2012 Annual Report submitted to NOPP

For work performed in the period 1 Oct 2011 to 30 Sep 2012 on the grant

"Portable and Persistent Autonomous Real-Time Marine Mammal Acoustic Monitoring"

Harold A. Cheyne II, Ph. D.
Bioacoustics Research Program, Cornell Lab of Ornithology
95 Brown Road, Room 201, Ithaca, NY 14850
Phone: (607) 254-6280 FAX: (607) 254-1132 E-mail: hac68@cornell.edu

Christopher W. Clark, Ph.D.
Bioacoustics Research Program, Cornell Lab of Ornithology
159 Sapsucker Woods Road, Ithaca, NY 14850
Phone: (607) 254-2408 FAX: (607) 254-2460 E-mail: cwc2@cornell.edu

NSF Grant Number: *OCE-1138098*
http://www.birds.cornell.edu/brp

LONG-TERM GOALS

Current marine mammal monitoring (MMM) methods that use archival recorders or towed hydrophone arrays have the disadvantages of being analyzed long after the acoustic events of interest, or being subject to the noise of the ship towing the array and require dedicated on-ship computers and human reviewers to acquire and process the data, respectively. To overcome these disadvantages, this joint work involving the Cornell Lab of Ornithology (CLO) Bioacoustics Research Program (BRP) and SAIC, Inc. will integrate archival recorder electronics and a broadband satellite communications system with on-board detection, classification, and localization (DCL) software onto a Wave-Powered Glider Persistent Autonomous Vehicle ("WaveGlider" from Liquid Robotics, Inc.), to develop a mobile marine mammal monitor (hereafter "M4") capable of transmitting DCL data in near real-time to an on-ship or on-shore Data Management and Communications (DMAC) receiver.

OBJECTIVES

The proposed project objectives are

1. Develop a real-time, portable, Marine Mammal Monitoring System.
2. Acquire marine acoustic data using a four-channel hydrophone array towed behind a WaveGlider, with modified acoustic acquisition electronics integrated onto the WaveGlider.
3. Transmit selected acoustic data and associated metadata in real-time to the DMAC receiver via the high-speed satellite data link.
4. Optimize detection, classification, and localization (DCL) operations both on-board the WaveGlider and at the DMAC receiver to achieve real-time performance similar to BRP's current Auto-Buoy system.[1]

APPROACH AND WORK PLAN

In project year 1 (1 July 2011 to 30 June 2012), the overall goal was to demonstrate the feasibility of a WaveGlider integrated with acoustic data acquisition electronics and a towed four-element hydrophone array to capture and output acoustic data to an on-ship data collection system. This goal was approached in three phases:

1. Hardware integration of electronics, hydrophone array, and WaveGlider
2. In-water testing of the WaveGlider system to capture four-channel data
3. Post-processing of the in-water data for evaluating existing detector performance

In the ongoing project year 2 (1 July 2012 to 30 June 2013), the overall goal is to demonstrate the feasibility of (a) using the SAIC Broadband Satellite Communication (satcom) system to transmit acoustic data from the WaveGlider to a remote DMAC, and (b) modifying the *Raven* and Auto-Buoy software as needed to perform as the remote DMAC interface. These goals also are being approached in three phases:

1. Laboratory development and testing of integrated Satcom and remote DMAC interface
2. In-water testing of the WaveGlider system to capture four-channel data
3. Post-processing of the in-water data for evaluating system performance

Key individuals participating in this work are listed with their respective project roles in Table 1 below.

Name	Organization	Project Role
Harold Cheyne	Cornell	PI
Christopher Clark	Cornell	Co-PI
Adam Strickhart	Cornell	Electrical Engineer (Note: Year 1 only)
Dean Hawthorne	Cornell	Software Engineer
John Walrod	SAIC	Advanced Systems Division Manager
Michael Ornee	SAIC	Program Manager
Michael Satter	SAIC	Advanced Systems Division Deputy Manager
Charles Key	SAIC	Systems Engineer

Table 1. Key personnel on the project.

