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estimation of marine mammals: final report

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**NAVAL
POSTGRADUATE
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MONTEREY, CALIFORNIA

**DETECTION, CLASSIFICATION, AND DENSITY
ESTIMATION OF MARINE MAMMALS:
FINAL REPORT**

by

David K. Mellinger

October 2012

Approved for public release; distribution is unlimited.

Prepared for: Chief of Naval Operations
Energy and Environmental Readiness Division,
Washington, D.C.

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**NAVAL POSTGRADUATE SCHOOL
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14. ABSTRACT Detection, classification, and localization (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. This project was aimed to begin development of high-performing automatic detection methods for the sounds of beaked whales and other odontocetes. Specifically, this report [1] details the newly collected odontocete recordings that have been added to the MobySound archive; [2] documents continuing development of methods for detection and classification, including improvements to the <i>Energy Ratio Mapping Algorithm</i> (ERMA) method for use on gliders and its extension to new species and populations; [3] reports on application of a newly developed method for population density estimation to field recordings; and [4] also reports on the successful 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.					
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**Detection, classification, and density estimation of marine mammals:
Final Report**

Award #N00244-10-1-0047

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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 has been in development since 1992. Methods for population density estimation using acoustic data have been in development since 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 1990’s, 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 vehicle 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; it recently underwent its first two field tests, correctly detecting killer whale clicks in real time in the Haro Strait, Washington, and then detecting beaked whale clicks in real time off Kona, Hawaii.

The major aim of this project was to begin development of high-performing automatic detection methods for the whistles of beaked whales and other odontocetes. Whistle identification is imperative to the success of detecting these species. The specific aims were to collect recordings with whistles, annotate these sound files to make them useful to researchers working on automatic call detection and classification, and make them

publicly available in an archive on the Internet; to continue developing and publishing detection and classification methods and software, to integrate these methods with new autonomous platforms and detection systems; to develop a new method for population density estimation based on sound density and apply it to field recordings; and to prepare a workshop dataset for the 2011 International Workshop on the Detection, Classification, and Localization of Marine Mammals using Passive Acoustics, which occurred on August 21-25, 2011, in Oregon.

In more detail, project tasks were as follows:

- (1) Annotate recordings of odontocete whistles 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 organized.

Results/Milestones

The results/milestones by task are as follows:

- (1) [Annotate recordings] We collected data sets of odontocete recordings containing whistles and clicks for addition to MobySound.org. Appendix 1 provides a full list of MobySound contents, including updates made under this grant. New 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 (*D. 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 (*S. coeruleoalba*), short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*), melon-headed whale (*Peponocephala electra*), bottlenose dolphin, rough-toothed dolphin (*Steno bredanensis*), and spinner dolphin (*Stenella longirostris*) from the eastern tropical Pacific; killer whale from the South Atlantic; and gray whale (*Eschrichtius robustus*) from the eastern Pacific (Mexico). Many of these recordings have been annotated for clicks and whistles. Recordings of Dall's porpoise (*Phocoenoides dalli*), harbor porpoise (*Phocoena phocoena*), and killer whales from the North Pacific are also in storage for eventual addition to MobySound.org.

We also developed a new algorithm for better estimating the signal-to-noise ratio (SNR) of whistles. Existing MobySound recordings have baleen whale tonal calls and odontocete clicks. The two methods for measuring the SNR of these sounds do

not work for whistles – particularly when clicks are present too, as is the case of most recordings that contain whistles. We developed a new algorithm, `snrWhistle.m` (in MATLAB), for measuring the SNR of whistles when clicks are present, and made it available on the MobySound.org website.

The web site, www.mobysound.org, is well-used. It has had 1583 unique visitors from Jan. 1 through Sept. 28, 2012; projecting to a full year, this would be 2111 visitors. A total of 375 gigabytes of data have been downloaded, an annual rate of 499 gigabytes/year.

- (2) [Detection/classification] The ERMA algorithm for click detection was improved, implemented on further sensor platforms, and applied to the analysis of large acoustic data sets.

Improvement: Adaptive noise-reduction algorithms were developed to improve the detection performance of ERMA. Results showed a significant improvement in detection performance for beaked whale clicks [31]. These algorithms have been tested in the lab and will be used on our autonomous platforms in the near future.

