Tracking Whales on the Scotian Shelf using Passive Acoustic Monitoring on Ocean Gliders

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***Abstract*— Expanded marine shipping and industrial activity has increased the risk of harmful effects on marine mammals. Quantitative estimates of marine mammal time and space distributions are essential for developing mitigation strategies designed to reduce the risks. Seasonal distributions of key marine mammals can be estimated by deploying passive acoustic monitoring (PAM) hydrophone systems and using the acoustic data to monitor, detect and identify species presence, often in near real-time. Most contemporary PAM deployments in the ocean are stationary and archive the acoustic data for post-recovery analyses after some extended period and are thus not ideal for addressing risk dynamics in near real-time. Substantive expansions of fixed PAM arrays over large ocean expanses can be economically and on-time limiting. Mobile autonomous vehicles now offer the economy of collecting the necessary acoustic and oceanographic data over extended periods and across large swaths of the ocean. They can operate with a high degree of spatial sampling flexibility in near real-time that cannot be easily achieved using fixed PAM arrays.**

The Whale Habitat and Listening Experiment (WHaLE), funded by the Marine Environmental Observation Prediction And Response Network (MEOPAR) at Dalhousie University, and using Ocean Tracking Network (OTN) autonomous vehicles, is searching for whale habitats and monitoring the distributional patterns of the endangered North Atlantic right whale and other at-risk baleen whales across the shelf waters of Atlantic Canada. This is being achieved through fixed PAM array deployments involving several research partners, as well as the deployment of profiling and surface gliders (autonomous vehicles) equipped with PAM systems capable of detecting and identifying baleen whales that produce sounds in the 10 – 2000 Hz frequency range. When fitted with onboard, automated detection and identification algorithms, the gliders can become powerful tools for near real-time monitoring of the at-risk whales and thus risk mitigation.

Keywords—gliders; passive acoustic monitoring; marine mammals; North Atlantic right whale

I. INTRODUCTION

Marine mammals have two aspects in common. They are ubiquitous in the world's oceans and they make noise. One thing they don't have in common is a healthy population status. Some species are relatively healthy while others, such as the North Atlantic right whale, are endangered and require extra protection. It is estimated that there are currently 500 North Atlantic right whales in existence, and their population, throughout their range, is listed under the Endangered Species Act.

Many programs exist, run in cooperation by universities, federal agencies and private industry that monitor marine mammals on the Scotian Shelf. These programs have been useful in elucidating areas where right whales congregate to feed. Because of these efforts shipping lanes were moved around the Grand Manan Basin in the Bay of Fundy and the Roseway Basin off SW Nova Scotia was designated an area to be avoided (ATBA) by vessels to help lessen right whale strikes in these critical feeding habitats.

The Whale Habitat and Listening Experiment (WHaLE) program is funded by the Marine Environmental Observation Prediction and Response (MEOPAR) Network Centre of Excellence to help reduce ship strikes of large whales on the east and west coasts of Canada. Working with partners, WHaLE uses glider-mounted passive acoustic monitoring of whales sounds as well as high frequency echo sounders to study whale food (zooplankton) and define whale habitat on the Scotian Shelf. WHaLE will also develop, test and implement a Canadian Whale Alert system whereby areas of concentrated and classified whale sounds will be available to mobile device users and can also be transmitted to vessels via an AIS-message. The primary objective of the research is to reduce the risk of ocean-going vessel strikes to large baleen whales by giving the shipping industry and the public better information on whale locations, in near real time via satellite communication.

II. METHODS

In support of WHaLE, the glider group at Dalhousie University, in conjunction with Woods Hole Oceanographic Institution (WHOI) and the Ocean Tracking Network (OTN), has deployed gliders on the Scotian Shelf since 2014. Two types of gliders are utilized, Slocum and wave gliders.

