3D TRACKING AND MONITORING OF SPERM WHALES WITH PASSIVE ACOUSTICS AND AMBIENT NOISE IMAGING TECHNIQUES

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Acoustic and physical interactions between human activities and coincident cetacean occurrence have become a threat to marine mammal conservation. Although we do not yet fully understand under what circumstances exposure to loud sounds will cause harm to cetaceans, scientific evidence indicates that such high intensity sounds can cause lesions in acoustic organs, severe enough to be lethal. The use of active acoustic solutions, i.e. acoustic deterrents and active sonar, in areas of interest (shipping, military exercises, gas exploration, etc.) to prevent unfortunate interactions is either range-limited and intrusive or ineffective on cetaceans, specially on those already highly tolerant to noise. An alternative solution based on passive detection, classification and localization has been therefore considered. Here, we introduce a time and cost effective minimal solution applied to sperm whales - but applicable to other cetacean species - to an automatic real-time 3D whale localization. The 3D localization is based on the acoustic signal arrival time-delays and the assumption that sound propagation can be modeled by straight rays, resolving both the azimuth and elevation on a short aperture triangular array of passive sensors and the source distance from the time arrival on a distant fourth hydrophone (wide aperture array). With this configuration, the 3D localization algorithm calculates the whale's position within a 3000m deep and 2500m radius cylinder with an estimated 200m maximum distance error. The system further integrates the tracking of acoustically passive whales by a sperm whale click-based ambient noise imaging sonar. A simulation tool for 3D acoustic propagation was designed to simulate a bi-static solution formed of an arbitrary number of active acoustic sources, an illuminated object, and a receiver all positioned in 3D space with arbitrary bathymetry. Detection and bearing estimates could be performed for silent whales at ranges of 1500m from a 4m diameter array of 32 hydrophones, in a simulated scenario where on-axis click source and ambient noise levels were respectively 200dBrms re 1µPa @1m (full bandwidth) and 60 dBrms re 1µPa in the 1-10kHz band. While an ambitious synthesis of many advanced acoustic technologies, the benefit is an efficient, non-intrusive system which can continuously 3D track cetaceans in areas of interest, therefore mitigating the impact of artificial sound sources on marine mammal populations.

A CLASSIFICATION SCHEME OF SPERM WHALE (PHYSETER MACROCEPHALUS) CODAS

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Sperm whales produce a small variety of broadband acoustic signals that include usual, rapid and slow clicks, creaks and codas. The use and importance of these signals are still poorly understood, but codas are believed to play an important social role. A coda consists of a short series of clicks repeated several times and is mostly heard when the whales are gathering at the surface. It has been hypothesized that codas are specific to a social group or geographical location. Considering their (assumed) social importance, codas form an interesting subject for study. In order to analyze the difference in coda structure between groups, a method needs to be found to classify them. This type of analysis is generally done using the rhythm of the coda, obtained by dividing the time intervals between consecutive pulses by the total coda length, and subsequently searching for rhythmic clusters. Current methods of classification are based on predefining the number of classes in advance or using the k-means algorithm where the correct value for k is found by visual inspection of the clusters. Rendell and Whitehead introduced the use of a ratio criterion to find a suitable value for k, which gives good performance in spherical distributions but may not give optimal results when the clusters do not have identical variance in all dimensions. To cluster the data in situations with more arbitrary cluster shapes we propose an additional clustering algorithm, also based on the k-means algorithm, with a stopping criterion depending on the distribution of a cluster in only one dimension. We propose a labelling approach for the resulting clusters that reduces subjective bias often found in the labelling process, allowing comparison of coda repertoires between studies.