Northeastern Pacific Blue Whale Offshore Call Variability

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Abstract

Blue whales are a species that are found worldwide that are split into several subpopulations. The northeastern Pacific subpopulation produces A- and B-type calls that can formed into AB- and ABB-type phrasing. In the Southern California Bight, it was found that ABB-type phrasing was more prevalent than AB-type in deeper offshore sites than near-shore sites. The subpopulation migrates north near fall close to the Washington and Oregon coast where their calls are recorded by hydrophones. Spectrogram data of sounds from this region were analyzed first for B-type calls using automatic detection. Later manual analysis was conducted to detect A-type and B-type calls in randomly selected times. Between 2018 and 2019 at this site, ABB-type made over half of the phrases sampled. B-type calls in general were also had a near 2:1 ratio compared to A-type calls for all reported months. This would suggest that the pattern found for offshore blue whale calls holds true. Overall B-type calls appear to be the favored call for offshore environments due to their ability to be transmitted over longer distances, potentially improving their ability to mate.

Plain Language Summary

The blue whale, the largest animal in history, was heavily hunted in the 1900s and is currently listed as an endangered species. The population off the western coast of the U.S. is known to produce pattern of calls in the form of a song that are thought to be related to mating. A study of blue whales off the coast of California found that the whales tended to use songs with more deeper calls while in deeper water than while in shallow water. I studied the whales further north, off the Washington and Oregon coast, to determine if this trend was true

for this region as well. I found that in the deep offshore environment, blue whales tended to use more songs with the deeper calls similarly to the study off the California coast. By understanding this trend, we can try to avoid using machines that produce noises that are similar to these deeper calls when traveling across the western U.S. coast.

Introduction

Blue whales are the largest animals known to have existed on Earth and are found worldwide(Sears and Perrin 2009). The species can be divided into at least eight groups with different song variations: the northeastern Pacific, southeastern Pacific, southwestern Pacific, north pacific, north Atlantic, Southern Ocean, north Indian, southeastern Indian, and the southwestern Indian (McDonald et al. 2006). Northern hemisphere blue whales tend to be smaller than their Southern hemisphere counterparts. Historically blue whales were more abundant in the Southern Ocean but due to whaling practices in the 1900s, 325,000-360,000 whales were hunted in Antarctic waters alone (Sears and Perrin 2009). The species has since been listed as endangered.

In the North Pacific there were originally five subpopulations of blue whales but now no more than two populations can be found (Sears and Perrin 2009). In the Northern Pacific, the Northeastern subpopulation is the most studied group. This group migrates between Alaska and the Costa Rica Dome. Typically, they can be found off the Washington Coast from summer to fall and early winter (McDonald et al. 2006). The Northeastern Pacific blue whales have been used as indicator species for the health of an ecosystem. By modeling whale movement

behavior, scientists were able to track where foraging was more likely to occur in the California Current Ecosystem, which can help to indicate the regions of high biological productivity (Palacios et al. 2019).

Studies into the calls of the Northeastern Pacific blue whales primarily produce 3 distinct calls: A, B, and D type calls (Stafford et al. 2005). A- and B-type calls have historically been produced at 17-20 Hz but over time there has been a worldwide trend in decreased frequency of the calls and are now near 14 Hz (Sears and Perrin 2009; McDonald et al. 2009). A and B types calls are unique to the Northeastern Pacific blue whale population and are typically produced by male whales and are thought to be related to mating (Lewis and Širović 2018; Oleson et al. 2007). A type calls are pulsed calls, near 14 Hz (McDonald et al. 2001), with multiple time-offset non harmonic components that lasts around 20 seconds (McDonald et al. 2006). B type calls are the loudest of the calls and are a 15-20 second slightly frequency modulated tonal with a series of harmonically related higher frequencies (McDonald et al. 2006). The down sweep of the B type call is typically around 1.6 Hz lasting 16 seconds (Stafford et al. 1998). D type calls are down swept calls of about 1 second duration ranging from 60 to 45 Hz (McDonald et al. 2001). Singular A and B type calls can be produced independently of each other but are typically produced with at least one additional blue whale, and other blue whales present within 1 km (Oleson et al. 2007). AB and ABB phrasing is common, with the A unit always initiating (McDonald et al. 2006), and are called songs. ABB type phrases can have a variable number of B type calls after the A call as seen in Figure 1 while the AB type is always ABAB patterning. Vocalization of these calls are typically produced at 10-40 m depth while the whales are traveling (Thode et al. 2000; Oleson et al. 2007).

