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Acoustic monitoring of dolphin occurrence and activity in a MINEX training range

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The naval forces of many nations conduct mine detonation exercises in coastal waters as part of their regular training. These exercises have the potential to disturb, injure or even kill marine mammals occurring in the same area. To address concerns about this possibility at the U.S. Navy's Virginia Capes (VACAPES) Range Complex, an effort was conducted to monitor odontocete activity at the mine exercise (MINEX) training range using passive acoustic methods. The objectives of the project were to document the daily and seasonal patterns of occurrence of dolphins in the VACAPES MINEX training area, to detect explosions related to MINEX activities, and to investigate potential behavioral and acoustic responses of dolphins to MINEX training events. Dolphins were detected almost daily in the training area. Acoustic activity levels approximately 1 km from the epicenter of training were examined for 22 events and were found to be on average lower during both the day of and the day following the event, suggesting that animals either reduced their signaling, left the area, or both.

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1. INTRODUCTION

The United States Navy is required to comply with Federal laws designed to protect marine species, including the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). As part of the regulatory process, the Navy must monitor and report on certain activities that have the potential to injure or kill marine mammals, such as sonar and underwater detonations. The Navy's Integrated Comprehensive Monitoring Program (ICMP) was created in December 2009 as a planning tool to focus the Navy's monitoring priorities pursuant to ESA and MMPA requirements. Two of the principal monitoring goals identified in the ICMP are:

A. To increase understanding of how many marine mammals are likely to be exposed to stimuli (e.g. sonar and underwater detonations) associated with adverse impacts, such as behavioral harassment and hearing threshold shifts (temporary or permanent).
B. To increase understanding of how marine mammals respond (behaviorally or physiologically) to sonar, underwater detonations, or other stimuli at specific received levels that result in the anticipated take of individual animals

In order to help meet these goals for the Virginia Capes (VACAPES) W-50 mine exercise (MINEX) training range off Virginia Beach, Virginia USA, a long-term passive acoustic monitoring study was begun in August 2012 to document the temporal occurrence of odontocete cetaceans in the W-50 area and examine their behavioral responses to underwater detonations (UNDETs). The objectives of this study were to:

1. Detail the daily and seasonal occurrence of resident bottlenose dolphins (*Tursiops truncatus*) near the primary location of MINEX activities.
2. Detect UNDETs associated with training events.
3. Quantify the acoustic activity of dolphins in response to UNDETs.

Here the results are presented from two years of acoustic monitoring. The implications of the findings are discussed and ongoing efforts to meet the research objectives are outlined.

2. METHODS

Passive acoustic monitoring was initiated in the W-50 training area on 15 August 2012, using bottom-moored Ecological Acoustic Recorders (EARs) (Fig. 1). The EAR is a microprocessor-based autonomous recorder that samples the ambient sound field on a programmable duty cycle (Lammers et al. 2008). Two EARs were programmed to sample at a rate of 50 kilohertz (kHz) for 180 seconds (3 minutes) every 360 seconds (6 minutes), providing ~25 kHz of Nyquist bandwidth recording at a 50 percent duty cycle. This bandwidth is sufficient to detect signals (whistles and the low-frequency end of clicks) from bottlenose dolphins and other delphinid species potentially occurring in the area that produce signals at frequencies below 25 kHz. The EAR recording periods were offset so that one unit was recording while the other was off. As a result, one of the units was always 'on' in order to detect any nearby explosions. The EARs were placed in 13-meter (m) and 14-m water depths approximately 1 km and 3 km from a location known to be the primary area of MINEX training activity. This is a search field location where the majority (~95 percent) of MINEX detonations were expected to occur each year and is referred to here as the "epicenter" of activity. The EARs were recovered, refurbished, and re-deployed approximately every 2 months, or as weather conditions and logistics allowed.

