Does Depth Matter? Examining Factors that could Influence the Acoustic Identification of Odontocete Species on Bottom-Moored Recorders

Marc O. Lammers
Oceanwide Science Institute
P.O. Box 61692
Honolulu, HI 96839
phone: (808) 375-0010 fax: (808) 572-9000 email: lammers@oceanwidescience.org

Julie N. Oswald
Bio-Waves, Inc.
364 2nd Street, Suite 3
Encinitas, CA 92024
phone: (858) 610-1893 email: julie.oswald@bio-waves.net

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LONG-TERM GOALS

Substantial advancements have been made in the identification of odontocete species based on the properties of their whistles and clicks. However, the suitability of species classifiers trained using data from the sea surface to analyze recordings obtained at depth is currently unknown. As a result, it remains unclear how depth, distance of animals from the recorder and sound propagation influence classification results. If classifiers perform differently on data recorded at depth than at the surface, it may be necessary to re-train them to ensure accurate results. Similarly, if the behavior of animals or signal propagation affects the identification of species using echolocation clicks, this must be understood and integrated into analysis methods. In this project, we examine how species-specific signaling cues are affected by recording depth by using both surface-deployed and bottom-moored vertical arrays of hydrophones and autonomous recorders to obtain recordings at different depths in the water column from a variety of free-ranging odontocete species. We also use localization and sound propagation modeling to address the following questions: Does the depth at which dolphin whistles are recorded affect the signal properties observed? If so, does the performance of species classifiers developed using whistles recorded at the surface change when applied to data from bottom-moored recorders? Do reported species-specific click characteristics remain consistent across recording depths? If they do, are the cues consistent across behaviors, such as diving, surface milling and travel? We are at the beginning of a two-year effort to examine these questions. The results of this effort will lead to a greater understanding of the strenghts and weaknesses of the acoustic species identification tools being employed for marine mammal monitoring and mitigation by the U.S. Navy.

OBJECTIVES

During fiscal year 2015 (FY15), the two primary objectives were to 1) assemble the surface-deployed and bottom-moored vertical arrays and field-test them off Maui, Hawaii to ensure functionality and 2) to optimize each array's configuration and deployment strategy. In addition, two secondary objectives were to 3) obtain pilot data from both arrays to test analysis algorithms and 4) evaluate the the data collection strategy for addressing the questions outlined above. During FY16, two 14-day data collection periods will be executed off Kona, Hawaii and San Diego, California targeting a variety of odontocete species typically identified using whistle classifiers or click characteristics. During both field periods, the objectives will be to 1) deploy the bottom-moored array for approximately two weeks at locations with documented high incidences of multiple odontocete species and 2) conduct vessel-based surveys and make recordings of as many odontocete species as possible using the surface deployed array of hydrophones and autonomous recorders (described further below). In addition, in a related NAVFAC Atlantic and LMR funded effort, we plan to obtain recordings of captive, Navy-trained dolphins stationed at known depths, distances and orientations relative to the recorders. These data will be obtained during the San Diego field effort. For both the free-ranging and captive settings, we will compare the characteristics of the sounds recorded using hydrophones placed at various depths in order to answer the questions outlined above.

APPROACH

Two types of vertical hydrophone arrays will be used to obtain the data needed for this project. One will be a surface array deployed from a vessel and will be composed of two vertical sub-arrays: a localization array with four broadband hydrophones spaced 10 m apart, and a line array made up of five microMARS recorders (http://www.desertstar.com/acoustic-recorders.html) spaced 50 m apart (Fig. 1). The four hydrophones in the localization array will be sampled simultaneously on a high-resolution portable recorder. This will allow fine-scale localization of phonating animals so their depth and distance relative to the line array can be established. The array of microMARS recorders will extend beyond the localization array with individual recorders separated by 50 m to a maximum depth of 250 m. Each microMARS recorder will be paired with a tilt/depth sensor to establish its actual depth and orientation. A miniature CTD probe will be fixed to the bottom of the array and will obtain temperature, salinity and depth information in order to calculate the sound speed profile at the deployment site. The surface array will be deployed in the proximity of odontocete groups and recordings will be made until the group moves out of acoustic range. This array will also be used to make recordings at different depths during the controlled experiment with captive, Navy-trained dolphins stationed at known depths.

