Behavioral Context of Blue and Fin Whale Calling for Density Estimation

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LONG-TERM GOALS

This is the second annual report for this project, in which we will determine the context-appropriate call production rates for blue and fin whales in the Southern California Bight, with the end goal of facilitating density estimation from passive acoustic data.

OBJECTIVES

Before a reliable estimate of blue and fin whale call production rates can be developed for use in density estimation, we must first understand the factors that influence calling rates (e.g. season, sex, behavioral state, time of day, group association, dive behavior, etc.). For this project, we will use previously collected tag data to determine the context-specific call production rates for blue and fin whales. In addition, we will elucidate gaps in the data which may affect our ability to develop a comprehensive behavioral model of calling; develop a strategy for filling those gaps; and conduct field data collection to address some gaps in the data coverage for these species.

APPROACH

We will focus on the current main gap in the density estimation process using passive acoustic data: the estimation of the average call production rate. We will use blue whales (*Balaenoptera musculus*) and fin whales (*B. physalus*) as our model species because, as endangered species that are common in many areas of naval activity, they are of special interest to the Navy. In the case of blue whales, there exists already a relatively large data set relevant to answering the question of their call rate production, while the data on fin whales are scarce. We will develop both the conceptual framework for analyzing these types of data and appropriate call rate models, as well as collecting additional data that will enable us to increase the robustness of these call rate models. In general, our approach can be broken down into four components: analysis of available tag data; analysis of data gaps; passive acoustic analysis; and field sampling efforts.

Analysis of available tag data

Available for this analysis are acoustic data collected by the Cascadia Research Collective (CRC) and the Scripps Institution of Oceanography (SIO) since 2002 from tags deployed on blue and fin whales for multiple projects, including the recent behavioral response studies (Southern California Behavioral Response Study, SOCAL-BRS, and Office of Naval Research (ONR) funded work on blue whale response to ship noise). To date, acoustic tags (B-probes, Acousondes, Dtag2s, and Dtag3s) have been successfully deployed on approximately 150 blue whales and 37 fin whales, with most deployments occurring between June and October off the coast of California. For our analyses, we used only deployments with more than 15 min of high quality acoustic data collected in order to avoid biasing the data with a possible response of the whale to the tagging event rather than its true behavior.

Deployments of the acoustic recording tags that were used in this analysis were conducted for a variety of research reasons. While all acoustic recording tags were attached without a priori knowledge of the whale's vocal behavior, different attachments were targeting animals in specific behavioral states or under different environmental and geographic conditions. Thus our collection of tag data cannot be considered a random sample of the population; especially for blue whales. We used a variety of behavioral and geographic parameters to stratify our data in an effort to account for the biases in the collected data, as well as elucidate gaps in the existing data. We will use these different parameters when building models of calling to evaluate their impact on changes in call rates.

Analysis of data gaps

In addition to temporal gaps in the data, possibly the largest bias in our blue whale data set stems from the data collection that was addressing a variety of research questions and targeting animals in different behavioral and geographic settings. These settings can be separated into four dominant categories:

1) *Coastal feeding aggregations*, represented by animals that were tagged close to shore and were often in larger feeding groups, which represent a large fraction of the SOCAL-BRS effort
2) *Southern California offshore animals*, which were tagged to address questions specifically relating to calling animals and thus represent a sample that is likely skewed towards callers
3) *Coastal callers* were animals sampled during the same effort as 2 above, but they were found much closer to shore
4) *Low density* were animals found in dispersed mode and these individuals were the ones most commonly tagged during the ship strike tagging effort

Passive acoustic analysis

To address the geographical sampling bias in our data set and evaluate the calling preference of inshore and offshore animals off Southern California, described in section Analysis of data gaps above, we used passive acoustic data previously recorded by High-frequency Acoustic Recording Packages (HARPs) deployed inshore and offshore of the Channel Islands. To evaluate how similar the calling is offshore and inshore, we manually detected all A, B, and D calls and calculated the ratios of these calls at three sites over a year. Based on the results of that test, we may be able to pool the two data sets from Southern California offshore animals and coastal callers (2 and 3 in section above) into a single behavioral setting category of "callers," which would provide a larger sample size for that category. A comparable spatial stratification to the fin whale 20 Hz and 40 Hz call data could show whether pooling of fin whale tag data can also be justified.

