

Blue and Fin Whale Habitat Modeling from Long-Term Year-Round Passive Acoustic Data from the Southern California Bight

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LONG-TERM GOALS

During this project, we will develop predictive, year-round habitat models of the presence of calling blue and fin whales in the Southern California Bight, to facilitate Navy's operational needs in this area.

OBJECTIVES

The primary objective of this research is to develop predictive, year-round habitat models of the presence of calling blue and fin whales in the Southern California Bight (SCB). We will also investigate the scales over which blue and fin whales respond to their environment to better understand the functionality of the predictive relationships in those models. We will base our models on the available passive acoustic and remotely sensed data, as well as buoy data available for the SCB.

APPROACH

Passive acoustic data have been collected using High-frequency Acoustic Recording Packages (HARPs) deployed at sixteen locations in the Southern California Bight (Figure 1). We have been using automatic detectors to determine the presence of blue and fin whale calls in the area of the SCB between 32° and 34° 20' N from passive acoustic recordings collected year-round between 2005 and 2012. This temporally extensive data set allows us to investigate the effects of environmental, remotely sensed variables, as well as a number of temporal variables, such as time-of-day, month, season, and year, on the distribution of these two species of whales. Such temporal variables are rarely included into models based exclusively on visual survey data thus our models are likely to offer new insights on the importance of these time scales on blue and fin whale habitat preferences.

Environmental variables obtained from remotely sensed data to be used for habitat modeling include sea surface temperature (SST), sea surface height (SSH), chlorophyll *a* concentration, and primary production. These data are available on similar temporal (weekly, monthly) and spatial scales (1 to hundreds of km) as passive acoustic whale monitoring. Data that are contemporaneous spatially and temporally for each deployment location and period were downloaded using the *Tethys* database tools developed by M. Roch (ONR grant N000141110697). Additional variables tested for inclusion

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included weather buoy data (e.g. wave height, wind) collected through the National Data Buoy Center for the parts of the SCB region with HARP deployments.