The second array will be a bottom-moored vertical array composed of four second-generation Ecological Acoustic Recorders (EAR2s) spaced 90 m apart (Fig. 1). The array will also include a RJE International ARS-100 pinger, which will provide a series of 4-7 kHz synchronization pulses every 30 minutes. These pulses will be recorded on the four EAR2 recorders and will be used to time-align recordings during analysis in order to localize signaling animals and determine their depth and distance from the EAR2 recorders. The bottom-moored array will be deployed on the sea floor at locations of known high odontocete activity at bottom depths between 500 m and 950 m for periods of ~2 weeks. As with the surface array, each EAR2 will be paired with a tilt/depth sensor to establish its actual depth and orientation. A miniature CTD probe will also be fixed to the bottom of the moored array to calculate the sound speed profile at the deployment site as the array is lowered to the bottom and recalled to the surface.

Data from both arrays will be used to compare the characteristics of the whistles recorded at different depths. Data obtained on the surface-deployed array from species that are included in the Real-time Odontocete Call Classification Algorithm's (ROCCA) Pacific whistle classifier will be used to test the null hypothesis that no significant differences exist in classifier performance on the same whistles recorded at different depths. Whistles with unknown species identity recorded on the bottom-moored array will similarly be analyzed using ROCCA in order to determine whether recording depth significantly influences species classification results (i.e. are the same whistles recorded at different depth classified as different species?). Features measured from whistle contours will be compared to examine which (if any) are most affected by recording depth and animal location.

The analysis of clicks will involve a three-fold approach. The first will be to examine the spectral characteristics of clicks recorded at different depths by calculating the average spectrum of the clicks obtained for the encounter. This information will be used to determine whether patterns of spectral peaks and notches that have been used by other researchers to make species identifications occur independently of recording depth and are therefore truly invariant and distinctive features indicative of species specificity. The second approach will be to compare the average click spectral properties of the different species recorded to determine which species are distinguishable and consistent at all recorded depths and which are variable. For those that are variable, the click structures will be examined in detail to determine the source of the variability. The final approach will be to use the localization array to establish the swimming depth of the species encountered. This information will be used to examine the influence of swimming depth on the received clicks of species that are not identifiable compared with those that are identifiable.

WORK COMPLETED

The award for this project was executed in May 2015. During the first year of this project (FY15), two tasks were planned and completed.

Task 1: Assembly of vertical arrays

The assembly of both arrays began in June 2015 with the procurement of the necessary materials and components, including tilt/depth sensors, batteries, lines, floats, mooring materials, etc. Both arrays were then assembled on the island of Maui in July 2015. This included 1) the integration of the four EAR2s, the ARS-100 pinger, and the acoustic release on the bottom-moored array, and 2) the integration of the five microMARS, the four broadband hydropones, weights and a motion attenuation buoy system on the surface array. Each array was designed so that it could be deployed and recovered using a small vessel. An electric crab-pot winch was purchased to facilitate the recovery of the surface array. The depth/tilt sensors and miniature CTD probes were not delivered in time for integration with the two arrays prior to field testing, but were later tested and calibrated separately (see below).

Task 2: Field test of surface and bottom-moored arrays

Between August 2nd and12th 2015 a field effort was undertaken off the islands of Maui and Lanai to test both arrays. On August 3rd, the 300 m bottom-moored array was deployed approximately 3 nautical miles south of Lanai in waters 355 m deep. A 26' vessel (the *Aloha Kai*) was used during the deployment. Approximately 400 lbs of weight were employed to keep the array moored in place.

Beginning on August 4th, vessel surveys to search for pods of odontocetes were conducted off the islands of Lanai and Maui (Fig. 2). Surveys were conducted on each day except on August 5th due to an approaching tropical storm, and on August 10th due to vessel engine problems. The vessel *Aloha*

Kai was used until one of its engines stopped functioning on August 10th and then OSI's 21' vessel *Coho* was used instead. A total of 31 hours of survey effort were spent searching for and recording pods of odontocetes over 6 days.