WORK COMPLETED

During the first project year, work focused on M4 system architecture development, data processing software modifications, and the in-water feasibility test. In the first few months of the second project year, the work focused on integrating the satcom subsystem and planning software architectures to achieve the DMAC goals. Through Nov 2011, BRP and SAIC pursued parallel development paths to assess two versions of acoustic data acquisition hardware, and decided to integrate modified versions of SAIC's hardware. Between Nov 2011 and Apr 2012, SAIC completed the modification and integration of their "24B" four-channel acoustic data acquisition hardware for use in the M4 system. In this same period, one of the original Year 2 objectives - modifying Cornell's *Raven* sound analysis software[3] to incorporate a detection algorithm as described by Gillespie[4] (hereafter the "Gillespie detector") and previously implemented on Cornell's Auto-Buoy system[1] - was moved to Year 1 and completed, to better allocate resources based on the use of the 24B hardware. In Apr and May 2012, two attempts were made to perform the in-water testing, but were canceled due to weather and ship mechanical problems. A successful in-water test occurred in Jun 2012 in the Gulf of Mexico. Planning for the project's Year 2 work was conducted in Jul and Aug 2012, culminating with an all-day group meeting at SAIC (Long Beach, MS) on 21 Aug 2012 to finalize the Year 2 plan. Between Aug and Sep 2012, initial work has begun on (a) evaluating the satcom subsystem's power consumption and transmission capability, (b) quantifying the expected average and maximum power available from the M4 system's photovoltaic panels and batteries, and (c) designing the software architecture required to fulfill the Year 2 DMAC goals.

RESULTS

Hardware. The parallel development paths during Year 1 produced two significant technical outcomes: demonstrated feasibility of modifying existing SAIC hardware to achieve the desired four-channel data acquisition at 24kHz while using 1.7W of power, and the prototyping of a microcontroller-based system to achieve similar performance while only using one-tenth of the power. The former outcome facilitated the decision to use the 24B hardware in the M4 platform for Year 1, while the latter provided the proof-of-concept for a more efficient future implementation where the saved power could be used instead for on-board signal processing or extending the deployment time.

Thus far in year 2 the lab-based hardware work has provided crucial data on the M4 system expected deployment time limitations, specifically the system power supply capability of 60 days at 6W of average power draw and the satcom subsystem power consumption of 10W average and 20W maximum during transmit.

Software. Moving the Gillespie detector modification for *Raven* into Year 1 can allow the data gathered during the in-water test to be processed immediately using a laptop in the field rather than as a post-processing step at Cornell - an approximation of the ultimate M4 system embodiment. Figures 1 and 2 show spectrograms from *Raven* with purple boxes indicating the detector outputs for synthetic and actual Northern Right Whale (NRW) vocalizations, respectively.

In-water testing. In preparation for the in-water testing, Cornell created a suite of acoustic stimuli including tones, synthetic NRW vocalizations, and actual NRW vocalizations. Cornell and SAIC estimated the expected ambient noise levels based on prior recordings in the region, and set the 24B hardware gain accordingly. During the in-water testing, the following results led the team to re-assess the preparation and performance of the in-water testing for Year 2.

1) The WaveGlider navigation control was mechanically compromised by the hydrophone array, such that the WaveGlider was required to be tethered for the testing.
2) The ambient noise levels in the testing area were significantly higher than estimated, resulting in masking of the signals of interest (see Figure 3) and some signal clipping (see Figure 4).

Many of the test tones were both audible and visible on spectrograms as recorded by the M4 system. In contrast, the synthetic and actual NRW calls were rarely audible or visible, making the Gillespie detector in *Raven* output spurious results. Figure 3 compares the synthetic NRW stimuli as played into the water (upper spectrogram) to the noisy received data (lower spectrogram) to highlight this challenge. Figure 4 shows examples of the ambient noise causing clipping of the recorded data.

To mitigate issue (1) in project year 2, we are planning to modify the array's mechanical attachment to the WaveGlider, and to conduct a separate WaveGlider in-water test trip for functional navigation command and control testing prior to the acoustic and satcom testing. For issue (2), the effects of the ambient noise will be mitigated by adding real-time control of the M4 platform's gain, plus additional filtering stages in the data collection hardware.

IMPACT AND APPLICATIONS

National Security

Successful development of the M4 platform will have the direct National Security impact of providing a more cost-effective way for the US Navy to monitor the effects its activities have on marine mammals. Indirectly, such a platform may have other National Security uses such as port monitoring or unmanned monitoring of activity in US or international waters.