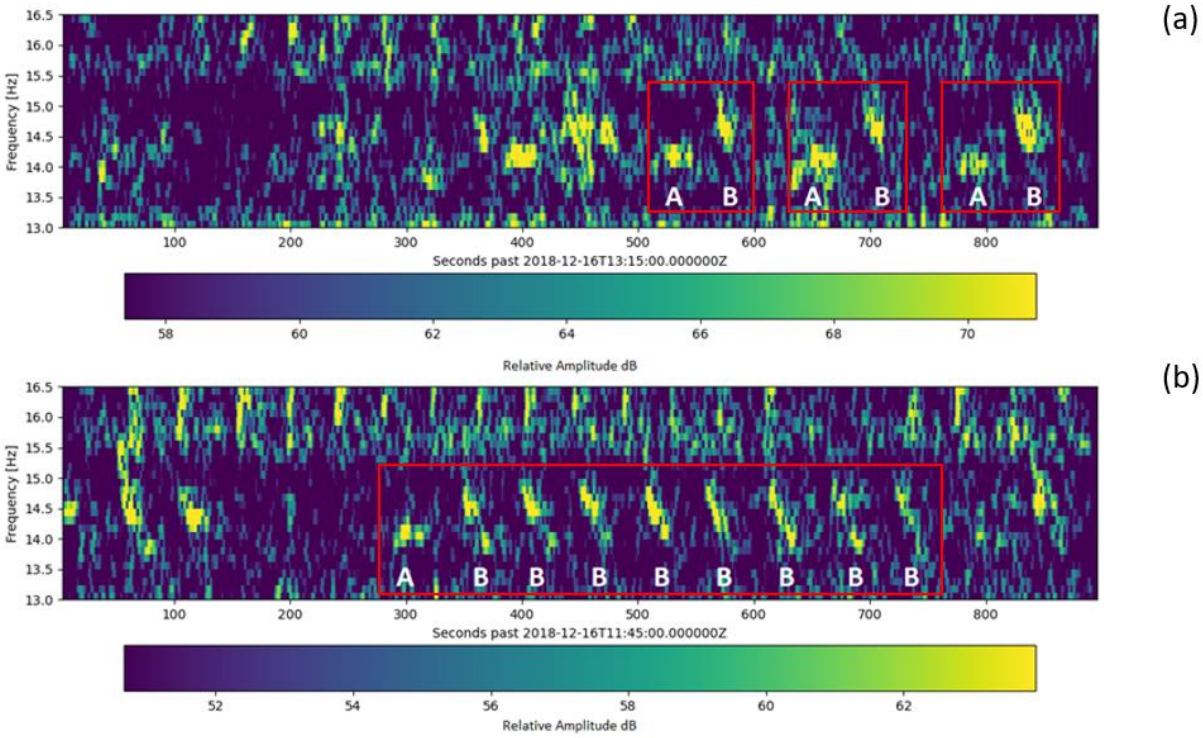


Figure 1: Spectrograms of patterned sequences of blue whale calls recorded near Axial Seamount. (a) Sounds can appear in singular A-B pairs as seen. (b) Spectrogram depicting ABB patterning. ABB patterns can have variable B-type calls after the initial A.

