OVERVIEW OF THE 3RD INTERNATIONAL WORKSHOP ON THE DETECTION AND CLASSIFICATION OF MARINE MAMMALS USING PASSIVE ACOUSTICS

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ABSTRACT

The *3rd International Workshop on the Detection and Classification of Marine Mammals Using Passive Acoustics* was held 24-26 July 2007 in Boston, MA. A dataset containing verified odontocete vocalizations from five different species, including Blainville's beaked whale (*Mesoplodon densirostris*), was provided for the testing and development of detection and classification algorithms. Data collected under different acoustic conditions were included along with a blind test dataset. Six research groups tested their respective algorithms against the unknown data and presented their results. Both the data set and the test results are presented.

SOMMAIRE

Le 3ème atelier international sur la détection et la classification des mammifères marins employant l'acoustique passive a été tenu le 24-26 juillet 2007 à Boston, MA. Un ensemble de données vérifiées de vocalisations d'odontocètes de cinq espèces différentes, y compris la baleine à bec de Blainville (*Mesoplodon densirostris*), était disponible pour l'essai et le développement des algorithmes de détection et classification. Des données enregistrées dans des conditions acoustiques différentes étaient incluses, ainsi qu'un ensemble de données pour test aveugle. Six groupes de recherche ont testé leurs algorithmes respectifs avec les données inconnues, et ont présenté leurs résultats. L'ensemble de données et les résultats du test sont présentés ici.

1. INTRODUCTION

Marine mammal passive acoustic methods to monitor individual animals and populations are undergoing rapid development. Algorithms for the detection, classification, and localization (DCL) of marine mammal vocalizations are critical to these methods. To foster this development, the *3rd International Workshop on the Detection and Classification of Marine Mammals Using Passive Acoustics* was held 24-26 July 2007 in Boston, MA, USA. Two previous workshops concentrated on detection and localization without emphasis on the problem of classification. This workshop emphasized classification as a core topic area. The workshop provided researchers from around the world the opportunity to present their work and to test the efficacy of their DCL algorithms on a common data set consisting of sounds recorded from odontocete species identified by experienced visual observers. The workshop drew participants from different fields and included specialists in biology, acoustics, signal processing, mathematics, electronics, and computer science. Topics for presentation were extended beyond passive acoustics to areas of research related to the effects of anthropogenic sound on marine mammals. The scientific topics encompassed by the workshop were as follows:

1. Underwater acoustics
2. Detection and Classification
3. Localization
4. Biology of Marine Mammals
5. Density Estimation
6. Applications

A half-day was reserved for the comparison of scientific methods applied to a common workshop data set of recorded odontocete clicks. The dataset allowed researchers to develop and compare DCL algorithms. It was provided by the U.S. Navy's Naval Undersea Warfare Center (NUWC), Division Newport and hosted by Oregon State University on the MobySound website. It can be accessed at:

http://hmsc.oregonstate.edu/projects/MobySound/MsSoundSets.html

The first five journal papers are from participants who developed detection and classification algorithms and attempted to identify the species in the workshop dataset test files. A summary of their results is included below. The next four papers are from participants who used the workshop dataset in other ways. The remaining papers are organized according to the scientific topics listed above.

2. WORKSHOP DATA

Data for the workshop dataset were collected by the NUWC Marine Mammal Monitoring on Navy Ranges (M3R) program during species verification tests at two U.S. Navy ranges: the Atlantic Undersea Test and Evaluation Center (AUTEC) located off Andros Island, Bahamas, and the Southern California Offshore Range (SCORE) off southern California (Figure 1). Animal vocalizations were recorded on wide-band bottom-mounted hydrophones located at these ranges. Data were analyzed and prepared for the workshop at NUWC and Oregon State University.

