

## Application of Density Estimation Methods to Datasets from a Glider

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### LONG-TERM GOALS

This is a new project that started in August 2013 and the long-term goal is to extend the use of population density estimation methods based on detections of marine mammal vocalizations to datasets collected by a moving platform. The moving platform under consideration is an electric underwater glider, which offers the potential of surveying a larger area than a fixed, single sensor. The glider also has the potential to surface and transmit data using a satellite modem. Moreover, fitting the glider with two hydrophones, one on each wing can provide bearings to vocalizing animals. Density estimation from glider datasets will be developed by looking at some of the species known to occur off the central Oregon coast, such as humpback and sperm whales as well as different dolphin species.

### OBJECTIVES

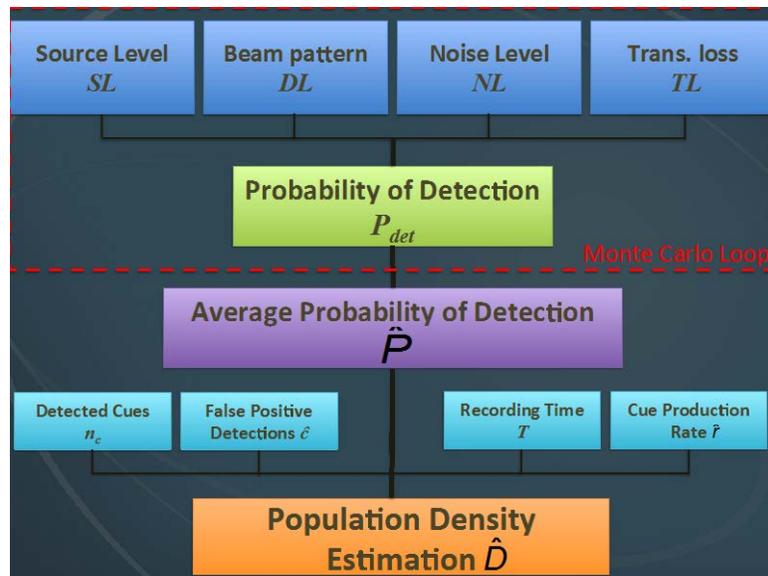
The objective of this research is to extend existing methods for cetacean population density estimation from fixed passive acoustic recordings to datasets recorded from a moving platform, in particular using an underwater glider. Instead of using datasets previously recorded for different applications, the current project will benefit from data collections designed specifically for density estimation purposes, with combined environmental sampling provided by the glider's Conductivity, Temperature and Depth (CTD) sensor. The central Oregon coast, where experiments and data collection will take place, is an easily accessible area for both project teams (PSU and OSU) working on this project with known occurrence of many marine mammal species, ranging from pinnipeds, to baleen whales, cetaceans and dolphin species (Carretta *et al.*, 2009). Extensive oceanographic (Pierce *et al.*, 2012) as well as noise characterization (Haxel *et al.*, 2011) has also been performed in this area, providing possible support data for the current project's data analysis. Because gliders offer low-cost, all-weather, remote-area operation, it is our goal to extend its usability to population density estimation surveys offering another tool to aid those involved in marine mammal research, monitoring, and mitigation planners.

## APPROACH

### *Approach to Estimating Population Density from a Glider Dataset*

The dataset to be used in the current project will be recorded off the coast of Newport OR, by using a Teledyne Webb Research electric glider (Webb *et al.*, 2001) owned by PSU's NEAR Lab. The glider can dive to a maximum depth of 200 meters, driven in a saw-tooth vertical profile by variable buoyancy. Preliminary planning of the data collection involves two-week glider deployments performed tentatively at four times of the year out to the shelf break to compare presence and population density of animals over the four seasons. By sampling the near shore, continental shelf, and shelf break, cetacean habitat use characterization will also be performed.

