Determining Fin Whale Call Counts in the Northeast Pacific using Hydrophone Data

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Abstract:

Fin whale call counts in the Northeast Pacific, between 2015 to 2020, were determined using hydrophone data from the Ocean Observatories Initiative's regional cabled array database. This study sought to determine if fin whale call counts in the NE Pacific increase in support with the 7.5% annual abundance increase estimated from visual surveys. A regional cabled array station at the base of the Axial seamount was used, and the hydrophone data was analyzed by spectrogram cross-correlation that detected the 20 Hz down swept call made by fin whales. From 2015 to 2018, fin whale call counts showed a continuous increase. Call counts between 2018 and 2019 decreased. From 2019 to 2020, call counts showed a significant increase. Fin whale call counts in the NE Pacific between 2015 and 2020 showed a 10.2% annual increase. However, the fit to a linear trend is weak and the data does not rule out a calling rate that is unchanged with time. Sea-surface temperature in the winter showed significant variations from year to year and there were fewer calls in the years when winter water temperatures were anomalously high. This suggests that fewer fin whales congregated near Axial temperatures when temperatures are warmer, but then returned the following year when the water temperature was more normal.

Plain Language Summary:

Fin whales are an endangered species that has shown an increase in population in the North Pacific since their protection from whaling in 1976. The National Oceanographic and Atmospheric Administration (NOAA) have made fin whale population assessment reports from 2000 to 2018 that show estimates on the increase in population. This study was to determine if fin whale call counts in the Northeast Pacific have increased over time between 2015 and 2020, as the number of animals increases. Call count numbers were found using a hydrophone. The results showed that call count numbers increased between 2015 to 2020. Call counts did not increase per year, there was a dip in calls between 2018 and 2019. This may have been because of an increase in water temperature during that year.

Introduction:

Fin whales are the 2nd largest cetacean in the world and found in all major oceans (Figure 1).

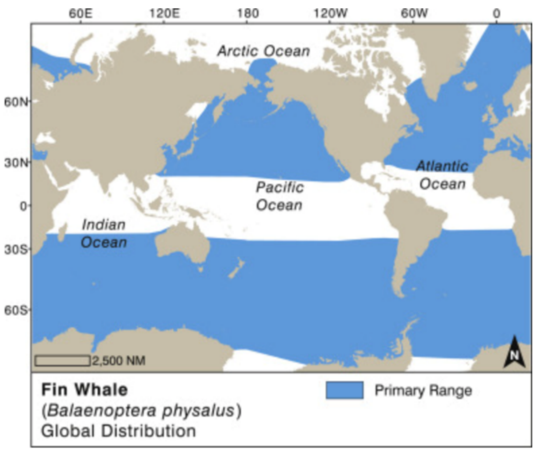

Figure 1: Fin Whale Global Distribution Adapted by Nina Lisowski from Jefferson, T.A., Webber, M.A., and Pitman, R.L. (2015). "Marine Mammals of the World: A Comprehensive Guide to Their Identification," 2nd ed. Elsevier, San Diego, CA.

There are two subspecies, *Balaenoptera physalus physalus* in the northern hemisphere and *B. p. qouyi* in the southern hemisphere (Aquilar and Garcia-Vernet, 2018). Between these two sub species, there are many differences. B. p. physalus have shorter bodies with shorter and broader fins compared to *B. p. qouyi.* In the northern hemisphere their diet consists of krill, other planktonic crustaceans, schooling fishes and sometimes small squid (Aquilar and Garcia-Vernet, 2018). While, in the southern hemisphere their diet is primarily just krill and other planktonic crustaceans (Aquilar and Garcia-Vernet, 2018). Like many cetaceans, fin whales are migratory, but there is little about the details of northern hemisphere migratory patterns compared to southern hemisphere fin whales. For example, *B. p. qouyi* have been clearly observed to migrate in the summer at high-latitudes for feeding and low-latitudes in the winter for breeding (Mizroch et. Al. 1984). So, the assumption is that *B. p. physalus* make the same basic movements. However, breeding grounds for fin whales in the northern hemisphere are still unknown (Mizroch et. Al. 2009). This study focuses on northern hemisphere fin whales, in the Northeast Pacific.