Implementation: ERMA was implemented on ocean gliders [32] and floats [33], and successfully detected beaked whales in several locations (*e.g.*, at AUTECH, at SCORE, off Hawaii). A dataset collected from hydrophones on an autonomous sailboat in July 2012 in the Baltic Sea was employed to modify ERMA for detecting harbor porpoise echolocation clicks; the modified version of the detector will next be implemented on the sailboat and used to detect harbor porpoises in real-time. We also plan, in collaboration with Jeff Nystuen of the University of Washington-Applied Physics Laboratory (UW-APL), to implement ERMA on the Passive Aquatic Listener (PAL). The modified PAL will be deployed at Ocean Station Papa near the U.S. Navy’s Northern Edge range in the Gulf of Alaska to monitor high-frequency cetaceans.

Data set analysis: We provided ERMA to Whitlow W. L. Au of the University of Hawaii (UH) for analyzing large acoustic data sets from cabled observatory ALOHA. ERMA allowed our colleagues at UH to analyze the data set quickly, and it accurately detected beaked whale echolocation clicks in the recordings (Au *et al.*, in review).

- (3)[Density estimation] We developed a new method for population density estimation. Unlike most estimation methods, which rely on counting the number of calls, call sequences, or individuals of the target species, and which thus take considerable manual work, this method relies on estimating the energy in the frequency band of the target species, then using acoustic propagation modeling and call intensity to estimate population density. The method was originally developed for fin whales in the Atlantic. We intended to use it for humpback whales in the Bering Sea, but we found

that there was too much noise in the (relatively wide) frequency band of humpback vocalizations to use the method effectively; so we switched to fin whales.

We realized that elimination of interfering noise sources was one key to effective use of this method, and developed a number of noise-reduction methods. These techniques are based on calculation and then averaging of the periodic sequence of linear power spectra of a recording (*i.e.*, a “power spectrogram”):

- For short-duration impulsive sounds such as seismic airgun sounds, noise is reduced by removing the spectrum of the impulses from the average.
- For wide-band, long-duration noise such as wind and waves, noise is reduced by estimating the noise level in frequencies below and above the target frequency band, then using interpolation to estimate what fraction of the received acoustic energy is from background noise and what fraction is from the target species.
- For harmonic sounds such as ship propeller noise, noise is removed by identifying peaks in the spectrum, removing them from the spectrum, and interpolating between the values that remain.

Because of the time taken to deal with these issues, density estimation was not completed, though we are pursuing the research goals in subsequent work.

(4) [Workshop dataset] We coordinated the production of datasets that focus on odontocete whistles and clicks for the 2011 Workshop on the Detection, Classification, and Localization (DCL) of Marine Mammals using Passive Acoustics, which we hosted at Timberline Lodge, Mt. Hood, Oregon, from August 21-25, 2011. In collaboration with Marie Roch (Scripps Institution of Oceanography *and* San Diego State University), we prepared datasets as common ground for comparing methods for the classification dataset, and with Eva-Marie Nosal (San Diego State University) for the localization dataset. These data sets were added to the MobySound.org website and made available for public use in April 2011, and widely advertised to the bioacoustics and marine mammal science communities through online announcements on the Internet.

In the course of this project, we mentored a number of students:

- Michelle Fournier, Oregon State University, USA;
- Marci Shindel, Oregon State University, USA;
- Qi Lou, Oregon State University, USA;
- Nikoletta Diogou, University of Athens, Greece;
- Selene Fregosi, University of California at Santa Cruz, USA;
- Darin Padula (NOAA Hollings intern), University of Hawaii, USA;

- Alice McKinstry, Oregon Coast Community College, Newport, OR, USA;
- Andrea Paula Capurro, University of Buenos Aires, Argentina.

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Appendix 1:

Status summary of recordings in or available to the archive

Red indicates additions/updates under this grant.