A. Profiling Gliders

Teledyne Webb Slocum electric gliders use buoyancy engines to change their density and attached wings to convert vertical velocity to forward motion, so that the gliders can profile the water column down to 200m, collecting information on water temperature, conductivity, oxygen concentration, downwelling irradiance, chlorophyll fluorescence, and optical backscatter by particles in the water column. Each glider is also equipped with a WHOI digital acoustic monitoring (DMON) instrument, a passive acoustic instrument that is capable of recording and processing audio in real time (Fig. 1). WHOI has implemented a low-frequency detection and classification system (LFDCS) [1] on the DMON to identify marine mammals calls from a variety of autonomous platforms, including gliders, profiling floats, and moorings [2]. The LFDCS produces pitch tracks of sounds with relatively high signal-to-noise ratios (>10 dB above background). Pitch tracks describe changes in the fundamental frequency (pitch) of a call over time. Scientists typically examine spectrograms to identify marine mammal calls. Pitch tracks are derived from these spectrograms. Subsets of the acoustic data, i.e., whale detections and identifications, along with ancillary oceanographic data, are sent to shore via Iridium satellite communication during regularly scheduled surface intervals occurring at approximately every 2 to 4 hours allowing researchers to verify the accuracy of the on-board software in near real time.

One of the Slocum gliders is equipped with an Imagenex 300 kHz active acoustic echo sounder that is most sensitive to particles in the 1.6 mm range, roughly the same size as the zooplankton prey of North Atlantic right and sei whales. The echo sounder is calibrated annually using titanium spheres of known acoustic reflectivity. With an effective range of 1-10 m from the glider, the echo sounder can quantify particles in the entire water column on the Scotian Shelf as the glider profiles vertically.

Fig. 1. Slocum glider equipped with externally mounted DMON

B. Surface Gliders

The Dalhousie glider group also operates a Liquid Robotics SV2 wave glider. The wave glider uses differential wave motion to provide propulsion and solar panels to power electronics. The wave glider is capable of staying at sea for several months. This unit is equipped with sensors to measure meteorological conditions, wave height and direction, surface water temperature, conductivity, oxygen concentration and chlorophyll fluorescence.

During the summers of 2015 and 2016 the wave glider was deployed with an Ocean Sonics icListen hydrophone to survey for marine mammals. The icListen is a self-contained digital hydrophone that records low-frequency sounds between 1 Hz and 1.6 kHz and has storage capacity for approximately 30 days. The icListen does not communicate directly with the wave glider and needs to be recovered to download the data.

C. Deployments

To date there have been 11 deployments of gliders with hydrophones. Dates and locations are shown in Table 1 while tracks of the missions are shown in Fig. 2. The missions have primarily focused on areas of known whale aggregations such as Roseway Basin off SW Nova Scotia. Despite the Gulf of St. Lawrence not being a traditional feeding area for right whales, a glider was deployed there in July 2016 due to a large number of local whale sightings in the summer of 2015.

D. Aid to Navigation

Pitch tracks sent back to shore from DMONs mounted on slocum gliders can be used to identify certain species of whales in near real time. This information can be transmitted to vessels via the Automatic Identification System (AIS), a system using VHF radio to broadcast vessel information such as type, speed, and bearing to all receivers in range. AIS information can be broadcast from shore or satellite and is two-way communication. Ships alerted to whales in the vicinity, in this case watch circles of roughly 10km, can choose to alter course and/or speed to avoid the risk of striking the whales. The system has yet to be fully implemented but plans are moving forward rapidly with the first test of the system expected in late 2016.

Table 1. Dates, types of gliders and locations of missions of gliders tracking marine mammals.

Mission Date	**Glider Type**	**Location**
02 Sep – 24 Sep 2014	WHOI slocum	Roseway Basin, NS
28 Jul – 04 Sep 2015	WHOI slocum	Roseway Basin, NS
27 Jul – 24 Aug 2015	Dal slocum	Halifax Line, NS
20 Aug – 16 Sep 2015	Dal wave glider	Scotian Shelf, NS
10 Sep – 05 Oct 2015	Dal slocum	Halifax Line, NS
14 Sep – 11 Dec 2015	Dal slocum	Roseway Basin, NS
27 Oct – 18 Nov 2015	Dal slocum	Halifax Line, NS
17 Mar – 16 Apr 2016	Dal slocum	Clayoquot Sound, BC
24 Jun – 10 Oct 2016	Dal slocum	Roseway Basin, NS
24 Jul – 05 Nov 2016	Dal slocum	Gulf of St. Lawrence
27 Jul – 26 Aug 2016	Dal wave glider	Scotian Shelf, NS