Field sampling efforts
In addition to already available data sets, and to complement other currently-underway tagging efforts that will provide additional data to our effort, such as the ONR funded blue whale ship-strike work (PI Calambokidis) and the SOCAL-Behavioral Response Study, we will conduct additional field work and continue testing new archival tags in order to evaluate the possibility of their use for long-term deployments. One key effort in development that could provide a major contribution to our effort are longer term attachments of archival tags incorporating high sample rate accelerometers that may be able to detect if the animal is calling.

WORK COMPLETED

- Completed analysis of blue whale A, B, and D call presence at three sites (one offshore and two inshore) in the SCB from one year of passive acoustic HARP data.
- Compiled all available non-BRS blue and fin whale acoustic tag data through 2014.
- Completed acoustic analysis of all available non-BRS blue and fin whale tag data from deployments through 2014.
- Formalized plans with the SOCAL-BRS team for obtaining data from BRS-based tag deployments that have occurred since 2010.
- Stratified tag data using behavioral and geographic parameters to account for biases and further elucidate gaps in the existing data.
- Started developing methods for conducting behavioral analysis of tag data, for the purpose of calculating context-appropriate call production rates.
- Conducted preliminary tests on new tags to evaluate the potential for longer-term deployments of tags incorporating high sample rate accelerometers to detect calling by the tagged animal.

RESULTS

Analysis of available tag data
Thus far, we have analyzed the acoustic data collected from 57 tags deployed during non-BRS research on blue whales off the coast of Southern California, totaling over 229 hours of recordings. A total of 557 blue whale calls were detected in these recordings. More detailed analysis of these detections, including the breakdown of calls to those from the tagged animal versus non-tagged nearby animals and behavioral state of callers are underway. Of the 13 non-BRS deployments of acoustic tags on fin whales, nine tags yielded over 14 hours of good quality data. No fin whale calls were detected on any of those tags.

Equivalent data from BRS-based tag deployments will be obtained from the BRS team once those analyses are completed.

Analysis of data gaps

Of the approximately 150 successful blue whale tag deployments with more than 15 min of high quality acoustic data collected, 118 tags were deployed on animals off the coast of Southern California. In an effort to account for biases and further elucidate gaps in the existing data, we stratified this SOCAL tag dataset using a variety of temporal, geographic and behavioral parameters.

A number of biases are apparent in the data: 1) only 82 of the 527 total hours of SOCAL acoustic data (16%) were recorded at night (Figure 1); 2) the majority of SOCAL deployments were targeting coastal animals, including coastal feeding aggregations (comprising 74% of all available acoustic data) and coastal callers (14%). On the other hand, data from deployments on low density animals and offshore callers constitutes just 7 and 5 percent of SOCAL acoustic data, respectively (Figures 2 and 3). When these geographic and behavioral categories are coupled with temporal stratification, only 10 hours of limited nighttime acoustic data (12%) were collected from offshore callers, with the other 88% of nighttime data recorded by coastal feeding aggregations or callers. No nighttime data were collected from low density animals.

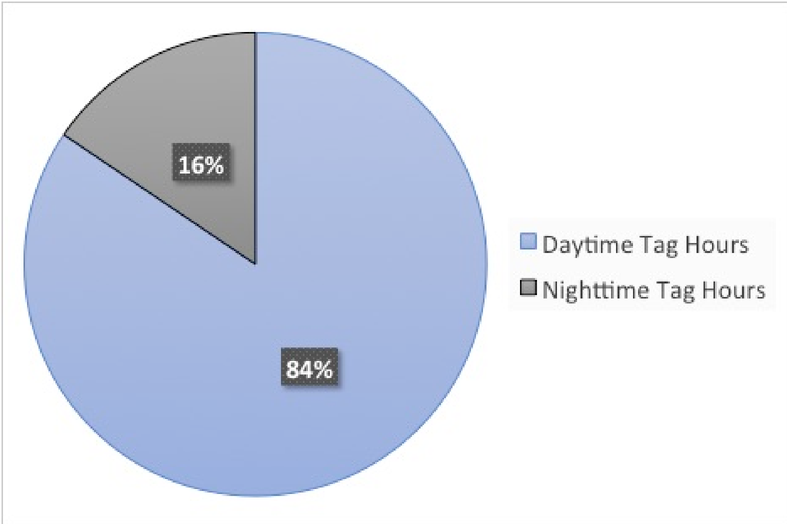

Figure 1. Percent of SOCAL blue whale acoustic tag data that was collected during the day (blue) versus at night (grey).