An experienced acoustic technician manually scanned recordings from both recording sites for the presence of UNDET events, and scanned recordings from the 1 km location (known as "site B") for dolphin signals, using the Matlab™ program Triton (Wiggins 2003). Recordings containing dolphin whistles, echolocation clicks, or burst pulses were considered a 'detection' of dolphins in the area. For periods when UNDETs were detected on either EAR, a detailed assessment was made of the dolphin acoustic activity on the site B unit for the day before, during, and after each MINEX training event. An acoustic activity index ranging from 1 for minimal signaling to 4 for a high rate of signaling was assigned for each 3-minute recording to quantify acoustic activity based on the number of whistles, burst pulses and echolocation click trains in each recording. Activity indices were then used to statistically compare the acoustic activity of dolphins during the day before, day of, and day after UNDETs. In addition to quantifying dolphin acoustic activity during periods associated with MINEX exercises, dolphin presence/absence was logged on a recording-by-recording basis at site B for the entire deployment period.

Figure 1. Images of an EAR prior to deployment and while deployed

3. RESULTS

A total of 128,471 recordings representing 6,423 hours of data were made at site B between August 15, 2012 and July 28 2014 over the course of eight EAR deployment periods. All deployments except number seven successfully recorded data from this location. The disk drive from deployment seven at site B malfunctioned, preventing recovery of the on-board data.

The analysis of recordings from site B for the presence/absence of dolphin signals revealed that dolphins were present daily in the MINEX range, with detections made on 97% of recording days. Although species identity could not be visually confirmed, it can be assumed that the majority of detections are from bottlenose dolphins (*Tursiops truncatus*), which are resident in the area (Barco et al, 1999). During the first year of monitoring between August 2012 and July 2013, substantial variation was observed in the mean number of daily detections each month (Fig. 2), with the lowest overall activity observed between December and February. No data are available for the month of November 2012 because the EAR was not deployed due to weather and logistical constraints. During the second year of monitoring from August 2013 to July 2014, there were again differences between months, with the lowest mean number of daily detections again occurring during February. However, there was more variability overall, with reduced numbers of daily detections during the months of August, September, November and March compared to the previous year.

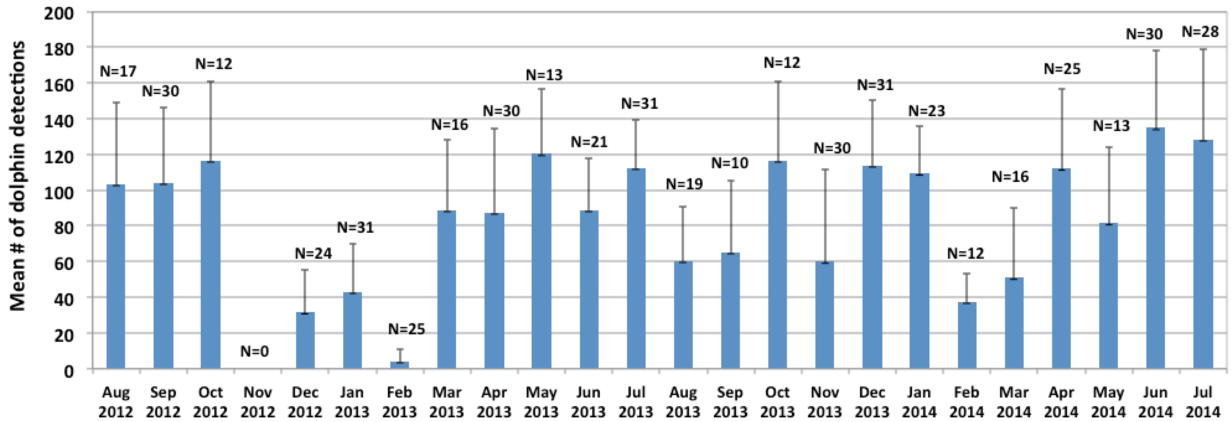

Figure 2. Mean number of daily dolphin detections at EAR site B by month. Error bars represent one standard deviation. 'N' values give the number of days that were monitored during each month. No data were collected in November 2012.