Three different microMARS hydrophones with different sensitivities and frequency ranges were tested to determine which would be best suited for this project. The configuration of microMARS hydrophones on the array was changed several times during the field testing period to compare their perfomance relative to one another. In addition, various strategies for deployment and recovery of the surface array were tested. Finally, the sub-array hydrophones and broadband recorder were tested using different gain levels.

Odontocete pods were encountered on six occasions. Spotted dolphins (*Stenella attenuata*) were encountered off southwest Lanai on August 4th and recorded using the surface array for approximately one hour. Spinner dolphins (*Stenella longirostris*) were found in shallow waters off west Maui on August 6th and were recorded with microMARS paired with different hydrophones (not as part of the array) over approximately two hours. On August 7th a pod of ~80 spotted dolphins was again encountered off southwest Lanai, but no recordings were obtained due to deteriorating surface conditions. A pod of ~50 bottlenose dolphins (*Tursiops truncatus*) was found west of Lanai on August 8th and tracked for approximately two hours, but could not be recorded because the surface array became entangled due to human error. Lastly, on August 11th a pod of short-finned pilot whales (*Globicephala macrorhynchus*) was encountered off west Lanai in the morning and a pod of spotted dolphins was found off southwest Lanai in the afternoon. The pilot whales were recorded with the surface array for approximately one hour and the spotted dolphins were recorded for 20 minutes.

The bottom-moored array was visited several times during the field period and communication was established with the acoustic release to determine whether the array had moved since being deployed. Each time, the test indicated that the array had not moved. On August 8th, the communication transducer for the acoustic release was used to transmit pulses at various distances from the moored array in order to generate ground-truth data for the localization algorithms. The bottom-moored array was successfully recovered on August 12th. All EAR2s recorded successfully during the deployent period and the ARS-100 pinger transmitted signals every 30 minutes as designed.

The EAR2s from the array were calibrated relative to one another at the Hawaii Institute of Marine Biology with the assistance of Dr. Whitlow Au on September 14th. The four EARs were co-deployed in shallow (~5 m) water and tonal pulses ranging in frequency between 5 and 60 kHz were projected from a known location. Received signal levels were then compared on each EAR. In addition, the Star-Oddi™ mini CTDs and depth/tilt sensors were tested during a separate effort on September 15th. The sensors were tested relative to a sound velocity profiler (SVP) provided by Abakai International.

RESULTS

The Maui/Lanai field effort was extremely valuable for testing microMARS functionality and the setup and deployment of the surface array. During the field test, we made recordings using microMARS units equipped with three different hydrophones, each with different frequency ranges and sensitivities. Upon examination of these recordings, we determined that the most broadband and most sensitive hydrophone (MH 125-2) will be most appropriate for this project. These hdyrophones have been ordered from Desert Star Systems and will be calibrated at Southwest Fisheries Science Center prior to the November field effort. In addition to determining the most appropriate hydrophone, the field tests allowed us to test several different deployment and recovery methods. Based on these tests, we determined that the microMARS should be left attached to the array for as long as possible and not removed at the end of each day to avoid potentially fouling the array. As such, we will use a 12 hour duty cycle and leave the microMARS on the array for as long as battery life will allow. Battery life testing is currently under way.

The EAR2 bottom-moored array performed as designed while deployed and can therefore be considered ready for use off Kona in November. The primary lessons learned from this field test involved the deployment strategy. Specifically, we learned that a 400 lbs mooring anchor is sufficient to hold the array in place for the duration of the deployment. In addition, we devised a modular anchor design to safely and efficiently deploy the array from a small boat without the need for a winch or other mechanical leverage. This will allow us to use most commonly available vessel platforms in Kona and San Diego for the array's deployment. We also learned an important lesson with respect to synchronizing the EAR2's clocks with the ARS-100 pinger. Namely, we established that duty cycled recordings should each contain calibration pings to avoid ambiguity resulting from small variations between the start times of duty cycled recordings. As a result, we will adopt a 33% recording duty cycle of 10 minutes 'on' every 30 minutes that will always include a series of ARS-100 calibration pings. We have successfully bench tested the EAR2 for these settings.

