be about 25 times louder.

Comparison with other sources of noise

In order to get some idea as to whether the noise levels described are acceptable it is necessary to compare them with noise levels to which whales are normally subjected. As described in the introduction there are a variety of naturally occurring sources of noise. Typical levels associated with some of them are shown in the following chart. Again it must be stressed that noise levels from sources such as seismic activity are highly variable, both because of the nature of the event itself, and because the distance of the whale from the noise source is a major factor in determining the noise level.

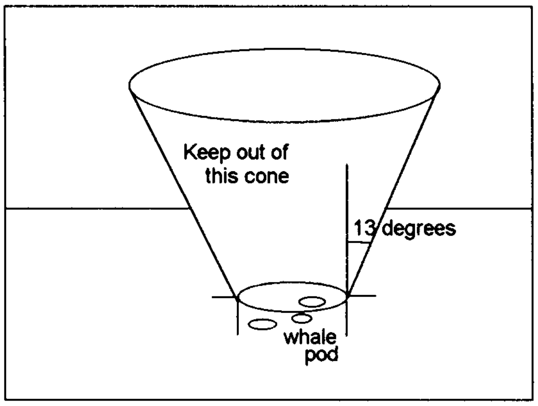
It can be seen from the chart that shipping noise will be a major source of noise at the lower frequencies. In most areas of the world, normal background noise levels are considerably higher than they are in New Zealand waters because shipping densities are far higher. Note that typical noise levels in the NE Pacific are greater than the noise that was measured from the tourist aircraft. It is also relevant to note here that whales do not seem to avoid ships because of high noise levels (see the 'ship at 1 mile' curve in the chart below). In fact some species, notably Minke whales, seem attracted to ships. They are fast swimmers and keep pace with ships travelling at speeds of up to 16 knots [5].

The conclusion to be drawn from this type of comparison is that noise levels from tourist operations are likely to be well within the levels that whales are normally likely to have to cope with.



Conclusions and recommendations

Tourist boats, aircraft and helicopters are not likely to produce noise levels which will cause problems to Cetaceans. Sudden noises do appear to trouble whales because they may indicate danger. Aircraft should therefore not 'buzz' pods of whales. Helicopters hovering directly overhead present whales with a source of loud noise which is not reduced when the whale swims near the surface. It is therefore recommended that aircraft and helicopters stay clear of an envelope above a pod of whales which is shaped like an inverted cone as shown in the figure. In other words tourist aircraft should view whales by circling around the pod.



References

1. Noise Ranging Report for the Department of Conservation, Vols 1, 2 & Executive Summary, RNZN Trial Analysis Unit, 22-24 February 1992.
2. Underwater Acoustics: Helicopter Noise, Malcolm Hunt, Malcolm Hunt Associates, 26 March 1992.
3. Underwater Acoustics: Helicopter Noise, RW Bannister, Defence Scientific Establishment, 7 April 1992.
4. CJR Robertson, Department of Conservation, 26 August 1992.
5. Sea Guide to Whales of the World, Lyall Watson, Hutchinson 1981.
6. Whales, Dolphins and Porpoises, Kenneth S Norris, U of California Press 1966.

Appendix

A few remarks on the data used and some of the adjustments made have been banished to an appendix to avoid over complicating the main text.

All units described as 'dB' are spectrum levels expressed in dB re 1 µPascal per 1 Hz band.

Levels used in the plot of noise level at 75m depth were obtained as follows. For boats the levels are derived from the approximate median (by eye) of the plots described in [11 as 'All serials average'. The levels have been re-corrected to actual levels measured at the hydrophone. For aircraft median data was extracted from the chart described in [11 as 'Aircraft measurements all serials'. In the case of the helicopter the data was obtained from the table in [3] described as 'Spectral data used in the report' from the row titled '75m altitude (water)'. A correction is necessary to translate these (surface) levels to levels that would be measured at 75m. It was calculated by comparing the area ensonified at the surface with the area ensonified after the sound has travelled a further 75m.

For the plot of noise levels near the surface, the levels were obtained as follows. For boats, the data obtained as described in the previous calculation was adjusted by assuming the receiver was situated lm from the surface at a distance of 75m from the source and applying a nominal dipole correction factor. In the case of aircraft, the data was obtained by applying the inverse correction to that described in the previous paragraph for deriving helicopter levels at 75m depth. The helicopter data used was the uncorrected data previously described.

Finally, the following comments are specific to the RNZN reports [1].

Volume 1: Boats

Plots 1 to 8 are, in effect, the 'raw data' of the noise ranging runs. They are produced by the RNZN system as 'source levels' and represent the level of sound at each frequency being put into the water by each craft. Note that they are not the levels measured at the hydrophones and must be re-corrected to account for spherical spreading from the source to a hydrophone (or whale).

Plots 9 to 16 are 'third-octave averages' of the raw data, and also show the data for frequencies up to l00kHz (note that the increase above 60kHz is not produced by the boats). An 'octave' is a band from one frequency to its double. 'Third-octaves' are standard frequency bands defined such that three bands cover each octave. Third octave data are smoother and easier to interpret over a wide frequency range.

Plot 17 is the most useful single plot (and was used for the data plotted in this paper). Note that to get equivalent levels that would be measured on a hydrophone at depth (or slant range) d metres, subtract 20 log d from the values shown (eg. for a hydrophone at a depth of 75m subtract 37 dB).

Plot 18 compares tourist boat source levels with source levels of large ships.

Plot 19 shows noise measured at the hydrophone when no tourist boats were around. Since source level estimates were made using a hydrophone "300 to 500 metres from the source" (para 11) the effect that this background noise would have on the estimates of source level can be deduced by adding 50 to 54 dB to the levels shown in plot 19.

Volume 2: Aircraft

Plots 1 to 20 are the corresponding 'raw data' for aircraft. Since it is not meaningful to plot source level these plots have been corrected by offsetting the vertical axes by 37 dB (the loss to the 75m hydrophone) and represent, therefore, measured levels.

Plots 21 (missing) and 22 are third octave averages. They are overplotted in plot 23 which is the source of the data plotted in this paper. Plot 24 shows the 1 standard deviation range of the measurements, but the vertical axis needs to be 'corrected' as above before this can be used.

Narrow band tonals for boats and aircraft are shown in plots 25 and 26. Tonals are narrow peaks in the frequency spectrum. They are important for naval tasks (such as detection of submarines) but are unlikely to be of any special relevance as a noise nuisance for whales.

Plot 27 shows averaged aircraft data.

Plot 28 shows how tonal levels vary with range. The main point of this plot is that even tonals disappear into the general underwater noise background at distances greater than one nautical mile.

Plot 29 attempts to show aircraft 'source level' in comparison with source levels of surface vessels.

Plot 30 provides a plot of background noise. This can be usefully compared with most of the plots (not 24 or 29) to show when an estimate of noise from an aircraft is likely to be just the normal background noise level.