2.1 Navy Ranges

The AUTEC range consists of 82 operational hydrophones covering a total area of over 1500 km^2. The hydrophones are at varying depths of approximately 1300-1900 meters. Sixty-two of the hydrophones are arranged in offset rows on approximately 3.8 km (2 nm) baselines, with a bandwidth of about 50 Hz to 45 kHz. Fourteen of the hydrophones are arranged into two 7-hydrophone hexagonal arrays with a center hydrophone. These hydrophones are on a baseline of about 1.8 km (1 nm), and have a bandwidth of 8 to 50 kHz. The AUTEC hydrophones are located east of Andros Island in the Bahamas in a deep ocean canyon known as the Tongue of the Ocean (TOTO).

The SCORE range contains 88 hydrophones covering an area of over 1800 km^2. The SCORE hydrophone baselines range between about 2.5 km (1.3 nm) close to shore to 6.5 km (3.5 nm) farther west, although a few hydrophone pairs have shorter baselines, with one as small as 1.65 km (0.89 nm). The hydrophones vary in depth from about 800 to 1760 meters. Twenty of the hydrophones are individually cabled with a nominal bandwidth of 8 to 50 kHz, and the other 68 are on multiplexed arrays, with a nominal bandwidth of 8 to 39 kHz. The range is located to the west of San Clemente Island, California.

2.2 Alesis recorders

The raw acoustic data are cabled to shore, where they are recorded using a bank of eight Alesis HD24 hard disk recorders. Each Alesis unit records up to 12 channels, with an IRIG time code on the 12th channel. The data are recorded as 24-bit samples at a 96 kHz sample rate using standard IDE hard drives.

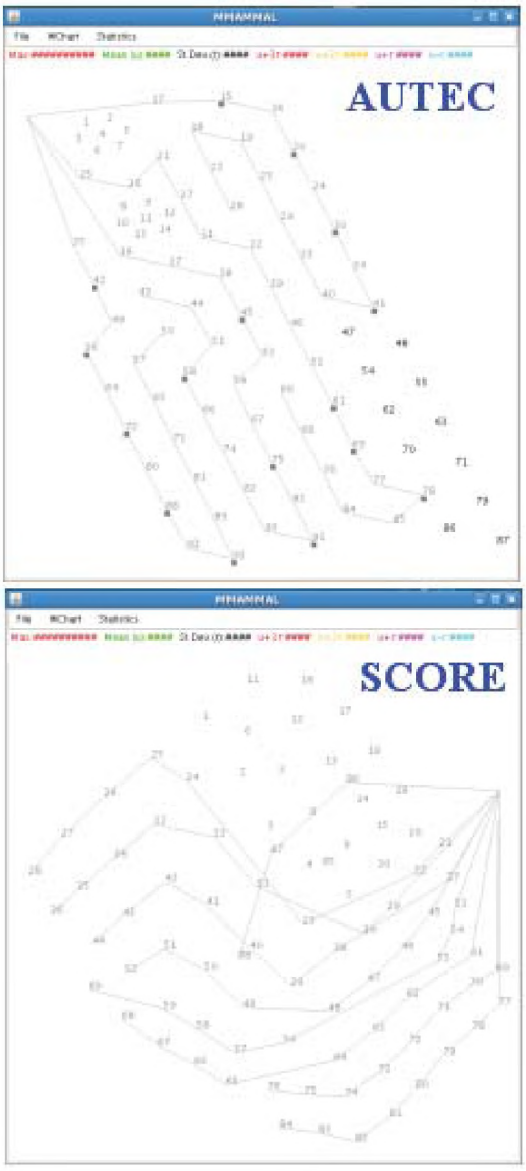

Figure 1. The AUTEC (top) and SCORE (bottom) ranges.

2.3 Species Verification Tests

M3R has conducted species verification tests at each of these ranges with highly trained surface observers. At the AUTEC range, M3R collaborated with the Bahamas Marine Mammal Research Organization and the Woods Hole Oceanographic Institution, and at the SCORE range with the Cascadia Research Collective and Scripps Institution of Oceanography. Animal vocalizations on the range were acoustically monitored in real-time using M3R software. The goal of the species verification tests was to use experienced surface observers to visually verify species that were acoustically detected and monitored on-shore. The shore team monitored the range for animals and directed the

observers to the location of vocalizations of interest. The surface observers found the animals, verified the species present, took photo IDs and recorded behavioral data. During the course of these tests all hydrophones were recorded. The data provided in the workshop were drawn from the closest recordings both spatially and temporally to verified sightings of the species of interest. Though care was taken to provide sound cuts matched to visually verified species, there are cases in which the cuts may be contaminated with vocalizations from other unsighted species in the vicinity of the recorded hydrophones. This is particularly a problem for Risso's dolphin sound cuts from the SCORE range, where the animal density is much higher than at AUTEC.