Economic Development

The M4 platform would potentially transform the current standard methods for monitoring marine mammals. Instead of requiring expensive ship time, which also uses significant amounts of fossil fuels, a renewable-energy-powered Waveglider could monitor the area instead. People who previously served as Marine Mammal Observers (MMOs) on-board operating vessels may instead be able to perform their duties on-shore by confirming detections by the M4 system. In addition, the enhanced capabilities of the SAIC 24B data acquisition hardware as modified for this work may impact SAIC's existing product line and revenue from that product line.

Quality of Life

The potential future impact of the M4 platform would be an improvement in general ocean ecosystem health due to greater monitoring and thus enhanced regulation of industrial activities. This would also contribute to more comprehensive coastal resource management, such as persistent acoustic monitoring of offshore wind energy sites before construction, during construction, and during operation.

Science Education and Communication

One of the key software components of this project is BRP's *Raven* software for acoustic signal visualization and measurement.[3] The addition of detection algorithm capability within the *Raven* software package is a novel feature enabled by this project, thus one potential future impact may be providing other bioacoustic researchers who use *Raven* with a tool for semi-automated data processing. *Raven* has a related application named *Raven Exhibit*, which is dedicated to using the *Raven* audio-visual software for science education and outreach, particularly in museum installations. A potential future impact on Science Education and Communication may be transferring some of the acoustic data from such a Waveglider MMM platform to Raven Exhibit to provide the public with a real-time auditory experience of the marine mammal environment.

TRANSITIONS

National Security	None as yet.
Economic Development	None as yet.
Quality of Life	None as yet.
Science Education and Communication	None as yet.

RELATED PROJECTS

There are three closely related projects to this effort: the ongoing BRP improvement of its Marine Autonomous Recording Unit (MARU), the CLO Acoustic Monitoring Project (AMP), and a grant award under ONR BAA 10-024 (PI: Peter Dugan). Both the ongoing MARU improvement and AMP are looking towards a microcontroller-based, low-power acoustic data acquisition system for their next generation of acoustic monitoring devices. These two efforts will differ from the M4 project in the number of channels to be recorded and in the peripheral communications, but the core acoustic acquisition and storage methodologies can be achieved in a synergistic development. Peter Dugan's grant focuses on developing novel detection and classification algorithms for marine mammal monitoring, and may provide a collaborative opportunity in reduction to practice by implementing an embedded version of such an algorithm on the M4 platform itself.

REFERENCES

1. Eric Spaulding, et al. "An autonomous, near-real-time buoy system for automatic detection of North Atlantic right whale calls," Proceedings of the 157th Meeting of the Acoustical Society of America, Portland, Oregon, 18-22 May 2009.
2. Cheyne, H., Walrod, J., Gholson, N., Ornee, M., Clark, C., Developing a Portable and Persistent Autonomous Real-Time Marine Mammal Acoustic Monitor. Proceedings of the Oceans 2011 MTS/IEEE Conference, 2011. ISBN: 978-1-4577-1427-6
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6107139&isnumber=6106891
3. http://www.birds.cornell.edu/brp/raven/RavenOverview.html
4. Gillespie, D. 2004. Detection and classification of right whale calls using an "edge" detector operating on a smoothed spectrogram. Can. Acoust. 32, 39–47.

PUBLICATIONS

Cheyne, H., Walrod, J., Gholson, N., Ornee, M., Clark, C., Developing a Portable and Persistent Autonomous Real-Time Marine Mammal Acoustic Monitor. Proceedings of the Oceans 2011 MTS/IEEE Conference, 2011. ISBN: 978-1-4577-1427-6
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6107139&isnumber=6106891

OUTREACH MATERIALS None as yet.

