UNDERWATER ACOUSTIC LOCALIZATION OF MARINE MAMMALS IN AN UNCERTAIN ENVIRONMENT

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1. INTRODUCTION

This paper describes an MSc thesis research project aimed at three-dimensional acoustic localization and tracking of vocalizing marine mammals, with the ultimate goal of providing a more reliable method for assessing temporal variations in walrus population distributions and habitat usage. Large changes in the degree of summer ice coverage in the Chukchi Sea over the last several decades, coupled with recent increased seismic survey activity in the waters surrounding Alaska, have the potential to impact marine mammals, including walruses.

The Pacific Walrus (*O. rosmarus divergens,* see Fig. 1) has been chosen as the focus for this localization study due to their presence in the study area (the Chukchi Sea northwest of Alaska, see Fig.2), and the acoustic characteristics of their calls. Current methods for locating and counting marine mammals are based on visual observations from vessels and aircraft. These visual methods require daylight and good visibility to be effective and only account for animals on the surface. It is hoped that acoustic methods can augment visual methods; for instance, aircraft-based visual methods could be employed over wide areas where acoustic means would be infeasible, whereas acoustic means could be used near feeding areas.

Two approaches to acoustic localization will be considered. The first approach makes use of several independent (but time synchronized) data acquisition systems, each involving a single omni-directional hydrophone and recorder, which are deployed on the seabed at separations of up to a few kilometres. The location of a vocalizing walrus can be estimated using acoustic triangulation if its call is recorded by at least three such systems. This approach is straightforward and fairly standard, but requires the expense and effort of deploying and recovering multiple acoustic systems. The second, more novel, approach involves evaluating the use of a single data acquisition system for three-dimensional localization. In this case, the acquisition system includes a directional sensor to provide bearing, and a vertical array of omni-directional hydrophones which can be used to estimate source range and depth from the multi-path acoustic arrivals. An important issue in this approach is that acoustic localization with a vertical array requires knowledge of the physical properties of the ocean environment (water column sound-speed profile and seabed geoacoustic parameters), which may not be readily available.

Figure 1: Pacific Walrus mother and calf (USGS).

Acoustic field trials for this project will be carried out in the summer and fall of 2009, and hence data are not yet available for analysis. Rather, the remainder of this paper will describe the experiment plan and data analysis methodology proposed for the project.

2. FIELD STUDYS

The first component of the field work will take place in the Chukchi Sea in the summer/early fall of 2009. Three single-hydrophone ocean-bottom data acquisition systems will be

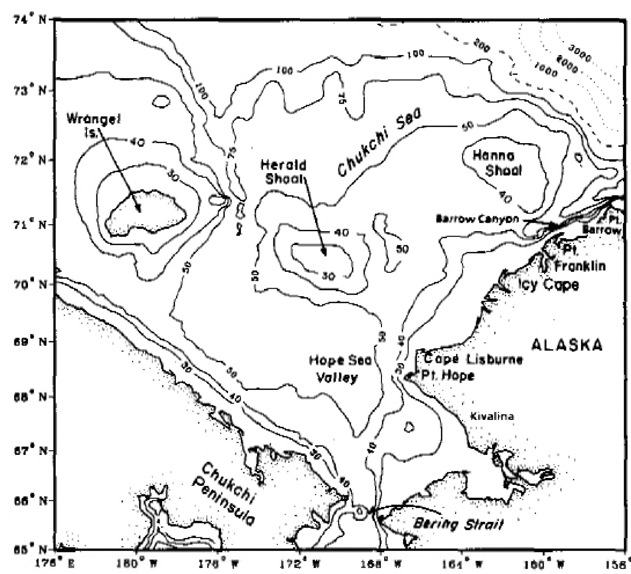

Figure 2: Field study location in the Chukchi Sea [2].

