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# Blue whale song occurrence in Central and Western North Pacific Ocean

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## ABSTRACT

Blue whales in the Northern Pacific sing at least three distinct, population-specific songs. These populations can overlap in time and space as they migrate across the ocean basin. Acoustic recorders were deployed at three locations in the central and western North Pacific Ocean in 2015-2016 to determine what populations were present in their vicinity and to investigate seasonality of their singing behavior in the areas. Of the four possible song types, only Central/Western Pacific (CWP) song was observed. This song was detected most often around Wake Atoll, which is located in the central North Pacific. At the other two locations in the Northern Mariana Islands, off Saipan and Tinian, the calls were detected regularly but were less common. Calls were concentrated in the summer months, May through August, with smaller peaks in singing during winter months at the Mariana Island locations. Song at these locations peaked slightly earlier than peak song periods previously reported at higher latitudes.

## INTRODUCTION

Blue whales produce high-intensity, low-frequency, long-duration songs that are ideal for passive acoustic monitoring (Cummings & Thompson 1971, McDonald et al. 2001, McDonald et al. 2006, Monnahan et al. 2014, Northrop et al. 1971, Stafford et al. 2001). The first recordings of their songs were sampled in 1971 off the coast of Chile, with reported intensity of 188 dB re 1 µPa (Cummings & Thompson 1971). Further research has demonstrated that these songs are regionally specific, stereotyped and patterned (McDonald et al. 2006). The songs are comprised of one or more units of pulsed or tonal calls emitted in a stable sequence. Up to four distinct blue whale songs can be found in the North Pacific Ocean (Northrop et al. 1971, McDonald et al. 2006, McDonald et al. 2017).

Blue whale populations in the North Pacific Ocean have traditionally been delineated into two broad categories: Eastern North Pacific, ENP, and Western North Pacific, WNP (Monnahan et al. 2014). Morphological examination demonstrated that the WNP blue whales are about 1m longer than ENP whales. During historic whaling nearly 9,000 individuals were harvested from the collective North Pacific populations; it is estimated that 65% of these caught whales were from the WNP stock (Monnahan et al. 2014). The ENP population is the most extensively studied blue whale population, ranging from the Costa Rica Dome to the Aleutian Islands (McDonald et al. 2006). The song this population produces is made up of two units, termed A and B calls. A call is comprised of a series of low frequency pulses with peak energy around 90 Hz pulses and this pulsed unit is typically followed by B call, a long, tonal unit with peak energy occurring in its third harmonic frequency, around 45 Hz. In the WNP population there are three known song types. The first was described in 1971 near the Wake Atoll and has been called the Enterprise call, which is a single tonal call that sweeps down for a short duration before sweeping back up (Northrop et al. 1971). This song has not been reported recently in the region. The other song type present in the central North Pacific is a tonal call that sweeps down slightly from 20Hz to 18Hz, called the North West Pacific (NWP) call (Stafford et al. 2001) or Central/Western Pacific (CWP) call (Rice et al. in press). Most recently, a new song has been documented off the coast of Japan consisting of multiple tonal units, which is thought to represent a distinct population and has been termed the Japan song (McDonald et al. 2017).

The seasonality and distribution of these North Pacific calls remains unresolved, although the CWP calls occur from Russia to the Gulf of Alaska (Monnahan et al. 2014). Song occurrence in the region is seasonal, with song most commonly detected in summer months (Northrop et al. 1971, Stafford et al. 2001, Rice et al. in press). The purpose of this study is to analyze passive acoustic recordings from the central and western North Pacific Ocean recorded in 2015 and 2016 to contribute to our current understanding of population distribution and possible overlaps in the northern Pacific basin.