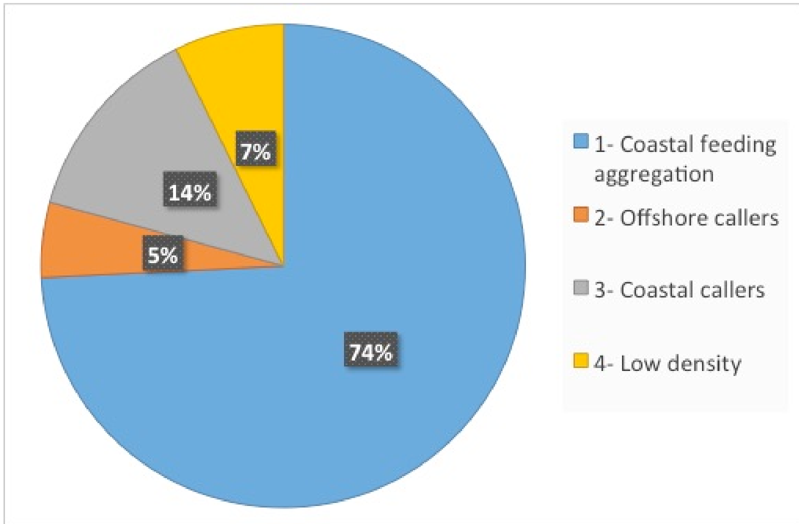

Figure 2. Percent of SOCAL blue whale tag deployments targeting specific behavioral states, showing a clear bias in the available dataset towards coastal feeding aggregations.

Passive acoustic analysis
Passive acoustic data from three HARP locations, one offshore and two inshore of the Channel Islands (Figure 3), were analyzed to evaluate possibility of different the calling states of inshore and offshore animals in Southern California. To test whether blue whale calling is similar at these three sites, we calculated A, B, and D call rates, and their relative percentages contributing to total calling, for each site over time. Over 11,500 blue whale A, B and D calls were detected between September 2009 and June 2010 across these sites. Seasonal differences in A and B call rates at and between the three sites were significant, with a fall peak in AB calling that continued into the winter months inshore. Overall, the total number of call detections offshore (1603 calls) was lower than detections at each of the inshore sites (4092 and 5597 calls).