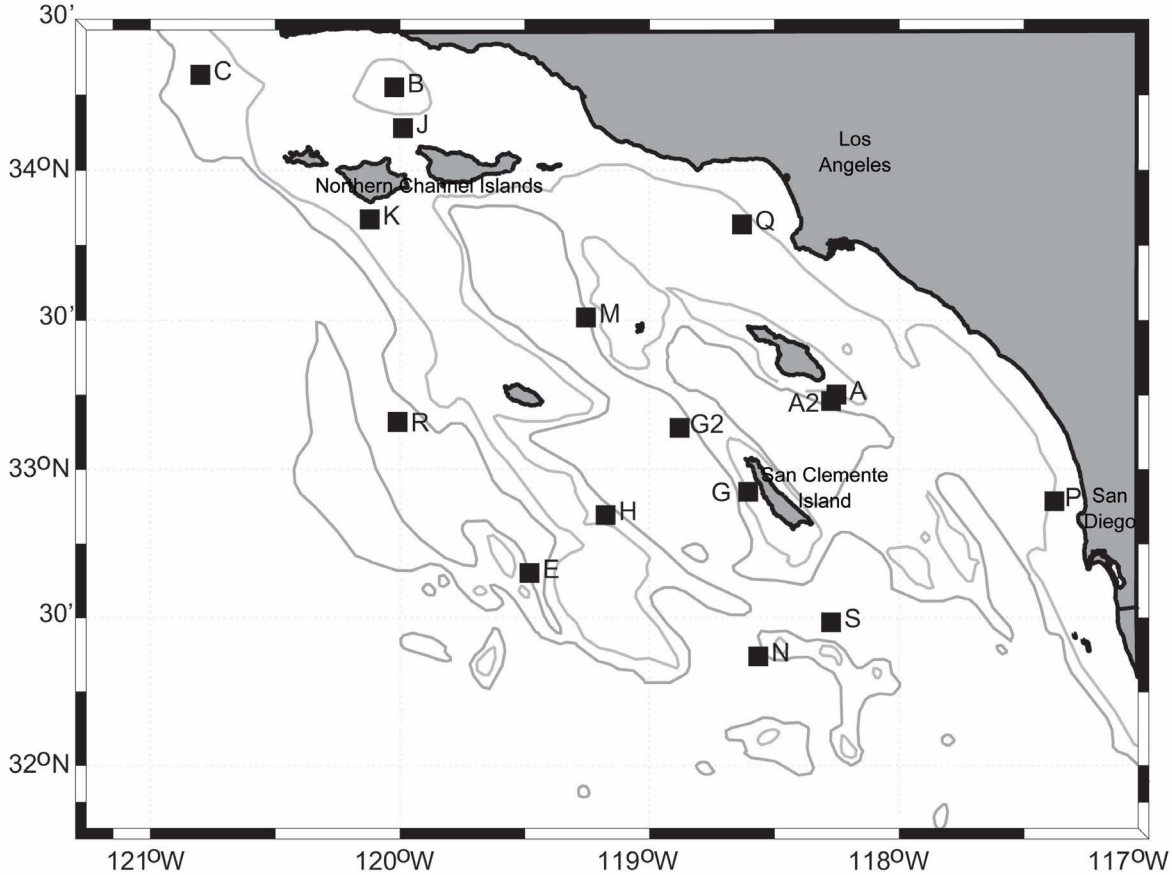


Figure 1. Sixteen HARP deployment locations (black squares) throughout the Southern California Bight between 2005 and 2012 from which data are processed for habitat modeling in this study. Light grey line denotes the 500 m bathymetry contour.

When comparing acoustic and remotely sensed data, and for meaningful habitat modeling, one of the major problems is determining the appropriate spatial scale on which to conduct the analysis. On the one hand, the choice of scale is limited by the spatial resolution in collected data, but in theory, it should also be driven by the scale of the whale's response to the environment. We will explore the effect of different spatial scales on blue whale habitat models. To use call detections for such an analysis, however, we first must determine the scale (range) over which whale calls can be detected. Using ESME workbench (developed under ONR grant to Dr. Mountain), we developed propagation models for areas around each of the HARP deployment locations to investigate the characteristics of propagation loss in the area. These models allow us to estimate propagation loss at low frequencies over different spatial scales and over different seasons (spring, summer, fall, and winter). They also allow for close coupling between passive acoustic and environmental data, enabling us to investigate the effects of range on the functional models affecting blue and fin whale distribution.

First, all data were spatially and temporally aligned to compare the presence of blue and fin whale calls with the environmental. Next, we used random forest framework to identify the variables that should be used for subsequent modeling. Independent environmental variables that were used for selection in

the models includes: SST, SSH, chlorophyll *a* concentration, primary productivity, and when available wave height and wind speed. Generalized additive modeling (GAM) framework was used subsequently to describe the functional relationships between calling abundance of these whales in the SCB and important environmental variables. We completed building single-site models and are in the process of extending the models to areas of high and low abundances and testing the predictive abilities of the models. The advantage of this method over the habitat models that have been developed from more traditional ship-based visual surveys is that passive acoustic data provide a much finer and also longer temporal resolution. Therefore, we are also developing models that look at the seasonal impacts on the distribution of blue and fin whales. By the end of the project, we will have developed separate GAMs for different calls, covering different areas, and seasons.

