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Datasets of Odontocete Sounds Annotated for Developing Automatic Detection Methods, FY09-10

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MONTEREY, CALIFORNIA

DATASETS OF ODONTOCETE SOUNDS ANNOTATED FOR DEVELOPING AUTOMATIC DETECTION METHODS, FY09-10

by

David K. Mellinger

September 2012

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Prepared for: Chief of Naval Operations Energy and Environmental Readiness Division, Washington, D.C.
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Datasets of Odontocete Sounds Annotated for Developing Automatic Detection Methods, FY09-10

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Datasets of odontocete sounds annotated for developing automatic detection methods, FY09-10

Report submitted pursuant to award number N00244-09-1-0079

Dr. David K. Mellinger
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Project Overview

The Navy is required by environmental laws, including the Endangered Species Act, the Marine Mammal Protection Act, and the National Environmental Policy Act, to conduct its research and operations with minimal impacts on marine mammals, and to mitigate any adverse impacts caused by those transactions. In compliance, the Navy has been compelled to monitor the occurrence and behavior of marine mammals before, during and after research and operational activities. Acoustic methods have become a primary tool used for this task; they are now routinely and widely used in marine mammal research, monitoring, and mitigation.

Item 9 of the document “U.S. Navy Living Marine Resource and Sound Research Requirements” calls for the Navy to “Determine what real time observation, detection, and classification measures are required to develop effective monitoring and mitigation procedures,” with special emphasis on sub-part (a), “Means to detect whether priority species have been affected by Navy sounds,” and (c), “Means to test the effectiveness of mitigation measures.” The advancement of methods and software for detection, classification, and localization (DCL) of marine mammal sounds has been one area of research which supports the Navy in fulfilling this requirement.

DCL research on marine mammal vocalizations has been in development for decades, and methods for marine mammal population density estimation using acoustic data have been in development since at least 2007. These efforts have been supported by MobySound, an archive of cetacean sounds used for studying call detection and localization that are annotated to facilitate research in DCL.

Since the inception of MobySound in the mid 1990s, it has expanded from being an archive of baleen whale (mysticete) sounds to include annotated recordings of toothed whale (odontocete) species. This expansion converged with the advent of the biennial Workshops on the Detection, Classification, and Localization (DCL) of Marine Mammals using Passive Acoustics. There have now been five of these workshops, and the data sets for all of them are part of MobySound. With the additions to MobySound in recent years, there are now 22 datasets covering 18 species in the archive.

Some of the better detection and classification methods that have been developed by using data sets in MobySound have been on endangered species, including sperm [1-4], blue [5-6], and right [7-19] whales, and high-priority species, including beaked whales [20-25]. These projects have used click characteristics as the feature for automatic detection, classification and identification; a recent application has been development of a low-power detection method known as ERMA [21, 23, 26-28] suitable for use on ocean gliders. MobySound data are being used to develop, test, and improve ERMA.
The major aim of this project was to begin development of high-performing automatic detection methods for the sounds of beaked whales and other odontocetes. The specific aims were to collect recordings with calls; annotate these sound files to make them useful to researchers working on automatic call detection and classification; make them publicly available in an archive on the Internet; continue developing and publishing detection and classification methods and software; integrate these methods with new autonomous platforms and detection systems; develop a new method for population density estimation based on sound density and apply it to field recordings; and prepare a workshop dataset for the 2011 International Workshop on the Detection, Classification, and Localization of Marine Mammals using Passive Acoustics, which occurred August 21-25, 2011, in Oregon.

In more detail, project tasks were as follows:

1. **Annotate recordings** of odontocete sounds (whistles, clicks) and add these to MobySound.
2. **Detection/classification**: Continue developing detection and classification methods and software, and integrating these methods with new platforms including gliders and robotic sailboats.
3. **Density estimation**: Apply a newly-developed method for population density estimation to field recordings.
4. **Workshop dataset**: Produce datasets for detection, classification, and localization for the 2011 DCL conference, which my lab is organizing.

**Results**

The results by task are as follows:

1. **[Annotate recordings]** We collected data sets of odontocete recordings containing whistles and clicks for addition to our archive site MobySound.org. These recordings include sounds of Baird’s beaked whale (*Berardius bairdii*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), northern right whale dolphin (*Lissodelphis borealis*), long-beaked common dolphin (*Delphinus capensis*), short-beaked common dolphin (*Delphinus delphis*), Risso’s dolphin (*Grampus griseus*), bottlenose dolphin (*Tursiops truncatus*) and killer whale (*Orcinus orca*) from the U.S. West Coast; sperm whale (*Physeter macrocephalus*), pantropical spotted dolphin (*Stenella attenuata*), striped dolphin (*Stenella coeruleoalba*), short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*), melon-headed whale (*Peponocephala electra*), bottlenose dolphin (*Tursiops truncatus*), rough-toothed dolphin (*Steno bredanensis*), and spinner dolphin (*Stenella longirostris*) from the eastern tropical Pacific; killer whale (*Orcinus orca*) from the south Atlantic; and gray whales (*Eschrichtius robustus*) from the eastern Pacific (Mexico). Many of these recordings have been annotated for clicks and whistles. Recordings of Dall's porpoise (*Phoocoenoides dalli*), harbor porpoise (*Phocoena phocoena*) and killer whales
(Orcinus orca) from the north Pacific were also collected for eventual addition to MobySound.org.

The MobySound archive has been accessed increasingly often since being moved to a new host. The website has had approximately 900 unique visitor usages in a one-year span and many thousands of accesses (hits). The front page of this website is shown in Appendix 2.