## METHODS

In 2015 and 2016 High-frequency Acoustic Recording Packages, HARPs (Wiggins & Hildebrand 2007), were deployed in the vicinity of Wake Atoll and the Northern Mariana Islands of Saipan and Tinian (Figure 1). Each HARP was bottom-moored and equipped with a hydrophone suspended approximately 10 m off the seafloor. All HARPs were outfitted with data loggers and battery packs as well as redundant acoustic release mechanisms. Each HARP sampled at a rate of 200 kHz with 16-bit A/D quantization. Recordings were duty-cycled with 5 min recording periods (Table 1). Saipan and Tinian recorders had a 7 min cycle interval while Wake recorder cycles were 30 min. Since baleen whales emit mainly low-frequency calls, data were decimated by a factor of 100 to create a dataset with an effective bandwidth of 1 kHz for more efficient analysis.

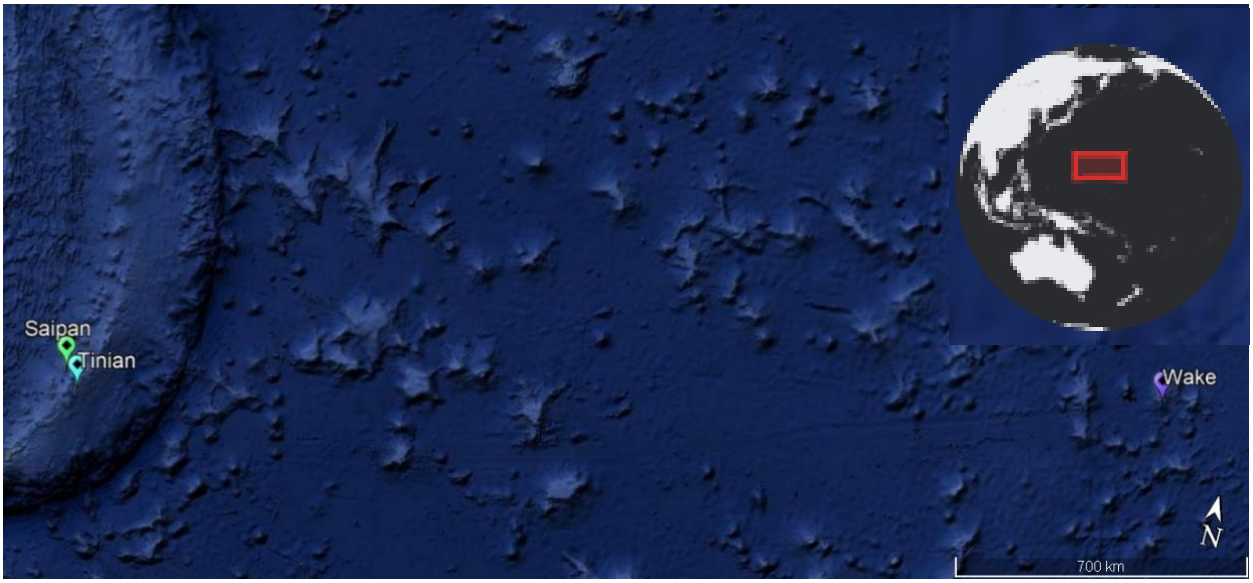


**Figure 1**: *Map of HARP deployment locations in 2015 & 2016: Saipan (green), Tinian (blue), and Wake (purple). The red box on the inset globe outlines the study area.*

**Table 1**: *Deployment details for each location, including latitude and longitude, depth, dates of recording, and duty cycle (interval of cycle/duration of recording, in minutes).*

| Deployment location | Latitude (N) | Longitude (E) | Depth (m) | Data Start | Data End | Duty Cycle |
|---|---|---|---|---|---|---|
| Saipan | 15˚ 19.05’ | 145˚ 27.43’ | 600 | 13May 2015<br>30 May 2016 | 2 May 2016<br>17 May 2017 | 7/5 |
| Tinian | 15˚ 02.40’ | 145˚ 45.38’ | 1,000 | 13 May 2015<br>30 May 2016 | 23 May 2016<br>5 November 2016 | 7/5 |
| Wake | 19˚ 13.40’ | 166˚ 41.67’ | 620 | 5 May 2015<br>12 April 2016 | 17 January 2016<br>16 December 2016 | 30/5 |