Studies off the coast of California have studied the patterns of the A and B type calls, observing the frequency of AB-type phrasing and ABB-type phrasing in the offshore and nearshore environment in the Southern California Bight (Lewis and Širović 2018). They observed that in the two inshore sites there was a larger percentage of AB phrasing versus ABB phrasing and the opposite in the two offshore sites as seen in Figure 2. Lewis and Širović (2018) hypothesizes that the higher abundance of solitary whales offshore and the ability for B calls to travel farther is the reason behind this trend. With fewer physical obstacles to obstruct the propagation of calls, the relatively long, low frequency tonal of the B call can be broadcasted

across greater distances. This would potentially increase the chances of a male's song being heard by other whales.

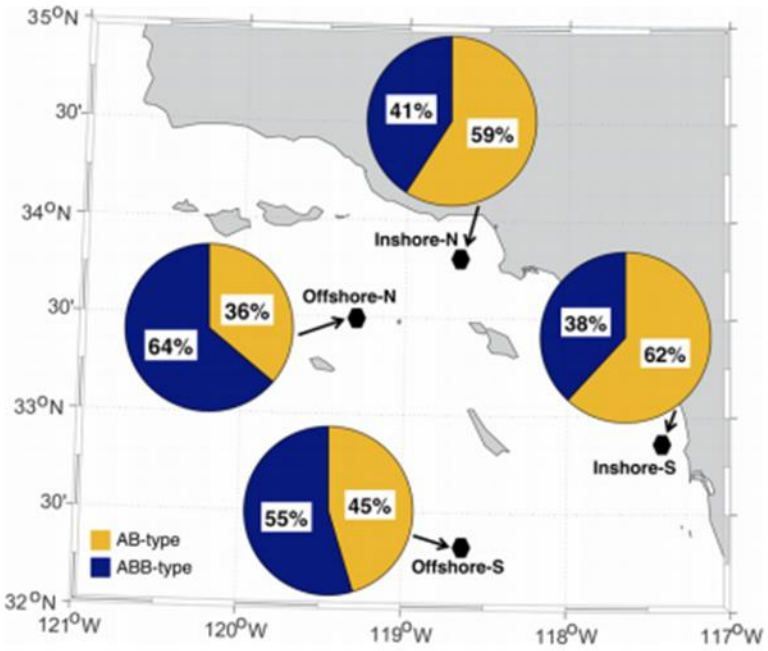


Figure 2: Percentage of songs recorded at inshore and offshore sites of AB and ABB phrasing blue whale calls between September 2009 and August 2010 (Lewis and Širović 2018).

The northeastern Pacific blue whale population is also observed further north offshore of Washington and Oregon in September before leaving the region in January and February (Burtenshaw et al. 2004). Whales off the coast of Washington and Oregon are further offshore than in the Southern California Bight (Stafford et al. 1998) which would suggest, if the trend that Lewis and Širović (2018) found is continuous for the range of this population, that their phrases would have a higher proportion of ABB-type versus AB-type phrases. This population passes by Axial Seamount, a submarine volcano 300 miles off the coast of Oregon, where

cabled hydrophone data is available deeper and further offshore than the Southern California Bight. In this study I will be examine whether the pattern observed by Lewis and Širović (2018) for offshore blue whale calls is consistent in this region.