We also developed a new method for measuring signal-to-noise ratio (SNR) of whistle sounds. Existing MobySound recordings comprise baleen whale moans and odontocete clicks; the methods for measuring SNR for these are not applicable to whistles--particularly whistles mixed with clicks, as are found in most whistle recordings. We developed a new method in MATLAB, snrWhistle.m, for measuring the SNR of whistles in the presence of clicks, and published it via the MobySound website.

(2) [Detection/classification] We continued to develop methods for detection and classification, including improvements to the ERMA method for use on gliders [26-28], and extended it to new species and populations. The methods were employed in the glider deployments collected in the Navy’s AUTEC range in the Bahamas in summer 2010 and off the Kona coast of Hawaii in late 2009. Species for which ERMA detectors have been developed now include Cuvier’s beaked whales (Ziphius cavirostris), Blainville’s beaked whales (Mesoplodon densirostris), and killer whales (Orcinus orca). ERMA, as part of its detection algorithm, incorporates information about confounding species in the geographic region where it is used; the list of regions for which this has been done now includes Washington state (Haro Strait area), Hawaii (Kona coast of the big island of Hawai’i), and the Bahamas (Andros Island area). Detection results from the Kona experiment showed that during the mission ERMA detected beaked whale vocalizations on 10 out of 85 glider dives. Manual analysis revealed that 7 of these detections were actual beaked whale encounters. During the other 3 glider dives the detection system was mistakenly triggered by delphinid vocalizations. The analyst identified a total of 109 sound files containing beaked whale clicks. The automated system correctly detected calls in 79 out of these 109 sound files (72%). Results from this development were recently published in a peer-reviewed journal [37].

(3) [Density estimation] A new method was developed for estimating the population density of baleen whales using the summed energy in a frequency band in which they vocalize. The method was not applied to the case study of humpback whales in the Bering Sea, because that dataset turned out to have too much confounding noise; instead, the case study used was of fin whales. The method produced a number for the population density, but has not been verified yet. A separate effort is under way (the Cheap DECAF project) to estimate the density of fin whales using other methods; and when that is done, the results from that project will be compared to results from this method. The method is the subject of a forthcoming paper [38] defining the method and showing its results for this case study.
(4) **[Workshop dataset]** We coordinated the production of datasets focused on odontocete whistles and clicks and baleen whale calls for the Fifth Workshop on Detection, Classification, Localization, and Density Estimation of Marine Mammals using Passive Acoustics, which we hosted at Timberline Lodge, Mt. Hood, Oregon, from August 22-25, 2011. We prepared these datasets as common ground for comparing methods in collaboration with Marie Roch (Scripps Institution of Oceanography and San Diego State University) for the classification dataset and Eva-Marie Nosal (University of Hawaii) and Steve Martin (SPAWAR) for the localization dataset. This dataset was released approximately six months before the workshop on the MobySound web site and was used by conference attendees. A comparison of results of methods tested on this dataset was included.
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38. MELLINGER, D. K., AND E. T. KÜSEL. **In prep.** Density estimation from received sound in a narrow frequency band.
Appendix 1:

Status summary of recordings in or available to the archive

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**Odontocetes- beaked whales**

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**Pinnipeds (seals)**

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**EXTANT: Annotated and available to archive**

**Mysticetes (Baleen whales)**

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**Odontocetes (toothed whales and dolphins)- beaked whales**

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<td><em>Delphinus capensis</em></td>
<td>long-beaked common dolphin</td>
<td>SCORE, Southern Calif.</td>
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<td><em>Delphinus delphis</em></td>
<td>short-beaked common dolphin</td>
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<td><em>Orcinus Orca</em></td>
<td>killer whale</td>
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<td><em>Physeter macrocephalus</em></td>
<td>sperm whale</td>
<td>Mediterranean</td>
<td>Univ. Crete</td>
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<td></td>
<td>Gulf of Mexico</td>
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**Pinnipeds (seals)**

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<td><em>Phoca vitulina</em></td>
<td>harbor seals</td>
<td>California coastline</td>
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*Abbreviations:*

- AUTEC: Atlantic Undersea Test and Evaluation Center
- CIMRS: Cooperative Institute for Marine Resources Studies
- NMML: National Marine Mammal Laboratory
- NOAA: National Oceanic and Atmospheric Administration
- NUWC: Naval Undersea Warfare Center
- PALAOA: Perennial Acoustic Observatory in the Antarctic Ocean
- SCORE: Southern California Offshore Range
- SIO: Scripps Institution of Oceanography
- UW-APL: University of Washington, Applied Physics Laboratory
- WHOI: Woods Hole Oceanographic Institute
Appendix 2:

Home page of open access website
Appendix 3: Publications and Presentations

Articles in peer-reviewed journals


Conference papers (non-refereed)


Presentations with published abstracts


Data exchanges

- Hundreds of data downloads from the MobySound.org web site (see above)
- Univ. Washington – beluga and bowhead whale recordings from the Beaufort Sea
- NOAA-NMML – recordings of many species from the Bering Sea
- Univ. New South Wales – Arnoux’s beaked whale recordings from Antarctica
- JASCO Applied Sciences, Inc. – bowhead whale recordings from the Chukchi Sea
- Greenridge Sciences, Inc. – bowhead whale recordings from the eastern Beaufort Sea
- Mamiferos, Encuentros, Educación, Reconocimiento (MEER) – short-finned pilot whale recordings from the Canary Islands
- Alfred Wegener Institute – crabeater seal recordings from Antarctica
- Univ. Crete – sperm whales from the Mediterranean Sea

Dissertations/graduate theses
None.
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