Fin whale populations were negatively impacted in the mid-1900s due to intense whaling, especially in the North Pacific. Pre-whaling, the estimated population of fin whales in the North Pacific were around 42,000 to 45,000 (Ohsumi and Wada 1974). In 1973, the estimated population of fin whales in the North Pacific ranged from 13,620 to 18,680 and of that, 8,520 to 10,970 were from the Eastern Pacific (Ohsumi and Wada 1974). By 1976, the International Whaling Commission (IWC) gave North Pacific fin whales protection and have been labelled as endangered (NOAA, Fisheries, 2014). Since then, a California Current study showed strong evidence of an increase in fin whale abundance along the east Pacific (Moore and Barlow, 2011). In the east Pacific, from 1991 to 1993 the abundance of Fin whales increased from 1,744 to 3,369 (NOAA Fisheries, 2018). From 1994 to 2014 the California coast showed a 7.5% annual increase in Fin whale abundance (Figure 2) (Nadeem et. Al. 2016). Today there is an estimate of 14,000 to 18,000 fin whales in the North Pacific as a whole, of that the best estimate is 9,029 in the California/Oregon/Washington Stock (NOAA Fisheries, 2018). Due to the IWC's constant effort in fin whale protection, the population of fin whales in the North Pacific have shown a steady increase since post-whaling. But it is unclear if fin whale stocks are still increasing or if they are stable. Figure 2 shows a fairly flat abundance from 2008 to 2014 but with large uncertainties that are also consistent with steady growth.

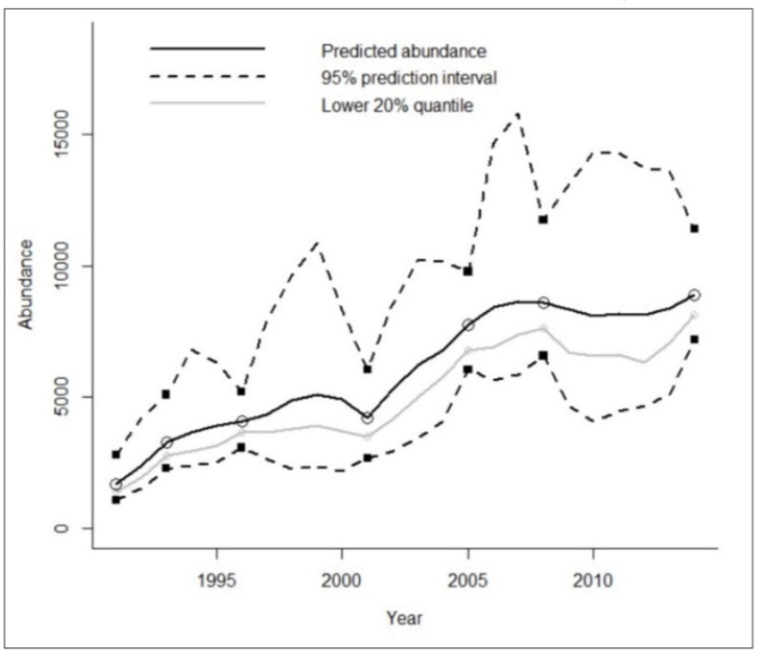

Figure 2: Fin whale abundance estimates from 1991-2014. (Nadeem et Al. 2016).

Traditionally, cetacean populations are determined by visual surveying (McDonald and Fox 1999). But these can be improved by using acoustic monitoring (McDonald and Fox 1999). For example, a study from 2006 to 2012 at the California Bight used passive acoustics to monitor population trends of blue whales and fin whales (Sirovic et. Al. 2015). It was determined that their call trends were consistent with their population trends (Sirovic et. Al. 2015). Acoustic monitoring works well with fin whales because they have an easily identifiable call at 20 Hz (Watkins et. Al. 2000). Fin whales have calls that last about 1 second that follow a down swept pattern. They also make songs which are a sequence of calls. Their songs can be described as low frequency, but high intensity, lasting from minutes to 16 hours or more. (Watkins et. Al. 2000). In the NE Pacific, fin whales were observed to have two distinct types of calls, a single call and a doublet pattern (Figure 3) (Weirathmueller et. Al. 2017).