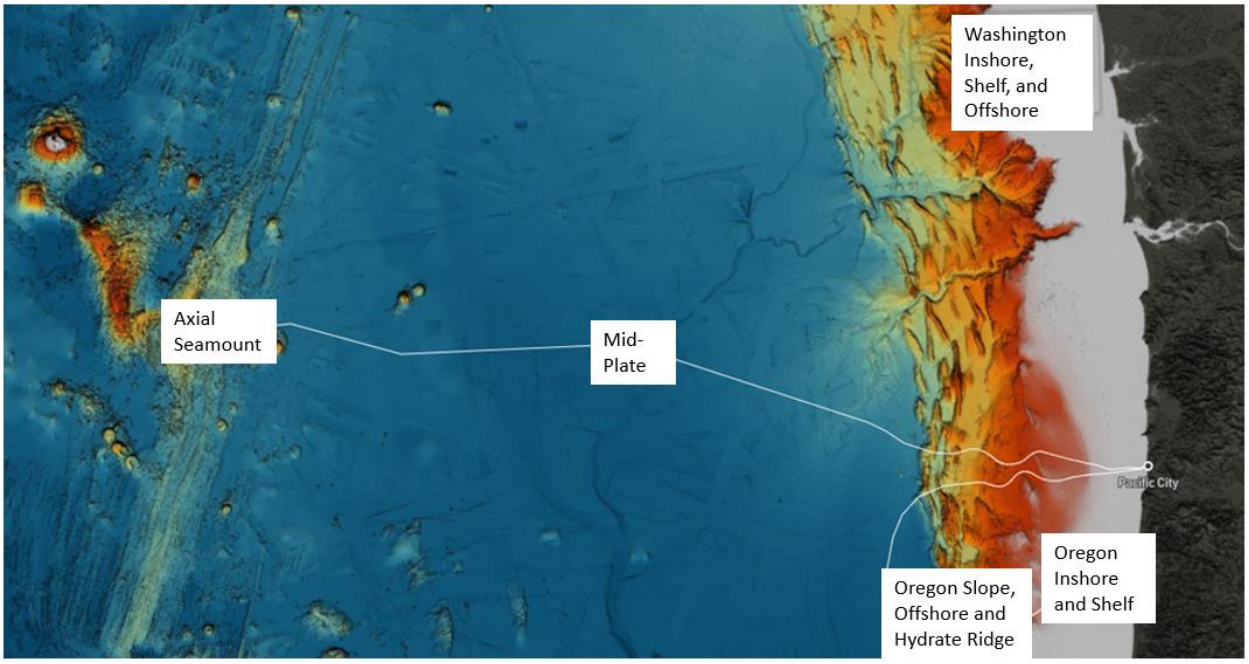


Figure 4: Map of Axial Seamount cable array.

https://app.interactiveoceans.washington.edu/map

Methods

Data for this research was obtain from the Ocean Observatories Initiative (OOI) cable array located at Axial Seamount. The OOI is an observing network that has several stations around the world including the Regional Cabled Array which has more than 140 instruments sending real time data (https://oceanobservatories.org/regional-cabled-array/, 10 March 2021). The Cabled Axial Seamount Array is located at approximately 1,500 to 2,800 meters water depth and focuses on environments that are greater than 500 km offshore

(https://oceanobservatories.org/array/cabled-axial-seamount-array/, 10 March 2021). 40 Hz BHZ seismometers from station AXBA1 (45.82018° N, 129.73671° W) located at -2607.2 meters elevation (http://ds.iris.edu/mda/OO/AXBA1/--/BHZ/, 10 March 2021) were used to sample blue whale calls.

Seismometer data from Axial Seamount has been transformed into spectrogram data hosted in the Incorporated Research Institutions for Seismology Data Management Center (IRIS DMC). Spectrogram data from station AXBA1 BHZ 40.0 Hz seismometers between May 2018 and April 2019 are run through a spectrogram cross-correlation detector (Mellinger and Clark 2000) to produce a csv file that contains detected B-type calls. The detector found calls between frequencies of 14 and 16 Hz with a minimum of 5 seconds duration. A minimum threshold of 0.5 was used to flag B calls.

Ten randomly selected three-hour periods on different days in months with at least 50 automatically detected B-type calls (August-February) were examined for occurrences of A- and B-type calls. The start time for each day was randomly selected to provide broad coverage across the 24 hours within a month. Call and phrase detections within the time period could be from any number of whales so no assumptions were made regarding independence within a day. If data was unavailable for a particular time, data was logged for the same 3-hour period on the following day. Low-frequency noises, whether due to anthropogenic activities or other sources, at times could mask blue whale sounds and only the calls that could be seen were logged for these times.

A-type and B-type calls were sorted by start of call and sorted between AB, ABB, and single A or B groupings. Phrases were sorted by proximity to the following call, where a phrase would be considered complete if no following call were detected after 2 minutes.