The metadata for all detected calls (location, time, and type of call) and, to the maximum extent practicable, our final, best habitat models will be incorporated into the Ocean Biogeographic Information System – Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) database for access by the larger community.

WORK COMPLETED

- Completed running blue whale B and fin whale 20 Hz call detectors for all available Southern California Bight data, covering over 26 instrument-years of data.
- Integrated all passive acoustic detection metadata into the *Tethys* database.
- Extracted all spatially and temporally collocated environmental data needed for the development of habitat models.
- Completed building single-site models for calling blue and fin whales.
- Started building models for different spatial scales (to cover areas of high and low abundances) and temporal scales (weekly versus seasonal).
- Started testing the predictive abilities of various models.
- Submitted manuscript on the temporal variation in the performance of automatic spectrogram correlation detector for peer-review.
- Prepared manuscript on seven years of blue and fin whale acoustic presence in the Southern California Bight for peer-review.

RESULTS

Over 3 million blue whale calls were detected at 16 sites during 9404 days (nearly 26 cumulative years) of effort, although some calls may have been detected on more than one instrument. Blue whale B calls were generally detected between June and January, with a peak in September (Fig. 2a black bars). Across the years, there was some variability in detection numbers, with a slight peak in 2007 and 2008, and a minimum in 2011 (Figure 2b), and with a slight overall negative trend (change of -1.6 daily calls per 1000 km² per year). Fin whale acoustic index, indicative of the 20 Hz calls, was highest between September and December, with a peak in November (Figure 2a red line). There was a secondary, smaller peak in fin whale acoustic index in March. Across the years of this study, there appears to be an overall increase in fin whale acoustic index at a rate of 1.3 daily per year (Figure 2b)

Generally, sites around the northern Channel Islands, particularly to the north in the Santa Barbara Channel, had the highest call abundances during peak calling periods, but blue whale B calls were also common along coastal sites near Los Angeles and San Diego (Figure 3). There may be a preference for Channel Island sites earlier in the calling season, while later in the season call distribution is more even across the SCB.

