The Energy Ratio Mapping Algorithm (ERMA): A Tool to Improve the Energy-Based Detection of Odontocete Clicks

Holger Klinck, David K. Mellinger, Sara Heimlich, and Sharon Nieukirk, *Cooperative Institute for Marine Resources Studies, Oregon State University and NOAA Pacific Marine Environmental Laboratory, Newport, OR, USA, Holger.Klinck@oregonstate.edu*

Energy-based detection algorithms are commonly used to detect many types of sound signals, including odontocete clicks, in real time. A major advantage of such algorithms is their relatively low computational cost, as they can operate in the time domain. However, for detecting a certain species of odontocete, using a time-domain algorithm often results in a high number of false positive detections caused by clicks of other odontocete species. The energy ratio mapping algorithm (ERMA) was developed to reduce the number of false positive detections while keeping the advantage of low computational cost.

For example, the power spectrum of Cuvier´s (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whale clicks shows a significant rise in energy between approximately 20 and 35 kHz. Thus the ratio between the energies in two frequency bands, one above and one below the rise, is a useful measure for detecting these beaked whale clicks. Calculating such a ratio is computationally simple, as it can be done digitally with a low-order IIR filter, or even in analog hardware.

However, clicks of other odontocete species have energy in these bands and can cause false positive errors. The question arises of how to choose the two frequency bands that will provide the best ability to discriminate between the target species and other odontocetes that are present in a given geographic area. To systematically assess the performance of different ratios, ERMA compares clicks produced by all odontocete species occurring in an area of interest. A number of sample clicks of all species present are collected and used as follows: For each species, ERMA produces a map of average energy ratios at different frequencies by applying a 1/3-octave filter bank to the given click samples and calculating the energy ratio between each possible pair of frequency bands. In a second step, ERMA creates a non-target species map by taking the maximum at each grid point over all maps of species which are not of interest. Finally this latter map is subtracted from the map for the target species. The resulting map – the ‘discrimination map’ – (1) indicates the best frequency bands for calculating a ratio to detect the target species, and (2) permits estimation of an appropriate detection threshold.

Figure 1 gives an example for *Ziphius cavirostris*. Figure 1a represents the energy ratio map evaluated from 100 *Ziphius cavirostris* echolocation clicks.

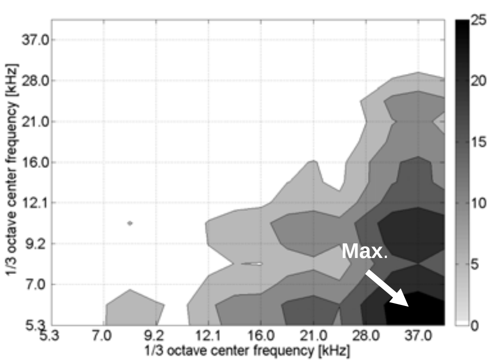

Figure 1a: Energy ratios [dB] calculated for *Ziphius cavirostris* (see text).

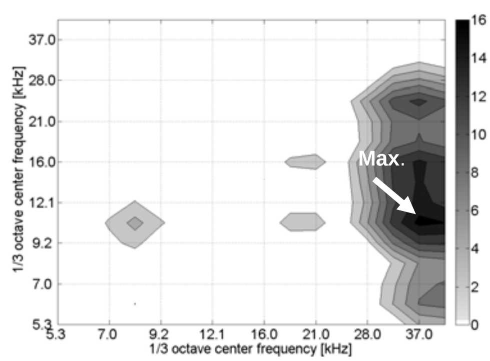

Figure 1b: Energy ratios [dB] calculated for *Ziphius cavirostris* under consideration of five additional odontocete species (see text).

The map indicates that the highest energy ratio occurs between the frequency bands with center frequency 37 kHz and 6.1 kHz. Upon consideration of five additional odontocete species (sperm whale, killer whale, pilot whale. Risso's dolphin and spinner dolphin), ERMA derives the optimum frequency bands for detecting *Ziphius* when these other species may be present: those with center frequencies 37 kHz and 10.1 kHz (Figure 1b). By comparing the values at the optimum grid point, 37 kHz/10.1 kHz, in both maps, a detection threshold can be estimated: 22 dB - 16 dB = 6 dB.

ERMA allows optimization of the performance of energy-based odontocete click detection by reducing the number of false positive detections caused by non-target species. This is especially helpful for applications in low-power environments, such as acoustic gliders, where sophisticated detection algorithms cannot be operated continuously. However, ERMA works best when used as the first step of a two-step detector; the second step can be a significantly more sophisticated classifier that improves detection performance. Such classifiers are typically quite computationally intensive, and are best used on only a tiny fraction of the input sound signal. As the first step, ERMA chooses only those clicks that have a high likelihood of being from the target species. By reducing the number of clicks which are sent to the second-step classifier, ERMA reduces the overall computational cost of the overall process.

Acknowledgements

The authors would like to thank Marie A. Roch, Melissa S. Soldevilla, Simone Baumann, John Hildebrand, Magnus Wahlberg, Ida Eskesen, Mark Johnson and David Moretti for providing data from various recording sites and odontocete species.