In total, 46 explosions were detected in the data comprising 22 training events, some of which spanned multiple days. Dolphin acoustic activity was quantified and compared on progressively longer time scales (seconds, hours, days) relative to each explosion. Detailed manual whistle counts in the 30-second periods before and after an UNDET were made for data through July 30, 2013; all other time scales (hours through days) were characterized using acoustic activity indices through July 28, 2014. There were significantly more whistles recorded in the 30 s immediately after an UNDET than in the 30 s prior (Mann-Whitney U-test, $n = 16$, $p = 0.02$), reflecting a short-term increase in whistle production by the animals (Fig. 3). Comparing the mean acoustic indices within the hours before and after an UNDET, a significant decrease in dolphin acoustic signaling was seen during the two hours following the event compared to the hour prior to it (One-way ANOVA, DF = 2, $F = 9.2$, $p < 0.001$) (Fig. 4).

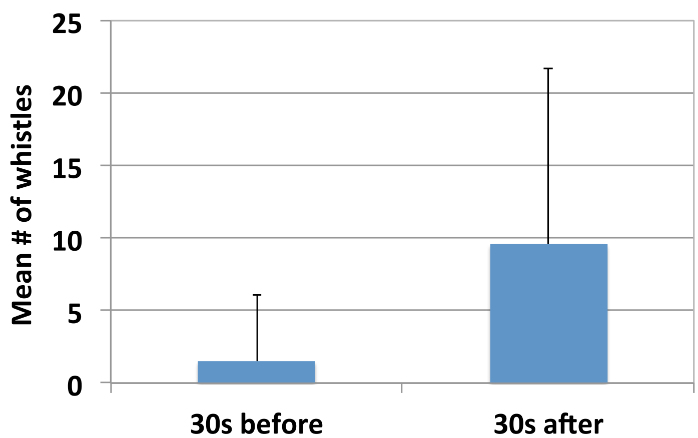

Figure 3. Whistle production observed 30 seconds before and after explosions (N = 16). Error bars represent one standard deviation.

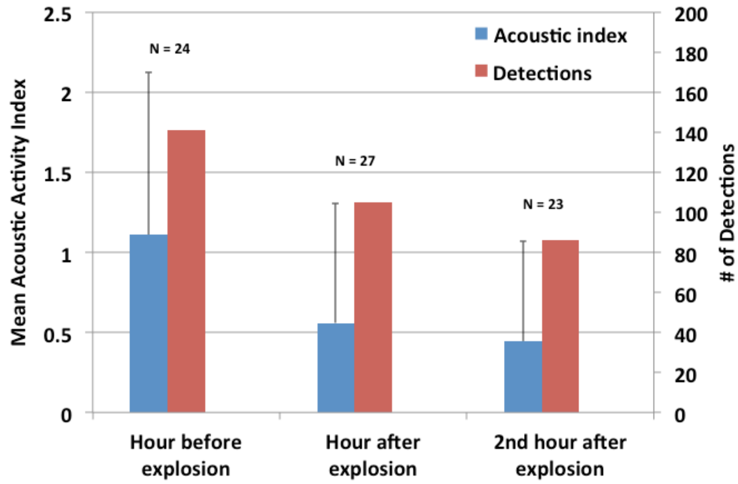

Figure 4. Dolphin acoustic activity observed in the hour before and the first and second hours after an UNDET. The different sample sizes reflect the fact that several UNDETs occurred within minutes or hours of each other and therefore were either treated as a single event or did not have baseline and/or post-UNDET data. Error bars represent one standard deviation.

The hourly mean of acoustic activity of dolphins the day before, the day of, and the day after MINEX training events is shown in Figure 5. During the day prior to an event, dolphins were most active during mid-day (11:00–12:00), late afternoon (15:00), and nighttime hours (19:00–04:00). On the day of MINEX training and the following day, the daytime peak in activity was reduced or absent, although the nighttime peak persisted. The difference in the acoustic activity index between the day before and the day of the exercise was significant for the period between 10:00 and 12:59 (Kruskall-Wallis test, $p < 0.05$). In addition, a significant difference was observed between the day before and the day following an exercise, with less activity for the period between 11:00 and 12:59 on the day after the exercise Kruskall-Wallis test, $p < 0.05$). The nighttime peak in activity persisted on the day of and day after MINEX training events, suggesting that the animals in the area resumed normal activity during these hours, but the decreased daytime activity observed on the day of and day after events might indicate avoidance of the area.

