

Glider-based Passive Acoustic Monitoring Techniques in the Southern California Region

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LONG-TERM GOALS

The long-term goal is to develop glider-based and autonomous-platform-based marine mammal monitoring for Naval environmental compliance, as well as for basic scientific studies of marine mammals. Autonomous glider-based passive acoustic monitoring of marine mammal presence is particularly needed within the southern California offshore region, a site of significant naval training. We aim to create operational glider-based marine mammal detection, classification, and localization systems to provide timely information on marine mammal presence to support Naval mitigation efforts in the southern California region.

OBJECTIVES

Our objective is to develop and test glider and autonomous-platform-based capabilities for marine mammal call detection, classification, and localization (DCL). Because of their long-duration on-station time and acoustically silent operation, gliders provide attractive platforms for acoustic monitoring over extended periods of time, with significant processing capabilities for detection, classification and localization of marine mammal calls. For gliders to be effective in this role, efficient algorithms for automated detection and classification of marine mammal calls are needed. In addition,

we are testing various autonomous platforms (submerged versus surface) for marine mammal call detection capabilities, and comparing these platforms against fixed bottom-mounted acoustic sensors.

APPROACH

We are exploring two autonomous platforms with capabilities for real-time, persistent, passive acoustic monitoring: the flying wing ZRay glider and the near-surface Wave Glider. The ZRay is the world's largest underwater glider, employing a high lift-to-drag ratio wing design allowing efficient long distance travel at higher speeds and with greater payloads than traditional profiling gliders. The Wave Glider has a surface float connected by cable to a submerged glider, using wave action for propulsion. The presence of the Wave Glider surface float, that includes real-time data communications, allows for instantaneous notification of marine mammal presence.

We have a collaborative team to investigate the ZRay and Wave Glider capabilities for marine mammal monitoring. Gerald D'Spain is responsible for ZRay glider development and integration with marine mammal DCL capabilities. John Hildebrand and Sean Wiggins are responsible for Wave Glider-based development of marine mammal recording and detection/classification hardware and software. Marie Roch is responsible for development of hardware and algorithms for real-time marine mammal detection and classification.

WORK COMPLETED

A Range Validation Test was conducted on January 3-9, 2011 to compare multiple autonomous platforms (gliders, autonomous surface vehicles, and freely drifting floats) at the Navy's SOAR Range (the instrumented part of the SCORE Range) against range-installed hydrophones. Glider operations were conducted simultaneously with the monitoring of range hydrophones by the M3R system (Dave Moretti, NUWC) and data collection by a High-frequency Acoustic Recording Package (HARP) near the range.

During the first quarter of FY11 we prepared for the Range Validation Test. Activities included preparing and submitting environmental paperwork, preparing a test plan, and coordinating the participation of research groups from six different institutions (Marine Physical Lab/Scripps Institution of Oceanography, Applied Physic Lab/University of Washington, Woods Hole Oceanographic Institution, National Oceanographic and Atmospheric Administration/ Oregon State University, Naval Undersea Warfare Center Newport, and SPAWAR Systems Center Pacific).

In addition to the ZRay and Wave Glider from SIO, other autonomous platforms participating in the Range Validation Test included: two Seaglidors from APL/UW, a Slocum glider and two freely drifting vertically profiling floats from WHOI, a freely drifting float from NOAA/Oregon State, and a Wave Glider from SPAWAR Systems Center Pacific (Figure 1). The Range Validation Test was successful for all participating organizations. The Seaglidors were able to dive to 1000 m to detect beaked whales, in addition to the Slocum glider from Woods Hole that was equipped with a digital acoustic monitoring (DMON) system. The Wave Gliders were equipped with towed hydrophone systems. The three freely-drifting autonomous buoys were each equipped with a single hydrophone system. Finally, all autonomous platforms were deployed over the field of bottom-mounted hydrophones comprising the Navy's SOAR Range (outlined in yellow in Figure 1) and the M3R detector outputs from all hydrophones were recorded during the test.