The bottom moored EAR2 array yielded 2,063 2-minute recordings, or approximately 68.7 hours of data per recorder. A prelinimary analysis of the data revealed that 28 encounters with odontocetes occurred over the eight-day deployment period. The data are presently undergoing in-depth analysis to characterize signal differences among recorders. These analyses will be presented at the upcoming Society for Marine Mammalogy Biennial Conference in San Francisco, CA in December 2015. Figure 3 shows the long-term spectral averages (LTSAs) of a multi-hour dolphin encounter recorded on each of the bottom-moored array's recorders. Note the differences in broadband click spectral patterns observed on each recorder. These differences will be examined in more detail in subsequent analyses and in future deployments to establish the source of the variation and the implications on species identification. Figure 4 shows an example of a sequence of whistles that were localized relative to the array using a custom program developed by Eva Nosal and Lisa Munger for this project. Similar localizations will be used to examine how the location of animals in the water column influences the received signal properties.

IMPACT/APPLICATIONS

It is important to accurately identify odontocete species in acoustic recordings because species may react differently to Naval activities and understanding species-specific responses is important for implementing effective mitigation measures. This study will test some previously unexamined assumptions associated with the acoustic identification of odontocete species. The results of this effort will ultimately provide a better understanding of the methods presently being employed for marine mammal monitoring and mitigation, and will lead to greater confidence in their application.

RELATED PROJECTS

None

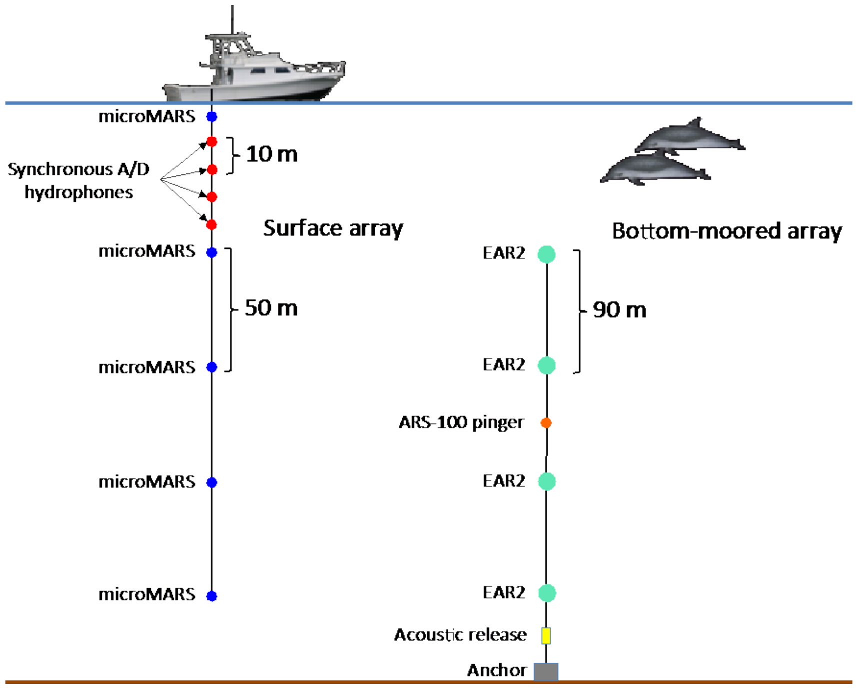

Figure 1 - Schematic of the surface array and bottom-moored array that will be used for this project. Drawings and measurements are not to scale. Note: the location of the ARS-100 pinger on the array is variable.