The month of January was reanalyzed for manual detections for non-random dates because the vast majority of automatically detected calls occurred over a three-day period, the 14th to the 16th. Data from these periods replaced three periods in January where no detections were observed.

Results

B-type calls were detected primarily between August 2018 and February 2019, with the largest number detected in January (Figure 5). While the automatic detector found B-type calls in every month, a visual inspection suggested all the detections for the months of March through July were false flags, registering other low frequency noises as B-type calls. The months with significant call counts were then manually analyzed for A-type and B-type calls.

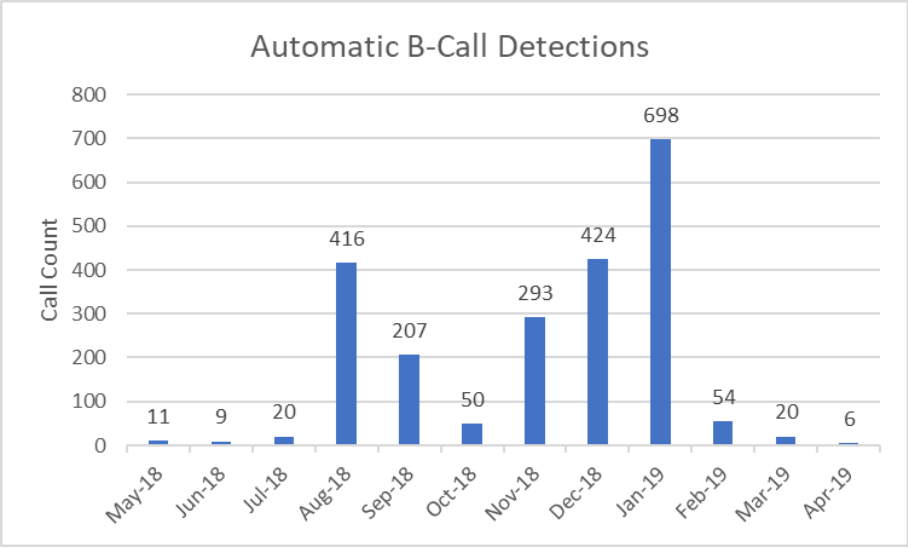


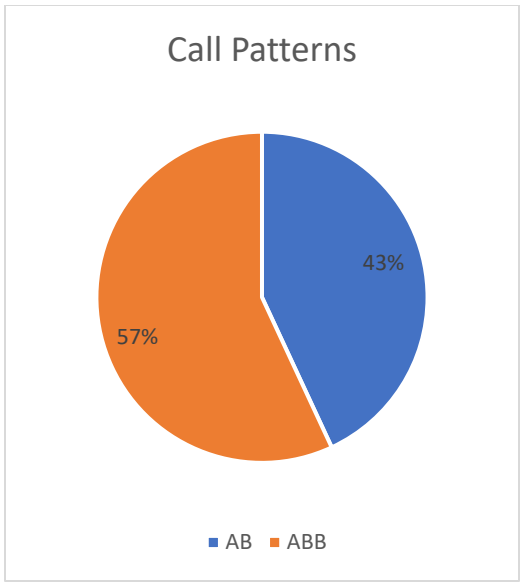
Figure 5: Distribution of B-type calls detected automatically between May 2018 and April 2019.

The months of September, November, and December contained the most manually detected calls from blue whales at Axial Seamount for the initial analysis (Table 1). In all the months that were analyzed, no months had detections in all 10 periods, averaging around 4 periods with detections per month. Over the whole year, ABB-type phrasing was more prevalent at this site than AB-type phrasing for the initial detection.

Table 1: Call and phrase counts for months with significant automatic B-type call detections. (*) symbol denotes use of revised January data.