FIGURES

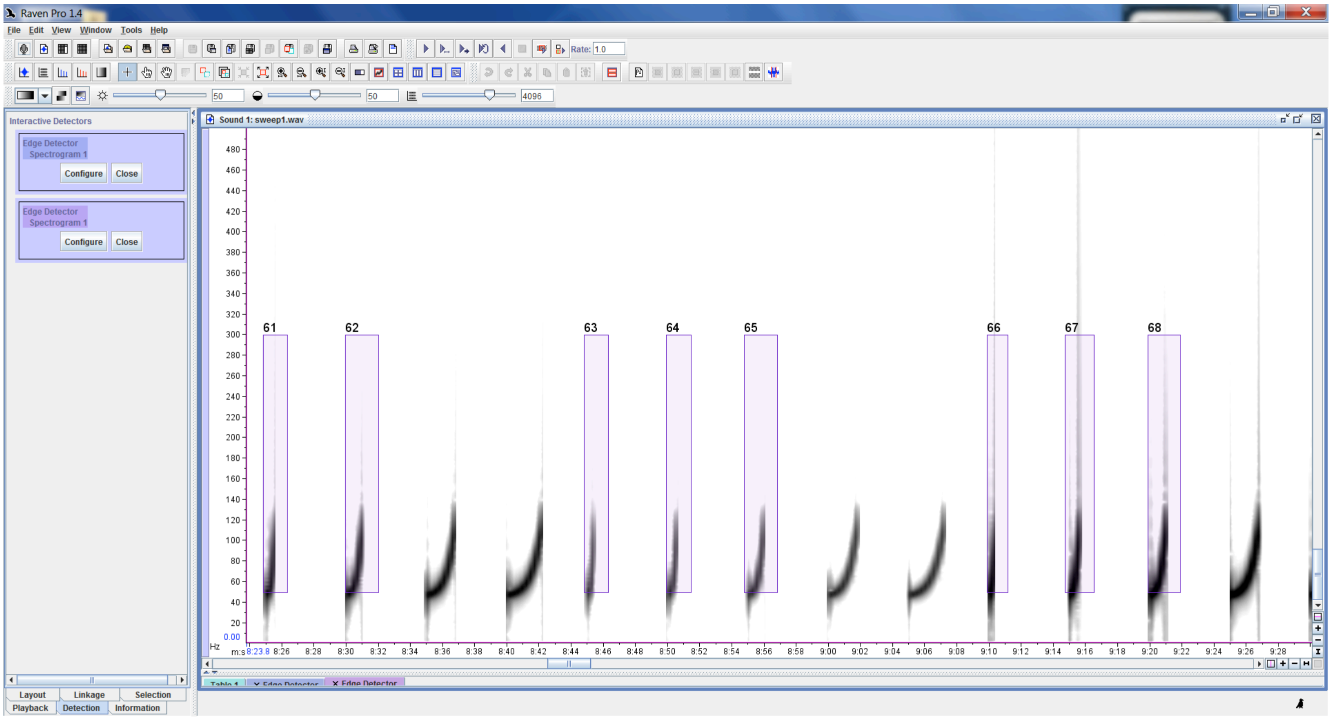

Figure 1. *Raven* screenshot of a spectrogram with numbered boxes showing Gillespie detector outputs for synthetic NRW vocalizations.

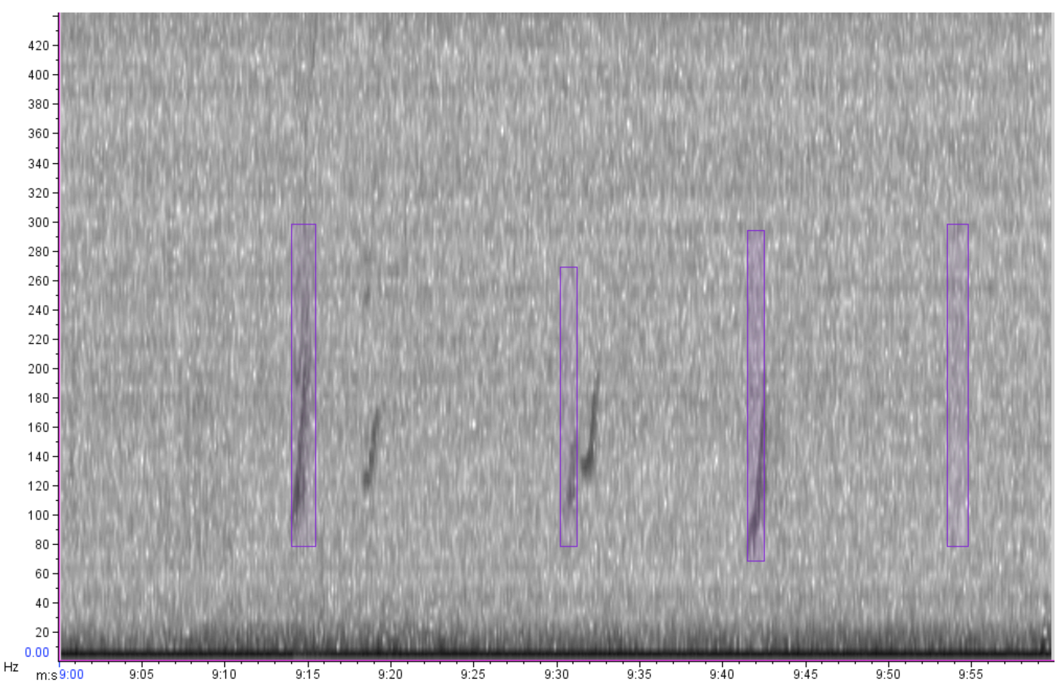

Figure 2. *Raven* screenshot of a spectrogram with boxes showing Gillespie detector outputs for actual NRW vocalizations. Note the missed detection around 9:20.