Species	Common Name	Region	N sounds	N files	N seconds of sound	Source
<i>CURRENT: In archive</i>						
Mysticetes (baleen whales)						
<i>Balaena mysticetus</i>	bowhead whale	northern Alaska	589	130	3580	NOAA/CIMRS
		northeastern Alaska		45	2500	Greenridge Sciences, Inc.
		northwestern Alaska		9	18313	JASCO
<i>Balaenoptera acutorostrata</i>	minke whale	North Atlantic	178	5	13198.2	NOAA/CIMRS
		western tropical Pacific		29		Bio-Waves, Inc.
<i>Balaenoptera borealis</i>	sei whale	western tropical Pacific		4		Bio-Waves, Inc.
<i>Balaenoptera edeni</i>	Bryde's whale	eastern tropical Pacific	136	12	14054.1	NOAA/CIMRS
		western tropical Pacific		7		Bio-Waves, Inc.
<i>Balaenoptera musculus</i>	blue whale	North Atlantic	486	9	36540.4	NOAA/CIMRS
<i>Balaenoptera physalus</i>	fin whale	North Atlantic	3066	15	75492.4	NOAA/CIMRS
<i>Eschrichtius robustus</i>	Gray whale	Sea of Cortez	9676	9676	13115.4	Independent researcher
<i>Eubalaena australis</i>	southern right whale	South Africa	67	5	2273	Independent researcher
<i>Eubalaena glacialis</i>	North Atlantic right whale			100		NOAA/CIMRS
<i>Eubalaena japonica</i>	North Pacific right whale	Bering Sea	38	6	4496	NOAA/CIMRS
<i>Megaptera novaeangliae</i>	humpback whale	eastern tropical Pacific	2310	14	7639.1	NOAA/CIMRS
		western tropical Pacific		11		Bio-Waves, Inc
Odontocetes (toothed whales and dolphins)						
<i>Delphinus capensis</i>	long-beaked common dolphin	SCORE, Southern Calif.				SIO
<i>Delphinus delphis</i>	short-beaked common dolphin	SCORE, Southern Calif.				SIO

<i>Globicephala macrorhynchus</i>	short-finned pilot whale	AUTEC, North Atlantic	66322	20	67500	NUWC
		North Atlantic, Canary Is.		1	2000	MEER e.V.
		northwestern Pacific		2		Bio-Waves, Inc
<i>Globicephala malena</i>	long-finned pilot whale	Mediterranean		16		Univ. Pavia, Italy
<i>Grampus griseus</i>	Risso's dolphin	SCORE, Southern Calif.	66322	15	26179.2	SIO
		Mediterranean		6		Univ. Pavia, Italy
<i>Lagenorhynchus obliquidens</i>	Pacific white-sided dolphin	SCORE, Southern Calif.	2672	1	586.9	SIO
<i>Lissodelphis borealis</i>	northern right whale dolphin	SCORE, Southern Calif.	225	1	394.1	SIO
<i>Peponocephala electra</i>	melon-headed whale	northwestern Pacific	9272	9	4058.1	Bio-Waves, Inc.
<i>Physeter macrocephalus</i>	sperm whale	AUTEC, North Atlantic	61118	3	2790.8	NUWC
		western tropical Pacific		61		Bio-Waves, Inc.
		Mediterranean		6		Univ. Crete
<i>Psuedorca crassidens</i>	false killer whale	western tropical Pacific		10		Bio-Waves, Inc
<i>Stenella spp.</i>	spotted dolphin	AUTEC, North Atlantic	498	17	30153.6	NUWC
		North Atlantic, Canary Is.		1	900	MEER e.V.
<i>Stenella attenuata</i>	pantropical spotted dolphin	western tropical Pacific	5153	19	8933.7	Bio-Waves, Inc
<i>Stenella coeruleoalba</i>	striped dolphin	western tropical Pacific	71	2	1026.5	Bio-Waves, Inc
<i>Stenella longirostris</i>	spinner dolphin (Gray's)	eastern tropical Pacific	1749	2	810.5	NOAA/SWFSC
<i>Steno bredanensis</i>	rough-toothed dolphin	AUTEC, North Atlantic		2	3600	NUWC
		North Atlantic, Canary Is.		1	900	MEER e.V.
		western tropical Pacific	75	1	412.7	Bio-Waves, Inc.
<i>Tursiops truncatus</i>	bottlenose dolphin	North Atlantic, Canary Is.		1	900	MEER e.V.
		western tropical Pacific		6		Bio-Waves, Inc
		eastern tropical Pacific	4410	4	2655.4	SIO
Odontocetes- beaked whales						
<i>Berardius arnuxii</i>	Arnoux's beaked whale	Antarctic	8594	3	8432.1	Univ. New S. Wales
<i>Berardius bairdii</i>	Baird's beaked whale	North Pacific		18	7797.1	UW-APL, NMML/NOAA
		northeast Pacific		6	55.7	Independent researcher
		Sea of Cortez	1383	245	159.4	NNML/NOAA
<i>Indopacetus pacificus</i>	Longman's beaked whale	eastern tropical Pacific	46	9	536.7	NOAA