Month	AB	ABB	Single A	Single B	Average # of B in ABB	Total A	Total B	Periods of Detection
Aug-18	5	3	1	8	3.0	9	22	4/10
Sep-18	23	37	0	10	3.2	60	148	4/10
Oct-18	3	3	0	3	2.0	6	9	2/10
Nov-18	22	15	29	40	6.1	66	132	6/10
Dec-18	20	34	37	28	4.9	91	193	7/10
Jan-19	0	2	0	1	2.0	2	5	1/10
Feb-19	11	17	8	15	2.5	36	57	2/10
Jan*-19	75	47	2	1	3.3	124	232	4/10
Total	84	111	75	105	[redacted]	270	566	[redacted]
Total*	159	156	77	105	[redacted]	392	793	[redacted]

ABB-type phrasing made up 57% of the phrases detected in this year (Figure 6A). Total A-type versus B-type calls show that B-type calls were the more common at this site, comprising close to 70% of all the calls manually detected (Figure 6B).

A. 

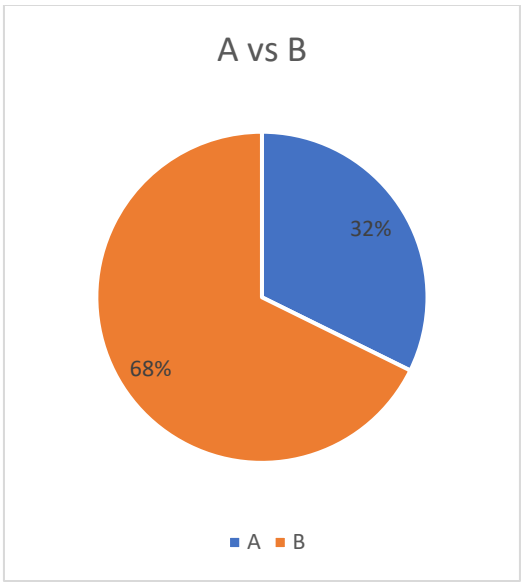
B. 

Figure 6: (A) Percent of all call phrases manually detected near Axial Seamount comprised of AB and ABB type phrasing between August 2018 and February 2019. (B) Percentage of all A- and B-type calls manually detected near Axial Seamount between August 2018 and February 2019.

Single A- and B-type calls varied through the year, peaking in the months of November and December (Figure 7). The average number of B-type calls in ABB phrases similarly peaked in November (Figure 8). In the 6 periods that detections of blue whales calls occurred in November, there was an average of 6.1 B-type calls per ABB phrases before steadily declining again.

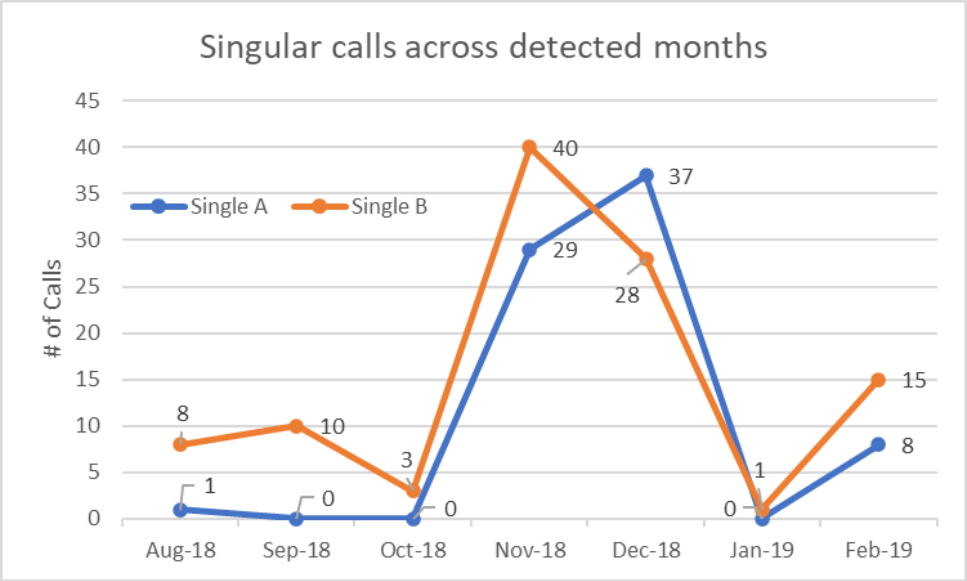


Figure 7: Month breakdown of detected single A and B calls.