There was also a seasonal cycle in the fin whale acoustic index (Figure 1a), coupled with a large amount of spatial variability across the SCB (Figure 4). Peak in the fin whale acoustic index occurred during fall, with a broad shoulder and a secondary peak in the winter and a minimum during June and July. Fin whale acoustic index was the highest farther offshore and farther south during peak calling periods (Figure 4) than was the case for blue whale call detections, with highest levels in the basin just to the west of San Clemente Island.

Overall, the developed GAMs were better at explaining the deviance in blue whale call detections than the fin whale acoustic index. Generally, month and sea surface temperature were the variables with the most predictive significance for blue whale B calls, both reflecting the seasonal cycle of their presence (Figure 5). For individual site fin whale acoustic index models, month was generally the most important variables, showing the seasonal cycle (Figure 6). However, in both cases there was a large amount of variability across sites and since data at different sites were available for different years, some of these differences could indicate year-to-year variability in blue and fin whale habitat preferences. To test this, we are using three sites that had continuous long-term records, to test year-to-year predictive abilities of the models. At two of the three sites the models performed relatively well, however, at one site the predictive ability was consistently low for both species, indicating the importance of the spatial context.

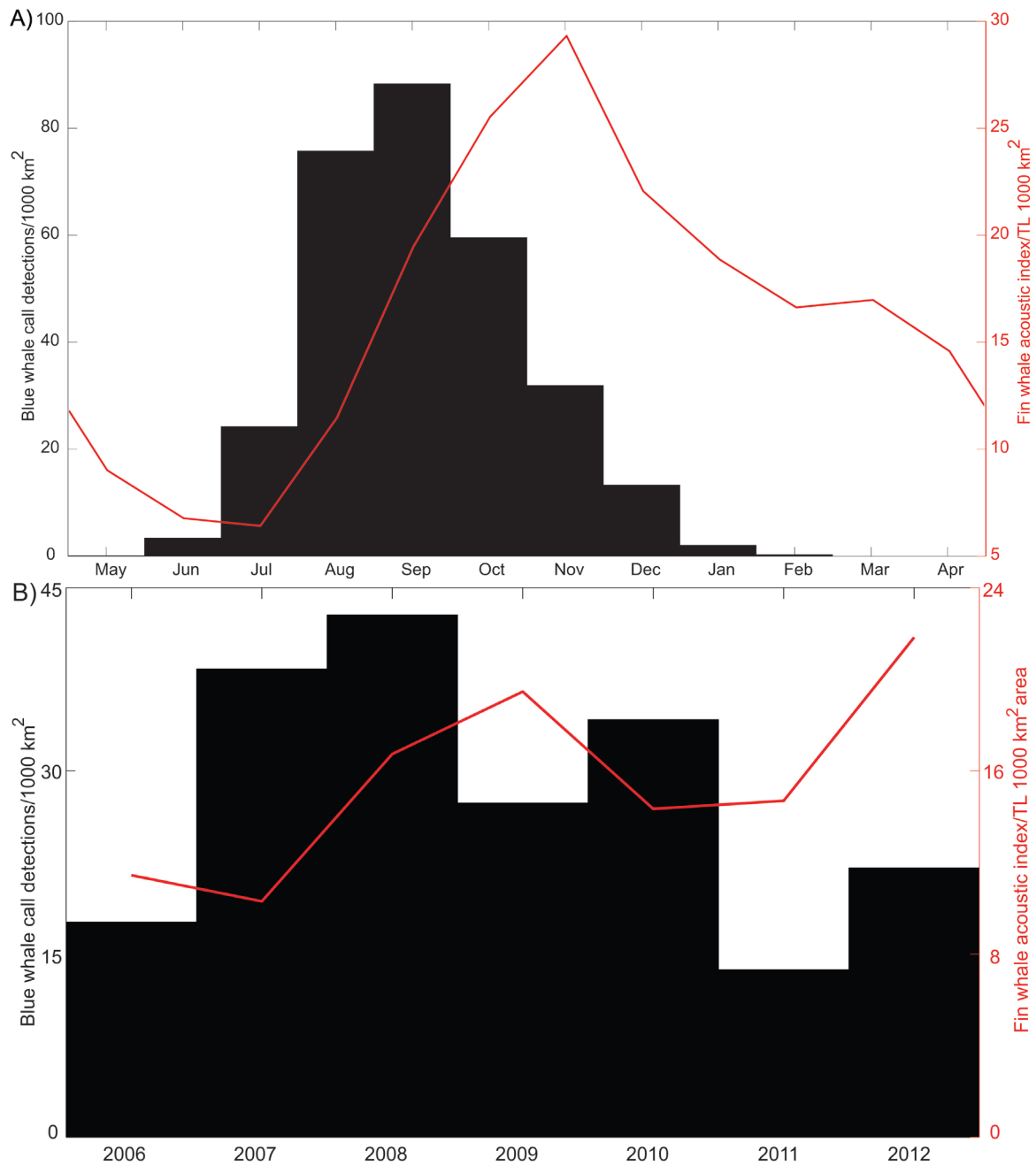


Figure 2. Overall (A) monthly seasonal and (B) yearly interannual trends of blue whale B call daily detections normalized by detection area (black bars) and daily fin whale call index normalized by detection area and transmission loss, TL (red line).

