Alternative Quieting Technology to Seismic Airguns for Oil & Gas Exploration and Geophysical Research

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To explore for oil and gas deposits in the marine environment, the current practice is to use, very intense, loud pulses or "shots" produced by releasing air under extremely high pressure, are used to image geological structures below the sea floor. These shots from airguns are used by industry during seismic surveys to find oil and gas deposits under the ocean bottom or to examine the Earth's crust under the sea for geophysical research purposes. Seismic surveys typically use 6-40 airguns arranged in an array, all firing together. It often takes months to seismically survey an area, during which time shots occur every 10-12 seconds, around the clock. The noise from seismic surveys can be heard almost continuously in some areas for distances of up to 4,000 km (Nieukirk et al. 2012), as airgun seismic surveys are among the loudest of human-produced sounds, and sound travels very fast and efficiently in water.

Both the very loud sound near airgun arrays and the less intense sound at large distances can produce negative impacts on marine animals. These impacts can include permanent damage to an animal's hearing, changes in vocalizations which could affect feeding, mating, or navigation, displacement from habitat, changes in abundance, or lower fisheries catch rates, physiological (stress) effects, and "masking," or obscuring of signals important to an animal, even at long ranges (Nowacek et al. 2015; Weilgart 2007).

Such negative effects have led to the search for quieter, less impactful alternatives, such as marine Vibroseis (MV). Vibroseis has been used successfully in land-based seismic exploration for many years. Instead of a sharp onset, loud intense "shot", Vibroseis uses the same energy but spread over a longer duration, thus eliminating the sharp rise time (sounds quickly increasing in loudness) and high peak pressure (volume or amplitude) of airguns--two characteristics of sound thought to be the most injurious to living tissues (Southall et al. 2007).

As Vibroseis is a controlled source, modifiable in real time, it also allows for greater control and tailoring of the signal amplitude and other characteristics to the particular situation. In airgun surveys, 30% of the emitted sound energy (frequencies over 120 Hz) is wasted, i.e. not used by industry or geophysical researchers (Pramik 2013). In contrast, with MV, there is practically no energy over 100 Hz, meaning little to no impacts are anticipated for animals such as dolphins, porpoises, killer whales, belugas, narwhals, or beaked whales.

A recent modelling study (Duncan et al., in prep.) comparing a realistic MV array with an airgun array with the same geophysical output found that the MV array was 13-22 dB lower (quieter) than the airgun array, even at a distance of 5 km, the furthest modelled range. This reduction in short-range peak levels could greatly reduce the number of animals exposed to noise likely to cause injury, to being only 1-20% of those exposed to injury from an airgun survey, by some estimates (LGL & MAI 2011).

Leaper et al. (2015) have also shown that there are seldom cases where Marine Mammal Observer mitigation can achieve a greater risk reduction than would be achieved by a 3 dB reduction in source level throughout the survey. An additional 30-50 dB reduction in amplitude might be attainable with MV using matched filters for signal processing (Weilgart 2010).

The reduction in peak pressure with MV was expected, but even Sound Exposure Level (SEL), which incorporates a duration (time) element of sound and is relevant for "masking", was lower for MV than airguns (Duncan et al., in prep.). SELs

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also dropped off more rapidly with range for MV than airguns. The effect became apparent at ranges of >1 km in shallow water and >10 km in deep water. For both shallow and deep water, SELs from MV were about 8 dB lower than from airguns at a 100 km range, confirming MV's lower potential for masking over large areas. Merely changing the MV array layout can reduce SELs by 4 dB. Moreover, MV can function in very shallow waters (<2 m), unlike airguns. MV could have particular advantages in shallow water, both geophysically and biologically, because SELs drop off more rapidly in shallow waters, which tend to be richer in marine life. Nevertheless, MV should still be field-tested for impacts on a wide range of sensitive marine taxa.

The development of MV could be greatly expedited with encouragement and pressure from regulatory governmental agencies. For instance, international agreements such as the Convention on Biological Diversity and the Convention on Migratory Species already require Best Available Technology (BAT) to be used. While MV is not yet commercially available, it could be with funding and incentives/disincentives from government. Areas rich in marine life that is sensitive to mid- or high-frequencies could be declared off-limits to seismic airgun surveys but MV may be allowed. Although there are only about 170 seismic ships worldwide, it would still require a fair cost investment to retrofit these for MV. On the other hand, airgun shutdowns, required when sensitive marine life enters safety zones around airguns, are also very costly and would be much less necessary with MV.

Overall, MV shows potential in providing an environmentally safer alternative to airguns without compromising effectiveness for seismic exploration. The acoustic footprint, as measured in terms of both peak pressure and sound exposure level, is substantially smaller for MV than airguns for the same geophysically-useful energy output.

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