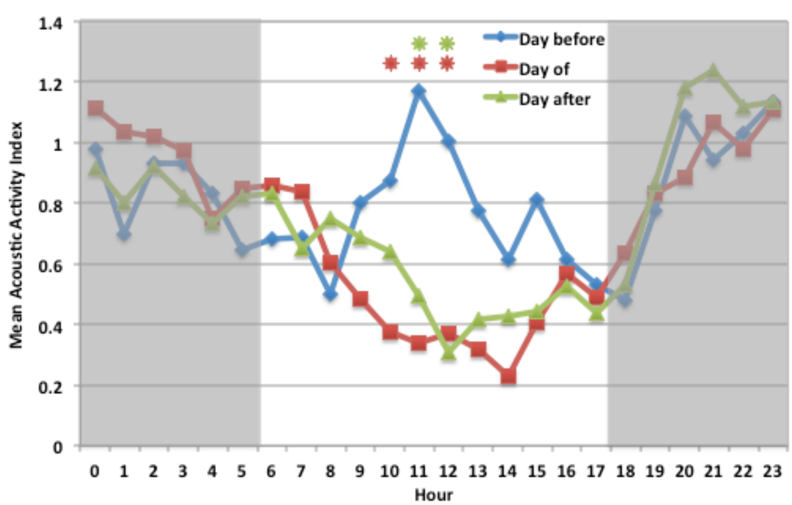

Figure 5. The hourly dolphin acoustic activity observed over the 24-hour period of the days before (N = 18), the days of (N = 22) and the days after (N =18) a MINEX training event at site B. Red stars indicate a significant difference (Kruskall-Wallis test, p < 0.05) between the day before and the day of

the event. Green stars indicate a significant difference (Kruskall-Wallis test, p < 0.05) between the day before and the day after the event. Shaded periods represent twilight/nighttime hours.

4. DISCUSSION AND CONCLUSION

The data obtained show that dolphins are present in the MINEX training area nearly every day. Seasonally, there appears to be a consistent period of low occurrence or reduced acoustic activity around the month of February. Year to year, differences were observed between a few of the same months, suggesting some inter-annual variability in the occurrence of dolphins in the area near the epicenter. These findings suggest that dolphins are periodically exposed to noise from UNDETs, although it is not clear yet at what range.

Based on two years of monitoring data, there is evidence that dolphins respond behaviorally to MINEX training events. In the seconds following an explosion, there is an immediate short-term acoustic response characterized by increased rates of whistling. Whistles are believed to function as cohesion calls (Janik and Slater, 1998), and this response may indicate that the animals were surprised or startled by the explosion and acted to re-establish or reinforce social cohesion. After the immediate response, acoustic activity decreases during the following hours, but only during daytime hours . It is still not clear whether this represents a suppression of acoustic activity by the animals, individuals moving away from the area, or both. In captive animals, stressful events can lead to periods of reduced or no acoustic activity lasting hours or even days (Sidorova et al, 1990, Castellote and Fossa, 2006). It is not known whether free-ranging animals respond similarly. The reduced acoustic activity in the middle of the day is repeated during the day following a training event, suggesting that animals may continue to avoid the area, perhaps anticipating more UNDET events.

The results presented here underscore the value of long-term acoustic monitoring to inform the military of the potential impacts on marine mammal populations from training activities involving UNDETs. Follow-on efforts continue to explore the trends reported here and also new questions, including: At what distance from the explosion site is an acoustic response observable? Do dolphins show evidence of re-distribution as a result of MINEX activities? How long after a training event does dolphin acoustic activity return to baseline levels? These questions are being addressed by the deployment of additional EARs at greater distances from the epicenter and by the analysis of additional data from the days following a training event.

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