2.4 Workshop Dataset

Cuvier's and Blainville's beaked whale species are among those most often involved in mass strandings linked to naval mid-frequency sonars. The workshop dataset consists of both training data and test data for a variety of odontocete species, with an emphasis on Blainville's beaked whales (*Mesoplodon densirostris*), as data from multiple verified sightings were available for this species. Sounds from each species comprised a number of "cuts", short segments of continuously-recorded sound.

Training data

Training data sound cuts were provided for the following three species:

1. Blainville's beaked whale (*Mesoplodon densirostris*)
2. *S*hort-finned pilot whale (*Globicephala macrorhynchus*)
3. Risso's dolphin (*Grampus griseus*)

The Blainville's beaked whale and short-finned pilot whale sound cuts were recorded at the AUTEC range, and the Risso's dolphin sound cuts were recorded at SCORE. Most training sound cuts were 2 minutes long, though they varied from 0.5 to 3 minutes in length.

Sixteen sound cuts of Blainville's beaked whale were provided. These data were collected at AUTEC on April 27, 2005 and September 24 and 27, 2005. Nine short-finned pilot whale sound cuts were available for training. These data were recorded at AUTEC on September 24, 26, and 30, 2005. The Risso's dolphin sound cuts were collected at SCORE on August 14, 16, and 19, 2006. Eleven of these sound cuts were provided for training.

Test Data

Nine longer, unidentified sound cuts, approximately ten minutes each, were provided as test data. Six of these files were from verified sightings. Three were unverified, but were from easily recognizable species (beaked whale and sperm whale). The test files were numbered one through nine and the species identity was withheld. The correct species identifications are shown in Table 1.

Test File	Key
1	Unverified Blainville's beaked whale (*Mesoplodon densirostris*) & verified short-finned pilot whale (*Globicephala macrorhynchus*)
2	Blainville's beaked whale (*Mesoplodon densirostris*)
3	Risso's dolphin (*Grampus griseus*)
4	Pantropical spotted dolphin (*Stenella attenuata*)
5	Risso's dolphin (*Grampus griseus*)
6	Unverified Blainville's beaked whale (*Mesoplodon densirostris*) & unverified sperm whale (*Physeter macrocephalus*)
7	Pantropical spotted dolphin (*Stenella attenuata*)
8	Short-finned pilot whale (*Globicephala macrorhynchus*)
9	Unverified sperm whale (*Physeter macrocephalus*)

Table 1: Species identifications for workshop dataset test files.

The test cases were organized into three categories, with the following species in each category:

1. High signal-to-noise ratio (SNR) sound cuts
   a. Blainville's beaked whale
   b. Short-finned pilot whale
   c. Risso's dolphin

2. Sound cuts with multiple species
   a. Unverified Blainville's beaked whale & verified short-finned pilot whale
   b. Unverified Blainville's beaked whale & unverified sperm whale

3. Sound cuts with no signal of interest
   a. Pantropical spotted dolphin
   b. Unverified sperm whale

High-SNR test cases were presented for the three species for which training data were provided. Alternate species and sound cuts with multiple species were also provided to test and compare the different methods for detection and classification. All the test cases were recorded at AUTEC except for the Risso's dolphin cuts, which were recorded at SCORE.

Dataset Annotations

A spreadsheet was provided listing the sound cut filenames and source files for the sound cuts; the date and location of the recordings; the type of recorder, sample rate and

bandwidth; start and stop times referenced to the local time, Greenwich mean time (GMT), and the Alesis recorder; length (in minutes) and size (in megabytes) of the source files; whether the source files were time-aligned and visually verified; the local sighting time, nearest hydrophone and common and scientific names of the species sighted; notations regarding the presence of clicks, whistles/moans, creaks/buzzes, man-made noise, boat/engine noise, unknown sounds; and more detailed comments describing the contents of the cuts.