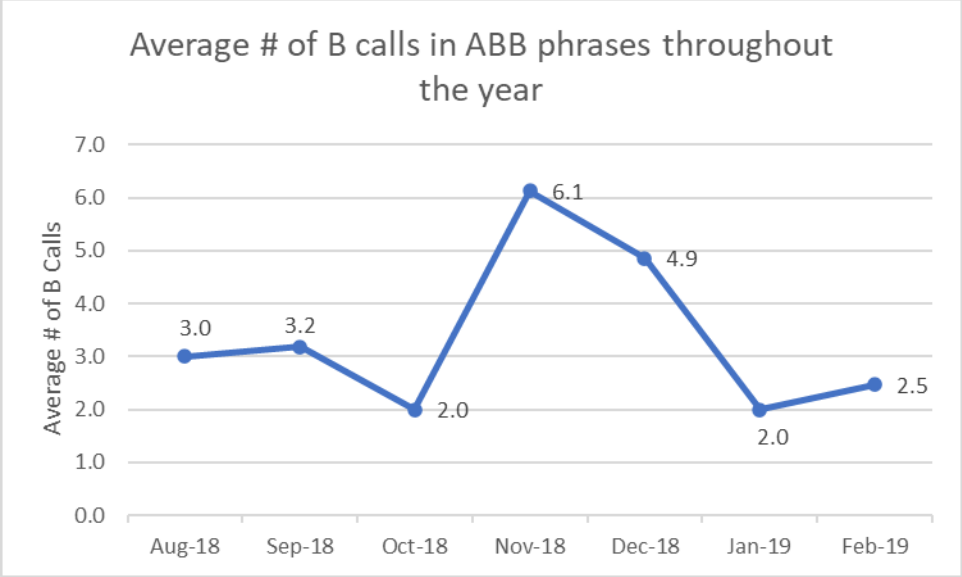
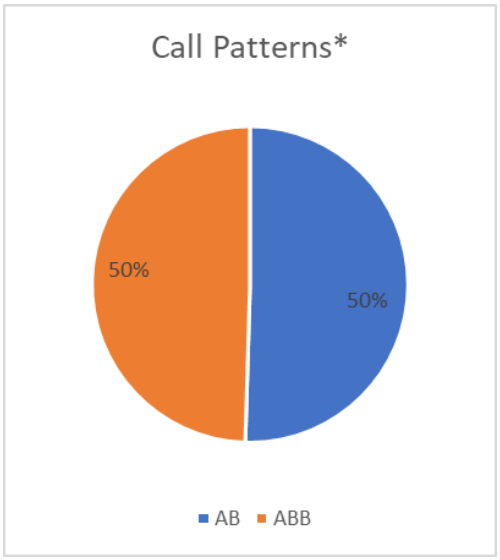


Figure 8: Monthly change in average B-type call in ABB-type phrases.

Figures 9A and 9B use data from the revised January detection that includes the three days of increased concentration of whale calling. While the ratio of A- to B-type calls does not shift by a large amount (Figure 9B), there is a shift in the ratio of AB to ABB phrases (Figure 9A).

AB type phrases now make up half of the phrases that are found in this region compared to the 43% observed in Figure 6.

A. 