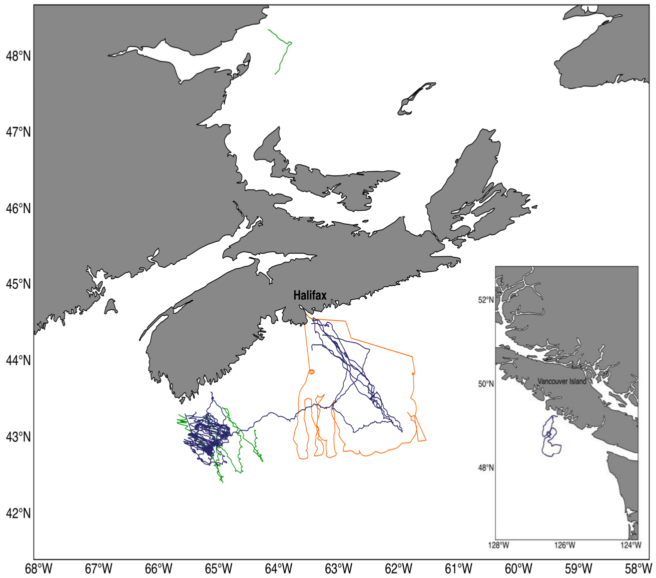

Fig. 2. Tracks of glider missions during which passive acoustic data were collected to monitor marine mammal habitats. Blue tracks are archived Slocum missions while green tracks are current missions. Orange tracks are archived wave glider missions. The map inset is the west coast mission from spring 2016. The large cluster of tracks off SW Nova Scotia is Roseway Basin.

III. RESULTS

Over the course of the 11 missions conducted and being conducted we have heard hundreds of marine mammals of varying species. Fig. 3 shows a slocum glider track in Roseway Basin from July 2015. Each colored dot represents a whale detection while the color of the dot indicates the number of calls heard during the sampling interval, typically 2 hours. The predominant species heard was fin whales but three other species were also detected, including the endangered North Atlantic right whale.

Fig. 4 shows the percentage of time that a fin whale was heard in Roseway Basin during each 15 minute summary period for each day of the nearly 4 month mission. For certain times of the year, particularly late fall, fin whales can be heard during the majority of the reporting periods. This result is typical of all of the missions where whale calls are detected routinely by hydrophones on the slocum gliders.

Only 5 hours of acoustic data were collected by the wave glider during its 30 day mission in 2015 due to a power problem experienced by the hydrophone. During the brief time that the hydrophone operated right whales were heard near the shelf break, showing that the wave glider can be an effective platform for listening for marine mammals.

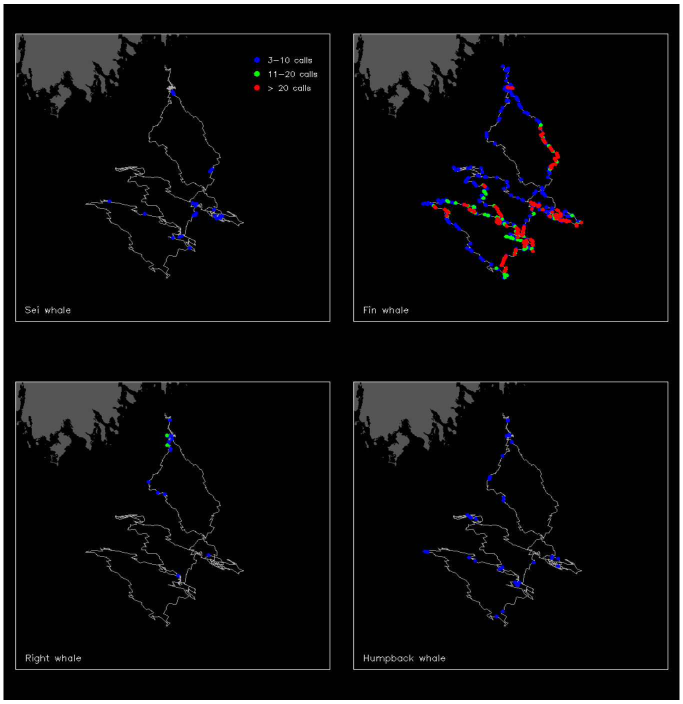

Fig. 3. Slocum glider transect in Roseway Basin in summer 2015 showing locations of discriminated whale calls of several species collected in near real-time.