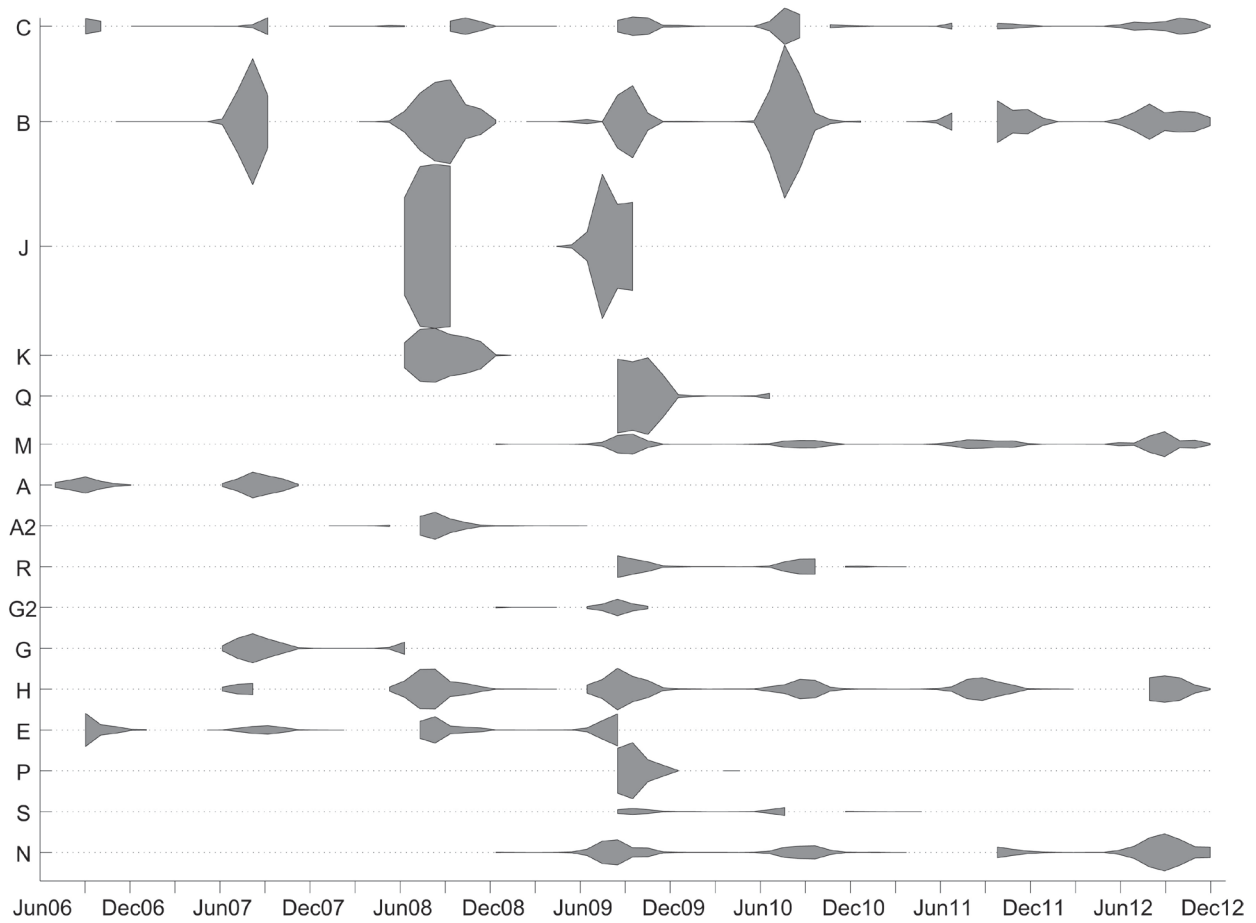


Figure 3. Monthly averaged daily blue whale B call detection rates at each site in the Southern California Bight. Sites are arranged, to the maximum extent possible, from the northernmost sites at the top towards the southernmost sites at the bottom. Size of the patch represents the daily call detection rate normalized by the modeled detection area. Dotted lines are periods with no data at that site and straight lines denote periods with recording but no detected calls.

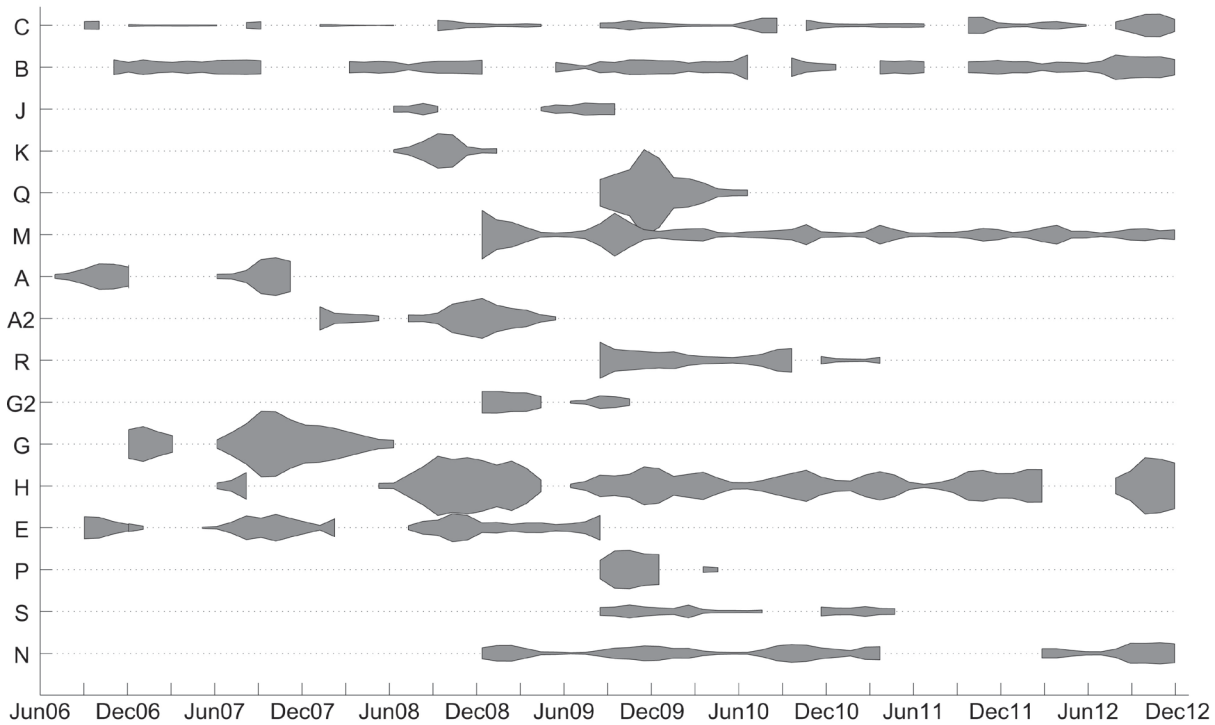


Figure 4. Monthly averaged daily fin whale call index at each site in the Southern California Bight. Sites are arranged, to the maximum extent possible, from the northernmost sites at the top towards the southernmost sites at the bottom. Size of the patch represents the call index value with periods that appear as straight lines denoting low acoustic fin index value. Dotted lines are periods with no data at that site.