Recordings were processed in MATLAB (Mathworks, Natick, MA) using the custom software program *Triton* (Wiggins and Hildebrand 2007). Long-term spectral averages (LTSAs) were calculated with 1 Hz frequency and 5 s time resolution. Each recording was manually reviewed in its entirety for the presence of different blue whale song types: CWP, Enterprise, or Japan song. Times with high levels of masking noise were marked and removed from recording effort. We investigated long-term temporal patterns in calling behavior and geographic variation in song behavior by examining changes in song unit counts across months and years and comparing the number of song units produced at each location and the types of songs observed.

## RESULTS

Only the CWP blue whale song was detected at the three recording stations across both years analyzed. This song type was most commonly detected off Wake, especially during the summer of 2016 (Figure 2). Blue whale song was notably rarer at both Tinian and Saipan, with no calls detected in Saipan after April 2016. The seasonality of these songs appears to differ between Wake Atoll and the Mariana Island locations. At Wake, the song occurred from May through August, with rare detections outside of this peak period. No song was detected at Wake during the fall months, September through October. In the Mariana Islands occurrence of singing appears to be bimodal, with peaks in winter and summer. At Tinian these peaks occurred in December 2015 and June 2016, while there was a single peak at Saipan in February 2016. Rare instances of song were detected throughout Tinian recording while singing at Saipan was isolated to late winter and early spring. The Enterprise and Japan songs were not detected at any of these sites during the monitoring period reported here.

