Chapter 97
Patterns of Occurrence and Marine Mammal Acoustic Behavior in Relation to Navy Sonar Activity Off Jacksonville, Florida

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Abstract Passive acoustic data collected from marine autonomous recording units deployed off Jacksonville, FL (from 13 September to 8 October 2009 and 3 December 2009 to 8 January 2010), were analyzed for detection of cetaceans and Navy sonar. Cetaceans detected included *Balaenoptera acutorostrata*, *Eubalaena glacialis*, *B. borealis*, *Physeter macrocephalus*, blackfish, and delphinids. *E. glacialis* were detected at shallow and, somewhat unexpectedly, deep sites. *P. macrocephalus* were characterized by a strong diel pattern. *B. acutorostrata* showed the strongest relationship between sonar activity and vocal behavior. These results provide a preliminary assessment of cetacean occurrence off Jacksonville and new insights on vocal responses to sonar.

Keywords Autonomous acoustic recorder • Marine acoustic recording unit • Midfrequency active sonar • Vocal behavior

1 Introduction

Passive acoustic monitoring using autonomous acoustic recorders deployed on the seafloor is an effective method for long-term monitoring of cetaceans (Mellinger et al. 2007). Autonomous acoustic recorders have been used to investigate the

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distribution, abundance, and acoustic behaviors of a variety of cetaceans in diverse habitats and in extreme or remote environments (e.g., Clark et al. 2002; Širović et al. 2004; Johnston et al. 2008). In the fall and winter of 2009–2010, the US Navy (Naval Facilities Engineering Command [NAVFAC] Atlantic) deployed nine marine acoustic recording units (MARUs) off Jacksonville, FL, in the US Navy's Jacksonville (JAX) range complex. The MARU deployments were timed to include antisubmarine warfare (ASW) training exercises. This provided a unique opportunity to examine cetacean vocal activity before, during, and after US Navy midfrequency active sonar (MFAS) events.

We present the results of a detailed qualitative analysis of passive acoustic data collected during these MARU deployments, including the occurrence of cetacean vocalizations and Navy sonar. We characterize spatial and temporal patterns in cetacean vocal activity as well as document vocal behavior in relation to sonar events. This analysis provides new insights as to which species may be sensitive to Navy sonar and recommendations for future research.

2 Methods

2.1 Deployments

Nine MARUs were deployed from 13 September to 8 October 2009 (fall) and from 3 December 2009 to 8 January 2010 (winter), ~60 to 150 km offshore from Jacksonville, FL (Fig. 97.1). The deployment area was located in the US Navy's JAX range complex, in an area that coincides with the planned undersea warfare training range (USWTR). MARUs were deployed in three depth ranges: on the shelf (44–46 m; "shallow sites"), just beyond the shelf (~183 m; "middepth sites"), and offshore from the shelf break (~305 m; "deep sites"). Three recorders were deployed at each of the three depth ranges, for a total of nine MARUs in each deployment. Two types of MARUs were deployed: units that recorded using a 32-kHz sampling rate and units that recorded using a 2-kHz sampling rate. The 32-kHz recorders were deployed at six sites and the 2-kHz recorders were deployed at three sites (Fig. 97.1).

2.2 Data Analysis

Triton software was used to create long-term spectral averages (LTSAs) for all data. Once the LTSAs were created, all biological sounds and Navy sonar events were logged by trained bioacoustic analysts. The unit of analysis was an "acoustic event," defined as any period containing cetacean sounds with <10 min of silence between individual sounds. Acoustic events were identified as to species or the highest taxonomic group (e.g., delphinids and blackfish) possible. "Blackfish" consisted of *Peponocephala*

