A Passive Mitigation Solution to the Effects of Human-Generated Sound on Marine Mammals

M. André, E. Delory, M. van der Schaar and J.V. Castell,
Laboratory of Applied Bioacoustics
Escola Politècnica Superior d'Enginyeria de Vilanova i la Geltrú
Universitat Politècnica de Catalunya
Avda. Víctor Balaguer s/n, 08800 Vilanova i la Geltrú, Barcelona, España.
tel. (34) 93 896 72 27 fax. (34) 93 896 77 00
michel.andre@upc.es

1. Introduction

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 technically applicable to other cetacean species - to an automatic real-time 3D whale localization.

2. 3D Passive 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).

To predict the estimation error a 3D error map is created considering and discarding when appropriate the following error-sources :

- Sound speed error and the straight ray assumption

The speed of sound is highly depth-dependent and therefore the estimated average used will give a quantifiable error. We use an average such that this error is minimal at low depths, accepting that it will give some error when the whale is at greater depth. A frequency dependent curved ray solution of click propagation showed a few microseconds differences in arrival times compared with straight rays when whales were 2km deep within the range of interest (~ 5km).

- Cross-correlation peak time

The top array has a relatively short aperture (a 3m side equilateral triangle), which will play a large role in the positioning error. We need either a high sampling frequency or a fast interpolating filter and an accurate matching algorithm to precisely calculate the TDOA of a click at different hydrophones. Accordingly, we use a wide bandwidth (100Hz-24kHz) to take advantage of the click inherent broadband transient characteristic and interpolate 10 times to recreate the analog signal shape and avoid round-off errors due to Nyquist sampling. With this configuration, the 3D localization algorithm calculates the whale's position in the 3000m water column and at a 5km diameter range with a 200m maximum error distance.

3. Silent Whale Detection

The system further integrates the tracking of acoustically passive whales by a sperm whale click-based ambient noise imaging sonar. As an alternative to conventional sonars, an innovative solution called Ambient Noise Imaging (ANI) fills the gap between active and passive solutions by using sound underwater in comparable ways as terrestrial life forms use daylight to visually sense their environment. Instead of trying to reject the surrounding ocean background noise, ANI indirectly uses it as the illuminating source and searches the environment for a contrast created by an object underwater. The solution introduced here is conceptually based on both ANI and multi-static active solutions, where the active sources are produced by surrounding foraging sperm whales at greater depths (from 200 meters downwards), which vocalize on their way down and at foraging depths, and in reported cases, likely on their way up until a few minutes before surfacing.

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.

precisely calculate the TDOA of a click at different hydrophones. Accordingly, we use a wide bandwidth (100Hz-24kHz) to take advantage of the click inherent broadband transient characteristic and interpolate 10 times to recreate the analog signal shape and avoid round-off errors due to Nyquist sampling. With this configuration, the 3D localization algorithm calculates the whale's position in the 3000m water column and at a 5km diameter range with a 200m maximum error distance.

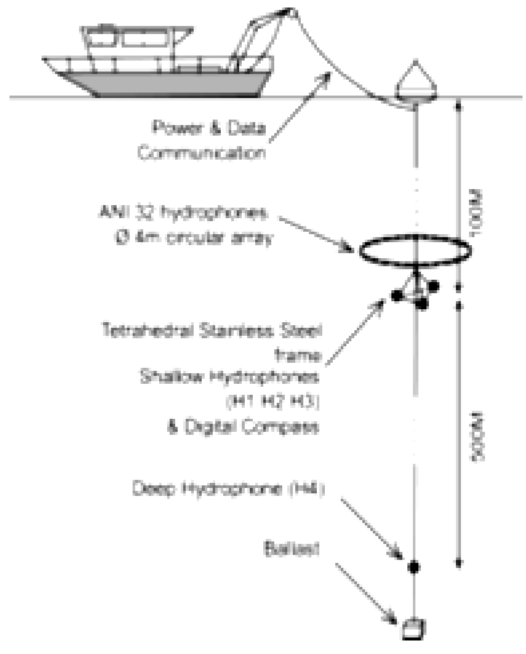
3. Silent Whale Detection

The system further integrates the tracking of acoustically passive whales by a sperm whale click-based ambient noise imaging sonar. As an alternative to conventional sonars, an innovative solution called Ambient Noise Imaging (ANI) fills the gap between active and passive solutions by using sound underwater in comparable ways as terrestrial life forms use daylight to visually sense their environment. Instead of trying to reject the surrounding ocean background noise, ANI indirectly uses it as the illuminating source and searches the environment for a contrast created by an object underwater. The solution introduced here is conceptually based on both ANI and multi-static active solutions, where the active sources are produced by surrounding foraging sperm whales at greater depths (from 200 meters downwards), which vocalize on their way down and at foraging depths, and in reported cases, likely on their way up until a few minutes before surfacing.

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.

4. Conclusion

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 (shipping, gas exploration, military exercises, etc.), therefore mitigating the impact of artificial sound sources on marine mammal populations.



Deployment of the Technical Demonstrator