Information was also provided describing the naming conventions for the files, the hydrophone locations and depths in meters, and additional sighting data.

Additional Data

Upon request, two additional datasets were provided. One was a Blainville's beaked whale dataset for localization, consisting of 18-minute long sound cuts from five neighboring hydrophones on the AUTEC range. These sound cuts were from a verified sighting at AUTEC on September 27, 2005. The second was an AUTEC noise dataset, consisting mostly of background noise. These were three files, each 30 minutes long, recorded from different parts of the range on April 26, 2005.

3. WORKSHOP DATASET ANALYSIS AND RESULTS

Six participants presented results from the application of their detection and classification algorithms to the test data set. The participants attempted to identify the species present in each of the dataset test files. Following the authors' presentations, the correct species identification for each vocalization test file was released.

The results of the analysis, based on each author's presentation, are provided in Table 2, which summarizes the number of species correctly identified, as well as those omitted, added, or misidentified. The table presents raw classifier outputs. To compile the results, the number of correctly identified species was first tallied. The number of species misidentified was then counted from those remaining, followed by the number omitted, and finally the number added. A direct comparison of the authors' results was difficult. In some cases, the results were open to interpretation, as they were simply a tabulation of the number of times a particular species was correctly identified. Future workshop organizers should provide participants with a clearly defined format for the tabulation of their results. A number of authors recognized that species were misidentified by their classifiers and suggested minor adjustments would improve performance.

Overall, Roch's classifier performed best, with the most correct species and the fewest misidentified ones. Van IJsselmuide's detector did nearly as well, and the detectors of Gerard and Jarvis had only slightly more errors.

4. CONCLUSION

This third workshop was a success, with a great deal of cross-fertilization of ideas among attendees. The direct comparison of detectors on a common dataset was successful, in part because the workshop dataset was prepared months in advance of the workshop. It is hoped that this workshop series will continue into the future.

5. ACKNOWLEDGEMENTS

The organizers would like to thank the Office of Naval Research and the Chief of Naval Operations for support of this workshop. We would also like to thank the scientific committee and the reviewers for their tireless effort. Finally, we would like to thank all of the workshop participants, particularly those who analyzed the workshop dataset.

	Key	Gerard	Gillespie	Harland	Van IJsselmuide	Jarvis	Roch
Test File 1	**Md, Gm**	Md, Gg?	Md, Gm	Md	Md, Gm	Md, Gm	Md
Test File 2	**Md**	Md, Gg?	Md	Md	Md	Md	Md
Test File 3	**Gg**	Md, Gm?	Gm	Gm	Gg?	Gm	Other
Test File 4	**Sa**	Md, Gm?	Gm	Gm	Gg?	Gm	Other
Test File 5	**Gg**	Gg	Gg	Gg	Other	Md	Gg
Test File 6	**Md, Pm**	Md, Other	Md, Gm	Md	Md, Pm	Md, Pm	Md, Pm
Test File 7	**Sa**	Gg	Gg	Gg	Md?	Md, Gg	Gg
Test File 8	**Gm**	Gm?	Other	Md	Other	Other	Gm
Test File 9	**Pm**	Gg?	Gm	Gm	Pm	Pm	Pm
# Species Correct		6	5	4	7	6	8
# Species Misidentified		5	6	5	4	5	2
# Species Omitted		0	0	0	0	0	1
# Species Added		3	0	0	0	1	0

Md *Mesoplodon densirostris* **(Blainville's beaked whale)**
Gm *Globicephala macrorhynchus* **(Short-finned pilot whale)**
Gg *Grampus griseus* **(Risso's dolphin)**
Sa *Stenella attenuata* **(Pantropical spotted dolphin)**
Pm *Physeter macrocephalus* **(Sperm whale)**

Table 2: Results for the participants who attempted to identify the species present in the dataset test files.

Photo Credit:Bahamas Marine Mammal Research Organisation