The methodology employed in this study to estimate the population density of marine mammals off Newport, OR, will be based on the works of Zimmer *et al.* (2008), Marques *et al.* (2009), Küsel *et al.* (2011), Ainslie (2013), and the results from the ONR-funded project "Cetacean density estimation from novel acoustic datasets by acoustic propagation modeling." In the latter, this study's PIs investigated the effects of call bandwidth, multipath arrivals, and the use of propagation models in population density estimation from single sensor datasets. Required steps for a cue counting approach, where a cue has been defined as a clicking event (Küsel *et al.*, 2011), to density estimation from data recorded by single, fixed sensors are summarized in Figure 1.



**Figure 1. Flow chart with the required steps for estimating the population density of a species from single sensor datasets.**

Fitting the glider with two recording sensors, instead of one, provides the opportunity to investigate other density estimation modalities (Thomas and Marques, 2012), such as individual or group counting. In this sense, bearings to received sounds on both hydrophones will be computed in a similar way as has been presented by Lewis *et al.* (2007) using a towed hydrophone array. The analysis of one and two sensors will also provide data with which to compare different density estimation methodologies.

The choice of target species will be largely dependent on the dataset obtained after a glider mission. Systematic compilation of marine mammal data present in the area, noting the observation time of year, from literature, stock assessments, visual observations, and acoustic sensors can aid in realizing what species will be expected during a given field experiment. The required animal acoustic behavior (source level, beam pattern, and cue production rate from Fig. 1) will come from information available in the literature and from available acoustic tags. Acoustic transmission loss will be computed using an acoustic propagation model chosen based on the call frequency content; Bellhop (Porter and Buckner, 1987) for high frequency calls, or RAM (Collins, 1993) for low frequencies (< 1000 Hz). From literature information on the target species' diving behaviors when emitting sounds, a 3D random distribution of simulated animals will be created taking into account their orientations with respect to the glider. The probability of detecting a cue as a function of distance from the hydrophone is necessary to estimate a detection function for each call type, or for each species. This can be accomplished by measuring the signal-to-noise ratio (SNR) of detected calls from a subsample of the data set and then estimating the proportion of those within an SNR bin that were detected. We further simulate the SNR of randomly distributed calls along the glider track by using the sonar equation with estimated ambient noise levels from the data set, and transmission loss calculated by a propagation model.

## **WORK COMPLETED**

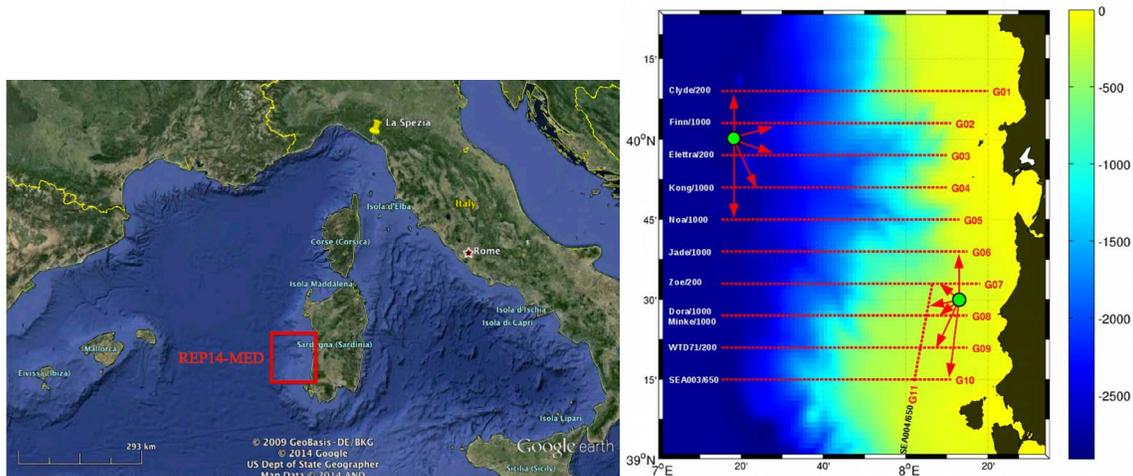
A preliminary test to evaluate the glider's operational functions before ocean deployments was conducted at Waldo Lake, OR, in September 2013. After system failures including inability to perform on-bench missions and communication issues, either through free-wave or Iridium, it was concluded that more tests were needed to identify operational problems.