<i>Mesoplodon densirostris</i>	Blainville's beaked whale	AUTEC, North Atlantic	3637	41	67613	AUTEC
		North Atlantic, Canary Is.	3000	1	1260	WHOI
		eastern tropical Pacific		3	19.7	NOAA
<i>Mesoplodon spp.</i>	beaked whales	western tropical Pacific				Bio-Waves, Inc.
<i>Ziphius cavirostris</i>	Cuvier's beaked whale	Mediterranean	3137	1	1800	WHOI
		Mediterranean		10		Univ. Pavia, Italy
<i>Ziphiidae spp.</i>	various	AUTEC, North Atlantic	1087	8	3900	NUWC
<i>Ziphiidae spp.</i>	various	AUTEC, North Atlantic		12	17894.1	NUWC
Pinnipeds (seals, sea lions, walrus)						
<i>Lobodon carcinophaga</i>	crabeater seal	Antarctic	3940	714	42840	PALAOA
<i>Hydrurga leptonyx</i>	leopard seal	Antarctic	7249	3923	235440	PALAOA
<i>Erignathus barbatus</i>	bearded seal	northern Alaska		2	1000	Greenridge Sciences, Inc.
Detection and Classification Workshop Data Sets (location is workshop location)						
1st Workshop	northern Atlantic right whale	Nova Scotia, Canada		88	4228.8	NOAA/CIMRS
2nd Workshop	sperm whale	Monaco		49	14700	NOAA/CIMRS
3rd Workshop	beaked whale	Boston, Massachusetts		20	22064.2	NOAA/CIMRS
4th Workshop	beaked whale	Pavia, Italy		559	37225.8	NOAA/CIMRS
5th Workshop	odontocete whistles	Portland, Oregon		46	46000.2	NOAA/CIMRS
EXTANT: in data base but not annotated						
Mysticetes (Baleen whales)						
<i>Balaenoptera acutorostrata</i>	minke whale	eastern tropical Pacific				Bio-Waves, Inc.
<i>Balaenoptera borealis</i>	sei whale	northern Alaska				NOAA/CIMRS
<i>Balaenoptera musculus</i>	blue whale	northern Alaska				NOAA/CIMRS
<i>Balaenoptera physalus</i>	fin whale	northern Alaska				NOAA/CIMRS
<i>Megaptera novaeangliae</i>	humpback whale	North Atlantic				OASIS, Inc
		eastern tropical Pacific				Bio-Waves, Inc.
		northern Alaska				NOAA/CIMRS
<i>Eubalaena glacialis</i>	North Atlantic right whale	Arctic				NOAA/CIMRS