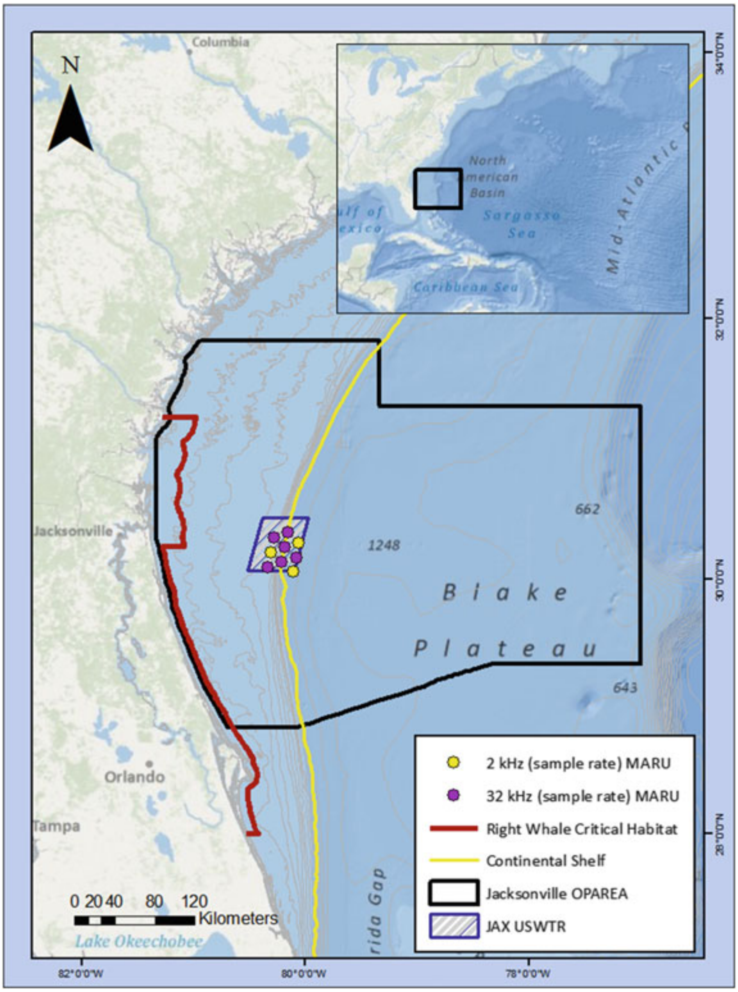

Fig. 97.1 Locations of the marine acoustic recording units (MARUs) deployed in fall and winter 2009–2010 in the planned Jacksonville (JAX) undersea warfare training range (USWTR). *OPAREA* area of operation

electra (melon-headed whales), *Feresa attenuata* (pygmy killer whales), *Pseudorca crassidens* (false killer whales), *Orcinus orca* (killer whales), and *Globicephala macrorhynchus* (short-finned pilot whales). "Delphinids" consisted of all delphinid species other than the blackfish. Blackfish were identified based on the presence of distinctive pulsed sounds as well as low-frequency whistles (2–8 kHz) with few inflection points (Oswald et al. 2004). Blackfish were identified conservatively, and if there was any doubt, the event was labeled as delphinid.

3 Results

3.1 Acoustic Recordings

The 32-kHz units recorded for ~21 days during both fall and winter (13 September to 4 October and 4 December to 26 December, respectively). The 2-kHz units recorded for 25 and 33 days during fall and winter (13 September to 8 October and 5 December to 8 January, respectively). A total of 10,132 h of 2-kHz data and 5,988 h of 32-kHz data were reviewed and analyzed.

3.2 Species Detected

A number of marine mammal species were detected acoustically during both deployments. The species detected as well as the total duration of their acoustic events for each deployment are summarized in Table 97.1. MFAS activity occurred during both deployments but was much more prevalent in the fall deployment than in the winter deployment (535 vs. 99 h, respectively; Fig. 97.2; Table 97.1).

Baleen Whale Detections

Balaenoptera acutorostrata (minke whale) sounds were not detected during the fall deployment but were detected nearly continuously in the winter deployment, representing the highest overall event duration of all species/species groups (1,429 h; Table 97.1). Vocalizations from *B. acutorostrata* were detected predominantly at deep sites and infrequently at shallow sites. Vocal activity was greatly reduced or, in some cases, completely absent during most days with concurrent sonar events (Fig. 97.2a).

Two other baleen whales were detected in the MARU recordings, although not as often as *B. acutorostrata*. Both *Balaenoptera borealis* (sei whales) and *Eubalaena glacialis* (right whales) were detected on recorders at all depths but had low overall event durations (Table 97.1). *E. glacialis* was detected at all sites during both

Table 97.1 Total duration of acoustic events by species

	Fall	Winter	Overall
Blackfish	2 h 17 min 7 s	6 h 35 min 15 s	8 h 52 min 22 s
Delphinid species	301 h 57 min 01 s	235 h 18 min 16 s	537 h 15 min 17 s
Balaenoptera acutorostrata		1,429 h 4 min 4 s	1,429 h 4 min 4 s
Physeter macrocephalus	297 h 29 min 41 s	395 h 10 min 54 s	692 h 40 min 35 s
Eubalaena glacialis	8 h 35 min 33 s	2 h 54 min 43 s	11 h 30 min 16 s
Balaenoptera borealis		8 h 47 min 26 s	8 h 47 min 26 s
MFAS	535 h 24 min 51 s	99 h 1 min 7 s	634 h 7 min 57 s