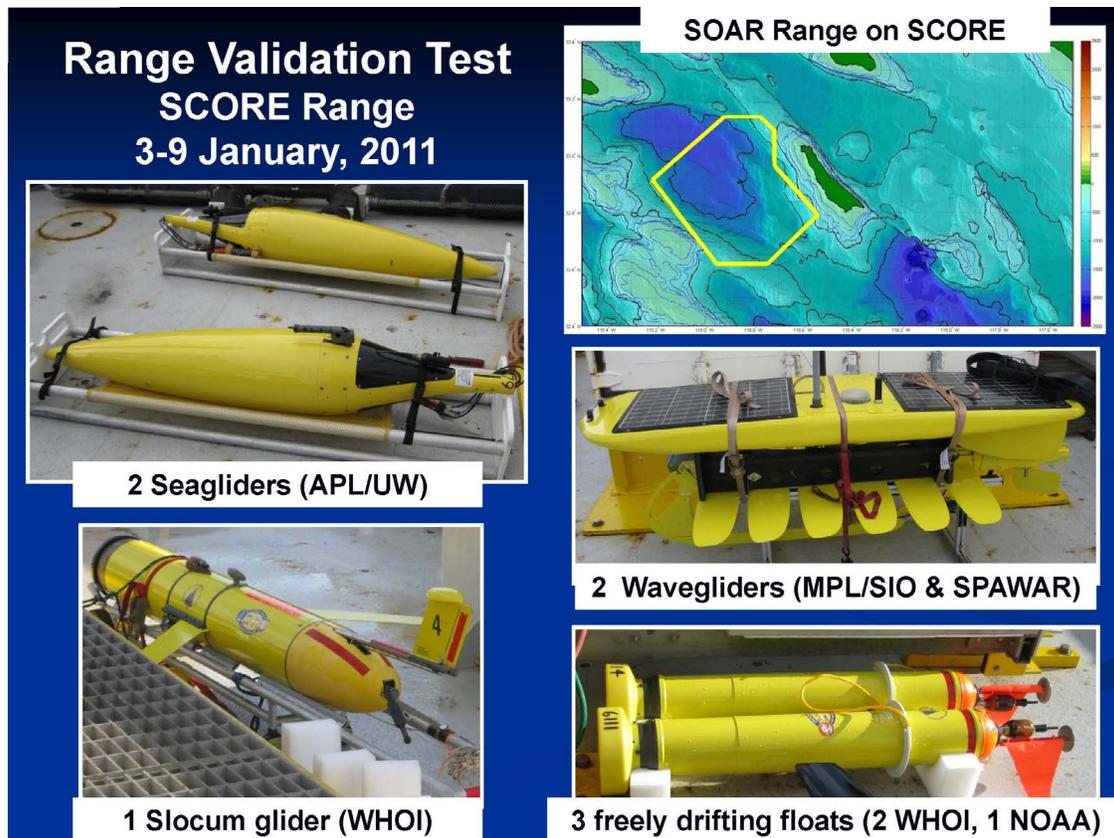


Figure 1. Location of SOAR Range, and autonomous platforms deployed during the Range Validation Test in addition to the ZRay flying wing glider shown in Figure 2.

The Range Validation Test was the first deployment of ZRay (Figure 2) and preparations for the test included ballasting, trimming, and testing its subsystems, and writing-testing modified flight software and real-time signal/array processing software. The real-time algorithm performs detection, classification, and localization (DCL) tasks and operates on the outputs a 27-element hydrophone array located inside a sonar dome along the wing's leading edge. The array was configured for 10 kHz per channel bandwidth during the Range Validation Test. The array outputs are connected to a low-power, single-board computer inside the glider's payload housing, which runs the real-time DCL algorithm, designed initially for humpback whale calls, and now being generalized to monitor a wide range of marine mammals. ZRay was also equipped with a single-hydrophone HARP and a three-channel (two mid-frequency channels and one low-frequency channel) DMON system from the Woods Hole, both configured in record-only mode.