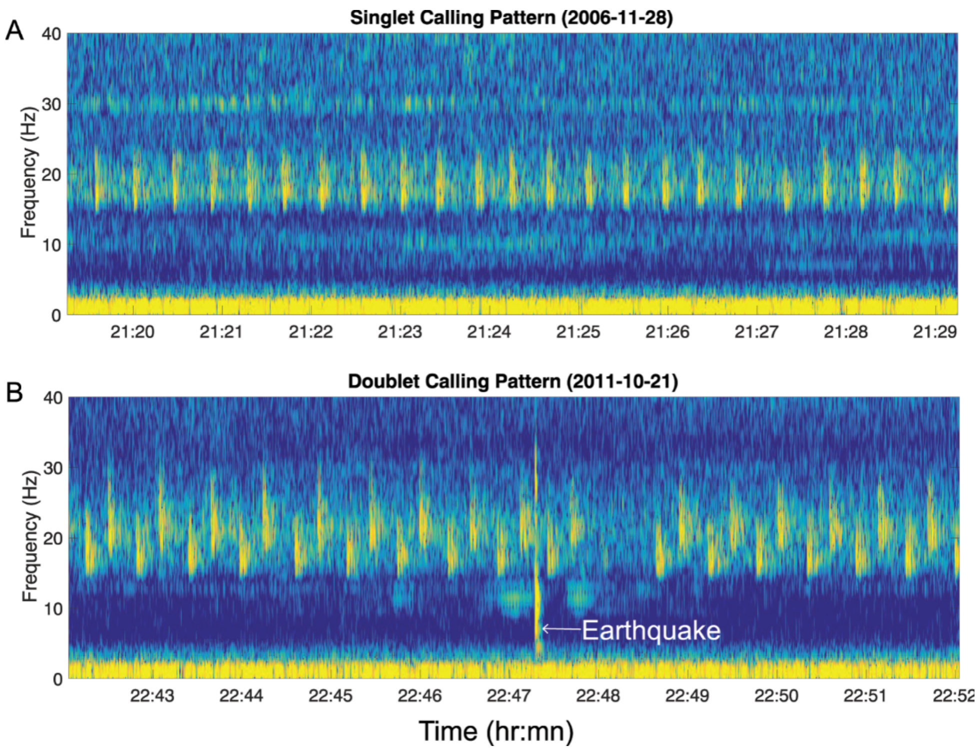

Figure 3: Singlet and Doublet calling pattern of Fin Whales in 2006 and 2011. (Weirathmueller et al. 2017).

These calls have been observed to only be produced by male fin whales (Croll et. Al. 2002). Because only males produce these calls, the assumption is that these calls are for breeding purposes.

The NE Pacific NOAA fin whale stock report only relies on visual surveying and fishing reports, not acoustic monitoring. If call counts can be shown to match the population increases, then they could be included in the stock assessment to improve its accuracy. In this study, I hypothesize that the fin whale call counts in the NE Pacific per year between 2015 to 2020 will increase parallel to the estimated 7.5% annual population increase.

Methods:

This study uses the Ocean Observatories Initiative's regional cabled array at the Axial Seamount seafloor. This cabled array has a low frequency acoustic receiver, or hydrophone, that can detect fin whale calls at their 20 Hz frequency. It has been acquiring hydrophone data from 2015 to 2020. The station used was AXBA1, the coordinates of this station are (45.82, -129.73). The instrument used was HT1-90-U/Diff Hydrophone-DM-24 Mk3 Fixed Gain and has a sample rate of 200 Hz. The time frame that was analyzed was between July 1st, 2015 to July 1st, 2020. Each yearly cycle is from July 1st to July 1st because fin whale calls are only made by males for breeding purposes, with the peak in calls in the wintertime.

