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Blue whale song occurrence in the North Pacific

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ABSTRACT

In the decade since McDonald and colleagues published a summary of biogeographic differences in blue whale songs worldwide, multiple new publications have explored seasonality of those songs. The goal here is to update the known spatial and temporal occurrence of the blue whale song types defined by McDonald *et al.* (2006) for the North Pacific Ocean. Two songs were described in this paper as occurring in the North Pacific, with the Northeastern Pacific (NEP) song occurring predominately along the west coast of America, and the Northwestern Pacific (NWP; AKA North Pacific) song occurring across the central North Pacific and in the western Pacific. Both songs occur in the Gulf of Alaska during summers, albeit with some temporal separation. They also co-occur along Hawaiian Islands during the winter. A new song has been described off Japan, with likely limited range of occurrence, and bimodal temporal occurrence with peak in January and September.

INTRODUCTION AND METHODS

In their paper, McDonald *et al.* (2006) described biogeography of blue whale song, reviewing nine distinct blue whale songs that had been described up to that time. Since that publication, new data collection in the central and western Pacific Ocean allows for better understanding of the spatial and temporal distribution of the different song types found in the North Pacific.

We surveyed published literature and gathered data from reports and other unpublished sources to provide a more detailed map of geographic and temporal occurrence of blue whale songs in the North Pacific. We are only focusing on the occurrence of songs that are dominant to the North Pacific. Based on song types defined by McDonald *et al.* (2006), two acoustic populations of blue whales were hypothesized to occur in North Pacific. The Northeastern Pacific (NEP) song, occurring predominately along the west coast of America, consists of two units: a pulsed unit A and a tonal unit B which often has harmonics (Rivers 1997). This song belongs to arguably the best studied blue whale population. The Northwestern Pacific (NWP; AKA North Pacific) song occurs across the central North Pacific and in the western Pacific (Stafford *et al.*, 2001). It consists of a relatively simple tone, sometimes split into two units. An additional, new song type has been recorded off Japan (McDonald *et al.* 2017) which we refer to as Japan-type song. For each of these songs we report locations where they were recorded and peak times of occurrence, defined as months with >80% of maximum reported level of occurrence at that location. For areas where multiple recordings exist, rather than reporting all reports of occurrence, we used the data with the most complete year-round recordings.





Fig 1. Locations of recorders with blue whale songs in the North Pacific. Blue X denotes location of Northeast Pacific (NEP), red hexagram Northwest Pacific (NWP), and green square Japan style (JAP) blue whale song. Months included for each site indicate peak months (>80% of maximum) of detection. Lighter color location markings indicate that the exact location of the recorder is not known, only its general area. In most cases year-round recordings were available. Fig. 2 includes a more detailed map of song occurrence in the Gulf of Alaska, since peak months marked on this map are general summaries. Black circles mark location where recordings exists but no blue whale songs were recorded. If three or more month of recording were missing per year, those peak months are marked with *.

Table I. Blue whale song types in the North Pacific, based on McDonald *et al.* (2006) and expanded with new information available since then. 'Type locality' is first/most complete published reference of the given song type, also after McDonald *et al.* (2006). All data sources used in Figs. 1-2 are provided.

Song type	Region	Type locality (reference)	Sources used to create Figs. 1 and 2
1	Northeast Pacific (NEP)	California (Rivers 1997)	Burtenshaw <i>et al.</i> 2004, Debich <i>et al.</i> in prep, Munger <i>et al.</i> unpublished, Oleson <i>et al.</i> 2007, Paniagua-Mendoza <i>et al.</i> 2017, Širović <i>et al.</i> 2015, Širović <i>et al.</i> in prep, Stafford <i>et al.</i> 1999, Stafford et al. 2001
4	Northwest Pacific (NWP)	Aleutian Islands (Stafford <i>et al.</i> , 1999)	Northrop <i>et al.</i> 1971, Stafford <i>et al.</i> 2001, 2003
12	Japan (JAP)	Hokkaido, Japan (McDonald <i>et al.</i> 2017)	McDonald et al. 2017

Northeast Pacific, NEP (song type 1)