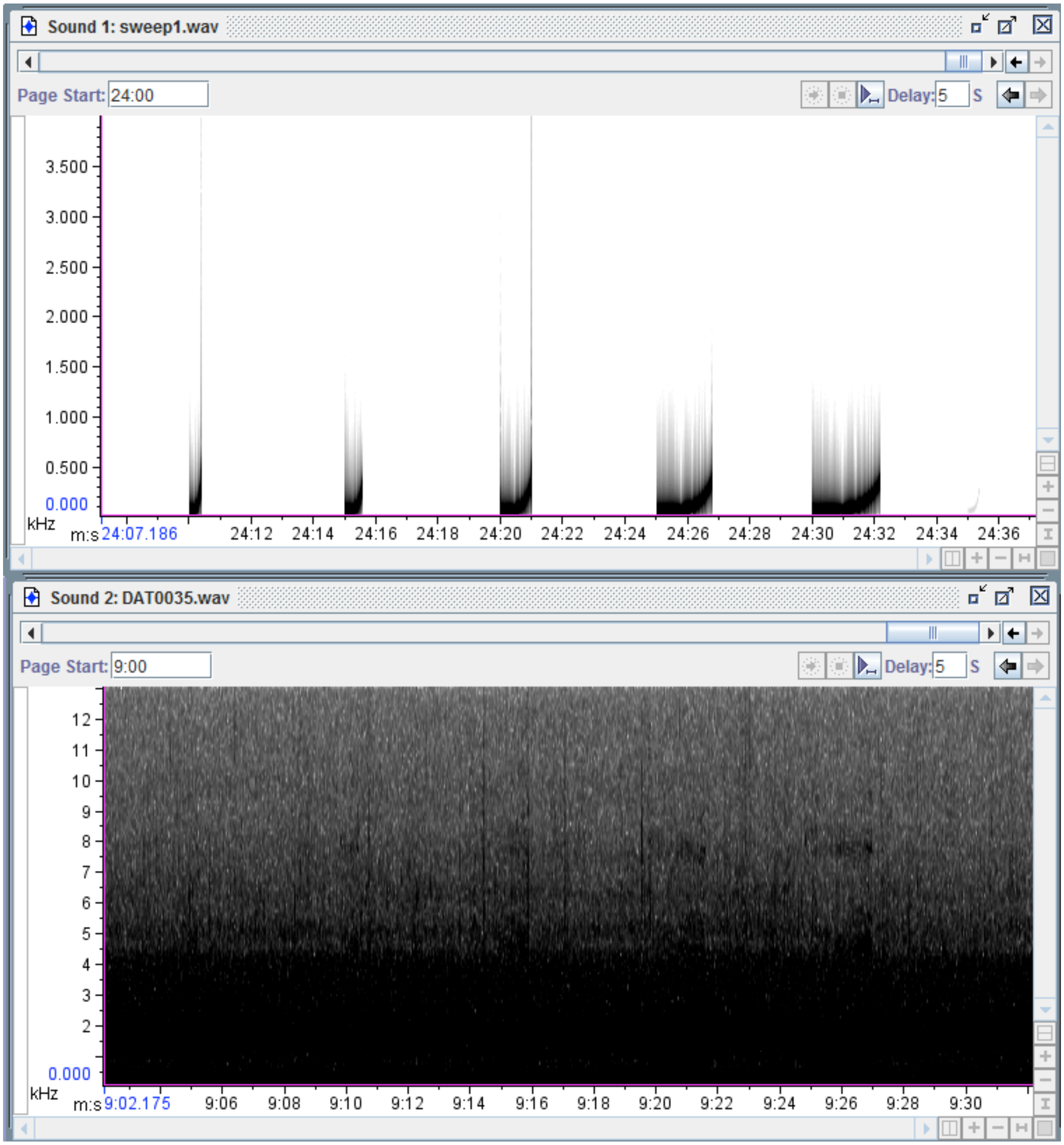

Figure 3. *Raven* screenshots of spectrograms showing synthetic NRW vocalizations used as stimuli during the in-water testing (upper) and the corresponding recorded data from the M4 system (lower). Note the intense noise in the lower spectrogram.