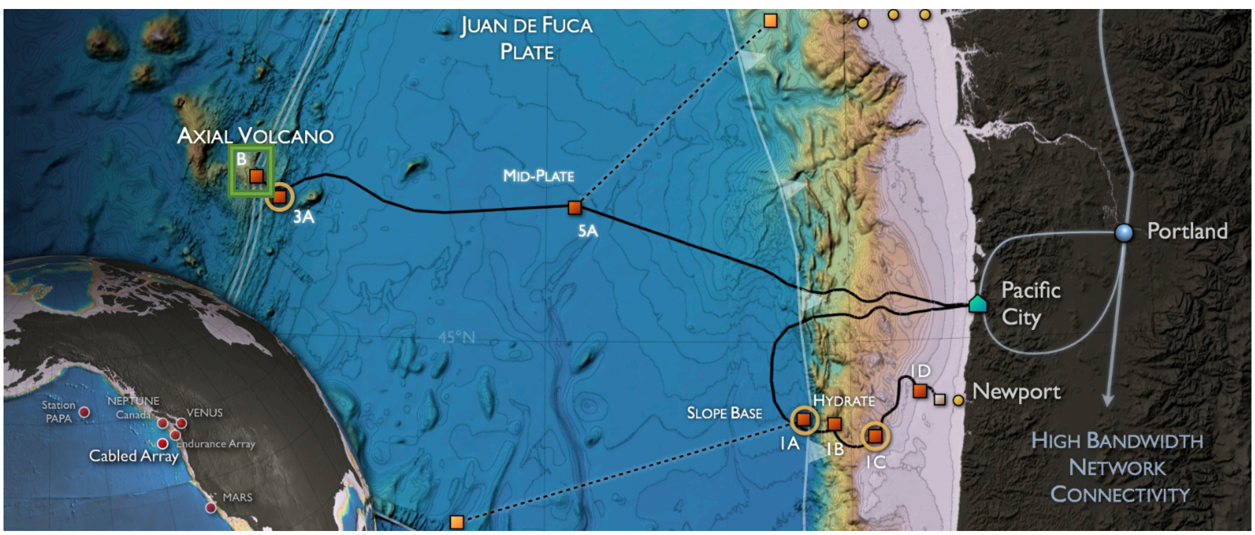

Figure 4: OOI Regional Cabled Array Map. Axial seamount instrument identified with green box.(NSF Ocean Observatories Initiative Data Portal (2020),

The hydrophone data was analyzed using a Python algorithm developed by Rose Hilmo (Github uwescience/whaletracks 2020 https://github.com/uwescience/whaletracks) that distinguishes the most prominent fin whale call made and records it to a comma separated variable file (CSV). The fin whale call count detector is comprised of three main parts as seen in Figure 5. The detector has the fin whale call kernel (Figure 5 C) that is cross correlated with a spectrogram (Figure 5 B) to make a detection score (Figure 5 A). The fin whale call kernel follows the 20 Hz down swept call that fin whales make. The kernel uses the frequency of the sound to determine if it is truly a fin whale call and makes a detection score. The more prominent the fin whale call, the higher detection score. The highest detection score in a 10 second window is then recorded in the CSV file. This ensures a nearby echo would not be considered because the detection score made would be less than the actual call. Also, an earthquake does not follow the down swept pattern or the average duration of a call, so a detection would not be made.

In this study, the fin whale call kernel had a frequency limit that was set to 15 Hz – 25 Hz, where the average start frequency was 25 Hz, and the average end frequency was 15 Hz. The duration of a fin whale call was set to 2 seconds. The minimum detection score threshold was set to .6, anything lower was not recorded on the CSV file. In Figure 5 A, the 30 seconds of detection score data, only one call exceeded the .6 minimum threshold meaning it was the only potential call.