Initial plans involved making use of a digital acoustic monitoring (DMON) instrument connected to the two High Tech Inc. hydrophones (model # HTI-92-WB) mounted one on each wing at a separation of 3 ft. (Fig. 2). Unfortunately, budget restrictions prevented the use of the DMON as a recording system. Therefore, an inexpensive, off-the-shelf linear PCM recorder manufactured by Tascam (model # DR-07 MKII) was adapted to fit inside the glider's science bay. The data acquisition system offers a sample frequency of 96 kHz, and is capable of recording of two channels of data at 16-bit resolution. It was further equipped with enough batteries (8 AA alkaline) to record data continuously up to 24 hrs to a single 32 GB micro-SD card.

An opportunistic experiment in the Mediterranean Sea provided another chance to test the glider's operation. Moreover, the experiment also provided an ideal situation to test the off-the-shelf acoustic acquisition system, with the possibility of recording marine mammal sounds. The sea-trial REP14-MED (Recognized Environmental Picture – Mediterranean) took place 6-26 June 2014 in the Sardinian Sea (Western Mediterranean) and is part of a series of multinational sea experiments dedicated to *Rapid Environmental Assessment*. Several gliders (2 ACSA Sea Explorers, 3 Kongsberg Sea Gliders, and 12 Teledyne-Webb Slocum Gliders) were deployed from the NRV Alliance and positioned perpendicular to the coast at regular intervals in order to collect oceanographic and/or acoustic data (Fig. 3). Each glider dove along its own transect back and forth from deep to shallow water for approximately 2 weeks, until they were recovered.



**Figure 2.** Slocum glider “Clyde” at NEAR Lab’s water tank at PSU, showing the configuration of the hydrophones attached to each of its wings. Photo: E. T. Küsel.



**Figure 3.** Left: Image showing the area of REP14-MED sea-trial (red box) in the context of the Western Mediterranean Sea and the island of Sardinia, Italy. Source: Google Earth. Right: Tracks of each of the 12 gliders deployed during the experiment. Green dots represent deployment sites. Source: REP14-MED Cruise Report.

