

ASSESSING THE EFFECTS OF MID-FREQUENCY SONAR ON CETACEANS IN SOUTHERN CALIFORNIA

Mariana L. Melcón, Amanda J. Cummins, Sean M. Wiggins and John A. Hildebrand

Scripps Institution of Oceanography, University of California San Diego, 9500 Gilman Dr., CA, USA, 92093 -0205
mmelcon@ucsd.edu

1. INTRODUCTION

Mid-frequency active sonar (MFA) is regularly used during naval exercises to provide an acoustic image of subsurface features, including natural and anthropogenic targets. Because MFA is often operated at high intensities, its sounds can be heard for thousands of square kilometers. MFA signal characteristics can vary considerably over its frequency band, 1-10 kHz, which coincidentally happens to be in the audible band for most, if not all, marine mammal species. Over the past decade, correlations have been found between MFA and anomalous mass strandings of beaked whales (Cox et al., 2006). However, the mechanisms by which MFA affects beaked whales are not well understood.

Beaked whales, like most toothed whales, emit echolocation clicks (e.g. Zimmer et al., 2005) which provide them with location and distance information on prey and other objects from returning echoes. These sounds allow beaked whales to be monitored in the same way as MFA using passive acoustic monitoring techniques.

To quantitatively assess the possible impact of the MFA on the beaked whales, we used autonomous passive acoustic monitoring devices at two different deep water sites offshore of southern California for one year to record both beaked whale and MFA sounds. From these recordings, we tested whether or not the presence of beaked whale sounds was less frequent when MFA was detected.

2. METHOD

High-frequency Acoustic Recording Packages (HARPs – Wiggins and Hildebrand, 2007) were deployed at two independent sites off southern California, north and south of San Clemente Island, at depths of ~1000 m. Continuous recordings were made between March 2009 and March 2010. HARP recordings are broad-band with an effective bandwidth between 10 Hz and 100 kHz allowing most sounds produced by marine mammals and anthropogenic sources to be monitored.

Trained analysts evaluated spectrograms using a MATLAB-based software package (*Triton*) to log MFA events and note various marine mammal sound occurrences in the data

sets. We also ran an automated detector on the HARP data for beaked whale echolocation clicks.

The detections of both MFA and beaked whales were merged into a sequential time vector, assigned identifying values and plotted to investigate potential patterns. To test whether there were significant differences in the presence of beaked whales when MFA was present (pb(BM)|MFA) or absent (pb(BW)|No MFA), we took 50 random samples of the time vector and calculated the probability of beaked whales with and without MFA. If $pb(BW)|No\ MFA > pb(BM)|MFA$, then the pb(BW)|MFA get a “+”, and vice versa. After repeating this procedure 1000 times, we counted how many “+” each of the situations had and calculated the associated p value.

3. RESULTS

Recorded MFA events consisted of a wide variety of signals, from constant frequency tones to frequency modulated sweeps, or a combination of both and lasted between a few minutes to days.

MFA and beaked whale sounds occurred more frequently at the southern site N than at site M (Figure 1). The probability of detecting beaked whales when no MFA was present was compared to beaked whale detection probability with MFA present. No significant differences were found ($p=0.47$ for site M and $p=0.26$ for site N) between both MFA conditions.

Time-lag response was investigated by calculating the same probabilities as before, but with one hour delay in beaked whale detections. Again, no significant differences were found for either site ($p=0.46$ for site M and $p=0.26$ for site N) between presence and absence of MFA.

4. DISCUSSION

In this initial attempt to assess the potential effects of MFA on the beaked whales offshore of southern California using passive acoustic monitoring, we did not find significant differences between the presence of beaked whales when MFA was present and when it was not with our current methodology.