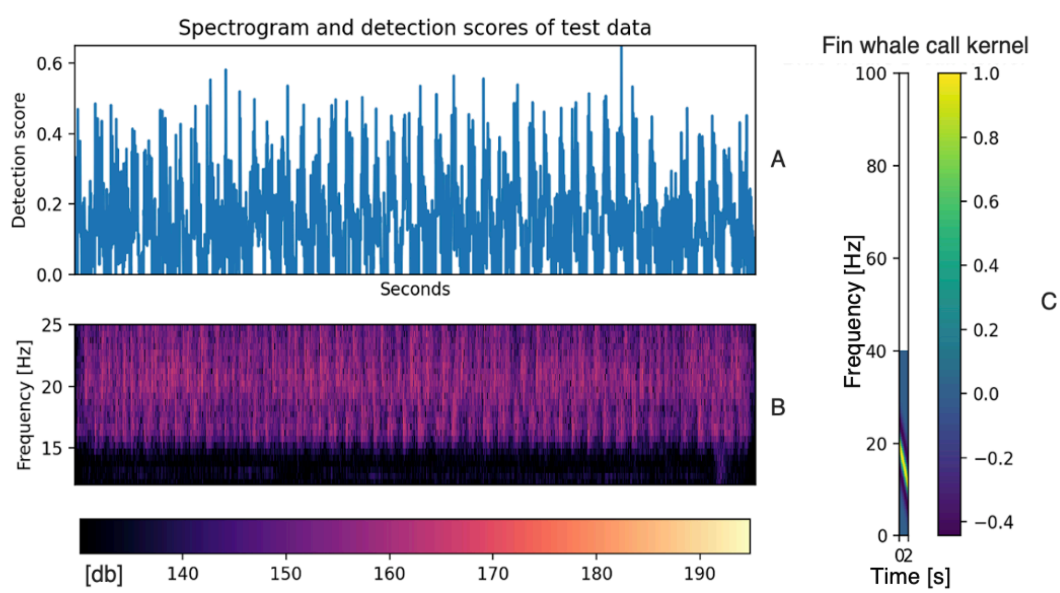

Figure 5. Fin whale call detector components, (B) Spectrogram of Fin whale calls, (C) Fin whale call kernel determines if the frequency of the call follows the down swept pattern of fin whale call, if true a detection score is made. (A) Displays detection scores made by Fin whale call kernel.

Results:

Figure 6 displays 5 histograms of the of total call counts for every year. From 2015 to 2018, there was a clear increase in call counts. Then, there was a drastic decrease in calls from July 1st, 2018 to July 1st, 2019. In the final year, 2019 to 2020, the number of call counts showed another increase. Also, what can be seen is that the years that had an increase in calls from the previous year (Figures 6B, 6C, and 6E) showed that calls persisted till around the beginning of May. With the years of the lowest calls (Figures 6A and 6D), calls only lasted to the end of March. Although there is an increasing call count trend throughout the years, the fluctuation in calls makes it hard to determine if this is significant. In Figure 7. the R^2 value is very low at .099, showing that the data is also consistent with a slope of zero or a call count that does not vary with time.

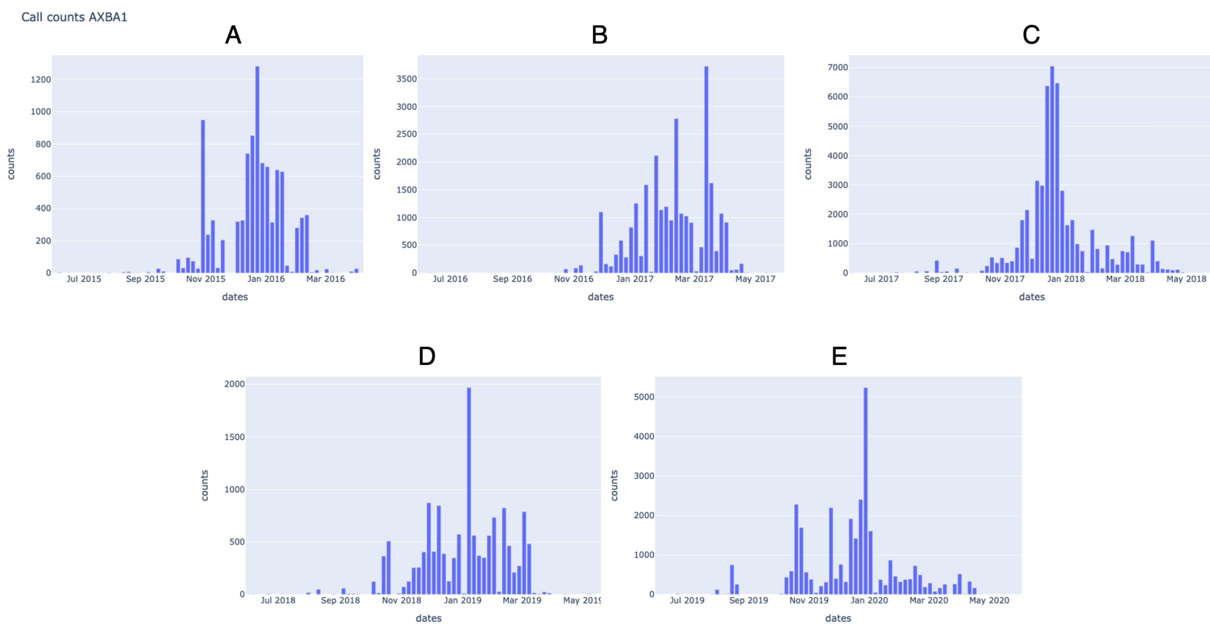

Figure 6. Histograms of total fin whale calls from (A) 06-01-2015 to 06-01-2016, (B) 06-01-2016 to 06-01-2027, (C) 06-01-2017 to 06-01-2018, (D) 06-01-2018 to 06-01-2019, and (E) 06-01-2019 to 06-01-2020.