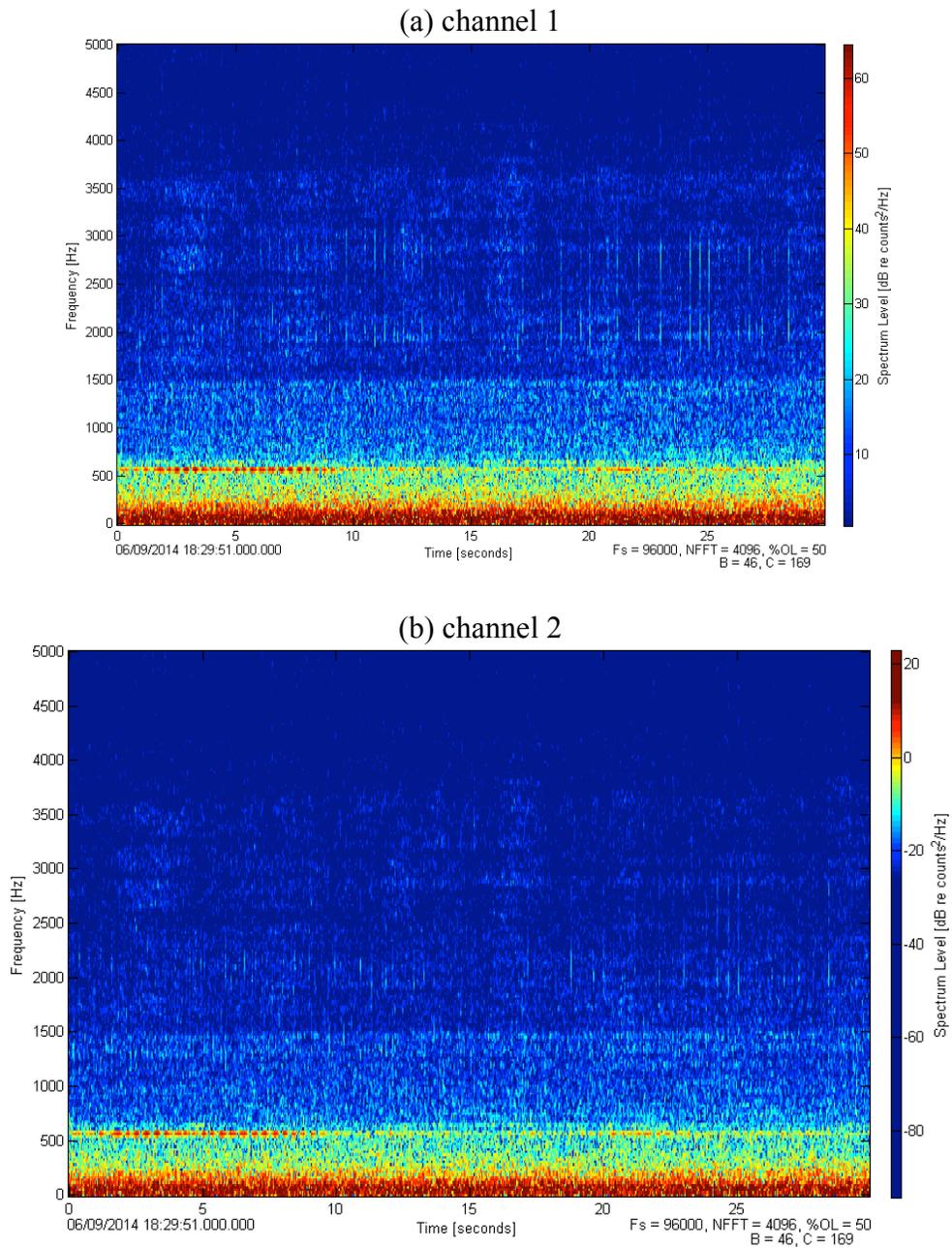
## RESULTS

The experiment off the west coast of the island of Sardinia was very useful to identify the glider’s operational issue and to evaluate the acoustic recording system. The glider presented hardware malfunction after its first day in the water performing the mission and therefore had to be brought back on board. However, the acoustic acquisition system was able to record approximately 20 hours of continuous data while diving in waters deeper than 1500 m. Such deep waters are known to be good habitats for species such as sperm and beaked whales. The acoustic data is currently being analyzed for the presence of marine mammal calls. Preliminary results indicate the presence of sperm whale echolocation clicks (Figs. 4 and 5). Overall, the quality of the acoustic files recorded with the off-the-

shelf acquisition system look promising for future deployments to study marine mammal population density. Files containing dive and CTD information were lost, and/or have been renamed with erroneous time stamps due to the hardware malfunction. This has also been diagnosed during the cruise with the help of engineers who are experienced with Slocum gliders. The problem seems to reside on a malfunctioning persistor, which is the main computer, responsible for all glider operations.