MFAS midfrequency active sonar

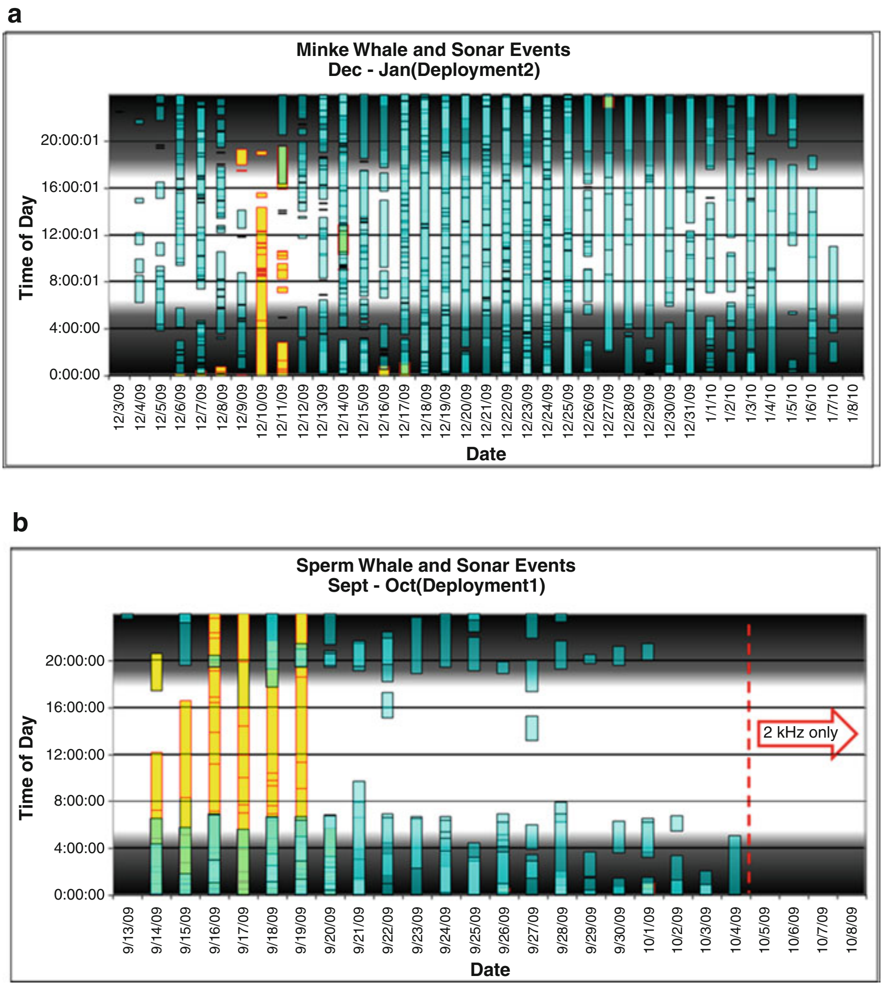

Fig. 97.2 Vocal events (*teal*) and sonar events (*yellow*) by day and time for all nine MARUs combined for *Balaenoptera acutorostrata* during winter deployment (**a**) and *Physeter microcephalus* during fall deployment (**b**). Shading is representative of event overlap, i.e., an event occurring at multiple MARUs. *White* is average daylight and *black* is nighttime for the deployment periods

deployments but was slightly more common during the winter, whereas *B. borealis* was detected during the winter only.

Odontocete Detections

Delphinid species and *Physeter macrocephalus* (sperm whales) were the most commonly detected species during the fall deployment and second and third most commonly detected species during the winter, respectively (Table 97.1). *P. macrocephalus* vocalizations were only detected on the 32-kHz units because energy in their clicks generally does not extend below 1 kHz (the upper recording bandwidth of the 2-kHz sites). Despite the fact that only six of the nine sites included 32-kHz recorders, *P. macrocephalus* was detected every day during the fall and on all but 2 days during the winter. *P. macrocephalus* was detected only at middepth sites during both deployments. Their acoustic events showed a strong diel pattern, occurring predominantly between sunset and sunrise (Fig. 97.2b).

Both delphinid and blackfish species were detected every day and at all 32-kHz sites for both deployment periods. Although some components of the sounds produced by these species can extend below 1 kHz, it was not possible to identify these two species groups based on the limited bandwidth recordings of the 2-kHz data. There were no obvious or consistent differences in the occurrence of delphinid or blackfish vocalizations relative to site depth or time of day.

4 Discussion

Analysis of the JAX MARU deployments provides information about the spatial, seasonal, and diel occurrence patterns for several species and species groups based on their vocal behaviors in an important area for naval activity. When interpreting these results, it should be noted that an absence of vocalizations does not necessarily mean an absence of animals because vocalizing is not an obligatory behavior for most species. Also, for species that produce loud, low-frequency signals (e.g., baleen whales), some sound types may propagate far enough to be detected by several recorders (i.e., at different sites), which may complicate interpretation of occurrence patterns. Despite these constraints, these data provide a more detailed picture of cetacean occurrence than was available for this region based on existing datasets. For example, visual survey data indicate that few *B. borealis*, *P. macrocephalus*, and *E. glacialis* are expected in the JAX USWTR study area (Department of the Navy 2008, 2013). However, *P. macrocephalus* was one of the most commonly detected species in the MARU recordings and *B. borealis* and *E. glacialis* were also more common than expected.