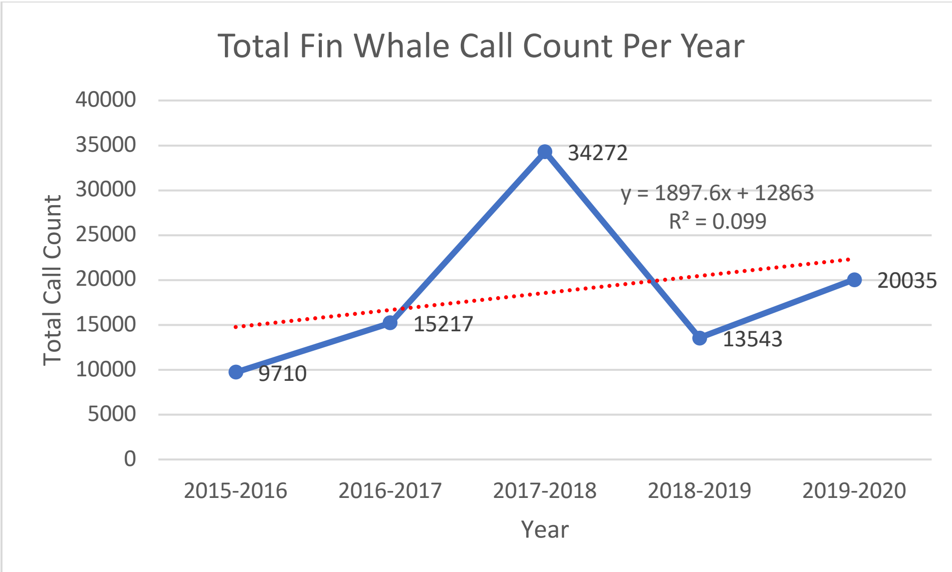

Figure 7. Plot of total fin whale call counts over the 6-year span.

Discussion:

There are no estimates beyond 2014 for fin whale population and abundance in the California/Oregon/Washington stock (NOAA, FIN WHALE: California/Oregon/Washington 2019). As mentioned before, Fin whale stock in the NE Pacific is determined only through visual surveying and fishing reports. With no reliable recent estimates, the estimate of a 7.5% annual increase of fin whales in the NE Pacific is not known to be accurate. There is potential for a trend showing an increase in abundance or the abundance has flattened. Figure 2 has a 95% prediction interval consistent with the population, showing to be staying stable or showing an increase. The fin whale call detector only makes a detection score for the most prominent call, therefore echoes will not be counted. In turn, there could be multiple calls from other fin whales being made, they are not being counted because their detection scores are lower at the same instant. While looking at the datasets it is important to take into consideration the uncertainties of the fin whale stock in the NE Pacific and how the Python algorithm does not count all calls made at the same instant.

Overall, fin whale call counts have increased from 2015 to 2020. Besides the dip in call counts from 2018 to 2019, fin whale call counts increased the following year from 2019 to 2020. My results showed that the 10.2% annual increase in call counts exceeded the estimated 7.5% annual increase in fin whale abundance. However, the R^2 value for a linear fit is very small suggesting the data is also consistent with a zero slope and no overall increases in calls or population. It was shown that the years of larger call counts, fin whales resided in the area much longer. For instance, in Figure 6 A and D calls stopped by the end of March. While the years of larger calls Figure 6 B,C and E showed that calls persisted all the way to mid-May.