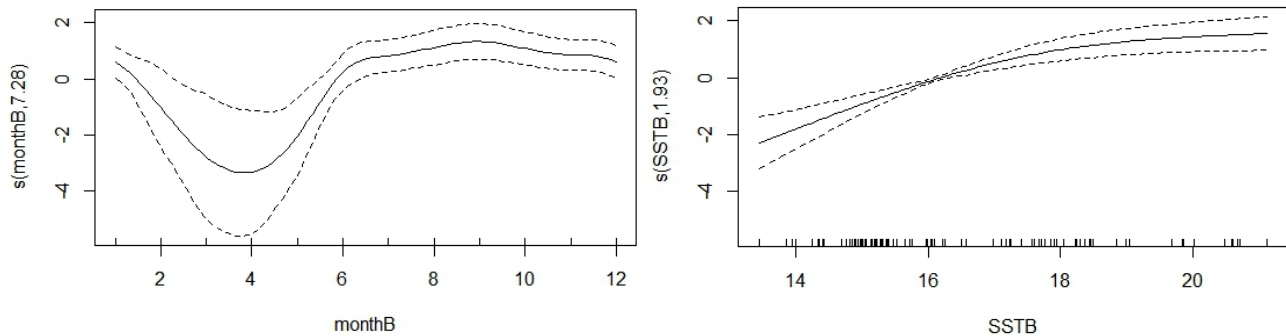


Figure 5. The mean-adjusted partial fit of each significant predictor variable for the best blue whale B call detection rate model for site N. Higher values on the y-axis indicate more whale detections. The plots show the average of the partial fit (solid line) and the standard error of the fit (dash-dot line). The vertical lines along the x-axis indicate the number of observations at each value of the predictor variable.

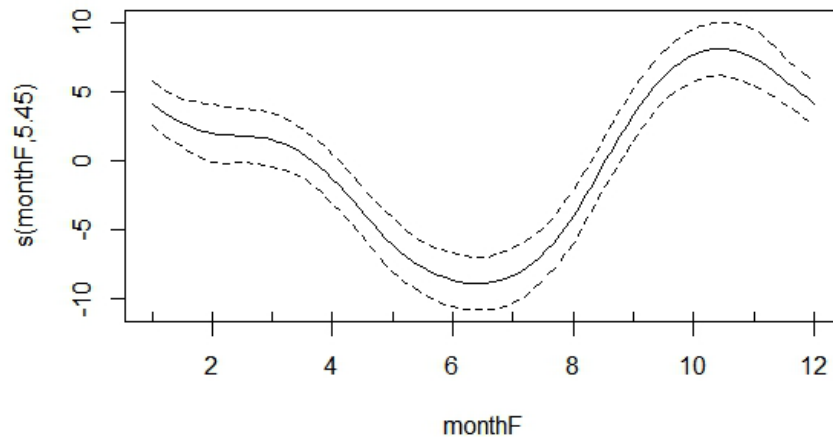


Figure 6. The mean-adjusted partial fit of each significant predictor variable for the best fin whale acoustic index model for site N. Line and values are the same as described for Figure 5.

IMPACT/APPLICATIONS

Understanding the distribution of cetaceans over space and time is relevant for the Navy’s operational needs in Southern California. Unlike visual observations that generally provide limited temporal resolution, passive acoustic methods have the potential to resolve changes in the distribution of marine mammals on both short and long-term temporal scales. Therefore, passive acoustic methods have the potential to be used to improve our understanding of the dynamics of habitat use and population distributions of vocalizing cetaceans. The currently-underway development of spatially-explicit habitat models for calling blue and fin whales, once completed, will enhance the ability of the Navy to predict blue and fin whale occurrence in the SCB region year-round. Incorporation of the models to the OBIS-SEAMAP environment will improve their utility for other users.

RELATED PROJECTS

During this project, we have been using the *Tethys* database (<http://tethys.sdsu.edu>) developed under the project “Acoustic metadata management and transparent access to networked oceanographic data sets” (ONR grant N000141110697, PI: M. Roch) for data management as well as easy access to oceanographic data needed for habitat modeling. We have also been using the ESME workbench (esme.bu.edu/index.shtml) for propagation modeling at sites in the SCB (ONR grants N0001411C0448, N000141210390, N000141310641, PI: D. Mountain).

REFERENCES

Širović A. (Submitted) Variability in the performance of the spectrogram correlation detector for Northeast Pacific blue whale calls. *Journal of the Acoustical Society of America*.