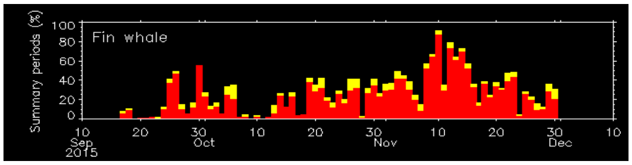

Fig. 4. Time series of real-time daily fin whale presence per 15 minute summary period in Roseway Basin collected during Fall 2015.

IV. FUTURE WORK

While the passive acoustic monitoring of marine mammals using profiling gliders is now operational among several agencies, the development of surface (wave) gliders for the same purpose is in its infancy. The advantages offered by a wave glider are several: speed over ground is two to three times greater than a profiling glider, solar power allows mission durations that can extend to months and 1000s of km, continuous communication between glider and pilots is enabled, changes in navigation parameters can be immediate, and PAM-based whale detections and identification can be communicated in real time.

To this end, MEOPAR-WHaLE and OTN recently engaged in a university-industry collaboration with GeoSpectrum Technologies Inc. (GTI) to integrate a directional hydrophone into the Liquid Robotics Inc. wave glider (Fig. 5). The M518-200 towed directional sensor captures low frequency directional acoustic data (up to 3 kHz). The acoustic signals are corrected to true bearing using data from an onboard heading sensor. The detection capability is further augmented in the M518-200 through inclusion of a high frequency (up to 100 kHz) omni-directional hydrophone. An innovative suspension is used to mount the directional sensor to reduce self-noise. The M518-200 communicates directly with the wave glider allowing for real-time detection of marine mammals.

One short test mission was conducted in June 2016. The relative change in bearing of a test target was visible in the acoustic data and the directional sensor exhibited significant improvements to self-noise using the new suspension method. We expect our first extended mission with the GTI M518-200 to be in late summer of 2016 for further testing of the directional sensor and recently integrated high frequency sensor. A new thin-line tow cable allowing the M518 to be towed at greater depths will also be evaluated.

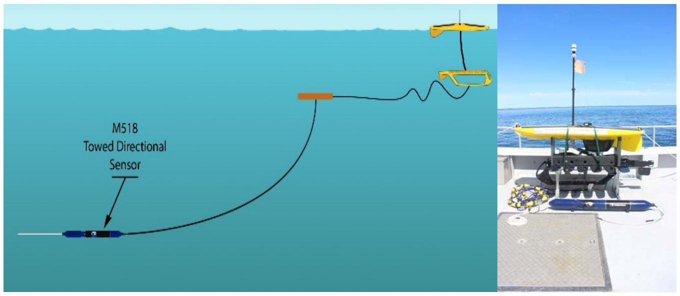

Fig. 5. The GeoSpectrum M518 directional hydrophone can be towed behind a Liquid Robotics wave glider at multiple depths depending on mission parameters.

A new Liquid Robotics SV3 wave glider has been purchased by GTI and will be operated by the glider team at Dalhousie University. Existing passive acoustic technology will be adapted and integrated into the new glider architecture. Having the directional hydrophone from GTI functioning on both platforms will both expand our observational capacity as well as open new markets for GTI products.

V. CONCLUSIONS

Passive acoustic hydrophones on autonomous vehicles have proven to be powerful tools for the study of marine mammals. The ability of the gliders to be at sea for extended periods of time coupled with their relatively quiet modes of operation means that high quality acoustic data can be collected in areas of expected marine mammal aggregation. The WHaLE program at Dalhousie University will continue to use both Teledyne Webb Slocum gliders and Liquid Robotics wave gliders to monitor marine mammal habitat, potentially reducing ship strikes on the endangered North Atlantic right whale by broadcasting locations to ships in real time. Both WHOI and GeoSpectrum Inc. are working on the next generation of passive hydrophones that will be smaller and allow for directional information so that more accurate estimates of whale location can be generated. As the network of gliders grows, in both the US and Canada, we hope that these types of systems can be routinely deployed to study whale distributions and mitigate ship strikes of marine mammals.

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REFERENCES

[1] Baumgartner, M.F. and S.E. Mussoline. 2011. A generalized baleen whale call detection and classification system. Journal of the Acoustical Society of America 129:2889-2902.

[2] Baumgartner, M.F., D.M. Fratantoni, T.P. Hurst, M.W. Brown, T.V.N. Cole, S.M. Van Parijs, and M. Johnson. 2013. Real-time reporting of baleen whale passive acoustic detections from ocean gliders. Journal of the Acoustical Society of America 134:1814-1823.