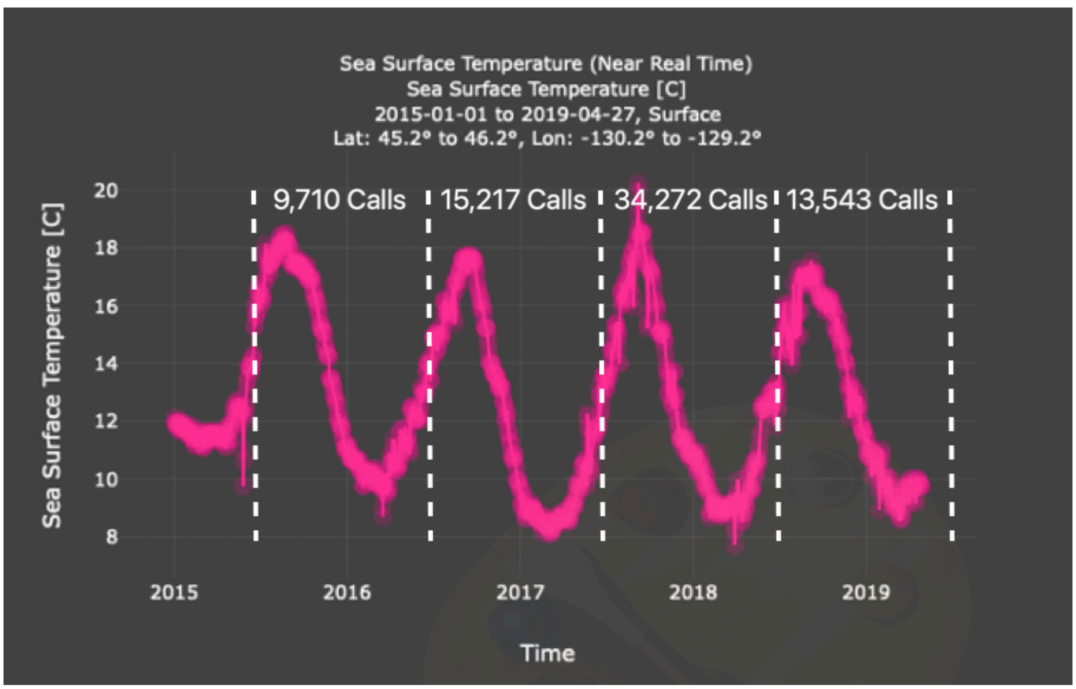

Figure 7. Sea Surface Temperature at AXBA1 station, developed using SimonsCMAP. Dashed lines indicate the time frame of the total calls listed. (JPL OurOcean Project 2016).

Both 2015-2016 and 2018-2019 showed the lowest amount of fin whale call counts. Two events that potentially connect the two-time frames are the effects of the 2014 marine heat wave, the “Blob”, and the marine heat wave in 2019 also known as the “Blob 2.0” (Amaya D. et. al. 2020). The first marine heat wave increased the sea surface temperature (SST) by 1°C-4°C (Cavole M. L. et. al. 2016). In 2019, the second marine heat wave caused the sea surface temperature to increase 2.5°C above normal temperatures

(Amaya D. et. al. 2020). In Figure 7, it is clearly seen that in the winter of 2015-2016 and 2018-2019 the SST was warmer compared to the other years. This increase in temperature caused major fluctuations in zooplankton abundances, which have drawn fin whales away due to zooplankton being their primary diet (Cabole M. L. et. al. 2016). Therefore, fluctuations in SST that directly impacted zooplankton abundance, could have potentially caused fin whales to reside in the area for a shorter amount of time. The change in fin whale presence could also be because of fin whale migratory patterns in the Pacific, but so little is known about that. Using one station is not enough to prove a clear population increase. It would be beneficial to use more than one station to observe whether one location is showing an increase in calls while the other is showing a decrease or if trends are consistent. It is also to monitor SST to see if the call counts decreased because of the change in temperature, supporting the idea that they'll migrate to cooler waters.

Conclusion:

Fin whale call counts in the NE Pacific have increased over time, between 2015 to 2020. This suggests that the fin whale population in the NE Pacific is still growing. My hypothesis stated that the fin whale call counts in the NE Pacific would increase parallel to the estimated 7.5% annual increase in fin whale abundance. The results are consistent with that statement because the data showed an increase in fin whale calls by 10.2% over the 6 years. This is relatively close to the 7.5% annual increase however, the large scatter in counts from year to year make it impossible to rule out a population that has remained constant. Environmental impacts, like the marine heat waves in 2015 and 2019 may have been the reason for the data showing fluctuations in call counts per year as opposed to just a gradual increase in calls per year. Very little is known about fin whales, in the NE Pacific specifically, and the data only targets a specific station. If more stations were incorporated, there could be evidence of fin whale call counts increasing in a different region that did not experience a drastic change in SST. This could potentially shed some light to where fin whales migrate in the NE Pacific or improve the accuracy of the stock assessment in the NE Pacific obtained by using acoustics.

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