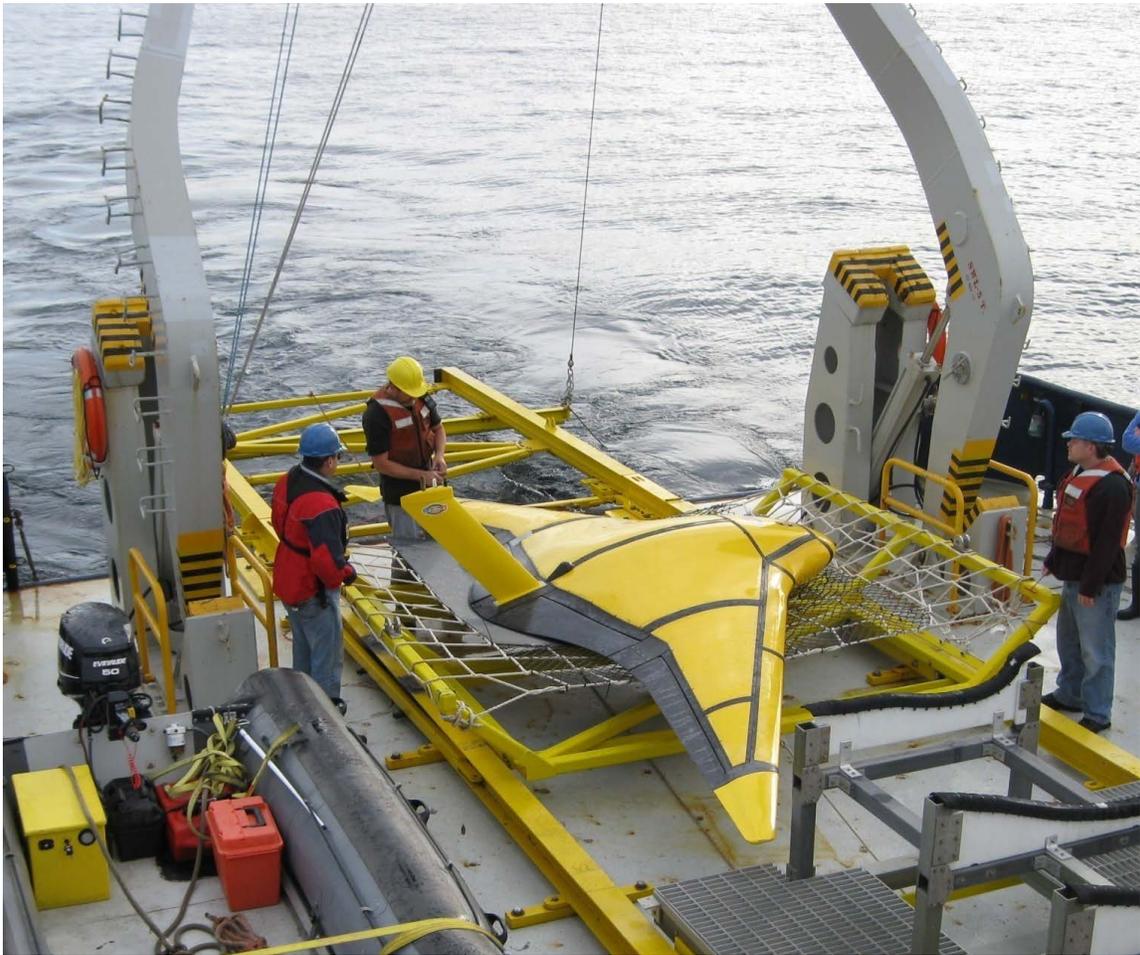


Figure 2. ZRay on the fantail of the R/V Sproul during the Range Validation Test.

In parallel with the Range Validation Test, a significant effort was devoted to developing an optimal approach for detecting transient signals, with a focus on marine mammal calls. The development of optimal detectors starts with the Likelihood Ratio Test (LRT). Application of the LRT, with subsequent approximations, leads to a power-law detector with a power significantly greater than that of an energy-based detector when used for detecting narrow-band transient signals. A paper submitted for publication describes the development of a modified power-law detector for humpback whale calls (Helble et al., 2011).

RESULTS

A comparison was conducted of the sound pressure levels recorded by a hydrophone towed behind the Wave Glider submerged wing at about 8 m depth below the sea surface, and a nearby HARP hydrophone located at about 500 m depth, 10 m above the seafloor. Both the Wave Glider and HARP passive acoustic systems are based on the same sensor and electronics, so the test reveals differences in the ambient noise environment owing to the different depths of the hydrophones and noise induced by the moving Wave Glider platform. Figure 3 shows calibrated noise spectra taken at the same time from the Wave Glider and HARP hydrophones. The Wave Glider and HARP noise levels are remarkably similar over the frequency band above 100 Hz. Below 100 Hz, the Wave Glider hydrophone spectrum increasingly diverges from the HARP spectrum, with about 35 dB higher noise

levels at 10 Hz. These differences may be a product both of higher ambient noise levels being present at the sea surface, and greater flow noise for the Wave Glider hydrophone. We are continuing to test different configurations of Wave Glider hydrophone to diminish the self noise below 100 Hz. The results of this test, however, suggest that for most marine mammal species, whose calls occur above 100 Hz, the Wave Glider hydrophone can produce results comparable to those obtained from a fixed bottom sensor (HARP).

