Predicting the Abundance of Deep-Diving Beaked Whales off Cape Hatteras, North Carolina, using Environmental Variables

Technical Approach

Overview

The purpose of this study is to assess the feasibility of using environmental variables to predict the abundance of deep-diving beaked whales on the continental slope off Cape Hatteras, North Carolina. These species have been identified by the Navy's Living Marine Resources Program (LMR) as a high priority marine mammal species, and the North Carolina coast is one of the high priority geographic regions for the LMR.

Recent studies (Gilles et al., 2013) have had some success correlating marine mammal abundance to oceanographic features, including blooms and fronts. Palacios et al. (2013) suggested using the oxygen minimum layer (OML) as a feature, as sperm whales may be foraging near there. Having good correlates for marine mammal abundance would give us a relatively inexpensive predictive tool. Whatever we choose as a feature, we must recognize that there may be a significant lag in space and time between the evolution of the feature and the change in marine mammal abundance (Palacios et al., 2013).

Off Cape Hatteras, warm, salty water from the South Atlantic Bight (SAB) converges with cooler, fresher water from the Mid Atlantic Bight (MAB). The convergence of these different water masses results in the Hatteras Front (Savidge and Austin, 2007). In this complex region, exchange processes between the shelf and the slope create conditions that are favorable for a diversity of marine life.

We know that several species of beaked whales spend time foraging on the continental slope off Cape Hatteras. Recently, Baird et al. (2015) observed and tracked Cuvier's beaked whales, with many sitings in this region. Furthermore, Byrd et al. (2014) looked at data for 12 years of marine mammal strandings on the beaches of North Carolina and found 34 different species of marine mammals, including Cuvier's beaked whale, Gervais' beaked whale, Blainville's beaked whale, and True's beaked whale.

We propose to use passive acoustic monitoring (PAM) to detect and classify the vocalizations of these deep-diving beaked whales on the slope off Cape Hatteras. Given the detection events, we propose to

correlate beaked whale abundance to observed oceanographic features, including the evolution of fronts, blooms, and the oxygen minimum layer (in space and time).

For the oceanographic data, we plan to take advantage of another proposed research project to be deployed in the same region at the same time, a project entitled "Processes driving Exchange At Cape Hatteras" (PEACH). The PEACH project has been proposed to NSF as a collaboration between our colleagues at the University of North Carolina at Chapel Hill (UNC-CH), the Skidaway Institute of Oceanography (SKIO), and Woods Hole Oceanographic Institute (WHOI). Some relevant details from the PEACH proposal are included below.

Passive Acoustic Monitoring

The echolocation signals of beaked whales are frequency-modulated (FM) pulses that are relatively high in frequency, with spectral peaks up to 67 kHz for some species (Baumann-Pickering, 2013). Therefore, to record these signals and accurately estimate their spectra, we'll need to record at sample rates exceeding 134 kHz. At this time, we are planning to use the Ocean Sonics icListen HF hydrophone, recording at a sampling rate of 200 kHz (200k samples/sec). Our study will require six of these high-frequency hydrophones. Each one will be fitted with a battery pack from Ocean Sonics.

In year 1, we propose to deploy three of these high-frequency hydrophones on the continental slope off Cape Hatteras, at depths of 300m, 500m, and 750m. After six months, the first set of hydrophones will be retrieved and the second set of three will be deployed. In year 2, the deployments will be similar, a deployment schedule of six months for each set of three hydrophones. However, we will have an opportunity to choose different depths; based upon the analysis of year 1 data, we will decide whether to redeploy at the same depths in year 2.

The icListen HF hydrophone will store the detected echolocation signals. After each six-month deployment period, we will analyze the data from the retrieved hydrophones. Using a combination of off-the-shelf software as well as custom matlab scripts, we will classify the echolocation signals, by species. Previous studies (Baumann-Pickering, 2013) indicate that we can classify the echolocation signals by species using spectral characteristics.

To measure the performance of our detection/classification algorithms, we will use the DCLDE 2015 high-frequency data set as a reference (from http://www.cetus.ucsd.edu/dclde/dataset.html). This data

set has echolocation signals from Baird's beaked whales and Cuvier's beaked whales already labeled. Therefore, we will be able to use this reference data set to measure the miss rate and false alarm rate for our detection/classification algorithms.

Correlating Marine Mammal Abundance to Environmental Factors

As mentioned above, we expect the oceanographic data to come from the PEACH project ("Processes driving Exchange At Cape Hatteras"). According to the PEACH proposal, "PEACH observations and modeling will provide unprecedented temporal and spatial resolution across the shelf, slope, and adjacent open ocean in this region of strong forcing, steep gradients, and persistent shelf-open ocean exchange." PEACH plans to deploy an impressive set of instruments for about two years (2017-2019), including six gliders, several ship transects, and an array of over ten moorings, spanning a region from 50km south of Cape Hatteras to over 100km north of Cape Hatteras, from a depth of 100m on the shelf to depths exceeding 1km on the slope.

If approved, PEACH will provide a wealth of physical parameters--velocity, temperature, and salinity fields as a function of space and time for a large area. Furthermore, the gliders will be equipped with not only CTDs but also optical instruments to measure chlorophyll and dissolved oxygen as functions of space and time.

At UNC-CSI, we hope to take advantage of the wealth of oceanographic data that the PEACH project will generate. With our hydrophones deployed in the same region during the same period of time, we will be able to correlate (in space and time) the PAM detection events to oceanographic features of interest, including (but not limited to) the following:

- Cross-shelf exchange rate
- Proximity to a bloom
- Proximity to the Gulf Stream
- Proximity to the Hatteras front
- Depth of the oxygen minimum layer (OML)

When performing these correlations, it is important to understand that there may be significant lags (1-3 weeks) between a bloom, for example, and an increase in foraging activity by marine mammals (Palacios et al., 2013).

Based upon the strength of these and other correlations, we will quantify how well we can predict the abundance of beaked whales on the slope of Cape Hatteras using environmental variables.

Background on UNC Coastal Studies Institute

At the UNC Coastal Studies Institute (UNC-CSI), we are well equipped to carry out such a study. We have experience deploying moorings on the continental slope off of Cape Hatteras, and we have experience acquiring and analyzing marine bioacoustic data sets.

First, UNC-CSI has been measuring the western boundary of the Gulf Stream off of Cape Hatteras since August 2013 as part of an ongoing project to assess the feasibility of capturing renewable energy from the Gulf Stream using turbines. This project has accomplished four successful mooring deployments and retrievals on the continental slope off of Cape Hatteras.

Also, funded by the North Carolina Renewable Ocean Energy Program, UNC-CSI is now evaluating the environmental impact of this renewable energy source, a project entitled "An integrative and holistic environmental and ecological assessment of the Gulf Stream current environment off the coast of Cape Hatteras, NC". This project has several components--remote sensing, biological sampling, tagging and tracking sea turtles, and passive acoustic monitoring of marine mammals. (Currently, we are using the Aural-M2 hydrophone, which has a maximum sample rate of only 32 kHz; therefore, we are now requesting higher-frequency hydrophones to record the beaked whales.)

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