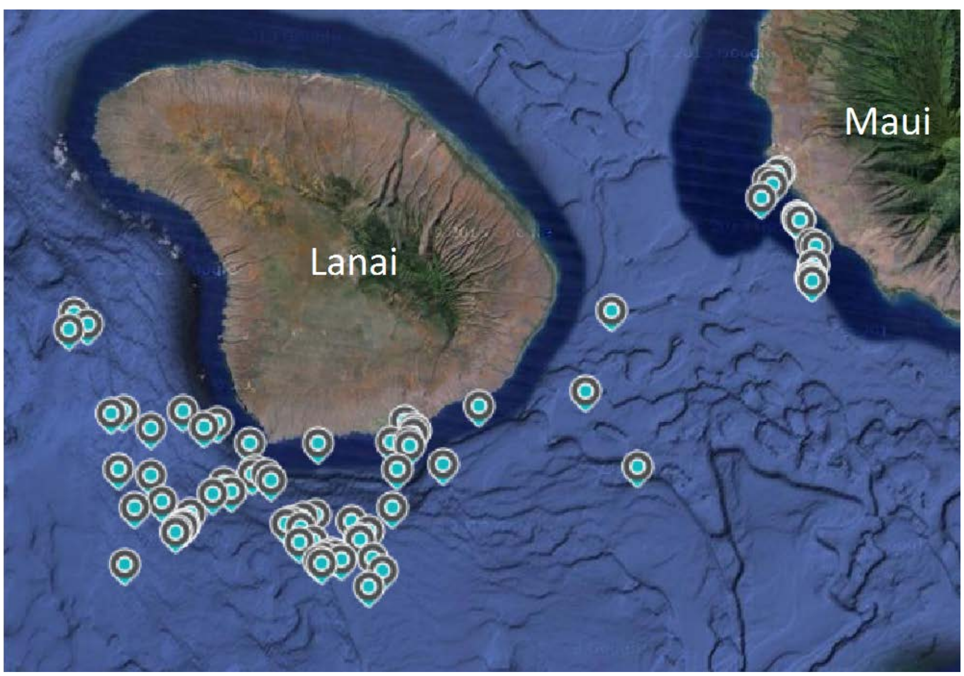

Figure 2 – GPS locations of survey vessel between August 3rd-12th recorded every 30 minutes