Song type 1 has been recorded along the west coast of North America, from the Costa Rica dome to the Gulf of Alaska (Fig. 1). The song has also been recorded further offshore, in the vicinity of Hawaii and Palmyra Atoll. The song occurrence peaks in the Gulf of California, off the Costa Rica dome, and in the vicinity of Hawaii in the winter (Stafford *et al.*, 1999). There were also out-of-season peaks at Palmyra and Hawaii during the summer (Stafford *et al.*, 2001) although the Palmyra recording did not have year-round information so that may not represent a true peak. In the summer, the song peaked off California and in the Gulf of Alaska (Burtenshaw *et al.*, 2004; Oleson *et al.*, 2007). In the fall, on the other hand, the song occurrence peaked off British Columbia and Washington and Oregon (Burtenshaw *et al.*, 2004).

Northwest Pacific, NWP (song type 4)

Song type 4 was the dominant song recorded across the western and central North Pacific (Fig. 1). This blue whale song (Rankin *et al.* 2006) was typically recorded at higher latitude locations during the summer and fall, from August to December (Stafford *et al.* 2001, 2003), and it was recorded at lower latitudes generally in the winter (December-January) and spring (March and May; Munger *et al.* unpublished, Stafford *et al.* 2001). In the Gulf of Alaska (Fig. 2), where the song coincides spatially with the NEP song type, it co-occurs temporally at southern locations (Stafford *et al.* 2003), but typically occurs earlier in the summer, in July, at the northern Gulf locations (Širović *et al.* in prep).

Song type 12 (Japan, JAP)

A new presumed blue whale song, type 12, has been identified off Japan (McDonald *et al.* 2017). Its peak occurrence was during January and September (Fig. 1). This song has not been reported at other locations with recordings in the western Pacific.



Fig. 2. Locations and peak occurrence months of blue whale songs in the Gulf of Alaska (NEP blue X and NWP red hexagram). Lighter color location markings indicate that the exact location of the recorder is not known, only its general area. If recordings were collected for less than nine months of the year, peak months of occurrence are marked with *.

DISCUSSION

Our meta-analysis suggests there is some sympatric occurrence of Northwestern Pacific and Northeastern Pacific blue whale song types in both high latitudes and low latitudes in the central Pacific Ocean. The cooccurrence in high latitudes appears to be temporally separated at locations further north in the Gulf of Alaska, but is more concurrent both at southern locations in the Gulf of Alaska and at lower latitudes. Blue whales are believed mate at lower latitudes, but they have a long and dispersed mating season (Tomlin 1967) so it is not clear how such sympatry may affect the relationship between acoustic song type and genetic population structure and whether it results in any genetic mixing of these acoustic populations.

To use acoustics for developing hypotheses on blue whale population structure, caveats associated with acoustic data need to be considered. Calls provide information only on the presence of calling animals. When calls are detected, it is clear that an animal is present, but lack of calls is ambiguous; it could mean that no animals are present, but it is also possible that the animal is present but is not calling. Another important caveat for our meta-analysis of published acoustical studies is that the effort to record and detect blue whales has not been standardized across studies. We have tried to make clear which of the presented data were based on a full year of recordings, and which were not, however the duration of the recordings is one of several measures of effort. In addition to differences in recording season and duration, the overall acoustic detection range of baleen whales can vary by orders of magnitude both within and among recording sites.

Generally, songs were more commonly detected between late summer and early winter, with a general decrease in call detections during winter and spring. This pattern may reflect seasonality of calling. Given the stereotyped and rhythmical repetition of these calls and evidence in some populations of blue whales that only males sing (McDonald *et al.*, 2001), they therefore may have a reproductive function and it is possible these whales do not sing as often during non-mating season. However, since often songs were

detected year-round (Stafford *et al.*, 1999), clearly blue whales produce them year-round and therefore they can be good indicators of presence. Many hydrophone locations used for these analyses were coupled to the deep sound channel and therefore could have been recording calls from very far away. Thus we believe using peak occurrence is likely to be a better indicator of more local blue whale presence.

To start testing the hypothesis whether different acoustic populations correspond to different genetic populations, focus should be in areas where there is a clear spatial and temporal separation in the acoustic realm (*e.g.* off west coast of North America versus in the western Pacific), before doing those tests in areas where there is overlap between acoustic populations (Gulf of Alaska and Hawaiian Islands).

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