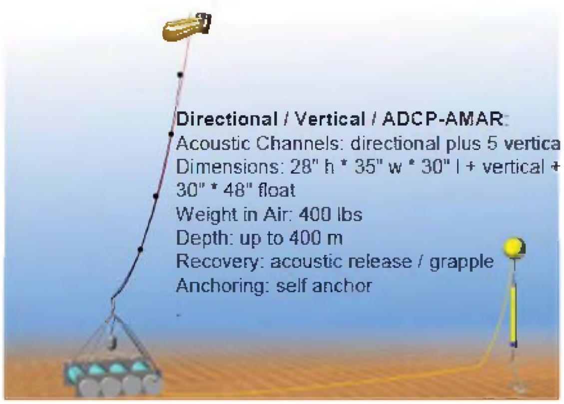

Figure 3 : Vertical array/directional hydrophone data acquisition system.

deployed by ship in the northeast Chukchi Sea in the vicinity of the Hanna Shoal, which is known to be a summer walrus gathering place (Fig. 2). The systems will be time synchronized onboard ship before deployment in early August, and will then autonomously record acoustic data at a sampling rate of 32 kHz for a 3-month period before being recovered in the early fall. The second field-work component will take place in the fall of 2009. A vertical array of omni-directional hydrophones together with a directional sensor (see Fig. 3) will be deployed outside Halifax harbour. Walrus calls will be played over an underwater transducer at a series of known locations. Data recorded in both field studies will be used to develop and test walrus call detection and localization schemes, described in the following section.

3. DATA PROCESSING AND INVERSION

The first aspect of acoustic marine mammal localization requires detecting mammal calls within a noisy time series. A sample walrus click-train waveform and spectrogram are shown in Fig. 4. A Gaussian mixture model, which has been applied to the detection of bat calls [3], will be considered for walrus call detection.

Two approaches to localizing an ocean acoustic source will be considered: matched field processing and ray travel-time inversion. In matched field processing, source range and depth are estimated by matching the measured complex (frequency-domain) acoustic fields measured at an array of hydrophones to replica acoustic fields predicted for a grid of candidate locations using a numerical propagation model. The range-depth grid point which produces the field that most closely correlates to the measured field is selected as the most likely source location. Propagation modeling requires specifying ocean environmental parameters; if these are unknown they can be included in an augmented search procedure usually involving numerical optimization or integration.

In ray travel-time inversion, relative arrival times along ray paths from the source to a series of receivers are inverted for source location. The data can include arrival times for direct-path rays and/or surface- and seabed-reflected rays, if these can be identified in the recorded time series. An iterative linearized inversion scheme, initiated from the results of a rough grid search, will be used for travel-time inversion [1]. If the water-column sound speed and water depth are not well known, these parameters can be inverted for in addition to the source location, provided sufficient acoustic paths exist in the data set.

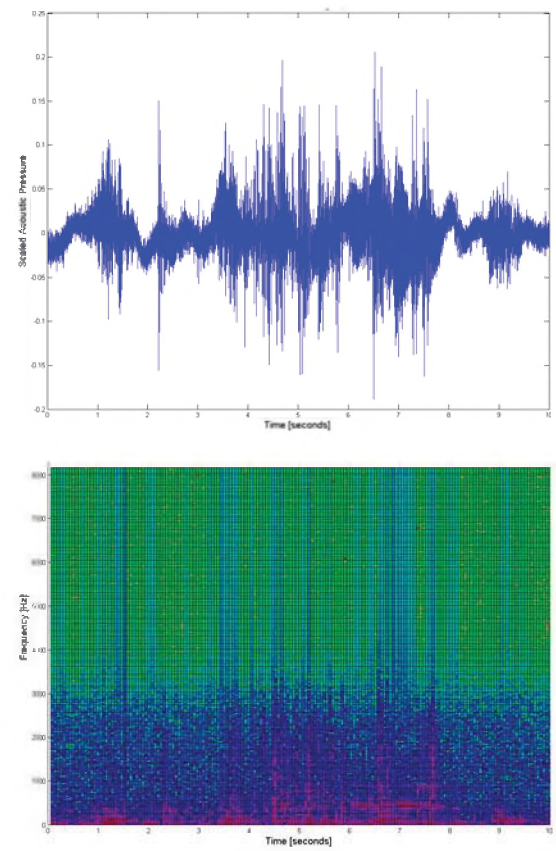

Figure 4 : Walrus click-train time series (upper) and spectrogram (lower).

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