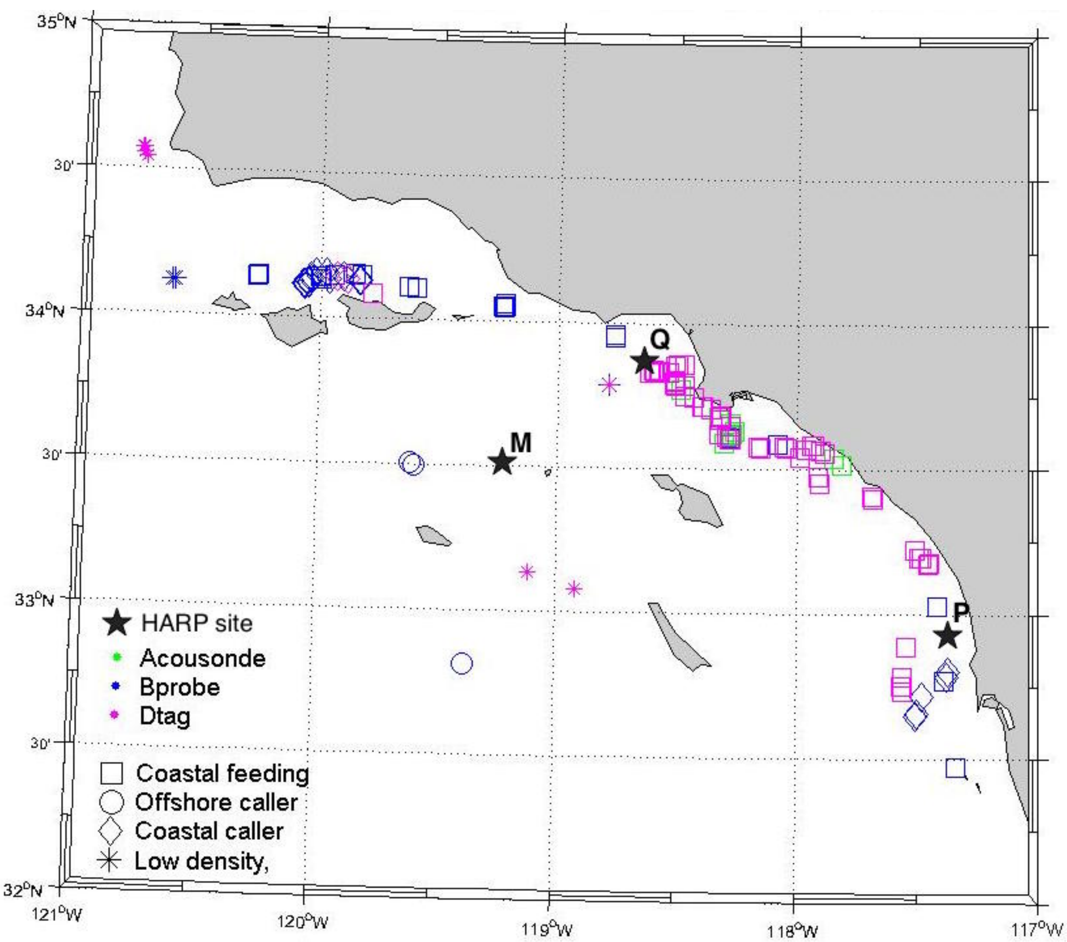

Figure 3. Map of blue whale tag deployments off Southern California, with colors designating the type of tag used, and symbol designating the behavioral state targeted. HARP locations are also shown.

During this seasonal peak in AB calling (from September through December), the ratio of A calls to B calls offshore was 0.32. At the inshore sites, the A to B call ratios were greater, around 0.50. Interestingly, during these four months, blue whale A calls constituted a higher percentage of all detections at the inshore sites (32 and 33%) than offshore (23%). In contrast, average D call rates showed no statistically significant seasonal variation between the three sites, and only a slight difference between the two inshore sites in November 2009. The shared seasonality in D call rates between the three sites suggests that D calls, rather than the commonly reported and widely studied A-B calls, may be a more robust proxy for density estimation using passive acoustics.

The higher percentage of A calls detected at the inshore sites versus offshore suggested that blue whales in the SCB may have a different song type preference. Blue whales producing one A call followed by a single B call (AB-type), repeated in regular intervals, would produce A calls more frequently than blue whales whose one A call was followed by two or more B calls (ABB-type). To test whether there is a difference in occurrence of different song types across sites, we classified all bouts of song (A and B calls detected at regular and repetitive intervals) longer than five minutes in duration as either AB- or ABB-type dominated bouts. The total counts of each call type were used to calculate overall percentages of each song type at each site.