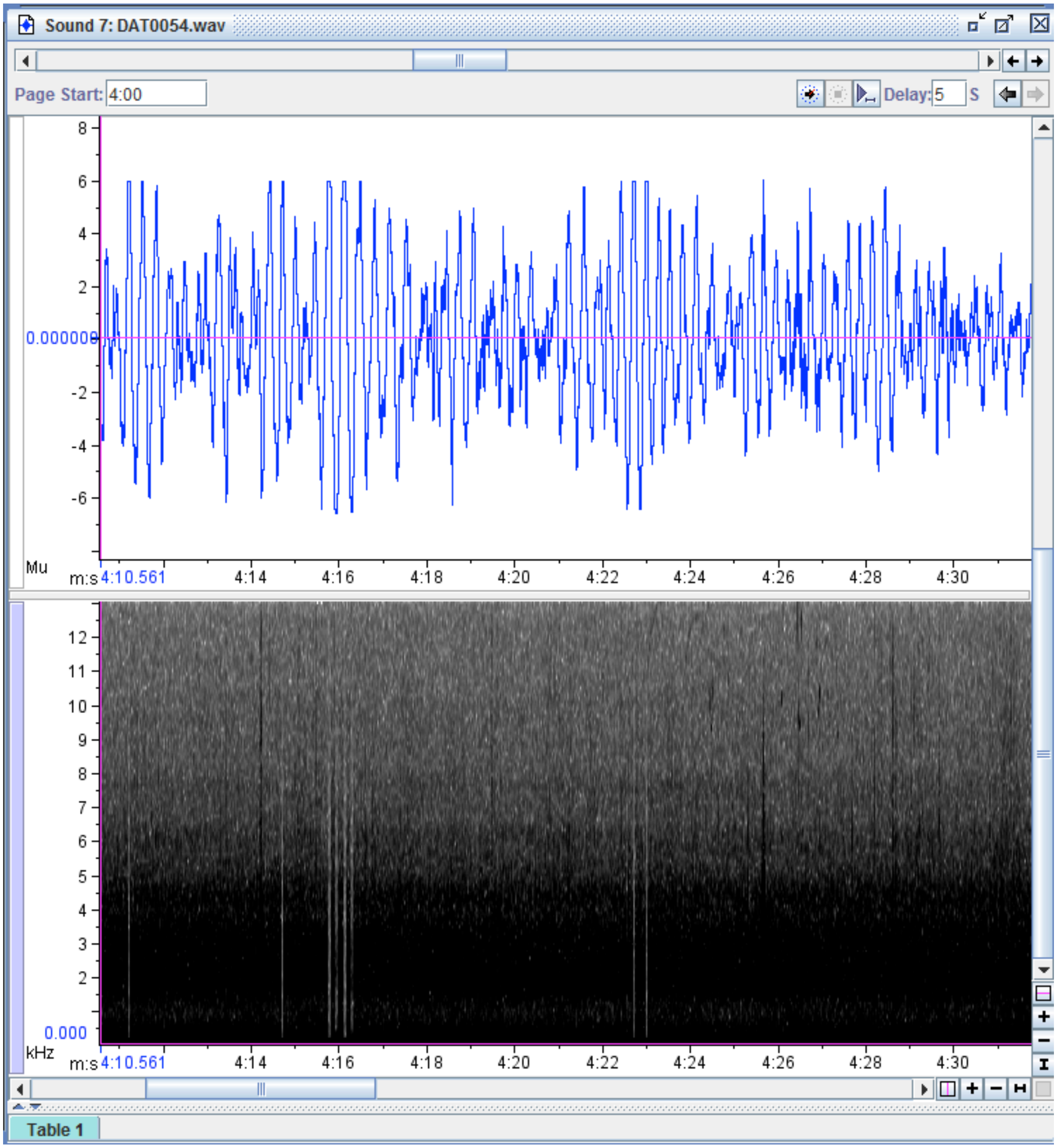

Figure 4. *Raven* screenshot showing waveform (upper) and spectrogram (lower) of selected data from the in-water test. Note the ambient noise causes clipping that manifests as white vertical bars in the spectrogram, particularly around 4:16.