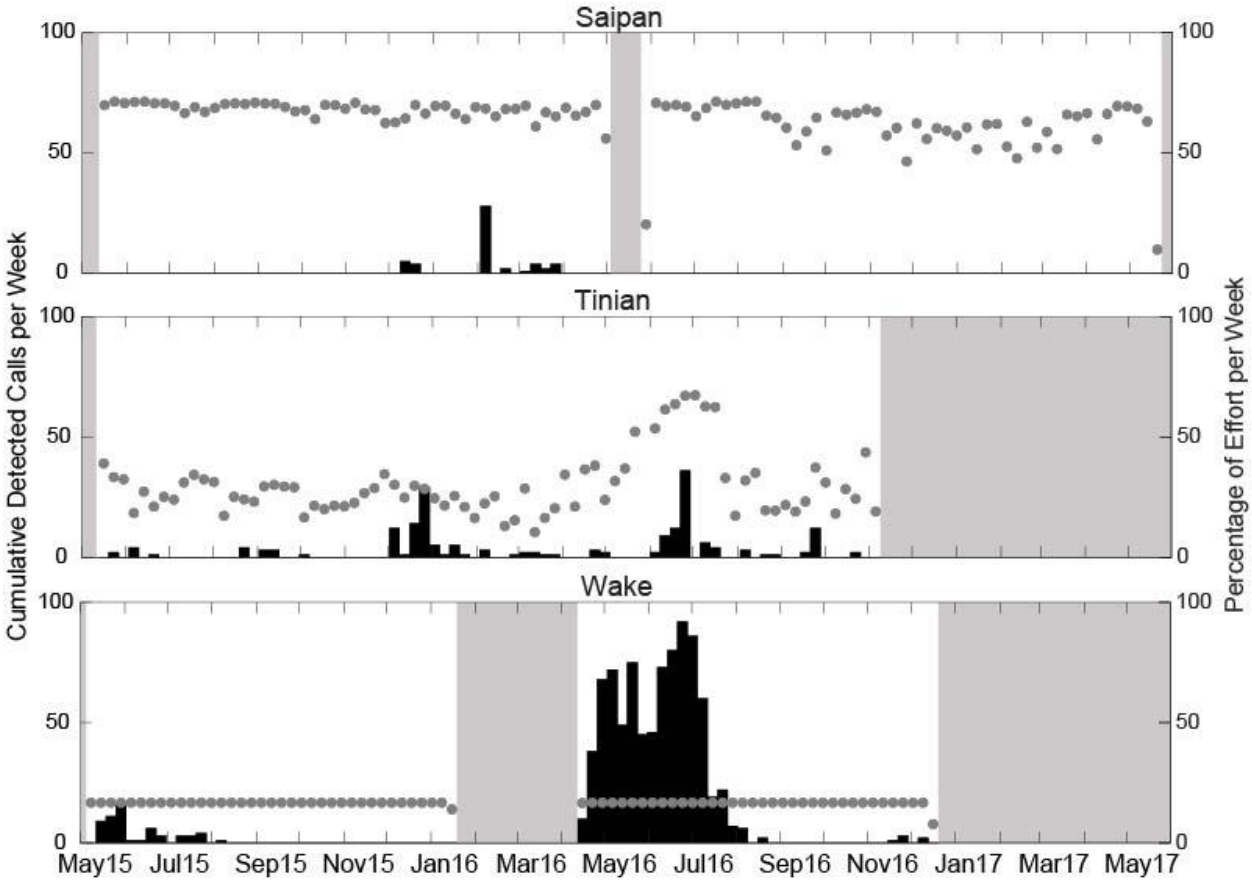


**Figure 2**: *Call counts per week from May 2015 through May 2017 at Saipan (top), Tinian (middle), and Wake (bottom). Black bars represent number of observed calls per week and gray dots denote percent recording effort based on recording duty cycle and level of masking due to low frequency noise. Grey shaded areas mark times with no recording effort.*

## DISCUSSION

Blue whale song around the Mariana Islands and at Wake Atoll appears to be restricted to the CWP song type. No observations of Enterprise or Japan songs were made during period of recording. This could indicate that these populations do not occur in the monitored areas of central and western North Pacific. Alternatively, it is possible that individuals from these populations were present at some point in the area but were not engaged in singing behavior.

The CWP song has been previously reported from the Aleutian Islands (Moore et al. 2002) to Wake Atoll (Stafford et al. 2001). In our study, song was most common near Wake Atoll, despite lower recording effort at that site, and was relatively rare around the Mariana Islands. Even if there is an intrinsic difference in the detection area around each site due to bathymetric differences or other environmental factors, the reduced duty cycle at Wake would be expected to result in overall lower detection counts, so the recorder at that locations was seemingly in an area with higher prevalence of blue whale song. Interestingly, in Northern Marianas more detections occurred at Tinian than at Saipan, even though higher portion of recordings at Tinian were not taken into account in this analysis due to high levels of masking noise. The two recorders in this area were monitoring different basins: Tinian site was listening to the open Pacific to the west while the Saipan recorder was listening to the east, towards the Philippine Sea. This difference in detection levels between the two sites likely indicates that blue whales are more common to the west of Northern Mariana Islands than to their east.

Singing was highest during summer months, which agrees with previous understanding of CWP song seasonality (Stafford et al. 2001). It is interesting to note, however, that earlier research found that CWP song was most common at the end of summer and into the fall, typically July-September, while in the data analyzed here it was most common in early to mid-summer, May through July. This could represent a difference in habitat use patterns between lower latitude and higher latitude grounds where previous studies were conducted, or it could reflect differing environmental conditions between our recordings and those previously analyzed.

Further research is needed to better understand how different populations of blue whales use habitat in the Central Western Pacific. Due to the central location in the Northern Pacific, it is possible that multiple different population stocks migrate through the area. Longer-term analysis of recordings can clarify population ranges. Additionally, seasonality in singing behavior throughout the area should be examined to determine if habitat usage has changes over decadal time frames, which could reflect environmental changes.

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