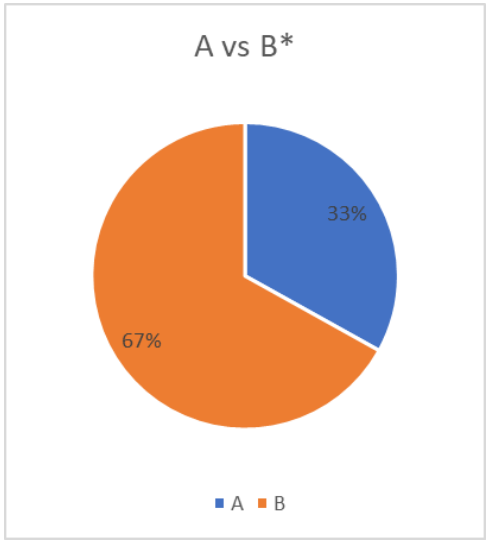
B. 

Figure 9: (A) Percent of all call phrases manually detected near Axial Seamount comprised of AB and ABB type phrasing between August 2018 and February 2019 using revised data from January 2019. (B) Percentage of all A- and B-type calls manually detected near Axial Seamount between August 2018 and February 2019 using revised data for January 2019.

Discussion

Contrary to what was suggested in Burtenshaw et al. (2004), the northeastern Pacific Blue Whales appear to be arriving off the Washington and Oregon coast as early as August. This is potentially related to warmer water temperatures shifting the migration period forward in the year over the 15 years since the study (Szesciorka et al. 2020). An examination of more years at this site or other sites off the coast of Washington and Oregon would be needed to confirm this observation.

Directly comparing to the results of Lewis and Širović (2018), I can observe that the trend that they found in the Southern California Bight for this population does seem to hold true for this site for the initial detections. While I cannot do a month-by-month breakdown of call patterns due to many months having limited detected calls, I can examine the site over the course of the year to conclude that ABB-type phrases seem more prevalent for offshore sites such as Axial Seamount. In the initial detections, of the phrases that were detected 57% of them were ABB-type. This fits well in-between the two offshore results found in Lewis and Širović (2018) of 64% and 55%. Additionally, there seems to be a peak period of increased B-type calls in ABB-type phrases in November, increasing to a peak of an average of 6.1 B-type calls in each ABB-type phrase. This seems to be a trend as there is a steady build up and decline after November of average B-type calls, especially given that November had the second most periods with detections.

Data from the revised January analysis causes the results to seemingly go against what was found in Lewis and Širović (2018). The 50:50 ratio of AB to ABB phrases falls outside the ranges of what would be expected for an offshore site. The calls in this period however may be from one whale that vocalized for several days. It is possible that the whale or whales that produced these calls could prefer the use of AB phrases over ABB phrases but confirm or deny this would require either a complete count of the year or a rerun of detections using times that whales are known to be present.

Figure 6B and 9B as well as Table 1 provide us with additional insight into this issue. There is a 2:1 ration of B- to A-type calls in this region. Even in months that have greater AB than ABB detections I can see this trend of a greater use of B-type calls than A-type. Lewis and

Širović (2018) suggest that the increased B-type call usage is related to their increased transmitability in deeper more open waters. A- and B-type calls are thought to be related to mating, so it is to a male whale's advantage to produce calls that a female whale might have a higher chance of hearing.

During the months of November and December I see peaks in several categories. These two months have the highest ratio of periods with detections, 6/10 and 7/10 respectively, the highest amount of single calls present, and the highest average number of B-type calls in ABB phrases. This time period is also well within the period that this population of blue whales is known to be in the region. It is possible that these months are when blue whales are most abundant off of the coast.

Conclusion

Similarly to what I see in the Lewis and Širović (2018), I see that at Axial Seamount, a site deeper and further offshore than those at the Southern California Bight sites, that there is an increased percentage of ABB-type phrasing compared to AB-type phrasing. B-type calls also seem to be more prevalent in general at this site than A-type calls at a near 2:1 ratio.

Further research into this pattern should be conducted to examine for spatial and temporal variations. An examination of a site in the near-shore environment off Washington or Oregon could determine if the pattern that Lewis and Širović (2018) found for those sites is also true. Reexamination of Axial Seamount for the same time period but different time windows to fill in the months that were lacking in data could expand the findings of this paper. Examining

additional years and sites could also be done to determine if there is a consistent pattern of phrase use in this region.

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