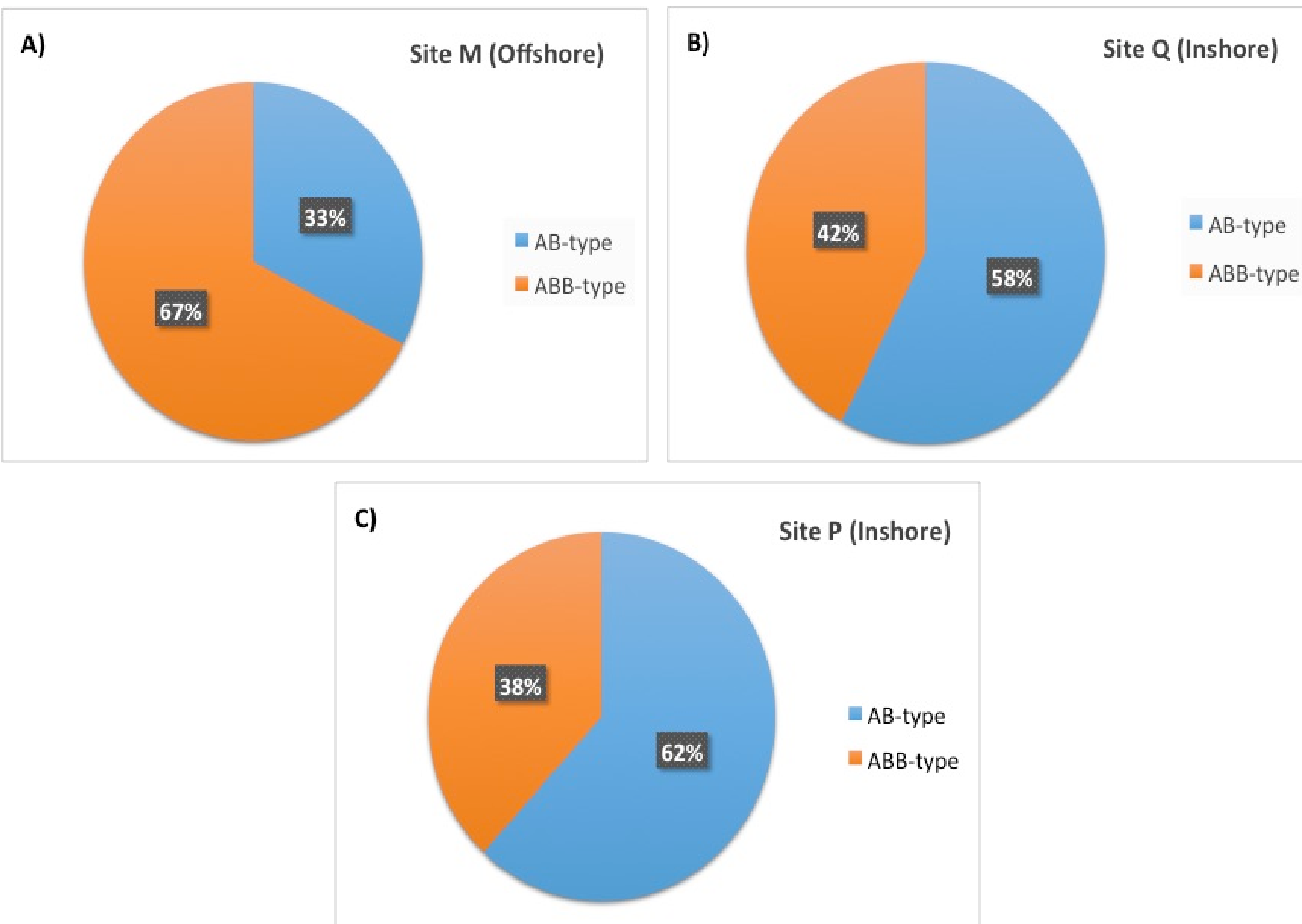

Figure 4. Overall percent song type detected at the offshore (A) and inshore (B and C) HARP sites.

Across 70 hours of song analyzed, there was some monthly variability in the dominant song type at each of the sites, but a higher proportion (67%) of all defined song bouts offshore was type ABB (Figure 4A), whereas 58 and 62% of songs at the inshore sites were AB-type (Figures 4B and 4C). Overall, the observed differences in calling and song preference between blue whales detected offshore and inshore in the SCB may identify two distinct behavioral settings that should be distinguished in future models of AB calling.

IMPACT/APPLICATIONS

Call rate estimates developed by this method will be of wide use to research of Navy interest. For example, these rates will be easily applicable to blue and fin whale recordings collected by other researchers conducting work in the eastern North Pacific Ocean to develop regional and seasonal blue and fin whale density estimates and will thus offer input for enhancing wider Navy monitoring efforts. In addition, it will be possible to use information on blue and fin whale call rates as a baseline for studies on the effects of noise on blue and fin whale calling behavior in this region.

RELATED PROJECTS

We are coordinating with other funded projects on density estimation using passive acoustics including "Large scale density estimation of blue and fin whales" (PI Dr. Miksis-Olds) and "Cheap DECAF: Density Estimation for Cetaceans from Acoustic Fixed sensors using separate, non-linked devices" (PI Dr. Thomas). Additionally, we expect to benefit from the data collection underway under ONR funded projects "Behavioral and physiological response of baleen whales to ships and ship noise" (PI Calambokidis), as well as the SOCAL-BRS tagging efforts.