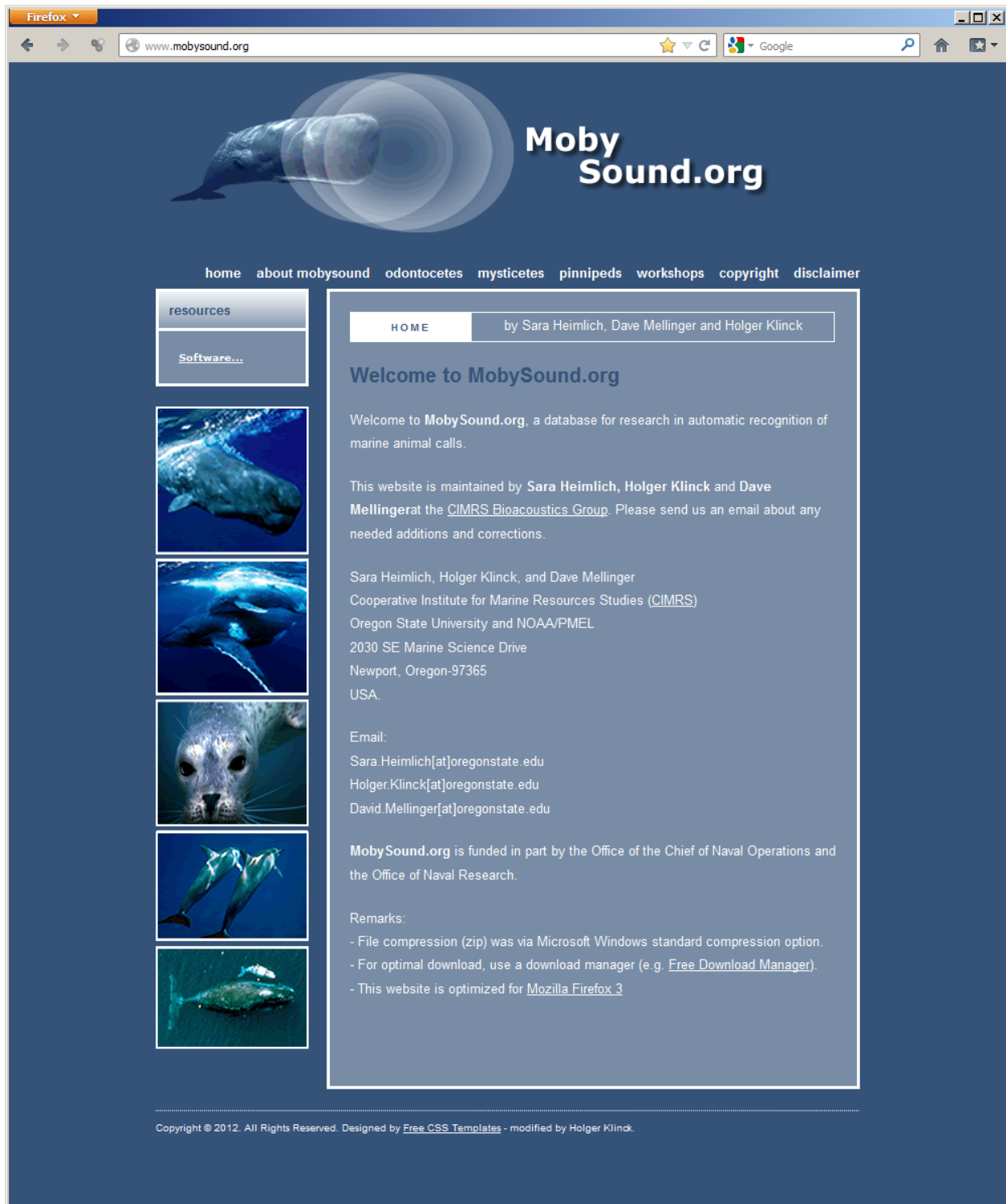
Odontocetes (toothed whales and dolphins) - beaked whales						
<i>Lagenodelphis hosei</i>	Fraser's dolphin	Atlantic		66	488.3	WHOI
<i>Peponocephala electra</i>	melon-headed whale	SCORE, Southern Calif.		4	2400	SIO
		Atlantic		60	153.4	WHOI
<i>Orcinus orca</i>	killer whale	Southern Puget Sound				Independent Researcher
<i>Physeter macrocephalus</i>	sperm whale	Mediterranean				Univ. Crete
		Gulf of Mexico				Univ. New Orleans
Pinnipeds (seals)						
<i>Phoca vitulina</i>	harbor seal	California coastline				NMFS/NOAA
Anthropogenic Sounds						
airguns		Fram Strait				NOAA/CIMRS
airguns		northern Alaska				NOAA/CIMRS
airguns		North Atlantic				NOAA/CIMRS
<i>EXTANT: not yet in data base</i>						
<i>Megaptera novaeangliae</i>	humpback whale	Southern California				Independent researcher
		Indian Ocean				Independent researcher
<i>Balaena mysticetus</i>	bowhead whale	Chukchi Sea				Bio-Waves, Inc.
		northeast Alaska				Independent researcher
<i>Delphinapterus leucas</i>	beluga	Chukchi Sea				Bio-Waves, Inc.
		St. Lawrence Estuary				Independent researcher
		northeast Alaska				Independent researcher
<i>Eschrichtius robustus</i>	gray whale	northeast Alaska				Independent researcher
	bottlenose dolphin	North Atlantic				Independent researcher
<i>Balaenoptera acutorostrata</i>	minke whale	North Pacific				Independent researcher
		northeast Alaska				Independent researcher
<i>Orcinus orca</i>	killer whale	northeast Alaska				Independent researcher
		Puget Sound				Independent researcher
	walrus	northeast Alaska				Independent researcher

<i>Erignathus barbatus</i>	bearded seal	northeast Alaska				Independent researcher
<i>Histiophoca fasciata</i>	ribbon seal	northeast Alaska				Independent researcher
<i>Phoca vitulina</i>	harbor seal	various				Independent researcher

*Abbreviations:

AUTEC	Atlantic Undersea Test and Evaluation Center	PALAOA	Perennial Acoustic Observatory in the Antarctic Ocean
CIMRS	Cooperative Institute for Marine Resources Studies	SCORE	Southern California Offshore Range
MEER eV	Mamíferos, Encuentros, Educación, Reconocimiento	SIO	Scripps Institution of Oceanography
NMFS	National Marine Fisheries Service	SWFSC	Southwest Fisheries Science Center
NMML	National Marine Mammal Laboratory	UW-APL	University of Washington, Applied Physics Laboratory
NOAA	National Oceanic and Atmospheric Administration	WHOI	Woods Hole Oceanographic Institution
NUWC	Naval Undersea Warfare Center		

Appendix 2: Open access website



Firefox

www.mobysound.org

Google

Moby Sound.org

home about mobysound odontocetes mysticetes pinnipeds workshops copyright disclaimer

resources

Software...

HOME by Sara Heimlich, Dave Mellinger and Holger Klinck

Welcome to MobySound.org

Welcome to **MobySound.org**, a database for research in automatic recognition of marine animal calls.

This website is maintained by **Sara Heimlich, Holger Klinck and Dave Mellinger** at the [CIMRS Bioacoustics Group](#). Please send us an email about any needed additions and corrections.

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Appendix 3. Publications and Presentations.

Publications

- BOGUE, N. M., J. C. LUBY, W. A. JUMP, J. M. PYLE, G. B. SHILLING, T. LITCHENDORF, A. S. WOOD, D. K. MELLINGER, AND H. KLINCK. **7-10 December 2009**. Passive acoustic monitoring using Seaglider: initial deployments. **Book of abstracts**, *ONR Marine Mammal Program Review*. Alexandria, VA. pp. 52-53.
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- KLINCK, H., AND D. K. MELLINGER. **2009**. A real-time detection system for odontocete echolocation clicks in the low-energy processing environment of an acoustic glider. *J. Acoust. Soc. Am.* **125(4)**: 2548(A).
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- MARTIN, S. W., T. A. MARQUES, L. THOMAS, D. MORETTI, R. MORRISSEY, N. DIMARZIO, S. JARVIS, AND D. K. MELLINGER. **July 2009**. Estimating minke whale density at Pacific Missile Range Facility, Hawaii. **Symposium:** *Estimating Cetacean Density from Passive Acoustics*. La Jolla, California. p. 8.
- MATSUMOTO, H., C. JONES, H. KLINCK, D. K. MELLINGER, L. WILLIAMS, C. MEINIG, AND R. P. DZIAK. **22-26 February 2010**. The QUEphone: a passive acoustic float for marine mammal monitoring. **Abstract BO45G-02**, *Ocean Sciences Meeting*. Portland, Oregon.
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- MELLINGER, D. K. **7-10 December 2009**. Automatic detection for long-term monitoring of marine organisms. **Book of abstracts**, *ONR Marine Mammal Program Review*. Alexandria, Virginia. pp. 54-55.
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- MELLINGER, D. Automatic detection of beaked whales from acoustic Seagliders. *Progress report for award N00014-08-1-1082*, **Office of Naval Research**.
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Data exchanges

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, Inc. – bowhead whale recordings from the Chukchi Sea
Greenridge Sciences, Inc. – bowhead whale recordings from the eastern Beaufort Sea
MEER (Mamíferos, Encuentros, Educación, Reconocimiento) – 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

Presentations/posters

- BOGUE, N. M., J. C. LUBY, W. A. JUMP, J. M. PYLE, G. B. SHILLING, T. LITCHENDORF, A. S. WOOD, D. K. MELLINGER, AND H. KLINCK. **7-10 December 2009**. Passive acoustic monitoring using Seaglider: initial deployments. **Book of abstracts**, *ONR Marine Mammal Program Review*. Alexandria, Virginia. pp. 52-53.
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- KLINCK, H., AND D. K. MELLINGER. **2009**. A real-time detection system for odontocete echolocation clicks in the low-energy processing environment of an acoustic glider. *J. Acoust. Soc. Am.* **125(4)**: 2548(A).
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- KLINCK, H., D. K. MELLINGER, N. M. BOGUE, J. C. LUBY, W. A. JUMP, J. M. PYLE, AND G. B. SHILLING. **7-10 December 2009**. Autonomous passive acoustic monitoring of marine mammals using the Seaglider: onboard real-time detection and classification of target signals. **Book of abstracts**, *ONR Marine Mammal Program Review*. Alexandria, Virginia. p. 86.
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