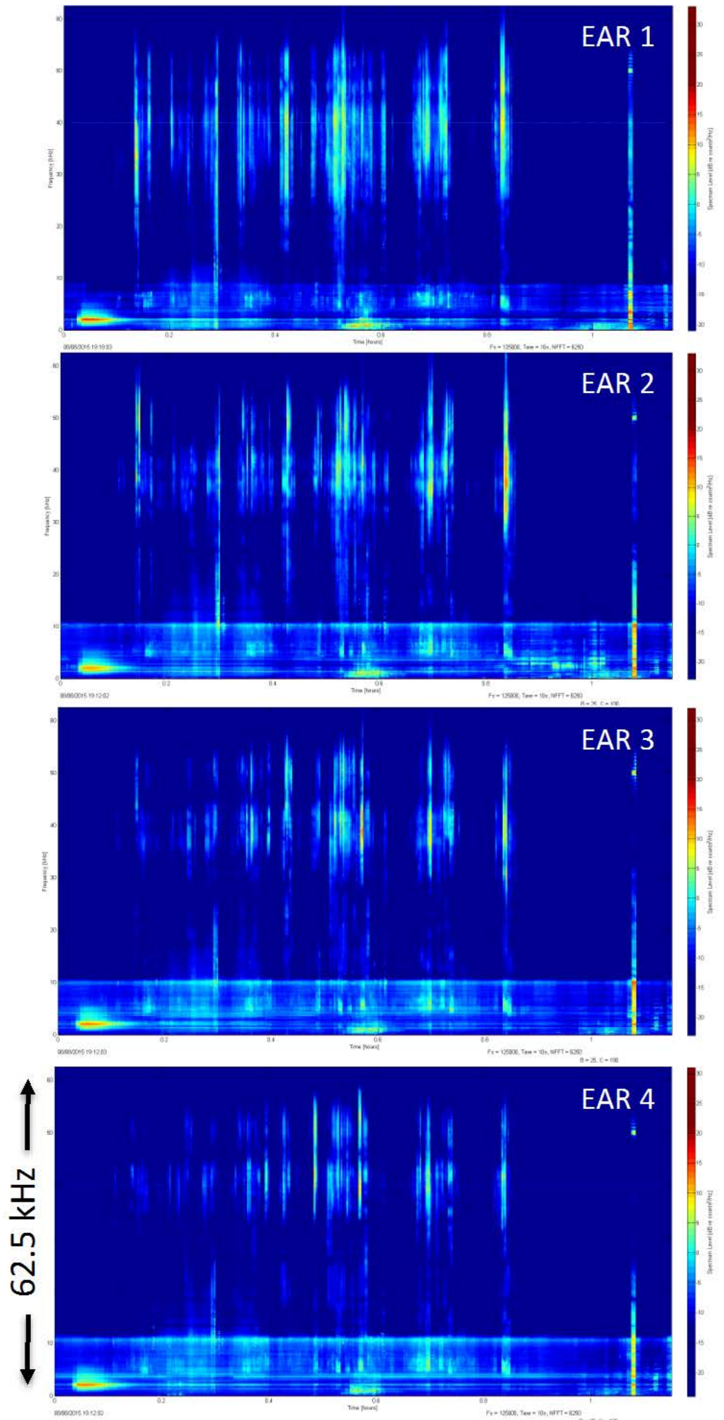

Figure 3 – Long-term spectral average of an odontocete encounter that occurred during the nighttime hours between August 8th and 9th recorded on the four EAR2s of the bottom-moored array. EAR #1 was closest to the surface and EAR #4 was closest to the bottom. The recorders were spaced 90 m apart.

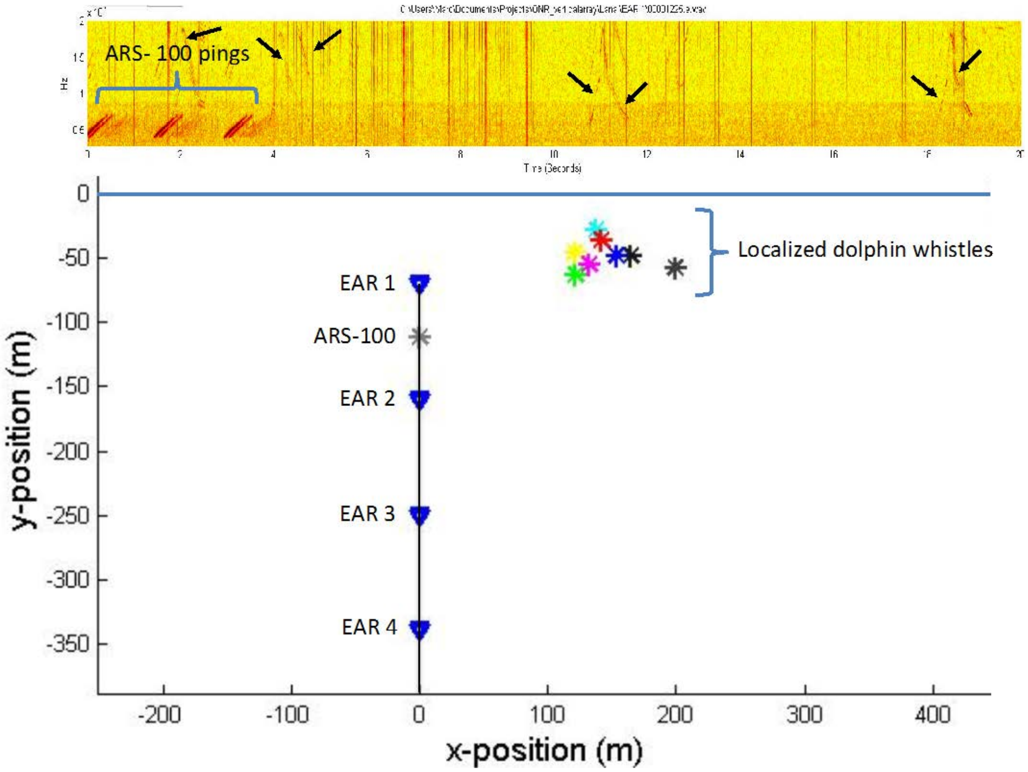

Figure 4 – Top panel: Spectrogram of a series of pings from the ARS-100 and concurrent dolphin whistles (arrows). Lower panel: localized positions of the pings and whistles relative to the array. The grey asterisk is the localization of the pings from the pinger. The dolphin whistles are plotted in color, with red being the most recent and gray the oldest in the sequence.