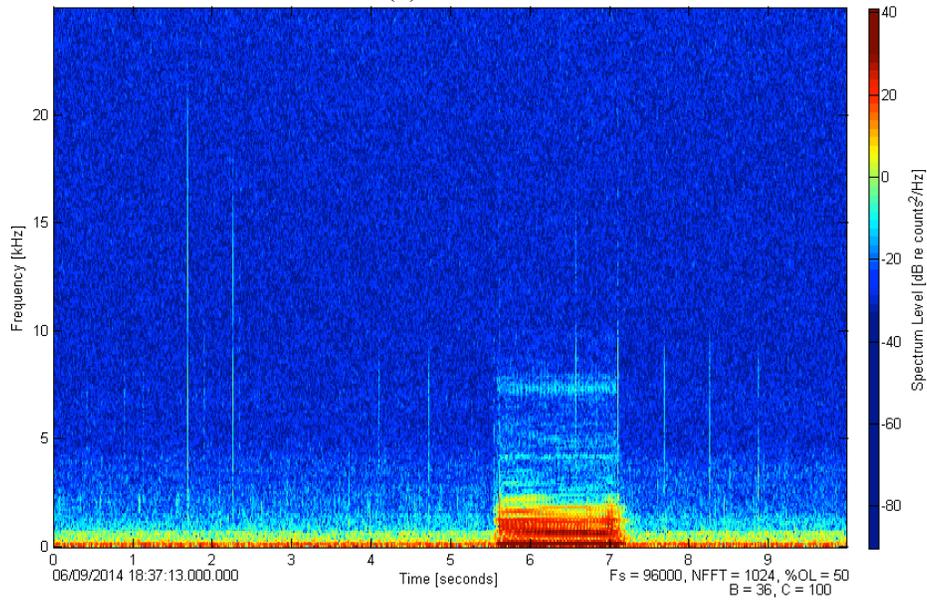
## **IMPACT/APPLICATIONS**

We expect to develop a density estimation method that can be applied to acoustically-equipped ocean gliders, making data from such gliders applicable for a wider range of applications – before-during-after exposure studies, seasonal distribution measurement, population estimates, etc. The application of recently developed density estimation methods to different data sets and marine mammal species also provides opportunities to improve the methodology and make it more general. By improving our capabilities for monitoring marine mammals we hope to contribute to minimizing and mitigating the impacts of man-made activities on these marine organisms.

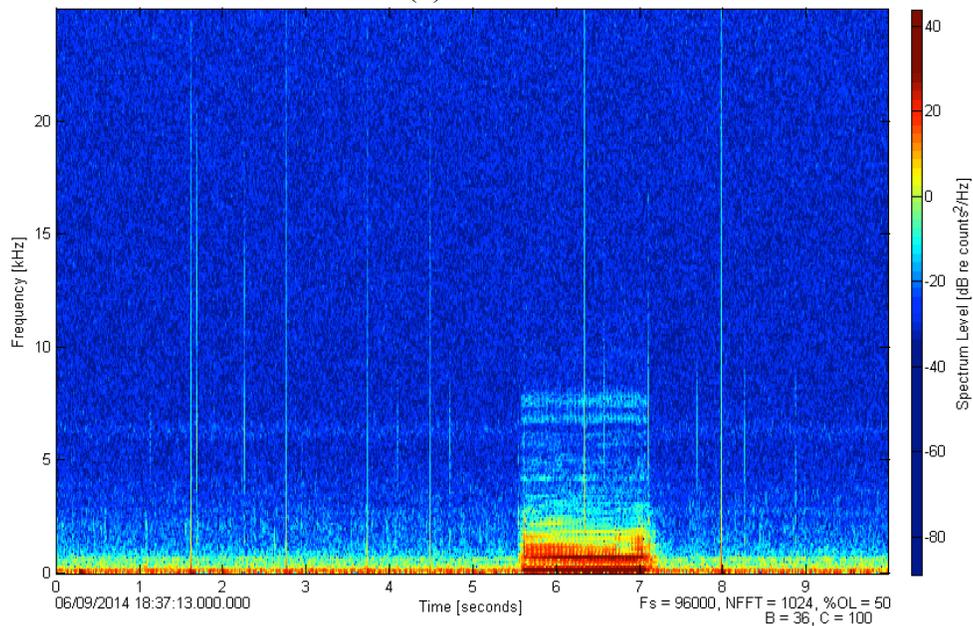


***Figure 4. Spectrograms of data recorded during the sea trial in the Mediterranean Sea on June 09, 2014. Thirty seconds of data were plotted from 0 to 5 kHz, and preliminary analysis by a human analyst indicated the presence of sperm whale clicks (*Physeter macrocephalus*), observed here between 1.5 and 3 kHz. The clicks appear stronger on Channel 1, but are observed on both channels.***

(a) channel 1



(b) channel 2



**Figure 5. Spectrograms of data recorded during the sea trial in the Mediterranean Sea on June 09, 2014, showing a broader frequency range, up to 25 kHz, for 10 s of data. The thin vertical lines correspond to odontocete clicks, likely sperm whales. The noisy patch between 5.6 and 7.1 seconds corresponds to glider self-noise. Glider self-noise is easily recognizable and should not interfere with the data analysis for population density estimates.**

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