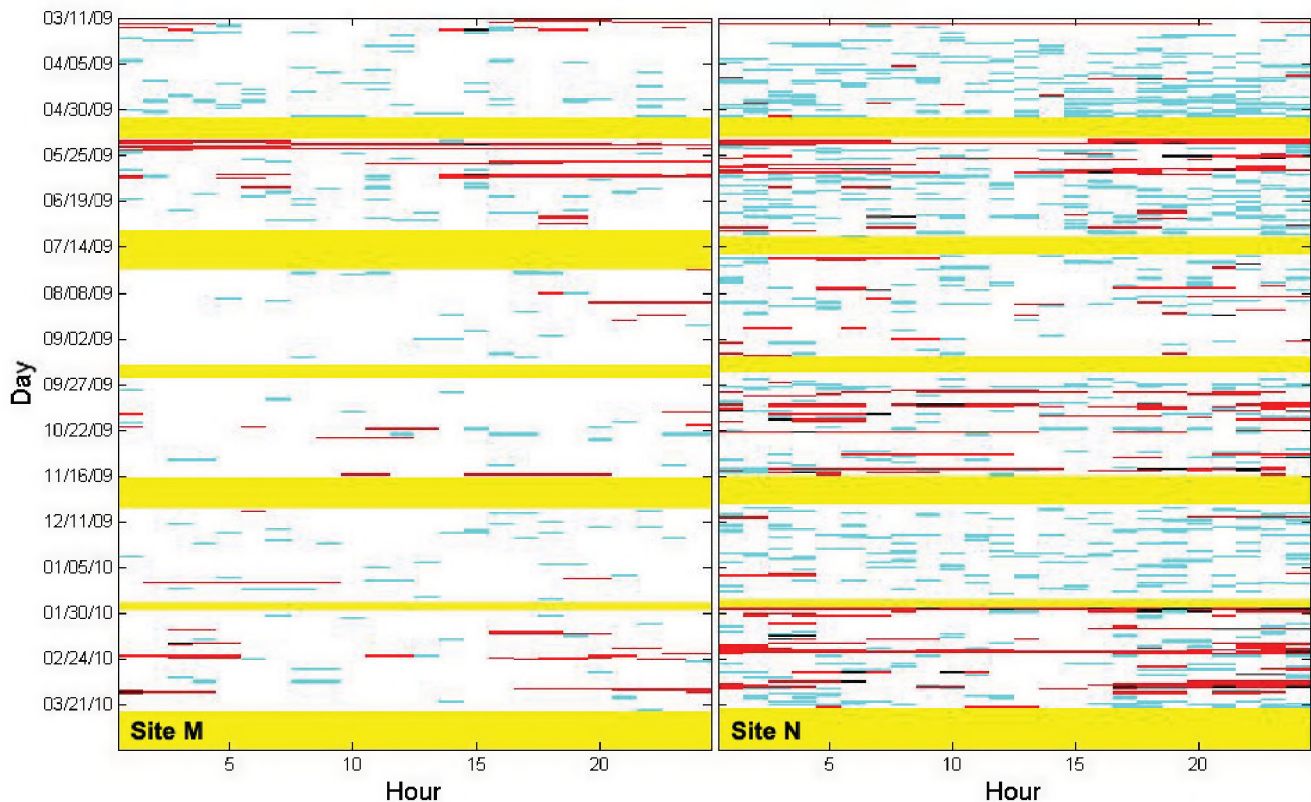


Figure 1. Co-occurrence of beaked whales and MFA in 1-hour bins for over one year of recordings in two different sites offshore of Southern California. Null detections are depicted in white, beaked whales in cyan, MFA in red and occurrence of both in black. No effort is marked in yellow.

Since no predictable periodic pattern was observed in the detections of MFA, it is expected that animals will need some time to react to it –if they show any reaction- instead of avoiding it simultaneously. Thus, the presence of animals was shifted by one hour to investigate if a temporal shift had an effect, but no significant difference in the presence of beaked whales was found when MFA was detected compared to when it was not. However, from this result, we cannot conclude that MFA has no effect in the population of beaked whales because of several issues.

First, the analysis was conducted with 1-h bins, which may be too long for acute responses and too short for long-term responses. Shorter duration bins and recordings over several years should be investigated for responses along with longer time-lags.

Second, all MFA events were considered equally, disregarding type, frequency, duration or intensity. For example, beaked whales may not react in the same way to an intense sound as to one that is barely audible suggesting MFA received sound levels are an important parameter.

Finally, presence or absence constitutes an “all or nothing” measure. However, in nature, responses are often gradual. Counting the number of calls or noting their intensity over time could provide a more progressive measure.

Further work should be conducted to evaluate potential causes and effects to properly assess and judge the impact of anthropogenic noise on these animals.

REFERENCES

- Cox, T.M.; Ragen, T.J.; Read, A.J.; et al (2006). Understanding the impacts of anthropogenic sound on beaked whales. *J Cetacean Res Manage* 7(3):177-187
- Wiggins, S.M.; Hildebrand, J.A. (2007). "High-frequency Acoustic Recording Package (HARP) for broad-band, long-term marine mammal monitoring" in *International Symposium on Underwater Technology 2007 and International Workshop on Scientific Use of Submarine Cables & Related Technologies 2007* (Institute of Electrical and Electronics Engineers Tokyo, Japan), pp. 551-557.
- Zimmer, W.M.X.; Johnson, M.P.; Madsen, P.T.; Tyack, P.L. (2005). Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*). *J Acoust Soc Am* 117(6): 3919-3927.

ACKNOWLEDGEMENTS

We would like to thank Dr. F. Stone and E. Young of CNO-N45, Dr. C. Collins of the NPGS and C. Johnson of PACFLT for project support, Dr. S. Baumann-Pickering for the data extracted from the automatic beaked whale detector, Dr. M. McDonald for guidance on beaked whale bioacoustics, G. Campbell for assistance in logging MFA events, and Dr. J. Zwolinski for useful advice on statistical methods.