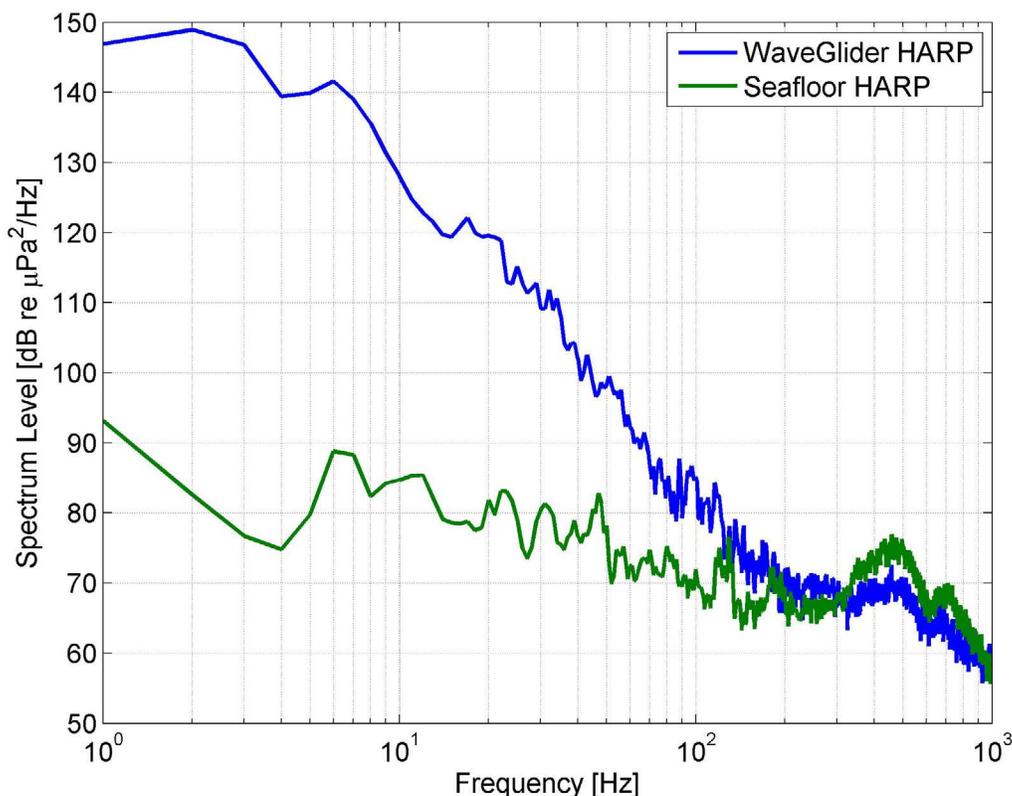


Figure 3. Sound pressure levels for a hydrophone connected to a Wave Glider (8 m depth) compared to an adjacent HARP (500 m depth).

Additional results from the Range Validation Test for all participating institutions were presented at the ONR Passive Acoustic Marine Mammal Monitoring Program Review in April 2011.

IMPACT/APPLICATIONS

The southern California Range Validation Test demonstrated the ability of properly-equipped autonomous gliders and platforms to detect marine mammal calls in near real-time. Gliders provide ideal platforms for marine mammal acoustic studies owing to their persistence and non-disruptive presence. These systems may play a significant role in future passive acoustic monitoring for marine mammals related to Naval environmental compliance and real-time mitigation prior to, during, and after Naval exercises in locations such as the SOAR Range.

RELATED PROJECTS

Project title: Southern California Marine Mammal Studies; John Hildebrand, Principal Investigator. Sponsor: CNO N45 and the Naval Postgraduate School; Support from this project allowed for development of the HARP and comparison of glider and HARP data.

Project title: Passive acoustic monitoring for the detection and identification of marine mammals; Marie A. Roch, Principal Investigator. ONR Grant: N00014-08-1-1199. This project aided in the development of algorithms for marine mammal detection and classification.

Project title: Flying wing underwater glider for persistent surveillance missions, Gerald L. D'Spain, Principal Investigator. ONR Grant: N00014-10-1-0045. This project supported development of large autonomous underwater gliders based on the flying wing design.

PUBLICATIONS and PRESENTATIONS

Helble, T. A., G. R. Ierley, G. L. D'Spain, M. A. Roch, and J. A. Hildebrand. A generalized power-law detection algorithm for humpback vocalizations. *J. Acous. Soc. Am.* Submitted.

Roch, M. A., H. Klinck, S. Baumann-Pickering, D. K. Mellinger, S. Qui, M. S. Soldevilla, J. A. Hildebrand (2011). Classification of echolocation clicks from odontocetes in the Southern California Bight. *J. Acous. Soc. Am.* 129(1) 467-475.

Wiggins, S., J. Manley, E. Brager and B. Woolhiser. Monitoring Marine Mammal Acoustics Using Wave Glider. OCEANS 2010 MTS/IEEE Seattle Washington State Convention and Trade Center Seattle, Washington, USA September 20-23, 2010.