In addition to being detected on the MARU buoys when very few have been recorded to date via visual monitoring (Department of the Navy 2013), *E. glacialis* was also detected in deeper waters than expected. Sightings of *E. glacialis* generally have been concentrated in continental shelf waters offshore from northeastern Florida and southeastern Georgia (e.g., Department of the Navy 2008). Based on the MARU data, it seems that the distribution of this species extends further offshore than sighting data previously indicated. Alternatively, it is possible that propagation of these vocalizations allows them to be detected at long distances and that at least some vocalizations produced in nearshore waters were being recorded by offshore MARUs. Acoustic propagation modeling should be conducted to investigate this possibility.

Both *B. borealis* and *B. acutorostrata* were detected only during the winter deployment. This suggests a seasonal component to the calling behavior and/or migration patterns of these species. *B. acutorostrata* are believed to migrate south to the Caribbean and other areas in the winter and spring (Mitchell 1991). Information about seasonal peaks in detection of *B. acutorostrata* at other recording sites along the US Atlantic coast are needed to fill in the gaps in the knowledge of their migration patterns. The high prevalence of calling events for almost the entire winter deployment indicates a continuous presence of this species during that time period. Further research is necessary to determine whether the animals are continuously migrating through the study area or if the animals are resident during this time period.

In addition to providing information on the spatial occurrence of species, analysis of these data has also highlighted temporal variability in vocal behavior. For example, *P. macrocephalus* exhibited a strong diel pattern, with vocalizations occurring almost exclusively at night. *P. macrocephalus* produce clicks during foraging dives and are generally quiet at the surface (Whitehead 2003; Miller et al. 2008). As such, the diel vocal pattern suggests that this species is spending more time at depth, likely foraging, during the nighttime in this study area. Aoki et al. (2007) and Whitehead (2003) both reported diel patterns in sperm whale dive records and acoustic observations collected around Japan and the Galapagos Islands, respectively. They suggested that these patterns were related to diel vertical migration of prey species. It is important to note that the lack of acoustic detection during the day does not necessarily indicate absence of the species. The animals may stay in the area throughout the day but remain quiet. This option is unlikely, however, because there are few visual records of sperm whales occurring in this area during the daytime. Visual surveys combined with 24-h acoustic tracking and satellite tagging of *P. macrocephalus* can be used to answer these questions.

Based on our qualitative analysis, *B. acutorostrata* was the only species to exhibit an obvious change in calling patterns associated with sonar events. This species called almost continuously during the winter deployment but greatly reduced or stopped calling during sonar events. This indicates either a cessation of calling or movement out of the area. McCarthy et al. (2011) found that beaked whales both reduced their vocal activity and moved away from sonar sources in the Atlantic Undersea Test and Evaluation Center (AUTEC) range in the Bahamas. Recent playbacks of sonar to a *B. acutorostrata* tagged with a radio transmitter and time-depth recorder indicated strong horizontal and vertical responses to sonar (Kvadsheim et al. 2011). Additional research is needed to determine if similar behavioral responses were occurring during the MARU deployments.

Neither diel patterns nor changes in vocal behavior in association with Navy sonar were evident in delphinids or blackfish. These patterns may exist for some species but, if so, they were likely masked by the fact that up to 15 delphinid species and 5 blackfish species were combined into two categories for analysis. Combining many species may result in species-specific patterns being missed or confounded. For example, if one species produces more sounds during the day and another produces more sounds during the night, these two patterns would effectively cancel each other out and make it appear as though calling was continuous, with no diel variation.

Because of the high variability in delphinid vocalizations and the overlap in time, frequency, and spectral characteristics among multiple species, classifying delphinid sounds to the species level would require a more detailed analysis, which was beyond the scope of this project. We are currently developing classifiers to identify whistles from several species of Atlantic dolphins and will apply these classifiers to the JAX MARU dataset. This will allow a more detailed analysis of species-specific vocalization patterns and possible responses to sonar. We are also collaborating with expert bioacousticians to develop a statistical framework for assessing species-specific vocal responses to sonar.

The analysis of autonomous recorder data from MARUs deployed concurrently with naval sonar exercises provided a unique opportunity to examine relationships between vocal behavior and sonar activity. Additionally, these data provided the opportunity to assess species presence as well as spatial and temporal patterns of vocal activity in the region. These types of information are important for developing monitoring and mitigation plans for these federally protected living marine resources.

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